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Editor's Corner

NASA has found performance problems with the ground system software required to control, monitor and schedule science activities on the Earth Observing System (EOS) series of spacecraft. These problems will cause a serious delay in the launch date of the EOS AM-1 spacecraft originally planned for late June 1998.

The Ground Control Software, called the "Flight Operations Segment" (FOS) software, is part of the Earth Observing System Data and Information System (EOSDIS), the ground system responsible for spacecraft control, and data acquisition, processing and distribution for NASA's Earth Science Enterprise, including the EOS missions.

The problem is with the control center FOS software that supports the command and control of the spacecraft and instruments, monitoring of spacecraft and instrument health and safety, planning and scheduling of instrument operations, and analysis of spacecraft trends and anomalies. As such, this is a critical piece of software that must be reliable, with the flight operations team sufficiently trained and confident in the software before the AM-1 spacecraft can be safely launched.

The Earth Science Enterprise is beginning a methodical planning exercise to ensure the logical progression of activities and missions to accomplish the science and applications objectives of EOS beyond the first series of missions. This is consistent with the oft-stated goals of EOS to:

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- develop an integrated, comprehensive observing system that combines spectral, temporal, and spatial measurements to maximize the scientific return;
- develop a long-term measurement strategy that resolves seasonal and interannual variability to improve the scientific understanding and provide a firm starting point for assessing decadal and longer changes (e.g., 15+ year data sets for global change research); assure that these observations are well calibrated and characterized, and that an end-to-end assessment of data product quality is performed, and
- make these data accessible to the broader user community at the cost of filling the user request.

As a part of this effort, NASA has extended the community an opportunity to participate in the development of the Earth science strategy for the next decade, and has posted a Request for Information (RFI), entitled "Concepts for Science and Applications Missions in the Post-2002 Era" on http://www.hq.nasa.gov/office/ese/nra/index.html. See page 5 for further details, or visit this Web site.

A major milestone has been reached in NASA's development of "faster, better, cheaper" space missions with the delivery of the SeaWinds instrument to Ball Aerospace in Boulder, CO, for integration into the Quick Scatterometer (QuikSCAT) satellite. The SeaWinds instrument is NASA's next generation sensor for measuring wind speed and direction over the world's oceans. QuikSCAT is a mission designed to complete turnaround from conception to orbit in a very short period of time. The QuikSCAT mission will restart the ocean-wind data stream that was lost when the Japanese Advanced Earth Observing Satellite (ADEOS) with a NASA Scatterometer onboard ceased functioning on June 30, 1997. Before the loss of ADEOS, NASA was able to obtain valuable data about summer and winter monsoon seasons and the onset of the El Niño event. QuikSCAT is scheduled for launch in November 1998 onboard a Titan II launch vehicle and, if successful, will be the first EOS spacecraft in orbit.

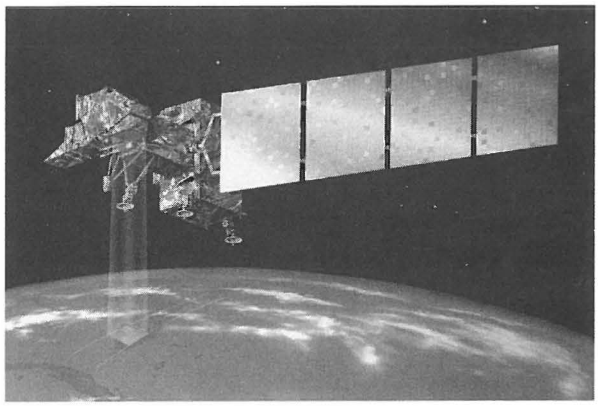
Mr. Christopher Scolese, EOS AM Project Manager, has been selected to be the Associate Director of Flight Projects for EOS, a new position at Goddard aimed at strengthening the overall management of Earth Science projects at the Center. Mr. Rick Obenschain, Manager of the Earth Science Data and Information Systems Project, will also serve as Deputy Associate Director of Flight Projects for EOS Operations, with specific responsibility for ESDIS. An additional position of Deputy Associate Director of Flight Projects for EOS Development has also been established, with specific responsibility for AM, PM, Chemistry, Landsat, and IceSat. This position will be handled initially by Chris Scolese in an acting capacity. Mr. Kevin Grady, Deputy EOS AM Project Manager, will serve as acting AM Project Manager. I would like to congratulate Chris, Rick, and Kevin on their new appointments, and welcome the opportunity to continue to work with them in NASA's Earth Science Program.

An Investigators Working Group (IWG) meeting is now scheduled for October 19-21 at the New England Center in Durham, New Hampshire. As in the past couple of years, the primary focus of this meeting is to (i) learn of recent progress and exciting accomplishments obtained thus far by various EOS investigations, (ii) assess progress and expectations for EOSDIS in the next couple of years, and (iii) review the status and plans for data processing and validation of EOS instruments to be launched in the next couple of years.

—Michael King
EOS Senior Project Scientist

Report on the Landsat-7 Science Team Meeting

— Darrel Williams (darrel@ltpmail.gsfc.nasa.gov), Landsat Project Scientist, NASA Goddard Space Flight Center
— Samuel Goward and Jeffrey Masek, Landsat Science Team Office, University of Maryland



The Landsat-7 Science Team held their semi-annual team meeting April 14-16 at the NASA Goddard Space Flight Center (NASA GSFC). Participants from the 14 research teams, as well as NASA, NOAA, and USGS attended the meeting, which was co-chaired by Landsat-7 Science Team Leader, Samuel Goward, and Landsat Project Scientist, Darrel Williams.

The first morning was dedicated to briefings on the status of the Landsat platform and ETM+ instrument by the Deputy Project Manager, Ken Dolan (NASA GSFC), and on the Landsat Ground System by Deputy Project Scientist, Jim Irons (NASA GSFC). The instrument briefing concentrated on the status of the ETM+ power supplies, which shut down anomalously during thermal-vacuum testing, forcing an indefinite delay in the launch of Landsat-7. It was reported that the power supplies were being reworked at Raytheon's Santa Barbara Remote Sensing (SBRS) facilities, and will be reintegrated with the instrument and spacecraft during the summer; both the instrument and spacecraft remained in residence at the Lockheed Martin Missiles and Space (LMMS) facilities in Valley Forge, Pennsylvania. Work at SBRS and GSFC had confirmed that the power supplies were overheating, and this overheating was traced primarily to "new" diodes that were used within the power supplies. These diodes met or exceeded all specifications. They were considered to be an improvement over diodes used previously, and they were chosen because the older style diodes are no longer in production. There was no way to predict the problem that we experienced with the diodes.

It has been decided that the revised, formal launch date will not be established until after the power supplies have successfully gone through thermal vacuum testing at the instrument level, which should occur by mid-August. We hope that launch could still occur in March/April time frame in 1999. Dolan also reported that preparations of the Landsat-7 platform at the LMMS Valley Forge facility are proceeding normally. [NOTE: As this report was being submitted in the mid-June time frame, the rework of the power supplies at SBRS had been completed successfully. The power supplies had been shipped back to LMMS, re-integrated with the instrument, and baseline testing under ambient conditions was completed successfully. To obtain up-to-date status on the Landsat-7 Project, please access the Landsat homepage at: http://landsat.gsfc.nasa.gov/project/projects.htm.]

The Landsat-7 ground system consists of ground receiving stations, the Landsat Processing System (LPS) for producing Level 0R products, the Landsat Product Generation System (LPGS) for producing Level 1G products, and the EOSDIS Core System (ECS), which performs data archive and distribution functions. Development of both the LPS and LPGS are proceeding normally, although continued delays of ECS are jeopardizing data distribution. To mitigate these risks, NASA and the EROS Data Center (EDC) are developing a DAAC Emergency System (DES), capable of temporarily distributing 100 Landsat-7 scenes per day in the absence of the ECS.

James Ellickson (NOAA) detailed progress on signing up international ground stations to receive Landsat-7 data. NOAA has introduced a more flexible licensing policy for international ground stations, with the licensing fee based on the number of scenes acquired by year, rather than a single flat rate. This policy makes Landsat-7 a more attractive investment, and to date some 10 to 12 ground stations have indicated that they will participate. Ellickson noted that the level of participation by stations in the Far East will probably be lower than for Landsat-5, largely due to the current Asian economic crisis.

Martha Maiden (NASA GSFC) presented the results of the NASA Earth Sciences Information Partners (ESIP) awards, focusing on serving data products of interest to the terrestrial science community. Of particular note are projects headed by David Skole (Michigan State University), John Townshend (University of Maryland), and Berrien Moore (University of New Hampshire).

NASA's current planning activities for the next generation of EOS measurements were reviewed by Anthony Janetos (NASA HQ). He pointed out that there are currently no concrete plans to continue Landsat-class measurements beyond the Landsat-7, which has a nominal ending date of ~2004. During the next several months, NASA will be soliciting measurement priorities from the science community, and crafting focused missions for the first decade of the next century using this input. Janetos indicated that contributions from the Landsat Science Team would be particularly important in assessing the proper role of Landsat-class measurements for NASA's Earth Science Enterprise (ESE).

The second day extended this theme, exploring various directions for future land observing missions. Stephen Ungar (NASA GSFC) reviewed progress on the upcoming New Millennium Program (NMP) Earth Observer 1 (EO-1) mission. EO-1 was designed to prototype advanced technologies, including hyperspectral imaging, for future land observation missions. Ungar noted, however, that development of both the Grating Imaging Spectrometer (GIS) and Wedge Imaging Spectrometer (WIS) was behind schedule, and testing indicated that performance of these components would not meet specifications. As a result, development of both the WIS and GIS had been terminated*, leaving only an advanced pushbroom multispectral imager, although other options for replacing the hyperspectral imaging capabilities were being explored. Initial testing of the multispectral imaging module were promising, suggesting much improved signal-to-noise ratios compared to the Landsat-7 ETM+ instrument. *[NOTE: Since the mid-April meeting, a decision was made to incorporate a TRW supplied hyperspectral device on EO-1 similar to what was to have been flown on the Lewis HSI mission. The projected launch date for this revised EO-1 mission is no earlier than December 1999.]

A number of companies have announced plans to launch commercial remote sensing missions during the next decade. Vic Leonard presented an overview of the planned Resource-21 mission, which is targeted toward agricultural users. The current specification calls for several platforms with high-resolution (10-20 m) multispectral sensors, with launch in the 2001 timeframe. Leonard noted that farmers and agribusiness require high-level information products (e.g. crop type, crop health, drought condition) rather than low-level data, and that rapid dissemination of these derived products was key to the commercial success of Resource-21.

Anne Kahle (NASA JPL) and Ray Taylor (NASA GSFC) gave an overview of a proposed hyperspectral thermal-IR mission. Kahle noted that hyperspectral measurements in the TIR had never been made from satellite, and that this avenue showed considerable promise for monitoring surface temperature, emissivity, geological composition, and atmospheric properties. Taylor presented an array of advanced technologies for on-board band selection, on-board data processing, and inter-satellite communications. This "database in the sky" concept would leverage advances in high bandwidth optical data transmission to make the satellites themselves active participants in data processing and distribution.

Jeffrey Masek (University of Maryland) concluded the morning presentations by reviewing the Landsat Science Team recommendations for the Landsat-8 mission. Team members had been asked to submit measurement requirements for their scientific studies. The principal recommendation was a desire for higher radiometric precision, from the current 8-bit system to a 12-bit system for Landsat-8, although most team members were satisfied with other aspects of the current Landsat-7 configuration. A number of participants also suggested the addition of specific spectral bands, primarily to mitigate the effects of atmospheric contamination.

Following lunch, Roger Mitchell (Earth Satellite

Corporation) presented EarthSat's Orthorectification Project, which was selected as a Phase 1 project under the NASA $50M data buy. Using NIMA ground control points and digital topography, EarthSat proposed to georectify a global collection of Landsat TM images to a precision of 60 meters. These data would be distributed to users through the EROS Data Center upon validation. During Phase 1, slated to end later this year, EarthSat was to generate a georectified Landsat data base for eastern Africa. Mitchell also outlined plans for producing global land cover assessments from these data, although Landsat Science Team members expressed some skepticism regarding the likely accuracy and utility of the land cover products.

The final day of the meeting began with presentations on outreach strategies for the Landsat-7 mission. Carolyn Merry (Ohio State U.), currently on sabbatical with the Landsat Project Science Office at Goddard, discussed approaches for using remotely sensed data in educational curricula. Her presentation included a comprehensive review of sources of support for K-12 and college education programs. Lynn Chandler, representing the Public Affairs Office at NASA GSFC, then introduced the NASA Goddard Landsat-7 public outreach strategy to the Science Team, concentrating on effective ways to communicate science findings to the local and national media.

The meeting wrapped up with presentations by Chris Justice (U. Virginia), Jeff Privette (NASA GSFC), Eric Vermote (U. Maryland), and Kurt Thome (U. Arizona) on EOS/Landsat-7 synergy. Jeff Privette presented an overview the EOS Core Validation sites, which will be monitored to provide validation of EOS science products. Landsat-7 data will be an important component for many of the validation projects. The Science Team took an action to review the site list, and suggest any additional sites that might be useful for calibration/validation of Landsat-7 data. Eric Vermote and Kurt Thome reviewed approaches for atmospheric correction of Landsat-7 and archival Landsat data. For the Landsat-7 era Thome recommended an approach based on Vermote's 6S model, with appropriate atmospheric inputs from the MODIS sensor, while for archival data Thome recommended a simple dark-object approach. Thome took the action to prepare software for the Science Team to use for both these cases.

The meeting also included presentations from all team members on their research activities during the last six months. Readers interested in specific science team investigations should consult the article on the October 1997 Landsat Team meeting in the February/March 1998 issue of the Earth Observer. The next team meeting will be held September 29-October 1, 1998 at the Patuxent Wildlife Visitor's Center in Maryland. Interested parties should contact Jeffrey Masek (jmasek@geog.umd.edu) for further information.

The following is a note addressed to the Earth Science Community from Dr. Ghassem Asrar, Associate Administrator, Earth Science Enterprise, NASA Headquarters, Washington, DC 20546

Concepts for Science and Applications Missions in the Post-2002 Era

OES Response [oesresponse@hq.nasa.gov]

Dear Colleague:

The Earth Science Enterprise is beginning a methodical strategic planning effort to ensure a logical progression of activities and missions that will accomplish our scientific and application goals beyond the time frame of the 1st series of Earth Observing System missions. As a part of this effort, we are extending to the community an opportunity to participate in the formulation of the strategy for the next decade. We have posted a Request for Information (RFI), entitled "Concepts for Science and Applications Missions in the Post-2002 Era," on the Earth Science Enterprise Research Announcement Web Page at: http://www.hq.nasa.gov/office/ese/nra/index.html

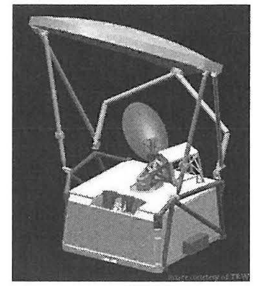
We are requesting short, mission-concept papers which address emerging science questions and will enable the development of a nominal, multi-mission profile for Earth observation satellite missions in the 2003-2010 time frame. The received mission concepts will be screened for scientific and technological merit by panels of peers. A subsequent workshop will enable the scientific, technological, and programmatic planning communities to work together in the preparation of a multi-mission profile which takes into account operational and foreign mission plans and potential commercial observations. This multi-mission profile will be used in planning future technology development, mission Announcements of Opportunity (AOs), associated NASA Research Announcements (NRAs), coordination with operational and foreign agencies, and commercial data purchases. The mission concepts and profile will be reassessed periodically to ensure that they continue to meet evolving science requirements and incorporate technology advances.

I encourage you to participate in this planning exercise for the implementation of our science-driven, technology-enabled approach to meeting our science and applications objectives.

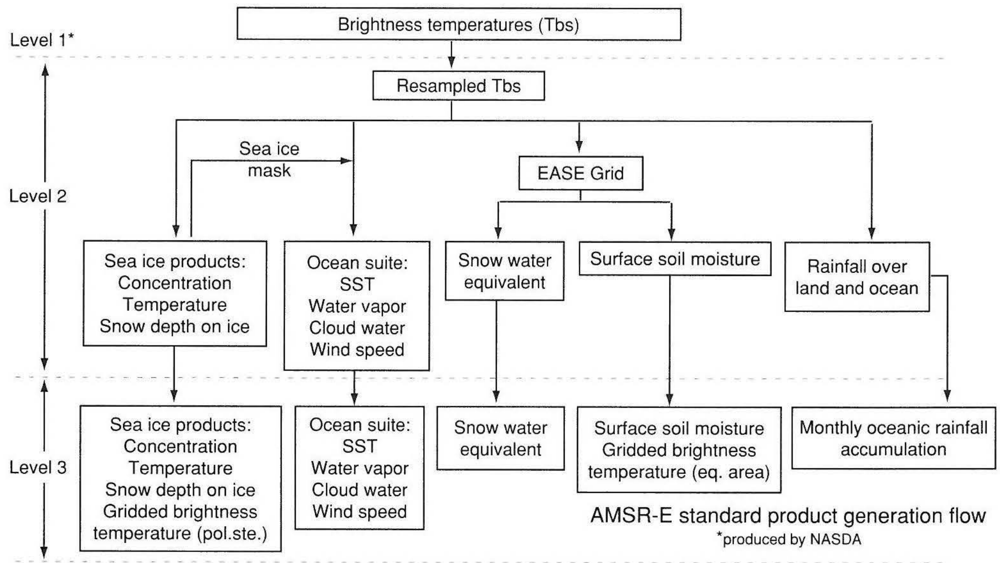
Thank you for your efforts in this regard.

Sincerely,
Dr. Ghassem Asrar

EOS PM-1 Advanced Microwave Scanning Radiometer (AMSR-E) Science Team Meeting



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



AMSR-E standard product generation flow

An AMSR-E Science Team Meeting was held on March 31, 1998, at the Goddard Space Flight Center. This meeting preceded the PM-1 Validation Workshop held at the Maryland Conference Center, in College Park, MD. The topics discussed were: software beta delivery, Equal Area Special Sensor Microwave/Imager (SSM/I) Earth (EASE) grid, and lessons learned from TRMM. Most of the day was then used to prepare for the Validation Workshop by going over the Science Data Validation Plan and summarizing it. A presentation was also made for an airborne instrument that has all the AMSR-E channels: Helsinki University of Technology RADiometer (HUTRAD).

Paul Hwang (EOS PM Project Office) gave the status of the project, including the status of the instruments that will fly on the PM-1 spacecraft. All instruments are on schedule for delivery to TRW, the spacecraft contractor. B. Graf (AMSR-E Instrument manager) summarized the Interface Review meeting that took place in Tokyo, September 5, 1997—all hardware issues have been resolved and the instrument development is on schedule.

Dawn Conway (AMSR-E Software Integrator) showed a new data products diagram (Figure above), and discussed the estimated data volumes for all AMSR-E products and three different configurations for Level-2 processing. The baseline is having the main routine read the entire data file and then call all the science subroutines in series. The two alternates were presented: (1) a scan-by-scan processing (reduced memory requirements, allowing for processing in parallel), and (2) a three-separate-subprocesses configuration: a. ocean products to include the sea ice and the ocean suite products; b. land products—land and snow; and c. precipitation).

Eni Njoku (AMSR-E Science team member—Land Products) presented his proposal for regridding the data using the EASE grid (an equal area grid). This regridding would be done before data are ingested in the retrieval algorithm. The usefulness of this scheme was questioned at high latitudes, where data would be oversampled manyfold.

Martti Hallikainen (Helsinki University of Technology, Laboratory of Space Technology) presented a summary of the research areas his laboratory is involved with

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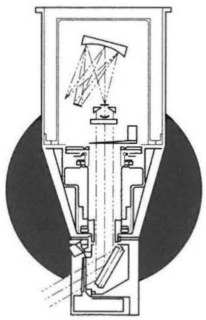

Summary of the SAGE III (Stratospheric Aerosol and Gas Experiment III) Science Team Meeting

—M. Patrick McCormick (mcc@cs.hamptonu.edu), SAGE III Principal Investigator, Hampton University

A Science Team meeting for the Stratospheric Aerosol and Gas Experiment (SAGE III) was held at Hampton University (HU) in Hampton, Virginia on March 26-27, 1998. SAGE III, which is part of the Earth Observing System, is having three flight instruments developed, with its initial flight aboard the Russian Meteor-3M spacecraft in 1999 in a sun-synchronous orbit. The second flight will be flown on a flight of opportunity (FOO) into a mid-to-high inclination orbit, necessary in order to provide global coverage. The third SAGE III instrument will be flown aboard the International Space Station (ISS), now scheduled for mid-to-late 2002. SAGE III will measure, using solar occultation, 1 km vertically-resolved middle atmosphere profiles of ozone, aerosols and a number of aerosol properties, water vapor, temperature, nitrogen dioxide, and cloud presence. Additionally, using lunar occultation, SAGE III will measure nitrogen trioxide and chlorine dioxide.

The meeting began with a welcome by the SAGE III Principal Investigator, **M. Patrick McCormick** of the Center for Atmospheric Sciences (CAS) at Hampton University (HU). After introduction of all participants, he gave a brief overview of HU and its history, described CAS, announced that CAS's first atmospheric courses would be offered this fall, and encouraged everyone to tour the campus and visit the newly-renovated museum on campus. In the absence of the SAGE III Program Scientist, Jack Kaye of NASA Headquarters, Pat presented a summary prepared by Kaye of recent activities related to NASA's newly renamed Office of Earth Science (OES) and planned research announcements likely to be of interest to the SAGE III Science Team. He also announced that Ghassem Asrar was named Associate Administrator of Code Y.

Shahid Habib, of the Earth Science Systems Program Office and the SAGE III Program Integration Manager, provided information about the project, especially those activities associated with the delay in launching the first SAGE III instrument on Meteor-3M from August 1998 to May 1999, and the potential FOO mission using a Russian Resurs launch in late 2000. After discussions with the Russian Space Agency (RSA) senior management in December 1997, it was concluded that since the RSA could not guarantee a three-year mission life, it was better to delay the launch of Meteor-3M until May 1999. Under the new schedule SAGE III will be shipped to Baikonur in April 1999. The Zenit-2 launch vehicle with contamination-controlled fairing will be used with a guarantee of a three-year plus mission lifetime. Habib then presented material on the SAGE FOO activities, stressing the need for an early flight in an inclined orbit to provide global coverage. This flight is a must to ensure bridging the data gap between SAGE II and SAGE III/ISS, and extending the 20-year ozone and aerosol data record of SAGE I and SAGE II for global change studies. He described the opportunities to fly the SAGE III FOO on Resurs in a 64.8-degree inclined orbit and the ideal coverage it would provide. These mid-inclination missions are very rare and the Resurs-DK is the most promising opportunity in the foreseeable future. He presented data about the builders, Ts SKB-Progress, and showed drawings of the spacecraft with SAGE III aboard. He concluded that the Ts SKB-Progress team is very capable and experienced in dealing with the West; no major technical risks or mission impediments have been identified; this is a cost-effective solution as opposed to committing large amounts of NASA funds for building a separate inclined orbiting spacecraft and launch vehicle; and it represents an excellent opportunity that meets OES science priorities. Habib is preparing a "white paper" encouraging funding from OES.

With respect to SAGE III on the International Space Station (ISS), NASA is working with Brazil to get an Express Pallet, and the European Space Agency (ESA) has signed a phase C/D contract with Alenia/Italy to provide the Hexapod. With delays of ISS to perhaps 2003, it becomes even more critical to launch the SAGE III FOO in 2000. Stratospheric chlorine and its effects on ozone depletion are expected to peak in this time frame.

Debra Carraway, the SAGE III Deputy Project Manager, described the detailed instrument and project schedule and status. She gave additional details on the issues leading up to the delay of the Meteor-3M launch date. All indications were that a launch after May '99 would provide greater mission reliability due to enhanced integration and testing capability, better familiarization with spacecraft systems and procedures, less risk of contamination, and more-realistic staff work schedules. The current integration and test schedule was developed with a goal of May 15, 1999 for launch as this is the date NASA requested from the RSA, but there has yet to be confirmation by RSA. With the May 1999 date as a goal, the SAGE III flight model is to begin integration with the Meteor-3M in late November 1998 and de-mated after testing in February 1999. The spacecraft and SAGE III will be shipped separately to the Baikonur Cosmodrome in February 1999 and April 1999 respectively. After re-integrating and testing in Baikonur, the SAGE III and Meteor-3M will be launched aboard a Zenit-2 rocket. Debra then reviewed the FOO and ISS instrument status. Fabrication is proceeding on both flight units with critical subsystems almost completely assembled and tested on the FOO instrument and piece part fabrication 95% complete on the ISS instrument. Mission uniques for these instruments are being defined and completed as reasonable. For example, the ISS instrument contamination door is being modified for a heavier duty cycle.

