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Editor's Corner

On October 27, the U.S. House of Representatives and Senate approved the Appropriations Conference Committee bill that provides funding to the Veterans Administration, Department of Housing and Urban Development, and Independent Agencies (including NASA) for FY 98. The NASA budget was approved at $13.6 B, of which the Office of Mission to Planet Earth Budget was $1.417 B. Of this budget, $679.7 M is for the Earth Observing System (EOS), $244.7 M for EOSDIS, and $325.3 M for science, including both the research & analysis program and the EOS Interdisciplinary Science (IDS) investigations. The conference report includes earmarks of $20 M of the MTPE budget for a lightning mapper for geosynchronous orbit, five consortia for regional use of EOS data, and funds for satellite imagery for use in urban planning.

NASA will fly an infrared coherent Doppler laser in the cargo bay of the Space Shuttle to see if a space-based sensor can accurately measure global winds within the Earth's atmosphere from just above the surface to a height of about 16 km. Successful measurements in this region of the atmosphere could lead to improved weather forecasting and better understanding of climate-related events. Based on technology tested aboard research aircraft, the Space-Readiness Coherent Lidar Experiment (SPARCLE) will detect the frequency shift of a laser pulse as it reflects off dust and aerosol particles moving with the winds. The resulting measurements should give researchers precise information about the speed, direction, and vertical profile of tropospheric winds. Due to launch in 2001 at an estimated cost of $15 M, SPARCLE will be the second Earth-orbiting mission, called EO-2, in NASA's New Millennium Program. If successful, a more robust system based on SPARCLE could be a candidate for launch aboard a free-flying satellite within the following few years. The experiment will be carried to orbit and back in two Space Shuttle Hitchhiker canisters that weigh approximately 320 kg each. Researchers hope to obtain approximately 50 hours of wind data. The co-Principal Investigators are Drs. G. David Emmitt (University of Virginia) and Michael J. Kavaya (NASA Marshall Space Flight Center).

A mission called Earth Orbiting-1 (EO-1), scheduled for launch in May 1999, will demonstrate an Advanced Land Imager system with a multispectral capability that can replace the current measurement approach used by such systems as the Landsat satellites. It also will demonstrate a hyperspectral capability that can break up the radiation reflected by Earth's land surfaces into hundreds of distinct bands, as compared to the half-dozen bands common on today's remote-sensing spacecraft.

Eleven offers have been selected for contract negotiations in the first phase of NASA's planned purchase of Earth science data and related information products that meet both commercial needs and the agency's scientific requirements (see list of successful offerors on page 25). The U.S. Congress approved the plan to initiate the data purchase activity in the fiscal 1997 NASA budget. A Request For Offers was made by NASA in May 1997 to provide unique Earth science data and related information products for purchase. The first phase of this effort will cover a maximum six-month period to be spent analyzing and validating sample data sets. Those proposals selected to continue to Phase II will receive a letter describing the price, quantity of data, and its required characteristics, based on terms and conditions commonly found in the commercial marketplace.

NASA has approved an immediate new start for the Quick Scatterometer (QuikSCAT) mission and has placed the first delivery order issued under the Indefinite Delivery/Indefinite Quantity (ID/IQ) contracts for rapid delivery of satellite core-systems to Ball Aerospace Systems Division, Boulder, CO. The ID/IQ procurement method provides NASA a faster, better, cheaper method for the purchase of satellite systems through a "catalog," allowing for shorter turnaround time from mission conception to launch.

The mission will fill in the ocean-wind vector data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS) spacecraft. The NSCAT instrument ceased functioning when ADEOS failed on June 30, 1997. The follow-on scatterometer for monitoring ocean winds, called SeaWinds, is scheduled for launch on the Japanese ADEOS-II spacecraft in 2000. QuickSCAT is planned for launch in November 1998, reducing the data gap by about one-half.

An Investigators Working Group (IWG) meeting was held from November 4-6 in Atlanta, Georgia. As in the past couple of years, the primary focus of this meeting was on scientific accomplishments obtained thus far by various EOS investigations. Participation was high, and included (i) a poster session on EOS validation plans in the next couple of years, (ii) science accomplishments in the areas of seasonal-to-interannual climate, atmospheric chemistry, and land cover/land use change, and (iii) integrated assessments of the consequences of global change for the nation, based on assessments of climate variability and change reflected in regional workshops conducted in 6 regions of the U.S. Plans and progress to date on two Earth System Science Pathfinders (ESSP), scheduled for launch at the beginning of the next decade, were also presented.

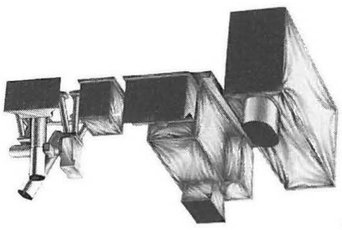
These included the Vegetation Canopy Lidar (VCL), which will map vegetation canopy heights, and the Gravity Recovery and Climate Experiment (GRACE), which will measure the Earth's geoid more accurately for the purpose of improving the accuracy of ocean altimetry. One science result of note was the report that stratospheric cooling, which accompanies tropospheric warming from greenhouse gases, appears to have lowered stratospheric temperatures to a point where polar stratospheric clouds, essential for the destruction of stratospheric ozone, have increased from 5-10% in the late 1970s to a current level of nearly 50%.

Finally, I am happy to report that the Tropical Rainfall Measuring Mission (TRMM) spacecraft arrived safely at the Tanegashima Space Center (TnSC), Japan, on August 23. In addition to the Precipitation Radar (PR),

(Continued on page 7)

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting

— by *Andrew Morrison* (andy@lithos.jpl.nasa.gov), Jet Propulsion Laboratory, CA



The thirteenth ASTER Science Team meeting was held May 20-23 in Sioux Falls, South Dakota. Approximately 100 participants attended the meeting. Progress was made in several areas including: (1) instrument resource allocation and tracking; (2) the process for reaching an agreement on the initial checkout period data acquisitions (launch+40 to launch+105 days); (3) joint development of mission analysis tools; and (4) plans for the data product validation experiments scheduled for this summer. In addition, the Joint Review Committee for Science Team Acquisition Requests (STARs) was formed and had its first meeting—this committee will review and approve requests for data acquisitions that are of interest to more than one investigator. The meeting included an opening Plenary Session, meetings of the various ASTER Working Groups, and a summary Plenary Session. The following narrative notes are excerpted from the opening and closing Plenary presentations and discussion.

Plenary I

R. J. Thompson, Manager of the Land Processes Distributed Active Archive Center (DAAC) at the U.S. Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center welcomed the ASTER Science Team. He expressed his appreciation for the opportunity to work with the ASTER Science Team.

A. Kahle reported that the ASTER Data Acquisition Request (DAR) Entry Tool and ASTER Home Page were both demonstrated at the IWG meeting in San Diego. She indicated that both were well received by the attendees who entered several DARs into the database. She also reported that:

√ At the SWAMP meeting, it appeared that the lunar calibration maneuver is going ahead. Y. Kaufman stated that he wants early mission data published within 40-to-60 days after launch.

√ A very successful TIR Workshop was held at JPL. The attendees unanimously supported a proposal to approach NASA HQ about flying the hyperspectral 2-meter resolution Spectrally Enhanced Broad-band Array Spectrograph System (SEBASS) instrument aboard a NASA aircraft.

√ The Japan AO has been issued. The U.S. will not issue an Announcement of Opportunity. Instead, the ASTER Science Team will accept and review unsolicited proposals for DARs and Science Team Acquisition Requests (STARs).

Y. Yamaguchi reported late news and Project status. He said that:

√ The ASTER instrument system proto flight model (PFM) tests were completed in February. The test data will be available to ASTER Science Team members.

√ The ASTER instrument was delivered to NASA in February.

√ Distribution of Japanese AO survey letters started in March. 1200 letters were sent out. More than 100 letters of intent have been received so far.

√ Development of the ASTER Global Data Set (GDS) is in progress and will be reported later in the meeting.

S. Lambros reported on the status of the ASTER instrument and other ASTER activities and the EOS AM-1 status and science maneuvers. He said that:

√ The instrument was delivered to Lockheed Martin Missiles and Space (LMMS), Valley Forge, on February 28, 1997. Mechanical integration was begun on May 7 and was expected to be completed by the end of May.

√ Both mechanical and electrical integration of CERES into the spacecraft was complete. The other instruments will follow ASTER.

√ Maneuver requirements and definitions will be documented in the Unique Instrument Interface Document (UIID) and instrument Interface Control Documents (ICDs), respectively. All Science maneuvers will be performed by reaction wheels; no thrusters will be used. Maneuvers will include CERES yaw, MODIS yaw and roll, and a deep space calibration constant-rate pitch maneuver.

Lambros is leaving the Project. He expressed his pleasure at having been a part of ASTER. He said that the new ASTER Instrument Manager contact will be Art Unger at 301-286-6161; e-mail arthur.unger@gsfc.nasa.gov.

M. Kudoh of the Japan Resources Observation System Organization (JAROS) reported on the ASTER instrument status. He noted that ASTER was the first EOS AM-1 instrument to be delivered. Following a successful Bench Acceptance Test (BAT), formal delivery was acknowledged by NASA, JAROS, and LMMS on March 19. A Spacecraft Comprehensive Performance Test is scheduled to begin in August of 1997. Various tests will continue until March, 1998, and launch site activities will be performed in May and June of 1998 at Vandenberg.

K. Ogikubo reported that the ASTER PFM Tests and Reviews were completed successfully in Japan, and the same functions and performance were verified by the ASTER post-shipment BAT. He presented examples of calibration data.

H. Watanabe reviewed the development status of the ASTER GDS. To begin, he showed a viewgraph depicting the management structure of ASTER in Japan: the "ASTER Trinity," in which Watanabe manages the ASTER GDS Project, Mr. Kawakami manages the ASTER Science Project, and Mr. Kudoh manages the ASTER Instrument Project. He then reviewed the GDS development mechanism and major Project milestone dates on the Japan and U.S. sides up to May of 1997. He reported three major new developments:

√ Design of the direct receiving station (DRS) has begun. 25 scenes per day will be downlinked, and selected data will be transferred to GDS for Level-1 processing.

√ Design for a web-based Data Acquisition Request Data Product Request (DAR/DPR) system has begun.

√ Design of a billing/accounting system has begun.

He reviewed the GDS schedule and the status of interface documents that involve the GDS. Finally, Watanabe said that the GDS will be able to produce expedited data to support early mission activities at about three times the rate projected for the rest of the mission.

Rick Obenschain reviewed the EOSDIS and ECS status for the Science Team. He announced that emergency back-up funds have been allocated and are being held to support AM-1, Landsat 7, and SAGE III, and he presented the status of the emergency back-up plans of the AM-1 instruments.

H. Fujisada presented the ASTER Level-1 development schedule and status. He also presented processing parameters and discussed the bad pixel replacement algorithm (simple linear interpolation method).

T. Kawakami summarized the Operations and Mission Planning Working Group (OMPWG) *ad hoc* meeting that was held in Tokyo, March 5-7, 1997. Among the topics addressed at that meeting were:

√ The status of the global prioritization map—the final version was presented.

√ The Japan AO status—1240 copies of the pre-announcement document were distributed: 107 were sent to the U.S.

√ Finalizing the Long Term Instrument Plan (LTIP)—the final version will be circulated for signatures.

√ The resource allocation plan—a revised resource allocation plan was confirmed.

√ The All-Data-Acquisition-Requests (xAR) Data Base (dB) status—an Earth Resources Satellite Data Analysis Center (ERSDAC) Science Server is planned. The flow of dB entries to GDS needs to be defined.

√ The STAR proposal review process—a STAR Review Committee will be formed and will meet for the first time at South Dakota.

√ Early mission data acquisition strategies—early mission activities and data acquisition priorities were agreed to.

√ Scheduling issues—scheduler performance test revealed improved performance.

A. Kahle asked that, in order to be responsive to Y. Kaufman's request for early mission results, the Science Team develop at this meeting a list of targets for the first 60 days of the mission. She said that for days 40 through 105, she expects targets to include Calibration and Validation sites, synergy with other instruments, "Hot" science, Public Relations (PR), and Global Map targets. Days 105 through 180 will continue Cal/Val algorithm test sites, Global Map, long-term-monitoring STARs, DARs for Team Members, and possibly other DARs.

I. Sato projected that a draft version of the ASTER Users' Guide would be ready for review at the December Science Team meeting in Japan, and that Version 1 (Launch Version) would be prepared by the end of March, 1998, and would be available for users by the end of the Initial Checkout Phase of the mission.

Y. Yamaguchi presented the final version of The Global Data Set Prioritization Map. He reviewed the process of the development of the Global Prioritization Map and summarized the schedule and details of the update of the map. The final global prioritization map is composed of 2 layers, a priority map layer and a parameter layer.

Ed Zalewski presented Vicarious Calibration VNIR-SWIR cross-comparison. He reviewed the results from last year's field experiment, which showed a 5% variation in VNIR results and 20% variation in SWIR results. He reviewed the objectives for this year's experiment and presented the schedule for this year's field activities.

Y. Yamaguchi presented "Issues for Discussion." Among them were:

√ Early Mission Activities—the final list of targets for the Initial Checkout phase would be completed by June 1.

√ ASTER Validation Plan—the revision of the Plan should be completed by July 11. It should be updated quarterly and a final pre-launch version should be completed in May, 1998.

√ STAR Generation Plan—descriptions of the xAR input processes and Geology WG plans for xAR inputs as an example. He also described the Proto-STAR Input process and a proposed schedule of Proto-STAR input to the Scheduler.

A. Kahle also discussed STAR collection. She noted that there is an immediate need for a realistic list of prospective STARs that represent the entire community. She reviewed the STAR proposal review process and the make-up of the Proposal Review Committee.

Plenary II

The second Plenary Session, held on the last day of the meeting, was composed of reports by the individual Working Groups on their sessions, a review of the ASTER calendar, and meeting wrap-up.

Y. Yamaguchi summarized the STAR Review Panel meeting. He reviewed the STAR Proposal Approval and Submission Process, which requires review of each STAR by the relevant ASTER Science Team Discipline Working Group. The Panel hopes to have a list of planned regional and local at-launch STARs by September '97 and completed at-launch STARs with xAR parameters by February '98.

E. Zalewski, Radiometric Calibration WG, said that the Radiometric Validation Plan Document will be delivered to S. Hook by mid-July. A possible vicarious calibration cross comparison in Tsukuba, Japan, to coincide with the next Team meeting, was discussed. There were also further discussions about future round-robin measurements and the status of NIST participation in the round robin.

H. Kieffer said that the Geometric Calibration WG discussed the planned AM-1 yaw maneuvers, but questioned whether ASTER will make any use of them. They do recommend a change to the UIID to include a note stating that the Lunar Maneuver shall be performed during Initial Check Out (ICO), six months later, and then at one-year spacing. Some refinements are still necessary in the list of Geometric test sites from the U.S. and Japan.

G. Geller summarized the Level-1 WG meeting. In that meeting, the Japanese L-1 developers said that:

√ Processing time benchmarks had increased a little due to algorithm updates, but that they were still within expected hardware limitations.

√ The Geometric Accuracy Test results showed some inconsistency in the TIR—this is currently under investigation.

√ They wanted to make clear that the product of the L-1A Cloud Assessment Algorithm is only an estimate whose accuracy will be improved by refining the band thresholds after launch.

M. Pniel, Operations and Mission Planning Working Group, said that the U.S. and Japan have agreed that, in the period Day 105 through Day 180, DARs will be limited to 'important' acquisitions. Japan and the U.S. continue to agree on the concept of constraints on the amount of requests scheduled for the first one-to-two years. He also said that the Instrument Support Terminal (IST) schedule for the installation of the IST in the U.S. is about 6-10 weeks behind, but that Watanabe had guaranteed the new mid-September, 1997 date.

The U.S. and the Japanese agreed that an operations manual is needed for use during normal operations. ASTER GDS will provide the manual for the Instrument Control and Operation System (ICOS) operator.

H. Lang summarized the presentations and discussions in the Digital Elevation Model (DEM) WG meeting. He said that all 12 DEM Standard Data Product validation sites in the DEM Algorithm Theoretical Basis Document (ATBD) and in the test site database have been submitted to be targets during days 40-105. The same sites are also submitted to be Local STARs to be collected annually. In addition, the WG proposed the Himalayan Mountains (Mt. Everest) and Vatnajoicull, Iceland, to be Early Mission PR/Hot sites.

F. Palluconi said that the Atmospheric Correction Working Group issues and actions included:

√ The WG will submit a single major STAR for cloud observations to support MODIS and CERES.

√ Five validation sites have been identified to be viewed at every opportunity during Days 40-105 after launch.

√ The correction algorithm for Adjacency Effect has been demonstrated through simulation for land/water transition for clear and hazy conditions. Speed improvements are underway.

√ The prototype Polar Cloud Mask algorithm for day-time observations has been delivered to JPL. Work continues on the nighttime version.

