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Editor's Corner

The most significant event of this summer was the review of the U. S. Global Change Research Program (USGCRP) by the National Academy of Sciences' Board on Sustainable Development. This review, co-chaired by Ed Frieman (Scripps Institution of Oceanography) and Berrien Moore (University of New Hampshire), was held in La Jolla, July 19-28. This was the first part of a two-part review and, as such, focussed largely on NASA's contribution to the USGCRP, Mission to Planet Earth, and the Earth Observing System. A final report was delivered to all members of the U.S. Congress as well as the White House Office of Science and Technology Policy. Among the many recommendations contained in this report were: (i) success in attacking the long-term scientific challenges of the USGCRP requires an adequate and stable level of funding that promotes management efficiencies and encourages rational resource allocation, and (ii) further budgetary reductions or imposed constraints on technical options could require the elimination of key sensors, slips in schedule, loss of data continuity, and the elimination of advanced technology development that could enhance future research and lower costs.

Some underlying tenets of the report included the need to: (i) maintain a science-driven approach to observational and information management technology, and (ii) implement the first group of EOS components without delay, including launching Chemistry-1 on schedule (December 2002) — focusing the tropospheric components of Chemistry-1 on the global distribution of ozone and its precursor gases. With regard to EOSDIS, the report recommended: (i) streamlining the EOSDIS plans for data downlink (command and control of spacecraft and instruments) and level-0 and level-1B (calibrated, geolocated) data processing, and (ii) reconfiguring EOSDIS to transfer responsibility for product generation, publication, and user services to a competitively selected federation of partners from government, academia, and the private sector. Finally, the NRC report recommended expanding *in situ* observations, process studies, and large-scale modeling activities, a direction that the EOS program has already begun to aggressively pursue. The NRC report further discussed the role of small satellites in Earth observation, and concluded "in some cases, physics, economics, and engineering constraints may preclude the application of small satellites. A balanced architecture for MTPE employs satellites of various sizes as appropriate to scientific needs."

As a follow-up to the NRC review in La Jolla, and in order to prepare for a January review of the remaining agencies of the USGCRP, a Payload Panel meeting is being scheduled for November 28-30 in Annapolis. In particular, items for discussion at this meeting will include: (i) EOSDIS restructuring, including recompetition of some DAAC functions, (ii) EOSDIS costs, (iii) new satellite systems, including science involvement and prioritization of Earth System Science Pathfinder and New Millennium programs, (iv) NASA/NOAA/DoD convergence and the National Polar Orbiting Environmental Satellite System (NPOESS), (v) the Tropospheric Emission Spectrometer (TES) and its role in tropospheric ozone and precursor gases, and (vi) spectrometer and interferometer concepts for temperature and moisture sounding from the polar orbiting satellites of the future. If time permits, some discussion on validation campaigns and plans may occur as well. Registration for this meeting can be done directly on World Wide Web from the Project Science Office home page.

The long-awaited NASA Research Announcement (NRA) for new investigations and investigators for the Earth Observing System will be available on the Internet (through both the Mission to Planet Earth and EOS Project Science Office home pages on the World Wide Web) on September 22. This method of distributing the announcement takes advantage of the breadth of EOS background information, such as the *Mission to Planet Earth/Earth Observing System (MTPE/EOS) Reference Handbook*, that currently resides on World Wide Web (http://spso.gsfc. nasa.gov/spso_homepage.html). The NRA solicits investigations in the following five categories: (i) Landsat Science Team Members and Team Leader, (ii) Team Members for EOS Facility Instruments (e.g., AIRS, MODIS, Microwave Imager), (iii) Interdisciplinary Investigations, (iv) New Investigators Program, equivalent to a Young Investigators solicitation, and (v) Science Education Grant Supplement. The first two categories are to be funded by my office, the third and fourth categories are to be funded by the EOS Program Scientist (Dr. Ghassem Asrar), and the last category is to be funded by the Education Program of the Office of Mission to Planet Earth (OMTPE). Neither the Radar Altimeter nor ODUS are included in this solicitation, nor is there a solicitation for a correlative measurement program. These three items will be included in a separate solicitation next year following further definition of the instrument and mission arrangements for the Radar Altimeter and ODUS instruments, as well as further definition of the gaps to be filled by a correlative measurement program.

After a lengthy process, Administrator Dan Goldin has authorized Bill Townsend, Deputy Associate Administrator of OMTPE, to sign the Common Spacecraft contract with TRW Inc. of Redondo Beach, CA. This cost-plus-award-fee contract for $398.7 M provides a firm contract for two spacecraft (PM-1 and Chemistry-1) along with options for two more spacecraft (for an additional $269.8 M). This very significant event allows EOS to proceed with the development of the PM-1 spacecraft for launch in December 2000.

Finally, I would like to congratulate Mr. Joseph Rothenberg for his selection as Director of Goddard Space Flight Center. His breadth of experience in both industry and NASA makes him an ideal person to lead Goddard in the years to come (see page 21).

—Michael King
EOS Senior Project Scientist

The Tenth EOS Investigators Working Group Meeting

Santa Fe, New Mexico, June 27-29, 1995

—**Renny Greenstone** (renny@ltpmail.gsfc.nasa.gov), EOS Project Science Support Office, Hughes STX Corp.

The tenth meeting of the EOS Investigators Working Group (IWG) and a special meeting of the EOS Payload Panel were held in Santa Fe, New Mexico, June 27-29, 1995. An undercurrent throughout the meeting was the need to face ever-tightening budgetary constraints.

In line with the strong concerns with budgetary issues there were major presentations on the implementation of Mission to Planet Earth (MTPE) in the post-2000 era by Bob Price, an EOSDIS cost model by Dale Harris, and an overall MTPE implementation review by the Payload Panel.

Other topics that received major attention were: (i) an increased focus on collaboration between NASA and NOAA, with special consideration of mutually supporting roles in the converged National Polar Orbiting Environmental Satellite System (NPOESS C-1) to be ready for launch in 2004; and (ii) the status of plans for, and progress in, developing an EOS Science Implementation Plan to be completed by the end of this year.

Tuesday Morning, June 27, 1995

Ghassem Asrar, EOS Program Scientist, presided over this plenary session.

Charles Kennel, Associate Administrator for Mission to Planet Earth, was the lead speaker, giving the philosophy of Earth observations, a short description of the evolution and current status of EOS, and then a discussion of the NASA/NOAA alignment process.

Kennel said that significant public expenditures must be sustained for global change research. "The world will need an Earth Observing System indefinitely. Scientific integrity is the *sine qua non*." There must be frank assessments of quality and open discussions of scientific uncertainty.

He started the evolutionary review by saying that following last year's August 1994 rebaselining, it was still possible to maintain the schedule for the first EOS series of platforms and instruments although the program was now reduced to its minimal cost and with considerable risk.

In January of this year, the President's FY 1996 budget request called for removing an additional $5 billion from the NASA budget through FY 2000. MTPE was asked to consider how to take its share of the cuts but responded that it was already too close to an ultimate minimum to lower its budget requirements any further. Following an assessment period, NASA Administrator Dan Goldin instituted a Zero Base Review. It was concluded that the agency would take a reduction in its infrastructure—thus there would be a drop in employment at each of the NASA Centers. In the President's budget request, the employment drop was pegged at about 30%, to be achieved through reduced staffing. Still, the science conducted at the Centers was largely protected. Another conclusion of the Zero Base Review was that NASA would now move toward a "full" accounting system in which government salaries and overhead would be taken into account as in the private world.

Also early this year there was a Federal Laboratory Review which caused NASA, DOE, and DoD to look for redundancies in their organizations. The NASA review was conducted by John Foster. They found that MTPE was among the most important of the NASA programs, but two elements were lacking: 1) no technology infusion was explicitly included in MTPE, and 2) there was no overall science plan, and planned-for short-term results were not defined.

Later, Robert Walker, chairman of the House Science Committee requested a General Accounting Office (GAO) study of the life-cycle cost of EOS over a 29-34 year lifetime. Kennel said that it is essential to respond immediately to such cost questions. He cited the Superconducting Supercollider debacle as an example of a program whose demise was caused by an apparent lack of attention to costs. For EOS there needs to be an explicit picture of the costs associated with the next phase, running out to the year 2022.

The Congressional Budget Office (CBO) in February of this year presented an analysis of how to achieve an $840 M cut in EOS through the year 2000. They concluded that this could be done through delaying the CHEM mission by five years and taking away 25% of the EOSDIS budget. In this approach, there would be delays in providing the data stream, and there would be no short-term benefits achieved.

In March of this year, OMTPE (the Office of Mission to Planet Earth) issued a white paper describing an EOS evolution study in which long-term costs would be reduced, and the program would operate under an annual budget cap after the year 2000. Also in March, OMTPE initiated a NASA/NOAA alignment study, which was to demonstrate how to achieve the benefits of data system synergy.

In April, Congressman Walker requested two coordinated studies: The National Academy of Sciences (NAS) Board on Sustainable Development was to conduct its Congressionally mandated five-year review of U.S. Global Change Research Program (USGCRP), especially EOS and EOSDIS, and NASA was to prepare a scientific and technical justification of EOS and EOSDIS.

In May, the House of Representatives budget committee passed a resolution calling for a $2.7 billion reduction in MTPE for the period FY 1996 to FY 2000.

As one sign in a more-positive direction, in June the Senate subcommittee on Science, Technology, and Space reported favorably on MTPE. Also in June, the GAO issued its study on EOS life-cycle costs.

Turning to the NASA/NOAA alignment study, Kennel said that there could be collocation synergy and also data systems synergy. Collocation synergy includes exploring greater collaboration in modeling and data assimilation, ground systems for spacecraft operations, and algorithm development and research data processing. Data system synergy discussions have included the possibility of integrating NOAA information technology requirements into EOSDIS. There would also be technology infusion from NASA directed toward the development of the National Polar Orbiting Environmental Satellite System (NPOESS).

Concerning the evolution of EOS, Kennel said it would be important to retain the standard 24 measurement sets. They would be accomplished through the flight of the first series of EOS satellites from AM-1 through Laser ALT. Then, it would be feasible to fly the following missions while maintaining a $1 billion cost cap, beginning in 2001.

An important news item was NASA's determination (the week before the IWG meeting) that ESA could not commit to providing the MIMR instrument with acceptable assurance. Accordingly, NASA is exploring the possibility of the Japanese providing an AMSR instrument as replacement for MIMR.

Kennel described the MTPE strategic plan for commercialization activities. The concept is to stimulate commercial involvement in MTPE in several possible ways: 1) through commercial use of MTPE data, 2) government purchase of commercial data, 3) privatizing certain MTPE functions (taking advantage of commercial assets—"anchor tenancy"), and 4) having commercial interests use government assets.

Kennel affirmed NASA's belief that the world needs and will need an Earth Observing System indefinitely, and he reviewed the question of whether the global change research is sustainable. If the House budget resolution to take $2.7 billion away from MTPE in the period FY 1996 to FY 2000 were to come to pass, and the amount came entirely from EOS, there would be a 79% reduction in the non-contracted effort. This would essentially allow completion of the spacecraft now in the development phase—TRMM, AM-1, and Landsat-7—but not allow the balance of the first EOS series to be initiated as planned. This would have the effect of unraveling the global climate change strategy.

Various discussion points followed Kennel's presentation. Reinhard Beer pointed out that technological infusion has already occurred in the EOS program—calling attention to the developments in cryogenic coolers that have been spurred by NASA. Peter Brewer stated that the National Science Foundation (NSF) is NASA's largest partner in U.S. Global Change Research and asked whether NSF is included in discussions on achieving the goals of MTPE. Kennel responded that there is no formal agency-to-agency partnership between the two agencies, but he does consult with Bob Corell at NSF.

Vince Salomonson urged that OMPTE develop a crisp statement on why Earth observations are needed indefinitely.

Kennel said that there had been a Marshall Institute report in response to a request from Representative Walker. The report was somewhat negative on global change research, but acknowledged the potential for global warming and agreed that there should be stable long-term funding for global change research.

Kennel said that there was a real possibility of a merger of appropriate elements of NOAA with NASA/MTPE. He also gave instances of coordination with other nations. He said that the draft plans of ESA, NASDA, and NASA all point to a global Earth observing system originating around the year 2015.

Robert Price, director of the Mission to Planet Earth Office (MTPEO) at the Goddard Space Flight Center (GSFC), gave a summary presentation on "EOS Program Reshape." In the presentation, he described MTPE implementation in the post-2000 period. The effort to redefine NASA's approach to accomplishing MTPE objectives in the post-2000 era has been termed "reshaping." The reshaping effort calls for the EOS program to fit within a cost cap and to end in the year 2019. It also calls for increased NASA/NOAA cooperation.

Price showed the new MTPE timeline. It includes the five-year USGCRP reviews called for by the Congress and two-year program reviews called for by MTPEO. Flights in the New Millennium Program (NMP) are to begin in about FY 98 and will take place on 18- to 20-month centers. They will focus on developing new technologies. New science is expected to come from applications of NMP developments to the new program of Earth System Science Pathfinders (ESSP). The year 2019 has been adopted as the date for ending the EOS program.

The steering committee for the reshape process was led by Charles Kennel for NASA and Robert Winokur for NOAA. The three study teams were: Science (Michael King, Chair), Flight (Chris Scolese, Chair), and Data (John Dalton, Chair).

The ground rules for the "reshape" exercise included changing the scope of EOS without increasing funding for the years prior to 2000 to do the following in priority order: 1) provide for NOAA and Landsat operational measurement sets beginning in 2004; and 2) support funding for future Mission Technology Flight Demonstrations in NMP.

There is a new proposed approach to defining EOS missions. Some are to be designated as "monitoring," and others are to be designated as "process study" missions. Monitoring missions are those that must be conducted continuously—without breaks—whereas process missions may be interrupted for periods of time.

The concept of the 24 EOS measurement sets is to be preserved, but it is understood that there is not a one-on-one correspondence between the instruments and the measurement sets.

Designing a smaller AM-2 mission will permit advancing the MODIS and Landsat Advanced Technology Instrument (LATI) measurements. There is to be an advanced MODIS and an advanced MISR on AM-2. The CHEM-2 mission will be split into a monitoring and a process study mission. In the new mission sequence, Laser ALT is advanced to 2001. A new PM-2A mission will be designed to complement the NPOESS C-1 mission.

Price presented seven options for reducing the costs of EOSDIS. Among them was decreasing the number of Distributed Active Archive Centers (DAACs). The recommended approach was to establish two "consolidated" hubs where the data processing hardware would be situated and five user support centers from which data processing can be accomplished remotely. This move is hoped to lead to considerable savings.

Regarding the NASA/NOAA alignment process, preliminary considerations have included program integration (referring to the science activities), technology infusion for both low-Earth orbit (LEO) and geostationary orbit (GEO) missions, and synergistic relations regarding the data systems.

Price said that the second series of EOS missions will incorporate developments from the New Millennium Program (NMP). The third series (referred to so far as "dash 3") are now designated "continuity" missions and will also feature developments from NMP. There are to be Announcements of Opportunity (AO) for participation in the Earth System Science Pathfinder (ESSP) missions.

Price gave a charge to the IWG and to its Payload Panel: 1) "Consider the proposed changes to the program and make recommendations"; and 2) "Offer suggestions to define your participation in a process to periodically review the program, including advances in the state-of-the-art and mission concepts."

Price concluded his presentation saying that the "reshaping" process preserves the 24 EOS measurement sets and will stay within a $1 billion annual budget cap in the years after 2000.

Berrien Moore discussed the forthcoming National Academy of Sciences/National Research Council (NASA/NRC) Summer Study, which will be a review of USGCRP and, therefore, MTPE/EOS. The review will be held at the Scripps Institution of Oceanography starting on July 19, and will be co-chaired by Ed Frieman (Scripps) and Moore (University of New Hampshire, EOS Principal Investigator). [Frieman is chair of the NAS Board on Sustainable Development, and Moore is chair of the Board's Committee on Global Change Research (CGCR)]. The review was called for in a letter from Congressman Robert Walker, Chairman of the House Committee on Science, addressed to Bruce Alberts, President of the NAS, and Robert White, President of the National Academy of Engineering (NAE). Walker's letter points out that the requested review is in line with Public Law 101-606, the Global Change Research Act of 1990. This law specifies that there be a five-year review cycle on USGCRP. (USGCRP was established in 1990.) The letter mentions changing needs for activities in support of public policy.

In the letter Walker states his interests in establishing the scientific progress that has been achieved to date; assessing the current observational strategy—taking into account the possible commercial uses of the products—considering the possibility of privatizing EOSDIS.

Moore presented the preliminary agenda for the Summer Study. Four science areas have been identified with the following panel leaders:

◊ Seasonal to interannual climate change—Edward Sarachik

◊ Decadal to centennial climate change—Eric Barron

◊ Atmospheric chemistry—Guy Brasseur

◊ Large-scale ecosystem change—David Schimel.

The Study is to end on Friday July 28, and hard copies of its findings are to be delivered by the end of August to the Congress, the Office of Science and Technology Policy (OSTP), and the administrators of the relevant federal agencies.

Bob Harriss, Director of the Science Division of MTPE, spoke on MTPE Science Implementation. He stressed that MTPE science needs to adopt an aggressive posture. We must get the message across that lots of progress has already been made. It is very important to have metrics of MTPE accomplishments.

The time is right to make it clear that NASA Research and Analysis (the R&A program) science and EOS science work together. There is, in fact, a fully integrated effort within NASA and within NOAA and NSF as well.

A draft MTPE science plan is to be issued this fall. Science priorities for the years 1995 to 2000 are as follows:

◊ detect causes and consequences of changes in atmospheric ozone—this includes tropospheric chemistry;

◊ conduct satellite observations and scientific studies necessary to the understanding that is required to improve forecasts of the timing and geographic extent of seasonal to interannual climate anomalies;

◊ document and understand trends in regional land cover and global productivity; and

◊ provide global observations, process studies, and Earth system modeling tools for the analysis of factors which determine long-term climate variability.

Harriss gave research goals that support each of the four science priorities and then listed observations that support the goals. In support of the seasonal-to-interannual climate change research goal are observations to characterize extreme climate events and natural hazards.

Harriss pointed out that NASA's space geodesy program is basic to conducting MTPE's sea-level altimetry mission. Good digital elevation model (DEM) data are needed and planned for in support of many aspects of Earth remote observations.

Looking at the USGCRP goal in regard to land-cover change and global productivity, Harriss noted that changes in "industrial metabolism" and land transformations are both examples of human forcing.

The ocean color community is pulling together a calibration/validation plan to make use of data from various observing programs, both interagency and international. The modeling community is finding that model intercomparisons are powerful tools to drive science forward.

A near-term product of Earth observing science is likely to be the development of high-precision agriculture.

The Upper Atmosphere Research Satellite (UARS) has provided a global perspective on stratospheric ozone changes and has been the basis for the action by society to restrict the uses of CFCs and thereby to bring human-caused ozone depletion to a halt. In this connection Goddard has a new space-based program to measure surface levels of UV.

Kennel added that a shuttle radar laboratory (SRL) mission could collect great amounts of topographical data. This would be an important supplement to the MTPE missions and to the work of the Defense Mapping Agency.

Tuesday Afternoon

Michael King, EOS Senior Project Scientist, presided over this plenary session.

Yukio Haruyama, National Space Development Agency (NASDA) of Japan, discussed NASDA future Earth observation plans. The ADEOS spacecraft is due to be launched in August 1996, and the launch of ADEOS II will permit an overlap between the two missions, leading to a continuous 10-year program.

AMSR is intended to fly on ADEOS II, and there are plans for a TRMM follow-on to be called ATMOS-A. However, there is no funding commitment for space missions beyond 2004.

NASDA's data policy is the same as that of EOSDIS. Procedures for getting data to the users are under development right now.

Chris Readings, European Space Agency (ESA), described ESA's future Earth observation plans. There is an intent to increase commercial and operational use of European space-based observations. Since his last presentation, the METOP program (polar) has changed to include three satellites; likewise, METEOSAT Second Generation (MSG) (in the geostationary line) will have three satellites. Meteorological Operational Satellite (METEOSAT) will be flying second-generation instruments; the Geostationary Earth Radiation Monitor (GERB) is an important addition to the program.

The scientific achievements of ERS-1 are now documented and available in book form. There have been 350 responses to the Announcement of Opportunity for participation in ERS-1. Land channels are a new addition for the version of the Along-Track Scanning Radiometer (ATSR) which is to fly on ERS-2.

METOP-1 will include a dual-swath wind scatterometer (ASCATT). An instrument called OMI (based on GOME) is planned as an ozone-monitoring instrument. An effort has been under way for the first time to get the operational community to state its requirements for OMI.

A Doppler wind lidar is still under study as part of an Earth Observations Preparatory Program (EOPP).

Readings defined candidate missions for the post-2000 era. The Earth Explorer missions will be dedicated to R&D. The Earth Watch missions are regarded as pre-operational. There were nine identified candidate Explorer missions—the first three are to have priority as important and feasible, but not being done elsewhere. A proposed chemistry mission was regarded as too ambitious, but it will be reconsidered when the requirements have been scaled back.

Five missions have been identified under the rubric of Earth Watch. The strongest push is for coastal zone observations—both land and water. ESA is also reviewing the future of synthetic aperture radar (SAR). A data system is now being built to accommodate data starting with ERS-1 and continuing to the time of ENVISAT. There is a concern with data transfer across international boundaries. Collaboration has been most successful on operational scenarios, e.g., EUMETSAT with NOAA.

Ichtiaque Rasool commented that at the Center for Earth Observations they are trying to form an entity among EUMETSAT, ESA, and the European Community.

Michael Freilich, chair of the Panel on Data Quality (PDQ), discussed developments that are directed toward an overall EOS Calibration/Validation and Quality Assurance Plan, which defines activities aimed at ensuring the ultimate scientific integrity of the EOS data suite. Uncertainties arising from different instruments contribute to the overall uncertainties associated with the various EOS measurement products.

Freilich gave his definitions of calibration, validation, and quality assurance:

◊ Calibration is the responsibility of the *instrument providers*. It involves specification of the transformations needed to extract basic instrument measurables from telemetry, and specification of the uncertainties in the basic instrument measurables over the entire range of input and environmental conditions.

◊ Validation is the responsibility of the *algorithm providers*. It involves specification of the transformations required to extract estimates of high-level geophysical quantities from calibrated basic instrument measurables and specification of the uncertainties in the high-level geophysical quantities.

◊ Quality assurance is the responsibility of the *data system* based in part on thresholds defined by instrument and algorithm providers. It involves the identification of data products which obviously and significantly do not conform to the expected "accuracies."

The Panel views as its key effort establishing the adequacy of the calibration/validation activities conducted in EOS.

Following an afternoon break, Drew Rothrock, as leader of the effort, described the status and gave an overview of the EOS Science Implementation Plan. He said that the Plan would fill a serious void for which EOS has been criticized for some time. He listed the chapters which address each of the seven themes of EOS, identified the lead chapter authors, and said that the intent is to have the Plan published by the end of this year. Also in his listing were the names of persons designated to provide specific sections within the chapters. With seven topical chapters of about 50 pages each plus additional front and back chapters, Rothrock estimated that this would turn out to be about a 500-page document.

There was some discussion as to whether this would be properly called an "implementation" plan if it did not carry dates by which things are to be accomplished. Another issue was whether specific individuals or groups in EOS would be named. Pierre Morel noted that there were parts of Earth science that did not appear in the outline of the Plan. For instance, he said, atmospheric circulation was omitted, the troposphere was omitted, and coastal zone activities were omitted.

Mous Chahine said that the Plan should give the hypotheses which have led up to the elements of the EOS program—Why are we doing this? We must also give the expected results of the program. Ricky Rood called attention to the need to have one specific place in the Plan where the assimilation effort could be described, showing its integrative effect over all the aspects of EOS science. He also argued for the use of timelines in the Plan and said that it would be important to specify uncertainties where they exist and indicate how they would be reduced.

Bruce Wielicki felt that it would be desirable to indicate new possibilities for measurements such as cloud radars. Correspondingly, Mark Schoeberl proposed that the Plan should identify measurements that are not being made by EOS.

The last speaker of the day was Dennis Hartmann who, as lead author for Chapter 4, Clouds, Radiation, Water Vapor, and Precipitation, of the Science Implementation Plan, discussed the status of the chapter. Material is coming in as requested. As described later, other chapters were discussed in breakout sessions on Wednesday afternoon.

Wednesday Morning, June 28, 1995

Ali Montasser, NASA Headquarters, chaired this plenary session, which was devoted primarily to developing an understanding of EOSDIS operations and associated costs.

Lead speaker was Dale Harris, Associate Director of Mission Operations and Data Systems for the Earth Science Data and Information System (ESDIS) Project at NASA Goddard, who gave the EOSDIS update and status. Harris said that there has been a complete reorganization of EOSDIS since last year and listed the program changes that have been made. Among these changes were: a tentative decision to abandon TDRSS for the missions that follow the AM-1 mission—using ground stations would lead to a cost increase for EOSDIS but a savings in costs attributed to the spacecraft; a decision to consolidate the EOS Data and Operations System (EDOS) at White Sands that would save on costs; and a decision to strengthen the system engineering and integration team in the ESDIS Project.

Organizational changes included: naming Harris to his present post with John Dalton as his deputy; naming Ellen Herring to head the System Management Office; Mel Banks to head the Development Office; and H. K. Ramapriyan to head the Science Office where he oversees the DAAC efforts.

Harris showed the TRMM launch schedule and said that EOSDIS will archive and distribute all TRMM data. While listing major accomplishments Harris noted that the DAACs now need test data sets from TRMM instruments.

The Version 0 (V0) Information Management System (IMS) has been on-line since August 1994. It has some problems due to bandwidth limitations. There is an approach to making V0 available through a World Wide Web gateway.

Jim Hansen noted that in the past civil servant costs have not been included in government cost budgets but that they will be in the future. This will be a significant consideration in evaluating the "real" costs of programs such as EOSDIS.