Pat McCormick reviewed the history of attempts to find a FOO mission for SAGE III. This included interactions with the Koreans, Chinese, Japanese, Canadians, Brazilians, and French. Much effort was expended by SAGE III personnel and foreign groups in studying the possibility of accommodating SAGE III in an inclined orbit. The possibility of a small dedicated spacecraft on a PEGASUS launch was also studied. Pat reviewed the requirements for such a flight and its necessity, as concluded by every science advisory group asked to endorse the need to fly SAGE III in a high-inclination orbit concurrently with a sun-synchronous orbit. These recommendations have come on numerous occasions from the EOS Investigators Working Group (IWG), its Payload Panel, its Atmosphere Panel, and most recently from the NASA Biennial Chemistry Review. Pat pointed out that the Resurs mission has an optimum orbit and is the only one found by the SAGE III team that will be available in the foreseeable future.

Bill Chu discussed the concept and need for "go/no go" criteria for launching SAGE III. Chu and the team will put together various scenarios based on our science objectives and standard data products. This study will be developed for our next science team meeting and include minimum science requirements and minimum lifetime. Chu also reviewed the Charge Coupled Device (CCD) defect issues of red leakage and etaloning, describing three possible solutions that were investigated to date. The red leaks on the present detector are longwave of 700 nm, and a software correction is being developed. Chu also is looking at long exoatmospheric measurements for characterization of the red leakage, although he thinks this is not a problem because signals are ratioed in occultation. He thinks etaloning is more of a problem; Didier Rault and Bob Veiga are modeling the effects on the returned profile species.

Bob Veiga presented several SAGE III spectrometer/telescope measurements of bandpass made with a monochromator as the source, and with several discrete sources. Straylight response measurements were also presented. The spectral response (full width at half maximum) of the instrument was estimated using all the above measurements, and was shown to be between 1.2 and 1.5 nm in most of the science channels. The bandpass of the 1550-nm channel was also presented.

The problem of background-offset correction was discussed. Segment-gap data as well as data showing the red leakage into the serial registers were shown. The charge-transfer efficiency (CTE) mode was presented.

Finally, a set of measurements made with the SAGE III instrument at the system level in the thermal vacuum chamber were presented, with concentration on the etaloning effect in the near infrared (NIR) pixels.

Larry Thomason described the status of the SAGE III production algorithm. He began by showing a table of the channel numbers and spectral characteristics for each channel, including numbers of pixels over specific wavelengths and the target species for each channel. He then showed a detailed modular flow diagram for the solar retrieval algorithm stating that the algorithm has been implemented following the description in the Algorithm Theoretical Basis Documents (ATBDs) and that a functioning form of all models exists. He noted that the cloud product production will be produced monthly rather than real-time to avoid "version" problems at the Distributed Active Archive Center (DAAC). A number of loose ends are being completed including a new version of the spectroscopy tool and data base, which has not yet been incorporated in the operational software, and a new version of the clearing module needs to be incorporated. In addition, the temperature/pressure module requires high-altitude smoothing and a final convergence criterion. Thomason has some algorithm concerns centered around the Emissivity Growth Approximation (EGA) tool (it's slow), incorporation of "version 6" transmission improvements (from SAGE II), improvements in the needed spectroscopy, and instrument accommodation (point spread functions and background subtraction, etc.), but Thomason felt confident that everything is in place or will be in place to produce the required data products. In the area of testing, the SAGE III forward simulator will be used to simulate a range of atmospheric conditions to test the performance of the operational algorithm and proposed modifications. Also, simple event testing will be carried out for basic module-by-module algorithm performance. More-complex atmospheric event testing will be carried out, such as sunrise versus sunset performance, volcanic recovery, ozone hole, etc. All testing will be accomplished by the end of February 1999 with a software review in March.

Eric Shettle gave an update on the current status of molecular spectroscopy related to SAGE III, focusing on ozone and NO_2. The major concern with the ozone absorption cross sections is not as much at the wavelengths primarily used to retrieve the ozone profiles (287-290 and 559-624 nm), but at wavelengths used to retrieve other species where ozone is a significant absorber. This is a particular issue in the SAGE III measurements in the oxygen A band (used to determine temperature & pressure profiles), and the water vapor measurements in the 933-958 nm spectral region. The problem is the lack of reliable measurements of the ozone cross sections at stratospheric temperatures (down to 180 K) in the near IR beyond 762 nm (which is in the middle of the oxygen A band). The uncertainties in the currently available ozone cross section data in this spectral region lead to potential systematic errors in the retrieved temperature of 8 K, 3% in the retrieved pressure, and 30% in the water vapor concentration near the peak of the ozone mixing ratio.

Shettle is a member of an international group currently reviewing several recent high-spectral-resolution measurements of the NO_2 absorption cross sections covering the near UV to the near IR, with the goal of developing a recommended standard set of data to use for atmospheric measurements of NO_2. The measurements include those from groups in France, Belgium, Germany, and the U.S. The data generally agree to better than 5%, and most of the measurements include the temperature dependence of the cross sections.

Victor Sothcott presented the process/method used to develop the code that will be used to develop a backbone, storage area, and to maintain the data products as they are calculated. With this method, they are able to implement each algorithm as an object that gets its input from the storage area and does not have to interface directly with any of the other algorithms. This allows one to easily plug in new or updated algorithms with very little trouble.

The snapshot of results currently being calculated looks pretty good. Transmission results, ozone results (using three methods for different altitude ranges), and aerosol results are all showing errors approximately ≤5%, which is felt to be good for the current state of each algorithm. As the algorithms mature and spectroscopy improves, the results will improve drastically.

Mike Rowland, the SAGE III Data Manager, discussed the focus of data management as it pertains to SAGE III. He went on to describe the development phase approach that the science software development team is using and how development methods have evolved over the life of the development cycle. He also described the scientist-programmer interface paradigm used in the LaRC Aerosol Research Branch to transmit algorithm requirements to the programmers and how both the scientist and programmer validate the resulting software modules. He described the software testing and validation procedures used with the science software. He provided a status of the development of quality assurance procedures and some of the specific activities that will occur during data processing. Rowland explained the configuration management procedures of the science software development effort and what procedures are to be used for data management during normal post-launch data processing. He reviewed the basic data flow of the experiment from instrument to release of the SAGE III data to the public. He presented an overview of the hardware arrangement of the SAGE III Science Computing Facility (SCF) and described its capabilities and science team interfacing features. He explained the current security features and procedures in operation at the SCF. Finally, Rowland presented a high-level schedule of the science software development activities based on a May 1999 launch of Meteor-3M.

Sudha Natarajan presented the SAGE III mission operations status. She talked about the SAGE III mission operation personnel organization chart, Meteor-3M mission configuration and upcoming scheduled events for Meteor-3M, flow of different software blocks on Meteor-3M mission development, and the ISS mission configuration status.

Chip Trepte presented an overview of the planned validation program for Meteor-3M/SAGE III and the major activities between June 1997 and June 2000. Trepte reported on a partnership formed between SAGE III and NASA's Upper Atmosphere Research Program (UARP), Atmospheric Effects of Aviation Project (AEAP), and the Atmospheric Chemistry Modeling and Analysis Program (ACMAP) to conduct the SAGE III Ozone Loss and Validation Experiment (SOLVE). This mission is a joint balloon and airborne measurement campaign to the Arctic designed to examine the processes that control polar to mid-latitude stratospheric ozone levels and aid in SAGE III validation. It is tentatively scheduled to span the period October 1999-March 2000 and will employ experiments for high altitude balloons and the DC-8 and ER-2 aircraft. A NASA Research Announcement for SOLVE will be released, perhaps this summer, inviting experimental and theory team proposals. Trepte presented the detailed SOLVE measurement objectives for all SAGE III-measured species and requirements for each.

He also described the project's coordination with the Network for Detection of Stratospheric Change (NDSC) for correlative measurements with SAGE III. A proposal from the SAGE III Principal Investigator (PI) was submitted to the NDSC coordination office at NASA Headquarters to formalize this cooperation. Trepte noted that three validation aids are under development at NASA LaRC: A data distribution system led by Larry Thomason, an isentropic trajectory package being developed by Brad Pierce and Duncan Fairlie, and a forward simulator being developed by Didier Rault. Finally, Trepte described the overall approach to SAGE III validation including self-consistency checks (solar/lunar events, alternate retrievals, and instrument data), use of the forward simulator, and the intercomparison by correlative measurements. Correlative measurement approaches were presented for each species to be measured by SAGE III.

Didier Rault reviewed his work on the development of a forward simulation of the SAGE III instrument being developed at Langley. The simulation provides radiation counts for each of the science channels and is presently being used in the preflight validation of the inversion algorithm for both solar and lunar occultation events.

Lynn Harvey presented a trajectory-based comparison of an UltraViolet DIfferential Absorption Lidar (UV-DIAL), SAGE II, and the HALogen Occultation Experiment (HALOE) ozone measurements during the 1996 Tropical Ozone Transfer Experiment/Vortex Ozone Transfer Experiment (TOTE/VOTE) DC-8 campaign, which illustrated the technique of trajectory mapping. SAGE II and HALOE coincidences due to initializing trajectories from occultations demonstrated the usefulness of airmass simulations. The advantages of trajectory analyses include providing a synoptic context for asynoptic data and improving data comparison and validation efforts through an increased number of coincident observations.

David Rind discussed validating SAGE III data with SAGE II data. Obviously, one of the prime methods of validating SAGE III data is to use SAGE II data (which have already been validated) for those gases/aerosols that both retrieve. As there is no certainty that SAGE II will still be flying, means and standard deviations of previous SAGE II data pre-Pinatubo have been prepared; the values have been gridded and placed on the standard pressure levels for each month as well as seasonally. Therefore, when a SAGE III retrieval is made, we will be able to quickly evaluate its relationship to past SAGE II values. When the values differ by more than one or two standard deviations, this approach will flag that retrieval as requiring increased scrutiny. As it would be advantageous for the SAGE II means/standard deviation to be available to the SAGE III team as a whole, Rind is considering generating a CD-ROM that would be distributed to all team members.

Although **Linda Brown** of JPL was not in attendance, she sent a set of overheads for Bill Chu to present and was available, via telephone, to answer any questions that arose. Brown was selected in the Fall of 1997 as part of the validation team for SAGE III via her proposal to NASA NRA EOS-AM/SAGE III. She is providing accurate line parameters for features of the oxygen A-band near 760 nm (13,100 cm^{-1}). The desired accuracies are 1% for intensities and 5% for width. She noted that published laboratory intensities agree only to 10% in intensity. At this point in her work, she concludes her results agree with the HITRAN 1996 database for line intensities and that the SAGE III accuracy requirements for the oxygen A-band line parameters will be met. Her "one year" task will be completed on time. A new database will be created in June 1998 that will serve the needs of many applications, and if additional funding were provided, she could use the 8 long-path laboratory spectra of water data she has collected between 690 nm and 1000 nm to improve the accuracies of water line parameters.

Similar to Linda Brown, **Stan Sander** of JPL was selected as a SAGE III validation team member and could not attend, but sent Bill Chu a set of overheads to present for him. His goal is to measure NO_3 vertical columns with the JPL Fourier Transform Spectrometer during SAGE III overpasses of Table Mountain, CA (34.4°N, 117.7°W). He will perform these measurements in the 651-667 nm spectral region using the moon as a light source. Sander has made NO_3 measurements since his selection, improved the instrument's signal-to-noise ratio with a new Avalanche Photo Diode (APD) detector and better band-pass filters, developed an automated pointing system that tracks the moon using a CCD camera, frame grabber, and PC control of the Heliostat, adapted the NDSC-accepted algorithm for Fourier Transform InfraRed (FTIR) data reduction to work in the visible range, and is using the HITRAN-96 line list to remove interfering H_2O lines from the NO_3 data.

Gary Morris discussed the use of trajectory mapping in validating ozone measurements.Ozone profiles from March 1997, measured by SAGE II, were validated against those measured by HALOE using the trajectory mapping technique and the traditional coincidence approach. The trajectory mapping results compare favorably with results obtained using the traditional coincidence approach, even for long-duration trajectory calculations. Furthermore, trajectory mapping dramatically increases the number of observations that can be validated and the latitude range over which coincidences occur. By accounting for dynamical changes in the atmosphere over short temporal and geographic scales, trajectory mapping can reduce the observed variance between the data sets. Comparisons of trajectory-mapped HALOE and SAGE data from December 1993 with ozonesondes from Hohenpeissenberg showed excellent agreement. These results suggest that trajectory mapping provides an effective tool for the validation of SAGE III data with data from other satellite, ground-based, and ozonesonde instruments.

Jacqueline Lenoble presented an overview of the planned European validation activities for SAGE III. She listed the various sites that will be making ozonesonde, ozone lidar, aerosol and temperature lidar, and balloon ozone and NO_2 routine measurements. She also described the major balloon-borne instruments and special campaigns that can be organized at Esrange -Kiruna, Sweden. Finally, she described the 11 sites possible for ground-based total ozone column measurements.

Volker Mohnen discussed the ozonesonde network and proposed guidelines for ozone validation. Recent developments by the Committee on Earth Observation Satellites (CEOS)-Integrated Global Observing Strategy (IGOS) focusing on cal/val issues emphasize the need for "continuous" validation of a satellite sensor over its "lifetime." A pilot project on "ozone density" is presently proposed to CEOS-IGOS, whereby these validation activities required for all sensors are coordinated in such a way that ground-based facilities needed for sensor validation are "shared." In addition, all parameters needed for sensor validation should be traceable to national/international standards.

Following these guidelines, it is proposed to proceed as follows for the ozone validation: All ozonesondes flown in support of SAGE III profile validation must be "characterized/calibrated." This would involve the World Calibration Facility (WCF) for ozonesondes of the World Meteorological Organization's Global Atmospheric Watch program (WMO-GAW); carefully selected ozone launch stations would be designated for SAGE III ongoing validation activities. These stations would only launch "characterized" sondes as part of their regular launch schedule or as directed to maximize coincidence conditions; SOLVE will also use "characterized" ozonesondes; and the Southern Hemisphere Additional Ozonesondes (SHADOZ) program is considered an integral part of SAGE III long-term validation efforts (2 years). Again, it is imperative that sondes flown in this program also be "characterized" by the WMO-WCF.

Phil Russell of NASA Ames described early results of comparisons between different algorithms that separate the aerosol and trace gas contributions to extinction spectra like those to be produced by SAGE III. The objective is to evaluate the performance of the retrieval algorithms described in the SAGE III ATBDs by applying them and other algorithms to measurements made by the 14-channel Ames Airborne Tracking Sunphotometer (AATS-14). Most of the AATS-14 spectral channels are matched to SAGE III channels. Results obtained by Beat Schmid of the Ames team were shown for two ozone-aerosol separation algorithms applied to AATS-14 optical depth spectra measured in the Aerosol Characterization Experiment (ACE-2) field campaign. This tropospheric data set may provide indications of the performance of SAGE III retrievals when they are extended downward from the stratosphere into the troposphere. The two algorithms (a SAGE III algorithm and a quadratic-fit algorithm) produced ozone values that agreed within about 5 Dobson Units (DU) for aerosol optical depths at 500 nm of less than 0.01, and within 10 DU for aerosol optical depths between 0.01 and 0.07. Differences were shown to approach 100 DU when aerosol optical depths at 500 nm were greater than 0.3.

Yuri Borisov discussed the following Central Aerological Observatory (CAO) activities. With respect to temperature and pressure algorithm inversions, the CAO is developing the analytical method for forward calculations of atmospheric O_2 slant path transmission. There are some differences between line-by-line and analytical calculations based on the error calculations. The inversion part of the algorithm is based on the "fitting" of inverted T and P profile transmission to the "measured" one. The accuracy of the "simulated" inversion is better than 10 K. There was a detailed discussion of the T and P algorithm and the schedule for algorithm comparison was agreed upon. The algorithm for NO_2, O_3, and aerosol profile inversions using 26 spectral channels (290 nm, 430-450 nm, 600 nm bands) were discussed. The analysis demonstrated that utilizing the 430-450 nm channels improves the accuracy of O_3 profile inversion, and "wrong" Rayleigh subtraction doesn't affect the NO_2 and O_3 retrieval. Separation of the total extinction into each species extinction provides better results than the separation of the total slant path optical depth. There is a systematic shift between profiles retrieved by those two approaches.

A plan for validating O_3, H_2O and validation at the Yakutsk and Salekhard stations was also presented. The proposal, however, supposes financial support for the soundings. The US side provided simulated SAGE III telemetry data and agreed to send their spectral data base to CAO.

Oleg V. Postylyakov discussed the Institute for Atmospheric Physics (IAP) activities. The IAP continues to develop a Russian validation network of NO_2 profile observations. In September 1997, IAP carried out an intercomparison of instruments for NO_2 profile measurements. Five instruments from Russian NO_2 observational stations together with a mobile train-mounted instrument took part in the intercomparison. The referee of the intercomparison was Paul Johnston of the National Institute of Water and Atmosphere, Lauder, New Zealand, who represented the Network for the Detection of Stratospheric Change (NDSC). The results of the intercomparison will become available when the NDSC presents an official conclusion on the intercomparison. The IAP organized colleagues at Russian validation facilities in central Russia. Three observational sites (Obninsk, 36.2°E; Moscow/Dolgoprudnuy, 37.61°E; and Nizhniy Novgorod, 43.82°E), in which the ozone vertical distribution can be measured by different methods, and Zvenigorod station, 36.47°E, observing NO_2 profiles, are located along approximately one latitude line 55.5°N at the distance of about 700-800 km. These observations were supplemented by NO_2 profile measurements using the mobile instrument near Nizhniy Novgorod. It was possible to obtain a few profiles of both O_3 and NO_2 along the SAGE II tangent to improve the quality of validation. During the last train expedition, TROIKA-4 in February 1998, UV and visible scattered solar radiation was measured to retrieve stratospheric O_3 and NO_3 vertical profiles. Algorithms for processing these data are now developed. Train expeditions will become a source of correlative data for validation in Siberia.

Amin Dharamsi presented measurements of oxygen A-band lines by modulation spectroscopy using single-mode diode lasers to measure the parameters of several oxygen A-Band lines. Each line is examined by using first, second, third, and fourth harmonic detection orders. Since Nth harmonic detection yields a signal with N+1 turning points, each set of harmonic detection order runs gives a large amount of experimental information.

Lines in the oxygen A-Band with integrated absorption cross-sections ranging from 10^{-24} cm^{-1} cm^2 mol^{-1} to 10^{-27} cm^{-1} cm^2 mol^{-1} have been measured. Several instances of overlapping lines were examined. It was shown that wavelength modulation spectroscopy allows one to accurately measure line separation and line strengths. One of the experimental results presented is the RQ (31, 32) line (5.06x 10^{-26} cm^{-1} cm^2 mol^{-1}). In the wavelength modulation experiments conducted, the absorption signal due to this line is affected by the wings of two adjacent lines, namely the RQ 27, 28 and RQ 25, 26 lines. These effects were discussed, and it was shown that each measurement in this region gives information about all three lines.

The effects of etaloning that tends to limit the signal-to-noise ratio in wavelength modulation experiments were discussed, and its was shown that use of higher harmonic detection can reduce the deleterious effects of such etaloning.

Dave Woods and **Susan Walters** gave a joint presentation on the planned SAGE III educational outreach program. A significant outreach program is being considered for SAGE III that will make the public aware of this NASA research and its benefits to the community as well as its educational benefits. The program should also stimulate a greater interest in science and, perhaps, influence career choices by exposing this research to school children. They are developing handouts, posters, brochures, and a web page on SAGE III. Also, they are developing related instructional materials that will help teachers. It is planned that presentations will be made to local students and teachers, and a nationwide network of science teachers will incorporate SAGE III materials in their classroom instruction. Finally, an inexpensive hands-on project will be developed that will allow students all over the world the opportunity to participate in our research. It is centered around a sun-photometer. Walters also presented a suggested logo for our outreach program and a questionnaire for the team to fill out reflecting their interest in participating in the outreach program.

Next **Larry Thomason** described the SAGE III homepage, how it is being redesigned, and ideas concerning on-line data browsing. The new project homepage will provide a unified site for secured SAGE III sites as well as links to other necessary pages. The public homepage is subdivided into subpages that concisely convey the key elements of the SAGE III project and provide, transparently, limited data browsing and ordering. It will introduce visitors to the project in a concise format for an informed non-specialist and is focused on explaining why it is important to the scientific community. It will allow visitors to perform up-to-date simple data browsing and ordering. Thomason showed the first page of the new homepage, which is a huge improvement over the old homepage. He also showed example data browser pages called the SAGE III Data Miner. They were quite impressive.

Rich McPeters, of NASA GSFC, presented an interesting overview of the Shuttle Ozone Limb Sounding Experiment (SOLSE) and the Limb Ozone Retrieval Experiment (LORE), which flew on the Shuttle in late November - early December 1997. Unfortunately, only two orbits of data were obtained by SOLSE and LORE. SOLSE is an imaging spectrometer with a CCD array detector having a vertical coverage of 30-60 km with 2-km resolution. The spectral coverage is 265-360 nm.

LORE is a multi-filter limb scattering instrument with a vertical coverage of 10-to-40 km and resolution of 2 km. It has channels at 345, 525, 600, 675, and 1000 nm. Rich showed preliminary data from an ozone profile comparison taken on December 2, 1997 between LORE (2°N, 15°W), SOLSE (3°S, 15°E), a balloon-borne ozonesonde launch from Ascension Island (8°S, 14°W), and an ozone zonal mean from HALOE. Limb scattering is a serious contender for future ozone profile measurements (e.g., in NPOESS) and, as such, this demonstration mission is important. Hopefully, another Shuttle flight of SOLSE/LORE will be accomplished. Limb scattering data will also be obtained by SAGE III. A cooperative effort between us and GSFC is being developed for working on these data.

Frank Schmidlin, of GSFC, presented SAGE III calibration/validation plans for lunar occultation measurements from the tropical sites in Brazil and Ascension Island. Approximately three balloon-borne ozonesonde measurements will be scheduled each month from each observation site. As part of the Memorandum of Understanding with Brazil, balloon ozonesonde observations will be made from the Instituto Nacional de Pesquisas Espaciais (INPE) site at Natal and probably from a university site at Alcantara. Measurements from Ascension Island, presently made weekly as part of a GSFC requirement, are scheduled to end in October 1999. This effort is arranged through the U.S. Air Force, which maintains a facility at Ascension. Observations for SAGE III will continue beyond October 1999. These tropical-site observations will also meet the requirements specified for the long-term weekly measurement program between NASA and INPE and the Southern Hemisphere Additional Ozonesondes (SHADOZ) experiment.

As in past SAGE programs, **Pat McCormick** assigns a science team member the responsibility to validate each measured species. In this manner, a scientist, other than the PI or a project team member, stands by the validation of each species. These leaders form subteams to accomplish this task, and are usually the senior author for subsequent validation papers. With respect to SAGE III, Phil Russell will be team leader for validating the aerosol products, Derek Cunnold the team leader for ozone, Geoffrey Kent for clouds, David Rind for water vapor, Jim Miller and Ron Nagatani for temperature and density, and Hope Michelsen for NO_2, NO_3, and OClO. Supporting all these teams will be a team developing trajectory techniques, 4-D simulators, and gaseous cross-section determinations. This team will be led by Chip Trepte with Eric Shettle leading the cross-section team. He also made assignments of science team members for each of the subteams. McCormick then showed a graphic of how these teams will be tied together to support the total SAGE III validation. He finished the open part of the science team meeting by requesting that, if they haven't already done it, all speakers should provide him with hard copies of their talks. These will be available from his office at HU if any member needs them.

The final session was a closed session for science team members only, in which many science team issues were addressed. These included: management issues including problems with the timing for their funding, discussions of future team activities including scheduling, ideas regarding the FOO, visiting scientists at HU or LaRC during validation and early data-use periods, their involvement in SOLVE and the PI's involvement in SOLVE, and their requirements for accessing data. The team was reminded of the need for developing "Go/No Go" criteria for launch, and were asked to provide Bill Chu with their thoughts before the next meeting. Finally, the team was reminded to send Pat two-page summaries of their SAGE III activities, status, and progress.

The meeting was adjourned by Pat McCormick at approximately 3:30 PM on Friday.

KUDOS

Dr. Eric Barron, Professor of Geosciences and current Director of Penn State's Earth System Science Center, has been named head of the newly established Environment Institute in Penn State's College of Earth and Mineral Sciences. The Institute will initially include two existing centers in the College of Earth and Mineral Sciences: the Earth System Science Center (ESSC) and the Center for Integrated Regional Assessment (CIRA).

Dr. Barron is past chair of the EOS Science Executive Committee and is an EOS IDS Principal Investigator.

The Earth Observer staff and the Earth Science community would like to congratulate Dr. Barron on his new assignment.

Summary of Total Ozone Mapping Spectrometer (TOMS) Science Team Meeting

— Jack Kaye (jkaye@hq.nasa.gov), TOMS Program Scientist, NASA Headquarters, Washington D.C.

The first meeting of the science team for the Total Ozone Mapping Spectrometer (TOMS) series of instruments was held on April 20-22 at the National Wildlife Visitor Center at the Patuxent Environmental Science Center in Laurel, MD. This science team was selected in response to a NASA Research Announcement (NRA) issued in 1997 and includes scientists funded through TOMS-related data analysis funding and also relevant investigators in the Atmospheric Chemistry and Modeling Program (ACMAP) of NASA's Office of Earth Science. The meeting provided an opportunity for the newly selected team members to meet each other as well as the scientists and programmers who have been carrying out TOMS processing and data analysis in recent years. Attention was focused on all of the TOMS observables, including total ozone, tropospheric aerosols, surface ultraviolet radiation, and stratospheric sulfur dioxide, as well as tropospheric ozone information, which can be obtained either from TOMS data alone or by use of TOMS data in conjunction with those from other space-borne sensors.