√ June 1997 field campaign plans are well under way. Participants will include personnel from U.S. and Japan ASTER, MODIS, Landsat, MISR, and several other U.S. and Canadian organizations.

Alan Gillespie reported that the Temperature-Emissivity (T-E) WG produced its list of STARs and Early Mission Target requirements. They propose to add a tropical site to their test site list—probably in conjunction with the Amazon people. He added that they hope to use SEBASS to validate their algorithm. With SEBASS, they can simulate ASTER data without having to worry about introducing errors during the process of producing simulated data. He said that a major concern with the present design of the algorithm is the difficulty of getting precise temperatures and emissivities in a case where the downwelling radiation is a large part of the emitted radiation.

H. Kayanne, Ecosystem WG, presented:

√ The domestic Japanese validation sites which have already been submitted for scheduling.

√ The WG's outside-Japan Regional Monitoring and Local STARs. Most of these center on the east-Asian region.

√ Possible local and regional STAR candidates from Long Term Ecological Research (LTER) sites. The STARs were presented by category (wetland, arid land, LTER, etc.).

√ Early observation and PR targets.

M. Abrams reported that the Oceanography WG had identified Biwa Lake, Shinji Lake, and Tokyo Bay as its validation sites for Days 40-105 of the early mission. Their objective is to acquire each target two times during the 65-day period.

L. Rowan summarized the Geology Working Group meeting. The meeting included status updates of science activities by P. Christensen (Urban Monitoring Potential of ASTER and Monitoring Sediment Transport in the Mojave Desert using TIMS data), D. Pieri (Volcano Monitoring), and B. Raup (Global Land Ice Monitoring from Space [GLIMS] Progress). Y. Yamaguchi reported on a problem with defining the sun angle for global mapping. The WG will produce STARs to collect data about volcanoes, glaciers, deserts, and coastal zones, and they identified several additional topics to which ASTER might contribute. They also identified three validation sites for d-stretch: Cuprite, Death Valley, and Mt. Fitton, and they proposed four additional PR sites: Yellowstone National Park, Chesapeake Bay, Las Vegas, and Phoenix.

G. Geller reported on the proceedings of the Higher Level Data Products Working Group meeting. A list of proposed Vicarious and Cross-calibration STARs for the period 40 days after launch through 105 days after launch was presented.

L. Rowan summarized all the discussion and commitments for the special ASTER JGR publication by presenting a list of eight potential papers. They were:

√ ASTER Instrument, Data Acquisition, Science Objectives, Data Flow;

√ Calibration/Validation (2);

√ Atmospheric Correction (2);

√ Temperature/Emissivity Separation (covering the algorithm, algorithm validation, and characteristics of the T/E Separation product);

√ DEM (will be submitted by Lang, Welch, and Murakami); and

√ Polar Cloud (Part III of III of a Polar Cloud Mask paper).

The next ASTER Science Team meeting will be held December 9-12 in Yurakucho, Japan.

(Continued from page 2)

Editor's Corner

TRMM Microwave Imager (TMI), and Visible and Infrared Scanner (VIRS), TRMM carries the first two sensors developed as part of the EOS program: CERES (Clouds and the Earth's Radiant Energy System) and LIS (Lightning Imaging Sensor). TRMM was successfully launched on November 27, and will fly in a mid-inclination (35°) precessing orbit at an altitude of 350 km. This international cooperative mission should provide invaluable measurements of precipitation in the tropical, 'heat-engine,' region of the Earth's atmosphere. Heat released in the atmosphere due to tropical precipitation is a major driver of atmospheric circulation.

— **Michael King**
EOS Senior Project Scientist

The first Biennial Review of Mission to Planet Earth was conducted in 1997. The Review focused on five key areas: EOS Chem-1 Mission Architecture; EOSDIS Core System; Program Balance; Technology Infusion Strategy; and the Implementation of MTPE Program After 2002. This document is available electronically via the Internet at the Mission to Planet Earth Home Page: http://www.hq.nasa.gov/office/mtpe/ under "What's News." Paper copies are available by calling (202) 358-3552.

First JPL Workshop on Remote Sensing of Land Surface Emissivity

— *Andrew Morrison* (andy@lithos.jpl.nasa.gov), Jet Propulsion Laboratory, CA

Summary

A very successful First JPL Workshop on Remote Sensing of Land Surface Emissivity was held at the Jet Propulsion Laboratory May 6-8, 1997. The workshop was organized by Anne Kahle and Dave Nichols of JPL, and Alan Gillespie of the University of Washington. Over fifty remote-sensing specialists from universities, government laboratories, and industry in the United States, France, the Netherlands, China, and Japan participated. The objectives of the workshop were to provide a comprehensive assessment of the past, current, and future technologies for thermal infrared (TIR) remote sensing, to identify current and potential uses for data in this region of the spectrum, and to identify the steps necessary to realize these objectives. Scheduled sessions addressed instrumentation, applications, and temperature-emissivity extraction. There was a great deal of information exchange both inside and outside of the technical sessions. An informal evening session covered a wide range of topics, including the trade-offs between pursuing new technologies (the 3-5-µm range, thermal and spatial resolution, algorithm development, etc.) or new science objectives. The group unanimously supported a concept introduced by Jeff Myers of Ames that NASA should fly the Aerospace Corp. high-resolution hyperspectral Spectrally Enhanced Broad-band Array Spectrograph System (SEBASS) instrument over sites of investigators to be selected via a NASA Research Announcement (NRA). Anne Kahle (JPL), Alan Gillespie (University of Washington), and Jeff Myers and John Hackwell (Aerospace) will follow up on the concept. The next workshop will be held in the summer of 1999.

Narrative Minutes

Diane Evans, representing JPL, welcomed the attendees to the Laboratory. She noted that the ASTER Project continues a long history of TIR remote sensing at JPL. She said that two objectives of the workshop are to understand the broad community's needs in thermal infrared sensing and to look for cooperative ventures to follow ASTER.

Overview Session

Alan Gillespie noted that this workshop is intended to complement other TIR workshops. He said that the rationale for holding this workshop at this time was the advent of new detectors/sensor systems, the upcoming launch of ASTER and MODIS, and the need to plan for the next decade in TIR remote sensing. He reviewed the special problems involved in land surface TIR sensing.

Anne Kahle presented an overview of thermal infrared remote sensing including:

√ fundamentals such as the process of deriving the properties of surface temperature and spectral emissivity from the observed variable of spectral radiance;

√ commercial and operational applications;

√ science applications; and

√ a survey of airborne and spaceborne multispectral thermal infrared instruments.

She emphasized the importance of letting the technology continue to improve to meet the demands of a new user community.

Alan Gillespie presented an overview of temperature-emissivity (T-E) extraction techniques. He pointed out that T-E extraction from remotely-sensed data is based on the assumption of homogeneous, isothermal, flat pixels, but that the assumptions are commonly violated. He followed with methods to obtain temperatures and emissivities as a function of the number of bands of data collected. He reviewed the multispectral and hyperspectral algorithms used to derive temperature and emissivity and noted that the large number of algorithms points out the artfulness needed to solve the problem. He also discussed the kinds of non-quantitative information that can be obtained from multispectral thermal infrared data that can be used to satisfy several different kinds of science communities without providing precise or accurate temperatures.

Stillman Chase presented an overview of thermal infrared technology. He talked about desirable TIR detector attributes and then described the characteristics of the various detectors available in the market today. His presentation emphasized the new silicon microbolometers produced by Santa Barbara Research Center (now SBRS Santa Barbara Remote Sensing) and Amber (both Raytheon subsidiaries).

Instrumentation Session

Sarath Gunapala (15 μm 128x128 GaAs/$Al_xGa_{1-x}As$ Quantum Well Infrared Photodetector (QWIP) Focal Plane Array (FPA) Camera—Gunapala and Bandara) spoke about the status and characteristics of the FPA Camera. He noted that four QWIP cameras have been sold to date by the manufacturer (Inframetrics). In addition, Inframetrics hopes to soon have available their new "palm-sized" QWIP camera.

Ed Blazejewski (Application of QWIP FPA Technology to the Integrated Multispectral Atmospheric Sounder (IMAS) - Blazejewski) noted that IMAS, which is in its formative stages, is currently viewed as the next-generation flight instrument after AIRS. He described the IMAS instrument and mission concepts, goals, and the instrument development approach and status.

A demonstration of the QWIP camera preceded the lunch break.

Anne Kahle (ASTER and Beyond—Kahle and Nichols) described the history, design, and characteristics of the ASTER instrument, and she presented an overview of the ASTER mission. This included operational constraints on instrument usage and the plan for allocation of instrument viewing resources. ASTER will be scheduled to collect an all-radiometer global data set, data for regional monitoring, and also targeted data for individual investigators. She then addressed the future for multispectral thermal infrared, noting that there are no TIR instruments scheduled to be launched after ASTER. She described Sacagawea and Sacagawea Light, concepts for compact high-resolution ASTER multispectral thermal infrared follow-ons being proposed by JPL.

Peter Kealy (ESA's Candidate Earth Explorer Mission for Land-Surface Processes: Its Thermal Capabilities—Kealy, Caselles, Coll, Rubio, and Valor) presented ESA's basic objectives and then explained that the Earth Explorer Mission is one of two missions planned to achieve ESA's objectives. He presented the mission requirements and instrument specifications — TIR channels at 8.45 and 8.95 μm will each have 0.5-μm bandwidth, T_{min} of 212 K, T_{max} of 360 K, and NEΔT@300 K of 0.1 K. He also presented the split window algorithm that will be used to extract land surface temperature and the Vegetation Cover Method that will be used to estimate emissivity. He concluded with the schedule from Phase A kick-off at the beginning of '98 through launch at the end of '03.

Carl Schueler (Advanced Multispectral TIR Land Imaging Sensor Concepts—Schueler and Blasius) described and compared the technologies and capabilities of two sensor concepts, multispectral uncooled microbolometers in a Pushbroom Imager vs. a hyperspectral Wedge Imaging Spectrometer (WIS). His conclusions were:

- √ sensors based on new uncooled microbolometer arrays promise ≈0.2-0.6 K NEΔT at ≈10% Δλ/λ, for Landsat-like spatial resolution, 60-200 m, by heavily exploiting Time Delayed Integration (TDI) (40 samples merged);
- √ cooled HgCdTe detectors offer NEΔT ≈1.5% Δλ/λ for 60-m spatial resolution with no TDI (potential is there); and
- √ microbolometer-based sensors will offer size/mass/power/cost savings for missions with lower spatial /spectral resolution requirements.

Simon Hook (Synergy of Active and Passive Airborne Thermal Infrared Systems for Surface Composition Mapping—Hook, Cudahy, Kahle, and Whitborne) described work collecting and comparing data from the Thermal Infrared Multispectral Scanner (TIMS) and the Australian Mid-infrared Airborne CO_2 Laser

Spectrometer (MIRACO_2LAS)). Data were collected over Mt. Fitton, South Australia, and processed to provide surface composition information (emissivity in TIMS and reflectivity in MIRACO_2LAS). The results compared well with field emission spectra and laboratory measurements. The authors conclude that future thermal infrared systems designed for geologic mapping should include both an imager for mapping units and a high-spectral-resolution profiler for mineral identification.

John Hackwell (LWIR/MWIR Imaging Hyperspectral Sensor for Airborne and Ground-based Remote Sensing—Hackwell, Warren, *et al.*) presented the Aerospace Corporation-sponsored SEBASS instrument history, design, and characteristics. The design goals (all achieved) of this line-scanner instrument included:

√ Operate in 2.1-to-5.2-µm and 7.8-to-13.5-µm bands
  ◊ Observe entire spectral range at once
  ◊ Resolving power $\lambda/\Delta\lambda$ of 200

√ Highest possible sensitivity

√ Operable from aircraft or ground-based platform

√ Ground sample distance 0.5 - 3 meters from 15,000
  ◊ 10,000 ft AGL

The SEBASS data cube is characterized by:

√ 128 pixels cross-scan

√ 6000 lines in-scan (maximum)

√ 256 wavelength bands
  ◊ 128 in LWIR: 7.8 - 13.5 µm
  ◊ 128 in MWIR: 2.1 - 5.2 µm

He also presented data showing the optical performance of the instrument and the spectral resolution of the LWIR and MWIR channels and median Noise Equivalent Spectral Radiance (NESR) of the two arrays (NESR $<10^6$ W/cm^2/ster/µm at 120 Hz [8 msec]).

Anu Bowman (Hyperspectral Mine Detection—Lucey, Williams, Julian, Kokobun, Stocker, Kendall, Schaff, Winter, Schlangen, Batik, and Bowman) talked about a Defense Advanced Research Projects Agency (DARPA) -sponsored two-phase effort to detect buried land mines. Phase 1 was a non-imaging phenomenology investigation and Phase 2 was an empirical study of remote detection of buried land mines. The empirical effort demonstrated that under some conditions, the ability of the hyperspectral sensor to distinguish disturbed soils could be used as a tool to locate buried land mines.

Applications Session

Frank Palluconi (Thermal Infrared Atmospheric Correction—Palluconi, Thompson, Alley) described the ASTER thermal infrared subsystem and the TIR atmospheric correction algorithm approach. He listed the atmospheric parameters and the effects of each on derived radiance. He also provided web sources for all of the NOAA data files used by the algorithm.

James Crowley (Death Valley Field Spectra/Image Data—Crowley and Hook) used remote sensing to survey the mineral suites of the evaporites in Death Valley. They were able to characterize the chemistry of the groundwater in the basin by studying the distribution of the various evaporites.

Tsuneo Matsunaga (ASTER Simulator Flight Experiment—Matsunaga, Rokugawa, Tonooka, Kannari, and Kato) presented the results of the 1996 flight experiment at Cuprite. He said that they plan to upgrade the instrument to improve the signal-to-noise ratio and also plan to tune the algorithm to better support the ASTER Airborne Simulator (AAS).

David Ripley (The Application of Atmospheric Corrections to Arbitrary Vegetation and Temperature—Ripley and Carlson) reported that he and T. Carlson have observed that, under certain circumstances, it may be possible to omit the application of atmospheric corrections and substitute temperature and albedo to obtain values of related surface parameters such as surface soil water content and fractional vegetation cover. An example using NOAA-9 AVHRR data was presented.

Mike Ramsey (Monitoring Potential Desertification via Airborne TIR Data: Sediment Transport in the Mojave Desert, California—Ramsey and Christensen) characterized mineral distributions in the Kelso Dune field in the Eastern Mojave and correlated TIMS data with mineral samples analyzed in the laboratory. The analyses confirmed that the dune fields did contain variations observed in the TIMS data, and that the fields were less mature than previously reported. The authors demonstrate that use of multispectral TIR data can provide the geologist with a synoptic look at the entire eolian system and argue that monitoring programs using instruments such as ASTER can benefit studies of dune encroachment and desertification.

Tom Schmugge (Application of TES algorithm to TIMS Data from the HAPEX-Sahel—Schmugge) reported that he tested a version of the Temperature/Emissivity Separation (TES) algorithm on TIMS scenes from the Hydrological and Atmosphere Pilot Experiment (HAPEX)-Sahel experiment. There was excellent reproducibility on data taken on the same day, but with differences noted for data taken on subsequent days—he speculates that this may have been due to changes in soil moisture. Temperatures for the vegetated areas are in good agreement with the air temperature at the time of the flights.

Tong Qingxi (Study on Some Land Surface by Thermal Infrared Multispectral Remote Sensing—Tong) reported on the development and application of the Modular Airborne Imaging Spectrometer (MAIS), described the application of the multispectral TIR system for retrieving temperature and emissivities, and discussed the T-E extraction methods used. He also described the 'ratio-weighted' method for extracting relative emissivity.

Dave Pieri (An Overview of Volcanological Application of Infrared Remote Sensing—Pieri and Realmuto) discussed the various applications of multispectral thermal infrared to volcanological studies including:

√ mapping the relative ages of lava flows based on emissivity variations;

√ mapping abandoned lava tubes based on detection of alteration near fumaroles or vents;

√ mapping high- and low-temperature geothermal features using the VNIR, and the short- and longwave infrared channels; and

√ mapping SO_2 and ash plumes based on absorption of ground radiance by the plumes.

He pointed out that, for several reasons, remote sensing is particularly well suited to monitoring dynamic volcanic processes.

John Schieldge (Comparison of Surface IR Radiometer and Near Surface Air Temperatures Over a Grass-Covered Field—Schieldge) reported that large-scale surface temperature fluctuations, due to turbulent horizontal eddy motions, could skew the results of TIR data taken during such temperature excursions. He concluded by advising that the effects of large-scale 'inactive' eddies may have to be taken into consideration in algorithms that are used to compute energy fluxes near the Earth's surface.

Kevin Czajkowski (Vegetation and Hydrology Applications—Czajkowski) listed air temperature, drought/soil moisture, and atmospheric moisture as variables that can be estimated using TIR data and land surface temperature. He gave examples of derived Temperature/Spectral Vegetation Index (TVX) and air temperatures. He presented four approaches that have been reported that can be used to estimate atmospheric water vapor: the split window technique, ratio of channel 4 and 5 variances, slope of channel 4 and 5 regression, and use of a radiative transfer model.