Dave Glover, Woods Hole Oceanographic Institute, chairman of the EOS Data Panel, gave a Panel update and status. He thanked Harris for his clarifications of the $2.2 billion EOSDIS budget, which would be the subject of Harris's follow-on presentation. He referred to the activities of the two *ad hoc* EOS study groups, the *Ad Hoc* Working Group on Production and the *Ad Hoc* Working Group on Consumers. He noted that projected savings in EOSDIS are to come from reductions in networks and reductions in personnel costs.

The new consolidation concept calls for having two Processing and Archiving Centers (PAACs) and establishing User Support Service Centers (USSCs) to replace the DAACs. The two PAACs would not necessarily be back-ups for each other.

Reinhard Beer commented that the instrument people worry about their data disappearing into a centralized facility and that his group would be perfectly happy to do its own processing. Bruce Barkstrom opined that it was highly probable that there would be no economies of scale due to centralizing—also communications costs would rise.

Much of the morning plenary session was given over to a major presentation by Dale Harris, simply titled EOSDIS Costs. The purpose of the presentation was to develop an understanding of the cost elements of EOSDIS to enable better participation by the science community in budget reduction decisions, and to build support by the science community for the resulting reduction decisions.

Harris started by saying that the Hughes contract known as the EOS Core System (ECS) delivers only a piece of the entire system. The Project at Goddard contracts to deliver the entire system. Referring to an earlier proposed change, he said that adding ground stations for data acquisition would lead to an added $100 million in costs. This is because data storage onboard the spacecraft following AM-1 would need to be increased.

Harris gave a detailed budget summary for EOSDIS. Columnar entries, listed by function, were for FY 1995 and prior years (one column) and then individual entries for each fiscal year from FY 1996 to FY 2000. The grand total was $2.2308 billion.

Among "individual functions," the two significantly largest cost items were data capture, initial processing, and archiving; and science data processing, archiving, and distribution. Among "engineering/integration functions" the standout cost item was ECS contract-wide functions.

In the discussion that followed, Pierre Morel asked how the requirements could be reduced so as to lower costs. He asked why there were so many flight operations instrument data sets. Who checks their quality (in view of the huge amounts coming down)? Harris responded that all data are saved in case problems should arise later. The requirement to have 95% availability of data for two orbits is a big cost driver.

Jeff Dozier said that we still need to be able to relate costs to requirements. We should be able to identify what would be lost if costs were to decrease? We also need an independent assessment of EOSDIS costs from experts in computer technology. The technological forecasts used by EOSDIS still need to be checked. (Montasser said that there is an independent organization, the Gartner Group, whose business it is to verify costs.) Dozier added that the chief cost driver is the requirement for high system reliability. Reber asked whether changing "requirements" to "goals" or "best efforts" would lead to savings.

Eric Barron, chairman of the EOS Science Executive Committee (SEC), discussed changes within the SEC.

Every year about half of the SEC Panel chairs are replaced, thus bringing in new members to share SEC responsibilities. New chairpersons at this time are as follows:

◊ Modeling Panel—Ricky Rood

◊ Oceans Panel—Jim Yoder

◊ Atmospheres Panel—Richard Zurek

◊ Payload Panel—Mark Abbott

◊ Biogeochemical Panel—John Melack.

Barron reported that the peer reviews for the Interdisciplinary Science Investigations are soon to be held. Principal Investigators may add up to five papers to the peer review package. These can be attachments to the specified 30-page progress report.

Wednesday Afternoon, June 28

Starting at noon and running in two-hour parallel sessions, reviews were held of the various chapters of the Science Implementation Plan, with lead chapter authors as follows:

◊ Radiation, Clouds, Water Vapor, and Precipitation—Dennis Hartmann (discussed in Plenary session on Tuesday afternoon)

◊ Oceanic Circulation, Productivity, and Exchange with the Atmosphere—Drew Rothrock

◊ Land Ecosystems and Hydrology—Steve Running

◊ Ozone and Stratospheric Chemistry—Mark Schoeberl

◊ Cryospheric System—Barry Goodison

◊ Greenhouse Gases and Tropospheric Chemistry—Dave Schimel

◊ Volcanoes, Aerosols, and Climate Change—Dennis Hartmann/Peter Mouginis-Mark.

At several of these chapter reviews the point was made that attention needs to be paid to the question of the social relevance of EOS science.

Thursday Morning, June 29

This was the beginning of an all-day session of the EOS Payload Panel. This morning session was largely devoted to providing information that the Payload Panel could use in its deliberations.

Mark Abbott, as new chair of the Payload Panel, opened the session and said that it is expected that the Panel will meet again in the fall. He then yielded the floor to Bob Price, for a presentation on the EOS "reshaping" exercise that has been going on since early March. Price noted that John Hrastar, his new deputy, led the exercise.

The guidelines were to reshape the program for the post-2000 era, to fit a cost cap, to adapt to the better, faster, cheaper mission design approach, and to increase NASA/NOAA cooperation. The task group for the exercise was to take a proactive role in redefining the program. The budgetary target was to stay within an annual $1 billion cost cap. Study teams that were formed included NOAA members as well as representatives of EOS science, flight programs, and data systems.

A ground rule was to retain the 24 measurement sets as a fixed requirement, but not necessarily to retain the specific instruments that might obtain the measurements. Any new science is to be added on as a "new start" under Mission to Planet Earth. The 24 measurement sets listed by Price are shown here as Figure 1.

In another chart, Price categorized those measurements that were felt to be appropriately described as "monitoring" and those described as "process." Monitoring denotes measurements that must be made continuously without interruption. Process measurements can be made with periods of gaps. Breakouts into monitoring and process studies are illustrated in Figures 2a and 2b.

The new proposed launch sequence is shown in Figure 3. Noteworthy on this chart are the appearance of PM-2A, the related NPOESS C-1, and CHEM-2 Monitor and CHEM-2 Process missions. PM-2A now

24 EOS Measurement Sets		
Atmosphere	Clouds & Radiation	GLAS, MIMR (AMSR), CERES, MISR, MODIS EOSP, AIRS/AMSU/MHS
	Precipitation	MIMR (AMSR), LIS
	Chemistry of Troposphere	TES, SAGE III, ODUS, MLS, MOPITT
	Chemistry of Stratosphere	SAGE III, MLS, HIRDLS, ODUS
	Aerosols	SAGE III, MISR, EOSP, GLAS, MODIS
	Volcano Effects	ODUS, MLS, TES, SAGE III
	Meteorological Variables (temp., humidity)	AIRS/AMSU/MHS, MIMR (AMSR), TES, HIRDLS
Ocean	Surface Temperature	MODIS, MIMR (AMSR), AIRS/AMSU/MHS
	Phytoplankton & Biological Production	MODIS
	Sea Ice	MIMR (AMSR), MODIS
	Surface Wind Fields	MIMR (AMSR), SeaWinds
	Ocean Circulation	SSALT/AMR
	Sea Height	SSALT/AMR
Land	Vegetation	MODIS, MISR, ASTER, ETM+/LATI
	Surface Temperature	MODIS, ASTER, AIRS/AMSU/MHS, ETM+/LATI
	Soil Moisture	MIMR (AMSR)
	Snow Cover	MODIS, ASTER, MISR, MIMR (AMSR), ETM+/LATI
	Surface Elevation	ASTER, GLAS, MISR
	Land Use	MISR, MODIS, ASTER, ETM+/LATI
	Fire Occurrence	ASTER, MODIS, TES
Solar	Total Solar Irradiance	ACRIM
	Ultraviolet Spectral Irradiance	SOLSTICE
Cryosphere	Ice Sheet Elevation	GLAS, ASTER
	Ice Volume	GLAS, ASTER

Figure 1. (Modified version of chart presented by Price)

is regarded as the research mission and is limited to three instruments: CERES, "passive microwave," and Advanced MODIS (AMODIS). The other key part of the original PM mission, the overall atmospheric sounding system, is to be carried by NPOESS, characterized as the operational mission. The split of the CHEM mission presumes that monitoring can be done by the Advanced MLS (AMLS) and SAGE III, whereas Advanced TES (ATES), Advanced HIRDLS (AHRDLS), and Advanced Science Instrument (ASI) will make the observations needed for the process studies.

In the discussion that followed an objection was voiced to the phrase that "science needs are met by the reshaped program." Kennel's response was that the program has indeed lost robustness but the measurement categories have been retained. Still the program has become more vulnerable through accepting gaps in the measurement process and through accepting greater reliance on programs conducted by others. Reinhard Beer urged that measurements of the oxidizing capacity of the troposphere be kept as a requirement for monitoring. Moore said that there is a concern about the nature of the collaborative effort between the EOS PM-2 mission and the NPOESS mission. Mouginis-Mark was concerned with the need to provide high-resolution bands to measure SO_2 in the atmosphere. He thought that this might be a suitable requirement for an Earth System Science Pathfinder (ESSP) Mission.

Possible Science Categorization

Current Measurements Program	
Watch—Monitoring/Pre-Operational	Explore—Process Studies/Exploration
• Stratospheric ozone • Surface temperature • Temp & humidity profiles • Cloud & radiative propertis • Stratospheric ozone • Snow cover/sea ice • Land cover & land use • Surface winds over ocean • Ocean topography • Solar insolation • Atmospheric aerosols	• Tropospheric chemistry • Ice sheet topography
Future Candidate Instruments	
Monitoring	Process Studies
• Tropospheric winds • Precipitation	• Soil moisture • Gravity • Sea surface salinity • Land surface topography

Figure 2a.

Possible Science Categorization

Current Program Instruments	
Monitoring	Process Studies
• MLS/HIRDLS/ODUS (TOMS) • SAGE III • AIRS/AMSU/MHS • MODIS/CERES • MIMR/AMSR • MODIS/Landsat • NSCAT/SeaWinds/TBD • SSALT/DORIS/SLR/AMR • ACRIM	• TES • MOPITT • GLAS • ASTER • MISR } Evolve one to monitoring • EOSP } • SOLSTICE
Possible Future Process Studies	
• Laser Wind Sounding • C & L-band passive microwave radiometer • Laser/SAR interferometer • Gravity	

Figure 2b.

Hartmann suggested that monitoring implies trend detection and, therefore, leads to a requirement for a well-calibrated instrument set. Rottman urged that SOLSTICE should be in operation at the same time as the CHEM mission. It would provide a key measurement set for monitoring.

Freilich asked whether the program now assumed that vector surface winds over the ocean would be determined by a passive microwave sensor. Price replied that it was indeed the assumption. Asrar added that it would take advantage of the polarization properties of the signal received from the surface and that this measurement scheme was desired by NOAA. Brewer suggested that sea surface salinity could also be measured by passive microwave using an L-band radiometer.

Continuing his presentation, Price said it is necessary to allow the possibility of new measurements entering the program—this could be accomplished through the 5-year USGCRP review cycle. It is also necessary to give more substance to participation with international entities and with commercial interests.

After the morning break Price continued to outline the cost-reduction plans that are part of "reshaping." He spent considerable time outlining possible changes to EOSDIS that would

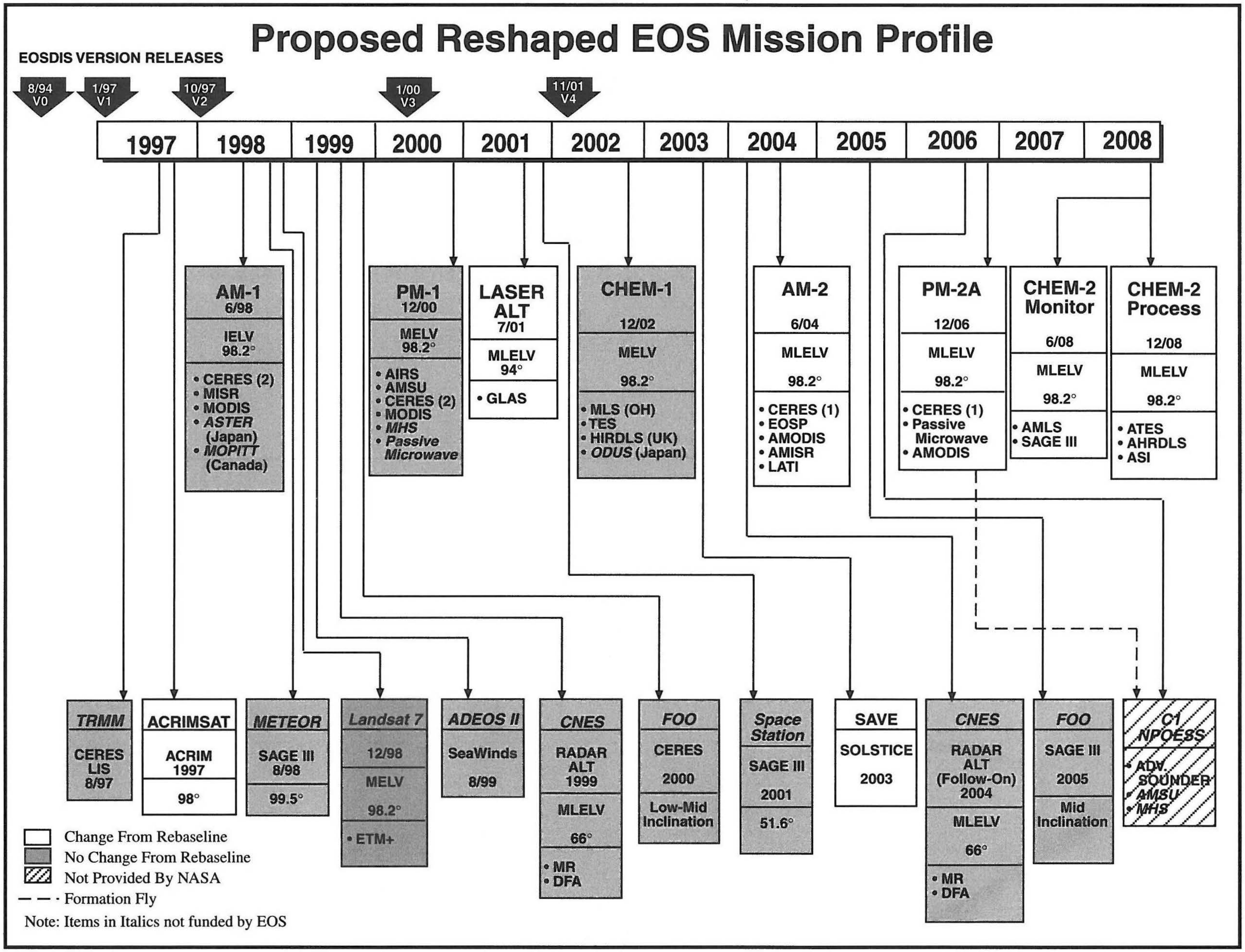

Proposed Reshaped EOS Mission Profile
EOSDIS VERSION RELEASES
8/94 V0
1/97 V1
10/97 V2
1/00 V3
11/01 V4
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
AM-1 6/98
IELV 98.2°
• CERES (2) • MISR • MODIS • ASTER (Japan) • MOPITT (Canada)
PM-1 12/00
MELV 98.2°
• AIRS • AMSU • CERES (2) • MODIS • MHS • Passive Microwave
LASER ALT 7/01
MLELV 94°
• GLAS
CHEM-1 12/02
MELV 98.2°
• MLS (OH) • TES • HIRDLS (UK) • ODUS (Japan)
AM-2 6/04
MLELV 98.2°
• CERES (1) • EOSP • AMODIS • AMISR • LATI
PM-2A 12/06
MLELV 98.2°
• CERES (1) • Passive Microwave • AMODIS
CHEM-2 Monitor 6/08
MLELV 98.2°
• AMLS • SAGE III
CHEM-2 Process 12/08
MLELV 98.2°
• ATES • AHRDLS • ASI
TRMM
CERES LIS 8/97
ACRIMSAT
ACRIM 1997
98°
METEOR
SAGE III 8/98
99.5°
Landsat 7
12/98
MELV 98.2°
• ETM+
ADEOS II
SeaWinds 8/99
CNES
RADAR ALT 1999
MLELV 66°
• MR • DFA
FOO
CERES 2000
Low-Mid Inclination
Space Station
SAGE III 2001
51.6°
SAVE
SOLSTICE 2003
CNES
RADAR ALT (Follow-On) 2004
MLELV 66°
• MR • DFA
FOO
SAGE III 2005
Mid Inclination
C1 NPOESS
• ADV. SOUNDER • AMSU • MHS
Change From Rebaseline
No Change From Rebaseline
Not Provided By NASA
Formation Fly
Note: Items in Italics not funded by EOS

Figure 3.

result in considerable cost savings. Figure 4 illustrates cost-reduction options that have been investigated.

An item that appears to be a major cost driver is the current EOSDIS requirement that "EOS shall be capable of delivering not less than 95% of all measurements made during any two consecutive orbits to the DAACs and the Level 0 backup archive." Price said that a cost-saving alternative would be to have the requirement changed from reading "any two consecutive orbits" to reading "each orbit repeat cycle." He argued that this would allow greater flexibility in spacecraft and ground system design.

EOSDIS
Cost-Reduction Options Investigated

G1. Automate Control Center operations eliminating two shifts/day

G2. Adopt common ground station interface across missions starting with PM-1

a. Ka-band
b. Ka-band—defer second ground station until AM-2
c. X-band—10 m antenna
d. X-band—3 m antenna

G3. Consolidate Ecom and DAAC-to-DAAC networks

G4. Change DAAC approach within EOSDIS (use approach considered by NASA/NOAA Data System Synergy Team)

a. Consolidate DAAC hardware system functions into two hubs controlled by nine User Support Centers
b. Consolidate into hubs, with fewer User Support Centers (former DAACs)

G5. Consolidate into fewer DAACs (no change to DAAC structure)

G6. Consolidate DAACs with NOAA

G7. EDOS simplification

a. Support all missions with current architecture
b. Redistribute Level 0 functions to ground stations and DAACs after AM-1

Figure 4.

Other portions of Price's presentation dealt with the nature of possible program collaboration between NASA and NOAA (NASA/NOAA Alignment) and with technology infusion into MTPE.

Following Price's remarks, Bruce Barkstrom gave his independent assessment of the possible cost reductions to be achieved in EOSDIS. He said that his analysis of hardware costs for the period 1996 to 2000 was in good agreement with the Project's figures. He felt that major savings would come from staff reductions and not from consolidation; and he questioned the Project's figures for network costs as being too high.

Barkstrom presented a strategy for reducing costs without consolidating facilities. This strategy is based on some preliminary results from an EOSDIS system model that he created. He felt that his model is in reasonable agreement with ESDIS Project estimates on hardware costs (computers, staging disks, and tertiary storage units) from 1996 through 2000, but is significantly lower in staffing costs than the ESDIS Project's estimates. He suggested that the Project had not adequately considered the amount of data required for quality assurance (QA) and validation in its estimates of network costs. (Barkstrom's model had not examined costs for flight operations or for capturing satellite data, considered only the TRMM and AM-1 missions with no allowance for later mission and data assimilation.

Barkstrom's strategy suggested: 1) accepting the Project's proposed actions to save costs on network development by consolidating EDOS and the ECS Science Network; and 2) reducing staffing through decreased staff growth at the DAACs, and through decreased effort on data schema design and development on the part of both the ESDIS Project and the ECS Contractor.

Barkstrom said that EOS scientists may need to take more responsibility for documentation and preparation of data products before turning them over to EOSDIS if some components of EOSDIS staffing are to be reduced. Savings could also come about through optimizing data delivery systems. Barkstrom's overall conclusions were that: 1) based on the available information, consolidation does not appear to be warranted; and 2) it appears that there are substantial possibilities for large cost savings through planning for decreased staffing and careful data delivery choices.

Barkstrom also noted that the DAACs currently provide the only substantive source of competition and innovation within EOSDIS. It is also clear that the DAACs are currently serving their user communities well and are generally supported by those communities. Thus, the suggestion of consolidation appears to place EOSDIS at unjustified risk of losing contact with the EOS user community.

Thursday Afternoon, June 29

In this final session, Mark Abbott summarized the NASA presentations and presented the challenges facing the Payload Panel. He began by saying that in the early days of EOS, the process for design and evolution of the payloads was relatively slow. The organizational structure (review committees, Academy panels, etc.) to implement this process worked well in an environment characterized by relatively stable funding and technology. The time scale for review was much smaller than the time scale for funding or technology changes. The situation has changed in the past five years such that these two time scales are nearly equal, but we still rely on essentially the same organizational structure. The challenge to the Payload Panel is to develop mechanisms to cope with this significantly changed environment.

Pressures on EOS include:

◊ the need to balance flexibility with clear objectives for long-term climate research;

◊ tension between needs for new science and technology, and consistency; and

◊ budget realism.

There are four elements that are needed to help balance these forces. We must have a prioritization and review process to insert new technology and new science into EOS. Second, we must consider how to transfer observing systems designed for research into ongoing, "operational" systems. Third, we need to establish a calibration/validation program to ensure inter-operability of the sensors. Fourth, we need a flexible data system that can incorporate new processing algorithms, support technology insertion, etc.

Four splinter groups considered these issues and also considered a request by Michael King to begin to categorize measurement types. The group chairs were Eric Barron, Dave Glover, Dennis Hartmann, and Berrien Moore.

The groups reported back in plenary, and Abbott summarized the findings:

1) There was general support for the "essential" measurement set described by King. There were suggestions for renaming the observation types to express the differences between measurements that were needed continuously and those where gaps could be tolerated. These lists will be distributed to the discipline panels for formal review and comment.

2) New technology will need to be inserted into the observing system to take advantage of new capabilities and potentially lower costs. This process needs to be opened up to the science community to ensure that the process is driven by science requirements and that there is a clear path from technology demonstration to operation. A full evaluation of the total system costs versus scientific benefits must be undertaken. The panel will begin to develop a plan to address these issues.

3) Convergence between the Earth science supported by NASA and the operational monitoring and forecasting conducted by NOAA has both opportunities and risks. Each agency is driven by different needs and requirements that are sometimes in conflict. The Earth science community must play an active role in this convergence process and define its expectations.

4) Calibration/validation is essential for the development of a long time series suitable for climate research. An equally important role is that it provides an underpinning for the insertion of new technology by quantifying the performance of different sensors that deliver the same data product. The newly-formed Panel on Data Quality is developing detailed calibration/validation plans, and it needs the support of both instrument and algorithm developers and the interdisciplinary science teams.

5) A flexible information system is necessary to support changes in technology and advances in science. It is clear that there is strong support for the present DAAC structure. Consolidation may not save money and will likely result in a deterioration in user services. The relationship between scientific requirement and data system cost is still unclear. The Panel should support studies that test whether the perceived cost drivers of EOSDIS are driven by science requirements or by the system implementation. The issue of governance of EOSDIS must also be examined. Is the present system adequate, and will it be flexible enough to respond to new requirements and new technology? The Panel will examine these issues as well.

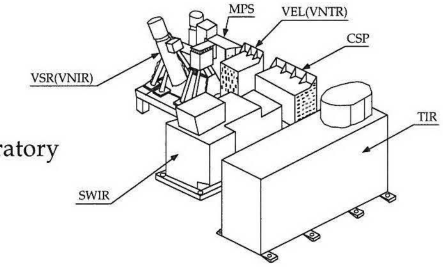
The "wrap-up" presentation for the meeting was given by Charles Kennel. He said that a NASA government group would meet that night to react to what had transpired at the three-day meeting. He saw the need to reconcile the cost estimates for EOSDIS and said that he felt that the cost numbers should have been presented to the IWG a year ago. He also said that he saw the need to improve on the terminology being used to distinguish monitoring from process study observations. He then outlined the activities that would be coming up prior to the National Academy of Sciences (NAS) review.

On July 5 the NASA employees would rehearse their presentations to the NAS. White House representatives would be there. To be taken into account would be the reshape exercise, EOSDIS, commercialization strategies, the international dimension, and NASA/NOAA convergence. Sixteen-to-seventeen issue papers would be reviewed. Documents being prepared would be for public consumption as well as for the Congress to see. On July 11 there would be a meeting with Administrator Goldin, and on July 12 position papers would be forwarded to the NAS members of the review committee.

Between July and Labor Day there would be decisions made on the FY 1996 budget with the hope that the future of MTPE/EOS would not be unduly constrained.

Kennel left the group with the final thought that we need to consider how to accomplish science and technology evolution in MTPE/EOS while continuing to focus on long-term science issues. ■

9th Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting



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

The 9th ASTER Science Team meeting was held at Flagstaff, AZ, May 22-26, 1995. The purposes of the meeting included addressing outstanding science and operations issues and furthering mission planning efforts. Over 80 attendees included representatives of the ASTER Science Team, the JPL ASTER Science Project, the EOS Project at GSFC, the EROS Data Center (EDC), the Landsat Project, Earth Remote Sensing Data Analysis Center (ERSDAC), Japan Resources Observation System (JAROS), the instrument developers, the ASTER Ground Data System (GDS), and EOSDIS contractors. The week-long meeting comprised opening and closing plenary sessions and meetings of all of the Working Groups.

Opening Session

A. Kahle, ASTER U.S. Science Team Leader, opened the meeting and welcomed the attendees. She reviewed the recent activities and plans of the U.S. Science Team. H. Tsu, ASTER Science Team Leader, reported that there have been many meetings to finalize the ASTER Memorandum of Understanding (MOU). Hopefully, the agreement will be concluded in the autumn.

H. Tsu reported on the status of JERS-1. He said that it's now been in orbit for 3 years. Approximately 80,000 image scenes have been taken, with about 20,000 cloud-free scenes, covering 20 to 30% of the land surface.

S. Hook reviewed the First ASTER Pre-Flight Calibration Experiment at Lake Tahoe, CA. The purpose of the experiment was to develop a methodology for assessing the in-flight calibration of the ASTER thermal bands and to provide the necessary measurements to enable a vicarious calibration. He presented examples of data acquired on the land and the water during the experiment. Surprisingly, a 1.5 degree C range in temperatures was recorded on the lake surface, perhaps due to differential heating.