The meeting began with greetings from **Jack Kaye**, Program Scientist for TOMS at NASA HQ, and continued with a summary of the TOMS series of missions from **P. K. Bhartia**, TOMS Project Scientist at NASA's Goddard Space Flight Center (GSFC). A total of four TOMS instruments have flown in space - Nimbus 7 TOMS (1978-1993), Meteor-3 TOMS (1991-94), ADEOS TOMS (1996-1997), and Earth Probe TOMS (1996 - present). A commitment has just been made by the government of the Netherlands to provide an Ozone Monitoring Instrument (OMI) using a similar observing technique to that used by TOMS for the EOS CHEM spacecraft for launch in late 2002 or 2003. NASA plans to issue an NRA for a U.S. Science Team for OMI later this year. Measurements with a TOMS-like technique are also expected to be part of the National Polar Orbiting Environmental Satellite System (NPOESS) through the planned Ozone Mapping and Profiling Suite (OMPS) instrument, although the first such instrument may not be launched until 2010.

The TOMS instruments have provided excellent data for total ozone, although there are some limitations that must be considered in certain applications, especially for studies of tropospheric ozone. In general, data at high solar zenith angles are less reliable than those at lower angles. Currently, no data are released for zenith angles greater than 84°, although data are in principle available for up to 88°. The validation of these high solar zenith angle data is difficult, however. The determination of surface flux of ultraviolet radiation from TOMS data appears to be quite robust, especially if ratios, such as that of UVA/UVB (UV radiation longward and shortward of 320 nm), are considered. The major factor affecting the determination of the surface flux of UVA radiation, which is not attenuated by ozone, is our knowledge of the UV extinction associated with aerosol particles, especially UV attenuating forms such as smoke or mineral desert dust. Results to date suggest that up to 50% of UVA can be attenuated by such aerosols.

The status of the Earth Probe (EP) TOMS instrument was reviewed by **Rich McPeters**, the EP TOMS principal investigator, of NASA/GSFC. EP TOMS was launched on a Pegasus XL rocket on July 2, 1996 into a 490 km orbit, which provided a 26 km field of view (FOV) at nadir. This is significantly better horizontal resolution than previously obtained by TOMS instruments (typically 50 km at nadir), but did not provide full daily global coverage at all latitudes (this was obtained only poleward of approximately 60 degrees). The EP TOMS instrument, like that of ADEOS TOMS, differed from the previous TOMS instruments (Nimbus 7, Meteor-3) through slight changes in wavelength (309, 313, 318, 322, 331, and 360 nm instead of 312, 317, 332, 340, 360, and 380 nm). The new instruments also include a carousel of three diffuser plates exposed at differing intervals (regularly, periodically, very rarely) so that the effects of diffuser plate degradation can be better characterized.

Data were obtained routinely from July 25, 1996 until December 3, 1997 except for a three-day period in mid-November, 1996. Following the failure of the ADEOS spacecraft in the summer of 1997 as mentioned below, a decision was made to boost EP TOMS to a higher orbit, and in early December 1997 this reboost was carried out, lifting EP TOMS to a 739 km orbit, providing a nadir viewing size of 38 km. This provides full daily global coverage except for small inter-orbit gaps in the tropics. This new orbit minimizes the need for orbital adjustments as we approach the maximum of the current solar cycle; without this boost, the orbit would have dropped by a half km per month, requiring orbital adjustments every few months. The instrument has operated in its normal observing mode except for several sequences designed to focus on regions where high concentrations of sulfur dioxide were expected, including the region of El Popocatepetl in Mexico during May 1997 and later for several large metropolitan areas. Such studies were terminated following the loss of ADEOS TOMS, when EP TOMS became the primary ozone mapping instrument.

The status of data from some of the other TOMS instruments was also reviewed. **Jay Herman** of NASA/GSFC summarized the three years of data from the Meteor-3 TOMS. The Meteor-3 spacecraft was in a non sun-synchronous orbit, and roughly half the data were obtained at sufficiently large solar zenith angles that the data must be used with great care. The first half of the Meteor-3 TOMS record overlapped that of Nimbus 7 TOMS, so these data have been examined only in a limited way. The second half of the Meteor-3 TOMS record helped extend the TOMS record, and has been more extensively used in long-term trend studies. He also discussed plans to fly a new TOMS instrument on a Russian Meteor 3M spacecraft scheduled for launch in the year 2000.

Arlin Krueger, also of NASA/GSFC, summarized the record of ADEOS TOMS. This instrument obtained data from instrument activation on September 12, 1996 until the end of mission on June 29, 1997. During that period, more than 99% of possible data were obtained, with the largest data gaps being in September and October of 1996. Because of the relatively high orbit of the ADEOS spacecraft, ADEOS TOMS provided full daily coverage of the sunlit Earth. The ADEOS spacecraft contained several other instruments whose data may be used together with those from TOMS both for scientific studies and to better understand the TOMS data. Those of greatest interest are the OCTS, an ocean-color oriented instrument using visible wavelengths whose data will be of great use in studying aerosol and cloud distributions because of their high spatial resolution (~1 km), and AVNIR, an infrared radiometer with very high resolution (6 m, 16 m), which can also provide information for use in radiative transfer studies.

The status of the Earth Probe TOMS ground operations (including processing to Level 0 data) was provided by **Ed Macie**, leader of the NASA/GSFC flight operations team for Earth Probe and the Upper Atmosphere Research Satellite (UARS), whose operations are collocated. Instrument status at the time of the meeting was excellent. One item that had been of particular concern was the battery (which is a critical non-redundant component). This has been showing no signs of degradation and has, in fact, been providing higher voltage than expected, but this is not expected to be a problem. The attitude control system is within required specifications, although the system is somewhat more susceptible to noise than was expected. The instrument does experience some electromagnetic noise when passing over the South Atlantic Anomaly. The flight software is currently being reviewed for year 2000 issues. The transmitter had been operating continuously during data collection periods in day-time. A failure of the primary transmitter after the meeting (late April, 1998) has caused a backup transmitter to be used, and this is only turned on for scheduled data downlinks so real-time downlink of data no longer takes place.

The status of TOMS data processing was discussed by **Charlie Wellemeyer** of Raytheon STX, Inc. TOMS level 2 and level 3 total ozone data are available from the Distributed Active Archive Center (DAAC) of the Earth Observing System Data and Information System (EOSDIS) at the Goddard Space Flight Center. Additional data are made available through an internal web site at GSFC; these include "research products" such as tropospheric aerosols. The available total ozone measurements are based on the Version 7 algorithm. Several known factors can contribute to errors, including the presence of UV absorbing tropospheric aerosols, the occurrence of high solar zenith angles, scan angle dependence during the cross-track scanning carried out by the TOMS instrument (this was a particular problem during the post-Pinatubo period when stratospheric aerosol distributions were largest), sun glint, and cloud heights, which are based on climatology rather than actual cloud heights. Some fixes for the last of these may be possible for Nimbus 7 TOMS during the time when the THIR instrument was operating (1979-1987).

Knowledge of the calibration of the TOMS instruments, especially EP TOMS, was reviewed by **Glen Jaross**, also of Raytheon STX, Inc. No major problems with the calibration for EP TOMS are known, although some small problems may exist. In particular, it is possible that the 360 nm channel center is actually 0.3 nm shorter than originally measured. This will have a small effect on the TOMS aerosol and ozone products. The degradation likely to have occurred in the diffuser plate during the period of operation of EP TOMS is not thought to have impacted TOMS ozone retrievals and to have only minimally affected those of tropospheric aerosols and surface UV radiation. This is in spite of a fairly significant reduction in signal strength of the instrument (~25%). Comparisons of EP TOMS total ozone columns to those measured with the World Standard Dobson instrument suggest that EP TOMS values may be about 1.5% too high.

Given this knowledge of the EP TOMS instrument, there was a discussion of the desirability of doing a reprocessing at this stage as opposed to waiting for an additional time period (e.g. one year) before considering a reprocessing. Based on the expected reduction in error, which is quite small for total ozone and only somewhat larger for aerosols and surface UV radiation, the assembled team felt that there was no need for an immediate reprocessing of the EP TOMS data.

A discussion on the ideal mechanisms for distribution of TOMS data was carried out, with the DAAC represented by **George Serafino** of NASA/GSFC. A particular issue was the need for availability of the detailed Level 2 data (individual measurements) instead of the Level 3 (gridded) data that have been used in most studies to date. The problem is data volume – about 6 Gb per year. The advantages and disadvantages of various media (CD-ROM, 8 mm tape, 4 mm tape), as well as the benefits of data compression, were all discussed.

Results of prior research and plans for current research by members of the TOMS science team were then presented. These were considered largely in three groups – research related to the TOMS total ozone product, to TOMS tropospheric ozone products, and to the TOMS aerosol and surface UV flux products (which are considered together because of the crucial role which aerosols have in affecting surface UV flux). Some related work was also discussed; this is included with the total ozone section that follows. Since some of the science team members are just in the process of beginning their investigations, some efforts are in their formative stages, while others are continuations of work with long heritage.

Total Ozone and Related Issues

Efforts to create a single long-term data set for total ozone derived from space-based measurements from multiple instruments were summarized by **Rich Stolarski** of NASA/GSFC. A data set covering the period from late 1978 till February 1998 for zonal mean ozone should be available in early May 1998. A more complete data set, providing some information on longitudinal distributions as well, should be made available in late 1998 or early 1999. One of the key questions to deal with is how to extend the total ozone record through the "TOMS gap" from the time of the Meteor-3 TOMS failure in late 1994 until the launch of EP TOMS in mid-1996.

Comparisons of TOMS total ozone amounts with those determined from ultraviolet and visible radiation measurements made using the Composition and Photochemical Flux Module (CPFM) instrument that flies aboard NASA's ER-2 aircraft were discussed by **Steven Lloyd** of the Johns Hopkins University Applied Physics Laboratory. The CPFM instrument could look upward, downward, and at the limb, so a combination of upward and downward looking observations provided a total ozone column that could be compared with TOMS observations made at similar times and locations. Comparisons will focus on the region near Fairbanks, AK which was the base for the ER-2 during most of the Photochemistry of Ozone Loss in the Arctic

Region in Summer (POLARIS) aircraft campaign in 1997. Given the high latitude of the aircraft observations, the ER-2/satellite comparisons will be particularly valuable in probing the effect of profile shape on the TOMS retrieval at high solar zenith angles. The possibility of combining aircraft- and space-based data will also be considered; an example might be the use of cloud top heights determined from CPFM 762 nm data.

The status of comparisons of TOMS-measured total ozone columns and those measured from Dobson instruments was summarized by **Sam Oltmans** of the Climate Monitoring and Diagnostics Laboratory of the National Oceanic and Atmospheric Administration. The most detailed comparisons carried out are those with the World Standard Dobson (#83), made each summer at Mauna Loa, Hawaii. Results to date have shown good agreement. Other Dobson instruments, such as that at American Samoa, do show systematic differences in comparison of total column ozone measurements with those made from TOMS. These comparisons are a critical component of the TOMS validation effort and will continue in the future.

The use of space-based ozone measurements as input for a data assimilation system designed to produce accurate and internally consistent ozone fields was described by **Ivanka Stajner** of the General Sciences Corp., who is working with Lars-Peter Riishojgaard of the University of Maryland at Baltimore County. TOMS total ozone Level 2 data are used along with partial profile information from the SBUV instruments. Chemical production and loss rates are provided at 10 day intervals and are used together with meteorological fields from the GSFC Data Assimilation Office GEOS system as input for the model. Ozone data are assimilated using a global, physical space based statistical analysis scheme. Results to date, which have focused on the winter of 1992, show that the calculated ozone fields compare better with those from ozonesondes (not themselves used in the assimilation process) than with those calculated using the GSFC parameterized chemistry-transport model. Further developments of the assimilation system should lead to improved ozone fields. The ozone assimilation system should become operational in the next several months.

The relationship between TOMS total ozone measurements and small scale tropopause dynamics was reviewed by **Mark Olsen**, who is working together with TOMS science team member John Stanford of Iowa State University. Analysis of TOMS data along with meteorological data (especially potential vorticity) and satellite-measured water vapor fields is being used to help understand the relationship between ozone distributions and the dynamics of the tropopause region. A particular emphasis is on how intrusions of stratospheric air into the troposphere affect the total ozone columns as measured by TOMS. Comparisons with the chemistry/transport model of NASA/GSFC are being used to help test understanding of these mechanisms. One potential spin-off of this work is improved knowledge of the relationship between the structure in the total ozone field measured by TOMS to the strength of the jet stream in the upper troposphere.

Studies of the interannual variability in total ozone and its long-term trends in mid-latitudes were reviewed by **Lon Hood** of the University of Arizona. This work was set up to better understand the sources of both interannual and long-term variability in ozone amounts, with a particular emphasis on dynamically-driven contributions. These are looked at through parallel analysis of TOMS ozone data and meteorological fields. Results to date suggest that changes in lower stratospheric temperature and/or tropopause height could be contributing significantly to the mid-latitude ozone decreases observed by TOMS. It was seen that short term meteorological events can significantly affect the zonal mean distributions of total ozone, especially in February when there can be enormous variations from one winter to the next. Changes in the zonal wind that may be occurring over the long term could influence the variability of planetary waves, which in turn may be affecting the forcing of stratospheric wave events, which can help mix mid-and high-latitude air in the winter.

Studies of ultraviolet radiative transfer algorithms for use in satellite measurements of ozone were discussed by **Dave Flittner**, who is working as part of the TOMS science team investigation of Ben Herman at the University of Arizona. A particular area of emphasis in this work is on the development of the ultraviolet limb scattering technique, which holds promise for being an excellent way to determine the vertical profile of ozone in the stratosphere. As part of this work, attention will be given to determining the effect of aerosols on ozone determination, as well as the sensitivity of the technique to horizontal variations in ozone distributions and the presence of broken clouds. Tests of the ozone algorithm may be made by analyzing data from the Shuttle Ozone Limb Sounding Experiment (SOLSE) and Limb Ozone Retrieval Experiment (LORE) instruments that flew on the Space Shuttle in the fall of 1997.

Measurements of other species with UV absorption in the ultraviolet using the Global Ozone Monitoring Experiment (GOME) instrument aboard the European Space Agency's ERS-2 spacecraft were discussed by **Kelly Chance** of the Smithsonian Astrophysical Observatory. The most observed of these species has been bromine monoxide (BrO), for which column distributions have been obtained, and interhemispheric differences have been demonstrated. Changes in the BrO column believed to be associated with tropospheric BrO in the springtime were observed. Studies of chlorine monoxide (ClO) are beginning, but the retrieval of ClO is much more difficult than that of BrO because of its overlap with the Hartley band of ozone. Studies of sulfur dioxide (SO_2) are underway, but must be considered as a work in progress. In some cases, strong correlations of SO_2 and ozone distributions are seen, and it is not clear whether this is a real geophysical signal or whether there is some aliasing of SO_2 by ozone. Future work will include derivation of ozone profile information (especially through use of information in the Chappuis bands of ozone) and column distributions of formaldehyde.

Tropospheric Ozone

A discussion of details of the TOMS retrieval algorithm and how those may be relevant to currently used methods for determination of tropospheric ozone was provided by **Bob Hudson** of the University of Maryland. The TOMS algorithm starts with a climatological ozone profile that assumes that some 90% of the ozone is in the stratosphere. Thus, if in reality there is an increased ozone column due to a larger amount of ozone in the troposphere, the algorithm will tend to "see" only a fraction of it. Depending on what altitude regions are considered, this fraction can be fairly small (in one study, only 22% of the ozone added in the 1000-891 mb region was observed, while the fraction rose to only 57% if the 1000-501 mb region was considered). This partial observation of tropospheric ozone must be considered in using techniques such as TOMS-SBUV residuals (in which tropospheric ozone is taken as the difference between TOMS total ozone and integrated stratospheric ozone from one of the Solar Backscatter Ultraviolet instruments) or the difference in ozone columns over mountains and nearby sea-level areas (such as have been carried out over the Andes Mountains and nearby Eastern Pacific). Other techniques tried to date should suffer less from such complexities, such as that which looks at the differences between total ozone columns over nearby clear and cloudy regions or that based on "scalloping" (small scan-angle dependence in the total column which may be due to differences in the ozone profile from that assumed in the TOMS algorithm). The latter technique is complicated by the presence of aerosols, with UV-absorbing and non-absorbing aerosols having very different effects.

Two methods of deriving tropospheric ozone information from TOMS data were discussed by **Sushil Chandra** of NASA/GSFC. One of these is a residual method, in which tropospheric ozone is obtained as the difference between TOMS total ozone and stratospheric ozone determined from a combination of the Microwave Limb Sounder (MLS) and Halogen Occultation (HALOE) instruments aboard UARS. The other, known as the Convective Cloud Differential (CCD) method, derives tropospheric ozone from the average difference between total column ozone over clear regions and over regions of high clouds. A key consideration in the latter method is having correct cloud top height information. The assumption is made that clouds with very high reflectivity are also at high altitudes. During the first part of the Nimbus 7 TOMS data, some information on cloud top pressure was available from the THIR instrument aboard Nimbus 7. The TOMS/MLS/HALOE differential method has been most extensively tested for the period of September 1992, during which the TRACE-A airborne campaign was carried out and the largest amount of data exists for testing the method. Analysis of time series of tropospheric ozone from these methods shows strong evidence of an effect of El Niño. The shift in location of convection during El Niño periods is believed to dominate these changes, although some contribution due to increased fires resulting from droughts in regions affected by El Niño cannot be ruled out.

Studies of tropospheric ozone based on TOMS were reviewed by **Jack Fishman** of the NASA Langley Research Center. After doing studies using TOMS data only and TOMS/SAGE residuals, more recent work has centered on a residual approach using TOMS and SBUV data. A key element of this method is the accurate placement of the tropopause so that accurate separation of tropospheric and stratospheric amounts can be made. Several different approaches have been tried, with a polynomial fitting routine being used most recently. This has led to some changes in the tropospheric ozone fields with respect to those defined previously. Results of the TOMS/SBUV residual method are being compared with available data, and attempts are being made to understand why the agreement appears to be good in only some cases. The long-range goal of the work is to look at air pollution events in the eastern U.S. and understand the contributions that satellite data can make to their characterization.

A new effort to help improve our knowledge of ozone vertical profiles in the tropical region was presented by **Anne Thompson** of NASA/GSFC. This effort is known as the Southern Hemisphere Additional Ozonesondes (SHADOZ) project, and will lead to more regular ozonesonde flights from several stations in the 0-20 degree South latitude band. No new stations will be brought on line as part of this effort; the focus will be on providing more regular flights at those stations that already exist. A fundamental goal of this two-year project is to help characterize the nature of the wave one pattern in ozone that is seen in the tropics. Currently available data do not yet provide definitive evidence for the origin of this pattern (although data seem to indicate that it resides in the troposphere). The assumption of a tropospheric wave one pattern is the basis of a new method for deriving tropical tropospheric ozone (TTO) at GSFC and the University of Maryland. Like the CCD technique, the new Modified-Residual Method is a TOMS-only method of obtaining both stratospheric and tropospheric column amount. The 14-year Nimbus 7 TTO maps, provided as 2-week averages at 1×2 degree resolution, can be previewed on a homepage. Further evaluation of the Modified-Residual Product will be performed by the ozone processing team and other TOMS science team members before the data set is released to the public.

Efforts to understand tropospheric ozone from TOMS data were presented **by Mike Newchurch** of the University of Alabama in Huntsville. Previous work with Jae Kim of the Korean National University of Education has emphasized the differential method in which TOMS ozone column amounts over high mountains and nearby sea-level regions were compared, with applications to date being the Andes Mountain region of South America and the mountain regions of New Guinea. These regions differ in that in the Andes the mountains are downwind of the region of biomass burning thought to be responsible for ozone production, while in New Guinea the biomass burning region occurs downwind of the mountains. However, in both locations significant increasing trends in lower tropospheric ozone of 1%/year were found. These ozone increases are attributed to increases in biomass burning. A new effort being undertaken is to study ozone amounts over mesoscale convective cloud complexes (MCCs). By looking at averages of the significant ozone variation between clear and cloudy pixels, information on tropospheric ozone should be retrievable from this technique.

Tropospheric Aerosols and Surface UV Flux

The effects of UV-absorbing and non-absorbing aerosols on surface UV radiation as seen by TOMS were discussed by **Jay Herman** of NASA/GSFC. One of the more difficult aspects of applying TOMS to this subject is differentiation of cloud- and aerosol-containing regions; to focus on the effect of aerosols, a reflectivity limit was put on scenes studied to select against high reflectivity cloud-dominated scenes. The TOMS surface UV product obtained compares well on the average to ground-based measurements, such as those made with Brewer spectrophotometers, although some systematic disagreements in such comparisons do exist and are not yet well-explained. For instance, the seasonal comparisons show that there is worse agreement between TOMS and Brewer surface UV values in summer than in other time periods. It is felt that TOMS can do a very good job in getting ratios of surface UV flux at different wavelengths.

The validation and interpretation of the TOMS aerosol product was described by **Sundar Christopher** of the University of Alabama in Huntsville, who emphasized the use of data from the Advanced Very High Resolution Radiometer (AVHRR) instrument that flies aboard the NOAA polar orbiting operational meteorological spacecraft. AVHRR provides aerosol information over water, and efforts using both spectral and textual information (e.g. homogeneity of background) are now being carried out to help determine aerosol amounts over land. AVHRR can also help locate fires that serve as the source of the UV-absorbing smoke detected by TOMS. Particular time periods examined include that of the Smoke, Clouds, Aerosols, and Radiation (SCAR B) mission, as well as the Zambia International Biomass Burning Experiment (ZIBBE) held in the summer of 1997.

Plans for the validation of the TOMS aerosol product through comparison with *in situ* aerosol measurements to be made from light aircraft were presented by **Joseph Prospero** of the University of Miami. A payload suitable for use in commercially leased light aircraft will be constructed and used in geophysically interesting regions for which information about aerosol properties is needed. Initial validation studies has focused on ground-based data, especially that taken from the Atmosphere-Ocean Chemistry Experiment (AEROCE) measurement network. This includes stations in Miami, Bermuda, Barbados, and Tenerife, among others. There is clear evidence for transport of material from African deserts to these stations. Preliminary results show good correlations of the TOMS aerosol index with the surface measurements of mineral dust concentrations. Attention should be paid to the fact that the TOMS measurements are at a single time of day (typically 11:30 AM), while the aerosol measurements tend to be longer-term averages (either one hour or nighttime). The location of the focused field campaigns to be carried out over the next few years has yet to be determined, but will probably emphasize aerosol measurements in "hot spots" - regions of expected aerosol sources.

Information on detection of volcanic ash using TOMS was summarized by **Nickolay Krotkov** of Raytheon STX, Inc., based on work he has done in conjunction with science team member Arlin Krueger. A case study examined was that associated with the eruption of Mt. Spurr in Alaska in August 1992. TOMS and AVHRR made measurements almost simultaneously on August 19, so direct comparisons of their observed aerosol field should be possible. One difficulty with such observations is that the particle size distribution is not known. The satellite systems were able to obtain information on the product of optical depths and the effective particle radius to give a column mass. There was good agreement between that calculated from TOMS and AVHRR, especially considering the significant error bars in the calculations. There appears to be significant potential for TOMS ash measurements to be able to provide information on total ash amounts from large volcanic eruptions. For some large eruptions, especially when plumes are in cloud-free regions, comparisons of TOMS ash amounts and sulfur dioxide columns may be carried out.

The comparison of TOMS measurements of surface UV radiation, total ozone, and cloud properties, with ground-based measurements at a single station in the U.S. Southwest (Socorro, NM), was presented by **Ken Minschwaner** of the New Mexico Institute of Mining and Technology. A Biospherical Instrument radiometer (GUV-511C), which combines a quartz teflon diffuser plate with 5 detectors (305, 320, 340, 380 nm and one measuring photosynthetically active radiation or PAR) in a temperature controlled jacket, is used at Socorro. This instrument was calibrated at the manufacturer before shipping and is recalibrated annually there against a double monochromator instrument. Its location in New Mexico means that it has cloud-free viewing conditions over much of the year. Comparison of the ground-based and TOMS ozone and UV measurements shows reasonable agreement. The ground-based measurements have also been used to measure the radiative amplification factor, and will be used to determine the direct/diffuse flux in solar radiation. These measurements can be useful in testing the algorithm used by TOMS for its surface UV measurements.