Alan Gillespie (Geologic Mapping in the Middle Mountains, Yuma County, Arizona, with SEBASS Hyperspectral TIR Images—Gillespie, Hackwell, Alexander, Alley, Cothern, Grove, Kahle, and Smith) reported on an experiment using the SEBASS hyperspectral TIR instrument to map rock-type distributions in Arizona. His objective was to present a 'sense' of the analytic process supported by SEBASS images. His conclusions included:

√ Hyperspectral TIR imaging will allow recovery of emissivity spectra and geologic mapping and rock-type identification.

√ Keys are:
- ◊ good NEΔT
- ◊ Sufficient $\Delta\lambda$ to resolve emissivity features (e.g., <0.5 µm)
- ◊ in-scene atmospheric corrections (pixel-by-pixel)
- ◊ lack of requirement for registration to Digital Terrain Model (DTM)

X. F. Gu (Short-term Fluctuations of Brightness Temperature Measured with a Thermal Video Camera—Gu, Lagouarde, Seguin, Hanocq, and Prevot) described the characteristics of their thermal video camera (256x250 pixels, FOV 7°, 20° or 80°, 26 images/sec, three spectral channels [8-13, 10-11.5, 10-13 µm], radiometric resolution of 0.1 K, Sterling cooled to 77 K) including a noise evaluation of the camera and the effects of digitization. He then presented data of observed temperature fluctuations of a sorghum canopy and of a forest surface. He reported that they also measured wind speed in four directions at the target and attempted to relate wind fluctuations to observed temperature fluctuations. He concluded that temperature measurements of 40-m resolution are significant, but wind fluctuations must be taken into consideration in satellite dual-angle observation, airborne measurement, and in-field sampling.

Alan Gillespie (Field TIR Imaging Experiments—Bland, Gillespie, and Kahle) used two experiments to relate 'snapshots' of temperature fields (equivalent to images taken from space) to short time series data of phenomena that vary with periods of minutes, etc. Data were taken using JPL's QWIP detector camera. False color displays (chronochromes) were produced. Conclusions drawn from a short time series of data from forests included:

√ short-term fluctuations may be due to wind;

√ changes due to sensible heat exchange are significant (e.g., ≈4 K) at the 5-minute time scale;

√ short-term variability will have implications for temperature product accuracy (but still may need accurate temperature for emissivity recovery); and

√ field imagery may prove useful in quantifying sensible heat exchange from canopies.

Conclusions from a day/night forest community mapping experiment were:

√ day/night ΔTs for conifers/deciduous stands behave as predicted; and

√ ΔT can be used as a basis for community mapping.

Kyle Bland presented a video tape showing the variability with time of temperature over a tree canopy. With the QWIP camera pointed at a buckeye tree (deciduous), wind-related local temperature variations of up to four degrees were observed (vs. 0.2 deg. instrument noise). Passing cloud shadows caused temperature variations of up to seven degrees. The demonstration highlighted the danger of dependence on 'snapshot' data and the importance of scale in temperature measurement.

Temperature/Emissivity Separation Session

Ken Watson (Three Algorithms to Extract Spectral Emissivity Information from Multispectral Thermal Data and Their Geologic Applications—Watson) is using remote sensing to study the geological units at Joshua Tree National Monument. He presented a historical review of the "two temperature" and "emissivity ratio" algorithms and then described his new "Inverse Wave" algorithm. The use of the new algorithm requires that you use the same algorithm when you analyze laboratory data as well. He showed the effect of removing $1/\lambda$, which is one feature of the new algorithm. One potential advantage is the removal of $1/\lambda$ levels from the spectra without losing the spectral shapes necessary to identify the minerals. He also developed an algorithm for when you have two overlapping flight lines which have the same data from different angles. Finally, he juxtaposed AVIRIS and TIMS data to show the complementarity of the two data sets.

Anu Bowman (Empirical Solutions for Land Surface Temperature Estimation from Thermal Remote Sensing: The Emissivity Factor—Bowman) using a derivative analysis of the radiance equation performed an empirical assessment of J. Salisbury's database in order to determine the role of emissivity in determining surface temperature (her Master's thesis). She concluded that:

√ emissivity spectrum is "flat" in portions of the thermal spectrum; and

√ direct calculation of surface temperature using laboratory-derived emissivity values is possible.

Alan Gillespie (TES: The EOS/ASTER Temperature/Emissivity Separation Algorithm—Gillespie, Rokugawa, Hook, Matsunaga, and Kahle) presented the basic structure and flow diagram of the algorithm and showed examples of emissivity and temperature recovered from Railroad Valley data by the algorithm. He summarized by saying that the accuracy of TES depends on ASTER's radiometric accuracy and the accuracy of the atmospheric compensation. He also discussed the advantage of sacrificing ASTER's band 10 (as proposed by Simon Hook), the shortest wavelength of the five TIR bands, which is the most error prone due to water vapor. This approach will be adopted in the algorithm. He also said that he is going to propose that for areas where the surface appears to be a black- or graybody, we should assume that we know the emissivity and derive the temperature, and then back-calculate the emissivity.

He noted that ASTER doesn't go out to 12-14 μm, and so TES doesn't specifically address this region. When applied to hyperspectral data, such as SEBASS data, the performance of TES in this region will have to be examined.

Zheng-Ming Wan (A Multi-method Strategy for Remote Sensing of Land-Surface Emissivity—Wan, Snyder, Zhang, Feng, and Li) listed the following four elements of their strategy for remote sensing of land-surface emissivity:

√ laboratory measurements

√ field measurements

√ airborne measurements

√ satellite measurements

He described the MODIS day/night method including the underlying physics, assumptions, and new features. He also described the sun/shadow method (similar to the day/night method) including its physics and advantages. He reviewed the MODIS team's validation methods and results (from Death Valley, Railroad Valley, and Mammoth Lake) and their error analysis.

Christopher Borel (Iterative Retrieval of Surface Emissivity and Temperature for a Hyperspectral Sensor—Borel) reviewed the problem of retrieving emissivity and temperature from remotely-sensed data and then presented a new technique to retrieve emissivity spectra from hyperspectral data. Using synthetic data and a thermal model described in his presentation, he generated a series of data cubes. He analyzed the results for temperatures and emissivities using an algorithm which depends on the smoothness of the spectral emissivity and variable temperature (Adaptive Spectrally Smooth E-T Retrieval—ASSETR-δT) and a similar algorithm with variable emissivity (ASSETR-δε). He demonstrated the effects of unknown atmospheric parameters. All of these simulations were illustrated in a video presentation.

Masao Moriyama (Sensitivity Analysis of Surface Emissivity Estimation—Moriyama) presented a summary of his work to develop a sensitivity of Quality Assurance (QA) error for ASTER pixels by varying the tunable parameters in the ASTER TES algorithm and applying an error-propagating formula to evaluate emissivity uncertainty.

X. F. Gu (Estimation of Spectral and Directional Thermal Emissivity from Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) Data Acquired Over the La Crau-Camargue Region—Gu, Seguin, Guyot, Hanocq, Clastre, and Wang) described data collected by the airborne MIVIS instrument and the radiometric and atmospheric correction applied to it. He showed the process flow for emissivity determination. He also showed the spectral variation of emissivity for different surfaces and the results of normalization of the spectral variation using a body of water. He then showed the relationships between temperature, emissivity, reflectance, and vegetation index for temperature-reflectance, temperature-Soil Adjusted Vegetation Index (SAVI) and emissivity-Normalized Difference Vegetation Index (NDVI).

Open Discussion Session

A special Open Discussion Session was held the evening of the second day of the workshop. The objective of the session was to bring out ideas that might not come out of the more-structured meeting sessions. Discussion topics are summarized here.

Dave Nichols presented a draft revision to the MTPE plan from NASA HQ. It included a proposed list of measurements to meet MTPE scientific priorities. Nichols asked:

√ What kind of science do we want to work on for MTPE?

√ Is there science we can do that is desired by more than one agency?

√ Do we want to proceed with some facility instrument to satisfy a large number of users, or should there be more focused efforts to satisfy individual users?

√ Do we want to ask what kind of instrument we want to have flying up there in a couple of years, or do we first want to identify what data we want or need?

Anne Kahle added the question:

√ When does an aircraft program make more sense than a spaceborne program?

John Schott said there is a good chance that Landsat-8 will not have thermal channels, meaning that there won't be any high-resolution thermal instruments flying in the foreseeable future. He noted that industrial plumes, volcano plumes, and calibration should each justify flying thermal instruments—and just thermal; adding visible capabilities, he said, is more difficult and more expensive.

Anne Kahle asked about the status in this country of registration software and **Frank Palluconi** replied that the opportunity will be there because AM-1 and Landsat-7 will be flying synchronously, and it will be needed.

David Ripley urged building broadly capable flight hardware and making it available to the scientific community. He said that this would produce science users. **Ed Winter** said that HYDICE and AVIRIS are examples of instruments that have exceeded their original promise, and there's nothing like them in the longer wavelengths.

Zheng-Ming Wan urged including the 3-5-µm range. "It's the future for vegetation, moisture, geology, etc.," he said. He added that spatial resolution is also important. He said that for a single instrument he would choose high spatial resolution. **Sig Gerstl** agreed about the 3-5-µm range. He said that they just measured fluoride emissions from a volcano using a Fourier Transform Infrared Radiometer (FTIR) in this range.

Kevin Czajkowski stressed the more-immediate need for surface temperature. He said that currently there is not a lot going into surface temperature validation and scaling. Now it is needed from AVHRR, and it will be soon needed from ASTER and MODIS.

John Hackwell asked about the need for a follow-on instrument. Is it that the community will fail if there isn't a Sacagawea? **Anne Kahle** replied that the future depends strongly on a follow-on. "The funding could dry up without it." She added that hyper-spectral is the wave of the future, and it should be explored to see what opens up.

Ken Watson said that the USGS is now struggling with the new USGS role. He feels certain that remote sensing will play an important part there, but it has to be demonstrated that it relates to the new USGS problems.

Jeff Myers proposed an integrated joint ground campaign using current instruments, including flying SEBASS on a NASA aircraft. **John Hackwell** agreed, saying that we should explore new applications—determining a direction is not a technology issue. **Ed Winter** also expressed his support for the proposal.

Simon Hook suggested that investigators should propose to participate in such an activity. He noted that investigators will participate if data are collected over their own sites. He thought that 20-30 investigators might propose to a hyperspectral TIR campaign in the U.S. Southwest.

The attendees of the workshop unanimously endorsed the concept of a NASA NRA to solicit investigators for an integrated joint air and ground hyperspectral TIR campaign that would fly SEBASS on a NASA aircraft as well as other multispectral TIR instruments to collect data over the selected investigators' sites. John Schott, Alan Gillespie, Anne Kahle, and Jeff Myers will take the action to pursue this concept with NASA HQ.

Next Meeting

It was generally agreed that the next meeting should be held during the summer of 1999, after preliminary data from ASTER and the results of the next ground campaign are received, and that it should be held jointly with Zheng-Ming Wan's Land Surface Temperature Workshop.

Marine Optical Buoy (MOBY) Evolves, While Marine Optical Characterization Experiment (MOCE) Continues in Support of SeaWiFS, MODIS, and OCTS

— *David Herring* (herring@ltpsun.gsfc.nasa.gov), EOS AM Science Outreach Coordinator,
Science Systems & Applications, Inc. (SSAI)

(Editor's Note: A detailed introduction to the MOBY/MOCE effort was published in the January/February 1994 issue of The Earth Observer. To access that article, please refer to http://eospso.gsfc.nasa.gov/eos_observ/1_2_94/p17.html.)

In its continuing support of NASA's Earth Observing System (EOS), NOAA's MOBY/MOCE Team conducted ship cruises over this past spring, summer, and fall off the southern coast of Lanai, HI, to refurbish its Marine Optical Buoy (MOBY) and to obtain Marine Optical Characterization Experiment (MOCE) data that were used to initialize the Japanese Ocean Color and Temperature Sensor (OCTS), and NASA's newly-launched Sea-viewing Wide Field-of-view Sensor (SeaWiFS). (See Figure 1.) Funded jointly by NASA and NOAA, the ongoing MOBY/MOCE efforts are primarily in support of the SeaWiFS and MODIS (Moderate Resolution Imaging Spectroradiometer, launching next year aboard EOS AM-1) instruments.

MOBY's primary purpose is to measure visible and infrared solar radiation entering and emanating from the ocean (see Figure 2). By monitoring variations in the reflected radiation, other quantities can be derived, such as the abundance of microscopic marine plants (phytoplankton). Over the last 3 months, the upgraded MOBY has provided an excellent time-series database facilitating SeaWiFS and MODIS bio-optical algorithm development for remote sensing over oligotrophic (low biomass productivity) ocean waters. Complementing the buoy data, a number of MOCE campaigns

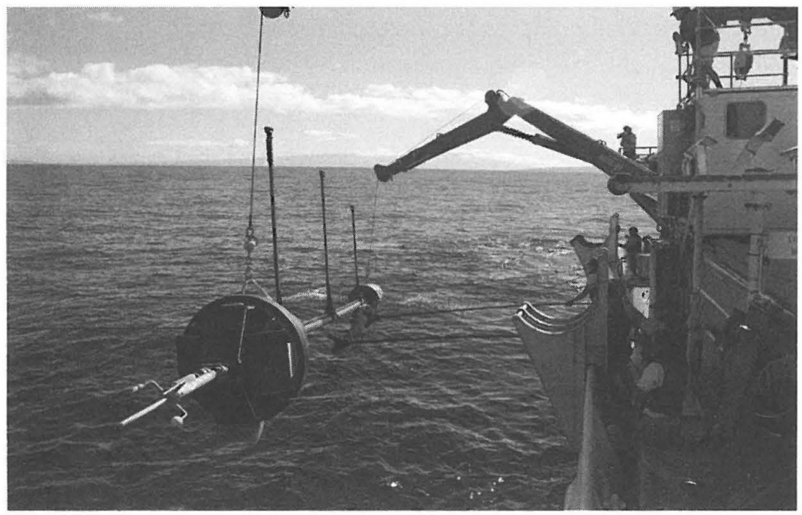


Figure 1. Shown here aboard the University of Hawaii's research vessel Moana Wave, the MOBY Team deployed one of the three newly-refurbished MOBY instruments off the southwestern coast of Lanai, HI this summer to provide data that will help in the initialization of SeaWiFS. (Photo courtesy of MOBY Team photo archive)

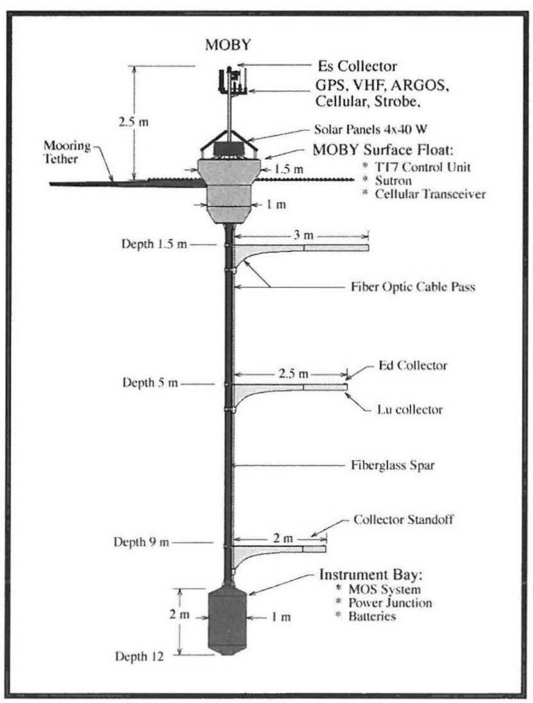


Figure 2. The Marine Optical Buoy measures visible and infrared solar radiation entering and emanating from the ocean. (Illustration courtesy of Gene Feldman, NASA GSFC)

were also conducted to collect some 38 oceanic physical and bio-optical measurements such as radiometry, pigment analysis, total suspended matter, beam transmittance, and attenuation coefficients.

"To make global observations from space, there must be long-term independent checks to ensure that the accuracy is there," explains Dennis Clark, MOBY/MOCE leader. "Our basic measurements, like phytoplankton concentrations, will be used to validate SeaWiFS' and MODIS' global primary productivity data products, which in turn figure significantly into the global carbon balance."

"We are also looking at what causes changes in ocean color, which is a basic science question," adds Charles Trees, oceanographer at San Diego State University's Center for Hydro-optics and Remote Sensing (CHORS). "What are the processes governing ocean color change? We're also gaining insights into those processes."

Although its prototype instrumentation has been successfully collecting scientific data over the last three years, the team has continually worked hard to refine and refurbish its facilities beyond state-of-the-art. To support these ongoing upgrades to instruments and software, Clark has assembled an elite and complementary team of scientists, programmers, and engineers—all hand-picked for their rich and diverse professional backgrounds. The end result is a suite of measurement capabilities that, collectively, render the MOBY/MOCE Team rare to the point of being unique in all the world.