A. Gillespie reported on temperature/emissivity (T/E) status. He said that at the previous Science Team meeting the Working Group (WG) had produced a single integrated T/E separation algorithm, based largely on the work of S. Rokugawa and T. Matsunaga. The new T/E separation algorithm has been evaluated over Hawaii (lava flow down to and into the ocean) and Castaic Lake.

Jim Irons, Deputy Landsat Project Scientist, reviewed the history, objectives, and capabilities of the Landsat-7 mission. The payload of Landsat-7, which will be launched by GSFC and operated by NOAA, will be the Enhanced Thematic Mapper (ETM+).

Scott Lambros reviewed the EOS Project/ASTER Instrument status. He reported that: 1) flight model builds of all AM-1 instruments have begun; 2) in general, AM-1 is progressing on schedule for a June 1998 launch; and 3) the decision was made for no covers after fairing encapsulation.

M. Kudoh presented the ASTER Instrument

Project status. He said that the ASTER subsystems developers are now fabricating proto-flight hardware. Integration and test of the ASTER system engineering model (EM) started in December and is almost finalized. The Project Implementation Plan (PIP) -Vol. 1 was signed January 31, 1995. An Instrument Operation Team, since renamed ASTER Operation Team (AOT), was formed in March. The AOT is a senior advisory body consisting of representatives from the Japanese Science Team, JAROS, and ERSDAC.

NEC Corporation reported that the mechanical and electrical integration of ASTER was completed and that the ASTER system Critical Design Review validation will be held in September.

H. Watanabe presented the plan for the development of the ASTER Ground Data System (ASTER GDS). He showed high-level and detailed development schedules and the organization for ASTER GDS development. He then described the three segments of the ASTER GDS.

M. Pniel (ASTER Product Generation System) reported that he has received the EOSDIS toolkits (TKs) 1-4. The toolkits have been incorporated into all the data products on which they have worked. Some minor problems have been corrected with the contractor's (Hughes) help. Most data products were converted to production versions for the beta version. By the next science team meeting, the beta version will be delivered to developers, and testing and integration will be underway for delivery to EDC.

H. Watanabe reported on the Level 1 (L1) *ad hoc* meeting that had been held in March. At this meeting the Japanese proposed that there is no need for Ground Control Points (GCPs) to produce geometrically corrected products and that additional flexibility (re-map projection, movable scenes, flexible interpolation) should be handled as Level 3 products. They also presented the status of the L1 algorithm development process and discussed the options for L1 browse. G. Geller reported that the meeting attendees resolved that L1 granularity will be scenes.

D. Nichols summarized the activities of the Operations and Mission Planning Working Group (OMPWG) since the last Science Team meeting. He reviewed the purpose and structure of the Functional Requirements for Mission Operations (FRMO) document and noted that he expected it to be finalized by the close of this meeting. He discussed the "Just-in-Time Scheduling" concept and presented a proposed 6-hour Uplink Timeline. A. Kahle noted that it appeared that use of the "Just-in-Time Scheduling" concept, as opposed to the baseline concept, could make possible acquisition of up to twice as much usable data from the mission.

Closing Session

A. Kahle opened the Closing Plenary Session and reviewed the agenda.

H. Kieffer, Geometric Calibration Working Group, noted that the WG plans to open discussions with the Landsat Team to collaborate on geometric test sites.

P. Slater, Radiometric Calibration Working Group, reported that new Action Items include organizing a joint field campaign for Japanese and U.S. ASTER team members and Landsat-7, probably in Spring '96, in the southwestern U.S. This involves the Geological Survey of Japan, ERSDAC, National Research Laboratory of Meteorology, JPL, University of Arizona, and GSFC. F. Sakuma, from the Radiometric Calibration Working Group, reported on a very successful cross-calibration experiment and also on the differences in philosophy between the U.S. and Japanese regarding reprocessing with changed calibration coefficients.

D. Nichols, reporting on the progress and plans of the Operations and Mission Planning Working Group, said that the ASTER Long-Term Instrument Plan (LTIP) is to be released in July for Science Team reaction and the FRMO document will be complete after addition of comments received by Team members at this meeting. He also noted that the "Just-in-Time Scheduling" concept has moved the uplink timeline from a 5-day scenario to a 17 hr+ scenario.

G. Geller, from the Level 1 Architecture Working Group, reported that: 1) Level 1 browse will be produced for Level 1A only, with 100% of the data being used for browse; rough radiometric/geometric corrections will be employed, and 2) criteria are needed to determine which of the maximum 310 scenes of the 780 daily Level 1A scenes will be processed to Level 1B.

F. Palluconi summarized the three elements of the Atmospheric Correction Working Group meeting: status of algorithm and standard data product production software development, discussion of the April 1995 Lake Tahoe validation experiment, and development of a validation-site list. He reported that beta versions of the production software for the reflection and emission region software will be completed and run at the DAAC early next year. He said that adjacency effects will be treated as special products in Japan.

T. Schmugge reviewed the Ecosystems Working Group's proposed test-site list. The WG interests include evapotranspiration estimation (U.S.), vegetation index (Japan), and coral reefs (Japan). They expressed interest in identifying joint test sites with other WGs or Science Team.

A. Gillespie, T/E Working Group, reported on U.S. and Japanese WG activities, issues, and plans. He expressed a concern about rough areas, and how the mix of cavity radiation and first emission might complicate the retrieval. He also noted that major sources of error are the atmospheric correction, regression for emissivity, and mixing (compositional mixing, temperature variations, and multiple scattering effects for rough surfaces). He said that up to 1° C temperature error may result from effects of large clouds up to 1 km away and that the WG needs to have the sensitivity to atmospheric correction quantified.

M. Abrams, Oceanography, Limnology, and Sea Ice Working Group, reviewed the discussions at the WG meeting. He identified three special products: water surface temperature (using AVHRR split window approach); turbidity (Secchi depth); and aquatic plants. The WG will invite a MODIS SST representative to attend its next meeting to discuss commonality.

L. Rowan, Geology Working Group, said that the WG focused on updating its regional monitoring requirements. Specific regional monitoring topics were assigned to individual WG members to prepare white papers. The WG is responsible for one algorithm, the decorrelation stretch, and it has identified three candidate algorithm validation test sites—Cuprite, Nevada; Death Valley, California; and Mt. Fitton, Australia.

A. Kahle summarized the Higher Level Data Products Working Group meeting. Each of the Working Group Chairs presented lists of proposed test sites and the rationale for their selections. The possibility of consolidation was briefly examined. Between now and the next Team meeting the individual Working Groups will explore consolidation with other ASTER working groups and other Instrument Teams. A. Kahle and Y. Yamaguchi will pursue interactions with MODIS, MISR, and Landsat. A SeaWiFS representative will be invited to the next meeting.

S. Hook and S. Rokugawa, Airborne Sensors Working Group, reported that the Ames C-130 is being terminated. The Wallops C-130 will be relocated to Dryden and retrofitted to take the Ames C-130 instruments including TIMS. This, however, will cause a hiatus during the refitting. M. Abrams reported that the Multispectral Infrared and Visible Spectrometer (MIVIS), a perfect simulator for ASTER, may be in the U.S. in June of 1996 and may acquire data over U.S. sites.

J. Salisbury, Spectral Library Committee, announced that the Committee plans to make new spectral data from Johns Hopkins University on igneous rocks, snow and ice, and vegetation available via Internet.

S. Rokugawa announced that a special issue of the Journal of the Remote Sensing Society of Japan focuses on ASTER. The issue is Vol. 15, No. 2, published in June 1995, which contains 14 papers (9 in Japanese, 5 in English). H. Tsu, ASTER Science Team Leader, is Editor-in-Chief of this special issue. Rokugawa said that this special issue will familiarize the Japanese with ASTER.

H. Tsu announced that a Japanese announcement of opportunity will be out this year, but the schedule is not fixed. T. Cudahy said that there will be an AVIRIS campaign this summer in Australia and invited anyone interested to contact him.

A. Kahle adjourned the meeting. She applauded everyone for such a highly productive meeting. H. Tsu thanked the U.S. Team and especially H. Kieffer for putting together such a successful meeting.

The next ASTER Science Team meeting will be held November 14-17, 1995 in Ikebukuro, Tokyo, Japan. ■

RELEASE: 95-126
July 27, 1995

JOSEPH H. ROTHENBERG NAMED DIRECTOR OF GODDARD

Brian Dunbar, Headquarters, Washington, DC (202/358-1547)
Jim Sahli, Goddard Space Flight Center, Greenbelt, MD (301/286-0697)

Joseph H. Rothenberg will become the Director of NASA's Goddard Space Flight Center, Greenbelt, MD, effective immediately, NASA Administrator Daniel S. Goldin announced today. Rothenberg has been the Center's Deputy Director since rejoining NASA from industry in April of this year.

In making the announcement, Goldin said, "Since returning to NASA, Joe Rothenberg has proven himself to be one of our most capable managers. I am very proud that he will be leading Goddard, our center of excellence for space and Earth sciences."

Rothenberg rejoined NASA from Computer Technology Associates, Inc., Space Systems Division, McLean, VA, where he was executive vice president. From 1990 to 1994, he was associate director of flight projects for the Hubble Space Telescope (HST) at Goddard. In this position, he directed the development and execution of the successful first servicing mission of the HST.

The new director began his career with Grumman Aerospace in 1964, ultimately serving as staff project engineer to the director of engineering for test and operations and as project manager for Goddard's Solar Maximum Mission.

In 1983, Rothenberg joined Goddard as operations manager for the HST. In that position he led the NASA team responsible for developing and conducting orbital operations of the HST.

In April 1987, he was appointed chief of Goddard's Mission Operations Division. In September 1989 he was appointed deputy director of Mission Operations and Data Systems, followed by his appointment in 1990 as associate director for flight projects for the HST.

Rothenberg holds a bachelor of science degree in engineering science and a master of science degree in engineering management from C.W. Post College of the Long Island University. He is a member of the American Institute of Aeronautics and Astronautics (AIAA) and past president of the Long Island Section of the Instrument Society of America. He was the recipient of the Presidential Rank Award in 1995, NASA's Distinguished Service Medal in 1994, Senior Executive Service Meritorious Executive Award in 1994, the AIAA's Goddard Astronautics Award and the National Space Club Goddard Memorial trophy in 1994, the Collier Trophy in 1993, and NASA's Exceptional Service Medal in 1990.

NASA press releases and other information are available automatically by sending an Internet electronic mail message to domo@hq.nasa.gov. In the body of the message (not the subject line) users should type the words "subscribe press-release" (no quotes). The system will reply with a confirmation via E-mail of each subscription. A second automatic message will include additional information on the service. Questions should be directed to (202) 358-4043.

Fourth International MIMR Science Advisory Group Meeting

—**Elena Lobl** (elena.lobl@msfc.nasa.gov), Earth System Science Laboratory, University of Alabama in Huntsville

The fourth international meeting of the Multifrequency Imaging Microwave Radiometer (MIMR) Science Advisory Group (SAG) was held at the European Space Research Institute (ESRIN), at Frascati, Italy, July 5-7, 1995.

Johnny Johannessen (MIMR SAG Coordinator, and Head of the Ocean/Sea-Ice Unit, Earth Science Division, ESA) opened the meeting by going over the last meeting minutes. He then expressed his gratitude to the U.S. scientists for attending the SAG despite ESA's not providing a MIMR instrument for the PM platform.

The agenda for the meeting listed several presentations to be made to the entire group before the subgroups would finalize the draft of the MIMR Interim Report. On the last day the mid-term results of the project studies were presented, and the meeting closed with planning for the next SAG.

Yvon Menard's (ESA, MIMR Program Manager) presentation included MIMR hardware status, polarimetry, spectral response, calibration/validation, preprocessing, and products. Evert Attema completed the presentation with a ground-processing discussion. Currently, the plan is to build 3 instruments: the first is an engineering model (not spaceworthy), and the others are radiometers for the Meteorological Operational Satellite (METOP) 1 and 2.

METOP phase B kick-off occurred July 12, 1995. The MIMR demonstrator work is on schedule with the final review planned for the end of May 1996. Ongoing work includes breadboarding receivers, calibration targets, scan/balance mechanism, and electrical and mechanical ground equipment. Remaining work is EMI/EMC testing, scan-mechanism life test and sensor calibration test.

The polarimetry discussion was shortened because of the revelation that ASCAT (Advanced Scatterometer) will fly on METOP (precluding the need for polarimetry), and that METOP is an operational program where an experimental add-on (such as polarimetry) is not warranted.

The resampling presentation led to a recommended scan speed of 30 rpm for precipitation measurements.

Finally, Menard showed an outline for the data preprocessing program. The Level 1b data (data available to scientists) will be corrected for all the instrument-induced errors (antenna pattern, spill over, polarization correction, incidence-angle bias, local oscillator (LO) leakage), and thus they are not reversible (for scientists that want to work with raw data).

E. Attema discussed the ground processing and data flow concepts. The European Meteorological Satellites (EUMETSAT) representative, Graeme Mason, gave a brief presentation on the EUMETSAT/NOAA joint polar system. Both METOP and NOAA satellites would directly transmit all data to their own and to each other's ground stations at all times. He also delineated ESA's responsibilities: develop ASCAT and MIMR Level 1b data, maintain algorithms and databases for the lifetime of METOP-1, and transfer working algorithms for database production and services to EUMETSAT when they are qualified for operational use with succeeding METOPs.

Short presentations on various research topics concluded the first day. L. Eymard (Centre Universitaire de Velizy, Velizy, France, eymard@piano.velizy.cnet.fr) presented work showing the need for algorithm validation, especially the sensitivity to the choice of radiative transfer model (RTM) used in parameter retrieval. She is also involved in the design of the Fronts and Atlantic Storm Track Experiment (FASTEX) campaign (occurring in early 1997) where she will be able to test some of the candidate RTMs. The scientific objectives of this campaign are: feasibility of "adaptive observational system," analysis and forecast of cyclone activity in Eastern oceanic basins, air-sea interaction and its role in cyclogenesis, and embedded mesoscale substructures.

Data will be taken by aircraft (NOAA Gulfstream, University of Washington Convair, USAF C-130, NASA DC-8, NCAR Electra), ships (Ukrainian, French Navy, NOAA oceanographic), satellites (NOAA and DMSP), and radiosondes along the U.S., Canadian, Greenland, and European coasts.

C. Mätzler (University of Bern, Institute of Applied Physics, Bern, Switzerland, fax 41-31-631-3765) found good agreement between different soil emissivities measured with a non-scanning, land-based radiometer and with the Special Sensor Microwave/Imager (SSM/I). P. Gudmansen (Electromagnetics Institute, Technical University of Denmark, Lyngby, Denmark, pg@emi.dth.dk) reported on a comparison between data from the Scanning Multichannel Microwave Radiometer (SMMR) and the Scatterometer on ERS-1 over the Greenland Ice Sheet. In comparing these data an anisotropy was detected, ascribed to *sastrugies* influenced by the dominant wind.

M. Hallikainen (Laboratory of Space Technology, Helsinki University of Technology) described a study conducted to design a MIMR airborne instrument simulator (called MAMR). This simulator would fly onboard a Skyvan aircraft, have four fixed channels (between 6.8 and 23.8 Ghz) and two conically scanning channels (36.5 and 89 Ghz), with a 55° incidence angle, each channel having a 3.3° beamwidth. The *challenging* specification, the pointing- and attitude-determination accuracy, was achieved with active stabilization of the instrument mounting platform.

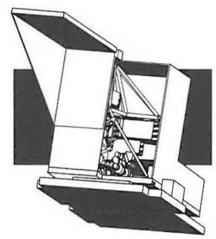
The final presentation of the day was a study on the use of cloud-radiation models for passive microwave precipitation retrieval given by G. Panegrossi (student of A. Mugnai, Instituto di Fisica dell'Atmosfera, Frascati, Italy, mugnai@hp.ifsi.fra.cnr.it). The main conclusion of this study is that microphysics changes affect the resulting precipitation rate. Thus, there is a need for more-accurate modeling of microphysical properties of hydrometeors and for more-accurate radiation transfer models.

The second day was dedicated to finalizing the Interim Report. The sub-group findings were then presented to the entire group at the end of the day. Most of the comments were directed to making the document uniform over all four disciplines. Regarding the need for polarimetry for the METOP mission, the consensus was that polarimetry is a good scientific experiment, but it does not belong on an operational satellite, especially when the satellite is flying a scatterometer. The Oceans and Marine Atmospheres sub-group discussed at length an algorithm conceptual model and a pre-launch validation plan to improve the radiative transfer model used. A work plan was developed to: a) do a direct intercomparison of RTMs, b) compare measurements with software simulations, and c) adapt the SSM/I and TRMM algorithms. It was also decided to append the earlier San Miniato report, which led to the MIMR concept, to this final MIMR Interim Report. Johannessen will incorporate all comments and send the report (as Draft 1.0) to the MIMR SAG members for a final review.

On the final day of the meeting, there were presentations on the mid-term results of different ongoing project studies. S. English (U.K. Met Office) reported on a variational analysis of MIMR sea surface temperature (SST) information content and some aircraft measurements of sea surface emissivities. M. Fischer discussed the impact of MIMR wind data on the El Niño/Southern Oscillation analysis and predictions. Preliminary results of the intercomparison of the Florida State University and SSM/I wind speed data indicate the need for more-accurate wind measurements from space. L. Phalippou (European Center for Medium-range Weather Forecasts [ECMWF], Reading, U.K.) reported on his work on the use of microwave imagery in numerical weather prediction. He concluded that the variational approach extension method for forecasting has more advantages than the regression methods. L. Eymard reported on her work in the laboratory measuring the dielectric constant of different salinity water, and Josef Noll [ESTEC], (Noordwijk, Netherlands, josef@estec. esa.nl) briefly discussed his collaboration with P. Schlüssel on studies of sea ice and atmospheres.

In closing, the logistics of membership, short presentation topics for next meeting, and time and place for the next meeting were discussed. John Foote (U.K. Met Office) is withdrawing from the SAG. The members agreed to have S. English as a replacement, and also have L. Phillapou become a member, as a representative of ECMWF. The presentation topics for the next meeting will be informational talks on the other METOP and EOS PM instruments, as well as the status of the PM platform and the potential PM radiometer, Advanced Microwave Scanning Radiometer (AMSR). It was tentatively decided that the next MIMR SAG will take place in New Orleans, LA, February 5-7, 1996. ■

Tropospheric Emission Spectrometer (TES) Science Team Meeting



—**Reinhard Beer** (beer@caesar.jpl.nasa.gov), Principal Investigator, Jet Propulsion Laboratory

The 11th Tropospheric Emission Spectrometer (TES) Science Team meeting was held at the San Juan Institute in San Juan Capistrano, CA, on May 24 1995, preceded by the Data Analysis Working Group (DAWG) on May 23.

Larry Sparks began the DAWG meeting with a discussion of the latest improvements in Sequential Evaluation Algorithm For Simultaneous and Concurrent Retrieval of Atmospheric Parameter Estimates (SEASCRAPE), among which is an improved memory management scheme that has significantly improved the speed of the algorithm.

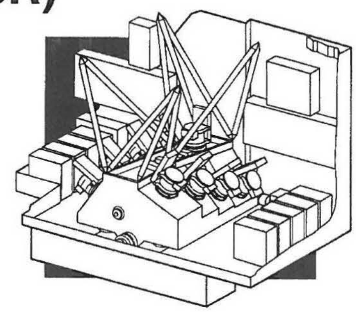
Tony Clough showed that pre-computing absorption coefficient tables have had a major impact on the speed of the line-by-line radiative transfer model (LBLRTM) algorithm. The subsequent discussion led to a decision that we should convene a special meeting of solely the formal co-investigators to discuss both this subject and the possible development of a joint "community" algorithm whose elements would be "owned" by individual team members, thereby giving them a greater stake in this entire process [this meeting was subsequently held in Denver in late June]. It was further decided that the DAWG has outlived its usefulness. Instead, the Co-Is will meet in executive session at all future team meetings in order to lay plans for the following months and will have a monthly teleconference starting in the fall.
The rest of this final DAWG session was primarily given over to discussions of the status of the spectroscopic databases, including the beta release of HITRAN 1995.

At the main, open session on the 24th, following a TES & Airborne Emission Spectrometer (AES) project update by Tom Glavich, most of the day was given over to a discussion of the Work Package Agreements between the TES project and the co-investigators. In view of the previous day's discussion, it was not possible to reach closure on this issue, and it is clear that the topic will require further discussion at the next team meeting.

Helen Worden described the analysis of last year's AES wildfire data that pointed to several deficiencies in the existing spectral databases when high-temperature sources such as fires are being observed. This work, which was presented earlier at the Chapman Conference on Biomass Burning in Williamsburg, VA (March 13-17, 1995), is now complete and is currently being prepared for publication in the Journal of Geophysical Research.

It was agreed that the next team meeting will be held in Cambridge, MA, at Atmospheric Environmental Research, Inc. on November 7-9, 1995. ■

Multi-angle Imaging SpectroRadiometer (MISR) Science Team Meeting



—**Daniel Wenkert** (dwenkert@haleakala.jpl.nasa.gov), Jet Propulsion Laboratory

For three days in June (Tuesday June 6 -Thursday June 8), the MISR Science Team, along with many colleagues and project personnel, gathered at JPL to discuss the status of the MISR instrument, scientific questions that need to be answered to develop product generation software, and the results of recent research. After a short welcome and introduction from PI, Dave Diner, Graham Bothwell and Terry Reilly presented recent accomplishments and the coming schedule for software and hardware deliveries, respectively.

The MISR Instrument

Terry Reilly, the MISR Project Manager, described the status of the Engineering Model (EM) and Protoflight Model (PFM) instruments. At the time of the meeting, the MISR PFM was to be delivered to Lockheed Martin in 21 months, and the MISR project had 11 weeks of slack.

Carol Bruegge began the discussions of EM testing and calibration. There are a number of reasons to believe that the goal of absolutely calibrating the MISR instrument radiometrically to 3% is being achieved. Performance specifications for signal-to-noise ratio and locally uniform response are being met. In general, the MISR cameras that have been built and tested are performing very well, with the exception of a larger-than-expected out-of-band spectral response and low-level "halos" around the point-spread functions. Bob Korechoff described the detective work in identifying the causes of these problems. Both arise because the MISR filters are mounted close to the CCDs. Following presentations on the status of the MISR on-board calibrator and the MISR error budget, from Valerie Duval and Nadine Chrien, the Science Team concurred with JPL's proposal to implement corrections for the spectral and point-spread-function response in ground data processing.

A discussion of MISR instruments for later missions, e.g., EOS AM2, was led by Dave Diner. NASA Headquarters insists that any follow-on EOS AM mission must be lightweight and use advanced technology. A number of options were discussed. There was a consensus to maintain the capability to image at nine angles, the capability to cover the Earth in nine days, and to keep the existing calibration requirements. There was no interest in continuous spectroscopy, but the Science Team did want the MISR Project to investigate extending the spectral range to 1.6 micrometers, provided this would not sacrifice the goal of a more-compact instrument.

Level 1 Software

On Tuesday, Graham Bothwell, the MISR Science Data System Manager, described the plan to ramp up MISR product generation at the DAAC. Before it is possible to retrieve many Level 2 parameters, it is necessary to co-register and ortho-rectify MISR data from all four spectral bands from all nine viewing angles. This requires the use of a global Digital Elevation Model (DEM). Richard Fretz of the Cartographic Group at JPL described their work on processing the Digital Terrain Elevation Data (DTED)-1 data set, to make it self-consistent and put it into a form in which it can be used by MISR. The MISR team plans to use the resulting data in on-orbit geometric calibration at the MISR Science Computing Facility (SCF). A lower-resolution version of these data will be sent to the DAAC for ortho-rectification of MISR data, as the DTED data set itself is not distributable.

Sue Barry discussed the planning of MISR Local Mode (completely high-resolution) observations, then Meemong Lee discussed footprint sharpening of MISR along-track pixels. After some discussion of whether "footprint sharpening" was useful in the presence of clouds, it was concluded that if we are computing-resource limited, then deconvolution of "halos" in the MISR point-spread function is more important than the footprint sharpening; however the Team is still interested in pursuing this option.

The purposes of geo-rectification and registration of MISR Level 1B data, and the techniques that will be used, were described by Veljko Jovanovic. Two sorts of Level 1B2 imagery will be generated: data that have been projected onto an ellipsoid, and data that have been projected onto the surface of the Earth, including the effects of topography. It was proposed and agreed upon that the WGS ellipsoid at sea level would be used for the ellipsoid-projected data, rather than an ellipsoid at 30-km altitude as previously planned. Error analysis for Level 1B2 geo-rectification was later described by Mike Smyth. MISR requirements are being met with the software currently prototyped.

After some discussion of other Level 1B2-related issues, led by Earl Hansen, Scott Lewicki gave a status report on 1B2 and described the work left to be accomplished for the beta delivery. He noted that the most difficult part of the algorithm, image matching for the nine high-resolution red-band images that MISR will continuously acquire, is being prototyped. This has allowed the team to make reasonable estimates of DAAC resources needed for Level 1 processing.

Top-of-the-Atmosphere (TOA) Radiation

On Wednesday morning, Roger Davies described some recent work by his group on top-of-the-atmosphere (TOA) radiation from variable-thickness and/or broken-cloud fields. Analysis of Earth Radiation Budget Experiment (ERBE) data from such fields does not agree with plane-parallel calculations for TOA radiation. He presented the results of Monte Carlo forward calculations, given realistic variable-thickness clouds. A number of very interesting effects were seen in the Monte Carlo calculations that mimic some effects seen in real data. These effects should go a long way toward explaining the "anomalous shortwave absorption" in clouds that has been discussed in the literature over the past year.