The use of TOMS data to study UV reflectivity of clouds, as well as the use of mountain-surface level differentials to help characterize total ozone distributions, were discussed by **Yuk Yung** of the California Institute of Technology. A long-term study on cloud optical thickness variations during the period from 1983 to 1991 was carried out using both TOMS UV reflectivity data and monthly mean cloudiness data from the International Satellite Cloud Climatology Project. The region emphasized in these studies was the Inter-Tropical Convergence Zone. The relationship between these two data sets, which are similar but not identical (and are based on different wavelength regions), is in the process of being understood. The origins of the variability observed over time are not yet known, especially the relative contributions from the solar cycle and from periodic El Niño events. The tropospheric ozone studies emphasized the region of

Taiwan, which is a mountainous region off the east coast of Asia. TOMS data were used to determine tropospheric ozone through use of the mountain effect technique noted above; results show evidence of significantly higher tropospheric ozone on the west (Asian) side than the east (Pacific) side of Taiwan. Long-term studies suggest a small increase in tropospheric amounts over the length of the TOMS record. Although this increase is quite small in an absolute sense, it is large in a percentage sense (1-2% / year).

The contribution of dust in forcing of climate as inferred by studies of meteorological data assimilation products was discussed by **Pinhas Alpert** of Tel Aviv University in Israel. The motivating question behind this work is to understand whether the neglect of dust in climate models is an important source of error. By comparing dust distributions over the Atlantic Ocean with the residual errors obtained in GSFC's data assimilation model over the Atlantic, it was shown that dust appears to be a non-negligible source of error in atmospheric climate models (where dust is most often present, there are larger errors in the assimilation system than in dust-free regions; such a relationship is seen to vary seasonally and spatially with dust loading). The initial work did not use TOMS data, but now the TOMS data are beginning to be used, and clear correlations between the TOMS aerosol index and the errors in the assimilation are seen. This is true over Africa, South America, and the region near China, all of which have large amounts of biomass burning. TOMS and surface observations of a large dust storm in the middle east in March, 1998 were also shown.

Analysis of TOMS data taken over South America and adjacent regions, and comparison with ground-based data from Latin America were presented by **Ruben Piacentini** of the Rosario Observatory in Argentina. The presence of high levels of surface UV flux in South America is well established. In one recent case, the total solar irradiation measured at the Earth's surface was well above the "solar constant" because of the contribution of broken clouds, leading to multiple scattering / reflection. Comparisons of total ozone measured from EP TOMS with measurements made from Dobson stations are typically quite good, although differences at higher latitudes, especially Ushuaia, Argentina and the Argentine Antarctic station in Marambio, can be somewhat larger. An event leading to low ozone amounts in the Austral autumn of 1997 was shown. This is similar to the "mini-hole" events seen in the Northern Hemisphere, and was observed by three different Dobson instruments in South America.

NSIDC DAAC User Working Group Meeting, also known as Polar DAAC User Working Group (PoDAG)

— David H. Bromwich (dbromwic@magnus.acs.ohio-state.edu), Co-Chair, PoDAG, National Snow and Ice Data Center

The thirteenth meeting of the PoDAG group was held at the University of Colorado, Boulder, Colorado on 19-20 March 1998. Below are reported the recommendations, action items and minutes of this meeting. Please consult the PoDAG Web site for a copy of the agenda and some of the presentation materials (http: / / www-nsidc.colorado.edu / NASA / PODAG /).

PoDAG Recommendations

1. The National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center DAAC should produce a CD-ROM for distribution at national and international scientific meetings to publicize the existence and capabilities of the Polar Pathfinder data sets. The content should sample the passive microwave, AVHRR (Advanced Very High Resolution Radiometer), and TOVS (TIROS Operational Vertical Sounder) products for a limited period, mapped to the same coarse-resolution grid (100 km), the so-called P-cube. In addition, the CD-ROM should include an illustrative sample of high-resolution products. The target

availability is for distribution at the American Meteorological Society Fifth Conference on Polar Meteorology and Oceanography in Dallas, Texas in January 1999.

2. NSIDC should continue to collect and process the "standard" Polar Pathfinder data sets (passive microwave, AVHRR, and TOVS) so that there is a minimum of a 1-year data overlap with corresponding products from the first EOS (Earth Observing System) satellite.

3. NSIDC should distribute all of the Equal Area SSM/I Earth (EASE)-grid passive microwave data using a methodology and media, which consider not only cost but also which best serves the needs of the user community. The specific media and methodology, which may well change over time, will be determined by NSIDC. NSIDC will also continue to distribute all the Special Sensor Microwave/Imager (SSM/I) passive microwave data on polar stereographic grids (SSM/I Grid) in the most cost-effective manner.

4. NSIDC should assess user needs for distribution media.

5. PoDAG recommends the inclusion in the NSIDC archive of the Comiso Antarctic surface temperature data set from AVHRR observations.

PoDAG Action Items

The following action items were noted. The individual responsible and approximate due date are in parentheses after the item.

1. NSIDC should provide an explanatory statement for all data sets (Parsons, 8/1/98).

2. NSIDC should resolve the possible confusion between its real-time snow-ice product (NICE) and the real-time product produced by the National Weather Service (R. Grumbine). NSIDC should make the NICE product available on its Web page for evaluation. NSIDC should provide a description of the NICE product and provide a link to R. Grumbine's site for real-time ice concentrations (Nolin, 6/1/98).

3. At the next PoDAG meeting, members should become better informed about the validation of cryospheric data from EOS sensors. Relevant scientists from the instrument teams and the interdisciplinary science projects should be invited to brief PoDAG Members (Steffen, Weaver, 8/1998).

4. Ron Weaver should circulate the strategic management plan for DAACs to PoDAG for evaluation and comment (Weaver, 5/15/98).

5. Jim Maslanik should contact all groups generating sea-ice-motion vectors from remote-sensing data to evaluate coordination of efforts and avoidance of duplication (Maslanik, 7/1/98).

6. Roger Barry should identify discipline areas not represented on PoDAG and potential candidates to fill these slots. The results should be circulated to PoDAG by email for evaluation and comment (Barry, 7/1/98).

7. Drew Rothrock will draft a letter to Vincent Salomonson about the desirability of the MODIS instrument team producing global analyses of surface temperature and surface albedo (Rothrock, 6/1/98).

Minutes of the 13th Polar DAAC Advisory Group (PoDAG)

Overview - Prasad Gogenini, NASA Headquarters Program Scientist

1. The long-term goals and present budgeting of the Polar Program were outlined. The results of the Research Announcement for studies of Arctic atmosphere-ocean-sea-ice interactions and Greenland Ice Sheet mass balance (July 1997 submission date) were summarized with 21 projects being funded. A $2.3 M combined NASA-NSF Research Announcement with a May 1998 deadline for similar studies in the Antarctic was discussed. Action is needed to conform to the Government Performance Review Assessment Act, and an activity report will be compiled within the next six months.

2. NSIDC Update Since Last PoDAG Meeting (#12) - Ron Weaver (Viewgraphs available on PoDAG website)

   a) *Major Data Set Releases, June 1997- March 1998*

Digital Synthetic Aperture Radar (SAR) mosaic and elevation map of the Greenland Ice Sheet. A variety of passive microwave brightness temperature, sea ice concentration, and snow extent data sets were updated and made available.

Three Arctic radiosonde archives.

Former Soviet Union monthly precipitation archive, 1891-1990.

b) *Major Accomplishments in Data Support*
National Research Council (NRC) review—see item 2 (c).

Sea ice data assimilation workshop (reported as item 7 below).

Snow cover algorithm workshop—see item 2 (d).

Review of Polar Pathfinder data sets.

Completion of assessment of "Application of satellite remote sensing techniques to the study of frozen soils."

c) *NRC Review*
Focus was on the state of readiness for the EOS Core System (ECS). What happens if there is some degree of failure?

Measures of performance were evaluated.

NSIDC-provided materials are on the NSIDC Web page.

NRC is requesting responses to a questionnaire.

d) *Snow Cover Algorithm Workshop*
12 invited participants met in Boulder in August 1997.

Purpose is to encourage collaboration and synergy in algorithm development and testing.

Identified common input data sets.

Collaborations continuing via the Web.

Second meeting scheduled to follow IGARSS'98 meeting in Seattle, July 1998.

e) *ECS Accomplishments*
Version 2 equipment installed.

Preparations are being made for delivery of ECS software.

f) *DAAC Overguide Proposal Status*
User impact assessment study—draft completed.

DAAC-wide electronic publishing has been initiated.

DAAC yearbook contributions are continuing.

g) *Users*
A broad range of requests by discipline and user sophistication.

Percentage of first-time users has increased steadily over the past few years.

3. Assessment of Ice Surface Temperature Data Set Developed by J. Comiso (reported by Ted Scambos)

The ice-surface-temperature data generated by J. Comiso were reviewed for possible distribution by NSIDC. The data are monthly mean temperature data for January and July for the 17-year period 1979-1996 for the continental ice sheet of Antarctica, using AVHRR resampled to 6.25-km grid spacing (in the SSM/I polar stereographic projection). An extensive comparison of the data with air temperature data from the Antarctic stations indicated a slight bias and a standard deviation of ~ 3K. However, it is speculated that this rather high standard deviation (relative to ocean surface temperature measurements using AVHRR) may be a result of a combination of differences between skin and air temperature, the difficulties in comparing point data with 6-km pixels (particularly in the vicinity of coastal stations), and some cloud contamination. A comparison of the temperature data with more-remote AWS stations was suggested. It was agreed that the data set would be a valuable addition to the products currently offered by NSIDC, and a complement to the upcoming Polar Pathfinder products. T. Scambos undertook to contact J. Comiso to acquire the products.

4. MODIS Snow and Ice Products at NSIDC—Greg Scharfen

The context for the MODIS snow and ice products within the framework of other MODIS standard products (approximately 44 products developed by 32 Principal Investigators at 20 institutions, and processed at 3 DAACs) was summarized. The snow and ice products will be available in orbital and gridded formats, and as daily, 8-day, or monthly composites. Current improvements to the snow and ice products include sea ice-surface temperature and use of a vegetation index to improve performance of the snow algorithm in boreal forests. A snow albedo product may be implemented after the launch of the instrument. NSIDC is preparing for launch by participating in science software integration and test activities and operations test scenarios, and by developing operations agreements with external interfaces. Facilities upgrades are in progress. Production will be phased in at the DAACs over several months. Quality assurance of products will be split, depending on the type of activity, among the MODIS Team and the DAACs. The MODIS Team and NSIDC are discussing the provision of the snow and ice products to selected operational users on a near-real-time basis. The MODIS Team has requested that the snow and ice products be available in the EASE-polar grid. ESDIS Project must approve the needed processing and network resources before this can happen.

5) Discussion of the Polar Pathfinder Data Sets

NSIDC was charged with handling the distribution and some generation of Polar Pathfinder data sets from within existing resources.

A review of the NSIDC budget revealed that the standard Polar Pathfinder products (passive microwave, AVHRR, and TOVS) could be generated (as needed) and distributed with existing resources for the next 2-3 years.

The funding for most Polar Pathfinder projects ends in September 1998. There are limited funds in the Polar Program for extensions. A new Pathfinder NASA Research Announcement (NRA) is expected to be released in summer 1998 for funding in spring 1999.

There was a general discussion of costs in relation to the media. It was generally recognized that charging users for reproduction of products was not practical. However, it was recognized that NSIDC needed to make sure that users receiving CD-ROMs regularly communicate their desire to continue receiving these products. NSIDC was encouraged to explore alternative cost-effective approaches for distributing products including FTP and DLT tapes.

There was extensive discussion of the need for a major effort to publicize the existence and availability of the Polar Pathfinder data sets to broaden the user community. Strong support was expressed for the idea of a sampler CD-ROM illustrating the capabilities of the standard Polar Pathfinder data sets on the same coarse resolution grid (100 km), the so-called P-cube, and including a representative sample of high-resolution products. Access tools should be included on the CD-ROM. The CD-ROM should be distributed at the American Meteorological Society's Fifth Conference on Polar Meteorology and Oceanography at Dallas, Texas, in January 1999. The International Union of Geodesy and Geophysics meeting at Birmingham, United Kingdom in July 1999 was another desirable distribution venue. Papers in journals and presented at scientific meetings are other publicity activities. The need for a long-time series from P-cube was emphasized.

Altimetry data for the polar ice sheets is an unresolved Polar Pathfinder problem and is not considered in the present budget scenarios for the Polar Pathfinders. Program Manager Prasad Gogenini will assemble a study team to review the current altimetry data processing, archiving, and distribution efforts by Dr. J. Zwally and colleagues.

RAMP (Radarsat Antarctic Mapping Project) data were not considered because of evolving limitations on usage.

6. AMSR-E Report from the Instrument Team—Don Cavalieri

Level 2 products will be sea ice concentration (21 km resolution), sea ice temperature (58 km), and snow depth on sea ice (21 km). Level three products will be produced on a polar stereographic projection (SSM/I grid) and include daily averaged brightness temperatures at three resolutions (25, 12.5, and 6.25 km), daily sea ice concentrations and sea ice temperatures at 25 km, and 5-day averaged snow depth on sea ice maps at 25 km.

7. Recommendations from the Sea Ice Data Assimilation Workshop held at NSIDC in December 1997—Ron Weaver

The objectives were to assess which data assimilation techniques are applicable to regional sea ice models and / or sea ice parameterizations in atmospheric and oceanic GCMs (general circulation models), and to guide NSIDC in the development of data sets for sea ice monitoring in both Polar Regions.

The primary recommendations were to take an incremental approach to assessment of the impact of data assimilation on sea ice simulations, to conduct a pilot study using simple data assimilation models, and to investigate the coordination of research and operational efforts to make more efficient use of resources. Secondary recommendations included: use of data assimilation only in conjunction with accurate error statistics; more emphasis on error assessment of radiances, data and models; much of the assimilatable data are available at 1-3 day intervals, and archival systems will need to be reconfigured if more-frequent inputs are needed; data sets must carry time tags for each pixel because actual observation time is essential in data assimilation; and a passive microwave test data set with error assessment and time tags for each orbit should be made available on FTP by NSIDC.

8. CRYSYS Interdisciplinary Investigation Update
   Barry Goodison

The project is in the strongest state ever, and is the focus of cryosphere-climate studies in Canada. Radarsat-2 is scheduled for launch in 2001 as a primarily private sector effort. There are unresolved data access questions for interested government agencies. A CD-ROM containing extensive historical snow cover and snow depth observations in Canada is about to be released. The cost will be around $C 150. Finally, the World Climate Research Programme is developing a global cryosphere and climate project including, for example, permafrost and mountain glaciers in addition to the Polar Regions.

There was discussion of a possible joint meeting of CRYSYS and PoDAG in Montreal during October 1998.

9. Global Land Information and Modeling System (GLIMS) Update—Bruce Raup (via written communication)

   a) *Data Acquisition*
   The map of global land ice compiled by GLIMS is reasonably complete. The ASTER Scheduler for data acquisitions will rely on a simple threshold algorithm to detect cloudiness in acquired images. Automatic re-acquisition will be scheduled for cloudy images. This approach will likely fail for snow- and ice-covered areas, and manual cloud assessment will be used for these areas. The ASTER Scheduler is complicated and may not be efficient; prioritization of glacier targets will probably be needed, and input from the glaciological community will be sought.

   b) *Organizational Status*
   Collaborators (11 at present), either in the form of Regional Centers or Stewards, continue slowly to sign up.

   c) *Technical Status*
   Software development for image classification and delineation of glacier boundaries is behind schedule because of other demands. Development continues on the GLIMS database, which will hold GLIMS analysis products at NSIDC. Prototype software has been developed to generate digital elevation models from ASTER stereo imagery.

Summary of Chemistry/Climate Modeling Meeting

— Jack A. Kaye (jkaye@hq.nasa.gov), Office of Earth Science, NASA Headquarters, Washington, DC
— David Rind (drind@giss.nasa.gov), NASA/GISS, New York, NY

A meeting of representatives of instrument teams and interdisciplinary investigators in the Earth Observing System (EOS) program, as well as scientists in other NASA research programs, working in the areas of global modeling and analysis of tropospheric chemistry and tropospheric aerosols was held at the Goddard Institute for Space Studies (GISS) in New York City on May 14-15, 1998. The meeting brought together some 40 investigators, including many added to the EOS program in 1996 following the NASA Research Announcement (NRA) soliciting additional interdisciplinary investigations issued that year. The primary purposes of the meeting were to bring together the tropospheric chemistry and aerosol modeling communities supported by NASA (regardless of which program provided their support) and to ensure that scientists doing both global-scale modeling and space-based measurements on these quantities were aware of all the work supported by NASA in these areas. David Rind of GISS was the chair for the meeting; Jack Kaye of NASA HQ worked with him in setting up the meeting.

The meeting began with **Yoram Kaufman** of NASA/GSFC, Project Scientist for the first EOS spacecraft (EOS AM, launch scheduled no earlier than December, 1998) describing aerosol data that would come from two instruments - the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Multi-Angle Imaging SpectroRadiometer (MISR). The latter was given on behalf of MISR aerosol scientist Ralph Kahn of JPL, who was unable to attend the meeting. MODIS will provide data on aerosols over both land and water by use of a wide range of spectral information covering the wavelength range from 0.4 to 1.4 μm. For aerosol measurement over land, the MODIS team will make use of "dark pixels." The aerosols have a relatively small effect at 2.1 and 3.7 μm, allowing surface properties to be detected, and the relationship between the radiances at these wavelengths and those in the visible (0.47, 0.66 μm) is thought to be well understood. Aerosol reflectance decreases with wavelength, but more so for sulfate than sea salt or smoke, allowing for some discrimination among the aerosol types. Cirrus clouds provide a major complication in MODIS analysis; their presence can be detected through use of a channel at 1.37 μm, although this coincides with a water absorption channel. Additional problems involve limitations on the number of different types and modes capable of being retrieved (currently a maximum of two). A key element of MODIS science will be comparison with surface-based measurements, notably those from the Aerosol Robotic Network (AERONET) of ground-based measurements which measure column integrated properties.

Aerosol measurements from MISR rely on its use of angular information, as 9 different directions are sampled. Therefore, over a period of a few minutes, 9 different observations of the same location are observed covering a range of measurement angles from -70 to + 70 degrees. MISR uses four spectral bands; there is therefore excellent complementarity between MISR's emphasis on angular information with MODIS's emphasis on spectral information, although the angular signal may be more difficult to deconstruct. MISR measures with a 360 km swath width allowing for 9-day global coverage. Among the information to be obtained by MISR are aerosol particle types over cloud-free calm ocean locations, aerosol optical depths to 0.05 or 10%, whichever is larger, for all common types of aerosols except soot, some sense of particle size (small, medium, or large), indices of refraction, and some sense of particle shape (spherical vs. nonspherical, which may be sufficient for differentiating large desert dust particles from others).

P. K. Bhartia of NASA/GSFC, Project Scientist for the EOS CHEM spacecraft, first briefly reviewed the three well-known instruments (HIRDLS, MLS, TES) to be launched in December 2002. He then spoke about a fourth instrument, referred to as the "Imaging Spectrometer" to be provided by the government of The Netherlands (with participation from Finland). The commitment from the Dutch government was only recently received. Some of the details of this instrument are yet to be determined, but it is expected that it will continue the data record from the Total Ozone Mapping Spectrometer (TOMS) series of instruments, including daily global measurements of total column ozone, UV flux, volcanic sulfur dioxide and ash, UV absorbing tropospheric aerosols. This new instrument is expected to have many more spectral channels than TOMS, however, and to cover a much broader wavelength region. Excellent spatial resolution should be obtainable through use of an imaging detector, and instrument reliability should be high because of the absence of moving parts. The finer horizontal resolution should reduce the effects of cloud contamination in a single pixel, which is a non-negligible problem given the spatial resolution of the current TOMS instrument. Work in progress includes the attempt to improve the instrument's horizontal resolution to 5 km (in the nadir), and to extend the long wavelength limit from its current 450 nm to 780 nm. Bhartia reviewed recent results from the current TOMS instrument for both tropospheric aerosols and tropospheric ozone; the latter of these requires the use of either some assumption about the distribution of either stratospheric ozone or total ozone, such as using the ozone column above convective regions to define stratospheric ozone amounts. Employing this technique, he concluded that in 1997 tropospheric ozone was greater over the Atlantic and less over the Pacific, anticorrelated with MLS 215 mb water vapor, perhaps due to biomass burning.

Joe Waters of the Jet Propulsion Laboratory discussed plans for the Microwave Limb Sounder (MLS) planned for EOS CHEM. This instrument will carry out "radio astronomy of the Earth" by passively measuring the microwave radiation emitted by trace constituents in the Earth's atmosphere. This instrument is a follow on to the current MLS instrument flying aboard the Upper Atmosphere Research Satellite (UARS), but has several improvements, including design to include upper tropospheric measurements (water, temperature, pressure, ozone, carbon monoxide, cirrus clouds), measurement capability for additional trace constituents (OH, HO_2, HCl, BrO, HNO_3, CO, HCN, and HOCl, as well as a dynamical tracer N_2O), better global coverage (measure daily between 82 degrees N and S), improved vertical resolution (2-3 km, roughly a factor of two better than the UARS MLS), and improved horizontal coverage (limb scans every ~170 km instead of ~500 km as for UARS). Results of the UARS MLS instrument for upper tropospheric water vapor were also shown, including clear evidence for an El Niño signal in upper tropospheric water vapor. A limiting factor anticipated for quantitative analysis of EOS CHEM MLS tropospheric data is the lack of knowledge of continuum absorptions for dry air and water vapor needed to more accurately obtain tropospheric parameters (current empirical expressions are thought accurate to around 20%). The ability to measure upper tropospheric temperature is resolution dependent: with 3 km resolution, zonal temperature retrievals of 0.1° C are thought possible, but this degrades to 1° C when 2 km retrievals are employed. For the sake of measuring trends, it was suggested that the former choice is preferable.

David Edwards of the National Center for Atmospheric Research spoke about the High Resolution Dynamics Limb Sounder (HIRDLS) instrument planned for EOS CHEM. The key aspect of HIRDLS is its ability to determine trace constituent profiles with ~ 1 km vertical resolution. Vertical profile information should extend from the stratosphere down into the upper troposphere. There are several aerosol channels in spectral window regions in order to get good aerosol information, as well as the trace constituent measurement capability (emphasizing long-lived tracers but also including a fairly comprehensive measurement of nitrogen-containing species). HIRDLS can make up to six azimuth scans in short order as it moves along the orbital track providing essentially global coverage in 24 hours. This type of coverage is unique to HIRDLS. The HIRDLS instrument also has programmable science modes, including one with one degree by one degree horizontal resolution that can be obtained if one is willing to sacrifice the cross-orbital track measurements.

The Measurements of Pollution in the Troposphere (MOPITT) instrument to fly aboard the EOS AM spacecraft was described by instrument PI, **Jim Drummond** of the University of Toronto. MOPITT is to fly on the EOS AM-1 spacecraft and is provided by the Canadian Space Agency (CSA). The objectives of

MOPITT are the determination of the vertical profile of carbon monoxide (CO) in the troposphere and a total column measurement of methane. CO accuracy is estimated at 10% (tropospheric variation of about 5x). Methane accuracy is 1% (total column variation of about 5%). For CO, channels at both 2.2 and 4.4 µm will be used - the former, mostly affected by surface reflection of solar radiation, can be used only in daylight, but provides column integrals (for both CO and CH_4). The latter uses thermal emission and can thus be useful for both day and night retrievals. Due to the difficulty of measuring the profile near the surface, near surface values of CO are obtained by comparing the column integral (at 2.2 µm) with the vertical profile (at 4.4 µm). The CO profile in the 0 to 15 km region should be able to be measured with vertical resolution of approximately 3-4 km (3 levels in troposphere). The horizontal resolution will be 22 x 22 km, with successive measurements being made at 0.4 second intervals. Nearly global coverage will be made every 4 days, but clouds will interfere with measurements reducing the potential viewing opportunities.

The Stratospheric Aerosol and Gas Experiment (SAGE) instruments were described by **Pat McCormick** of Hampton University. The currently operating SAGE II instrument, flying since 1984 aboard the Earth Radiation Budget Satellite (ERBS), has provided long-term measurements of the distributions of ozone, water vapor, aerosols, and nitrogen dioxide. These data have been particularly useful for helping to define the long-term trend in stratospheric ozone, especially in the lower stratosphere (perhaps down to 17 km), as well as long-term variations in stratospheric aerosol, loading. Stratospheric aerosol column loadings seen recently are the lowest yet observed by SAGE II, including the pre-Pinatubo values. The new SAGE III instrument planned for EOS was also described. This will have numerous enhancements over the SAGE II, including added wavelengths, much higher spectral resolution, and direct measurement of temperature and pressure so that external information is not needed to convert from the measured number density vs. altitude to the mixing ratio vs. pressure more commonly used by atmospheric scientists. SAGE III also has a lunar occultation capability designed to measure OClO and NO_3 at night. The first SAGE III instrument is planned to fly aboard a Russian Meteor-3M spacecraft in 1999 and the second aboard the International Space Station in 2002. A third SAGE III instrument is being constructed but is currently unmanifested as a "flight of opportunity" is sought. A flight aboard a Russian RESURS spacecraft in 2000 is a distinct possibility, although no commitments have been made for this flight at this time.