Proof of Concept

According to GSFC's Charles McClain, SeaWiFS Project Scientist and Cal/Val Manager, MOBY is the cornerstone of both the MODIS and SeaWiFS Teams' strategy for vicarious calibration of their ocean color detectors, and MOCE is one of the primary efforts for validation of their data products. Yet, with the delay of the SeaWiFS launch date to Aug. 1, 1997, and MODIS not scheduled to launch until June 30, 1998, the 1996 OCTS launch aboard the Japanese ADEOS platform provided the team its first opportunity to help initialize a satellite. (Unfortunately, ADEOS was rendered inoperable early this summer when its solar panel failed.)

McClain explained that as part of the EOS theme of international cooperation and sharing data, the Japanese space agency (NASDA) relied on NOAA and NASA to provide infrastructure to help calibrate its sensors and validate their data products. In its first test as a satellite initialization station, the MOBY/MOCE operation proved to be a resounding success. Using software developed by GSFC's Watson Gregg and Gene Feldman (SeaWiFS Project members), NASA began receiving, processing, and distributing OCTS data in near real-time as early as October 1996. Shortly thereafter, Gregg and Feldman discovered some erroneous results in the OCTS data represented by negative water-leaving radiance measurements.
"It became pretty clear that the instrument had fallen out of pre-launch calibration specifications," Gregg stated. "That's when we began looking for *in situ* data corresponding to overpass data. Dennis (Clark's MOBY/MOCE Team) provided us with high quality *in situ* data. By comparing the water-leaving radiances measured by OCTS to those measured at the surface, we were able to iteratively adjust the total at-satellite radiance. Then, after applying an atmospheric correction algorithm, I arrived at the new OCTS water-leaving radiance values."

Gregg says it is not known exactly how OCTS lost its pre-launch calibration. Perhaps there was degradation due to either (or both) vibration during launch, or outgassing during deployment. Whatever the cause, shifts in pre-launch calibration are common during the mission lives of space-based remote sensors and, therefore, must be anticipated and corrected.

"The technique of acquiring MOBY/MOCE *in situ* data and comparing them to satellite data has now been mastered," Gregg observes, "and so we expect to be able to apply the same technique to SeaWiFS and MODIS in a fairly straightforward manner." (Refer to Figure 3.)

According to McClain, the earliest measurements from SeaWiFS look good but the main initialization activities for SeaWiFS will not take place until January 1998. He summarizes the MOBY/MOCE contributions: "Dennis has the most advanced shipboard system in the world at this point in terms of the suite of measurements he can make to support a satellite mission. He offers truly unique, first class facilities."

Science Results

Aside from helping to initialize satellite sensors, both MOBY and MOCE have yielded some interesting scientific results on their own. For instance, due to recent technological upgrades in the buoy's optical system, giving it higher spectral resolution and greater sensitivity, the team is now able to see Fraunhofer lines *in situ*. Fraunhofer lines are constant, narrow gaps in the solar electromagnetic spectrum where the sun's atmosphere has absorbed energy. But, why is this significant?

"If we measure energy where there should be gaps (Fraunhofer lines), then that means energy is being scattered (Raman scattering) into the gaps from other parts of the spectrum," Clark reasons. "This improved observation capability is important in the remote sensing of fluorescence line height, or energy emitted by phytoplankton during its photosynthetic process, and enables more-accurate correction of those data. "

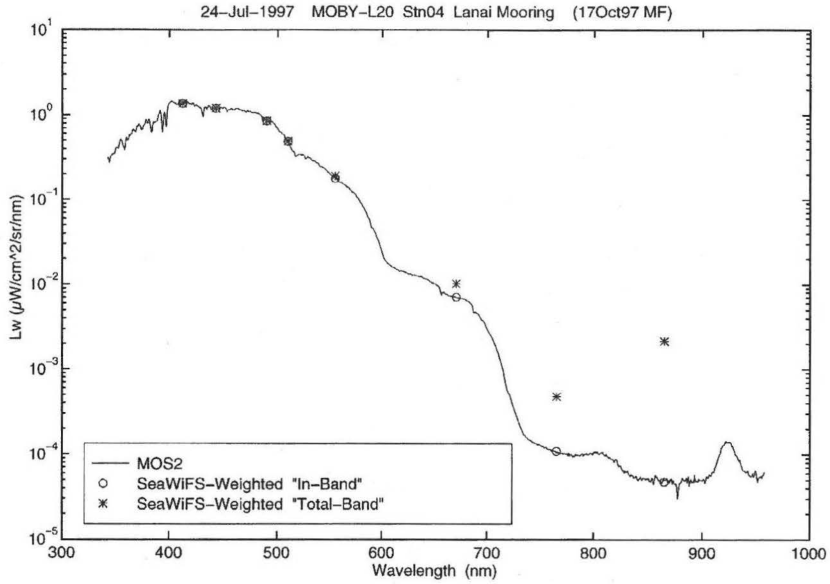


Figure 3. This spectrum shows the water-leaving radiances measured by the high-resolution spectrographs on MOBY. Superimposed on the spectra are the SeaWiFS in-band water-leaving radiances and total band water-leaving radiances. These SeaWiFS water-leaving radiances were computed using SeaWiFS' spectral band passes convolved with the high-resolution MOBY data. It is apparent that the SeaWiFS filter imperfections, or "leaks," in the blue part of the spectrum for the long wavelength band passes produce large discrepancies at wavelengths above 600 nm. The major advantage of MOBY's high-resolution capability is that it can accurately replicate any remote sensor's spectral band characteristics; e.g., SeaWiFS, MODIS, or MERIS. (Graphic courtesy of Dennis Clark, NOAA)

"This is also significant in that ordinarily it is not possible to get more energy at deeper ocean depths (due to absorption and reflection of incoming sunlight)," Clark adds, "but it could appear so in some wavelengths due to Raman scattering."

As part of its ongoing operations, the team has been working to evaluate and refine the SeaWiFS beta correction protocols to the measurement of reflection and absorption of light in the ocean. "There are classical protocols written for in-water radiometry and these are well understood," Trees explains. "Now, we are using a new, above-surface protocol for remote sensing of reflectance and evaluating the uncertainty between the two measurement protocols."

"Chuck Trees, through MOCE, has one of the best high-performance liquid chromatography (HPLC) data sets in the world," adds Clark. "By using this 12-year data set, we can compare systematic differences in old measurement techniques to his new HPLC technique using old data." With a better understanding of the errors inherent in the older validation measurement techniques, Clark hopes to pave the way for improved reprocessing of Coastal Zone Color Scanner (CZCS) data—a heritage instrument for both SeaWiFS and MODIS.

As another dividend from improvements in its measurement capabilities, the team recently learned that there is another aspect to pigment measurement gain which must account for the presence of divinyls—a form of chlorophyll a which is uniquely found in the pigment of picoplankton. "HPLC enables differentiation of compounds measured and enables us to improve our estimates," Trees states. "So, we have progressed scientifically to be able to get at real measurements of whatever compound you're interested in. For example, uncertainty in the measurements of CZCS data was about 25 percent, but now we're measuring all major pigment compounds to within 5-to-8 percent uncertainty."

Trees explains that the decrease in uncertainty is based on following the pigment protocols as outlined in the SeaWiFS Validation Plan and the U.S. JGOFS (Joint Global Ocean Flux Study) Plan. Extensive time and effort were spent in the separation and quantification of individual pigment compounds.

Clark and Trees hope to push the uncertainty figure even lower. "We are pushing the state of the art and refining our measurement techniques because we want the datasets from the next generation of remote sensors—SeaWiFS and MODIS—to be good for another 10-to-15 years. We want the best possible set of (validation) data to go into those measurements."

The team is also now obtaining very accurate solar sky radiance data across the spectrum at very high resolution, which will also be useful data to complement atmospheric modeling of the marine environment. To help in this effort, the MOBY/MOCE Team uses an AERONET CIMEL sun photometer on Lanai to measure atmospheric optical depth. This photometer is part of the worldwide AERONET (aerosol robotic network) deployed and maintained by GSFC's Brent Holben.

Mother nature offered the MOBY/MOCE Team a unique opportunity to observe the impact of atmospheric aerosols on regional measurements during the redeployment of MOBY this summer when the Pu'u O'o vent of Mt. Kilauea on the island of Hawaii became active again. Clark reports that, within a half-mile radius from the volcano's plume, the in-water light beam transmissivity over a 1-meter path length dropped by 15 to 20 percent. But, he adds, the measured chlorophyll fluorescence didn't change at all.

"We could see what appeared to be small, thin glass shards (silica) from the lava flow entering the water," Clark recalls. "Sometimes, there would be small explosions at the sea surface, sending some of these glass-like shards up into the atmosphere. We believe the decrease in transmissivity in the water is due to an increase in scattering from the silica shards."

Clark points out that, normally, the trade winds will carry particulates from the volcano away from MOBY; but, if there are wind shifts, it will help to know how these particulates affect the regional atmospheric properties.

A Refusal to Fail

What does it take to maintain a world-class marine optical measurement operation? Sometimes it takes engineers who are willing to work around the clock, under almost any circumstances, and who simply refuse to fail even when circumstances conspire against them.

Clark recounts an incident in which his team was due to make the delivery of an upgraded MOBY system to NASA in July of 1996. In January of that year, all of the new modifications were predicated upon upgrades to the spectrographs (modified charge-coupled devices), which had been delayed by the contractor. So, to help accelerate and assist in the delivery of the upgraded spectrographs, the MOBY team engineers went to Massachusetts and worked in the contractor's facility there to actually help with the assembly and testing of the prototypes. The net result of this upgrade is an improvement in measurement spectral resolution, while increasing the signal-to-noise ratio from 100-to-1 to 200-to-1.

"We discovered some major errors in the original mechanical design," Clark recalls, "so we redesigned and refabricated the new spectrographs at their facility. It was very nice of the contractor to give us that opportunity, but the bottom line is we wouldn't take 'no' for an answer. It had to be done."

No one can doubt the commitment of the divers who go down periodically to test the calibration of the currently deployed MOBY. A tough day at the office for them is swimming in rough Pacific waters to shine calibration lamps into the buoy's optics (see Figure 4) while 10-foot white tip sharks cruise by often to see what's on the menu. It is well known that larger fish, such as sharks or mahi, like to school around floating obstacles (e.g., buoys) in the water to prey upon the smaller fish that, in turn, prey upon whatever is growing on the obstacle. In short, a complete food chain is now flourishing around MOBY and its companion mooring buoy. On a number of occasions the divers have had to evacuate the waters when the sharks got too aggressive.

Technological Upgrades

Through many changes since its prototype was built, MOBY has seemingly gone through a steady evolution.

Figure 4. Diver calibrations on MOBY optics are performed once a month to maintain data integrity. Instrument stability and effective measurement capability are evaluated by illuminating the buoy's optics with highly stable, NIST-standardized spectral calibration lamps before and after the optics have been cleaned. (Photo courtesy of MOBY Team photo archive)

For instance, the material of the buoy itself was changed from a hollow aluminum cylinder to a solid nylon foam. Whereas the original design could have corroded and, if punctured, actually sunk, the new material corrodes much less readily and will not sink even if flooded. Also, the buoy's shape was changed to be much wider at the top and tapered toward the bottom, thereby further increasing its buoyancy.

Unfortunately, its increased buoyancy caused the new MOBY to move up and down in the water like a piston as it was rocked by waves. The team noticed that this motion added some "noise" to the data and also changed the depth dependency a little as MOBY's "arms" were being constantly shifted vertically. So, the MOBY team added fifteen anti-roll plates, suspended below the buoy at a depth of about 50 m, to increase drag and dampen the vertical oscillation of the buoy. Clark dubbed these plates "flopper stoppers." The flopper stoppers recently saved MOBY from drifting into oblivion when they reanchored MOBY on the shallow Penquin Banks off of Molokai, HI. MOBY was set adrift after its tether was cut, probably by the propeller of a passing fishing vessel.

Additionally, extra batteries and solar panels were added to increase the buoy's weight and prolong its capacity for operation between refurbishments. Stainless steel and copper anti-foulant tubes, with a granular bromide coating, were placed around the upwelling radiance collectors to limit the biofouling that the team had observed growing quickly over the optics of MOBY's earlier incarnations. Copper is widely used as a marine anti-foulant and has proven effective here, too. The steel and copper electrolytically interact, releasing a copper ion that reduces the fouling effects. The material comprising the irradiance collectors was also changed to a type of Teflon that is much more slippery and, therefore, reduces organisms' ability to attach themselves. Optically, this material was found to yield superior cosine response and increase throughput by 50-to-60 percent.

Ready for Operations

"MOBY is part of a calibration and validation infrastructure that is ready to go operational," states Clark. "We have also built an operations support infrastructure (at the MOBY/MOCE base in Honolulu) that is ready. We have added semi-clean rooms, a calibration lab, storage vans (acquired from the military), access to power, and a good communications infrastructure." (See Figure 5.)

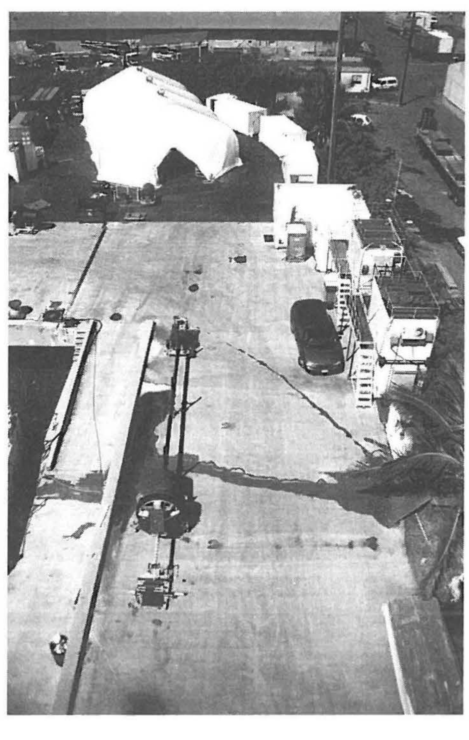


Figure 5. Over the last 3 years, the University of Hawaii has allowed the MOBY/MOCE Team to base its operations on part of its property at the Honolulu shipyard. This aerial photo shows the entire MOBY/MOCE base site. Towards the rear of the site, a large tent houses the three buoys during refurbishment. The small "vans" to the right are the team's mobile labs. These vans house the team's clean room, calibration lab, storage facilities, and office space. For ship-board operations, the mobile labs are actually placed on the RV Moana Wave, to minimize set-up and tear-down time between cruises. (Photo courtesy of MOBY Team photo archive)

Good communications capabilities are essential for scientific field campaigns. The MOBY/MOCE Team has integrated its communications system with that of the University of Hawaii's satellite receiving station. This affords them access to both the local telephone service and to a T1 data line. The team also recently implemented an infrared relay system that enables fast communication from the MOBY mooring site, off the southwest coast of Lanai, to its base in the Honolulu shipyard. This has proven to be a major upgrade as the prototype system had trouble completing near-real-time cellular data relays, mainly due to the modems' burning up in the severe heat of the afternoon sun.

Today, not only MOBY's marine optical data, but also its housekeeping data are available in near real-time to team members as nearby as the lab site in Honolulu, or as far away as the Moss Landing Marine Lab in Monterey, CA. To take advantage of its new measurement and communications capabilities, Stephanie Flora, a programmer at Moss Landing, wrote new system software, tailor-made for the modified MOBY.

"When Stephanie arrives at work in the morning, MOBY has already called and sent its data to a computer in her lab, where she processes them and places them on a semi-secure Web page for the team's use," Clark explains. "Also, (the buoy's) diagnostic data are there, such as battery power or temperature, to characterize the housekeeping functions of the system. Ultimately, these data will be used by the SeaWiFS and MODIS teams to match with the data taken by those sensors."

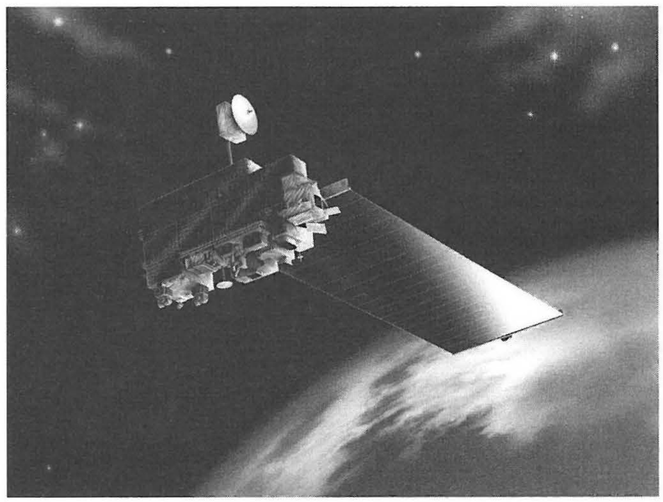
Clark invites other SeaWiFS and MODIS team members to use the MOBY/MOCE facilities. "Very few other groups can accomplish what we can and still turn around data as quickly," he concludes. "We want this to be a world-class facility for supporting ocean remote sensing."