Tom Ackerman presented some work by his group on TOA radiation from clouds. He described the origin of the "anomalous shortwave absorption" issue in analysis of ERBE data and aircraft data. He then described some of his own aircraft data and some Monte Carlo simulations. His feeling is that TOA flux is a fundamentally ambiguous concept; that what one really wants to measure is radiance as a function of illumination and viewing angles. The latter is what MISR will uniquely measure. Both Ackerman and Davies agreed that MISR has a unique role to play in working out issues of TOA radiation in real Earth environments, at moderate and high spatial resolution.

Davies followed these discussions by presenting the current status of developing the algorithms for Level 2 TOA/Cloud (Level 2TC) product generation. He mentioned the major progress made in the spring in building fast and accurate stereo algorithms for retrieving cloud-top height fields. His major concern was the availability of simulated MISR data (from multiple view angles). Peter Muller described the specific stereo algorithms that had been developed and the plan for merging the best parts of these algorithms in the MISR L2TC software.

Later on Wednesday morning, Tamas Varnai and Siegfried Gerstl described progress in developing Azimuthal Models (AZMs). These will be used to retrieve TOA albedos by integrating the observed bi-directional reflectances. Varnai (a graduate student working for Roger Davies) has simulated the up-welling radiation from a variety of broken and continuous cloud fields, while Gerstl and his group have simulated the radiation field above a variety of

Earth surfaces under a variety of cloud-free atmospheric conditions.

Clouds and Level 2 Software

Most of Wednesday afternoon was devoted to discussions of cloud-screening in MISR data. Larry Di Girolamo (a graduate student working with Davies) and Eugene Clothiaux (a post-doc working with Ackerman) presented the results of their work. Both Di Girolamo and Clothiaux are developing their techniques on 1-km resolution AVHRR data.

Di Girolamo is developing techniques for detecting clouds at any altitude, which have at least a moderate optical thickness, by comparing reflectance-based signatures against thresholds appropriate for the class of surface being observed. This technique will be applied to single pixels in MISR images separately at all nine viewing angles. Another method he has developed is the "Band Difference Angular Signature," which is sensitive to the presence of clouds with low optical depth, especially at high altitudes and high latitudes.

Clothiaux is developing a technique for detecting clouds at any altitude which have at least a moderate optical thickness, over snow, ice, and bright land. This technique relies on measuring the textural properties of neighboring groups of pixels in MISR images (separately for each viewing angle). The exact texture parameters that are calculated are determined by a neural net analysis of a large number of images of sea ice, clouds, snow fields, etc. An alternative technique for cloud-screening over such bright surfaces using MISR data compares the stereoscopically retrieved cloud-top height with the known surface height.

A presentation by John McGuffie on the status of Level 2TC software wrapped up the discussion of TOA radiation and clouds.

Non-MISR Data in MISR Processing

Daniel Wenkert presented the current plan for using non-MISR data in processing MISR data at the DAAC. The plan is to use output data from the Goddard Data Assimilation Office (DAO) for as much of the needed atmospheric data as possible. Information on snow and ice cover will come from analysis of passive microwave data (currently Special Sensor Microwave Imager [SSM/I]) at the National Snow and Ice Data Center [NSIDC] (or the MSFC DAAC). As MODIS data products are validated in the post-launch period, Level 2 MODIS data are expected to enter the MISR processing stream.

Larry Thomason, from the SAGE team at Langley Research Center, described the status of the SAGE II and planned SAGE III instruments and their data products, and presented the results of some stratospheric aerosol research using SAM-2, SAGE II, and Lidar In-space Technology Experiment (LITE) data. It is hoped that SAGE instruments capable of measuring stratospheric aerosols at all latitudes will fly throughout the lifetime of MISR, since SAGE data would be used to filter out the signal from stratospheric aerosols.

Aerosols

Ralph Kahn began the discussion of aerosol retrievals late Wednesday afternoon, by describing the aerosol properties that the MISR team will retrieve and how some constraints can be added to the retrieval, by using data on real measured aerosols. He then described the sort of sensitivity studies being done by the MISR team at JPL, with forward radiative-transfer calculations and retrievals.

Bob West presented results using the discrete dipole approximation (DDA) to calculate the scattering phase function of non-spherical particles. This technique is computationally intensive and can be used only for small particles. He recommended using ray tracing to do these calculations for large non-spherical particles. Michael Mishchenko, from the Goddard Institute of Space Studies, presented the results of his work calculating the phase functions of intermediate-size non-spherical particles using the T-matrix (equivalent spheroid) technique, and the ray tracing technique for larger particles. He noted the overlap in the applicable size range of the two approaches.

The presentations on Wednesday ended with Tom Ackerman's description of the work he and his group are doing on the sensitivity of the calculated radiation field to errors in the aerosol retrieval. Thursday morning began with a presentation by Howard Gordon on his group's work on developing aerosol retrieval algorithms for ocean regions. His group is using linear mixing models in their calculations; these models assume that the radiances due to each physical component, e.g., soot, sulfates, etc., of the aerosol can be added in proportion to its abundance. Wedad Abdou of JPL also discussed the linear mixing approximation. It appears to be good under all conditions except for high optical thicknesses of absorbing aerosols (like soot or mineral dust). The Science Team concluded that linear mixing can be used in calculating radiances "on the fly" at the DAAC, using look-up tables of pre-calculated radiances due to "pure" particle types (including specific size distributions). This will simplify those look-up tables.

Surface Properties

On Thursday morning, John Martonchik presented his work on developing a vegetation index which is less sensitive to atmospheric conditions and sun and viewing angles. He described an index based on extrapolating the NDVI calculated at MISR's nine viewing angles (for airmasses between one and three) to an airmass of zero. Martonchik also described the results of a sensitivity study in which he showed that differences between hemispherical-directional reflectance factors (HDRFs) and bidirectional reflectance factors (BRFs) are comparable in magnitude to retrieval errors expected from an imperfect characterization of the atmospheric properties.

Michel Verstraete presented the results of his work with the Terrestrial Environment and Atmospheric Modeling (TEAM) group he heads at Ispra. He proposed modifying the MISR aerosol retrieval algorithm over dense, dark vegetation by permitting the surface reflectance to be a free parameter. The approach subsequently adopted by the team fixes the bidirectional reflectance function angular shape, while allowing the absolute surface reflectance to be a free parameter.

Peter Muller described the work he is doing with Alan Strahler, developing techniques for retrieving Bidirectional Reflectance Distribution Functions (BRDFs) from combined MODIS and MISR data.

Jim Conel described the plans (including instruments) for validating MISR algorithms on multi-angle imagery before the EOS AM-1 launch and validating MISR Level 2 products after launch. This discussion focussed especially on surface and aerosol parameters.

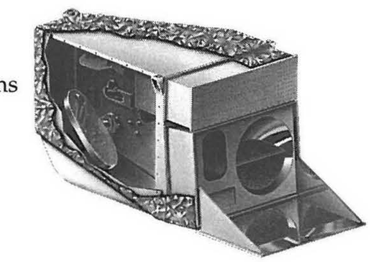
After Susan Paradise described the current state of development for Level 2AS product generation software, Daniel Wenkert brought up some cloud-screening issues that cut across the Level 2 software system. After much discussion, it was decided that certain cloud-screening procedures would be performed in the Aerosol/Surface algorithms when these are not used in TOA/Cloud processing, and that each subsystem would be responsible for gathering histograms of cloud-screening observables for the purpose of calculating thresholds for cloud screening.

Wrap-up

At the end of the day Bob Vargo and Bob Lutz described the overall MISR software system and data quality assurance issues, respectively. Ralph Kahn discussed some issues involving Level 3 products and gridding schemes. Finally, Dave Diner concluded the meeting by summarizing all decisions made. ■

Moderate-Resolution Imaging Spectroradiometer (MODIS) Science Team Meeting

—**David Herring** (herring@ltpmail.gsfc.nasa.gov), MAST Technical Manager, Science Systems & Applications, Inc.



Meeting Overview

The MODIS Science Team Meeting took place in Greenbelt, Maryland on May 3-5, 1995. It was chaired and called to order by Vince Salomonson, Team Leader. The emphasis of this meeting was to provide a working session for the Science Team.

EOSDIS Status Report

John Dalton, Deputy Associate Director of the Earth Science Data and Information System (ESDIS) Project, presented a status report on EOSDIS. Dalton reported that the first quarterly review of science software for AM-1 instruments was held recently. Also, EOSDIS hosted a Science Software Integration & Test Workshop, attended by instrument team software developers and representatives from the Distributed Active Archive Centers (DAACs), to discuss and delineate the science software integration procedures and deliverables. At the workshop, the MODIS science software integration and testing procedural steps were reviewed and modified. Also, at that meeting it was determined that the GSFC DAAC will be available to the MODIS Team for pre-acceptance testing. The first draft of the MODIS/GSFC DAAC Science Software Integration and Testing Agreement was due June 1, 1995, and the final draft is due Oct. 1, 1995. EOSDIS is now beyond its Preliminary Design Review (PDR) and is preparing for its Critical Design Review (CDR).

EOS AM Platform Status Report

Chris Scolese, EOS AM Project Manager, told attendees that assembly of the hardware has begun for the spacecraft and sensors. Scolese reported that the EOS AM-1 bulkhead structure assembly is underway and will be completed late this summer. Testing of the structure will begin by December 1995. In January 1996, Lockheed-Martin will begin integrating spacecraft flight hardware onto the platform.

Scolese stated that discussions regarding a lunar-view maneuver for calibration are still ongoing. He observed that some lunar-view maneuvers cannot be completed within half an orbit. He explained that the EOS AM Project would like to be able to rotate the spacecraft to look at the moon and deep space, and then back at the Earth again before the spacecraft comes around to the dark side of our planet. There are concerns about the solar impingement on the EOS instruments.

Data Assimilation

Ricky Rood, Head of the Data Assimilation Office, delivered a presentation on data assimilation. Rood explained that the data currently obtained from all sensors—ground-based, airborne, and satellite-based—are very irregular in spatial and temporal scales. Data assimilation provides added value to these data in that it organizes the data, complements the data and fills in unobserved regions, supplements the data and provides unobserved quantities, provides a means of quality control, and can assist in instrument calibration. In short, data assimilation provides the best estimate of the state of the system in that it allows extraction of maximum information content from data and it allows more-quantitative interpretation of satellite data.

SDST Status Report

Ed Masuoka, Science Data Support Team (SDST) Leader, told the Science Team that SDST is producing a Validation Plan, the first draft of which will be produced by December 1995. Masuoka told the Team that the Level 2 Beta 3 integrated (swath) science software is due in July 1995; the Level 3 Beta 3 integrated (grid) science software is due in August 1995. He stated that by January 1996, end-to-end system tests will be complete, and the beta releases will be baselined and delivered to the DAAC. By April 1996, the integration and debugging of all MODIS software at the DAAC will be complete.

Al Fleig, of SDST, announced that two primary products are now complete: 1) complete test data sets and 2) tools for making test data on order. The data in the first data set include correct viewing geometry according to the characteristics of an EOS platform orbit. The data include a characteristic MODIS scan pattern with all 36 channels and the bowtie effect, and are processed into MODIS Level 1B format (250 m and 500 m data are replicates). Sun-Earth/orientations are included as a function of time, date, and location.

Steve Ungar, of SDST, presented his work in producing simulated MODIS data scenes of the United States. He showed sample TOA (top of the atmosphere) radiances that are not based on any observations—they are totally simulated. Ungar stated that he is putting together a simulated MODIS data set to include all 36 MODIS bands at a resolution of 1,534 by 1,534 pixels (1.7 km is the average size). Ungar refined the simulated scene over the U.S. to include the MODIS instrument response functions supplied by Ed Knight. The next level of refinement will include an improved representation of the MODIS scan geometry and variable atmospheric path length. The ground truth elements consist of primary surface type (11 categories), secondary surface type (16 categories), mixture ratio, and elevation. The surface-type assignment is based on the classification of eight 1-km AVHRR Normalized Difference Vegetation Index (NDVI) images from March to November 1991. Ungar stated that his simulated data may be accessed via anonymous file transfer protocol (FTP) at highwire.gsfc.nasa.gov in the "/pub/modsim" directory.

MODIS Project Status Report

Richard Weber, MODIS Project Manager, reported that ambient and thermal vacuum tests of the Engineering Model (EM) are complete at the Santa Barbara Research Center (SBRC). Weber reported that all materials are either on order or have been received for the Prototype Flight Model (PFM) and Flight Model 1. He stated that cost remains a major concern, as is the development schedule in that any slips will negatively impact cost. Weber listed his top five technical concerns currently facing MODIS development: 1) transient response, 2) scan motor lifetime, 3) bandpass filters, 4) radiative cooler, and 5) electronics.

Lee Tessmer, MODIS Project Manager at Hughes SBRC, stated that the MODIS EM optical bench is assembled and the onboard blackbody has been integrated. Regarding the MODIS PFM, Tessmer reported that the engineering documents from the EM are readily transferable to flight status, noting that there are only minor changes to 10 of the 52 drawings. The procurements of hardware for the PFM have already begun. He reported the results of SBRC's EM tests. Overall, the polarization meets most requirements. All bands are within specifications except Band 3. He stated that the thermal vacuum testing includes comprehensive spatial, spectral, and radiative tests, the results of which show excellent co-registration, and low scan-to-scan jitter, as well as optimized gains and offsets.

Tessmer stated that the near-field response tests verify SBRC's test methodology. They found that there is an unacceptable problem with the first dichroic. They have all the instrumentation in house they need to make a new, modified first dichroic and plan to begin immediately. He said that SBRC's ambient test demonstrates good spatial performance—ambient spectral data were acquired for all MODIS bands. In summary, the EM is fully functional and robust. It performed as expected, demonstrating good linearity, high SNRs, low polarization, and good registration. The instrument meets specifications in terms of size, mass, power, and data rate.

MCST Status Report

Bruce Guenther, MODIS Characterization Support Team (MCST) Leader, announced that MCST recently completed the transition to its new support contractor—General Sciences Corporation (GSC). Guenther said his team established a MODIS Test and Analysis Computer (TAC) at GSFC for processing MODIS test data sets. Also, a Risk Management Board was established to identify, track, and control risks. Guenther reported that the MCST Algorithm Theoretical Basis Document (ATBD) was recently revised and will be revised again in early 1996.

MCST will host a vicarious calibration workshop in August at Wallops Flight Facility to focus on its Level 1B data products. Their objective is to identify vicarious calibration data sets, to review the instruments that produce them, and to consider ways to use the data sets in developing Level 1B data products. Guenther noted that some vicarious calibration data sets are produced with varying concepts for error bars. He hopes to establish a common scale for quantifying error and uncertainty.

Guenther reported that MCST is conducting analyses of MODIS' key characteristics, such as scan-angle effects. He explained that in the infrared there are instrument characteristics that pose challenges in determining scan-angle effects. Consequently, there is concern as to how to track these effects once MODIS is in orbit. MCST is considering the following strategies: 1) placing a second onboard blackbody in the scan cavity near the diffuser, 2) using deep space to observe emissive infrared wavelengths, and 3) using the moon to observe reflected solar wavelengths.

MCST is analyzing another key MODIS characteristic including near-field scatter. Guenther stated that at present the MODIS ghosting problem seems to be well understood and well corrected. Guenther stated that, according to test measurements, the filters for Bands 20 - 25 μm need attention. John Barker, of MCST, is conducting sensitivity analyses to understand the impact of the performance of these filters.

Roundtable Session Summaries

The emphasis for this MODIS Science Team Meeting was to provide a working session for the Science Team. Therefore, rather than split into discipline groups, the Team divided into interdisciplinary groups to hold "roundtable" discussions restricted primarily to selected panelists and a moderator. The following sections summarize each of the sixteen roundtable sessions.

Calibration—One session focused on strategies for vicarious calibration. Phil Slater summarized this session, stating that for the first time ever we will have a great deal of calibration information available to us from the moment the EOS sensors are in orbit. If we are to make the most of this information, we must get organized and determine the relative accuracies of the various methods of vicarious calibration being used. Slater suggested that the EOS Calibration Scientist could coordinate this organization activity. Specifically, this person could: a) coordinate vicarious calibration activities between different vicarious calibration groups nationally and internationally, b) centralize the evaluation of different techniques used by different groups, c) arrange the cross-comparison of measurements between various groups to help in evaluating vicarious calibration methods, and d) depending upon a through c above, recommend the role(s) MCST may play in the calibration/characterization of MODIS. Slater pointed out that error budgets between different vicarious calibration teams are not always the same.

Remote Sensing of Aerosol and Atmospheric Correction—Yoram Kaufman proposed holding an international workshop in April of 1996 to broaden the scope of the MODIS Science Team Members and to enhance or facilitate further involvement with other investigators around the world. He reported that some discussion focused on spectral measurements from both ground-based and satellite instruments in determining the effect of single scattering albedo. Kaufman stated that there is a need for strong, continuous interaction among those developing algorithms and acquiring observations and those, in particular, who are modeling aerosols.

Regarding use of AFGL atmospheric models and dynamic models, Kaufman said most groups using models suffer from the fact that they are models of averages, not actual conditions. Kaufman concluded that there is a need to integrate satellite- and ground-based campaigns.

Gridding and Averaging—Alan Strahler stated that gridding deals with the Level 3 products. His panel concluded that it is probably better to work with a fine-resolution grid (250 m) and collapse to coarser grids. An Action Item was assigned to Bob Evans, Robert Wolfe, Dave Diner, and Bruce Barkstrom to pursue this issue with the Science Working Group for the AM Platform (SWAMP).

Strahler recounted that the proposed grid is more or less an equal-area grid, but not exactly. The proposal is for a modified, nested International Satellite Cloud Climatology Project (ISCCP) grid that is defined on the basis of 1.25-degree squares. Steve Ungar persuaded the Panel to move to a fine grid of 270 m so that it will be easy to collapse down to 1.25 degrees. Strahler told the team that the edges of each grid cell will appear ragged like a postage stamp. There is a need for cartographic tools and resamplers so that modelers can go from basic to angled grids to derive map projections.

Resampling and Remapping Procedures—Strahler also summarized Session #3. Strahler stated that there is a need for a MODIS-specific tool for producing interpolated projections with observed physical features or phenomena in the proper place. For the MODIS Land Group (MODLAND), developing this tool is trivial, but for cloud observation it becomes much more difficult.

Strahler explained that trying to fit a MODIS image onto a map projection is going to be difficult, and will require some means for resampling. If we don't resample, then we can take those data and place them into a grid. This logic led to Eric Vermote's idea of a Level 2G data structure for forward binning the data, which would work well for computing surface reflectance and Bidirectional Reflectance Distribution Function (BRDF). Strahler pointed out that the Oceans Group is doing something similar, but with a coarser grid.

The panel also examined the MODIS bowtie effect to determine how it affects Level 2 processing. The panel concluded that the bowtie provides interdetector calibration, which is good, but makes resampling with interpolations difficult, which is bad.

The panel concluded that Level 1G and 2G products would be very helpful in some cases, but further work and thought are needed there by Catherine Harnden, Howard Gordon, Paul Menzel, Robert Wolfe, Steve Ungar, and Strahler. The panel recognized that there is a need to define a "day." The grid may represent a unit of time, Strahler rhetorically asked, but what do you do if the dateline falls in the middle of a swath?

Algorithm Integration—Ed Masuoka reported that the Science Team needs to deliver its Level 2 code at the end of July and Level 3 code at the end of August. He noted that the Atmosphere Group may need some help from SDST in integrating the cloud products. Masuoka stated that for MODLAND, integration and testing of algorithms for scientific accuracy will require more scientifically accurate synthetic data. Ancillary data will be necessary for beta and should be consistent with the simulated data. He announced that a second MODLAND/SDST meeting is scheduled for late July 1995, at which metadata for version 1 delivery will be discussed. Masuoka noted that the Ocean Group will use RATFOR programming language for its beta delivery, and FORTRAN 90 for delivery of version 1. He stated that the Ocean Group will provide their own simulated input data that SDST can put into a scan cube.

Remote Sensing in the Infrared—Bill Barnes stated that a full-swath scan of deep space is vital to calibration, so the MODIS Team should continue requesting this capability. Barnes said he is developing a white paper on the subject and is working with the Science Working Group for the AM Platform.

The panel would like the Team to consider the possibility of applying a new coating on the scan mirror in order to reduce polarization in the visible region of the spectrum. Barnes said he will review this possibility and report his findings to the MODIS Technical Team. The panel also urged the Team to continue studying the possible use of a second blackbody in the scan cavity as a "pseudo" blackbody to obtain calibration data at a large angle of incidence to the scan mirror. Barnes pointed out, however, that a second blackbody is no substitute for a deep space view, which will still be required.

Barnes noted that MCST was given an Action Item to evaluate TOA (top of atmosphere) data taken by the MODIS Airborne Simulator (MAS). Jim Smith was asked to locate carbon dioxide polarization data to complement MCST's efforts. Considerable discussion was devoted to the thermal environment of the scan mirror under various conditions and maneuvers. Barnes reported that he expects the scan cavity temperature to change only by a few degrees. The panel asked SBRC to complete and analyze the new scan-mirror temperature measurement design and report at the next Science Team Meeting.

Barnes reported that the latest version of the Level 1B infrared calibration algorithm will soon be forwarded to the Science Team for review. MCST must examine approaches for post-launch validation of infrared radiances.

Simulated Data and Software Verification—In lieu of moderator Wayne Esaias, Al Fleig summarized session # 6. Fleig quoted a point made by Steve Ungar: it is important post launch to have a way to simulate and study any artifacts found by the Team. Fleig reminded the Team that there is a MODIS simulated data set and it is evolving. In its discussion, this panel decided that software verification is similar to quality assurance and validation, so the panel decided to leave further discussion up to those session panels.

MODIS Data Product Browse Capability—Fleig said the purpose of the browse panel was to determine what browse products should be available for MODIS, keeping cost and utility in mind. The purpose of the browse product is to help data users sort through large volumes of data to decide what data to order, what each data product looks like, and whether the requested data segment is a good one. The panel recognized that the nature of browse products can vary for each MODIS product. Fleig stated that we need to be responsive to the Science Team's, as well as the Interdisciplinary Science (IDS) community's, browse needs. SDST will follow up with EOSDIS Core System (ECS) to determine their plans. Consideration will be given to providing browse capability via the WWW.

Ancillary Data and Assimilation—Kendall Carder reported that there are three primary concerns for ancillary data and assimilation: 1) timeliness issues, 2) spatial issues, and 3) pooling ancillary data requests. The panel determined that MODLAND needs precipitation, soil moisture, photosynthetically active radiation (daily), maximum and minimum temperature, and surface pressure data. The Ocean Group's needs have not yet been determined. The Atmosphere Group needs surface emissivity maps over land for its shortwave and longwave IR products. Atmosphere also needs aerosol ancillary data.

The panel concluded that the timeliness of MODIS model outputs will be dependent upon MODIS coverage. The first iteration of Ricky Rood's model will be available within 24 hours using National Meteorological Center (NMC)-like input fields, and the second iteration will be available within 1 month using EOS data fields. Spatially, 1.25 degrees by 1.25 degrees is an adequate grid size to allow modeling—each discipline group will interpolate in space as needed. Regarding quality assurance of ancillary data sets, Carder stated that each algorithm should be tested independently. Ancillary data sets should be sent to the Team Member computing facilities along with MODIS data sets for quality assurance.

SCAR-B Update—Yoram Kaufman told the team that SCAR-B is the third and last of a series of field campaigns focused on the interactions of Smoke, Clouds, and Radiation. SCAR-B will be conducted in Brazil. Kaufman reported that a Memorandum of Understanding (MOU) has yet to signed. [Subsequent to the MODIS Meeting, the MOU was signed by the President of the Brazilian Space Agency (AEB) and the Administrator of NASA.] Otherwise, significant progress is being made in preparation for the campaign. Ground sites for AERONET instruments have been chosen, calibration preparations are being made, a communications infrastructure is being developed, and dates of operation have been determined (August 15 through September 25, 1995). MODLAND plans to participate in the campaign along with the MODIS Atmospheres group.

Cloud Masking and Cloud Products—Vince Salomonson reported that, in short, what is needed to develop a cloud mask algorithm is calibrated, navigated radiance data in fifteen channels, as well as certain ancillary data, such as 1-km land/water maps from the EROS Data Center (EDC) and 1-km topography data. Additionally, snow/ice maps and cloud radiance composite maps are needed. According to Steve Ackerman, University of Wisconsin, the cloud mask will be implemented as a 32-bit word. He said there is some question as to whether cloud shadow can be determined at 250 m resolution—an issue that still needs further research. Ackerman concluded that the cloud shadow efforts should be conducted spectrally initially, and then spatial/geometric algorithms should be added afterward.

Salomonson stated that the 32-bit approach looks good and development should continue. Enhancements will be added as resources and time permit. The data sets currently being used for development are the HIRS/AVHRR cloud mask, AVHRR LAC data, and MODIS Airborne Simulator (MAS) Gulf Experiment data. Salomonson told the team that the main issues remaining are: 1) development of a land/sea cloud flag, 2) confidence flags, and 3) input from the Team stating how complex they want the cloud mask to be. Salomonson concluded that although there was some nervousness last summer during the review of the cloud mask ATBD, it appears now that good progress is being made.

Resources for Product Generation—Masuoka summarized the panel discussion that had been moderated by Wayne Esaias. Masuoka reported that 100 percent of the bandwidth required by MODIS products will be available at launch. In terms of CPU capacity, four times more will be available than MODIS' stated needs; however, this capacity will be phased in. At launch, MODIS storage space allocation will be 400 Gbytes. Capacity models are being developed for the processing of MODIS Level 1 and 2 data products. Masuoka stated that the question of where time slicing will occur still remains. Also, the decision process for determining standard versus research products needs to be established.