Daniel Jacob of Harvard University presented a summary of the Tropospheric Emission Spectrometer (TES) planned for the EOS CHEM spacecraft. TES is a Fourier Transform Spectrometer, measuring in the 650 to 3000 cm^{-1} wavelength region using both nadir and limb viewing geometries; spectral resolution is 0.025 cm^{-1} in the limb mode and 0.1 cm^{-1} in the nadir mode. The primary focus of the TES instrument is the measurement of ozone and its precursors in the troposphere, although TES has excellent capability for detecting a broad range of species because of its high resolution. In its nadir viewing mode, TES should be able to get 3-4 km vertical resolution if single pixels are considered; if averaging over multiple pixels, better vertical resolution should be possible. Besides ozone, carbon monoxide and water vapor should be measurable in nadir mode. In limb mode, with 2-3 km vertical resolution, these species as well as some nitrogen-containing species should also be measurable. Nitric acid should be measurable through most of the troposphere in this mode, while nitrogen dioxide is likely only to be measurable where it is present in elevated amounts (e.g. due to air pollution), and nitric oxide retrieval is only likely in the upper troposphere where concentrations exceed approximately 100 pptv, which corresponds to the standard background level (if one is willing to average over successive spectra, increased sensitivity can be obtained). Ozone measurements can conceivably be made down to the surface, and carbon monoxide measurements should be usable down to the planetary boundary layer. However, in most cases profiles will not extend below approximately 5 km. An airborne version of the TES instrument has flown several times, notably as part of the Southern Oxidant Study in 1995. Species detected included ammonia, methanol, and formic acid; high CO was observed over downtown Nashville. It was noted that validation of some species may be difficult due to lack of independent measurements.

Vertical profiles of ozone, water vapor, and clouds obtained by the Differential Lidar (DIAL) technique were described by **Bill Grant** of the Langley Research Center, on behalf of the principal investigator Edward

Browell. In particular, observations of water vapor from the LASE instrument originally designed for ER-2 use but now being modified for the DC-8 (including both upward and downward viewing) were described. There is long term interest in evolving the DIAL technique for space-based measurements, but it is expected that this may take 5-10 years before being practical. Wavelength regions suitable for stratospheric and tropospheric ozone are 305-315 nm and 308-300 nm, respectively. For aerosol and cloud studies, the 820 and 940 nm spectral regions are of greatest potential use. In initial application, space-based DIAL would probably involve purely nadir pointing, although it would be desirable to have side scanning in order to obtain increased horizontal coverage. Specific case studies discussed include an O_3 bulge off of Africa, and low O_3 values in both the boundary layer and upper troposphere over the Pacific.

An EOS interdisciplinary effort on the integrated impact of urban areas on tropospheric trace gas burdens was described by **Mark Zahniser** of Aerodyne Research Inc. on behalf of investigation principal investigator Chuck Kolb. The investigation focuses on several different types of species, including gaseous smog precursors, greenhouse gases which provide for direct and indirect radiative forcing, photochemical oxidants, aerosol precursors, and particulates. Geographical information system (GIS) techniques are used to help relate known information about land surface properties (including land use characteristics), knowledge about population and industry distributions, and topographic and meteorological information to observed trace constituent concentrations. Measurement capability for Aerodyne's mobile laboratory include a HeNe methane monitor, an infrared carbon dioxide monitor, an electron capture detector gas chromatograph for sulfur hexafluoride, a condensation nucleus counter, and a tunable diode laser which can be used for simultaneous measurements of several species (e.g. nitric oxide, nitrogen dioxide, ozone). Results shown for Manchester, New Hampshire using SF_6 as a tracer, indicated the buildup for CO_2 (with levels up to 450 ppm) as well as high methane values over a landfill and a sewage treatment plant. Several campaigns are planned for Manchester in the coming few months. Subsequent field studies are planned for the larger urban area of Boston, Massachusetts.

Jim Hansen of the Goddard Institute for Space Studies reviewed the sources of changes in radiative forcing that have occurred and what is believed to be their effect on climate. Key information needed includes the exact nature of changes in the vertical distribution of ozone (especially to see if increases in tropospheric ozone may have countered decreases in stratospheric ozone in their contributions to radiative forcing) and the nature of aerosol particles (especially single scattering albedo) as well as their height. With reasonable estimates of aerosol absorption, aerosol cooling is reduced from previous assessments. Although changes in methane amounts are well characterized, their variability is not well understood, and accurate future predictions require that future methane amounts be well modeled. The observed long-term change in diurnal temperatures is best modeled in terms of corresponding changes in cloudiness, although these have not been detected. The effect of changes in vegetation and land use on the climate system may be significant, although this has not been well characterized. It is also possible that when looking at the last 150 years the net effect of changes in solar irradiance on the climate system may not be negligible relative to the sum of all other changes. In the longer term, changing aerosol distributions due to increased Asian development are likely to be important to the climate system.

An interdisciplinary study to characterize aerosol forcing over the Atlantic Basin was summarized by **Brent Holben** of NASA/GSFC. This investigation focuses on the improved knowledge of direct aerosol forcing through analysis of satellite measurements, focused *in situ* and remote sensing measurement campaigns, long-term ground based measurements, and aerosol models. Key data sets include the TOMS and Advanced Very High Resolution Radiometer (AVHRR) satellite data sets, the ground-based AERONET and Baseline Surface Radiation Network measurements, and aircraft campaigns such as TARFOX, SCAR-A/SCAR-B, and ACE II. The biggest uncertainty in interpreting existing data is the lack of information on the vertical distribution of atmospheric aerosols. Observations of aerosol thickness for some 800 days at Goddard found a distinct seasonal cycle, with values ranging up to 0.5 (at 0.5 μm) amid much variability in summer, and 0.1 in winter.

Studies of the use of satellite measurements to determine the effect of smoke particles on clouds and climate were reviewed by **Yoram Kaufman** of NASA/GSFC. Over the ocean, spectral information can be used to help get size information on aerosol particles, but over land the aerosols affect the outgoing radiation and the problem is much tougher. Cloud information can be obtained in the infrared (3.75 μm) but this may only pertain to some parts of the cloud. The indirect effects of smoke on clouds remains a difficult problem. The obvious response of clouds is to brighten in the vicinity of fires, especially in regions of high precipitable water. At relative humidities in excess of 90%, some particles are very effective as cloud condensation nuclei, although not as good as sulfates. It is clear that cloud effects of smoke can occur far from the areas of emissions, given an approximate 5 day time constant for smoke.

A newly initiated investigation of tropospheric trace gas budgets and their interactions with aerosols was described by **Joyce Penner** of the University of Michigan. In prior work, three dimensional distributions and specified size distributions were calculated for different types of aerosols (aerosol sulfate, organic carbon/black carbon, dust, sea salt), from specified initial distributions for ammonium ion, ammonia, and water vapor. Future work will involve the calculations of partitioning of materials between the gas phase and aerosols, and understanding the implications of this partitioning for particle size distributions which govern dry deposition rates. Significant data needs include measurements of aerosol composition, especially if organic aerosols are to be understood and well simulated.

Bob McGraw of Brookhaven National Laboratory summarized work being done on the representation of aerosol microphysics in regional to global scale models. This work involves two parts - treatments of aerosol microphysics, including both basic nucleation and aerosol dynamics in complex flow fields, and the representation of aerosol transport and transfer in large-scale models, notably the Brookhaven three-dimensional model. A particular focus has been the study of sulfuric acid-water hydrates, including the temperature dependence of vapor pressure of sulfuric acid in these systems. The computational work centers on the use of the method of moments, in which particle size distribution information is carried without having an explicit representation of the nature of the size distribution. As implemented numerically, a quadrature method of moments approach is used. This approach is being implemented in the Brookhaven 3D transport and transformation aerosol model, which covers the latitude range of 81N-81S with a horizontal resolution of 1°x1° and 27 vertical levels from the surface to 100 hpa.

Steve Ghan of the Pacific Northwest National Laboratory (PNNL) described the PNNL MIRAGE (Model for Integrated Research for Atmospheric Global Exchange), a global model developed to estimate direct and indirect forcing by anthropogenic sulfate aerosol. MIRAGE couples PNNL's version of the Community Climate Model (CCM2) (with cloud microphysics coming from the Colorado State University's RAMS model), with the PNNL global chemistry model. Results for July-August, 1994 suggest that the total radiative forcing due to aerosols is -2.7 W m^{-2} (-0.8 direct, -1.9 indirect), although there is significant temporal variability in this number because of variability in clouds. Comparison of simulated and observed "aerosol radiance" suggests the direct forcing estimate is too high; the explanation for the bias has been identified as a bias in the simulated relative humidity, which influences water uptake on soluble particles.

Efforts to develop an "event oriented" study of atmospheric aerosols using global models were summarized by **Brian Toon** of the University of Colorado and members of his research group. Particular foci of his group's efforts include algorithm development for aerosol microphysics, studies of direct aerosol effects, examining of the relationship of atmospheric chemistry to aerosol formation, and investigations of indirect effects of aerosols on both stratus and cirrus clouds. A variety of numerical models are used for these investigations, including the MATCH model from NCAR, the NASA/Ames Research Center stratospheric dynamics model, the NOAA/NCAR two dimensional stratospheric chemistry model, and a 3D local event simulation model used for stratus cloud studies. Key data sets utilized include SAGE II, AVHRR, and UARS. Concern is also focused on the effects of optical properties of dust (including, for instance, the role of iron on visible absorption, which is variable in concentration but dominant when present, so that no set of optical constants is appropriate everywhere). Non-volcanic stratospheric aerosol studies were summarized by **Mike Mills**, who found through use of a version of the NOAA/NCAR 2D model modified to include sulfur chemistry and aerosols (45 size bins) that observed aerosol distributions in the lower stratosphere could not be understood solely on the basis of carbonyl sulfide but rather required the considering of sulfur dioxide and tropospheric aerosols. **Andy Ackerman** reported on comparisons between theory and measurements of cloud susceptibility from the Monterey Area Ship Track (MAST) experiment, and also used large-eddy simulations with explicit microphysics to show that boundary layer depth and cloud fracitonal coverage depends strongly on cloud droplet concentrations under very clean conditions.

Ina Tegen of Columbia University described work carried out on soil dust aerosol modeling. After sulfates, soil dust, especially mineral desert dust, is the second largest contributor to atmospheric aerosols. Long-term studies on the troposphere should look at long-term changes in dust loading, including whether or not there is any dynamical feedback between dust concentrations and dust lofting. Interannual variability in dust can be simulated through the use of meteorological models simulating phenomena such as El Niño and the North Atlantic Oscillation that may affect atmospheric dust distributions. The GISS GCM contains four size classes for aerosol particles, and assumes a fairly simple relationship between deflated dust mass and surface wind velocity, with consideration of effects of soil types and surface wetness. Dust concentrations calculated with the model were compared to those of observations. Both the model and observations showed significant interannual variability, but the model did not get the seasonal cycle on dust right in all locations. In particular, the model did a poor job in estimating the seasonal cycle of Saharan desert dust, underestimating summertime dust in Izana and Barbados, perhaps due to underestimation of surface winds in coarse GCM grids. If one includes the radiative feedback on atmospheric dust, there is a 10-15% decrease in dust loading, especially over Asia, due to stabilization of atmospheric temperatures. Estimation of Saharan dust radiative forcing can range from +1 to -1 W/m^2 by changing the single scattering albedo by ±10%.

Studies of subvisible cirrus clouds using the interactive two-dimensional model developed at NASA/GSFC were described by **Joan Rosenfield**. Subvisible cirrus clouds have optical depths of approximately 0.01 and are seen in satellite data (notably the SAGE II climatologies developed by Pi-Huan Wang and coworkers). The GSFC 2D interactive model used allows for creation of subvisible ice clouds below the tropical tropopause when appropriate temperature and water vapor distributions exist for supersaturation to occur. The zonal variations in temperature that may be important in cloud formation are included based on analysis of meteorological data sets. Radiative heating of ice particles and changes in temperature and circulation are calculated with the model. A log normal size distribution is assumed. The net result of the calculations is that the subvisible cirrus lead to a heating of the tropopause region that allows more water vapor to enter the stratosphere. The smaller the size of the particles, the more heating takes place and the larger stratospheric response occurs. A 1-2° K temperature change led to an increase of 0.1-1 ppmv in stratospheric water vapor.

Radiative and chemical modeling of the troposphere and stratosphere carried out for NASA's Atmospheric Effects of Aviation Project were described by **Jose Rodriguez** of Atmospheric and Environmental Research, Inc. The effects of both a projected fleet of high speed civil transport (HSCT aircraft) and the current and projected future fleet of subsonic aircraft are considered. Both chemical effects due to aircraft-emitted nitrogen oxides and sulfate particles, as well as the climate effect due to these emissions and those of water vapor are considered. The numerical models designed to represent the response of the stratosphere to emissions of nitrogen oxides give a range of responses, but the ozone column changes tend to be fairly small (typically 0.1% in mid-latitudes, slightly higher in the polar regions), although some models actually suggest increases in ozone. A range of responses (~0.2 to 0.6 ppmv increases) in stratospheric water vapor was calculated. The models in which the largest increase in total inorganic nitrogen (NOy) were calculated also showed the largest increases in water vapor; curiously, models with the most realistic age of air in the lower stratosphere seem to have excessive NO_y. Tropospheric phenomena being investigated include the production of ozone from nitrogen oxides emitted by the aircraft, particle production (from sulfate and soot), contrail formation, and the role of other greenhouse gases, notably carbon dioxide. Nitrogen oxide levels in aircraft corridors can be enhanced by up to 50%, and maximum ozone increases of 10-16 ppbv are calculated for the aircraft corridor (maximum in summer, minimum in winter). There are significant limitations in the models used for these simulations, including relatively coarse resolution of the tropopause region, the uncertain magnitude of other sources of nitrogen oxides, such as lightning and convective transport of surface-produced gases, and unidentified sources of odd hydrogen in the upper troposphere, which may be important for converting nitrogen dioxide to nitric acid. Less is known about the impact of aircraft generated aerosols. The models suggest that the effect of aircraft-generated sulfur in plumes may be large, although the best estimate is that it is at the 5-10% level. It seem that aircraft generated particles will constitute only a small perturbation to total mass loading near the tropopause and to direct radiative forcing, although the small size of the particles means that the contribution to total particle surface area may not be negligible, meaning the contributions to heterogeneous chemistry and indirect radiative effects cannot be ruled out. An estimate of contrail extent is that they provide a global coverage of about 0.1%. The best estimate to date of the total radiative forcing due to aircraft effects is now ~0.02 W m^{-2}, although this could increase to something like 0.1 W m^{-2} by 2050. It is not clear whether any observable impacts have yet occurred.

The status of the Global Modeling Initiative (GMI) developed by AEAP to help support assessments of atmospheric effects of aviation was reviewed by **Doug Rotman** of the Lawrence Livermore National Laboratory. The GMI model is being developed for both supersonic and subsonic assessment applications. The GMI model is designed to provide several different representations of key model components and input data sets so that the sensitivity of calculations to different approaches can be understood. For instance, meteorological fields used as inputs include the data assimilation products developed by the Data Assimilation Office at NASA/GSFC, and winds from both the CCM2 from NCAR, and general circulation models (GCMs) from GISS (GISS model II/II'). Advection schemes include the flux-form semi-Lagrangian model of Lin and Rood, the semi-Lagrangian technique of Rasch and Williamson, and the second order moments scheme developed by Prather; the age of air in the upper stratosphere can vary by 2 years depending upon which scheme is used. Chemical schemes include those of Brasseur and Lamarck, ONERA, and a parameterization developed by Malcolm Ko and Clarisa Spivakovsky. Photolysis rates use a look up table technique developed by Randy Kawa, and "cold chemistry" driven by the presence of polar stratospheric clouds is simulated with the approach developed by David Considine. Comparisons of model results with satellite and ozone data, including an ozone climatology being developed by Rich McPeters and Jennifer Logan, are important efforts. Some of the modules have been modified to run on parallel computers in order to increase computational speed.

Guy Brasseur of NCAR described simulations of ozone and related chemical tracers being done with the Model for Ozone and Related Chemical Tracers (MOZART) at NCAR. This makes use of an off-line version of the most recent version of the NCAR Community Climate Model (CCM3), including T42 horizontal resolution (corresponding to 2.8 x 2.8 degrees), 25 vertical levels, a time step of 20 minutes, and 50 transported species. Comparisons with available data have been carried out and show that, for instance, calculated carbon monoxide distributions agree well with observations, but nitric acid is much less well modeled (model-calculated ratios HNO3/NOx are much greater than those observed). A simulation of changes in surface ozone since preindustrial time has been carried out, and results show that changes in ozone amounts of some 30-40 ppbv in July over the U.S. and much of Europe along with those of 20-30 ppbv over most of Eurasia have occurred. The average radiative forcing coming from these increases should be approximately 0.45 W m-2 (higher in the northern hemisphere, smaller in the southern hemisphere). Predictions for the future (2050) show the largest changes in surface ozone are likely to come in the tropics, with some seasonal dependence (July changes of 30-40 ppmv are largest in central America, the Middle East, and Asia, while January changes are larger in South America and Africa). In the upper troposphere, increases of close to 20 ppbv are suggested over the northern India/Himalayan region. When aircraft are included, similar increases are seen at high latitudes, so it is likely that the actual evolution of the troposphere will reflect a broad range of gases. The evaluation of tropospheric chemistry models is complicated by the limited information in the troposphere coupled together with its significant variability; a "climatology" of trace constituent measurements in the free troposphere is being assembled at NCAR, although even this may be sufficiently limited that it cannot fully represent the range of actual variability.

The Chemistry, Aerosols, & Climate Tropospheric Unified Simulation (CACTUS) effort was described by **Daniel Jacob** of Harvard University. The purpose of CACTUS is to improve our understanding of chemistry-aerosol-climate interactions through development of modeling tools incorporating fundamental representation of chemistry and aerosol microphysics. The present targets of the effort include the climate effect of changes in emissions of precursors to tropospheric ozone formation, the feedback of climate change on tropospheric ozone, the climate effects of changes in emissions of sulfate precursors, and the response of sulfate aerosols to climate change. The model used 24 on-line tracers of 90 species, the Fast-J photolysis code of Prather, and the SMV GEAR chemical solver. The strategy for cactus involves using the same chemical models on-line in the GISS Model II' GCM for climate change studies, and in a CTM using data assimilation fluxes from the GSFC DAO GEOS system for chemical model validation. Identical emission inventories, chemical reaction sets and solvers, deposition models, etc. would be used with both models. Calculations have been carried out for emissions corresponding to the 19th century, but the model cannot simulate the low ozone observed at European stations. The need for high vertical resolution in the tropopause region is being actively considered; a 23-layer version of the GISS GCM appears to have realistic tropospheric/ stratospheric exchange but runs some six times slower than the current 9 layer model. The simulation of aerosol sulfate is being carried out on-line at GISS, and the importance of including the ammonia is being investigated at the California Institute of Technology. Data from the SUCCESS mission carried out by AEAP provide an important data set for the analysis of the aerosol models.

A simplified but very fast chemical reaction scheme suitable for use with the suite of modeling tools developed for CACTUS was described by **Drew Shindell** of Columbia University. This scheme uses chemical families and so is sufficiently fast that it can be run rapidly within the general circulation model, allowing for interactive treatments of chemical effects on radiation and dynamics and numerous sensitivity tests. The present version of this scheme involves 9 advected constituents and families and a total of 51 reactions (including photolytic reactions). A major limitation of this scheme is its restriction to single carbon containing species only. Most of the results obtained to date were from a previously used 5-tracer version, which did a reasonable job in simulating the bulk features of tropospheric ozone distributions. This scheme needs to be integrated with other modules (emissions, deposition, lightning) so that it can be run more usefully in long-term simulations. Potential applications include comparisons with other models (e.g. the same GISS II' GCM but different chemistry from CACTUS, or different (ECHAM) GCM/CTM but similar chemistry, at Ultrecht, Holland), calculations of radiative forcing in interactive systems and for surface ozone, and agricultural and human health impacts.

Greg Carmichael of the University of Iowa presented results on the interaction between tropospheric trace gases and aerosol particles, notably possible reactions involving particulate nitrate, particulate sulfate, and dissolved oxidants. Considerable attention has been paid to the atmosphere near Asia, where there is high aerosol loading involving many different types of aerosols. Unfortunately, there are very few data available on size-resolved aerosol composition, although some data do exist near Japan. A regional scale model was used for much of the Asian studies, although a global model has also been used. The role of calcium in the aerosol particles is of special interest, and the fraction of calcium in soils has been shown to be highly variable. Dust sources have been calculated based on models including the effects of vegetation, moisture, and surface winds; different meteorological models have been used as inputs to these efforts. Model simulations of the day-to-day variability in dust loading have been reasonable but not perfect. A particularly interest episode was one measured during the PEM-WEST B mission, in which a small dust storm was sampled by the aircraft. A significant role was found for calcium (or carbonate) in the partitioning of nitrogen oxides - increasing calcium in the fine particle mode shifts nitrogen into nitric acid. Some experimental work has also been done to look at nitrogen dioxide on various surfaces, including elemental carbon and various oxides (aluminum, iron, titanium, calcium, and silicon). This type of reaction could affect the general model problem of excessive HNO_3/NO_x ratios in the troposphere. The effect of relative humidity on surface reactions with ions has also been studied.

Cloud processes of particles in gases in stratus clouds were described by **Graham Feingold** of NOAA. Boundary layer models incorporating dynamics, microphysics, and radiation were used for studies of local events. Both Eulerian (Large Eddy Simulation, LES) and Lagrangian (Transformed Ensemble Models, TEM) were used to study dynamics in and near clouds. The TEM model was also used with a cloud parcel model plus chemistry to simulate aerosol size growth. The distribution of sulfate, nitrate, ammonia, and hydrogen peroxide in air parcels were calculated, and the relative concentrations in parcels that went into and did not get into the clouds were studied. Particular application has been made to the North Atlantic Regional Experiment (NARE) aircraft campaign, in which the effect of nitrogen oxides produced in the northeastern U.S. on clouds in the Atlantic was examined. For in-cloud depletion of SO_2, mean conditions with one parcel overestimates somewhat the effect compared to the average of 500 parcels. Bulk chemistry calculations without size resolution overestimates SO_2 depletion leading to an underestimation of sulfate generation.

Nonlinear interactions involving methane in the troposphere and stratosphere were examined by **Don Wuebbles** of the University of Illinois. Methane is involved in non-linear chemical cycles in the troposphere, and also is critical in chlorine deactivation in the stratosphere through formation of hydrogen chloride. There are significant questions on how emissions of other trace gases (nitrogen oxides, carbon monoxide, nonmethane hydrocarbons) will affect methane distributions, and how changing climate will affect methane. The effect of methane on ozone is also not completely clear. These effects become particularly important when considering long term scenarios, such as those developed by the Intergovernmental Panel on Climate Change (IPCC) for its deliberations on future climate. Given the change in methane growth rate (reduced from some ~12 ppbv/year to ~5 ppbv) future forecasting of methane growth is complicated. It also depends on future changes of NO_x, CO and non-methane hydrocarbons. The IS92A scenario projection used in the most recent IPCC report assumed no changes in these species; if reasonable changes are assumed, it reduces the magnitude of methane increase by 2100 by a factor of two. Hydroxyl will respond to the methane changes, and will affect numerous other gases. If policies are to be developed to try to stabilize methane concentrations at some levels, then methane sources and sinks will clearly need to be better understood.

A study of carbon monoxide using a three dimensional chemistry transport model was described by **Prasad Kasibhatla** of Duke University. The goal of this project is to help get global distributions of CO by filling in the gaps between spatially limited data sets. The ones of most interest will be the Measurement of Air Pollution from Satellites (MAPS) that flew on the Space Shuttle and the upcoming MOPITT instrument. Specific objectives include the development of a comprehensive model of spatial distributions and temporal variability of CO in the troposphere, elucidation of the interplay between sources, transport, and chemistry on tropospheric CO distributions, and combination of *in situ* and remote sensing measurements to better define the global distributions. The primary modeling tool is a chemistry transport model developed at NASA/GSFC, using input from the GSFC DAO GEOS product. This has already been applied to transport of CO in large-scale turbulent and convective regions. Currently, the chemistry in the model is being modified to provide for interactions between CO and OH using the parameterization developed by Spivakovsky. Statistics for CO distributions in 1994 have been compiled, and preliminary calculations are being done for that year. The model does a good job of simulating the amount and seasonal cycle of surface CO except for the rapidity of the summertime increase (possibly due to northern hemisphere forest fires). The amplitude of the seasonal cycle (~100 ppbv) is well simulated. Both the model and data show a reduced seasonal amplitude at low latitudes, but the model underestimates the seasonal change, perhaps because of an overestimation of biomass burning. There is also too much CO in the tropical upper troposphere, perhaps associated with the model's convective transports. In the southern hemisphere the model calculated amounts are above observed levels (e.g. at Ascension Island). Future work involves development of an improved OH parameterization, update of the biomass burning source, sensitivity studies, and design and implementation of approaches to the assimilation of CO in the model.