Mission accomplished.

Looking Down, Looking Across: NCAR's Contributions to EOS

— ***Carol Rasmussen***, UCAR Communications

(Reprint from *UCAR Quarterly*, Vol.22, Summer 1997)



An artist's rendering of the EOS AM-1 satellite, which will carry MOPITT. (Illustration courtesy of NASA.)

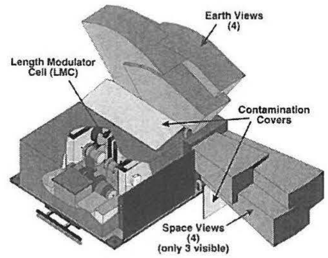
Two NCAR teams, both under the leadership of John Gille (Atmospheric Chemistry Division [ACD]), are participating in the development of instruments as part of NASA's Earth Observing System (EOS). One instrument, Measurement of Pollutants in the Troposphere (MOPITT), will be launched next year on EOS AM-1; the other, the High-Resolution Dynamics Limb Sounder (HIRDLS), is planned for launch in 2002.

MOPITT

Measuring carbon monoxide (CO) and methane (CH_4) in the troposphere—the lowest part of the atmosphere, up to about 11,000 meters (36,000 feet)—MOPITT is a nadir-pointing instrument: it looks straight down at the Earth's surface.

In the troposphere, chemical reactions that involve oxygen transform many common pollutants into less noxious molecules. "Oxidation is the air's most important cleansing mechanism," says Mark Smith

(ACD), who's preparing a simplified, aircraft-borne version of the instrument for intercomparison flights. Most of these reactions involve the hydroxyl radical, the most reactive chemical compound in the atmosphere. "CO would like to grab another oxygen atom from hydroxyl and become CO_2 [carbon dioxide]," says Smith. "It's competing with a lot of other pollutants for chemically available oxygen."



The MOPITT instrument. The instrument is more or less a rectangular box; the extending sections labeled "earth views" and "space views" indicate the angular field swept by the gas correlation cells alternating between a short and a long path of gas. They contain different pressures, in order to measure different parts of the gases' spectral lines, and thus different altitudes. (illustration courtesy of James Drummond.)

Measuring CO from space, however, has proved to be a challenge. The troposphere is "a difficult region in which to make remote measurements," says Gille. "Tropospheric chemistry is fairly complicated, and to date, most remote instruments have used passive technology, looking at scattered radiation in the atmosphere. This gives poor vertical resolution."

In that case, why not stick with surface measurements? The problem with that approach stems from the fact that CO has a relatively short lifetime in the atmosphere—around two months. This is not long enough for the gas to become evenly mixed throughout the global atmosphere, so its distribution is irregular and changes rapidly. Only remote measurements can capture this patchy and evolving global picture.

Methane, on the other hand, is longer-lived, so it mixes well in the atmosphere and becomes evenly distributed vertically over the globe. Long-term measurements of the gas at NOAA's atmospheric monitoring sites have given scientists a considerable degree of confidence that they know the total amount of CH_4 in the atmosphere and the rate at which that amount is increasing (until recently, about 1% annually; that rate has now decreased). Many questions remain, however, about the gas' sources and sinks—the processes by which methane is emitted and absorbed or transformed chemically at the Earth's surface. The NOAA sites were purposely located far from pollution sources on the continents, so by the time methane reaches the sites, it's too evenly distributed to supply many clues as to where it came from and where it's being removed. Other surface measurements have offered some answers, but what is needed are daily observations over the entire globe—and that is what MOPITT will supply. "Some people think there may be some surprises," says Smith.

MOPITT, which is being developed by the Canadian government, is the only chemistry instrument on next year's first EOS satellite launch, the AM-1. This instrument platform will have a sun-synchronous polar orbit that takes it south over the Northern Hemisphere in the morning hours. The other AM-1 instruments are:

- the Moderate-Resolution Imaging Spectroradiometer (MODIS), a multipurpose device taking land, ocean, and atmospheric soundings;
- the Multi-angle Imaging Spectroradiometer (MISR), which measures sunlight reflected by the Earth into space using nine viewing angles;
- Clouds and the Earth's Radiant Energy System (CERES), which observes cloud properties and the net flow of radiation toward and away from the Earth; and
- the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which will map Earth surface properties with high resolution.

The MOPITT principal investigator, James Drummond (University of Toronto), is overseeing the construction of the instrument itself, while Gille's group prepares the software that will capture and process the data collected (called the data retrieval algorithm). Paul Bailey, Liwen Pan, Jinxue Wang, David Edwards, and Chris Halvorson are working on the scientific data; Cheryl Craig, Frederick McCloskey, Dan Packman, Leslie Mayer, and Charles Cavanaugh are developing the operational code.

Gille's scientific career has focused on limb-sounding instruments: space-based devices that look toward the horizon, through a section of the atmosphere and out the other side. MOPITT is his first experience with a nadir-pointing instrument. His involvement stems from a long friendship with Drummond, who was at NCAR on sabbatical in 1987. Gille explains, "We talked about the coming EOS experiment, and I said, 'The world really needs a way to measure tropospheric CO.'" Gille suggested the technique for measurement, and NCAR provided the environment where Drummond devised one of the novel elements MOPITT needed. MOPITT was selected in the first batch of EOS proposals in the late 1980s, and it has survived the program's many revisions and cuts.

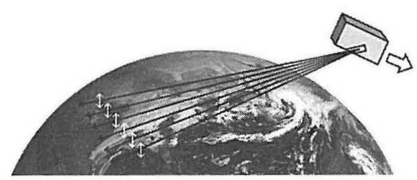
As infrared (heat) radiation trickles upward from the Earth's surface through the troposphere, it is absorbed and re-emitted by CO. To an instrument observing the Earth's electromagnetic spectrum, infrared absorption looks like a series of sharp spikes, known as lines, concentrated in bands. MOPITT has four channels tuned to different parts of the spectral lines for CO. The center of the line shows absorption and emission at higher levels of the troposphere, and the parts farther away from the center show activity at lower altitudes. The four channels of CO measurements use four gas correlation cells—chambers full of CO—each at a different pressure to observe the different parts of the spectral lines, and thus of the troposphere itself.

The methane-observing regime is considerably simpler, requiring only a single chamber that measures the amount of CH_4 in the entire column of air directly below the instrument's field of view. MOPITT's resolution is "reasonably high," 22 km horizontally and 3 km vertically (13 miles and 1.8 miles, respectively).

As the instrument itself is being finished by a Canadian contractor, the data group at NCAR continues to refine its work. The aircraft instrument has made several test flights; it will fly again in the fall. The retrieval algorithm will be tested on data from these flights. Once AM-1 is launched, the data will be available "to anyone in the general research community," explains Paul Bailey, data manager for MOPITT and HIRDLS. The contractor developing the infrastructure for the EOS data processing centers "is in an intensive development cycle to create at least rudimentary data processing and distribution capabilities in a time frame to support launch next summer. However, as a precaution, NASA is asking the various instrument teams to develop emergency plans in case the contractor isn't ready."

This additional work, Bailey says mildly, "is a burden at this late date. But we, being a small instrument with relatively few data products, have more flexibility [than some other AM-1 instrument groups] in what we can do."

For more information on MOPITT, check its Web page: http://eos.acd.ucar.edu/mopitt/home.html. The EOS program office's Web site (http://eospso.gsfc.nasa.gov) offers general information and links to sites for most instrument teams.



As the satellite bearing HIRDLS orbits the Earth, the instrument will scan for radiative emissions in the upper troposphere, stroposphere, stratosphere, and mesosphere along six tracks (black lines). The tracks are separated by five degrees of radial distance at the observation point (white lines), where they are perpendicular to the Earth. A set of observations is taken once every five degrees of orbit—about once a minute. (Illustration courtesy of HIRDLS, adapted by Liesel Brunson.)

HIRDLS

Also an EOS choice since the late 1980s, HIRDLS has entered an intensive design and construction phase to prepare for launch on the EOS chemistry platform, known as CHEM-1. HIRDLS measures the temperature and concentrations of the atmospheric constituents listed below, as well as the presence of miscellaneous aerosols (sulfuric acid from volcanoes, for instance).

- √ ozone (O_3)
- √ water vapor (H_2O)
- √ nitric acid (HNO_3)
- √ nitrous oxide (N_2O)
- √ nitrogen dioxide (NO_2)
- √ dinitrogen pentoxide (N_2O_5)
- √ methane (CH_4)
- √ chlorofluorocarbons (CFCs) 11 and 12
- √ chlorine nitrate ($ClONO_2$)

Temperature and ozone will be measured from 8 to 80 km (5 to 50 miles)—the upper troposphere, stratosphere, and mesosphere—with other species being measured over part of that range. All will be measured with a vertical resolution of about 1 km (0.6 mile). At higher altitudes, the atmosphere is so thin that each species can maintain a different temperature. However, says Gille, "for the altitudes of greatest interest to us, molecules collide with each other enough so that all the temperatures are the same."

Observations in this atmospheric region should give a fuller picture of the interchange between the troposphere and stratosphere, where chemical, aerosol, and momentum exchange play a role in weather and climate near the surface as well as in phenomena such as ozone depletion in the stratosphere. HIRDLS will provide a dense grid of measurements, with data collected twice a day over the entire Earth from grid points separated by five degrees of latitude and longitude. "We'll get within 300 kilometers [180 miles] of every point on the Earth twice a day," notes Gille. Moreover, HIRDLS has a programmable scanning feature allowing it to zoom in on areas of particular interest at a resolution of just one-by-one degree.

Working on the limb-sounding HIRDLS, Gille is in familiar territory. More than two decades ago, he conceived and designed the Limb Radiance Inversion Radiometer, launched in 1975. "LRIR proved that the concept of limb sounding worked and provided some very interesting results, as well as showing us how to do it right." After LRIR came LIMS, the Limb Infrared Monitor of the Stratosphere, deployed in 1978. It provided the first high-resolution look at stratospheric temperature and ozone and the first global measurements of stratospheric water vapor, nitric acid (present in concentrations of a few parts per billion), and nitrogen dioxide (a naturally occurring gas that catalytically destoys ozone). By the mid-1980s, Gille was involved in the planning for EOS. "In the process of thinking about where the science was going, I came up with the original idea for HIRRLS [High-Resolution Research Limb Sounder], as it was then called." At about the same time, a group at Oxford University proposed a separate dynamics limb sounder. "NASA and the British National Space Agency said, 'Hey, these proposals are very similar. Let's combine them and develop a single instrument.' " Gille met with British investigator John Barnett in 1989, and HIRDLS was born later that year as an NCAR/Oxford collaborative project. The project recently took another major step when the HIRDLS administration moved to the Center for Limb Atmospheric Sounding (CLAS) at the University of Colorado (CU) at Boulder.

With only five years remaining before launch—none too much time, in aerospace terms—the pace is picking up at the CLAS office. "As we get into the detailed design and start to build things, there are a lot of people coming on board," says Gille. The project may offer collaborative opportunities for researchers from a number of CU departments, as well as graduate and undergraduate students. "Planning for a launch in 2002, it's going to be tight."

HIRDLS' home page address is http://eos.acd.ucar.edu/hirdls/home.html.

A Brief History of EOS

The launch next year of the AM-1 platform will climax some 15 years of planning, rethinking, and revising how we can best study our changing Earth from space. When NASA's Mission to Planet Earth (MTPE) initiative was first conceived in the early 1980s, EOS was envisioned as encompassing two school-bus-sized space platforms with 12-15 instruments on each. The instruments would monitor an enormous number of Earth processes, from incoming solar radiation to plankton growth. A data and information system (EOSDIS) would handle the trillions of bits of data collected daily, and an interdisciplinary research program would carry out investigations using EOS data and compare them with existing models and other data.

But almost from its announcement, this megascheme received serious criticism. Sentiment in Congress was turning against big science, as witness its decision not to continue funding the superconducting supercollider. In the Earth science community, some researchers were concerned that EOS would gobble up all U.S. global monitoring funds, which might otherwise be used for Earth-based or shorter-term projects, while delaying the onset of a comprehensive measurement program until the first launch, planned for 1996. Finally, the astronomy community was also competing for satellite funding.

NASA immediately began modifying the program in response to the critical reviews. The program that has evolved relies on a series of smaller satellites, each carrying a few complementary instruments; other EOS instruments will also be placed on flights of opportunity, both U.S. and foreign. Over the years, the program's scientific planners have pinpointed 24 key Earth processes that are most critical to monitor; at least one EOS instrument will collect data on each of the 24 processes. (Some instruments will monitor more than one process, and several instruments will be flown on more than one platform to create denser networks or increase the number of looks per day.) Three series of satellites will collect 15 to 18 years of data, which will be processed, stored, and made widely available through the EOS Data and Information System. EOSDIS and the interdisciplinary science program continue to be major components of EOS.

Another driver for the program changes has been extensive budget cuts. The total cost of EOS has been slashed by more than half, from $17 billion in 1990 to $7 billion today. MTPE's FY 1997 budget is $1.3 billion, of which $571 million is allocated to EOS flights. If proposals for major budget cuts to NASA over at least the next three years come to pass, MTPE and EOS will be severely affected. To counteract the U.S. budget realities, the agency has worked with notable success to foster international collaborations and cost-sharing that would reduce some instruments' price tags. In fact, 19 countries are now involved in MTPE to the tune of $7.5 billion—an investment roughly equal to that of the United States.

Earth System Science Interdisciplinary Investigations

Besides its satellite missions, EOS funds proposals for interdisciplinary research to make use of data from existing and planned NASA Earth science missions to address some key areas of uncertainty in the global climate system or intercompare remotely-sensed data and coupled Earth system models. Three NCAR principal investigators and their teams were selected as part of this program:

Guy Brasseur, Climate and Chemical Cycles: The Role of Sulfate and Ozone in Climate Change

Linda Mearns, Analysis of the Effect of Changing Climate Variability on Crop Production in the Southeast: An Integration of Stochastic Modeling, Regional Climate Modeling, Crop Modeling, and Remote Sensing Techniques

David Schimel, Using Multisensor Data to Model Factors Limiting Carbon Balance in Global Arid and Semiarid Land.

An Organization with CLAS

When HIRDLS entered its most recent design phase—Phase C/D, in NASA terminology—it also moved to a new institutional home. The Center for Limb Atmospheric Sounding officially opened in the Graduate School of the University of Colorado at Boulder on February 1. Although they remain physically located at NCAR, the seven people working in the HIRDLS Project Office are now employees of CU. Gille works half-time for CU and half-time for NCAR, and several other co-investigators and scientists have remained at NCAR.

Under federal acquisition regulations, the Phase C/D work—substantially more involved than the conceptual design work of Phase B—would have been subject to cost-accounting standards which are different from the practices in place at UCAR. The creation of CLAS lessens that major administrative burden: CU becomes the prime contractor for NASA ($118 million from February 1997 through 2008). NCAR will be a subcontractor ($19.7 million for the same period) for scientific and computing facility use and reimbursement of investigators who remain at NCAR. Accounting standards differ when the primary contractor is a university, so the overall administrative burden on the project will be lessened significantly.

Many other positives could emerge from the creation of CLAS. "It's a mutually beneficial project," says CU professor Susan Avery, the founding director of CLAS and former chair of UCAR's Board of Trustees. According to the CLAS program plan, the center "will complement the existing array of Earth remote-sensing research activities at the university and provide a new link to the national and global Earth science research communities." Avery adds, "There will be educational opportunities for students and collaborations across many parts of the university, as well as with NCAR and Oxford."

First Phase of Earth Science Data Purchase Awards Selected

— *Douglas Isbell*, NASA Headquarters, Washington, DC. (Phone: 202/358-1753)
— *Lanee Cobb*, NASA Stennis Space Center, Stennis, MS. (Phone: 228/688-3341)

Eleven offers have been selected for contract negotiations in the first phase of NASA's planned purchase of Earth science data and related information products that meet both commercial needs and the agency's scientific requirements.

"This is truly a new way of doing business for NASA," said William Townsend, Acting Associate Administrator for the NASA Office of Mission to Planet Earth, Washington, DC. "But it's just one step in a longer, multifaceted process of NASA working more aggressively with industry and other non-governmental organizations to advance scientific understanding of our Earth as a total environmental system."

The U.S. Congress approved the plan to initiate the data purchase activity in the fiscal 1997 NASA budget. It will be managed by the NASA Commercial Remote Sensing Program at Stennis Space Center, Stennis, MS, the Agency's lead center for fostering commercial applications of NASA Earth science data and related technology.

A Request For Offers was made by NASA in May 1997 to provide unique Earth science data and related information products for purchase. The purchased information will be used by research teams within NASA's Earth science enterprise, which manages the agency's portion of an internationally coordinated research effort to study the Earth's land, oceans, atmosphere, ice, and life as a global environmental system.