DAAC-Team Leader Computing Facility (TLCF)-Science Computing Facility (SCF) Interactions—Masuoka reported that discussion focused on EDC's beginning software testing early to iron out operational issues before the 1997 delivery deadline. The EDC DAAC is willing to provide time on an SGI system connected to their tape archive but ESDIS will need to increase the capacity of that machine to support MODIS testing. Both the GSFC and EDC DAACs stressed the importance of recruiting highly skilled science and operations staff throughout early software and system integration and later operational processing. This staff would provide better feedback on lessons learned, as well as quicker response time in resolving operational problems. Currently, each DAAC has one full-time person supporting MODIS science software, and both would like to add several more personnel.

MODIS Data Quality Assurance Plan—Bob Evans reported that the MODIS Data Quality Assurance Plan is currently being developed and is in draft form now. He told the team that the EOS Panel on Data Quality is chaired by Mike Freilich. Evans stated that quality assurance (QA) in an algorithm context refers to spectral checks, spatial checks, and temporal checks within one day of obtaining the data. Validation refers to all other tests. The QA process will identify or "flag" pixels to granules which obviously do not conform to expected accuracy. Evans added that QA will also allow the Team to monitor the health of products. Evans said that the beta version of the QA Plan will be submitted by January 1997, and the final version will be completed by mid-1997.

Validation—Chris Justice stated that there are some good models in place as to how the MODIS validation effort can proceed, including the sun photometer network, the SCAR campaigns, land test sites, and the Ocean Color Working Group initiative. He said the Team needs "community" guidelines on the level of required validation. He pointed out that validation planning is a problem in light of the constantly changing budget. For example, he asked, who pays for aircraft for field campaigns?

Justice observed that there are various international coordination mechanisms for validation already in place. He feels that the Land community needs a distributed network of sites to supplement intensive NASA campaigns, such as the First ISLSCP Field Experiment (FIFE), Boreal Ecosystem-Atmosphere Study (BOREAS), and validation field experiments in Amazonia. Dave Starr, EOS validation scientist, encouraged the Team to continue developing its "bottom up" validation initiatives. Justice concluded that to achieve product validation, the Team will need help from the EOS Project with coordination—particularly with interagency and international coordination and funding.

Plans for Flying Aircraft Over Ocean Test Sites— Frank Hoge stated that plans are needed for Case 1 and Case 2 Atlantic Ocean field experiments involving the MODIS Atlantic Test Site (MATS) and the Bermuda Atlantic Time Series. He added that plans are progressing for a joint Marine Optical Buoy (MOBY)-MAS campaign in Hawaii in the spring of 1996 contingent on the launch of ADEOS and SeaWiFs. [Subsequent to the meeting this planned compaign was delayed one year.] He feels there is a need for the Team to identify post-launch airborne field experiments. Hoge concluded that airborne platforms, sites, and institutions do exist to conduct robust experiments—he recommended holding focused planning sessions.

Conclusion

Salomonson concluded the meeting with a discussion on the meeting format. In brief, he liked the roundtable panel discussion format and plans to reuse it. The next meeting, scheduled for Nov. 13-17, 1995, will feature a shorter plenary session, roundtable discussions, discipline group splinter sessions, and a final plenary summary session. ■

New Satellite Image Map of South Florida Will Aid Ecosystem-Restoration Efforts

Excerpts from Press Release, Department of the Interior U.S. Geological Survey, Public Affairs Office, phone (703) 648-4460

A new satellite image map of south Florida that will aid resource managers planning a $2-3 billion restoration effort in the Everglades and Florida Bay was presented to the Governor's office August 23.

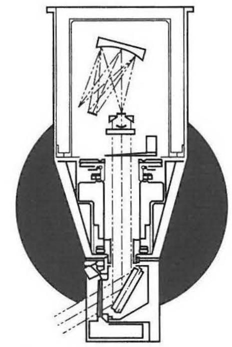
The "snapshot" image covers over 35,000-square miles of the state, from north of Orlando to Key West, and provides a key to 21 vegetation types and other land-cover features. The map was produced by the U.S. Geological Survey (USGS) in collaboration with the National Biological Service, also of the Interior Department, which provided the interpretive key to land-cover information.

The 1:500,000-scale map is designed to aid the efforts of the South Florida Ecosystem Restoration Task Force, a partnership of federal and state agencies and Native American Tribes that are involved in planning and implementing the changes to restore natural ecosystem functions. This map combines images from an Earth-observing satellite with latitude, longitude and map-scale references using high-technology image processing and computerized cartographic techniques. The USGS-prepared map provides more up-to-date, land-cover information than was previously available and shows exceptionally clear Landsat Thematic Mapper images taken during 1992 and 1993.

This satellite image map is one of the first products of the USGS South Florida Ecosystem Program, which provides scientific information to land and resource managers and other potential users so that they can improve their understanding of the ecosystem and enhance their ability to predict the effects of restoration efforts. This program is a collaborative effort between USGS, the South Florida Water Management District, the Corps of Engineers, the National Park Service, and other agencies within the South Florida Ecosystem Restoration Task Force.

More information about the USGS's South Florida Ecosystem Program is available through fax-on-demand as document 2052 on USGS EarthFax, phone 703-648-4888, and on the World Wide Web at http://fl-h2o.usgs.gov/sfei.html. Additional information about the USGS is available on the World Wide Web at http://www.usgs.gov. ■

Stratospheric Aerosol and Gas Experiment (SAGE) III Science Team Meeting



—**Lelia Vann** (l.b.vann@larc.nasa.gov), SAGE Science Manager, Aerosol Research Branch, NASA Langley Research Center

On the evening of July 11, a Science Team meeting of the Stratospheric Aerosol and Gas Experiment (SAGE) III was conducted in Boulder, CO, at the NOAA facility. The SAGE III Principal Investigator, Patrick McCormick, was unable to attend so Co-Investigator, William Chu, kicked off the meeting with a quick overview of the meeting agenda. The objective of this Science Team meeting was primarily to discuss the Algorithm Theoretical Basis Document (ATBD) development status. Other topics included a review of the schedule milestones and a discussion of the formation of data validation teams.

Each data product team gave a status report on the ATBD development for its responsible data product. In particular, Phil Russell and Geoff Kent passed out draft versions of their ATBDs; namely those for aerosol and cloud, respectively. Russell felt that his aerosol team was on track.

Kent gave a detailed status report on the cloud identification ATBD. The objective of the cloud ATBD is to identify the presence of cloud at all altitudes between 6 km and 30 km, not just to locate the cloud-top altitude. The theoretical basis for the cloud identification ATBD is different from that of the other ATBDs because cloud determination uses aerosol extinction rather than transmission as an input and, therefore, is a higher order product. The cloud identification algorithm is based on those used to separate aerosol from cloud in the SAGE II data. This algorithm uses aerosol extinction data at 0.525, 1.02, and 1.55 μm and relies on the wavelength variation in extinction to distinguish aerosol from cloud. This algorithm performs better than the two-wavelength methods used with the SAGE II data but still fails at times of strong volcanic activity. In the ATBD this algorithm is discussed in detail, and performance results of the simulation studies are included since there is no published information on this algorithm. Kent pointed out that this "may not be the only, or the best, algorithm but it is the only one that we have at this time."

Derek Cunnold stated that he had sent out an e-mail message to the ozone ATBD team members and would appreciate input from them.

David Rind stated that his draft water vapor ATBD contained approximately 20 pages of text and 9 figures and graphs. The math description is missing, and he would appreciate inputs from the other water vapor ATBD team members.

Alvin Miller discussed the temperature and pressure ATBD. He also discussed the data validation product and the various groups that make these measurements. The Russians run temperature lidars that may be of interest to us as well. A master list of all stations and their ties to each species would be highly desirable.

Joe Zawodny stated that a draft of the NO_x ATBD should be available by the end of August. The theoretical basis for the NO_2 and NO_3 ATBDs should not be difficult to draft. However, the section on NO_3 validation will be difficult due to the lack of direct measurements of the NO_3 density profile. There are currently only a few twilight column measurements of NO_3. It is possible to get some limited information on the NO_3 profile from the changes in the twilight column during sunrise. This needs to be investigated further.

There was a general discussion on the SAGE III need for a spectroscopic data base. It was decided that the sections from the individual ATBDs on spectroscopy should be combined in a single document, and the general topic of EOS spectroscopic needs should be brought to the attention of the EOS Project.

Hope Michelsen substituted for Co-Investigator Steven Wofsy and stated that the OClO was a difficult nighttime measurement. She briefly explained some of the difficulties they will encounter and stated the goals of the OClO measurement.

Mark Abrams discussed the activities and status of the transmission, inversion, and software ATBD team. Primarily, this team has focused attention on generating the necessary description of the algorithm. Areas of interest include:

- ◊ transmission data statistics (binning and variance);
- ◊ comparisons with SAGE II;
- ◊ measurements classification;
- ◊ determination of viewing geometry;
- ◊ decoupling of transmission data from pressure-temperature retrieval; and
- ◊ independent determinations of temperature (Abel transform) and viewing (ephemeris).

Zawodny has demonstrated that the SAGE II (and therefore SAGE III) data have higher vertical resolution than the 1.0 km binning used in the present transmission algorithm. It was also found that the methodology used for binning the data (mean value) is more easily biased than a median calculation and that calculation of variance (initial estimate of error) can be refined. The recommendation is that the transmission profiles be binned into 0.25 km intervals with a 0.5 km bin width internally and that the results be reported at 0.5 km intervals. This doubles the data volume relative to the baseline considered in the SAGE III software design, but it should not be an EOSDIS or DAAC requirements driver.

SAGE III differs from SAGE II in the following critical areas: the increased spectral resolution, the possibility of 'clearing' aerosol from all channels (or making the measurements insensitive to continuum level by using differential measurements), and the direct determination of temperature and viewing geometry.

The SAGE III measurements can be broken into three classes:

- ◊ differential: NO_2, H_2O, O_2 (p and T), OClO, and NO_3, which are largely insensitive to aerosol clearing, but have some residual temperature sensitivity;
- ◊ broadband: O_3 and Rayleigh (recommend the evaluation of differential O_3 channel); and
- ◊ aerosol: residual.

A key element of the retrieval algorithm is the coupling of the viewing geometry and temperature determinations with the measurement of the transmission profiles. In the traditional approach, an assumed temperature profile is used and the process iterated to convergence. However, since the bending angle is directly related to the tangent altitude, there is a possibility (that can be tested with the SAGE II data) of decoupling the transmission data from the p-T process. Additionally, an independent determination of temperature is possible from the Abel transformation, which would supply the density profile to corroborate the retrieval from the O_2 A band. Similarly, the ephemeris calculation and the measured locations of sun top and bottom can be combined to validate the viewing geometry as a consistency test.

The gaseous species inversion discussion is largely common to all of the species, with an obvious separation between lunar and solar. However, if an O_3 differential measurement is possible, then the differences are smaller. The inversion ATBD outline highlights six major areas:

- ◊ introduction (geometry and forward problem);
- ◊ input/output data products;

◊ inversion problem (solar/lunar);

◊ uncertainty estimates;

◊ data processing sequence; and

◊ numerical considerations.

A majority of the first two sections of the inversion ATBD is complete, and the last two sections will be addressed later this year as code is developed.

Several areas which are new to SAGE were discussed:

◊ The inclusion/omission of photochemical correction for diurnal variations of O_3 (mesosphere), NO_2, OClO, and NO_3. A discussion of the tradeoffs concluded that inclusion of photochemical correction in the standard products introduces two problems: (1) packaging and documenting such a model for operation by the DAAC, (2) the concern that photochemical models are currently insufficient and inappropriate in the generation of data from which trend analyses are to be performed.

  It was suggested that diurnally corrected profiles could be a "research product (level 4)" rather than a standard product. (It was noted that for OClO and NO_3, which will be nighttime measurements only [no twilight measurements], the diurnal variation appears to be small.)

◊ Definition of data granule (per occultation, per day, per month, etc.).

◊ Vertical grid: should pressure become the vertical coordinate rather than height? What about potential temperature (which can be derived from p and T)?

Chu reviewed the SAGE III schedule. The ATBDs have a deadline of January 1, 1996. The team should get together to critique the algorithms. Michael King, EOS Senior Project Scientist, will assemble a review panel to evaluate the ATBD next year, and hence it would be prudent to submit the documents for review by outside members of the community beforehand.

Chu also mentioned that validation teams are needed and suggested that the leads for the data product ATBDs would be the obvious candidates for the validation team leads. Everyone was asked to give this serious consideration.

At the next meeting, there will be five topics of discussion:

◊ channel selection;

◊ spectroscopy;

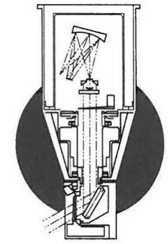
◊ high-level data (CERES, MISR, MODIS). (Jack Kaye pointed out that it is critical to show how these pieces fit together. This could be taken to the EOS Atmospheres Panel as well.);

◊ algorithm review;

◊ software review.

Of course there will be updates and discussions of the final form of the ATBDs. ■

SAGE III Preliminary Design Review



—**Lelia Vann** (l.b.vann@larc.nasa.gov), SAGE Science Manager, Aerosol Research Branch, NASA Langley Research Center

On July 12 and 13, a systems Preliminary Design Review (PDR) of the Stratospheric Aerosol and Gas Experiment (SAGE) III was conducted at the instrument developer's (Ball Aerospace) facility in Boulder, CO. The PDR team consisted of the following people, all from NASA Langley except for John Loiacono from NASA Goddard: Len McMaster, Chair; Lelia Vann, Executive Secretary; Mike Blythe; Richard Foss; John Greco; John Gustafson; Reginald Holloway; Sam Joplin; John Loiacono; Jim Miller; and Pamela Rinsland.

The PDR objectives were to:

- ◊ Demonstrate that the preliminary designs meet system requirements with acceptable risk as defined by the classification of the payload
- ◊ Identify all verification methodologies and interfaces.

To help ensure that the PDR objectives were met, the SAGE III Project Manager, Ed Mauldin, held subsystem "table-top" reviews of the instrument two weeks prior to this system-level review for a more-detailed review of each of the major subsystems. In addition, where possible these table-top reviews were chaired by the subsystem technical expert from the system-level PDR review team to enhance continuity between the reviews. The table-top reviews that were held and the respective leads are identified below:

Optical	Wes Lawrence
Electrical	Mike Blythe
Pointer/Scanner	Jim Miller
Mechanical/Thermal	Richard Foss
Software	Pamela Rinsland

During the system-level PDR each table-top lead summarized the respective table-top review and highlighted any concerns as a result of the review. The corresponding Ball subsystem manager followed each lead with a summary of the subsystem and an explanation of the plans to resolve any concerns which were identified.

The SAGE III Project Manager gave a brief overview of the Master schedule. Several of the major milestones were the Critical Design Review (CDR) one year from now, the first instrument delivery to the Russians in December 1997, the Meteor-3M flight in mid-1998, the second instrument delivery (Flight of Opportunity (FOO)) in mid-1998, and the third instrument delivery (International Space Station Alpha [ISSA]) in December 1998.

In addition, Mauldin pointed out that this PDR was to review the technical portions of the Meteor-3M mission. A delta PDR will be conducted for the FOO and the ISSA mission at a later time because of undefined interfaces for those missions at this time. Also, a delta PDR will be held this fall after contract negotiations with Ball Aerospace to baseline the program cost and schedule.

Co-Investigator, Joseph Zawodny, presented the SAGE III science objectives, including justification and heritage, importance to the Earth Observing System (EOS) program with its global coverage and long-term trend measurements, and predictions. He identified the main differences between the SAGE III and the SAGE II instrument, which were to enhance measurement capability and provide additional nighttime measurements (namely, NO_3 and

OClO, which are key to the O_3 chemistry) via lunar occultation.

Jim Miller characterized the overall pointer/scanner mechanical and electrical design as being mature due to strong SAGE II heritage. The SAGE II-specific components will be procured to SAGE II specifications from the original vendor or alternative sources which he identified. His concerns were issues related to the elevation motor sizing, the azimuth slew rate (5 deg/sec to 10 deg/sec), the flex-pivots, and the sun/lunar sensor ambiguity.

Art Ray, Ball Instrument Manager, followed Miller with a description of the sensor design. The ISSA mission is currently driving the mirror scan motor development because it requires the mirror to scan +/-3.7°. The Meteor-3M mission only requires the mirror to scan +/- 1.8°, which is within the SAGE II scan motor design. The SAGE III/Meteor-3M orbital parameters are 1020-km altitude, 99.53° inclination, and 9:15 a.m. ascending node. The viewing angles on Meteor-3M for both elevation and azimuth axes were shown and seemed adequate for both the solar and lunar events. The Meteor-3M has a 105-minute period. The 99.53° inclination places SAGE III over latitudes between +/- 80°. Each orbit offers a sunrise and sunset event of approximately 2 minutes; approximately 15% of the orbits offer a lunar event; and approximately 1% of the orbits offer both a moonrise and moonset.

The science and low-rate data are stored in the data storage unit (DSU). The DSU is dumped once every 12 hours over both Russia and the U.S.

To predict the characteristics of the SAGE III sun/lunar viewing events, Ball has developed an analytic tool which will determine the frequency of the sun/lunar limb viewing, the duration of opportunities, the azimuth/elevation line-of-sight directions of each opportunity, the sensitivity analysis for solar zenith angles for 95-to-98°, and the translation of GPS data on-orbit to initialize on-orbit event prediction. In summary, there are ample sun viewing opportunities (twice per orbit revolution for 120 seconds of viewing). The lunar viewing is limited by season and moon phase. There are simultaneous dual sun/lunar viewing opportunities that exist which require targeting preference of one or the other, but not both. The solar zenith angle 98° versus 95° has small impact on the number of lunar-viewing opportunities. Lastly, there are no field-of-view interferences with the sun/lunar azimuth line-of-sight directions and the METEOR-3M hardware.

Mike Blythe summarized the electrical subsystem table top as being a "good thing." The architectures are established and the interfaces are well defined. There were no show stoppers in sight with the possible exception of meeting the power budget for a FOO. His primary concerns were the power budget, no limit check on the elevation motor, charge-coupled device (CCD) and analog/digital (A/D) converter not on the same board as the CCD, potential noise due to long wires, termination of the 1553 bus, time alignment of science and engineering data, and the ground support equipment (GSE) design and staffing.

Richard Tarde, the Ball Electrical Subsystem Lead, gave an overview of the electrical subsystem and concluded by specifically addressing the concerns which were presented by the table-top reviewers. The time alignment of the science and engineering will be studied. There is most likely a time delay on the elevation scan mirror. Zawodny pointed out that the scientists need to know the elevation position at a known time. They can live with a known time delay.

Pamela Rinsland summarized the software subsystem table top as being successful and highlighted that the subsystem requirements, detailed top level diagrams and the process flows, and operational scenarios were well presented. Her concerns included the definition of detection and recovery from error conditions, requirements clarification/enhancements, short-term specifications, long-term design goals (patchability on orbit and that the bench checkout unit [BCU] software should be designed to be reused for the mission operations), and that the GSE may need more staffing. Overall, however, she felt that the Ball team was ready to move on to detailed design for the Meteor-3M mission.

Larry Zimmerman, the Ball Software Subsystem Manager, followed Rinsland with a summary of the flight software capabilities, which include autonomous science-event prediction, controlling the science data collection, and on-orbit reprogramming. SAGE III also has two flight computer software configuration items (CSCIs), the instrument controller (master) and CCD controller (slave). The GSE software capabilities include the BCU and the instrument simulator unit (ISU). Ball plans to simulate the 1553 serial data bus interface with the Russian spacecraft. Also the Russians have agreed to provide a spacecraft simulator to Ball. The interface between the MIL Std 1553B dual redundant bus and the Russian triple bus is critical to the instrument operation and should be checked out prior to spacecraft integration and test (I&T).

Richard Foss summarized the mechanical/thermal subsystem table-top review and stated that the overall mechanical design and structural/thermal analysis relied heavily on SAGE II heritage and that the majority of the design and analysis was based on the Meteor-3M mission requirements because the ISSA and FOO are not yet fully defined. He had concerns such as the power budget, undefined Russian interfaces, and some modeling updates and analysis needed but saw "no show stoppers."

Dane Schnal, the Ball Mechanical/Structural Subsystem Manager, followed Foss with an overview of the mechanical subsystem. SAGE III consists of the following mechanical assemblies: spectrometer/telescope/lunar sensor, the azimuth system, and the scan head. Areas of greatest concern include the elevation motor trade, the flex pivots, and the Russian interfaces (specifically the Russian interface definition document [IDD] indicates a 0.1 g wide spectrum vibration possible).

Lenny McMaster summarized the spectrometer/telescope subsystem table-top review. The concerns highlighted included the linearity of the CCD array responsivity, the quantum efficiency stability of the CCD array, and the spectrometer stray light analysis, which thus far indicates minimum margin.

Jim Baer, the Ball Aerospace Spectrometer/Telescope Subsystem Manager, followed McMaster with an overview of the spectrometer/telescope assembly. The changes to the design since the System Requirements Review (SRR) include an all-aluminum telescope, including the primary and secondary mirrors; the secondary mirror monolithic with a spider support ring; the telescope, spectrometer, slit mounting, and registration have been detailed; and an improved grating substrate is under consideration (all aluminum grating). The primary issues identified and plans discussed for potential resolution were the need to measure stray light levels internal to the spectrometer (out-of-band rejection is the primary concern); the stray light effect on the lunar azimuth sensor; the contamination level effects on the scan mirror and slit; the location and use of the witness samples; and the CCD stability and linearity.

James Flores, Ball Aerospace, presented the effects of radiation on the CCD arrays. The silicon damage and the dielectric damage were analyzed. The results from the analyses were that the CCDs will need to be warmed to +20° C for a few hours once a week (or CCDs could be controlled to 20° C) to meet the radiation model projections; the end of life (EOL) linearity issues can be controlled with clock voltage optimization; and it is likely that the overall radiation damage rate can be mitigated by reducing the gate e-fields between operations.

Art Ray presented the trade-offs and changes to the azimuth tube, azimuth sensor, universal asynchronous receiver/transmitter (UART), scan head parts, calibration, and telescope from the SRR design approach. For the azimuth tube, material trade-offs are being made to consider the thermal properties. For the azimuth sensor, a large FOV azimuth sensor was added to ensure solar acquisition and a study to combine this function with the small FOV is being made; a small FOV azimuth sensor was moved to ease the alignment and installation; and a study was made of moving the science slit alignment toward the limb edge of the azimuth sensor to accommodate small limb angles on the Meteor-3M mission.

Next, Art Ray presented the "acceptable risk" for the power estimate, CCD performance, lunar acquisition, and the spacecraft disturbances. *Power:* Ball recommends proceeding with the current design and negotiating with the Russians for additional power. *CCD:* A waiver request has been submitted to retest the Scientific Imaging Technology CCD arrays for quantum efficiency (QE) repeatability and linearity. Also provision will be made for warm-up to anneal out dark current and radiation effects. Plans are to calibrate linearity on-orbit. *Lunar Acquisition:* For the Meteor-3M mission, offset the science slit toward the limb edge of FOV to avoid its brightness. For the ISSA mission, use the large FOV to do a better job with the small FOV and develop an "expert" system to take out ISSA deterministic pointing errors. *Meteor Disturbances*: Work with the Russians to understand the interface. The 0.05 g to 150 Hz is unbelievable, especially if this is applied laterally.

External interfaces were shown and discussed. Richard Tarde presented the electrical external interfaces. Fred Hausle presented the mechanical external interfaces. Armen Melikian presented the thermal external interfaces. He reviewed the requirements, the thermal design approach, and the results of the analysis. The Meteor-3M mission thermal predictions indicate that all the thermal requirements are being met.

Mike Cisewski, Lockheed/Martin, presented the mission operations concept for the Meteor-3M mission, which is based on the Meteor-3M/TOMS mission. Commands to the instrument are transmitted from the SAGE III mission operations to Russia via Internet every 2 weeks. These commands will be uplinked to Meteor-3M/SAGE III once every 2 weeks.

Tim Torphy, Ball Aerospace, presented both the electrical and mechanical ground support equipment (GSE). He also presented the system performance requirements verification and validation plan and demonstrated the system used to track these requirements. The performance requirements come from the Statement of Work and the Instrument Design and Performance Specification. He then presented the integrated test plan for the SAGE III project. The integration and testing is divided into the development testing, the flight unit testing, and the post-shipping testing. The development testing is dry running the flight testing and will use the verification unit (VU). The calibration plan includes developing a transfer reference spectral radiometer (TRSR) which will be characterized and calibrated by doing a side-by-side viewing of the sun with a "calibrated" radiometer. The TRSR will then be used at Ball to look at the sources for the calibration tests. The SAGE III instrument will be tested by looking at both the sun and the Radiometric Source Unit (RSU).

Dave Wilson, Ball Aerospace, presented the radiation effects analysis for electical, electronic, electromechanical (EEE) parts. The worst case radiation environment (Meteor-3M) was used in the analysis. Of the 130 parts evaluated, four were considered risk items. Of the four, one was considered moderate risk and the other three were considered low risk.

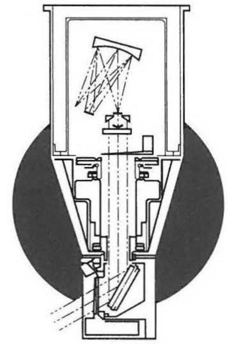
Don Alderman, Ball Aerospace, presented the reliability analysis. Attention areas, which have been mentioned previously, are the flex pivots and the attenuator mechanism. The preliminary failure modes and effects analysis (FMEA) has been completed. The most critical failure mode is the potential for shorts on the -27 V input power bus lines.

A project descope plan was presented by Ed Mauldin. The PI defined the minimum success criteria at the SRR, and the Project Manager developed a plan based on the minimum success criteria. For severe unexpected problems, the science and engineering team will consider cancellation of one of the instruments for one of the three missions. For known problems that start causing cost/schedule creep, a case-by-case descope plan will be developed by the science and engineering team and parallel efforts to recover the science will be implemented as well.