Ken Pickering of the University of Maryland reported on tropospheric convection and stratosphere-troposphere exchange (STE) effects in photochemistry, aerosols, and climate. The objective of this effort is to examine the effects of vertical mixing processes such as deep convection and STE on the distributions of photochemically active trace gases and aerosols. The long-term goal of this effort is to help improve the ability of global CTMs to account for vertical mixing under a range of model resolutions. The strategy of the effort is to enhance the vertical resolution of the Goddard chemistry/transport model near the tropopause, and in the longer run couple the CTM with the stretched grid GCM developed at the University of Maryland. The role of chemistry in the Goddard Cumulus Ensemble (GCE) will also be expanded, and simulations of specific events will be carried out. Observations of 222Rn will be important for validation of the new modeling tools. Future work for this effort will involve comparisons with airborne measurements made during the SONEX aircraft campaign sponsored by AEAP in late 1997, as well as earlier aircraft campaigns (PRE-STORM in 1985) and the MAPS shuttle flights (especially the two in 1994).

Areas of mutual interest to oceanographers and atmospheric scientists interested in atmospheric aerosols were summarized by **John Marra** of Lamont-Doherty Earth Observatory. These include the regulation of ocean (and terrestrial) productivity through supply of aeolian iron and nitrogen to biological systems, and the importance of iron to ocean biogeochemistry. The use of satellite measurements to study both climate and the ocean surface is also of interest to both communities. Finally, the study of DMS fluxes from the ocean to the atmosphere has the potential to help improve understanding of the naturally occurring sources of atmospheric aerosols, especially in remote regions.

There was appreciable discussion throughout the meeting. One item mentioned especially frequently was the importance of having good altitude information about the distribution of tropospheric aerosols. This is very difficult, if not impossible, to obtain from passive instruments that look down (nadir-viewing) from space or up from the ground. The use of active techniques, such as lidar, together with passive instruments to obtain aerosol information was felt to be of critical importance to improving our understanding of aerosols and their effects on climate. The truly significant difficulty of understanding the indirect effect of aerosols on climate because of aerosol-cloud interactions was also made clear to all the meeting participants. It was suggested the cloud radar observations from space would be quite useful in this regard. Observations of the correlation of CCN with aerosol loading (e.g., non sea-salt sulfate, as presented by **Jeff Kiehl** of the National Center for Atmospheric Research) show great scatter, perhaps due to the lack of constraints on other influences in previous studies; it was further noted that the CCN measurements themselves are quite difficult. Finally, it was felt that laboratory studies of the interaction of aerosols and atmospheric chemical species have to date been quite limited.

Acknowledgment

We acknowledge the assistance of Drew Shindell and Lee Grenfell in preparing this article.

(Continued from Pg. 6)

AMSR-E Science Team Meeting

and the many airborne instruments they have developed. He described in detail HUTRAD, the airborne microwave radiometer system with radiometers that have center frequencies similar to AMSR-E, and showed some preliminary data. The HUTRAD discussion was followed by the presentation of a radiometer system being developed at Goddard: Airborne C-Band Microwave Radiometer (ACMR). This radiometer will have only one frequency (6.925 GHz) and one polarization with future plans to develop it into a two polarization, scanning system.

Chris Kummerow (AMSR-E Science Team member concerning rainfall products and TRMM Project Scientist) relayed the lessons learned from TRMM and made suggestions for planning public outreach for the AMSR-E program.

For the rest of the meeting, the Science Data Validation Plan summary was discussed and revised. Our team members decided that the suggested outline for the plan does not work well in the case of AMSR-E, and thus we will reorganize it before the peer review is held next year.

The next team meeting will take place in Seattle, WA., July 7, 1998.

EOSDIS Networks

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The EOSDIS networks support a diverse set of data flows, from raw telemetry data received at the ground stations to science products delivered to the end users. These can be grouped into mission operations flows and science data distribution flows as summarized below:

Mission Operations Flows:

√ data flows from ground stations to the EOS Data and Operations System (EDOS);

√ Level 0 data flows to DAACs and Instrument Teams performing product generation;

√ data flows from non-EOS missions to DAACs; and

√ other support for non-EOS missions and cooperative programs (e.g., NOAA).

Science Data Distribution Flows:

√ telemetry and planning and scheduling data flows between the control center and Instrument Teams to support instrument operations;

√ data flows between DAACs and Instrument Teams to support product generation and quality assessment;

√ ancillary data flows to DAACs to support product generation;

√ inter-DAAC data flows to support data production interdependencies;

√ expedited data to Instrument Teams to support instrument operations, field campaigns, and targets of opportunity; and

√ network data distribution from DAACs to the EOS scientists, the broader science community, and other users.

Mission operations network requirements are derived from the instrument data rates and the locations to which the data are to be sent as documented in Earth Science Data and Information System (ESDIS) Project Level 2 requirements and various inter-project agreements. Science data distribution network requirements are derived from information regarding product sizes, production rates, Instrument Team member locations, and flow requirements provided to the ESDIS Project by Instrument Teams. These requirements were formerly collected through the Ad Hoc Working Group on Production (AHWGP) and resulted in the establishment of the "February 1996 Technical Baseline." This is the baseline with respect to which the budget is computed and adjustments are made as changes occur (e.g., the Biennial Review Committee's recommendation to ramp-up generation of higher level products). Changes to the requirements requested by the Instrument Teams are submitted to the Data Processing Resources Board (DPRB) chaired by Skip Reber (Deputy EOS Senior Project Scientist and Acting EOSDIS Project Scientist). The ESDIS Project's networks group supports the DPRB with analyses of cost impacts and other implications on implementation that result from the requested changes. In the past several months the networks group has performed analyses of proposed changes to the February 1996 Technical Baseline and provided cost and schedule impacts to the DPRB. Requirements changes are analyzed by the ESDIS Project and NASA Integrated Services Network (NISN) for their effect on the existing infrastructure. The raw data flow requirements have various functions applied to arrive at the implemented data rate capacities. These functions account for network loading and other network performance characteristics, network protocol overhead, network and end system downtime, and several other factors which clarify DAAC data pull characteristics.

The EOSDIS networks consist of the NISN EOS Backbone Network (EBNet), and the NASA Internet (NI). The EBNet supports EOS mission operations and inter-DAAC flow of science data for standard data product generation. The NI supports EOS science data distribution to the Instrument Teams' Science Computing Facilities to assure the basic level of connectivity needed to support data flows for performing timely quality assessment of standard data products. Large data flows, such as EDOS-to-the-DAACs and DAAC-to-DAAC, are being implemented on the NI (ATM) backbone, procured from Sprint. The ATM backbone implementation is replacing the existing backbone based on dedicated circuits. Data flows to non-NASA instrument team sites use existing Internet connectivity or tail circuits to the NI. The NI circuits are installed, or existing circuits upgraded, at the ESDIS Project's request based on the requirements and currently available performance. For those customer sites with shared resources, the present circuit load is monitored, and in some cases the link is tested by installing a test program at the user site to exercise the link. Depending on the results of the monitoring and tests, the link may be upgraded, or other options explored. The ESDIS Project is currently performing an assessment of the user sites, and is testing the performance of many sites' existing connectivity to determine if the performance meets the user requirements.

The ESDIS Project is actively working with other organizations to apply emerging technologies to increase network performance and reduce cost. Three notable activities involve an agreement to use the National Science Foundation's (NSF) "very high speed Backbone Network Service" (vBNS) for EOS science data distribution, consolidation of numerous EOSDIS related network connections in the Boulder area, and participation in the Great Plains Network Consortium, which should improve EROS Data Center (EDC) DAAC connectivity. Through a pending agreement with the NASA Research and Education Network (NREN) and the NSF, ESDIS Project has negotiated use of the vBNS to support the distribution of science data to non-NASA sites. Approximately 25 EOS science team sites are served by vBNS, providing DS-3, 45 Megabits per second (Mbps), OC-3, 155 Mbps, and higher speed connections to the sites. The vBNS connectivity to the DAACs will be provided by NREN. In exchange for this service, EOSDIS sites may be asked to participate in any of several network prototype activities. A meeting will be held at the end of May with the Boulder area organizations to plan a consolidation and, ultimately, connection to the NI ATM backbone. The Great Plains Network Consortium is currently having discussions to solidify requirements and participation in the network.

Joint Rosenstiel School of Marine & Atmospheric Science (RSMAS)

Committee on Earth Observation Satellites (CEOS) Validation Workshop

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— Frank Palluconi (frank.d.palluconi@jpl.nasa.gov), Jet Propulsion Laboratory

Participants

The workshop was held at RSMAS March 5 and 6 and was chaired by Ian Barton (CSIRO). Participants included Otis Brown (RSMAS), Peter Minnett (RSMAS), Walt McKeown (NRL), Craig Donlon (CCAR, University of Colorado), Jennifer Hanafin (RSMAS), Goska Szczodrak (UBC, Vancouver), Andy Jessup (Applied Physics Lab [APL], University of Washington), Gary Wick (University of Colorado), Andy Harris (UK Met Office), E. Theocharous (NPL), Fred Prata (CSIRO), Tim Nightingale (Rutherford Appleton Lab), Tom Sheasby (University of Leicester), Jim Butler (NASA/GSFC), Bob Evans (RSMAS), Frank Palluconi (JPL), Carol Johnson (NIST), and Bob Kannenberg (NASA/GSFC).

Introduction

Barton welcomed participants and announced that this workshop is intended to be a forum in which the various groups involved in the validation of satellite measurements of surface temperatures can discuss sharing data and participating in one another's field activities. He encouraged participants to look beyond their respective areas of expertise when considering inter-comparison activities (i.e., how can the validation community most effectively work together as a whole?).

Objectives and Outputs

Barton cited the following objectives and outputs for the workshop:

a. Establish a mechanism where sea surface temperature (SST) and land surface temperature (LST) validation plans of each agency are available to other agencies. Currently, official plans for the Moderate Resolution Imaging Spectroradiometer (MODIS) and other instruments are in various stages of development and many are available on the Web. There are other CEOS agencies with plans, and we need to look at strengthening the links between the various agencies, plans, etc.

b. Recognize that, for each new instrument, no single agency has all the necessary facilities available for validation.

c. Develop measurement and data exchange protocols to maximize benefits.

d. Devise a strategy for ensuring that the exchange of satellite and ground data for validation purposes occurs, so that each agency can benefit from the validation campaigns of other agencies. This may be done through CEOS working groups, or through separate agreements or Memoranda of Understanding (MOU) with each agency (some already exist, like that between NASA and NASDA).

e. Produce a document or establish a Web page describing the validation instruments, points-of-contact, planned cruises, etc. Establish guidelines about a period of exclusive use of campaign data.

f. Produce a document containing the essential information about future satellite radiometers and how to ensure getting access to their data. This may be done using existing CEOS facilities.

g. Publish a meeting report to ensure that our deliberations and decisions are available to a wider audience.

SST Validation

Advanced Along Track Scanning Radiometer (AATSR)

Nightingale reported that the AATSR instrument, the third in the ATSR series, is to be a payload instrument on ESA's ENVISAT-1 polar-orbiting mission (scheduled for launch in 1999). AATSR has the same signal channels and embodies exactly the same viewing principle as ATSR-2 (i.e., thermal channels at 3.7, 10.8, and 12-μm wavelengths, and reflected visible/near infrared (IR) channels at 0.555, 0.659, 0.865, and 1.61-μm wavelengths). The main objective of AATSR is to contribute to the long-term climate record of global SST by extending the current ATSR-1 and -2 global data sets well into the next decade. Nightingale stated that requests for AATSR data must be made through ESA. McKeown asked what AATSR's approximate SST accuracy will be, and Nightingale replied that it will be 0.3 K. Sheasby provided an overview of the AATSR Validation Plan, available online at: http://www.le.ac.uk/physics/research/eos/aatsr/val1.html.

The group debated the merits of providing raw data to the validation community at large. Brown cited the example of brightness temperatures, where the original counts are also provided. In the future somebody may come up with a better way to compute the brightness temperatures from the counts so, from that standpoint, it makes sense to provide the counts as well. Barton asked that AATSR and other instruments publish detailed validation campaign plans on the Web, to facilitate inter-comparison of data; most instruments currently have some kind of plan available. Brown added that the information should include not only where and when campaigns will be held, but what kinds of products and measurements will be involved, and how these can be obtained. An exchange needs to be mediated somewhere as to how data changes hands, and CEOS is probably the right place to begin this discussion. Brown stressed that the IR community needs to look at long-term cross-comparison and cross-validation plans so as to have consistent data sets for use by future environmental scientists.

MODIS

Minnett reported that the MODIS IR SST Validation Plan is available online at: http://www.rsmas.miami.edu/modis. Minnett pointed out that MODIS includes both land and atmosphere components, and the MODIS Ocean group will be collaborating with the Atmosphere group (ER-2 flights, etc.) as well as other instrument teams. The MODIS SST Validation Plan is really a validation of the atmospheric correction. The plan calls for comparison of "like with like" (i.e., IR radiometry from ships and aircraft). Measurements will be taken with the Marine-Atmosphere Emitted Radiance Interferometer (M-AERI), band-pass radiometers, and conventional *in situ* sensors (buoys). Issues for analysis include regional and seasonal effects, the skin effect, and diurnal heating. Minnett listed the objectives of MODIS field programs as follows: use M-AERI; take ancillary measurements in the atmosphere and ocean; make measurements in varied regions; study ocean thermal skin effects; improve robustness of SST retrieval (e.g., variations in water vapor and aerosols); and validate SST retrievals. Upcoming M-AERI cruises include a voyage from Seattle to either New Zealand or Tasmania in Fall 1998. Minnett indicated that the results of the previous three-day IR radiometer workshop (refer to summary on page **51**) will help to determine the type of band-pass radiometer selected by MODIS to supplement M-AERI measurements.

Donlon noted that so far discussion has not touched on a sea state measurement. Currently this is a very subjective measurement, perhaps taking the form of a half-hourly visual report from a ship's bridge. McKeown stated that an NRL scientist has developed an algorithm to calculate sea state in the visible range—perhaps this can be modified and applied to IR?

Global Imager (GLI)
Barton briefly discussed the National Space Development Agency's (NASDA) GLI validation plans, as NASDA representatives were unable to attend the workshop. GLI is very similar to MODIS in both design and validation strategy, and there has been a good deal of synergy between the two instrument teams. GLI validation activities will be conducted from test sites in the Bering Sea and the Japan Sea, as well as coastal sites in Japan. The Japanese fishing industry has so far provided strong support for validation activities. Bulk SST (BSST) and skin SST (SSST) measurements are among the highest priorities for GLI validation.

CSIRO
Barton indicated that CSIRO is working with MODIS, AATSR, and GLI. CSIRO has placed instruments aboard commercial ferry boats (Townsville and Perth) in order to collect daily data over a fixed area. CSIRO also plans to place instruments aboard ships of opportunity operating in Australian waters. Barton presented examples of ATSR and AVHRR data, looking at the skin/bulk temperature difference. *In situ* data taken by CSIRO (using both a radiometer and a thermosalinograph) compared well with the satellite data. Barton noted that so far modellers have relied primarily on BSST measurements, but the true SST picture is much more complex than that, and requires an algorithm that factors in the SSST.

Land Surface Temperature (LST) Validation

CSIRO
Prata stated that he has been asked to derive IR LST algorithms for both AATSR and GLI. The LST algorithm will be a regression-based algorithm that will factor in 16 types of existing land classifications, thus bypassing the surface emissivity problem. (Prata will not derive a snow or ice algorithm.) He explained that LST is not really a skin temperature, as radiation is being emitted from a variety of sources (deep within the canopy, leaves, ground, etc.). There are also angular effects to consider. Analysis of ATSR-2 data shows that there can be significant variations in emissivity depending on viewing angle. Prata presented some ATSR images taken over Australian validation sites, as well as visible LST data collected in April 1997 during a collaborative effort between CSIRO and the University of Nottingham. The purpose of this activity was to validate ATSR-2 spectral radiance measurements. Overall ground measurements compared well with the ATSR-2 measurements.

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
Palluconi explained that the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) validation effort focuses on LST. ASTER will validate the radiance at sensor (Level 1), and then the surface leaving radiance (Level 2). ASTER consists of three separate instruments, or components: Visible Near Infrared (VNIR), Shortwave Infrared (SWIR) and Thermal Infrared (TIR). There will be no space-view calibration for ASTER. Jessup stated that he may be interested in obtaining some high-resolution ASTER data, and he will discuss this with Palluconi. Primary ASTER validation sites are Lake Tahoe, Salton Sea, Railroad Valley, and White River Valley. Barton suggested that ASTER could benefit greatly from collaborative validation efforts with MODIS. Prata noted that ASTER could use SST data to help validate its atmospheric correction measurements. Palluconi indicated that six months after launch anybody can request ASTER data, and he encouraged participants to do so.

University of Washington APL

Jessup reported that APL will participate in a NOAA cruise in May and June of 1998. He hopes to have his prototype radiometer unit built by July 1998 and then conduct testing from the Hood Canal Bridge and the ferry in Puget Sound. Platform Harvest in 1999 may be another possible testing site. Jessup is also interested in taking measurements in the Gulf of Mexico in 1999, and this is the experiment for which he would like to obtain high-resolution ASTER data. Minnett suggested that Jessup may want to investigate putting a radiometer package aboard one of the ships that travels between Seattle and Yokohama.

Radiometer Designs

Ship of Opportunity Sea Surface Temperature Radiometer (SOSSTR)

Donlon asserted that there is presently a serious lack of geographically widespread and temporally dense *in situ* SST measurements. This hinders the validation, long-term stability, and interpretation of SST satellite measurements. It also hinders the development of skin-to-bulk temperature transfer models. Donlon cited the high cost and limited availability of extremely accurate radiometers as another limiting factor for *in situ* SST measurements. He presented data gathered with Tasco THI-500L radiometers, which are inexpensive but require constant calibration. When compared at sea to the precisely calibrated sea surface temperature radiometer (SISTeR), the Tascos provided good data even without protection from the elements, although the data did not reach the desired 0.1°C accuracy . To improve the accuracy of the Tascos, Donlon has housed two of them within an enclosed (but not sealed) unit called the SOSSTR. One radiometer looks at the sea, while one looks at the sky. SOSSTR also contains two blackbodies, one ambient and one hot. Donlon believes that the SOSSTR units can be constructed inexpensively enough to be practical for a large deployment.

Proposed University of Washington Applied Physics Lab (APL) Radiometer Design

Jessup reviewed his proposed radiometer design, which calls for enclosing the sensors and blackbodies within a sealed, temperature-controlled housing. (The radiometers inside the unit would be Heimann KT-15 models.) The housing would be filled with dry nitrogen, and the sensors would look out through an IR-transparent window, equipped with a wiper and fluid reservoir to periodically clean salt, spray, etc. Harris asserted that adding the window means that there is no true end-to-end calibration. Jessup acknowledged this, but said that if he can find an IR-transparent window that can be very accurately characterized, the protection it would afford the sensors could more than account for the added uncertainty introduced. He added that he may be over-engineering in response to the worst-case scenario (e.g., a huge wave hits the unit), and asked participants for their feedback. Barton and Donlon suggested that the error introduced by the window may well eat up the 0.1° C accuracy, but agreed that the window is worth checking out so long as the design of the unit allows the window to be removed later. Jessup has begun investigating IR window materials (e.g., zinc selenide), and will look at testing windows and the effects of various cleaners.

JPL ASTER Radiometer

Palluconi explained that the ASTER unit contains an Everest 4000.4GL radiometer, housed within a very well-insulated box. The attempt to isolate the radiometer passively with the insulation appears to have caused temperatures to drift up significantly.

Scanning Infrared Sea Surface Temperature Radiometer (SISTeR)

Nightingale described the SISTeR, developed at Rutherford Appleton Lab. SISTeR is based on an ellipsoid mirror that allows a small foreoptics window. This permits smaller internal blackbody calibration targets and a narrow exit slit, which protects against the elements. The radiometer's optical path is chopped at 100 Hz, and the radiation is passed through one of six possible filters before arriving at a DLTGS detector. The chopper is close to the detector, and the filter is between chopper and detector. Barton pointed out that the chopper could change temperature when the hot and cold blackbody are viewed. For an SST measurement including a sky scan, the measurement cycle is about 2 minutes, which includes a look at the two blackbodies. *In situ* calibration with the CASOTS blackbody indicates no bias and a peak-to-peak noise of about 0.1 K.

NRL Buoy Radiometer

McKeown stated that the NRL hopes to install IR radiometers on some 300 buoys to make SSST measurements. There is a proposal to mount a system at

20-25 m with a rain shield, spray shield, and a rotating radiometer (possibly a Tasco model) with a single calibration blackbody. A conical mirror above the radiometer is to be used to feed the radiometer and create a large footprint. A full-sky radiometer will be used to obtain sky irradiance measurement.

Improving Radiometer Design and Testing

Donlon advised that radiometer developers try to keep their units as lightweight as possible. Also, for most point-and-shoot radiometers, a look angle of less than 40° is desirable; otherwise, roll and pitch must be sampled very precisely. Jessup suggested that at the next radiometer comparison workshop a surface disrupter and an imager be used for the measurements taken from the rooftop platform. He indicated that for a future workshop instruments might be mounted on the Floating Instrument Platform (FLIP), which is unique in that it orients itself with the wind and remains very stable. This platform would be safe and stable enough so that the NIST or APL blackbody could be used onboard. Barton stated that one of these two blackbodies, plus an M-AERI, should be incorporated into future workshops and field activities whenever possible.

Surface Temperature Validation Web Site

Barton suggested that a CEOS IR Cal/Val Web page be established to provide a link to the data sets that are maintained by individuals or organizations. Individual Web pages could be established for instrumentation description, contacts, field campaigns (oceans and land, with protocol descriptions), meetings (CASOTS, RSMAS, etc.), and metadata data sets. Evans indicated that RSMAS will have all AVHRR and MODIS data, and for cal/val purposes, they would be willing to do the extractions to match the cal/val data. Barton indicated that the general agreement of the CEOS member agencies is that data for climate research, including cal/val, should be freely available. He added that it may be necessary to respond to the recent ENVISAT AO to ensure timely delivery of data and data of the highest spatial resolution.

Measurement Database

The question of a database of measurements was discussed and Evans offered to use the resources at RSMAS to help set up a Web page to point to the sources of data themselves (especially for the large continuing data sets). He pointed out that some countries do not have a problem with individuals using data; however, where the interest is to provide data to the general community, much more extensive negotiations (i.e., several years) may be required. Barton suggested that there be a separation of data used for cal/val and that used for research, in that cal/val data should be made widely available as soon as it is reduced and understood by the generator. Cal/val data would be released quickly, but if the same data were used for research, CEOS could recommend that the originators be contacted and informed of this use. Minnett proposed a 9-month submission period for data; after 12 months the database administrator would release any data in the database to qualified users.

Conclusion

Participants agreed that it would be useful to hold another IR Instrument Comparison Workshop and CEOS Validation Workshop within the next 1-to-2 years. The next CEOS Cal/Val meeting will be held in July 1998 in Tokyo, and Barton will report on these workshops there. He thanked Bob Kannenberg (NASA/GSFC) and Frank Palluconi (JPL) for providing meeting minutes. He also thanked Otis Brown, Peter Minnett, and RSMAS for hosting the workshops.

Recommendation

As a result of the workshops, Barton will make the following recommendation to the CEOS Plenary: "The thermal infrared validation community met in Miami during March 1998 for a round-robin instrument inter-comparison and a satellite validation workshop. The meeting agreed to foster close international collaboration in the collection and analysis of ground truth data for the validation of geophysical products derived from thermal infrared satellite data. To ensure that validation data sets are available to the satellite operators in a timely manner, it is recommended that the appropriate satellite data be made available to the ground data providers in near real time and free of any charges. In return, the ground data collectors will provide validation data sets to the satellite community in a timely manner. It is also recommended that both the ground data supplied by the data collectors and the associated satellite data are only initially available for use in satellite instrument calibration and data product validation, and should not be used in any other manner unless agreed to by the data producer."

Description of a portable spectroradiometer to validate EOS radiance scales in the shortwave infrared

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I. Introduction

The Earth Observing System (EOS) is an 18-year international, multi-instrument, multi-satellite program in global remote sensing of the Earth. The overall goal of the program is to advance the scientific understanding of the entire Earth system and its changes on the global scale. To accomplish this goal, EOS instrumentation will measure the Earth's radiation flux at wavelengths ranging from the UV to the IR, producing global, long-time-series, remote sensing data sets. To correctly interpret the scientific information produced by a variety of instrumentation on different satellite platforms over the 18-year life of the program, it is critical to be able to discriminate between changes in the sensor performance used for the global change study and actual changes in the Earth's radiance. Consequently, accurate calibrations of sensors used to measure radiance properties of the Earth are central to the success of the mission. A variety of calibration methods have been developed, including ground-based calibrations prior to launch, ground-truth measurements of satellite-based sensors after launch, periodic lunar and deep-space observations, and incorporation of on-board calibration sources.

As part of the overall sensor calibration scheme, several portable radiometers have been developed or are under development at the National Institute of Standards and Technology (NIST) to provide ground-based radiometric traceability to NIST of EOS instrumentation radiance responsivity scales [1,2]. In practice, these radiometers will travel to National Aeronautics and Space Administration (NASA) instrument calibration and validation facilities and measure optical sources used to calibrate the sensor responsivities. The result is a validation of the radiance scale of the ground calibration sources. Sources are typically lamp-based integrating sphere sources for the visible and shortwave infrared wavelength regions, and large area blackbodies for the thermal infrared.