By purchasing data upon delivery from private industry instead of developing, building, and launching new satellites, NASA may be able to conduct and expand its scientific investigations at a much lower cost, while encouraging the growth of this economic sector, Townsend said.

The first phase of this effort will cover a maximum six-month period to be spent analyzing and validating sample data sets. Those proposals selected to continue to Phase II will receive a letter describing the price, quantity of data, and its required characteristics, based on terms and conditions commonly found in the commercial marketplace.

Awards were based on several criteria, including "best science value" to the government, and the degree to which the offered data met the business and performance characteristics of the solicitation, including scientific utility, data rights, and the proposed price.

The successful offerors are:

Earth Satellite Corporation, Rockville, MD, will provide a medium-resolution common global geographic reference database using Landsat Multispectral and Thematic Mapper images.

Jackson and Tull/Woods Hole Oceanographic Institute, Seabrook, MD, will provide high-volume, on-site ocean data using demonstration ocean buoys with interactive telemetry links.

User Systems/Space Imaging-EOSAT, Gambrills, MD, will process and provide distribution capability for 18 terabytes of Shuttle Imaging Radar data in support of land surface classification research.

Earthwatch, Longmont, CO, will provide high-resolution imagery from the Earlybird commercial remote-sensing satellite, over the Upper San Padre Basin, CA, and Stennis Space Center. Phase II imagery acquisitions will be determined by the Earth science community.

The University of Wisconsin, Madison, WI, will provide a complete dataset of upper tropospheric water vapor and cloudiness data using the Visible/Infrared Spin Scan Radiometer Atmospheric Sounder aboard U.S. GOES weather satellites.

Space Imaging-EOSAT, Thornton, CO, will provide three-foot (one-meter) resolution panchromatic and 13-

foot (four-meter) resolution multispectral imagery. In Phase I it will be simulated; Phase II data will be from the IKONOS satellite constellation that will be launched by the company later this year.

Final Analysis, Lanham, MD, will provide measurements of atmospheric aerosols and trace gases from the deployment of a planned 12-satellite constellation.

Positive Systems, Whitefish, MT, will provide three-foot (one-meter) resolution multispectral imagery over the Sevilleta National Wildlife Refuge, NM.

TRW Civil & International Systems Division, Redondo Beach, CA, will provide airborne hyperspectral imagery (384 channels) based over the highly characterized region around Jasper Ridge, CA.

Astrovision, Inc., Stennis Space Center, MS, will provide 24-hour imagery from geostationary orbit to provide real-time documentation of public and environmental hazards such as tornadoes, hurricanes, lightning, fires, volcanoes, meteors, and floods.

Resource 21, Englewood, CO, will provide data for extracting land resources management information from multispectral imagery that could provide continuity with Landsat-7 data.

Further information about these products and awards is available on the Internet at URL: http://procurement.nasa.gov/EPS/SSC/award.html.

Hierarchical Data Format for the Earth Observing System (HDF-EOS) Software Developer/Vendor Workshop

— *Candace Carlisle* (ccarlisle@mindspring.com), NASA/Earth Science Data and Information System Project

Representatives from software developers and vendors, EOS Distributed Active Archive Centers (DAACs), Instrument Teams, and the Earth Observing System Data and Information System (EOSDIS) attended an HDF-EOS workshop September 8-10. The workshop provided a forum for interaction between these communities, and encouragement for software developers and vendors to develop tools that support the HDF-EOS data format. Presenters described the large and growing community of EOSDIS users among the public sector, scientific researchers, commercial users, the education community, and international partners. Discussions identified the need for tools for browsing, viewing, subsetting, image analysis and enhancement, mathematical and statistical analysis, processing, graphics, and animation for EOSDIS data.

Approximately 150 people attended the workshop, which was held at Goddard Space Flight Center. NASA, the EOSDIS Core System team, Hughes STX, and the National Center for Supercomputing Applications (NCSA) sponsored the workshop.

HDF-EOS is the primary data format standard for EOSDIS data distribution, production, and archiving. It provides self-definition of data content, flexibility, support for a broad set of data types, and extensibility, allowing EOSDIS to achieve the goals of high levels of data service, access, and interchange. HDF-EOS adds EOS data features to the National Center for Supercomputing Applications' Hierarchical Data Format (HDF). HDF was chosen as the best of the alternatives after a study of available data format standards and EOS science data needs. EOSDIS does accept data and provide conversion for other formats, but full EOSDIS services are supported only for HDF-EOS.

During the workshop, EOSDIS and NCSA speakers provided an introduction to EOS and EOSDIS, overviews of HDF, HDF-EOS, EOS metadata, available tools, and an overview of needs. DAAC representatives described the scientific focus and user community of the DAACs, current and future data holdings, available tools, and tool needs. Goddard DAAC

(George Serafino), Langley DAAC (Linda Hunt), EROS Data Center (John Boyd), Jet Propulsion Laboratory Physical Oceanography DAAC (Carol Hsu), and Alaska Synthetic Aperture Radar Facility (Chris Wyatt) representatives presented information about their DAACs. A science panel discussed their scientific areas of interest, how EOS data contribute to scientific investigations in their areas of interest, what kinds of tools are needed in order to productively use EOS data, and specific capabilities needed in these tools. The EOSDIS Project Scientist (Carl Reber) led the discussion, with representatives from the National Center for Atmospheric Research (Cheryl Craig), Jet Propulsion Laboratory ASTER team (Moshe Pniel), Woods Hole Oceanographic Institution (Mike Caruso), and Simpson Weather Associates (G. David Emmitt). An "Ask the Experts" panel, composed of representatives from the Earth Science Data and Information System Project, the EOSDIS Core System team, Hughes STX, and NCSA answered questions about EOSDIS and HDF-EOS.

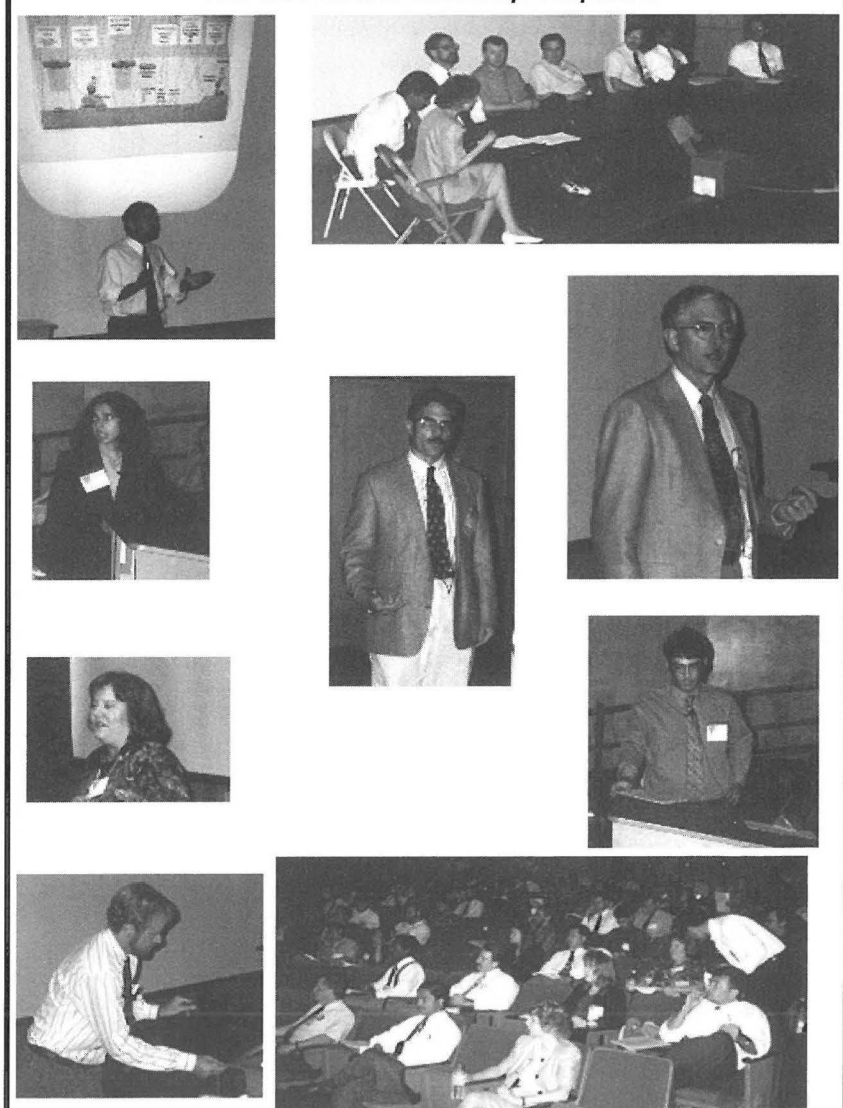
Many software developers and vendors were represented at the workshop. Several of these organizations expressed commitments to supporting the HDF-EOS format with their commercial products. The following software developers and vendors made presentations about their work: University of Alabama at Huntsville, NCSA, Hughes STX, Ames Research Center, University of Wisconsin, Jet Propulsion Laboratory, Ecologic, Fortner Software, Lawrence Livermore National Laboratory, Pegasus Imaging, Flashback Imaging, Research Systems Incorporated, Simpson Weather Associates, and IBM.

The workshop ended with a wrap-up session. Participants discussed action items, HDF-EOS resources, and ideas for the future.

HDF-EOS frequently asked questions, HDF-EOS documentation, HDF-EOS source code, links to useful sites such as NCSA and DAACs, and further information about the workshop, including most of the presentations and workshop notes, are available at: http://ulabhp.gsfc.nasa.gov/~workshop/workshop.html. This web site will be updated with additional presentations, action item responses, and links to related sites.

A new EOS tools e-mail list for discussion of data analysis and visualization tools for use with EOS data products; issues related to EOS data, metadata standards, and software tools; and HDF-EOS is also available. To subscribe to this list, send a note to majordomo@eos.nasa.gov with the following line as the only line in the body of the message:
subscribe eostools <your e-mail address>.

HDF-EOS Vendor Workshop Snapshots



Landsat 7 Data Prices Announced

Technical Contacts:
USGS — ***R.J. Thompson*** (605) 594-6161; NOAA — ***Jim Ellickson*** (301) 457-5210;
NASA — ***George Komar*** (gkomar@pop100.gsfc.nasa.gov), (301) 286-0007

The Federal government has established prices for basic image-data products that will be available from the Landsat 7 Earth-observation satellite scheduled for launch in July 1998.

Approximately 90 days after the satellite is launched, minimally-processed Level Zero R full-scene digital products, covering 115 x 105 miles (185 x 170 km), will be available from the U.S. Geological Survey's EROS Data Center (EDC) near Sioux Falls, South Dakota, at $475 each. A Level Zero R product is a reformatted raw digital image acquired by the Enhanced Thematic Mapper Plus (ETM+) instrument on Landsat 7. Reformatting includes re-establishing the order of the reversed scan-mirror data, aligning the staggered sensor detectors, and nominally aligning the forward and reverse scans. Image data are not radiometrically corrected, pixels are not resampled, and pixels are not registered to a map projection for a Level Zero R product; however, each image product includes the associated metadata and calibration parameter file.

Current plans call for full scenes that have been corrected for sensor effects and spacecraft geometry (Level One processing) to become available from the Sioux Falls site in limited quantities within a year after launch, at a price not to exceed $600 each. Two choices will be available at Level One:

√ A Level One R product is a radiometrically corrected ETM+ digital Earth image along with files containing metadata, calibration parameters, payload correction data, mirror scan correction data, a geolocation table, and internal calibration lamp data. Image pixels are not resampled for geometric correction and registration.

√ A Level One G product is a radiometrically- and geometrically-corrected ETM+ digital Earth image along with metadata, calibration parameters, and a geolocation table. The radiometrically corrected pixels are resampled for geometric correction and registration to a user-specified map projection.

Prices for data products from Landsat 7 were established by the three agencies partnering in management of the Landsat Program: the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the Department of the Interior's U.S. Geological Survey (USGS). With the objective of providing these basic data products at the lowest possible cost, the agencies will review the prices annually and publish any changes each year that the satellite is in operation. Value-added film and digital products are expected to become available from commercial vendors.

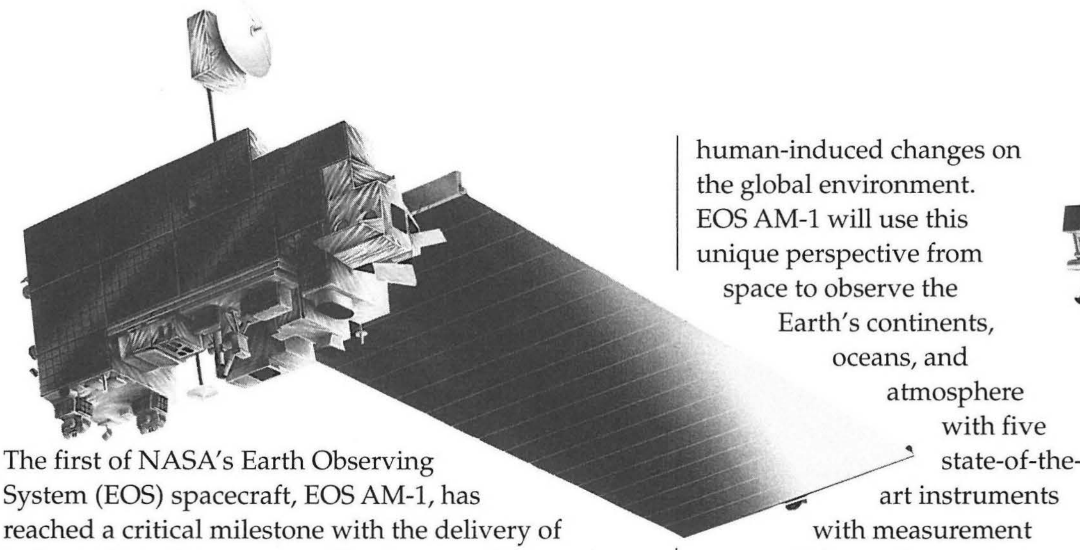
Landsat 7 will provide the data continuity that began with its program predecessors 25 years ago. Throughout this period, Landsat data have been used worldwide by the scientific community, government agencies, commercial enterprises, educational institutions, and private citizens for observation and analysis of land cover and land-cover change.

The primary mission of Landsat 7 is to acquire and periodically refresh a global archive of daytime, generally cloud-free images of land and coastal areas. Landsat 7 will capture and transmit approximately 250 full scenes per day to the primary U.S. receiving station at EDC. Within 24 hours after ground reception of data, users will have electronic access to information about each day's acquisitions. The Sioux Falls facility will have a 100-scenes-per-day processing and distribution capacity—initially at Level Zero R and later including Level One, at an initial capacity of 25 scenes per day.

General information on Landsat 7 is available through the Landsat Gateway Web page at http://landsat.gsfc.nasa.gov/; a detailed description of the Level Zero R product format can be found at http://ltpwww.gsfc.nasa.gov/IAS/htmls/17_review.html.

Major Earth Science Spacecraft Reaches Critical Milestone

— ***Douglas Isbell***, NASA Headquarters, Washington, DC (Phone: 202/358-1753)
— ***Jim Sahli/Allen Kenitzer***, Goddard Space Flight Center, Greenbelt, MD (Phone: 301/286-8955)



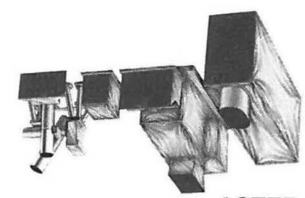
The first of NASA's Earth Observing System (EOS) spacecraft, EOS AM-1, has reached a critical milestone with the delivery of its last science instrument, allowing completion of module testing and integration of the instruments and the spacecraft. The last instrument arrived on Aug. 25.

EOS AM-1 begins a new generation of Earth science—one that studies the Earth as a global system. EOS will carry a complement of five synergistic instruments. "We're absolutely thrilled to reach this milestone," said Dr. Robert Price, Director of NASA's Mission to Planet Earth Program Office at the Goddard Space Flight Center, Greenbelt, MD. "We're now well on our way to having the spacecraft ready for its June 1998 launch."

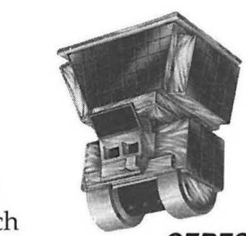
The next critical step for EOS AM-1 is to complete systems tests which validate the ability of the integrated spacecraft to withstand the harsh environment of space and to work with its ground system. Following that, the spacecraft will be delivered to Vandenberg Air Force Base, CA, for launch processing.

The EOS AM-1 spacecraft is being assembled and tested by Lockheed-Martin at its Valley Forge, PA, production facility.

The EOS series spacecraft are the cornerstone of NASA's Mission to Planet Earth (MTPE) Enterprise, a long-term coordinated research effort to study the Earth as a global system and the effects of natural and human-induced changes on the global environment. EOS AM-1 will use this unique perspective from space to observe the Earth's continents, oceans, and atmosphere with five state-of-the-art instruments with measurement capability and accuracy never flown before. This unique approach enables scientists to study the interactions among these three components of the Earth system, which determine the cycling of water and nutrients on Earth.