In conclusion, the PDR panel felt that the SAGE III program had demonstrated that the preliminary designs for the Meteor-3M mission met the system requirements with acceptable risk as defined by the payload classification and that all verification methodologies and interfaces had been identified and satisfactorily addressed. The panel consensus was that the SAGE III Project is ready to proceed into detailed design for the Meteor-3M mission. ■

The 3rd NIIEM NASA Meteor-3M/SAGE III Interface Meeting

—**Lelia Vann** (l.b.vann@larc.nasa.gov), SAGE III Science Manager, Aerosol Research Branch, NASA Langley Research Center



Representatives of the Scientific Research Institute of Electromechanics (NIIEM) and the National Aeronautics and Space Administration (NASA) conducted a meeting at NIIEM, located in Istra, Russia, July 24-28, 1995, to discuss the technical interface between the Russian Meteor-3M spacecraft and the U.S. Stratospheric Aerosol and Gas Experiment (SAGE) III. The meeting was co-chaired by Rashid Salikhov, Deputy Director of NIIEM, and Victoria Hall, SAGE III Program Manager at NASA Headquarters. Representatives of NIIEM, NASA Headquarters, NASA Langley Research Center (LaRC), NASA Wallops Flight Facility, Ball Aerospace, Central Aerological Observatory (CAO), NPO "Planeta," and IDEA, Inc. took part in the meeting.

The meeting consisted of discussions by management, technical, and science groups of the Meteor-3M/SAGE III project. Splinter discussions were held for the following subgroups:

Project Management
co-chairs: R. Salikhov, V. Hall
Mechanical and Thermal Interface
co-chairs: G. Petrenko, S. Holloway
Electrical Interface
co-chairs: A. Vladimirov, J. Quinn
Science and Data Processing
co-chairs: Y. Borisov, L. Vann
Contamination Control
co-chairs: N. Lobakov, S. Holloway
Integration and Test
co-chairs: V. Zavgorodny, D. Carraway
Mission Operations
co-chairs: R. Salikhov, M. Cisewski.

Several significant changes to the design of the Meteor-3M(1) spacecraft were presented by the Russian side. The Meteor-3(8) meteorological spacecraft will not launch in 1996 as planned. Therefore, the Meteor-3(8) subsystems will be used to the maximum extent possible in the development of the Meteor-3M(1) spacecraft; however, subsystems will be modified as necessary to accommodate all of the SAGE III instrument requirements. These design changes will be reviewed by the American side to ensure that all SAGE interface requirements are met by the revised Meteor-3M(1) spacecraft design.

The following changes were discussed:

◊ The payload, AMAS, is no longer being considered for Meteor-3M(1), but remains in consideration for Meteor-3M(2).

◊ The mounting platform for the instruments has been changed from a honeycomb structure to a truss structure.

◊ The power supply system that was used on Meteor-3 will be the system for Meteor-3M(1). Both sides agree that this system satisfies the SAGE III instrument requirements.

◊ An 8.2 GHz transmitter will not be installed. The 466 MHz transmitter from Meteor-3 will be installed instead.

◊ A command-measuring system with transmission frequency of 2.3 GHz and reception frequency of 7.0 GHz is now being used on the spacecraft.

These changes will be reflected in the interface control document (ICD).

Both sides agreed that the goal for the mission duration will be three years, and the launch date will be August, 1998. The launch vehicle for Meteor-3M(1) will be the Zenit 2.

Both sides reconfirmed that the nominal altitude for the spacecraft would be 1020 kilometers, the inclination would be 99.53°, and the ascending node crossing time would be 9:15 a.m., plus or minus 15 minutes. Both sides also reconfirmed that the 1553B Bus will be employed for the exchange of commands and information between the Meteor-3M(1) and SAGE III.

The requirements for the science data telemetry format have been changed. This change deletes the requirement to use the NOAA PCM Frame structure.

Because of spacecraft changes, the SAGE III configuration may not be known until late October. Therefore, both sides agreed to delay the delivery of the antenna model until December 31, 1995.

The Mechanical and Thermal Subgroup discussed the following topics:

◊ Design of the Meteor-3M's three new platform design options and agreement on both the truss option concept for the platform and a one-piece design for the SAGE III instrument.

◊ Uncompensated momentum.

◊ Thermal control for SAGE III and multi-layered insulation (MLI) attachment.

◊ Mounting issues and precision alignment of SAGE III.

NIIEM and NASA agreed to requests for technical drawings, tolerance analysis for the mounting holes, temperatures of the mounting sites, stiffness matrix, and a mass budget for SAGE III of 80 kg.

The Electrical and Mission Operations Subgroup discussed the following topics:

◊ SAGE III power supply diagram and its operation timing diagram;

◊ connection of analog, digital, and thermal sensors to the spacecraft housekeeping telemetry;

◊ grounding of electrical interface circuits;

◊ procedure for EMC testing;

◊ instrument synchronization and time code transmission to the instrument;

◊ downlink of scientific data through a 1.7 GHz radio line and necessary data formats;

◊ transmission of discrete controlling commands and also commands and data through the 1553B bus; and

◊ spacecraft and instrument simulators and instrument testing.

The Mission Operations Subgroup met for the first time. Representatives from NIIEM, NPO "Planeta," and CAO participated in the discussions from the Russian side and representatives from LaRC and Wallops Flight Facility participated from the American side. These discussions focused on SAGE III data reception. In addition, a very informative tour of the Russian Space Agency (RSA) Spaceflight Control Center was conducted. Both sides agreed to begin work on the Joint Mission Operations Plan.

The Contamination Control Subgroup discussed the preliminary Contamination Control Plan. This subgroup also participated in discussions with the Integration and Test (I&T) Subgroup on the I&T Development Plan. Both sides agreed that the Contamination Control Plan would be a joint document which will be prepared by both sides.

The Science and Data Processing Subgroup discussed the general algorithms used for the SAGE II and SAGE III scientific data. Considering the high importance of the accuracy of the science data, the limited time for algorithm development by both sides, and the SAGE II experience gained by the American side, the Americans agreed to inform the Russian specialists about the details of the methods and algorithms used by NASA for the SAGE II and SAGE III data. The Americans invited the Russian specialists to attend the SAGE III algorithm review scheduled to be held in the U. S. during the month of October 1995.

The Russian's ozone data from their chemical and optical rocketsondes were discussed. The Americans agreed to consider this ozone measurement capability as part of the SAGE III correlative measurement validation program.

The Russians agreed to identify the Russian members of the SAGE III Science Team and the members of the SAGE III Algorithm Working Group by August 10, 1995.

The I&T Subgroup held discussions concerning places and procedures for Meteor-3M/SAGE III I&T. The Russian specialists provided a tour of the MIK 1 and MIK 2 areas where integration and test of the flight model will occur. The SAGE III antenna model was discussed. It was proposed that the delivery be delayed until the end of 1995. The American specialists submitted a design for this model to the Russian specialists. It was approved. The flight model I&T process was discussed in detail. The preliminary plan provided by the Russian specialists was adjusted and agreed to by both sides. The Russian specialists provided preliminary requirements for the thermal model. These requirements will be clarified by November 1995. The issue of how the test procedures used for functional testing will be transferred to the Russian test computer system was discussed. The Russian specialists provided a sample of the test complex program.

The process for guaranteeing the cleanliness of the instrument and spacecraft was discussed with the Contamination and Control Subgroup. Contamination and control procedures were incorporated into the I&T Plan and were further defined in the Contamination and Control Plan.

The Russian side provided the following documents to their American counterparts:

◊ Interface Definition Document (IDD) (third writing)
◊ Simulator of the spacecraft "Meteor-3M/SAGE III" for testing interfaces
◊ Draft Meteor-3M/SAGE III Contamination Control Plan
◊ Draft Interface Control Document (ICD)
◊ Draft Integration and Test Plan for the SAGE III Instrument on the Spacecraft "Meteor-3M."

The American side provided the following document to the Russian counterparts:

◊ Interface Design Specification (IDS).

Both sides agreed to acknowledge receipt of information via fax, electronic mail, or letter mail. It was agreed that "express mail" should be used.

Both sides agreed to investigate upgrading Internet connectivity to NIIEM with regard to equipment, leased communication lines, satellite links, and network software. Currently, e-mail communications are via a dial-up line at a maximum rate of 2400 bps. Due to interference on the line, long e-mail messages and/or attached files are difficult or impossible. NIIEM is currently attempting to procure a dedicated leased line.

The two sides have proposed to hold the next meeting on the Meteor-3M/SAGE III project on October 23-27, 1995, in the United States.

The meetings were conducted in the spirit of partnership and mutual understanding. ■

The Good, The Bad, And The Useful: Do Things Ever Go Right?

— **Bruce Barkstrom** (brb@ceres.larc.nasa.gov), NASA Langley Research Center

During one of the early EOSDIS design reviews, Dave Emmitt and I were lamenting the fact that the production scenarios being used to scope out the amount of computing power and disk storage didn't really represent the experience of validating large data sets very well. Right after the EOS satellites are launched, we expected the instrument teams to be as busy as they'll ever be, trying to piece together how their instruments are behaving and why the algorithms don't give what their inventors expected. However, the processing scenarios used in the review looked benign—continuous increases in computer power for algorithm testing and integration and gentle turn-ons for reprocessing—no frustrating error diagnosis sessions while Headquarters is breathing down your neck asking for "spectacular results." At the same time, we didn't really have a specific counterproposal to make.

By happenstance, a book I read, called "Just in Time" Production (Manufacturing Systems Engineering by Stanley Gershwin [1994]), has an interesting model for machines that fail and then have to be repaired. Either a production machine is "working," or it is "under repair." I thought "that's like algorithms— either they're working correctly or we have to fix them!" In Gershwin's book, just as with real algorithms, we find machines breaking at random (or, to be a little more precise about our problem, we discover at random that our algorithms aren't working). The time it takes us to fix what's broken is also random: sometimes we can find what we have to change quickly; at other times it takes almost forever.

The model Gershwin describes looks at a machine producing μ products in a given time. We might call μ the "rate of production." The probability that this machine fails in a time δt is $p\delta t$. When the machine is "down," the probability that it gets fixed and can return to production in a similar time interval is $r\delta t$. The interesting outcome is that over a long time, the average rate of production is

$$q\mu = \frac{r}{r+p}\mu \qquad (1)$$

If we imagine that the machine doesn't necessarily stop production when it fails, but that it produces "defective" products, then we could interpret q as the probability that the machine is producing good products.

Does this make sense for algorithms and data products as well as machines? Well, if we discover a lot of errors in a short time and if it takes us a long time to fix each one, then p is high and r is low—q will be small. In this case, interpreting q as the probability of having a good product makes sense, because we will develop a backlog of errors and what we produce when we run the algorithm isn't likely to be right. On the other hand, if we fix errors quickly and don't discover very many new ones, we're likely to have a lot of confidence that the products are good.

It's also reasonable to expect us to find fewer errors as we go forward in time. In a sense, we expect the pool of errors to be fixed and "the faster we find 'em, the fewer there are left." Thus, a plausible way in which our error discovery rate will behave over time is

$$\frac{dp}{dt} = -\frac{1}{\lambda}p \qquad \text{or} \qquad p = p_0 e^{-t/\lambda} \qquad (2)$$

Here, p_0 is the rate at which we discover errors initially. We might call λ the "error discovery lifetime." If we use these two equations together, we obtain the "famous" logistic equation

$$q(t) = \frac{1}{1 + p_0 \overline{T}_r \exp(-t/\lambda)} \qquad (3)$$

Instead of using r, we have used $\overline{T}_r = 1/r$, the mean time to repair the algorithm. Initially, q has a value of $1/(1+p_0\overline{T}_r)$. If we look at the situation several error discovery lifetimes after we start, then $q \approx 1$. Figure 1 shows how q depends on time for a rough estimate of the parameters, p_0, $\overline{T}_r$, and λ.

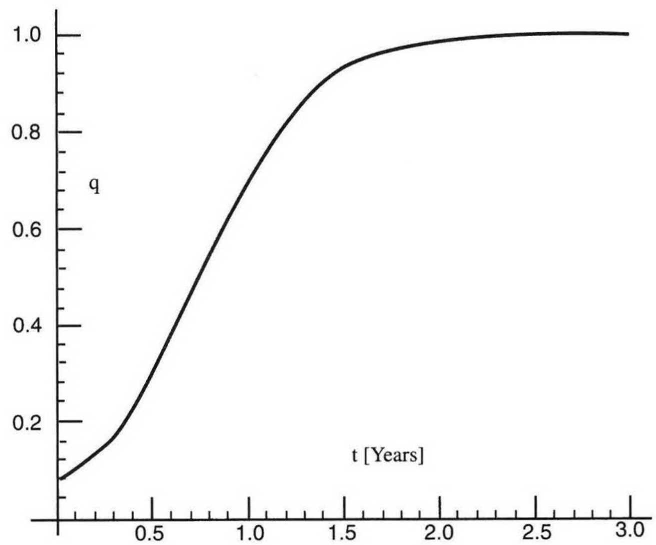


Figure 1. Estimated Probability of Reliable Data from a Single Algorithm. q is the probability of producing "good" data with an algorithm as expressed by equation (3). We have taken $p_0 = 24$ per year, $\overline{T}_r = 0.5$ years, and $\lambda = 0.3$ years, based on informal estimates from ERBE experience.

For right now, we'll use some rough estimates of the parameters based on my own memories of the kind of struggle we had getting the Earth Radiation Budget Experiment (ERBE) data into condition for archive. I remember looking at image-like plots we made of those data in the first month or two after launch, and recall several errors we had to fix immediately. From this recollection, it seems that setting $p_0 = 2$ per month (or 24 per year) as the initial error discovery rate puts us in a reasonable ballpark. The second parameter we need is $\overline{T}_r$. In thinking back over the ERBE experience, I recall many errors that were easy to fix— simple one-line problems in the code. However, the mean time to repair is strongly influenced by the errors that were hardest to fix: the "more than one year" struggle to get the Angular Distribution Models right, the six-month ordeal with "striping," the several-year struggle with "offsets." Thus, six months $\overline{T}_r$ seems reasonable. And finally, what do we do about λ? I'll take it to be about 0.3 years, hoping to catch at least a rough sense of how long it takes our error discovery process to damp out.

What Happens When Things Don't Go Right

Of course, if you're a data producer and discover problems, your immediate thought is: "Where's the problem?" After you've gotten some data and looked at it, you're likely to respond: "I need to make some more runs with this program—but with a few changes!!" Life in the Distributed Active Archive Centers (DAACs) and in the Science Computing Facilities (SCFs) is really fun when this happens.

There are several strategies we could apply to error diagnosis and repair. One that we used on ERBE was to concentrate on small samples of data and work on them until we seemed to remove the errors. Then, we would take a larger sample and reexamine that for errors, using the corrections we had developed on the first, small sample of data. Finally, we would try integrating the correction into the operational code and modify the statistics we were tracking to monitor the data product quality. Often, we stopped production while we searched for good ways to fix the algorithms. Of course, this made error detection slower, since then error detection and fixes became a strictly serial processing procedure.

The important thing to note is that error diagnosis and algorithm repair are major activities after launch. Somehow, we feel that the amount of diagnostic processing should be related to how bad the data seems to be and how rapidly we're finding and correcting errors. The good side of this model is that it's simple, it's continuous, and (intentionally) doesn't care about the real details of the repair and production strategy we're using. The bad side of the model is that it doesn't give us an easy way to estimate the three parameters from our previous experience without a fairly detailed study.

In the absence of a detailed historical study or a better theory, we'll make the simplest assumption we can: the amount of work we have to do is proportional to how many errors we've found recently. With the curve in Figure 1, we'll have lots of work early, and then as the algorithm's reliability improves, the amount of additional diagnostic work will decrease as well. Thus, if μ is the number of jobs we have to run in a given month for "standard production," we estimate the number of jobs we'll have to run at the PI's SCF to be about $(1 - q(t))\mu$, and the number at the DAAC to be about $\mu + (1 - q(t))\mu = (2 - q(t))\mu$. The primary reason the DAAC load increases with this model is that we're accounting for a continuous flow of algorithm repairs, which have to be tested and integrated into the standard production software.

It also seems that it's reasonable to expect the network traffic to increase. No PI is a team unto himself or herself. Other members of an investigation will need to look at the data to make their own judgments of what needs to be done. If this assumption is reasonable, the diagnostic data flow will probably be proportional to $1 - q(t)$. Building up a detailed traffic model that estimates how many diagnostic files have to be transfered from the production site to other locations is a matter for another article.

We can also use this model of data quality to estimate when the teams will want to start reprocessing. The usual philosophy seems to be "wait until the data are good enough before we start re-doing products." In more-quantitative terms, if we set a threshold, q_0, such that we don't start reprocessing until $q(t_{reproc}) > q_0$, then we wait until

$$t_{reproc} = -\lambda \ln[(1 - q_0)/(q_0 p_0 \overline{T}_r)] \qquad (4)$$

If we allow the teams to be careful, and $q_0 = 0.99$, so there's only about a 1% chance of something being wrong, we find $t_{reproc} \approx 2.1\ years$—a calculation we can perform just with a $15 pocket calculator.

Some Implications

This model for how algorithms act under stress is a lot simpler than real life. However, it seems to have the right sense in three important ways: a) diagnostic work will be heavy at first and will taper off; b) both the estimated initial data product quality and the length of time needed to get things to the point where reprocessing is justified seem in accord with my experience as a data producer on ERBE; and c) the time to start reprocessing looks "reasonable."

In talking with other EOS data producers who've had experience with large-scale data production, this model also seems to fit with at least a rough characterization of their experience.

One important way in which EOS production differs from this model is that all of the EOS data producers have "algorithmic food chains," in which higher level data products have dependencies on lower level products that we now see to be of evolving quality. A simple way to look at how good the higher level products are is to assume that the errors lower down are independent of the errors higher in the food chain. If we do such a multiplication, we can expect the higher level products to take longer to get right—it takes a while to find out which errors come from products lower down and then it takes more time to fix them. This observation also fits with our ERBE (and other data producer) experience.

This model is also likely to be useful for investigators who want to do science with EOS products (or with other data—there's no reason to think EOS is exceptional in this regard). Clearly, if you want to use Level 1 (radiance) data, the parameter q in Figure 1 is probably descriptive of whether you're likely to have reliable data. If you want to use higher levels, the product reliability is likely to look like some integer power of this curve until the data are reprocessed.

Certainly, there's a lot of work to do. For one thing, the numerical parameters I've suggested here need a stronger basis in what we've recorded from our past history. I have used this model to estimate how many computers we need for the early years of production. Ellen Herring in the Earth Science Data & Information System (ESDIS) Project's System Engineering Office suggested that these estimates need to allow the computer MFLOPS ratings to grow with time. Her group's experience on the Upper Atmosphere Research Satellite (UARS) may be very helpful in setting up contingencies for EOSDIS. It may even be useful to consider other models to estimate how much diagnostic work we have to do and how that diagnostic work is related to data quality.

An Opportunity For Reader Involvement

For those members of the EOS community who want to take a more-active interest in these kinds of problems, here are a few "brain teasers" to work on. I won't offer any prizes, except to suggest that good answers be published here or in some other suitable place:

1. Either suggest an alternative form for this data quality expectation or provide a more-detailed justification for this curve—preferably with some empirical or theoretical justification for any parameters you need to apply the model to practical problems of EOSDIS production. Extra credit for detailed empirical studies with documentation.

2. Confirm or provide a theoretical or empirical counterexample to the suggestions that the number of processing jobs at the DAACs will scale as $(2 - q(t))\mu$ and that the diagnostic product flow between the production site and the SCFs will be proportional to $(1 - q(t))\mu$. Extra credit to anyone finding the constant of proportionality. Failing mark awarded for mere complaints that the form suggested here is unreasonable.

3. Determine an optimal quality assurance (QA) processing strategy that jointly minimizes the cost of processing and the delay in archiving high-quality data for the following conditions: a) all errors to be found are initial errors of omission in the algorithms; b) continuous generation of new errors due to instrument perturbations such as contamination of calibration sources, or radiation damage and aging of electronics; and c) continuous creation of new errors by code used to fix old errors [this possibility suggested by Rich Ullman].

   Answers to this problem must be accompanied by a *bona fide* proof of optimality. Practical answers or hypotheses should be identified as such, although good reasoning gets partial credit. Without proof, answers are subject to trial by battle with real data from EOS.

4. Provide a closed, analytic form for the expected data quality of a chain of algorithms and products as production and algorithm repair proceed. In the absence of such a solution, establish a plausible form by computer simulation or analytic approximation. If either of these two solutions proves too difficult, at least provide a study of some simple cases.

References

Gershwin, Stanley B., 1994: Manufacturing Systems Engineering, Prentice-Hall, Englewood Cliffs, NJ, 501 pp.

Note: The author hopes that this article will be the start of a regular series of columns in the *The Earth Observer* on Engineering EOSDIS. As part of the work the EOS Ad Hoc Working Group on Production (AHWGP) has done to improve our understanding of production, I've begun to build an integrated computer model of EOSDIS and its costs. There are several topics that have surprised me as I've tried to put this model together, and I'd like to share them with the community. If time allows, I may also be able to assemble this material into a more-extended form. ■

Committee on Earth Observation Satellites (CEOS) Ocean Color Meeting

—**Ian Barton** (ian.barton@ml.csiro.au), Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia

The Infrared and Visible Optical Sensors (IVOS) sub-group of the Committee on Earth Observations Satellites (CEOS) Working Group on Calibration and Validation (WGCV) held a special meeting in Lanham, MD May 1, 1995, on international activities related to ocean color sensors. The meeting was aimed at exchanging information on future ocean color sensors and developing closer collaboration in the calibration/validation (cal/val) activities of the various national space agencies and institutes.

The IVOS chairman, Ian Barton, welcomed the representatives from the international ocean color community and gave a brief description of CEOS, its structure and charter, and how the ocean color community could benefit from participation in CEOS activities. Several invited experts from different agencies then described the cal/val activities of their national programs.

A general overview of ocean color physics was presented by Howard Gordon of the University of Miami. Correcting ocean color radiances for the effect of the atmosphere was described as one of the major sources of error. The techniques used for the Coastal Zone Color Scanner (CZCS) were outlined and these were extended to SeaWiFS and MODIS, where there are more bands available and a better correction is possible. A range of aerosol models was used in the correction procedures, and simulations had been carried out for different sun angles, view angles, and aerosol loadings.

Chuck McClain (Goddard Space Flight Center) presented details of NASA's plans for SeaWiFS calibration. An update on the status of SeaWiFS and the Seastar spacecraft was given: the hardware integration of SeaWiFs is now complete and the launch manifest showed a launch as early as September, but February 1996 was a more-likely launch date. (NOTE: Since the Pegasus XL failure in June 1995, the SeaWiFS launch remains uncertain.) Data from SeaWiFS should be available about 6 weeks after launch. The cal/val program would concentrate on algorithm development, calibration verification, and derived-products validation. The calibration/verification would rely on the Marine Optical Buoy (MOBY) to be deployed off Hawaii and the use of high-altitude lakes. On-board calibration would use the sun and the moon as standard sources.

A report on a recent ocean color meeting held in Miami was presented by Wayne Esaias, NASA Goddard. He reported that there was a decision not to fly an ocean color sensor on Landsat-7. The Miami meeting had been more of a fact-finding meeting where the need for a 3-day, international cal/val meeting coupled with MODIS and SeaWiFS plans was stated. Some form of international infrastructure was required that would coordinate at-sea activities for the different ocean color missions. (NOTE: This now seems to be under way—see later discussion on international collaboration.)

The Japanese National Space Development Agency's (NASDA) plans for Ocean Color and Temperature Scanner (OCTS) calibration were outlined by Masanobu Shimada of NASDA. A delay of six months was now expected in the ADEOS launch date (launch date is now August 1996). The ADEOS platform was described and details of the cal/val goals for both the thermal and visible channels of the OCTS instrument were presented. The main post-launch validation would be undertaken using an optical buoy moored on Yamato Bank in the Japan Sea. Currently, a network of sites is logging the aerosol distribution around the Japanese islands. Mutsu Bay, in the north of Japan, is also being used as a validation site for the thermal channels. Several instrumented buoys have been deployed in this large, partly land-locked, bay. OCTS also has an on-board calibration capability using an internal lamp and the sun as alternative sources.

Giuseppe Zibordi of the European Joint Research Center at Ispra, Italy, presented European plans for ocean color validation. Current activities center on two major campaigns, but a proposal to the European Commission's Marine Science and Technology (MAST) Program is seeking funding to operate a total of four European sites. The first program described was CoASTS (Coastal Atmosphere and Sea Time Series Project), which involves the deployment of an optical buoy in the northern Adriatic Sea near Venice. The data collected would be used to develop atmospheric corrections and bio-optical algorithms for ocean color data from OCTS, SeaWiFS, and Polarization and Directionality of Reflectances (POLDER). The second campaign was PlyMBody (the Plymouth Marine Optical Buoy), which would be moored off the south coast of England. This program would include weekly collection of *in situ* water samples. The MAST proposal (with the acronym of PICASSO) included these two sites plus two more—one in the Nordic Sea and the second in the North Sea.

Lasse Petterssen (Nansen Environmental Research Centre, Norway) and Gerald Moore (Plymouth Marine Labs, UK) also presented some further details of PICASSO plans in the Nordic Sea and southern UK waters respectively.

Robert Frouin of NASA Headquarters presented details of a proposal for the formation of an international ocean color working group. The proposal suggested that the international working group would present their recommendations to CEOS. In particular, the CEOS WGCV would review techniques and standards for calibration of the ocean color sensors and validation of the geophysical parameters. The proposal also suggested that a special CEOS standing subgroup on ocean color could be established to deal with ocean color issues. This subgroup would report to the two working groups of CEOS (WG on Data [WGD], and WGCV).