A total of three radiometers, the Visible Transfer Radiometer (VXR), the Short-Wave Infrared Transfer Radiometer (SWIXR), and the Thermal Infrared Transfer Radiometer (TXR), are currently planned to cover the wavelength range from 0.4 µm to 10 µm. Radiance scales will be verified in the visible using the VXR, a six-channel filter radiometer with channel wavelengths ranging from 411 nm to 870 nm. The VXR is a modified version of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Transfer Radiometer [3]. The TXR, a two-filter radiometer with channels at 5 µm and 10 µm, will measure cryogenic blackbody working standards either in air or in a vacuum environment [4]. In this article, we will focus on design and characterization details of the SWIXR radiometer under development for radiance scale validations of integrating sphere sources in the 0.8 µm to 2.5 µm wavelength range. In Section II, the system layout and design will be described. In Section III, details of the system characterization and calibration plans will be presented.

II. System Layout and Design

A radiometer is in general composed of three basic components: collection optics, a spectral filter, and a detector. The SWIXR instrument is equipped with all-reflective input optics, a double-grating monochromator for spectral selectivity, and a liquid-nitrogen-cooled indium antimonide (InSb) detector. Each of these components will be described briefly.

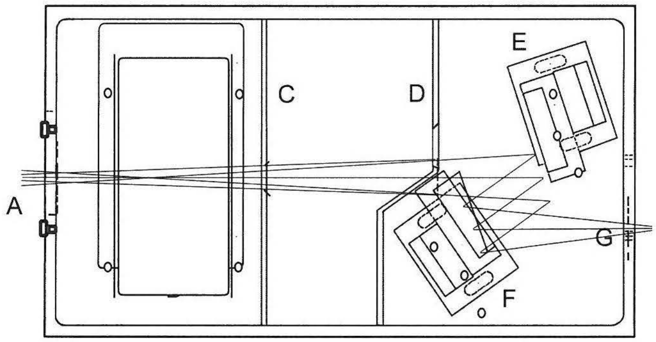

Fig. 1. Schematic diagram of the input optics module for the SWIXR transfer radiometer. A is the entrance aperture (6 mm x 6 mm); B is the optional filter wheel/chopper insert; C is a baffle with a 15.75 mm diameter aperture; D is a baffle with a 21.7 mm diameter aperture; E is a 300 mm focal length, gold-coated spherical mirror; F is a 100 mm focal length, off-axis parabolic mirror; G is the exit aperture.

The input optics for the SWIXR, shown in Fig. 1, consist of an entrance aperture (A); an optional insert to hold a filter wheel and a chopper (B); baffles with defined apertures (C and D); two gold-coated mirrors, the first a 300 mm focal length spherical mirror (E) and the second a 100 mm focal length off-axis parabolic mirror (F); and an exit aperture (G). The 6 mm by 6 mm entrance aperture is imaged to a 2.2 mm square spot at the entrance slits of the monochromator — located 6 mm behind the exit aperture (G). The aperture stop is located at aperture D while the entrance slits of the monochromator act as the field stop. The f/# of the radiation imaged onto the monochromator entrance slits is approximately f/3.95, closely matching the f/# of the monochromator for maximum throughput and spectral resolution. The system has a full angle field-of-view of 5.2°, resulting in a 9.6 cm by 9.6 cm square entrance window at the exit port of the integrating sphere source if the SWIXR is located 1 m from the sphere. The input optic housing is 36.7 cm long and 16.7 cm wide. The overall height is 6.1 cm. The optional chopper/filter wheel assembly extends an additional 6.8 cm above the top of the housing.

The monochromator is an ISA, Inc.† 0.18 m, f/3.9 double grating instrument (Fig. 2). It has a stray light rejection of approximately 10^{-7}, wavelength reproducibility of 0.1 nm, and an uncorrected wavelength accuracy of 0.5 nm. The incident light slightly underfills the monochromator's optical elements to minimize scattered light. Protected silver coatings were used on all mirrors for maximum throughput. The instrument comes with two sets of interchangeable gratings with groove densities of 600 g/mm, one set blazed at 1.5 µm and a second set blazed at 2.0 µm. The nominal bandpass of the instrument with these gratings is 7.2 nm/mm. The entrance, center, and exit slits are externally controllable, enabling user-selectable bandpasses throughout the entire wavelength range. The monochromator is 45.7 cm long, 41.9 cm wide, and 21 cm tall.

The output from the monochromator is imaged onto the detector using an adjustable, silver-coated, elliptical mirror (not shown). The nominal spot size of the imaged radiation at the detector surface is 0.5 mm by 0.5 mm. A 2.5 mm diameter InSb photodiode mounted in an evacuated dewar and cooled to 77 K is used to detect the transmitted radiation. A 2.0 mm diameter aperture is located less than 1 mm in front of the detector to reduce detector instabilities arising from light hitting the edge of the detector. A silicon diode temperature sensor located on the cold finger measures the diode temperature. The dewar is equipped with a sapphire entrance window. A cold filter with a transmittance of less than 10^{-3} over the spectral range from 3.0 µm to 5.5 µm is placed behind the sapphire window to reduce stray light and thermal infrared background radiation incident on the detector [5]. Order sorting filters further reduce stray light in the

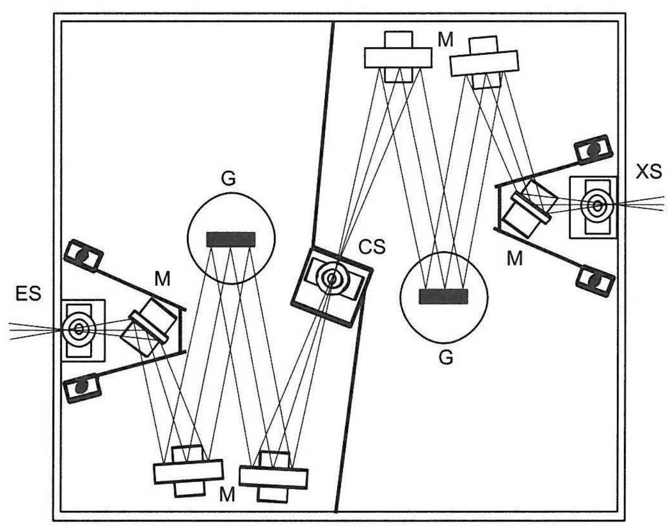

Fig. 2. Schematic diagram of the ISA, Inc. 0.18 m double grating monochromator†: (M) Mirrors, (G) Gratings, (ES) Entrance Slits, (CS) Center Slits, (XS) Exit Slits.

system. The chopped output from the detector is sent to a three-stage trans-impedance amplifier and then to a lock-in amplifier. The signal measured by the lock-in amplifier is recorded with a computer.

The radiometer is approximately 1 m long, 0.5 m wide and weighs approximately 25 kg. The instrument is mounted on an optical breadboard and placed on a small adjustable table for orientation. A removable visible diode laser mounts to the front of the radiometer to aid in the proper alignment of the instrument during sphere measurements.

III. Characterization and Calibration

The measured signal S(λ) from the radiometer is proportional to the area of the entrance pupil, A; the projected solid angle, Ω; the radiance of the source being measured, L(λ); the transmittance of the spectral filter (and any other optical components), T(λ); the spectral responsivity of the detector, R(λ); and a detector amplifier gain factor, G:

$$S(\lambda) = A\Omega G \int L(\lambda)T(\lambda)R(\lambda)d\lambda. \qquad (1)$$

To calibrate the radiometer for absolute responsivity, we relate the measured signal S (V) to the radiance of a calibration source L ($W/m^2 \cdot sr \cdot \mu m$):

$$S(\lambda) = \int R(\lambda)L(\lambda)d\lambda, \qquad (2)$$

where the integration is over the spectral bandpass of the monochromator. R′ includes the area, solid angle, system transmittance, detector responsivity and gain factor from Eq. 1. The complete calibration of the instrument consists of measuring the absolute spectral radiance responsivity at each wavelength (or known spectral bandpass) over the entire spectral range.

In general, radiance scales can be maintained with either calibrated detectors or stable sources of known radiance. In this case, the radiance scale will be transferred from working standard lamps to a lamp-based integrating sphere source at the NIST Facility for Automated Spectroradiometric Calibrations (FASCAL) [6]. The integrating sphere source radiance will be measured every 50 nm, and also at wavelengths corresponding to the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Moderate Resolution Imaging Spectroradiometer (MODIS) band center wavelengths [7,8]. This calibrated integrating sphere source will subsequently be used to calibrate the SWIXR for spectral radiance responsivity.

The integrating sphere source will be chosen to have a radiance level and spectral distribution similar to sphere sources used for EOS instrument calibrations. For example, in Fig. 3 we show the spectral radiance of an Optronic Laboratories, Inc. OL 450 integrating sphere† along with the maximum and low radiance levels of the ASTER sphere source [9] at wavelengths corresponding to ASTER bands 4 through 9. A similar integrating sphere source will be used to calibrate the SWIXR for absolute spectral responsivity.

Prior to calibration, the instrument will be characterized for linear response, wavelength accuracy and repeatibility, spectral bandpass, stray light, and size-of-source error. Many of these measurements will be made at a new large-area monochromatic Lambertian source facility currently under development at NIST [10]. While we are interested primarily in the short-wave infrared region, this tunable-laser-based facility will enable measurements over the wavelength range from 0.2 µm to 12 µm.

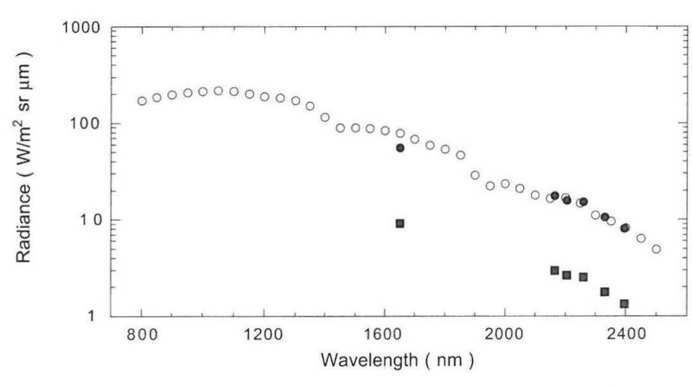

Fig. 3. OL 450 sphere† radiance (open circles) and maximum (solid circles) and low-level (solid squares) radiance levels of the ASTER sphere source.

To provide a general assessment of expected uncertainties of measurements made with the SWIXR, we estimate errors arising from wavelength error, stray light, bandpass filters, and signal-to-noise. These sources of measurement uncertainty will be combined in quadrature with other sources of uncertainty arising from the instrument calibration to give us an estimate of the total uncertainty.

For calculations of errors arising from wavelength error and stray light, we need an estimate of the spectral dependence of the measured signal. For this estimate, we neglect optical elements in the radiometer, such as mirrors, which have little or no spectral variation over the wavelength range of interest. Only the grating diffraction efficiency and the responsivity of the InSb detector show a pronounced spectral dependence. The monochromator transmittance is proportional to the product of the two grating diffraction efficiencies. For the grating diffraction efficiencies, we take the diffraction efficiency provided by ISA, Inc. for a grating blazed at 2.0 µm, measured under Littrow conditions. We also consider only the relative responsivity of the InSb detector. In this case, we allowed the relative responsivity to vary linearly from 1 to 3 over the wavelength range from 0.8 µm to 2.5 µm, in rough agreement with published values. Using the spectral power distribution of the OL450 integrating sphere, we then calculate the relative spectral distribution of the signal.

i. Wavelength Error

To estimate effects of wavelength error on measured radiance, we simply take the ratio of the derivative of the estimated signal and the signal, $\frac{1 \Delta S}{S \Delta \lambda}$ Results are shown in Fig. 4. The wavelength expanded uncertainty of the monochromator is 0.5 nm. With wavelength calibration using pen lamps, the expanded uncertainty should be reduced to at least 0.3 nm or less, the limit being given by the reproducibility of the wavelength setting—0.1 nm. Expanded uncertainties in the radiance arising from monochromator wavelength error should therefore be on the order of 0.45% or less throughout the entire wavelength range.

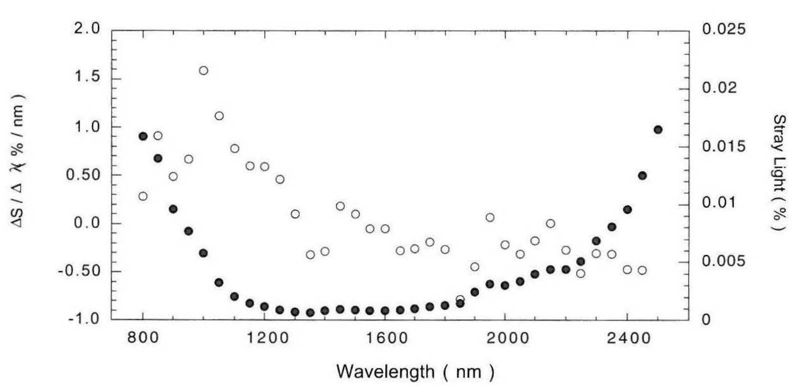

Fig. 4. Estimated error in measured signal as a function of wavelength error (open circles) and stray light (closed circles) for a stray light factor of 10^{-7}.

ii. Stray Light

For stray light, we take the ratio of the out-of-band signal to the in-band signal, and express that ratio in per cent:

$$\frac{S_{SL}}{S_{in-band}(\lambda)} = 10^{-7} \frac{\sum_{\lambda'} R'(\lambda')L(\lambda')\Delta\lambda'}{R'(\lambda)L(\lambda)\Delta\lambda} \qquad (3)$$

For simplicity, we have replaced the integral in Eq. 2 by a summation and assumed a constant bandpass of 10 nm. We have also assumed a slit-scattering function of 10^{-7} out-of-band and 1 in-band. While the summation is in principle over all wavelengths, we perform the summation over the restricted wavelength range from 800 nm to 2500 nm. This is reasonable because order-sorting filters further attenuate visible light by a factor of 10^3 and the cold filter attenuates longer-wavelength radiation by an additional factor of 10^3. Based on these calculations, stray light of 10^{-7} should introduce errors less than 0.02% (Fig. 4).

iii. Order Sorting Filters

Order sorting filters are necessary to eliminate higher order diffracted light from passing through the monochromator. Spectral selectivity is typically achieved by using multilayer dielectric coatings. Due to thermal expansion and contraction, the relative thickness of the layers will change slightly with temperature, and the filters will exhibit a temperature dependence to their spectral transmittance. While typically 'very small', this effect has not been well characterized. Interference filters, for example, will shift to longer wavelength with increasing temperature. This wavelength shift is on the order of 0.01 nm/°C to 0.2 nm/°C, depending on the particular interference filter.

Well away from the cut-on wavelength, the typical filter transmittances of the two order sorting filters in the radiometer are smoothly varying with small oscillations on the order of 5% of the transmittance with an interval of 100 nm to 200 nm. The change in transmittance as a function of wavelength shift (or changing temperature) should therefore be fairly small, on the order of 0.05% / nm. For temperature variations as large as 5° C , the maximum filter wavelength shift would be 1 nm, corresponding to a change in filter transmittance of approximately 0.05%.

iv. Signal-to-Noise Ratio

The signal-to-noise (S / N) ratio can be expressed as the ratio between the effective flux incident on the detector and the noise equivalent power (NEP). The effective flux is proportional to the radiance of the source, the area of the entrance pupil, the projected solid angle, the bandwidth of the spectrometer, and the transmittance of the optical system:

$$\phi_{eff} = A\Omega L(\lambda)\Delta\lambda T(\lambda) \quad (4)$$

We will estimate the S / N at 2.5 µm, a wavelength where the transmitted flux is small. For a radiance value, we take the radiance of the OL 450 sphere, ~5 W / cm^3sr. In estimating system transmittance, we include spectrometer transmittance (for a bandwidth of 15 nm), losses due to mirror reflections, and losses due to window and filter reflections. Taking all these parameters into account, $\phi_{eff} 2nW$

The noise equivalent power is the incident power that produces an rms output signal equal to the rms noise voltage [11]. The NEP is often expressed in terms of the detectivity D*(cm $Hz^{1/2}$ / W),

$$NEP = (A_d \Delta f)^{\frac{1}{2}} / D* \quad (5)$$

where A_d is the detector area and Df is the detection bandwidth. For our InSb detector, D* is at least 10^{12}, the detector area approximately 5 mm^2, and the detection bandwidth 1 Hz. The NEP is therefore approximately 0.20 pW. The minimum S / N ratio should correspondingly be on the order of 10,000 during calibrations. In measuring sphere sources, the incident flux could be an order of magnitude lower. In this case, the S / N ratio should be on the order of 1000. This estimate does not take into account other sources of noise, such as amplifier noise.

The dominant sources of uncertainty arise from the calibration of the radiometer. The uncertainty in the radiance scale transfer from FASCAL to the integrating sphere source used to calibrate the SWIXR may be as high as 1.5%, and the uncertainty in the measurement of the calibration sphere as high as 0.5%. Using these upper-bound estimates, the root sum square of the individual uncertainty components gives a maximum total expected uncertainty in measurements of sphere radiance using the SWIXR of 1.7%. While this is a rough estimate of the uncertainty budget, based on this result we anticipate having the capability to make radiance measurements of EOS calibration sphere sources in the short-wave infrared with a maximum total uncertainty of 2% or less.

IV. Summary

A portable short-wave infrared radiometer is under development at NIST to provide ground-based radiometric traceability to NIST of EOS instrumentation radiance responsivity scales in the 0.8 µm to 2.5 µm wavelength range. This instrument is one of three portable radiometers being developed at NIST to validate radiance scales of sources used at NASA calibration facilities to measure the absolute spectral responsivities of space-based instrumentation prior to launch. This is one step in a calibration chain designed to enable accurate long-term monitoring of the Earth's radiation properties as part of NASA's Earth Science Enterprise.

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† Identification of commercial equipment does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment identified is necessarily the best available for the purpose.

TRMMing the Uncertainties: Preliminary Data from the Tropical Rainfall Measuring Mission

— Mitchell K. Hobish (mkh@sciential.com), reprinted from Earth Sciences News, Vol. 3, No. 1

It's always a welcome situation when a recently launched satellite begins to transmit the data it was sent to acquire. The members of the Tropical Rainfall Measuring Mission (TRMM) science and engineering teams were elated when several of the instruments on TRMM recently demonstrated the robustness of their design by providing data that—in the case of the Precipitation Radar—even exceeded the science team's expectations.

The key objectives of the TRMM program are to obtain and study multi-year science data sets of tropical and subtropical rainfall measurements; understand how interactions among the sea, air, and land surfaces produce changes in global rainfall and climate; help improve modeling of tropical rainfall processes and their influence on global circulation in order to predict rainfall and its variability at various time-scale intervals; and test, evaluate, and improve the performance of satellite rainfall measurement techniques.

The primary scientific instruments on TRMM include the TRMM Microwave Imager (TMI), the Visible Infrared Scanner (VIRS), and the Precipitation Radar (PR). These three instruments work in a complementary manner, and serve as a kind of "flying rain gauge." The VIRS will bridge the gap from the TRMM rainfall estimates to those estimates made with geostationary and low-Earth-orbiting satellites using visible/infrared techniques. This will help overcome the temporal and spatial sampling problem inherent in a single satellite's coverage. This primary complement is accompanied by the secondary scientific instruments, a Clouds and the Earth's Radiant Energy System (CERES) and a Lightning Imaging Sensor (LIS).

The TRMM observatory was successfully launched on November 27, 1997 from Japan's Tanegashima Space Center by a Model H-II launch vehicle. The 96-minute orbit is inclined 35° to the Equator and is circular, with an altitude of 218 nautical miles (350 km). This orbit allows collection of tropical rainfall data from the passive microwave sensor (TMI) every 16 orbits, with a diurnal precession rate arranged so that it comes over any given point roughly an hour later each day, so it repeats approximately every 30 days. The orbit was intentionally kept low in order to resolve radiances over the 10 km scales typical of convective clouds.

"It's really too early to draw conclusions about total rainfall estimates," says Chris Kummerow, the TRMM Project Scientist, "but indications are that the data coming down from the recently calibrated sensors will make significant contributions to our understanding of rainfall mechanisms and processes." That's not to say that the preliminary data aren't useful; quite the contrary.

Indeed, Kummerow noted that, "With TRMM's high-resolution radar data, passive microwave data, infrared (IR) data, and lightning data, we are finding unambiguous evidence that the passive microwave is consistently putting more rainfall over the oceans than the IR, and consistently less rainfall over the land than the IR. The lightning data show that lightning is confined almost strictly to over-land cases, with very little lightning over the oceans."

He continued, "The nice thing about TRMM is that we can subset all the different data sets to exactly the same time and area. We've known for a while that the physics from IR data from geostationary sensors wasn't as good as that from passive microwave. But, by virtue of looking at a scene basically all the time, it does provide better sampling. But we could never untangle how much of what we saw was due to sampling, and what was due to errors. So, by being able to subset everything to the same sampling, we can really start looking at the physics."

Such insights allow the TRMM team to explore the differences in ice scattering between over-land storms and oceanic storms. Said Kummerow, "Ice scattering at the shortest wavelength of the passive microwave sensor appears to be about the same in these storms. That, we think, is indicative of the total amount of ice being roughly equivalent in oceanic and land storms. But, when we start going to longer wavelengths, the ocean storms don't show any signature. We think that's because the ice crystals are smaller in the oceanic storms."

Such surmises would acquire increased validity with more thorough analysis and with collection of data from aircraft flights through the storms synchronized with TRMM passes. In conjunction with ground-based radar studies—the aircraft studies are to begin in April in Houston, then move to Florida in the summer, Brazil in January 1999, and the Kwajalein Atoll in September 1999—these data will allow TRMM scientists to determine just what is happening in these storms.

The TRMM science team already has had a few surprises, requiring some fast reworking and development of algorithms to analyze the data. Initial radar data analysis has given indications that estimates of radiative transfer to space may be in error. According to Kummerow, this could come from the models' not putting enough liquid into the atmosphere to match the passive microwave observations. One possible source of error is the drop-size distribution. Kummerow said that, "The raindrops don't all come down in the same size; there's always a distribution of drops, and it's the mean of the distribution that affects the radar. It's clear from these early experiments that something we're doing is not quite right. We may be assuming that the drops are too big, but the most likely mistake is that we're assuming that the drop-size distributions are the same from the surface all the way up."

While drop sizes have been measured near the surface, it is very difficult to get drop-size distributions above the surface. Kummerow says that, to a first-order approximation, this may be the source of the error. The mechanisms of drop-size growth or diminution may be critical to understanding several phenomena. Drop size in stratiform storms, which generate relatively gentle rain, likely diminishes due to evaporation as the drops travel through the atmosphere. On the other hand, in convective storms the raindrops may continue to grow through accretion as they descend.

"None of that has really been incorporated into rainfall algorithms. It appears as though it could have a fairly big impact," said Kummerow. But now, with TRMM data covering footprints much smaller than those used previously, details should be forthcoming. He continued, "The tropical rain systems are mostly driven by sporadic convection—thunderstorm convection. A lot of the mid-latitude rain falls from frontal bands. There's every reason to expect that these two have very different dynamics and have very different features in them. We're very lucky in that TRMM goes as high as 35° latitude. At 35° we do catch a lot of wintertime frontal precipitation."

Several other research and operational areas have been affected by the preliminary TRMM data.

For example, TRMM has pointed up some difficulties in interpreting rainfall echoes from ground-based radar data. According to Kummerow, "When you get sufficiently far away from ground-based sites, ground-based radars can start intercepting the region where the snowflakes melt, giving you very, very large echoes that are not really surface rainfall. This problem is well known to the radar meteorology community, but it's a huge problem when you start providing operational accumulations that are then used drive models in terms of surface moisture. TRMM, even with only occasional overpasses, may be able to sort out some of these ambiguities."

Another area opening up for discussion deals with the processes that give rise to so-called "warm rains," such as are found in Hawaii. In Hawaii, these rains are orographically induced, i.e., when very moist Pacific air runs into the mountains it's lifted up a little, and water condenses out—dramatically. Hawaii is the rainiest place in the world, and yet these rains have no signature in the IR.

"Most IR algorithms don't assign rain until you get to about 235 K," said Kummerow, "so we're talking about 40° below zero, Celsius. So, when you have these clouds that never reach freezing level, the IR says (by and large) that there's no rain." The passive microwave sensors over land cannot see anything but ice particles in the clouds, and raindrops over land are indistinguishable from the land itself. "So the passive microwave sensors have been happily assigning a zero rain rate to the rainiest place in the world," says Kummerow. He continued, "With the TRMM precipitation radar we're going to start looking at how much rain we're really missing. We also need to know in how many places this occurs. We know about Hawaii; there are places in India that favor this kind of precipitation. But we don't really know how important it is to global processes: is this a big chunk of rain that we're missing, or is it just a scientific curiosity?"

The answer to this question is important because the total amount of energy that is produced in the atmosphere and drives the worldwide atmospheric circulation is directly proportional to the total amount of rain that falls.