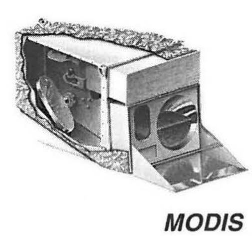
ASTER



CERES

"EOS AM-1 will study simultaneously clouds, water vapor, aerosol particles, trace gases, terrestrial and oceanic properties, the interaction between them, and their effect on atmospheric radiation and climate," said Dr. Yoram Kaufman, EOS AM-1 project scientist. "Moreover, EOS AM-1 will observe changes in Earth's radiation energy budget, together with measurements of changes in land/ocean surface and interaction with the atmosphere through exchanges of energy, carbon, and water. Clearly comprehending these interactive processes is essential to understanding global climate change," he said.

MISR



MODIS

MOPITT

A polar-orbiting spacecraft, EOS AM-1 is scheduled for launch in June 1998 aboard an Atlas-Centaur IIAS launch vehicle from Vandenberg AFB. Because the AM series emphasizes observations of terrestrial surface features, its orbit is designed to cross the equator at 10:30 a.m., when cloud cover is minimalized.

The Clouds and the Earth's Radiant Energy System (CERES) instrument will perform measurements of the Earth's "radiation budget," or the process in which the Earth's climate system constantly tries to maintain a balance between the energy that reaches the Earth from the sun, and the energy that goes from Earth back out to space. The components of the Earth system that are important to the radiation budget are the planet's surface, atmosphere, and clouds.

The Multi-Angle Imaging Spectroradiometer (MISR) will measure the variation of the surface and cloud properties with the viewing angle. Meanwhile, the Moderate-Resolution Imaging Spectroradiometer (MODIS) will measure atmosphere, land, and ocean processes, including surface temperature of both the land and ocean, ocean color, global vegetation, cloud characteristics, temperature and moisture profiles, and snow cover. The Measurements of Pollution in the Troposphere (MOPITT) instrument is an infrared gas-correlation radiometer that will take global measurements of carbon monoxide and methane in the troposphere. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) will measure cloud and vegetation properties, surface mineralogy, soil properties, surface temperature, and surface topography for selected regions of the Earth.
The CERES, MISR, and MODIS instruments are provided by the United States; MOPITT by Canada; and ASTER by Japan. Several hundred scientists from the U.S. and abroad have been preparing to take full advantage of EOS AM-1 observations to address key scientific issues and their environmental policy impacts.

EOS is managed by Goddard for NASA's Mission to Planet Earth strategic enterprise, Washington, DC.

"A Victory for Common Sense"

— State of Utah

On October 15, 1997, Utah's Governor Michael Leavitt, along with State or Regional Directors of the Bureau of Land Management, U.S. Geological Survey, Forest Service, National Park Service, U.S. Fish and Wildlife Service, Natural Resources Conservation Service, Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and the Utah Association of Soil Conservation Districts, signed a Memorandum of Understanding for the Utah Digital Spatial Data Sharing and Integration Project.

It was recognized that federal, state, and substate agencies need and use similar data. This agreement provides a mechanism to cooperatively create and share impartial and credible digital spatial data. The agreement will help decrease the duplicated development of the same data and will generate standardized data. The agreement will also promote the exchange of data and foster communication between agencies in Utah. Significant aspects of the agreement include:

1.) Creation of agency-specific data catalogs, all connected to the State Geographic Information Database
2.) Adherence to the Federal Geographic Data Committee's Metadata Content Standard
3.) Prioritization of 15 themes of data (geodetic control, digital ortho-imagery, elevation, transportation, hydrography, government units and boundaries, cadastral reference system and administrative ownership, demographics, wetlands, geology, wildlife habitat, climate, ground cover, land use, and soils) to create, integrate, and distribute through the State Geographic Information Database.

This agreement authorizes agency personnel to participate in cooperative data efforts. It expands existing regional agreements or agency-specific-agreements to a statewide level for the purpose of data coordination and sharing. As Governor Leavitt remarked at the signing ceremony, "It is a victory for common sense."

For additional information, please contact Dennis Goreham, (801) 538-3163.

Tropospheric Ozone Measurements and Their Use in Validation of TOMS and SAGE Data Products

— *Jack A. Kaye* (jkaye@mtpe.hq.nasa.gov), Office of Mission to Planet Earth, NASA Headquarters, Washington, DC
— *A. James Miller*, National Centers for Environmental Prediction, National Oceanic and Atmospheric Administration, Camp Springs, MD

The availability of ground- and balloon-based measurements of ozone distributions in the lower stratosphere (LS) and upper troposphere (UT), and their use in the validation of space-based measurements of ozone profiles in these altitude regions, were explored in a meeting held in Silver Spring, MD, in April, 1997. Some 30 scientists and managers from several U.S. government agencies, universities, and the private sector participated in the meeting, which was organized under the auspices of the Office of the Federal Coordinator for Meteorological Services and Supporting Research. The meeting was posed to help explore several issues, including:

- √ better coordination among U.S. programs that obtain UT/LS ozone measurements, especially for obtaining correlative observations for validation of space-based measurements;
- √ determination of measurement frequency and density of coverage for definition of UT/LS ozone trends;
- √ determination of optimal approach for U.S. agencies to participate in international programs and interact with meteorological agencies to work to improve quality and density of UT/LS ozone measurements;
- √ understanding the relationship between ozone measurement needs of global change and local/regional air quality programs; and
- √ understanding how these issues can best be addressed through the U.S. government planning process.

Several scientific issues were emphasized at the meeting. In particular, the distribution of tropospheric ozone in the tropics was discussed at some length, spurred on by the satellite-based observations showing significant zonal asymmetries in tropical distributions of tropospheric ozone. The satellite determinations typically use data from NASA's Total Ozone Mapping Spectrometer (TOMS) instruments in one of two ways. In one, the TOMS data are used together with measurements of the vertical profile of stratospheric ozone so that tropospheric ozone is calculated as the residual difference between total ozone and stratospheric column ozone. In the other, some data-based assumption is made about the nature of stratospheric column ozone variability so that tropospheric ozone could be obtained by a similar subtraction method. There remain some important scientific questions on the exact characterization of the altitude and time dependence of these zonal asymmetries, as well as the relative contribution of dynamical and *in situ* photochemical sources of enhanced ozone. Direct comparison of the satellite-derived product with *in situ* data is complicated by the limited *in situ* measurements available from ozonesondes in the tropics, especially the lack of near-simultaneous observations of ozone profiles in the high-ozone (Atlantic) and low-ozone (Western Pacific) regions.

Considerable discussion also took place on the status of current ozonesonde networks in the U.S. and around the world. The main subjects of interest included data availability, which is seen to be a problem for certain stations, ozonesonde inherent accuracy, intercomparisons, and "infrastructure support" for continuing calibration and intercomparison activities. Particular attention was given to the Julich Ozonesonde Intercomparison Experiment (JOSIE), carried out in an environmental simulation chamber in Julich, Germany, so that performance of different *in situ* ozone measurement devices (notably balloon payloads) could be compared under realistic conditions. The results of this experiment, which was supported by the World Meteorological Organization and hosted by Forschungszentrum Julich, showed that there were appreciable differences between the measurements made by different instruments, and that it is possible that some instruments can get the "right" answer for the wrong reasons, especially where corrections for pump efficiency and background current are used, but may not be completely rigorous. The importance of continuing such realistic intercomparisons was stressed, and the need for reliable and long-term international funding to support these activities was made clear to the participants.

The increasing role which ground-based ozone lidars may play in the study of UT/LS ozone was also addressed. The need for measurements in both regions has led to development of different lidar systems for the troposphere and stratosphere, driven by the need to use different wavelengths for optimal measurement in each altitude region, given the different abundances of ozone. The stratospheric ozone lidars typically work from approximately 10-15 km up to 45 km, while the tropospheric ozone lidars work from approximately several kilometers above the surface up to 12-15 km. The lidar systems are particularly useful for the study of short-term meteorological variability of ozone distributions (such as tropopause folds) as they can operate routinely, in both day and night. They may provide a biased climatology, however, because of their inability to penetrate thick clouds. Airborne lidars were briefly discussed at the meeting; they have made significant contributions in both upward- and downward-looking modes.

The status of satellite measurements of ozone distributions in the UT/LS was also reviewed. The most direct measurement of the ozone profile in this region is that of the Stratospheric Aerosol and Gas Experiment (SAGE) instruments. It has been shown that the SAGE II instrument can see through the stratosphere and down into the middle troposphere as much as 50% of the time at mid-latitudes. The quantitative validation of the SAGE data does not extend below the stratosphere, however. The version of SAGE II data most recently developed (version 5.96) has improved correction for aerosol interference over the previous version, which has led to improved agreement with ozonesondes (notably those flown from Hohenpeissenberg) in the 20-25-km region (mostly 5% differences); in the 15-20-km region there are still problems (~10% differences), and below 15 km there are greater differences which remain to be evaluated. These are primarily associated with the lack of detailed knowledge of altitude registration of the satellite instruments at these levels.

The TOMS data that form the basis of the tropospheric ozone residual determination of column tropospheric ozone have become much better with the reprocessing of the data to version 7, which includes a calibration correction and improved treatment of cloud heights. The correction of the TOMS calibration (leading to lower TOMS ozone amounts by approximately 3%) has meant that the residual ozone has been reduced by a few Dobson Units everywhere, with larger changes in north sub-tropical Africa. The TOMS data still appear to have some inaccuracies for solar zenith angles greater than 75 degrees, however. At this point, there have been few attempts to derive tropospheric ozone column amounts from high-latitude TOMS data, so these errors are unlikely to have an impact for this particular issue.

Tropospheric ozone residuals using TOMS and data from the Solar Backscatter Ultraviolet (SBUV, SBUV/2) series of instruments have also been carried out. The SBUV data do not suffer from the spatial sampling limitations of the SAGE data as a source of stratospheric ozone information for use in residual calculations, but there are significant questions about the information content in the SBUV profiles, especially in the tropopause regions. The TOMS-SBUV residuals are of particular interest in attempts to compare space-based determinations of tropospheric ozone to surface-level ozone measurements made as part of air pollution networks, given the presence of daily measurements at all latitude regions in SBUV. Residuals have also been carried out using data from TOMS and the Microwave Limb Sounder aboard the Upper Atmosphere Research Satellite. These new methods, as well as other methods being developed for determining tropospheric ozone from TOMS data (e.g., those relying on the difference between ozone columns in clear and cloudy scenes) all require careful validation and intercomparison.

Some information on tropospheric ozone distributions is starting to become available from the Global Ozone Mapping Experiment (GOME) instrument flying aboard the European Space Agency's ERS-2 satellite.

The publicly available GOME products include total column ozone and also column nitrogen dioxide. The GOME total ozone measurements appear to be good to 3% for solar zenith angles below 70 degrees, and to approximately 8% for higher solar zenith angles. Comparisons suggest the problems are associated with the GOME algorithm, as using GOME radiances at the TOMS wavelengths in the TOMS algorithm gave ozone values which agreed well with TOMS. Initial studies on GOME ozone profiles have been carried out, and there is some evidence that variability in tropospheric ozone can be seen in the lowest level of the profile, including, in one case, a region of enhanced ozone near the California-Nevada border that is thought to be a high ozone plume formed downwind of Los Angeles.

Some general issues were discussed at the meeting; in many cases definitive answers could not be reached, but a clearer sense of the questions was arrived at. These issues include the following:

There appears to be a problem with rapid and public availability of sonde data from some stations. The workshop participants called for all groups making regular sonde measurements to be sure that their data are made available quickly through the standard channels (for ozone profiles, the World Ozone Data Center in Toronto, Canada).

There was a strong sense that a minimum frequency of one sonde flight per week was required for a given sonde station to provide useful data for trend determination.

There was concern as to whether or not the available sonde data records are being examined sufficiently closely that previous errors, inconsistencies, etc., which may have been incorporated, would be located and corrected. It is hoped that the current ozone profile activity going on under the auspices of the Stratospheric Processes and their Role in Climate (SPARC) group of the World Climate Research Programme will encourage sonde stations and measurement agencies to do this work.

There was a clear sense that continuing calibration and intercomparison efforts for ozonesondes are important and should be supported. Given the role which sondes play in supporting the validation of space-based data, the suggestion that space agencies should provide some financial support for this effort was discussed. International efforts being organized to look at global measurement activities, such as those associated with the International Global Observing Strategy, should consider the status of such calibration and intercomparison efforts.

There was a clear recognition that our ozone measurements are lacking in certain well-defined geographical regions. In particular, there was a strong desire to have concurrent operations of sonde stations in both the Atlantic (Ascension Island) and Pacific (Samoa) oceans, which has not typically been the case. Such data could be very useful in understanding the zonal asymmetries seen in the satellite data. Additional data from Latin America could be very useful, especially in interpreting the TOMS-only tropospheric residual product derived by separating out TOMS column observations over the Eastern Pacific from those over the nearby Andes mountains.

Continuing efforts need to be made to ensure that the ozone profile needs of air quality agencies, like the Environmental Protection Agency, and those of global-change-oriented agencies, are coordinated, and that data obtained in support of one set of objectives will be routinely available to scientists involved in both.

The community needs to better understand the tradeoffs between ozonesondes and lidars, especially for tropospheric ozone.

A new philosophy of satellite validation for ozone measurement appears to be in order; this philosophy recognizes that validation is not a one-time effort done at the beginning of a flight period for a given satellite instrument, but one which continues over the course of a lifetime of a satellite instrument. Evidence from past satellite instruments suggests that this "lifetime" commitment to validation is very important (e.g., consider the increased rate of degradation of the Nimbus 7 TOMS instrument near the end of its lifetime, and also the increased inaccuracies in SAGE II ozone measurements which resulted following the Mt. Pinatubo eruption in 1991, when stratospheric aerosol layers became high for several years). Also, given the multiplicity of launches of space-based ozone measurements involving several countries and agencies, it is important the validation not be considered on a "satellite-by-satellite" basis, but as part of a total and international plan so that the full validation capability of all nations' ground- and balloon-based research communities can be applied to the total suite of space-based ozone measurements.

Further information about this meeting can be obtained from the authors of this article, who served as convenors of the meeting. The authors thank the participants of the meeting and, in particular, those scientists who helped develop the agenda (Jack Fishman, Jennifer Logan, Anne Thompson, Volker Mohnen, Guy Brasseur, and P. K. Bhartia).

UNEP's Environmental Effects of Ozone Depletion: 1997 Interim Summary Available at SEDAC

— *Mitchell K. Hobish* (mkh@sciential.com)

CIESIN and its Socioeconomic Data and Applications Center (SEDAC) are pleased to announce on-line availability of the United Nations Environment Programme's (UNEP) Environmental Effects of Ozone Depletion: 1997 Interim Report. Written at UNEP's Environmental Effects of Ozone Depletion Panel meeting last month in Erlangen, Germay, this summary is the last one between the full assessments of 1994 and 1998 on environmental effects of ozone depletion. The aim of the summary is to keep the parties to the Montreal Protocol informed about new scientific developments. The full text to the 1997 Interim Summary is found at SEDAC's Stratospheric Ozone and Human Health website: http://sedac.ciesin.org/ozone.

A link to the 1997 Summary may be found at the "New" section of the home page. Links to UNEP's 1996 summary and the full text to the complete 1994 Assessment are also available at this site.

For more information, please contact CIESIN User Services by e-mail at ozone@ciesin.org or by telephone at (+1) 517-797-2727.

1998 USRA/GSFC Graduate Student Summer Program in Earth System Science

GSSP Program Coordinator, e-mail: GSSP@gvsp.usra.edu

http://www.usra.edu/whats_news/app.html

The Universities Space Research Association (USRA), in collaboration with the Goddard Space Flight Center's (GSFC) Earth Sciences Directorate, is offering a limited number of graduate student research opportunities for the summer of 1998. The program is scheduled for June 8 through August 14, 1998. Now in its eighth year, the program is designed to stimulate interest in interdisciplinary Earth science studies, by enabling selected students to pursue specially-tailored research projects in conjunction with Goddard scientific mentors. During the first full week (June 8-12) the selected students will attend a concentrated public lecture series that will provide an overview of important scientific problems and investigations in Earth system science. The title of the 1998 lecture series is "The Oceans: Society & Science."

Introduction

USRA is a non-profit consortium of universities, chartered to establish and operate cooperative institutions and programs that advance research and education related to space science and technology. GSFC is recognized as a world leader in the application of remote sensing and modeling aimed at improving knowledge of the Earth system. The Goddard Earth Sciences Directorate has a central role in NASA's Earth Observing System (EOS) and the U.S. Global Change Research Program.

Planned for full implementation during the next ten years, EOS will require highly-trained professionals with significant interdisciplinary backgrounds for the design, implementation, and analysis of data from this comprehensive satellite system. The aim of this program is to attract and introduce promising students to Earth system science career options through hands-on educational research experiences in the Earth sciences at NASA.