These proposals were discussed at length, and it was felt that the endorsement of cal/val procedures was outside the charter of CEOS WGCV. Also the formation of a specific subgroup on ocean color would not be necessary as the current working groups of CEOS encompass the interests of the ocean color community. Data management and data exchange issues were discussed briefly, and it was decided that these matters should be brought to the attention of the CEOS WGD.

The funding of cal/val campaigns was briefly discussed, but it was agreed that while each agency should go ahead and fund its own campaigns, they should also be aware of the great mutual benefits to be gained from close collaboration in international activities.

In summary, the outcomes of the ocean color meeting were:

1) the ocean color community is better informed about CEOS, its structure, and its role in international Earth observation activities;

2) the ocean color community is more aware of international activities and future collaborative opportunities in validation campaigns;

3) the CEOS working groups should include members with interests in ocean color science; and

4) the ocean color community is to proceed with the establishment of an international working group and to seek representation on CEOS WGD and WGCV subgroups. Those interested in participating in this activity should contact Robert Frouin (rfrouin@mtpe.hq.nasa.gov). ■

EOS Workshop on Land Surface Evaporation and Transpiration

—**Doug Miller** (miller@essc.psu.edu), Pennsylvania State University; **Jim Washburne** (jwash@hwr.arizona.edu), University of Arizona; **Eric Wood** (efwood@pucc.princeton.edu), Princeton University

Introduction

The EOS Workshop on Evaporation and Transpiration (ET Workshop) was held June 1-2 at Goddard Space Flight Center (GSFC). The aim of the workshop was to develop a working relationship among the various EOS Interdisciplinary Science (IDS) Teams, Instrument Teams (IT), and Distributed Active Archive Centers (DAACs) interested in land surface evapotranspiration by encouraging complementary activities and a better understanding of each other's needs.

The specific goals the conveners set for this workshop were the following:

1) review the current status of the application of satellite data to the determination of land surface evapotranspiration and delineate the pressing problems, limitations, uncertainties, and dilemmas that must be overcome;

2) summarize algorithms and subsequent data products, on the part of both IDS and Instrument Teams, that are currently being planned as a part of pre-launch and post-launch activities;

3) develop coordinated plans between IDS Teams and Instrument Teams in pre-launch studies designed to test proposed algorithms and data product generation; and

4) establish relationships and means for cooperative research among IDS Teams, Instrument Teams, DAACs, and EOSDIS in evapotranspiration algorithm and product development.

We want to continue to provide an open forum and discussion environment that will allow all interested parties to address the specific goals listed above and to continue building a consensus on future directions and coordination among the EOS elements represented. This report and several information supplements will be posted on the Physical Climate and Hydrology Panel's homepage: http://www.hwr.arizona.edu/pchhome.html, to facilitate communication. Below, the salient resolutions and outcomes of the meeting are listed in the Executive Summary. The issues addressed by the group in discussion are described and then summarized in tables.

Executive Summary

There was general agreement that process-based parameterization of land surface evaporation and transpiration is possible and appropriate. The estimation of these fields using remotely sensed and ground data, however, needs a more thorough evaluation across a wide range of scales and climates. There was concern about the lack of adequate observations and the poor accuracies of a number of variables.

A significant outcome of this meeting was the identification of those parameters or data sets that will be of most interest to EOS scientists working with evapotransporation (ET). This list is important for several reasons: it clearly identifies standard products that are required to calculate ET; it identifies this group as advocates for these products; and it represents a consensus view and thus carries more weight.

The parameters detailed in Table 1 are characterized by a wide range of space/time resolutions. A major effort will be required to properly assimilate these diverse data sets in order to produce a standard ET product. This synthesis must encompass *in situ*, satellite, and model data. It can also be seen that EOS-generation data resolutions will not be significantly different from those possible today. The expectation, however, is for data quality and availability to far exceed current norms.

	Spatial Resol, Temporal Resol, Satellite/Sensor			
	Regional		Global	
Precipitation	4 km, 1 hr	NEXRAD	1°, 5 day	TRMM
Net Radiation	50 km, 1 hr	GOES	2.50°, daily 2.50°, daily 1.25°, 3 hr	ERBE (TOA) SRB (SFC) CERES (both)
Gnd Meteorology	10 km, 1 hr	4DDA	50 km, 3 hr	4DDA
Vegetation	30 m, 3 wk 90 m, 3 mo 500 m, 1 mo	TM/SPOT ASTER MODIS	1 km, 1 mo 1 km, 1mo	AVHRR MODIS
Soil	4 km, 1wk	4DDA	25 km, 1 day	MIMR/AMSR
T_S, emissivity	90 m, 3 mo	ASTER	1 km, 1 mo	MODIS
Runoff	basin, day	USGS	basin, 1mo	GRDC
DEM, streamlines	120 m, once 15 m, 3 yr	USGS ASTER	1 km, 1996 100 m, 3 yr	USGS/DCW ASTER
Atmospheric profile	1°, 12 hr	NWS	50°, 12 hr 1-2 km vert	AIRS 1 K
4DDA = four-dimensional data assimilation		TOA = top-of-atmosphere		SFC = surface

Table 1. ET Parameter Requirements / Most-likely Products

ET Parameter Requirements: The estimation of ET requires the following data: precipitation, net radiation, surface meteorology (air temperature, wind speed, vapor pressure deficit), vegetation (cover, biomass, vegetation index, fractional photosynthetically active radiation [fPAR]), soils (moisture, class), surface temperature and emissivity, runoff, streamlines, Digital Elevation Models (DEMs) and atmospheric profiles. Where possible, pre-EOS data sets should be identified and developed to evaluate the accuracy, sensitivity, and robustness of potential EOS ET products.

Model and Product Development: ET models and algorithms can be broadly classified as physical, empirical, and boundary-layer. Variants exist for both the energy- and water-balance approaches. Every effort should be made to develop and share model concepts and procedures prior to the launch of EOS AM to better identify the strengths and weaknesses of our varied approaches.

Calibration/Validation Sites: The IDS teams recognize that validation test sites and calibration sites are important. It is now more likely that our IDS teams will coordinate with the instrument teams in choosing joint sites to maximize the benefits from our calibration/validation efforts. The workshop endorsed having a number of different sites that spanned a variety of climates and land surface types across the globe. Further, it was recognized that international sites would be beneficial to the EOS program.

EOSDIS and Other Collaborations: The EOSDIS Data Handling System (EDHS) is making a strong effort to interface with science groups such as ours but many details of the system remain ambiguous. Data issues that remain poorly resolved in the face of regular program restructuring include: a fully operational (HDF) standard, generation of Level 3 & 4 data products, mechanisms to interchange experiment data sets among EOS teams and the utility of Level 1 data visualization/access efforts.

There are striking similarities and common objectives between this group and organizations such as the Global Energy and Water Cycle Experiment (GEWEX) and the International Geosphere-Biosphere Program (IGBP). We need to make greater efforts to develop collaborative research and stay abreast of each other's activities.

Issues and Discussions

Many issues were brought forward as part of background presentations and were then discussed in greater detail by all the attendees. We have tried to capture the gist of these discussion periods in the four sections below.

ET Parameter Requirements

◊ Scale: ET parameter requirements are driven by different objectives. These are related to the spatial and temporal scales of interest. It quickly became clear that there is a valid need to pursue model development and observations at a range of scales from local to global. There are IDS investigations across this range of scales, and this diversity should be encouraged.

◊ Precipitation: The overall importance of precipitation as an input and validation parameter was widely acknowledged. The usefulness of any global-scale precipitation estimates outside of the Tropical Rainfall Measuring Mission (TRMM) seems doubtful and was a concern to many of the IDS teams. Since direct observations from TRMM are infrequent, it will be important to have access to supplemental observations from GOES, gauge, and runoff data sources within EOSDIS. TRMM's operational product will be monthly precipitation totals at a 5 degree bin. Higher spatial and temporal products (1 deg, 5 day) are also being considered. Many participants seemed unaware of the current capabilities and limitations of these products and were encouraged to contact the TRMM program to evaluate pre-launch products in their models. The use of surface radar at regional scales, particularly NEXRAD data, should improve our knowledge of precipitation and hydrologic processes and should be an active link within the EOSDIS system.

◊ Radiation: Net radiation is another critical parameter. Assuming that estimates of solar radiation will never be practical at a resolution of 1 km/10 min, then resolutions of 50 km/60 min are desirable in that the space/time variability due to partly cloudy conditions is much reduced. The CERES radiation product at 1.25 deg/3 hr resolution is slightly coarser than desired but is acceptable. Hourly cloud cover from NOAA's GOES satellites is, and will continue to be, a high-priority data product.

◊ Soil Moisture: Soil moisture was repeatedly cited for its importance yet there seems to be some resignation that little can be done to improve our knowledge of its space-time distribution. A more-optimistic outlook is possible by considering that new 4D-data assimilation (4DDA) models and better land-surface parameterizations will greatly improve the representation of soil moisture in the coming generation of GCMs. Care must be exercised in recognizing the inherent model-derived limitations of these products. Any wide-spread, long-term surface monitoring programs should be encouraged for a variety of calibration and validation uses. This community should monitor and champion the need and development of sensors such as the Multifrequency Imaging Microwave Radiometer (MIMR), Advanced Microwave Scanning Radiometer (AMSR), and Global L-band Observations of the Earth (GLOE).

◊ Surface Meteorology: Near-surface winds, air temperature, and vapor-pressure deficit are required to estimate ET using robust physical models. This kind of information is not available from satellite, so non-EOS data sources must be identified and evaluated. Some useful work is being done to assess the utility of forecast-model-derived fields (from the National Center for Environmental Prediction [formerly NMC] or European Center for Medium Range Weather Forecasts [ECMWF], for example) for this purpose. Climatologically-derived fields, particularly with respect to wind and precipitation, are also of interest. None of these techniques provides data at better than 50 km/3 hr resolution at the global scale. Higher resolution data will be of use in areas of high relief and land-cover diversity.

◊ Surface Characteristics: Slowly-varying surface characteristics such as soil and vegetation parameters are required by many models as boundary conditions or are directly active in the partitioning of energy and mass at the surface. At global scales, the International Satellite Land Surface Climatology Project (ISLSCP) Initiative 1 soil data (texture, depth, slope) and vegetation data (NDVI, fPAR, land cover) represent a solid reference from which improvements can be made. At regional scales, improved data are desirable and may exist although more could be done to index available sources. MODIS is expected to provide improved estimates of fPAR and vegetation index, which need to be mapped to canopy conductance for estimating transpiration. The ability to quantify these parameters for different vegetation types and in different climates is critical and needs further testing. Soil temperature and emissivity are useful and recommended for model validation, data assimilation, and energy-balance calculations.

Red/Arkansas - Little Washita - CART/ARM area Climate: Semi-Humid Activities: USDA Experimental Watershed, EOS IT and IDS validation/study site, DoE CART/ARM site, GCIP focus area, proposed CASES site
Lower Colorado - San Pedro - Walnut Gulch Climate: Semi-Arid Activities: USDA Experimental Watershed, EOS IT and IDS validation/study site, NASA/ARS field MAC '90, '91, '92, proposed SALSA site
Susquehanna (or TVA region) Climate: Humid Activities: Both are EOS IDS study sites
Sahel (West Africa) Climate: Semi-Arid to Arid Activities: Hapex-Sahel remote sensing experiment, possible validation/study site
Amazon Climate: Tropical Activities: Site of a geochemistry-geomorphology IDS study, location of planned WCRP (ISLSCP) and IGBP (BAHC) experiment
Mackenzie River basin - BOREAS Climate: Boreal to Arctic (tundra) Activities: ISLSCP BOREAS field MAC '94, '95, & '96 (?), Mackenzie River basin is a Canadian GEWEX study site

Table 2. Potential Calibration/Validation Sites

Calibration/Validation Sites

◊ Coordination: Many Instrument Teams (IT) have the need for and are planning to establish surface calibration/validation sites. There is much to be gained by co-locating some of these sites, and a clear willingness to increase this type of collaboration was expressed. In order to accommodate different levels of resolution, a nested-watershed approach is recommended.

◊ Potential Site List: Several potential IT/IDS test sites were identified across a wide range of environments. These are listed in Table 2. Important factors to consider include: site/model objectives, areal coverage, climate, vegetation, existing data base and data availability, existing and planned activities/commitments.

◊ Exemplary Site: The roughly collocated DOE Cloud and Radiation Testbed (CART)/Atmospheric Radiation Measurement (ARM) site and GEWEX Continental-scale International Project (GCIP)-SW area is exemplary of the synergies we would like to have. Prominent and desirable features of this area are:

- institutional commitment;
- open data policy;
- Baseline Surface Radiation Network (BSRN) - NEXRAD precipitation coverage;
- Oklahoma MESONET;
- ARM extended facilities with soil moisture - nested watersheds (ARS Little Washita, Walnut, Arkansas/Red); and
- NWS/ARM Radio Acoustic Sounding System (RASS).

Model and Product Development

◊ Validity: The validity and ability to estimate regional-scale ET was questioned. This critical view is justifiable since even local-scale measurements are difficult and any estimate is by necessity indirect. Still, large-scale ET estimates are commonly being made and have shown real value in a range of hydrologic applications. One mitigating factor is that spatial and temporal averaging act to dampen much of the apparent contrast due to heterogeneity. Our goal should be a clear statement of the inherent parameter accuracy, sensitivity, and error structure as a function of model or observation and an effort to steadily improve these measures as models, instruments, and data assimilation techniques mature. We must guard against thinking we have the right answers.

Rather, a logical approach that stresses space/time congruence is recommended—products at large spatial scales must be validated against large-area average data sets.

◊ Accuracy: Calculations of ET are the most sensitive to precipitation, radiation, and soil moisture. Thus, the accuracy of ET is largely limited by our knowledge of these parameters. It was suggested that current ET accuracies are on the order of 10-20 W/m^2 or 10-20% but there are (unknown) sensitivities to space/time scale.

◊ Instrument/Product Status: The Internet allows us all unparalleled access to up-to-date information concerning other components of the EOS project. (See Table 3.)

EOSDIS and Other Collaborations

◊ EOSDIS: The Version 0 EOSDIS is operational, and a Web version is on its way. The DAACs at Marshall (hydrologic cycle), and Goddard (meteorology) are all producing and archiving data sets that are useful for ET estimation. However stronger involvement with the user community is required to ensure that the capabilities of the DAACs are fully exploited. The DAACs seek to better support the IDS teams through: 1) involvement of IDS and Instrument Team members on the DAAC User Working Groups, 2) supporting data set generation and compilation, e.g., ISLSCP Initiative I CD-ROM data set, 3) outreach activities conducted by the DAACs with the science community, and 4) user-driven functional and performance improvements to the Version 0 Information Management System, user search, order, and data manipulation capabilities.

◊ Related Efforts: Other groups such as GEWEX and the ARM program are conducting observation and analysis activities related to regional ET assessment and we must work to integrate better. This is particularly important over the Cloud and Radiation Testbed (CART)-ARM site, which is a common area of interest for us all.

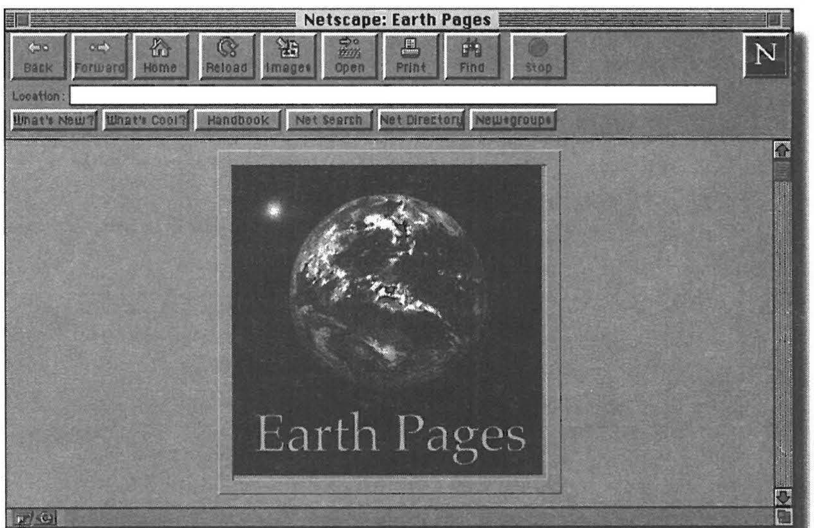
◊ ISLSCP Initiative I: The results of the ISLSCP Initiative I GCM baseline data synthesis were presented. The experience gained in producing this and follow-on data sets is useful to better understand the relationships between mixtures of model, satellite, and *in situ* data. ■

EOS Project Science Office http://spso.gsfc.nasa.gov/spso_homepage.html Find Algorithm Theoretical Basis Documents (ATBD) here for ASTER, CERES, LIS, MISR, and MODIS.
EOSDIS Core System (ECS) Data Handling System (EDHS) http://edhs1.gsfc.nasa.gov Use "QuickSearch" keywords "HDF" and "Science Requirements Summary" to find some very good papers on the future of EOSDIS.
EOSDIS Core System (ECS) Web server: http://newsgroup.hitc.com See "User recommended database."
EOS Data Products, Processes and Input Requirements Report, V.3.0 http://spsosun.gsfc.nasa.gov/spso/text-vol1.html Tables of your favorite data products - up-to-date!
MSFC HYDRO - Hydrologic data search, Retrieval and Order homepage http://wwwdaac.msfc.nasa.gov/ims/hydro.html
Physical Climate and Hydrology Panel Homepage: http://www.hwr.arizona.edu/pchhome.html See hydro_link list to simplify your hydro surfing needs.
TRMM Science and Information System (TSDIS) http://ame.gsfc.nasa.gov/tsdis/tsdis.html
ASTER homepage http://haleakala.jpl.nasa.gov/asterhome.html
CERES homepage http://spocls.larc.nasa.gov/ceres/cereshome.html
MODIS homepage http://ltpwww.gsfc.nasa.gov/MODIS/MODIS.html
NOAA/NASA Pathfinder Program http://xtreme.gsfc.nasa.gov/pathfinder Follow the links to the GLOBE pathfinder.
ISLSCP Initiative I homepage http://daac.gsfc.nasa.gov/WORKINPROGRESS/ISLSCP/islscp_il.html
Atmospheric Radiation Measurement (ARM) Program http://info.arm.gov
Global Energy and Water Cycle Experiment (GEWEX) http://www.cais.com/gewex/gewex.html
International Geosphere-Biosphere Program (IGBP) http://www.met.fu-berlin.de/english/IGBP/index.html

Table 3. Useful Internet URLs

EOSDIS Core System Releases "Earth Pages" for Public Use in September 1995

—**Judy Feldman** (judy@eos.hitc.com) and **Tim Pruss** (tpruss@eos.hitc.com), EOSDIS Core System, Hughes Applied Information Systems, Landover, MD



The EOSDIS Core System has released its Earth Pages service for public use on September 1, 1995. Earth Pages is a World Wide Web navigation tool that allows users to search an extensive database of Earth Science WWW sites using keywords. The user receives a list of URLs that match the search criteria. In addition, Earth Pages provides a description of each WWW site that the user may read before deciding to link to the site.

A unique aspect of the service is that users are allowed and encouraged to contribute to Earth Pages by advertising their own WWW sites on the system. Earth Pages includes a submittal form that data and service providers may fill out with their site's URL, title, description and keywords. Once the advertisement is submitted it is immediately searchable through Earth Pages.

Earth Pages began as a prototype 'advertising service' that was tested by EOSDIS Core System 'tirekickers' in January 1995. Evaluators made several suggestions for improvement of the prototype, including a simplified search interface, capability to submit advertisements and have them available to users immediately, and use of a WWW browser as the user interface. An improved version of the prototype was developed and tested at an EOSDIS Core System prototype workshop in May 1995. Again, evaluators made many useful suggestions for improvement of the service. The version of Earth Pages that will be released in September, 1995 has been built incorporating lessons learned from evaluation of the previous 'advertising service' prototypes.

Earth Pages will be incrementally upgraded after the initial release to accomodate more complex search capabilities and other enhancements based upon user feedback received.

Earth Pages is available at http://epserver.gsfc.nasa.gov/earth/earth.html ■

Physical Oceanography DAAC Users Working Group Meeting

—**Victor Zlotnicki** (vz@pacific.jpl.nasa.gov), Task Scientist, Jet Propulsion Laboratory

The Users Working Group (UWG) of the EOSDIS Physical Oceanography DAAC (PO DAAC) met May 15-17 at the Jet Propulsion Laboratory, Pasadena, CA. The UWG members are: David Glover, Woods Hole Oceanographic Institution (co-chair); William Emery, University of Colorado (co-chair); David Adamec, Goddard Space Flight Center; Bruce Douglas, Director of NOAA's National Oceanographic Data Center; Robert Evans, University of Miami; Michael Freilich, Oregon State University; Lee Fu, Jet Propulsion Laboratory; Tim Liu, Jet Propulsion Laboratory; C. K. Shum, University of Texas-Austin; Victor Zlotnicki, Jet Propulsion Laboratory (Task Scientist).

The afternoon of May 15 was a closed-door session in which the UWG, the PO DAAC Manager, and Deputy Manager reviewed the UWG Charter of September 1991, and discussed the UWG's internal organization, responsibilities, and mode of operation. The result was not a change in the charter, rather a clarification of issues to all involved and an agreement to work in a collegial fashion.

On May 16 the UWG reviewed all PO DAAC FY 95 activities and heard a detailed assessment of the PO DAAC's progress during that fiscal year from Mary Reph of the Earth Science Data and Information System (ESDIS). UWG members found the DAAC's users were very happy with its service, and ESDIS praised the PO DAAC's technical expertise and technical contributions to EOSDIS Version 0 (V0). ESDIS also suggested improvements in the cost of supporting flight projects, in communications between PO DAAC, ESDIS, and the EOSDIS Version 1 Core System contractor, and in responding to ESDIS requests. During the discussion it became clear that PO DAAC has an operational satellite flying (TOPEX/Poseidon) and one about to launch (NSCAT on ADEOS in August 1996), in distinction to other DAACs except the Alaska SAR Facility. As such, the conflicts imposed by the operational nature of a flying satellite and a developing system, i.e., during V0 to V1 migration, must be considered as prototype "lessons learned" for EOSDIS.

Subsetting data generated considerable discussion. The cost/benefit ratios of two different approaches were compared. One approach involves subsetting data on demand and transporting the subset over the Internet to the recipients. The other approach is based on generating CD-ROMs (or equivalent high-capacity, random-access media) that include all the data and sending it to users for subsetting at their local workstation. It was found that, for TOPEX/Poseidon altimeter data, the cost of central subsetting and electronic delivery was lower only if the networking cost was zero, i.e., was paid out of another budget line, as it is today. For higher volume imaging data sets, such as Pathfinder AVHRR sea surface temperatures, central subsetting can make the difference between a usable dataset or having a user swamped with data, and so is the preferred mode of handling.

Networks generated some concern. William Emery presented some costs of connecting universities to the wide area network. He expressed the concern that funding for networks needed by EOSDIS, for DAACs and users, may be falling through the cracks, even though electronic data delivery is planned for 50% of the data. The installed bandwidth appears to be sufficient, but the cost may be unaffordable to academic institutions.

On May 17 the highlights of the FY 96 workplan were presented to the UWG. Subsequent to the meeting, a formal draft of the plan was mailed to all UWG members, and their responses were incorporated into the final plan submitted to NASA Goddard on July 1. ■

The Multi-Center Airborne Coherent Atmospheric Wind Sensor (MACAWS)

—**Jeffry Rothermel** (jeff.rothermel@msfc.nasa.gov), MACAWS Principal Investigator, Global Hydrology and Climate Center, Marshall Space Flight Center

Background

The Multi-Center Airborne Coherent Atmospheric Wind Sensor (MACAWS) is a scanning pulsed coherent Doppler laser radar (lidar), developed by the lidar remote sensing groups of Marshall Space Flight Center (MSFC), NOAA Environmental Technology Laboratory (R. Michael Hardesty, lead), and Jet Propulsion Laboratory (Robert T. Menzies, lead). Because of the extensive experience of each organization with laser remote sensing, development costs have been minimized through shared use of field-proven hardware and software subsystems wherever possible. Laboratory integration and testing were completed in July, and first flights are scheduled for September 1995 on the NASA DC-8 research aircraft. The concept of two-dimensional wind measurements with scanning Doppler lidar was demonstrated in 1981. Substantial improvements to scanner control and pointing accuracy were subsequently made, and the modified system was reflown in 1984 (Bilbro *et al.* 1986). Since then, developments in the technology of high-energy-per-pulse, frequency-stable lasers led to significant improvements in lidar remote sensing capabilities for winds and aerosols. These developments were implemented in MACAWS.

The motivation for MACAWS is three-fold. First, fine-scale, distributed measurements of sub-grid-scale processes are necessary to improve parameterizations in large-scale atmospheric/hydrologic models, e.g., WMO 1992. Second, similar measurements are necessary to increase understanding and improve predictive capabilities on the mesoscale. Finally, airborne Doppler lidar permits evaluation of various concepts for global tropospheric wind measurement with satellite Doppler wind lidar.

Principle of Operation

The following table summarizes MACAWS performance specifications.

Category	Specification
Transmitter	CO_2 laser, 20 Hz, 0.8 Joule/pulse
Range Resolution	100-1000 m (500 m nominal)
Vertical Resolution	Variable
Radial Velocity Accuracy	≤ 0.5 m s^{-1}
Slant Range*	10 - 30 km
Measurement Duration**	Up to 8 hr

**depends on aerosol properties and meteorological conditions*
***standard DC-8 flight crew*

The anticipated improvement in performance over the lidar flown in the 1980's is due chiefly to a factor of 60 increase in energy-per-pulse. During operation, a pulsed lidar beam is generated and precisely directed into the atmosphere using a refractive scanning device mounted on the interior left side of the aircraft. A portion of the radiation is scattered back to the lidar from natural or anthropogenic aerosols, which act as passive wind tracers. Clouds are also a significant scattering target, and, depending on opacity and distribution, may inhibit or extend the measurement coverage. The frequency of the backscattered radiation is Doppler-shifted in proportion to the component of wind velocity along the lidar line-of-sight. By scanning the lidar beam forward and aft of the aircraft heading such that the radial velocity vectors fall within a common plane, a field of two-dimensional, ground-relative wind estimates is obtained (Figure 1).