Program Activities

Research Projects: Each student will be teamed with a NASA scientist mentor with similar scientific interests to jointly develop and carry out an intensive research project at GSFC over a ten-week period. NASA mentors will be drawn from within the three participating Earth Science laboratories at Goddard: the Laboratory for Atmospheres, the Laboratory for Hydrospheric Processes, and the Laboratory for Terrestrial Physics. Students will be expected to produce final oral and written reports on their summer research activities. Examples of past summer research projects include: Forest productivity in the Pacific Northwest using Landsat imagery; Global teleconnections between sea surface temperature and continental precipitation; Interpretation of GPS data from subduction zone plate boundaries; Use of DMSP/OLS night-time imagery in mapping urban areas; Simulation of sensible and latent heat fluxes using SSM/I winds; Generation of runoff using a probability-distributed model; Observation of chlorophyll A in the U.S. South Atlantic Bight using the Ocean Color and Temperature Sensor (OCTS); Sensitivity of a cumulus convective scheme to data assimilation.

In addition to the introductory lecture series, students will also participate in weekly informal lunch discussions with GSFC researchers, and have the opportunity to tour key NASA facilities and to meet with NASA and industry scientific managers.

Eligibility and Selection Criteria: The program is open to students enrolled in or accepted to a U.S. accredited graduate program in the Earth, physical or biological sciences, mathematics, or engineering disciplines. Students will be selected on the basis of academic record, demonstrated motivation and qualification to pursue multidisciplinary research in the Earth sciences, clarity and relevance of stated research interests to NASA programs, and letters of recommendation. Preference will be given to students who have completed at least one year of graduate study. Minorities and women are encouraged to apply.

Students *must* commit for the full ten-week period (June 8 - August 14, 1998). Because of NASA/GSFC security regulations, citizens of certain proscribed nations *may* be ineligible. If in doubt, please inquire.

Compensation and Support: Students selected for the Program will receive a $340/week living expense allowance for the 10-week period. In addition, USRA will reimburse reasonable domestic travel expenses for participants needing to relocate to the Greenbelt, MD area. Housing at the University of Maryland will be provided at program expense, for program participants only. Alternate accommodations cannot be supported.

To Apply: A formal application may be obtained by contacting the GSSP Program Coordinator at the mail address or e-mail address below, or downloaded from http://www.usra.edu/gssp. The completed application must be received along with an updated resume, at least two letters of reference, and undergraduate/graduate transcripts no later than *Monday, February 9, 1998*. Selectees will be notified before *April 1, 1998*.

USRA Contact Address

To request an application, to register for the 1998 lecture series, or for other inquiries contact:

GSSP Program Coordinator
Universities Space Research Association
7501 Forbes Boulevard, Suite 206
Seabrook, MD 20706
E-mail: GSSP@gvsp.usra.edu

Kudos

New Chair and Vice-Chair SC-IGBP

At the end of 1997 Peter Liss will step down from the Scientific Committee of the IGBP after serving as chair for four years. His position will be taken over by Berrien Moore III, currently the chair of the GAIM Task Force. (Moore heads the EOS Interdisciplinary Science Investigation: "Changes in Biogeochemical Cycles.") In addition to a new chair, the SC-IGBP will welcome a new vice-chair, Paul Crutzen, who formerly served as vice-chair of the IGAC SSC and is a recipient of the Nobel Prize in Chemistry in 1995. Both nominations will take effect on January 1, 1998.

EDUCATION HIGHLIGHTS

AGCI LAUNCHES PESTO FOR TEACHER ENHANCEMENT

From NASA Mission to Planet Earth Education Program Update
— Nahid Khazenie (khazenie@istbsun.gsfc.nasa.gov), Managing Editor

In response to NASA Research Announcement-96-MTPE-07, the Aspen Global Change Institute (AGCI) developed the Pre- and In-Service Earth Science Training Opportunity — PESTO (NAG5-6072). PESTO was designed to coincide with AGCI's ongoing program of interdisciplinary science meetings for the research community that it holds each summer on topics in global environmental change. Twenty-four pre- and in-service teachers from across the country assembled for the week-long workshop in August. By having the two programs concurrently, the PESTO students were able to benefit from guest discussions and presentations from AGCI's science program. Guests included Stephen Schneider from Stanford University, Amory Lovins from the Rocky Mountain Institute, and Cheri Morrow from the Space Science Institute in Boulder.

The workshop faculty consisted of Richard C. J. Somerville, Professor of Meteorology at Scripps Institution of Oceanography, the University of California, San Diego, and Milton McClaren, former Dean of the Division of Continuing Education and currently Director of Field Relations and Teacher In-service Education for Simon Fraser University, British Columbia. The hands-on workshop utilized a variety of NASA educational materials, AGCI's Ground Truth Studies Teacher Handbook, and, as a pre-workshop reading, Dr. Somerville's new book, "The Forgiving Air." Graduate and undergraduate credits were available to the students.

AGCI was excited by full enrollment, the cooperation of partnering organizations, and the highly-positive evaluation comments from the participants for PESTO's first year. If you are interested in PESTO for the summer of 1998 or would like additional information, please contact John Katzenberger at the Aspen Global Change Institute, 100 East Francis, Aspen, Colorado 81611. Email: agcimail@agci.org.

GSFC Maryland Earth and Environmental Science Teacher Ambassador Program

Twenty Earth and environmental science teachers from the GSFC Maryland Ambassador Program will continue the work begun in 1997 to develop Internet-based Earth system science instructional activities that incorporate NASA data. Selected ambassadors will expand the repository with a new set of investigations to be developed in a July 1998 workshop. Their focus will be on developing investigations to incorporate data available via the EOS platform to be launched in 1998. This project will be conducted in partnership with the GSFC Education Office, NASA Headquarters Code FE, Mission to Planet Earth Education Office, the Maryland State Department of Education, and twenty local Maryland School Systems.

The project goals are to:

√ foster the implementation of NASA Goddard Earth and space science resources available on the World Wide Web into viable classroom activities;
√ use the Internet as a major communication vehicle for the dissemination of Earth and space science curricular support materials to Earth and space science teachers primarily at the secondary level;
√ develop a resource bank of Earth and space science activities using Internet web sites linked to the resources of the Earth and Space Sciences Directorates at NASA Goddard; and
√ correlate the instructional resource bank with national standards for Earth and space sciences.

For information contact:

Stephen Gilligan, Principal Investigator,
charles1@mail.ameritel.net
Vern Smith, Co-Investigator,
vern@aesp.nasa.okstate.gov

Global Learning and Observations to Benefit the Environment (GLOBE)

There are now 58 countries participating in GLOBE, and over 2000 schools from around the world having reported data.

Growth in GLOBE is projected to accelerate in the coming two years. Through the National Oceanic and Atmospheric Administration (NOAA), GLOBE has competitively selected 8 sites across the country and awarded them contracts to host a total of 40 GLOBE Teacher Training Workshops starting this October and continuing through summer 1999. In addition, during this period an estimated 130 workshops will be held by U.S. GLOBE franchises along with over 150 international workshops. Based on typical attendance levels at GLOBE teacher workshops, an additional 9000 teachers will become involved in this program through these workshops. This will approximately triple the number of teachers involved.

GLOBE has reevaluated the way in which it counts observations. At present, in many cases, sets of data involving many student observations are counted as a single measurement report. A new accounting of measurements, which more-accurately reflects the extent of the GLOBE data and student efforts, will be released shortly. It is anticipated that with this more-accurate count, there are already more than 2 million GLOBE student measurements.

The on-going El Niño offers a significant opportunity for GLOBE schools to contribute to contemporary scientific research. Most effects of El Niño in the northern temperate zone are predicted to occur from November to March. GLOBE schools are being told of the role they can play as students by measuring daily air temperature ranges, precipitation amounts, and other parameters. These measurements should reveal the quantitative extent of El Niño effects for the area around each GLOBE school and augment data from other sources. Visualizations of El Niño-related data will be provided via the GLOBE Web Site. What follows is a brief message that is being posted on the Web introducing this activity:

"El Niño is a major shift in the ocean-atmosphere system in the tropical Pacific which has important consequences for weather in many regions around the world. In contrast to the seasonal cycle, which is fairly regular and therefore highly predictable, El Niño events occur at irregular intervals, generally ranging from two to seven years. No two events are alike, and in the early 1990s, El Niño conditions prevailed for four out of five years.

GLOBE students can help scientists learn more about El Niño events by consistently reporting GLOBE measurements. Air temperature, rain, solid precipitation, soil moisture, and quantitative land biology measurements from GLOBE schools will provide direct observations of the changes in temperature and precipitation which are predicted to occur in various regions at different times. The other GLOBE measurements may reveal secondary effects of El Niño-induced changes and help scientists determine the full effects on our environment.

GLOBE will provide schools with a world map showing the changes expected in different regions now and in the coming months. This prediction will be based on the observed effects of past El Niño events and will serve as a hypothesis which we can test with our GLOBE measurements. As the data come in, GLOBE will provide periodic assessments of what they are showing about this event. Seven or eight months from now, if schools are very active in taking data, GLOBE student measurements will have revealed much about the effects of this El Niño.

Throughout the year, GLOBE will feature special learning activities and visualizations to facilitate classroom study of El Niño and to encourage GLOBE schools to engage in their own investigations of this phenomenon and its history. The El Niño has begun, so watch for more information from GLOBE and get going or keep going on taking and reporting GLOBE data."

Resources On The Internet

El Niño Web Site:
http://nsipp.gsfc.nasa.gov/enso
Guide to U.S. Department of Education Programs & Resources:
http://web99.ed.gov/GTEP/Program2.nsf
Learning Technologies Channel:
http://quest.arc.nasa.gov/ltc/

RADARSAT Gives First Mapping of the Antarctic

WASHINGTON, DC (Nov. 18) BUSINESS WIRE -Nov. 18, 1997— Canadian Space Agency (CSA) and National Aeronautics and Space Administration (NASA) released today the first mosaic generated from a compilation of images from the Antarctic Mapping Mission (AMM). RADARSAT, Canada's first Earth observation satellite, has returned to routine operations after having successfully completed the AMM. The RADARSAT Mission Control Office has indicated that the satellite has been programmed to return to its original right-looking orientation and is operating at full capacity. "The first mapping of Antarctica by RADARSAT is now complete, and it has been a resounding success—far exceeding my expectations both in completeness of coverage and in quality and information content of the images" said Dr. Robert Thomas, program manager for polar research NASA.

The AMM began on September 9, 1997, with a 180-degree rotation of RADARSAT to allow the satellite to begin taking radar images of the entire Antarctica, an uncharted region the size of Canada and Alaska combined that had never been fully mapped by high-resolution radar remote-sensing technology. Following a 14-day commissioning stage, RADARSAT took more than 8,000 images of Antarctica over an 18-day period. The entire mission was completed almost five days ahead of schedule, and successfully acquired 2,000 images more than initially proposed.

Scientists at the Byrd Polar Research Centre are now compiling the images to complete a high-resolution digital mosaic of the ice sheet, and exposed portions of the continent will help us to better understand why changes in the ice sheet occur, providing more insight into the effects of human activity and global warming on the rapid retreat of large portions of the ice shelves in the Antarctic Peninsula. In addition, many of the additional 2000 images collected at the end of AMM form interferometric pairs when matched with images collected over the same terrain 24 days earlier, when the satellite was in the same location. Analysis of this interferometric data set will provide detailed estimates of the ice topography and ice motion in central parts of the ice sheet, where scarcely any other measurements have been made. This information will significantly enhance the first detailed map of surface features over all of Antarctica that the AMM will provide.

Partners in the mission included the CSA, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Jet Propulsion Laboratory (JPL), Byrd Polar Research Centre of Ohio State University (OSU), Alaskan SAR Facility (ASF), VEXCEL Corporation, Boulder, Colorado, Canada Centre for Remote Sensing (CCRS) and RADARSAT International (RSI).

NASA's principal involvement in RADARSAT is part of the agency's Mission to Planet Earth enterprise, a long-term coordinated research program to study the Earth's land, oceans, air, ice, and life as a total system.

Launched in November 1995, RADARSAT is owned and operated by the CSA in Saint-Hubert, Quebec. Canada's remote sensing expertise is housed in the Canada Centre for Remote Sensing, of Natural Resources Canada, with RADARSAT imagery marketed and distributed by RADARSAT International, a Canadian company located in Richmond, British Columbia. The satellite was designed and built in Canada by a team of 30 companies from across the country, led by prime contractor Spar Aerospace.

The mosaic being released today is available at: ftp://iceberg.mps.ohio-state.edu and pub/mosaic.tif and readme.txt. Further images from the Antarctic Mapping Mission are also available on the CSA Web Site at http://radarsat.space.gc.ca.

CONTACT: Canadian Space Agency, Isabelle Hudon, 514/926-4355, URL at http://www.space.gc.ca, or NASA/Doug Isbell, 202/358-1753, URL at http://www.nasa.hq.gov

EOS Science Calendar

January 8-9	User Working Group Meeting for the ORNL DAAC, (site TBD). Contact: Robert B. Cook, tel. (423) 574-7319, e-mail: cookrb@ORNL.GOV
January 12-16	7th Annual JPL Airborne Earth Science Workshop. Pasadena, CA. Contact Catherine Hormann, tel. (818) 354-0963, e-mail: cat@gomez.jpl.nasa.gov
February 17-18	TES PDR, NASA/Goddard Space Flight Center. Contact: Rudy Larson, e-mail: Rudolph.K.Larsen.1@ gsfc.nasa.gov
February 23-25	AIRS Science Team Meeting, Santa Barbara, CA. Contact: George Aumann, e-mail: hha@williwaw.jpl. nasa.gov
April 1-2	PM-1 Science Data Validation Workshop, University of Maryland Inn & Conference Center, College Park, Maryland. Contact: Mary Floyd, tel. (301) 220-1701, e-mail: mfloyd@pop200.gsfc.nasa.gov

Global Science Calendar

— 1998 —

January 11-16	American Meteorological Society, Phoenix, AZ. Contact AMS Office, tel. (202) 682-9006, fax: (202) 682-9298, e-mail: ams@dc.ametsoc.org.
January 25-29	Space Technology & Applications International Forum, Albuquerque, NM. Contact Carolyn Marcum, tel. (505) 277-2813, fax: (505) 277-2814, e-mail: cmarcum@unm.edu.
March 10-13	XVth Oceanology International Exhibition & Conference in Brighton, UK. Contact Bob Munton, tel. +44 (0) 181 949 9222; fax: +44 (0) 181 949 8186/8168, e-mail: versha@spearhead.co.uk.
March 16-20	Workshop on Inverse Modeling of Global Biogeochemical Cycles, Heraklion, Crete. Contact Dork Sahagin, tel. (603) 862-3875, e-mail: gaim@unh.edu, URL at http://gaim_unh.edu.
March 25-29	Association of American Geographers, Boston, MA. Contact AAG, tel. (202) 234-1450, fax: (202) 234-2744, e-mail: gaia@aag.org, URL at http://www.aag.org.
March 30 - April 4	ASPRS-RTI Annual Convention, Tampa, FL. Call (301) 493-0290, fax: (301) 493-0208. e-mail: asprs@asprs.org.
April 2-4	Johns Hopkins Conference in Environmental Fluid Mechanics, Baltimore. Contact Haydee Salmun, e-mail: haydee@jhu.edu.
June 8-11	9th Global Warming International Conference & Expo, Hong Kong. Contact Sinyan Shen, tel. 1-630-910-1551, e-mail: Syshen@Megsinet.net, URL at http://www2.msstate.edu/~krreddy/glowar/glowar.html
June 8-12	27th International Symposium on Remote Sensing of Environment. Tromso, Norway. Contact 27th International Symposium on Remote Sensing of Environment, Norwegian Space Centre, P.O. Box 113 Skoyen, N-0212 Oslo, Norway. fax: +47 22 51 18 01, e-mail: isrse@spacecentre.no. Information will be posted on the 27th ISRSE web site as it becomes available: http://www.spacecentre.no/
July 6-10	International Geoscience & Remote Sensing Symposium, Seattle, WA. Contact Tammy Stein, tel. (281) 251-6067; fax: (281) 251-6068, e-mail: tstein@phoenix.net
July 19-24	SPIE International Symposium, Optical Science, Engineering, and Instrumentation. Call for Papers. Contact William L. Barnes, wbarnes@NEPTUNE.GSFC.NASA.GOV, see update at http://www.spie.org/info/sd/
July 20-24	9th Australasian Remote Sensing Photogrammetry Conference, Sydney, Australia. Contact Gramme Tupper, tel. 063.913.143, fax: 063.913.767, e-mail: tupperg@agric.nsw.gov.au.
August 17-21	International Conference on Satellites, Oceanography & Society, Lisbon, Portugal. Contact David Halpern, e-mail: halpern@pacific.jpl.nasa.gov, or URL at http://www.unesco.org/ioc/iyo/icsos/.
October 25-28	Geological Society of America Toronto. Call (303) 447-2020; fax: (303) 447-0648.

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