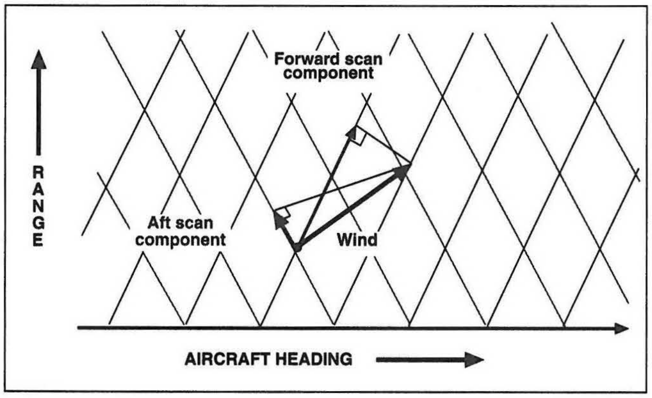


Figure 1.

The contribution to the Doppler shift due to scan angle and aircraft attitude and speed are removed using rapidly-updated inertial measurements from a dedicated inertial navigation system. Multiple scan planes can be generated to reveal velocity and aerosol (or cloud) distribution over a three-dimensional region (Figure 2).

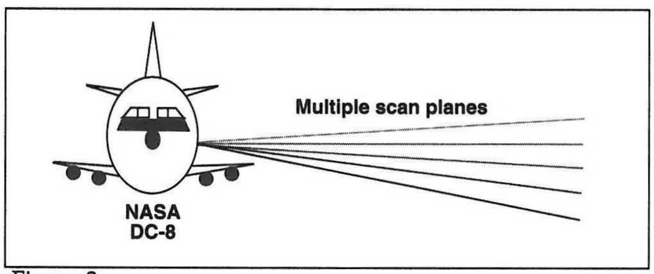


Figure 2.

Research Applications

Previous experience indicates that airborne Doppler lidar can successfully measure atmospheric dynamical processes in the planetary boundary layer and free troposphere, in geographic locations and over scales of motion, for which other research, or operational, sensors may not be well-suited. As such, a variety of research activities are planned with MACAWS in 1995 and beyond, including participation during enhanced observational periods of the GEWEX Continental-scale International Program (GCIP) (IGPO 1994). Measurements will be used concurrently to address concepts in prospective satellite-borne, lidar-based Doppler wind sensors, as ground-based lidar measurements alone are insufficient to address all performance-related issues. Plans are also underway for validation of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS).

Atmospheric Dynamics Studies

Airborne Doppler lidar measures velocity and aerosol properties in optically clear air, from cloud boundaries, and within optically-thin clouds. Despite similarities to conventional radar, differences between radar and lidar are significant (see, for example, Rothermel *et al.* 1985 for a comparison and discussion). Lidar is attenuated by optically thick cloud and heavy precipitation, and typically has shorter range. However, lidar does not require hydrometeors for sufficient scattering, to first order the motion of the aerosol scatterers is unbiased, lidar beam divergence is orders of magnitude smaller compared to radar, and marginal lidar return signals are not susceptible to ground clutter contamination compared to radar. In consideration of these characteristics, anticipated contributions from MACAWS are based on: measurement resolution at critical scales (down to 1 km); measurement synergisms with radar and satellites, e.g., lidar measurements in the optically clear free troposphere in the vicinity of deep convection; unique measurement capability over complex terrain; and the ability to monitor evolving processes and features that drift in and out of ground-based measurement networks. A few examples of planned research applications are described below.

Sub-grid-scale measurements of winds are highly desirable to improve parameterizations in climate and general circulation models. For example, mesoscale coherent structures in the planetary boundary layer (PBL), sometimes referred to as organized large eddies (OLE), can affect the accuracy of PBL flux parameterizations (Foster and Brown 1991). Examples are quasi-steady two- and three-dimensional circulations, often manifested, respectively, as cloud streets and mesoscale cellular convection (Rothermel and Agee 1980). These features may occupy the entire PBL and possess horizontal length scales of order 10-100 km. MACAWS will be capable of providing unprecedented measurements of these and other examples of

OLEs. Airborne Doppler wind lidar can map flows over complex terrain, providing data sets against which to validate existing regional-scale numerical models or develop new models, e.g., Carroll 1989. Characteristics of low-level jets, which can play a significant role in lower troposphere moisture transport, and which are difficult to resolve with operational sensors, are also amenable to study. Under circumstances where attenuation by optically-thick clouds can be avoided, airborne Doppler wind lidar can potentially provide much-needed measurements of high-altitude circulations in and around hurricanes, as well as planetary boundary layer processes.

Simulations of Satellite Doppler Wind Lidar

In the absence of a space heritage of global tropospheric wind measurements with Doppler lidar, assessments based on measured—as opposed to simulated—data are highly desirable to evaluate and refine design concepts, to reduce uncertainties in performance assessments, and to begin to develop necessary interpretive skills. Results can be used to enhance the realism of observing system simulation experiments (OSSEs) for various satellite Doppler wind lidar concepts, e.g., Baker *et al.* (1995). These experiments depend critically on instrument designs, which currently favor instruments in the small-satellite class, e.g., Kavaya *et al.* (1994). Ultimately, the reduced costs of small-sat missions will need to be carefully balanced against constraints on power, mass, volume, and heat rejection when evaluating performance.

Using appropriate scanning techniques, airborne Doppler lidar can be used to simulate a lidar perspective from space and thereby address key performance issues. For example, in the absence of optically thick cloud, spaceborne Doppler lidar will contain a frequency-distributed surface return signal with a mean and variance, absent from ground-based lidar observations. Surface returns are potentially useful for calibration and atmospheric extinction estimation, as well as identification of apparent Doppler surface velocity "ground truth" which may be used to minimize instrument biases. The properties of surface return signals depend on reflectance, which is a function of location, season, incidence angle, and sea state, for the case of ocean returns. Other issues that are addressable with airborne Doppler lidar include: velocity retrievals at marginal signal levels; the impact of spatial wind variability, including coherent structures; the effect of aerosol vertical gradients, particularly for wind measurement near sea surface; and accounting for vertical velocity contribution from cloud. Clouds will constitute a frequent scattering target for spaceborne lidar; on an annual basis, over 60 percent of the globe is covered by cloud of some type at some level (Rossow *et al.* 1993). Airborne scanning Doppler lidar is well-suited for high-resolution assessments of cloud-free line-of-sight, cloud dimensions (height, possibly thickness and base), and optical properties (optical depth, extinction, and speckle statistics). A number of satellite Doppler lidar scanning, or sampling, strategies may be simulated. For optimum efficiency, sampling strategies must take into account the extremes of marginal signal and abundant signal, or oversampling, conditions. Each scanning concept has major implications for system design, hence coverage and resolution.

Conclusion

Integration and flights are scheduled for August and September 1995, respectively. Ames Research Center, Moffett Field, California, will be the primary base of operations. The initial emphasis will be placed on verifying that MACAWS is performing properly. However, several science demonstration flights are planned for the western U.S. and eastern Pacific Ocean. Measurements will be made of boundary layer dynamics, velocity distribution in and near clouds, cloud optical properties, angular dependence of sea surface returns, and near-sea-surface velocity profiles. Correlative measurements are planned with on-board and external instrumentation, including focused Doppler lidars, microwave radiometers (near-sea-surface winds), dropsondes, ground-based Doppler radar and lidar, instrumented buoys, and polar orbiting satellites. There is also potential for one or more hurricane survey missions from either the east or west coast, in coordination with NOAA hurricane research aircraft.

A homepage has been established on the World Wide Web to provide a more thorough description of MACAWS, to give examples of previous airborne Doppler wind lidar studies, and to post late-breaking results from the 1995 MACAWS flight program (http://wwwghcc.msfc.nasa.gov:5678/macaws.html). Further inquiries from interested researchers are welcomed.

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EOS/Goddard Scientists Earn Prestigious Awards

Dr. Piers Sellers, an Interdisciplinary Principal Investigator, a co-investigator on the MISR instrument, AM Project Scientist, and Panel Chair for the Science Working Group for the AM Platform (SWAMP), has received an Arthur S. Flemming Award for his achievements in research in the areas of biosphere-atmosphere interaction modeling; the design, implementation, and conduct of large-scale field experiments; and remote sensing science. These awards are given to outstanding young federal workers for their scientific, technical, and administrative achievements. Sellers has been a key scientist in the conception and design of several major, international field experiments related to land-atmosphere interactions. His pioneering work in the use of radiative transfer theory shows that small-scale biospheric processes can be measured by satellite.

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Congratulations to Dr. Michael D. King, EOS Senior Project Scientist, who was recently awarded an honorary Doctor of Science degree by Colorado College for his recognition as a world expert in remote sensing of the Earth and its atmosphere. The citation reads "... Michael King has devoted his career to remote sensing and its application to our environment. He is at the forefront of our nation's effort to obtain reliable and significant information on which to build national and global environmental policy." The EOS community salutes Dr. King for this outstanding accomplishment.

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Dr. Mark R. Schoeberl was selected as an AGU Fellow in 1995. This selection was based on the individual's attainment of acknowledged eminence in a branch of geophysics. The number of Fellows selected annually is limited to no more than 0.1% of the AGU membership . Dr. Schoeberl is recognized for his leadership in the field of stratospheric and mesospheric dynamics, outstanding works in quantifying the role of transport in global ozone depletion, and fundamental contributions to geophysical fluid dynamics.

New CODATA Study On Issues In The Transborder Flow Of Scientific Data

—**R. Stephen Berry** and **Paul F. Uhlir** (bits@nas.edu)

Scientists commonly encounter barriers in gaining access to data relevant to their research. These barriers, both technical and non-technical, have been a topic of increasing concern in recent years. Sheer volume has been one factor, but by no means the only one. The integration of multidisciplinary data on an international basis to address problems such as global environmental degradation or disease epidemics raises new kinds of challenges in this regard.

The National Research Council has organized a study, chaired by R. Stephen Berry of the University of Chicago, to investigate the barriers and other issues in the transborder flow of scientific data. The study's goal is to help improve access to scientific data and services internationally. The primary focus is on data in electronic forms, a topic of increasing complexity and importance in scientific research and international collaboration. The study is outlining the needs for data in the major research areas of current scientific interest in the natural sciences. The legal, economic, policy, cultural, and technical factors and trends that have an influence—favorable or negative—on access to data by the scientific community are being characterized. The study also is identifying and analyzing the barriers to international access to scientific data that may be expected to have the most adverse impact in the natural sciences, with emphasis on factors common to all the disciplines. The study will recommend to the federal government and the scientific community approaches that could help overcome barriers to access internationally.

The study is being performed under the auspices of the U.S. National Committee for CODATA (USNC/CODATA), a standing committee organized under the National Research Council. The Council is the principal advisory body to the federal government on scientific and technical matters. The USNC/CODATA serves as a bridge between the scientific and technical community in the United States and the international CODATA regarding data issues in the natural sciences.

CODATA—the Committee on Data for Science and Technology—is an interdisciplinary committee organized under the International Council of Scientific Unions, a nongovernmental organization created in 1931 to promote international scientific activity in the different branches of science and their applications to humanity. According to CODATA's charter, the committee is concerned with all types of quantitative data resulting from experimental measurements or observations in the physical, biological, geological, and astronomical sciences. CODATA's general objectives include the improvement of the quality and accessibility of data, as well as the methods by which data are acquired, managed, and analyzed; the facilitation of international cooperation among those collecting, organizing, and using data; and the promotion of an increased awareness in the scientific and technical community of the importance of these activities.

In order to obtain broad input from the users and suppliers of scientific data, the study committee has developed an "Inquiry to Interested Parties" requesting information on: barriers to data access, pricing of data, protection of intellectual property, problems of less-developed countries, scientific data for global problems, the use of electronic networks, and other technical issues. Anyone interested in providing views to the study committee is invited to respond to this public inquiry, which is posted on CODATA's World Wide Web Home Page (located at http://www.cisti.nrc.ca/codata/welcome.html). Information about the study and CODATA activities generally may be obtained from Paul F. Uhlir, Director, USNC/CODATA, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. ■

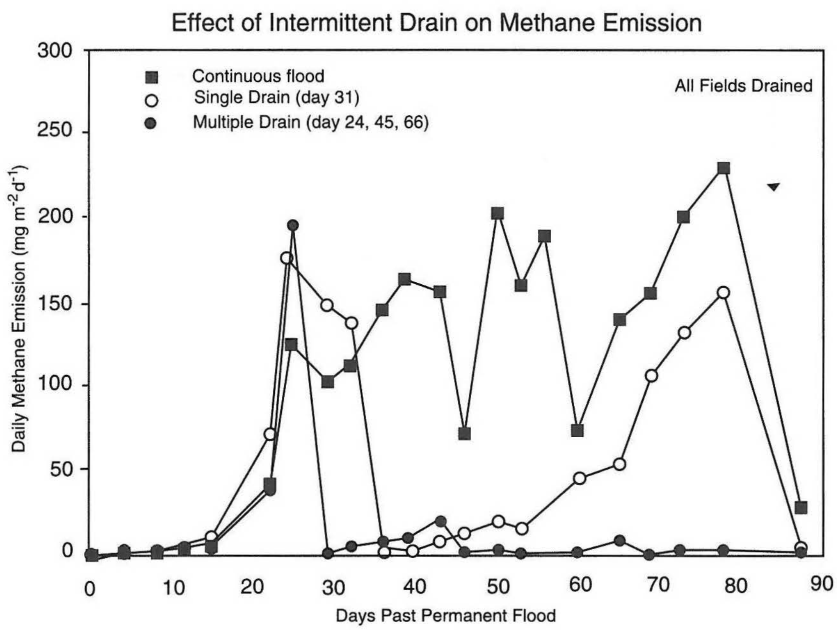
Mitigation of Methane Emissions from Irrigated Rice Agriculture

Reprinted from the IGAACtivities Newsletter of the International Global Atmospheric Chemistry (IGAC) Core Project of the International Geosphere-Biosphere Programme (IGBP).

Contributed by R. L. Sass, Rice University, Houston, Texas, USA

The total annual global source strength of atmospheric methane, an important greenhouse gas, is estimated to be 500 teragrams, with anthropogenic sources accounting for 340 teragrams. With an estimated sink strength of 460 teragrams per year, the annual increase of atmospheric methane is 40 teragrams. Methane emission from flooded rice cultivation is currently estimated to be 60 teragrams per year; among the highest sources worldwide.

It is recognized that to meet the rice supply of growing populations, rice cultivation will continue to increase at or beyond its current rate. It is estimated, for example, that the world's annual rough rice production must increase from a 1990 value of 518 million tons to 761 million tons by 2020—a 47% increase—just to maintain current nutritional levels. Because arable land is highly limited in major rice-growing areas, increased production has to be achieved mainly by intensifying cropping, i.e., two or three crops per year, rather than expanding the area of rice cultivation. Irrigated rice will continue to dominate production. Irrigated rice land now comprises about half the total harvested area but contributes more than two-thirds the total grain production. With present agronomic practices, this will lead to increased methane emissions.



Because rice agriculture is one of the few sources of methane emission where management of the system is possible, it has become a critical focus of mitigation efforts. However, because rice is also the world's most important wetland crop and the primary calorie source of a large fraction of the world's population, mitigation efforts must be based on sound agricultural practices as well as good scientific judgment.

A primary mitigation "switch" of the production and emission of methane is the presence of oxygen in the rhizosphere environment. Removal of oxygen from the rhizosphere is normally through consumption by soil bacteria. The presence of flood water impedes the diffusion of oxygen from the atmosphere into the soil and thus keeps it anoxic. It has been observed by Sass *et al.* (1992) that a single drain of the flood water at the end of the vegetative stage allowed the soil to be reoxidized, reducing the seasonal methane emission by nearly 50%. Repeated drains every three or four weeks throughout the rice growing season, reduced seasonal methane emission by 88%, without affecting grain yield. Yage *et al.* (1994) observed methane emission reductions of approximately 50% in intermittently drained plots when compared with continuously flooded Japanese rice paddies.

An important contributor to variations in observed methane emissions and a strong candidate for mitigation is the use of different rice cultivars. There are currently some 80,000 different rice cultivars available through the germplasm bank at the International Rice Research Institute in the Philippines and others are being sought. Most of these were developed for specific areas of the world and many are in current use. Yet, very few methane emission studies have considered cultivar differences. Methane emissions from eight different cultivars grown under similar conditions near New Delhi, India differed by as much as an order of magnitude (Parashar *et al.* 1991). A study of five rice cultivars in irrigated fields near Beijing, China indicated that methane emission during the tilling-flowering stage varied by a factor of two (Erda 1993). A preliminary study by Sass and Fisher (private communication) using ten cultivars showed seasonal methane emissions ranging from 18.2 to 41.0 g m^{-2}. All three studies show a significant variation in methane emission that is solely dependent on cultivar choice. Cultivar choice by individual farmers could thus greatly influence regional and global estimates of methane emission from rice fields.

The wide variation of traits and related emission rates among cultivars opens the possibility for the choice of existing cultivars and the breeding of new cultivars as a method for mitigation of methane emission. However, the relationships between different cultivar characteristics and methane emission have yet to be elucidated. Some cultivars may have more-or-less efficient conduits for the removal of methane from the soil through the rice plant, others may deposit different amounts of organic matter in the soil during the growing season or may differ in the ability to transfer oxygen to the rhizosphere, thus altering the redox potential of the soil system or modifying the bacterial response of the rhizosphere. In other cultivars, differential allocation of translocatable carbon may even promote higher grain yield in preference to root processes and eventual methane production and emission.

The reported effects of different mineral fertilizer applications on methane emission are inconsistent. Schütz *et al.* (1989) concluded that the type and method of application strongly influenced methane emission rates. Lindau *et al.* (1991) observed increased methane emissions with increased urea application. Cicerone and Shetter (1981) reported large increases in emission after fertilization with ammonium sulfate while other studies (Schütz *et al.* 1989, Yagi and Minami 1990) show a decrease. Lindau *et al.* (1990a, 1990b, 1991, 1993) found significantly different rates of methane emission for a variety of fertilizer types and treatments (urea, ammonium sulfate, potassium nitrate). Others have found that methane emission rates are affected by the method of fertilizer application (Schütz *et al.* 1989, Kimura *et al.* 1992). Many other studies agree that the application of organic matter to rice paddies strongly increases methane emission rates over that from mineral fertilization. Emission rates are dependent on amount, kind, and prior treatment of the organic components (Sass *et al.* 1991, Chen *et al.* 1993, Lindau and Bollich 1993, Wassmann *et al.* 1993, Yagi and Minami 1993, Neue *et al.* 1994).

Current research efforts clearly indicate that realizable options are available to mitigate methane emissions from flooded rice fields. Successful implementation of these options will depend upon the collective acceptance by the rice farmers of Asia and the rest of the world. In order for that to happen, research results must be able to demonstrate that: 1) grain yield will not be decreased and may increase by a particular mitigation practice, 2) that by adopting recommended mitigation practices the farmer will benefit through better water utilization, reduction of labor, or a decrease in production costs, and 3) the rice cultivars that lead to reduced methane emission are those desired by local consumers. ■

Note: Contact author for references.

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Cooperative Work Develops Low-Cost Digital Terrain Flyby Program

—Kathleen Gohn (703) 648-4460

Low-cost animated aerial views of the Earth's surface—known as terrain flybys—have been developed by a team of scientists from the U.S. Geological Survey (USGS), the Jet Propulsion Laboratory, and the National Aeronautics and Space Administration (NASA). The team combined USGS data sets with a commercial Geographic Information System (GIS) and low-cost or free software to produce the animations.

"Typically, the software used to build and view animated flybys is very expensive," explained USGS computer scientist Robert G. Clark, one of the principal investigators on the project. Terrain flybys are used by a number of agencies, such as NASA and the Department of Defense, to analyze and present terrestrial and planetary data. "Because of decreasing government and university funding, buying the analytical software is becoming prohibitively expensive. We set out to integrate more-readily-available Earth science software to help reduce costs," Clark said.

The terrain analysis technique developed by the USGS is based on the integration of GIS, image processing, and animation software. First, the team merged USGS digital orthophoto quadrangles (aerial photographs that have the characteristics of maps), a digital elevation model, and transportation and hydrography digital line graph data used in the production of USGS paper maps for a mountainous area in Idaho.
This data set was preprocessed by using a commercial GIS software package, then further analyzed by using free or inexpensive image processing and animation software. "By integrating these three software packages, we were able to exploit the best features in each of them, and save money by avoiding the costs of an expensive software package," Clark said.

Several single images and an animation from the project will soon be available over the World Wide Web through the USGS home page (http://info.er.usgs. gov).

Details on the team's work can be found in "Using Geographic Information, Image Processing, and Animation Systems to Visualize a Digital Terrain Flyby," by Robert G. Clark, John W. Jones, Thomas E. Ciciarelli, and Daniel F. Stanfil IV, part of "Selected Papers in the Applied Computer Sciences 1994," U.S. Geological Survey Bulletin 2103. U.S. Geological Survey Bulletin 2103 is available from the U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, Colorado 80225. Order must specify the report number and the full title. Copies of the report are available for $4.25. All orders must be accompanied by a check or money order payable to U.S. Geological Survey - Department of the Interior. ■

Science Calendar

October 17-19	AIRS Science Team Meeting, University of Maryland, Baltimore County. Contact Hartmut H. Aumann (hha@airs1.jpl.nasa.gov) at (818) 354-6865.
October 23-27	Russian/U.S. Meteor-3M/SAGE III Technical Interchange Meeting, Hampton, VA. Contact Jennifer Fraser (j.e.fraser@larc.nasa.gov) at (804) 864-3712.
November 7-9	TES Science Team Meeting, Cambridge, MA. Contact Reinhard Beer (beer@caesar.jpl.nasa.gov) at (818) 354-4748.
November 2-3	SWAMP meeting, GSFC. Contact Piers Sellers (piers@imogen.gsfc.nasa.gov) at (301) 286-4173.
November 13-17	MODIS Science Team Meeting, GSFC. Contact David Herring (herring@ltpmail.gsfc.nasa.gov) at (301) 286-9515.
November 14-17	ASTER Science Team Meeting, Tokyo, Japan. Contact H. Tsu (tsu@ersdac.or.jp) or Anne Kahle (anne@lithos.jpl.nasa.gov) at (818) 354-7265.
November 28-30	Payload Panel Meeting, Annapolis, MD. Contact Mark Abbott (mabbott@oce.orst.edu) at (503) 737-4045.
Nov 30 - Dec. 1	SAGE III Algorithm Review, Langley Research Center, Hampton, VA. Contact Lelia Vann (l.b.vann@larc.nasa.gov) at (804) 864-9356.

Global Change Calendar

October 11-13	Environmental Computing & Technology '95 (ECIT '95), environmental information management conference and exposition, Washington Convention Center, Washington DC. Exposition is free. Contact ECIT'95, Tel. (703) 683-8500 or 800/930-ECIT. WWW URL: http://www.clark.net/ntp/.
October 23-26	International Conference on Image Processing, Washington, DC. Contact Billene Mercer, 2553 Texas Avenue South, Suite C-283, College Station, TX 77840, Tel. (409) 696-6576; FAX: (409) 696-6653; e-mail: icip95@ieee.org; or mercer@conf-mgmt.com. WWW URL: http://www.ee. princeton.edu:80/~icip95/.
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February 27-29	Eleventh Thematic Conference on Geologic Remote Sensing, Las Vegas, Nevada. Contact Robert Rogers, ERIM, Box 134001, Ann Arbor, MI 48113-4001. Tel. (313) 994-1200, ext. 3453; FAX: (313) 994-5123; e-mail: raeder@vaxc.erim.org.
March 6-8	ISPRS Workshop on New Developments in Geographic Information Systems, Milan, Italy. Contact James B. Johnston, Tel. (318) 266-8556, FAX: (318) 266-8616, e-mail: johnstonj@nwrc.gov.
March 25-29	8th Australasian Remote Sensing Conference, Canberra ACT. Contact Secretariat: ACTS, GPO Box 2200, Canberra ACT 2601, Tel. (+06) 257-3299, FAX (+06) 257-3256, e-mail: acts@ozemail.com.au.
May12-15	ICASSP '96, Atlanta, GA. For information see WWW at http://www.ee.gatech.edu/conferences/icassp96 or e-mail: icassp96-info@eedsp.gate.edu.
May 27-31	International Geoscience and Remote Sensing Symposium (IGARSS'96), Lincoln, Nebraska. See IGARSS'96 WWW at http://doppler.unl.edu /igarss96, e-mail: stein@harc.edu, Tel. (713) 291-9222, or FAX: (713) 291-9224.
June 17-21	Second International Scientific Conference on the Energy and Water Cycle, Washington, D.C. Contact International GEWEX Project Office at (202) 863-0012; (gewex@cais.com) or Judy Cole (cole@stcnet.com); FAX: (804) 865-8721 .
June 24-27	Second International Airborne Remote Sensing Conference and Exhibition: Technology, Measurements, and Analysis, San Francisco, CA. Contact Robert Rogers, ERIM Conferences, Box 134001, Ann Arbor, MI 48113-4001; Tel. (313) 994-1200, ext. 3234, FAX: (313) 994-5123, e-mail raeder@erim.org. Information available on WWW at http://www.erim.org/CONF/.
August 20-22	William T. Pecora Memorial Remote Sensing Symposium, "Human Interaction with the Environment-Perspectives from Space," Sioux Falls, SD. For preliminary program information, contact Gary Johnson, Technical Program Chair, at pecora13@edcserver1.cr.usgs.gov.

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