Another area that is being examined is the effect of the diurnal cycle on rainfall. Climate modelers need to know that they are capturing the diurnal cycle properly, because this will tell them if their models properly drive the convection.

"Nagging questions about the accuracy of the physics in the models, the amount of warm rain, and the effects of the diurnal cycle have left us with an uncertainty in global rainfall of about 30%," says Kummerow. "The TRMM observations and the physics we are starting to understand will have a huge impact on our ability to quantify rainfall processes. Errors smaller than 10% are certainly achievable using all the sensors that we have today and will even improve our estimates from previous years as well as into the future."

The data were closely held until mid-May to allow the TRMM team to ensure that the data they released to the larger science community was of decent quality, and that it was formatted properly. They see this as but another service to the community, part of their mandate to provide TRMM data, and to help us understand how rainfall affects—and is affected by—our environment.

IR Instrument Comparison Workshop at the Rosenstiel School of Marine & Atmospheric Science (RSMAS)

— Bob Kannenberg (rkannenb@pop900.gsfc.nasa.gov), Science Systems & Applications, Inc.

Sea Surface Temperature and Global Change

El Niño has received more ongoing media coverage than perhaps any other weather phenomenon in recent memory, although this coverage tends to focus on the aftermath of severe weather systems attributed to this phenomenon. By now it is commonly known that El Niño's development is related to a change in sea surface temperature (SST), as warm water spreads from the western Pacific towards the east. What is not as well-publicized is the fact that the SST change associated with El Niño is only a matter of roughly 3° C. This change seems trivial to most of us, as we typically think in terms of the air temperature and its daily fluctuation; to the oceanographic community, however, a change of 3° C is extremely significant. The expected average change in SST due to global warming is only about .03° C per year. Understanding the triggers of El Niño, and indeed global climate change as a whole, requires the ability to make extremely precise and reliable measurements of SST, ideally with an accuracy of better than 0.2° C.

MODIS Science Team member Ian Barton (CSIRO) mounts an IR radiometer on the rooftop instrument platform.

Validation of MODIS SST Measurements

The Moderate-Resolution Imaging Spectroradiometer (MODIS), scheduled to fly aboard the EOS AM-1 and PM-1 satellites, will measure SST with an absolute accuracy of 0.3 to 0.5 kelvins (K). The Kelvin scale begins at absolute zero (-273.15° C). So far the most accurate satellite-based SST measurements (~0.3 K) have come from the Along Track Scanning Radiometer (ATSR), although ATSR does not provide daily global coverage as MODIS will. MODIS SST data will of course have to be validated with ship- and aircraft-mounted instruments that can provide a comparable level of accuracy. "There are very few variables that are unequivocal indicators of climate change, and one of these is SST," explains MODIS Science Team member Peter Minnett of the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS). "Because of the high innate spatial and temporal variability of SST, large areas have to be considered, and time series of global or ocean-basin-scale SST fields are potentially crucial parameters for the study of global change. Satellite instruments offer the only mechanism for providing these large-scale fields, and self-calibrating infrared (IR) radiometers produce the most accurate SST retrievals." Covering the "large areas" that Minnett refers to would require thousands of daily SST retrievals to be made by IR radiometers mounted aboard ships-of-opportunity and other available platforms. Currently, the most accurate ship-based radiometers, such as the Marine-Atmosphere Emitted Radiance Interferometer (M-AERI), are prohibitively expensive for this kind of wide deployment. The harsh marine environment (e.g, saline aerosol contamination of optics, extreme temperature and humidity changes) to which the widely-deployed radiometers will be exposed requires them to be extremely durable and, in the worst cases, expendable.

Bulk vs. Skin SST Measurements

Researchers deriving SST algorithms have typically not used IR radiometer SST measurements but, rather, *in situ* bulk SST (BSST) measurements obtained from thermometers on buoys or ships. BSST measurements are made at a depth of perhaps a couple of meters. However, what is measured from a satellite is the sea surface skin temperature (SSST). The difference between the skin and bulk temperature can be a degree or more, and it is crucial to quantify that difference. So far nearly all satellite measurements have been validated with BSST measurements, and scientists at RSMAS and the University of Wisconsin are leading the effort to use SSST measurements to validate satellite measurements. Minnett states that, "The absolute accuracy of the SST retrievals must be determined to establish whether apparent signals in time-series of SST are real or noise. Radiometers mounted on ships and aircraft, provide the best method of comparing "like with like" and removing the uncertainties resulting from variations in the thermal skin effect and near-surface temperature gradients that are folded into conventional comparisons of satellite-derived SST and *in situ* measurements of bulk temperatures."

IR Instrument Workshop

In order to compare and gauge the accuracy of the various IR radiometers available, and discuss their applications in validation activities, Minnett and Otis Brown, MODIS Science Team members, and Dean at RSMAS, hosted two workshops March 2 - 6, 1998. The first was a 3-day instrument comparison workshop, or "round robin," whose purpose was to provide a framework in which investigators using IR radiometers, spectrometers, and imaging devices could meet to compare instruments, calibration targets, and measurement protocols. This is to ensure consistent and accurate data sets for future use in validating IR retrievals of surface temperature from current and future satellite measurements. The instruments compared will have applications in the validation of surface temperatures over land as well as oceans. Immediately following the 3-day instrument workshop, a 2-day validation workshop was held, and this was conducted by MODIS Science Team member Ian Barton of the Commonwealth Scientific and Industrial Research Organization (CSIRO) Marine Labs of Australia. (For a summary of discussion at the validation workshop, refer to page 38).

In addition to the RSMAS/MODIS and CSIRO/MODIS participants already mentioned, the instrument comparison workshop included representatives from the following organizations: the EOS Project Science Office at Goddard Space Flight Center (GSFC); the Advanced Spaceborne and Thermal Emission and Reflection Radiometer (ASTER) Project at the Jet Propulsion Laboratory (JPL); the Space Science and Engineering Center (SSEC) at the University of Wisconsin; the University of Colorado; the Applied Physics Laboratory (APL) of the University of Washington; the University of Leicester; the University of British Columbia; the National Institute of Standards and Technology (NIST); the Naval Research Lab (NRL); Rutherford Appleton Lab; the UK MET Office; and the National Physical Laboratory (NPL). Over the course of the workshop, participants used a wide range of radiometers, of varying degrees of cost and accuracy, to take turns making temperature measurements in the laboratory against five different blackbody calibration sources, also of varying degrees of cost and accuracy. At the beginning of the workshop it was agreed that lab measurements would be taken with the blackbodies at temperatures of 20° and 30° C. (Supplementary measurements were taken by some participants at other temperatures [e.g., 60° C], or over a range of temperatures while a blackbody source was ramped up from one temperature to another.) In addition to making measurements inside the lab, participants mounted instruments on a platform on the roof of the laboratory building, overlooking the ocean.

Blackbodies at the Workshop

Blackbodies were brought to the workshop by NIST, APL, JPL, CSIRO, and the European Union's Combined Action for the Study of the Ocean Thermal Skin (CASOTS). The common central component to all of these blackbodies is a cavity containing a copper cone which is gold-plated on the outside and painted black on the inside (for high emissivity). IR instruments are focused on the aperture of the cone, whose temperature is controlled by a surrounding water bath. It is primarily the sophistication of the water bath thermometry, heating, cooling, and mixing equipment that separated the blackbodies at the workshop according to temperature stability and cost. The NIST and APL blackbodies represented the most sophisticated units and are intended primarily for laboratory use. (The APL unit copied the NIST design.) According to Joe Rice of NIST, the standard deviation of their blackbody's water bath is stable to roughly 200 microkelvin, or 0.0002° C. The JPL blackbody, developed by Frank Palluconi, is actually intended to be filled with lake water and used as a one-point calibration source for buoys; the aperture is located on the bottom of the unit, and Palluconi used a hand-held drill to drive the water-stirring mechanism. Barton supplied the CSIRO blackbody, a portable unit intended for use at sea, with neither water temperature control nor stirring mechanism. The CASOTS blackbody unit, provided by Craig Donlon of the University of Colorado, is also intended for use at sea. The blackbody is housed within an insulated plastic beverage cooler. This unit has a stirring mechanism but no water temperature control. Measurements taken with the M-AERI indicated hardly any difference in precision between the CASOTS blackbody and the NIST blackbody. Donlon anticipates using the M-AERI as a transfer standard so that the CASOTS units can be "NIST-traceable."

Radiometers at the Workshop

Radiometers measured against the blackbodies ranged from relatively inexpensive, hand-held models to the very expensive and extremely accurate M-AERI. Radiometer data are still being compiled, and Minnett will publish the data on the Web as it is received. (A complete listing of the radiometers brought to the workshop is now available on the Web at: http://www.rsmas.miami.edu/ir. Radiometer data will also be posted at this site.) Fred Prata of the CSIRO Division of Atmospheric Research has already made available measurements he made with four radiometers; three of these were inexpensive, hand-held models (one made by Tasco, the other two by Everest). The fourth radiometer was a more-expensive, home-grown Airborne Hazard Detection System (AHDS) 5-channel filter model. (The AHDS was originally designed to utilize IR radiation in the detection of hazardous volcanic ash, clear air turbulence and low-level wind shear.) After plotting the data from all four models, Prata concluded that the AHDS can easily achieve an accuracy of 0.02 K. The other three models could not achieve this level of accuracy; there appears to be an order of magnitude difference between the AHDS and the others. Prata's data indicate that good internal calibration (i.e., good internal blackbodies) provides better accuracy but costs more. Prata suggested that the AHDS, while not suitable for a wide deployment, might be used as a traveling standard against which cheaper radiometers could frequently be compared.

Other home-grown radiometer designs brought to the workshop included the CASOTS ship of opportunity sea surface temperature radiometer (SOSSTR) and the University of Washington's "dual-Heimann" model. Both of these designs are intended for use at sea, and employ two radiometers (CASOTS uses Tasco THI-500L models, while the University of Washington uses Heimann KT-15 models) and two blackbodies (one ambient and one hot) within their housing. One radiometer looks at the sea, while the other looks at the sky, to provide data with which to correct for the small component of reflected sky radiance in the sea measurement. Andy Jessup from the University of Washington would like to take the design one step further and enclose the radiometers and blackbodies within a sealed, temperature-controlled housing. The housing would be filled with dry nitrogen, and the sensors would look out through an IR-transparent window equipped with a wiper and fluid reservoir to periodically clean sea spray and other contaminants. Jessup hopes to find a window that can be very accurately characterized, so that the protection it would afford the sensors could more than account for the added uncertainty it introduces.

M-AERI

The most accurate and expensive radiometer at the workshop was the Marine-Atmosphere Emitted Radiance Interferometer (M-AERI). The M-AERI is a ship-based instrument designed and built at the University of Wisconsin's Space Science and Engineering Center, and one of its applications is the validation of MODIS SST algorithms. (For more information on the M-AERI, go to the RSMAS Web site referenced earlier.) Minnett explains the importance of the M-AERI to the MODIS validation effort as follows: "The essence of post-launch validation of SST derived from the MODIS thermal infrared channels is in determining the accuracy of the correction for the effect of the intervening atmosphere. By using an accurate infrared spectroradiometer close to the sea surface the effects of near-surface vertical temperature gradients, caused by heat exchange between the ocean and atmosphere (the thermal skin effect) and by the absorption of solar radiation in the upper few meters of the ocean on days of low wind speeds (the diurnal thermocline), can be removed from the comparison. The conventional approach of comparing the satellite-derived SST with bulk sea temperatures taken at a depth of a meter or more includes the effects of variation in these gradients, and these are included in the estimate of the inaccuracies of the satellite retrievals. The size of these effects is comparable, and larger in some cases, to the target accuracy of the MODIS SST retrievals (~0.3 K rms), and so cannot be ignored. The M-AERI is a spectroradiometer that can achieve both the high absolute accuracy necessary for the comparison and the good spectral resolution (~1 cm^{-1}) necessary to resolve the effects of absorption and emission spectra of the atmospheric gases. In addition, the spectral resolution permits the synthesis of the precise wavelength response of each of the MODIS channels, which would be very difficult to match accurately using filter radiometers." At the Miami workshop the M-AERI achieved excellent results when compared to the NIST blackbody. M-AERI agreement with the NIST blackbody was better than 0.03° C at the 30° C test point, and better than 0.02° C at the 20° C test point. (More M-AERI results can be found at: http://arm1.ssec.wisc.edu/~bobk/miami_ir/miami_ir.htm.) Commenting on the M-AERI results, Bob Knuteson from the University of Wisconsin said that, "The fact that the NIST blackbody and M-AERI agree as well as they do seems like the way it has to turn out if both NIST and Wisconsin are doing their jobs correctly. So it's really a consistency check on our calibration procedures more than anything else." Wayne Esaias, MODIS Ocean (MOCEAN) Group leader, enthused that, "The M-AERI is completely revamping the way SST is validated. It has demonstrated a level of accuracy that is nearly an order of magnitude better than some scientists thought possible for a radiometer."

Results and Future Activities

Overall, the results of the radiometer workshop were very encouraging, and participants are already talking about the applications of lessons learned, as well as future workshops. Walt McKeown of NRL was impressed by the radiometer designs of Jessup, Donlon, and others, and will recommend to the Navy that the best design be implemented on the National Buoy System. McKeown was also impressed by the large amount and quality of the research cruise data, especially that from RSMAS and Wisconsin, and he is proposing to the Navy that a National Radiometric Library of this research cruise data be collected along with the collocated satellite data. This could be used to radiometrically calibrate the world's satellites as well as to study other phenomena that affect SST, such as the thermal skin effect and diurnal thermocline. Prata suggested that the results of the Miami workshop are also beneficial to the Land community, and stated that, "At the moment there have been (and still are) some large field programs (e.g., FIFE, BOREAS, HAPEX) which made use of IR radiometery but perhaps lacked the kind of calibration and validation protocols that are being pursued by the SST people. I believe that both communities (Land and Ocean) can benefit from some closer collaboration and exchange of ideas." It is likely that another IR radiometer workshop will be held within the next two years. It may include additional measurement environments, such as aboard a ship or in a lab environment where the ambient temperature is precisely controlled. If new models of radiometers are introduced prior to the next workshop, it is hoped that these will be available for comparison purposes. Barton concluded that, "The radiometers calibrated and compared at the Miami workshop are those that will be used to validate the data products derived from IR measurements from space over the next 5-to-10 years. It is thus important that these are calibrated against NIST and other standards to ensure that consistency is obtained with the different measurements. It will also be important to again compare these instruments in 1-to-2 years time, after they have been used to validate products from EOS and other Earth observing systems."

KUDOS

Dr. Geoffrey Kent, Science and Technology Corporation and an EOS science team member, has been selected to receive NASA's Distinguished Public Service Medal for his contributions to the success of programs in the Aerosol Research Branch, NASA Langley Research Center. This award "is granted only to individuals whose distinguished accomplishments contributed substantially to the NASA mission. This is the highest honor that NASA confers to a non-Government individual." He will receive the award at a ceremony and reception to be held in Washington, DC, June 4, 1998.

The Earth Observer staff and the EOS community wish to congratulate Dr. Kent on his outstanding accomplishment.

EOS Land Validation Coordination: An Update

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Validation of EOS data products is an integral part of the EOS Program (http://eospso.gsfc.nasa.gov/validation/valpage.html). The responsibility for product validation will be shared between the EOS Instrument Team Investigators and EOS Validation Investigators selected through the 1997 NASA Research Announcement. Summaries of the individual instrument team validation plans can be found at http://eospso.gsfc.nasa.gov/validation/valcharts.html, and abstracts of the Validation Investigators projects can be found at http://eospso.gsfc.nasa.gov/validation/frame.html. In the longer-term, contributions to validation will also be made by the broader user-community, through application of the data products to science questions. A distinction is made here between quality assurance for products and product validation, the latter generally relying on comparisons to independent correlative measurements and the former focused on the operational algorithmic implementation.

The EOS Validation Program sets a precedent in terms of a funded 'community' validation of land satellite products. As a relatively new endeavor shared between different research groups and spanning several disciplines, global data set validation necessitates community coordination. To initiate coordination, a preliminary meeting was held in March 1996 (*The Earth Observer*, Vol. 8, No. 2) to assess various approaches to land product validation and a range of long-term monitoring activities related to EOS validation. Following the selection of the EOS Validation Investigators in the fall of 1997 (http://eospso.gsfc.nasa.gov/directory/validation/validation.html), a Science Working group for the AM Platform (SWAMP) Land Validation Coordination meeting was held in December 1997 and attended by 60 scientists. The objectives of this meeting were: 1) to present individual investigator validation plans around themes of surface radiation and temperature, vegetation properties, and snow and ice product validation, 2) to assess aircraft validation missions in terms of site over-flight opportunities, 3) to agree on a number of Core Test Sites for EOS land validation, 4) to discuss standards for field/air measurement protocols, and 5) to develop a validation data policy and management plans both for satellite data products and correlative measurements. Breakout group sessions were held on biophysical/vegetation measurements, albedo measurements, snow and ice measurements, instrument calibration, test sites, aircraft coordination and data management.

Biophysical/Vegetation Measurements

The biophysical/vegetation breakout group was chaired by Alfredo Huete (University of Arizona) and Betty Walter-Shea (University of Nebraska) and discussed the design and protocols for the validation of the leaf area index (LAI), fraction of photosynthetically active radiation absorbed (fAPAR), net primary productivity (NPP), and vegetation index products. The objective was to develop a set of *standardized* procedures for the validation of vegetation-related satellite products across a global range of biomes, over the phenologic cycle, and within expected sun-target-sensor conditions. A standardized methodology is considered essential for cross-site comparability. Crucial to the measures discussed is the need for ground-to-air-to-satellite registration with the Global Positioning System (GPS).

Discussions focused on the need for field measures of both fraction of photosynthetically active radiation intercepted (fIPAR) and fAPAR. The group noted the need for daily measures of fAPAR with a minimum requirement being that instantaneous measures should be made close to time of overpass and over a range of sun angles bracketing the time of the satellite overpass. Since the interception and absorption of incoming photosynthetically active radiation (PAR) varies throughout the day, fAPAR measurements at various sun angles enable: (1) better integration into daily fAPAR—and photosynthesis/carbon uptake; and (2) standardization of fAPAR measures to constant sun angles, when spatial/temporal comparisons of instantaneous fAPAR are desired. The primary instruments required are ceptometers and line quantum sensors. A quantum sensor is also needed in an open area. Both instruments need calibration and cross-calibration to a standard reference and caution is needed with their sun-angle dependency on calibration.

The group defined LAI as one-half the total leaf area (i.e., one-sided) per unit area of ground surface. The group further distinguished between the LAI of broadleaf canopies (one-sided leaf area) and the LAI of needleleaf canopies (the projected area). The group recommended that measures of LAI be separated into green LAI (active canopy component) and non-green LAI, and noted that the non-green component may have large effects on the remotely-sensed interpretation of green LAI. Direct measures of LAI involve destructive harvesting and associated allometric equations. More indirect measures include use of ceptometers and the Li-Cor LAI-2000 instrument. Indirect methods measure light transmittance. The relationships of light transmittance with LAI are land-cover dependent, and corrections are generally needed. Initial discussions were held on sampling design, with each biome and land-cover class having an existing and recognized procedure for "point-based" LAI measures. Coupling the Li-Cor 2000 to such a reference will allow for the most accurate LAI measures to be extended from a meter-scale footprint of *in situ* sensors to the kilometer-scale footprint of satellite sensors.

Validation of the Vegetation Index (VI) products, will be coupled to biophysical vegetation measurements, as well as radiometric measurements of canopy reflectance properties. Since it is the output of the VI that must be validated, it is necessary to ensure that the variance or invariance in VI values corresponds to real, surface-related canopy behavior. Thus, measurements required are similar to those of the fAPAR and LAI products. As with the fAPAR product, VIs exhibit pronounced diurnal variations and require measurement over a range of sun angles. Preliminary discussions on sampling design focused on site heterogeneity issues, sampling statistics, and scaling issues.

Albedo Measurements

The surface albedo breakout group was chaired by Alan Strahler (Boston University) and examined the issues involved in validation of the surface reflectance, the bidirectional reflectance distribution function (BRDF), and albedo land products from the MODIS and MISR Instrument Teams. The group stressed the conclusion that the best validation strategy would acquire data that could be used to reproduce and validate the entire chain of surface radiometric products, beginning with aerosol retrieval, through surface reflectance, to BRDF and albedo. This requires measurements of downwelling irradiance, both for characterization of illumination and for aerosol-sun photometry, using instruments such as the CIMEL and the Multi-Filter Rotating Shadowband Radiometer (MFRSR); upwelling radiance measurements, preferably directional and spectral in at least PAR wavelengths; and broadband hemispherical albedo measurements, preferably in the visible (<0.7 micrometers) and in the near-infrared and infrared regions (>0.7 micrometers). The CERES Team has developed a helicopter-based, multi-spectral radiometer system to measure the BRDF for various surface types. The CERES system will be used to measure BRDF at the ARM CART site in Oklahoma during an August 3-28, 1998 campaign. The group agreed to develop a validation protocol document for the entire measurement chain to include science principles, MISR and MODIS product descriptions, instrument measurement principles and procedures, and related information. The first draft of this protocol has been prepared and is now circulating for comment.

Snow and Ice Measurements

The snow and ice validation group was co-chaired by Anne Nolin (University of Colorado-Boulder) and Dorothy Hall (NASA/Goddard). EOS AM-1 cryospheric products to be validated include snow-covered area, snow albedo, sea ice surface temperature, and sea ice extent and concentration. During the working group session, product-specific test sites were chosen and prioritized (see section on **Test Sites** and Table 2a). These include both U.S. and international sites in polar, mid-latitude, and mountain regions. The group also discussed the planning of two upcoming field and ER-2 aircraft missions involving the MODIS Airborne Simulator (MAS) (http://ltpwww.gsfc.nasa.gov/MAS/). The first of these snow validation experiments was held following the validation meeting between March 10-20, 1998, in the vicinity of Mono Lake, California. Anne Nolin and Julienne Stroeve worked in coordination with members of the MISR validation team (Jim Conel and Mark Helmlinger). The experiment was headed by Zhengming Wan (University of California-Santa Barbara) whose group was on hand to measure surface temperature as part of their MODIS validation activities. Both AirMISR and MAS were flown on an ER-2, but due to technical and weather-related problems only MAS data were acquired. This experiment focused on validation of snow albedo. Ground support from the Jet Propulsion Laboratory (JPL) was supplied by the MISR team, and their measurements were critical to the success of the experiment. A second snow validation experiment is planned for winter, 1999 in the upper Midwest, with ER-2 flights out of Madison, Wisconsin. This project will serve as a follow-on to last year's Winter Cloud Experiment (WINCE) (http://cimss.ssec.wisc.edu/wince/wince.html). Again MAS and AirMISR will be flown in tandem on the ER-2, with ground measurements of albedo and snow-covered area to be made at various locations below the four flight lines. For sea ice validation, *in situ* measurements will be made in the Ross Sea by Li and colleagues from the University of Alaska.

Instrument Calibration

The instrument calibration validation group was chaired by Kurt Thome (University of Arizona). Several topics need to be addressed concerning validation instrumentation. The first of these is the obvious need to determine the precision and accuracy of correlative measurements. To obtain better precision, it was decided to develop sets of protocols for the correlative validation measurements and to ensure traceability to a set of standards. To validate the accuracy of the measurements requires comparisons of results to sets of independent measurements with well-known precision. Two pathfinding activities known as the Prototype Validation Exercise (PROVE) campaigns, were undertaken in 1997 to establish such inter-instrument validation protocols (http://pratmos.gsfc.nasa.gov/~justice/ modland/valid).

Surface reflectance retrieval is one measurement that is common to many investigations. Methods for ensuring data consistency for this parameter were discussed. Several groups expressed an interest in comparing reflectance retrievals to evaluate differences caused by instrumentation, reference field standards, and general methodologies and sampling strategies. It was decided that rather than create a new experiment to examine this problem, the groups would attempt to participate in an upcoming experiment in the Fall of 1998 at the Maricopa Agricultural Center, near Phoenix, Arizona (http://gaea.fcr.arizona.edu/MAC.html). Work in a similar fashion related to other parameters, such as albedo, fAPAR, LAI, NPP, and surface temperature and emissivity will also be done, but no specific plans have yet been made.

Test Sites

The EOS Core Test Site Group was co-chaired by Jeff Privette (NASA/Goddard) and Ken McGwire (Desert Research Institute). Final agreement was reached at the meeting on a set of EOS Core Test Sites for land validation (Table 1).

Table 1. EOS Land Validation Core Test Sites

Grassland/ Cereal Crop	Shrubland/ Woodland	Broadleaf Cropland	Broadleaf Forest	Needleleaf Forest
Konza LTER, KS	Skukuza, South Africa	USDA-ARS, Beltsville, MD	Harvard Forest LTER	Wisconsin LTER/ AMERIFLUX
Sevilleta LTER, NM	Mongu, Zambia	Maricopa Agr. Center, AZ	Walker Branch, TN	Cascades, OR (H.J. Andrews LTER)
Uardry, Australia	Jornada LTER, NM	VA Coastal Reserve LTER	Howland, ME	BOREAS NSA, Canada
Ulan Bator Mongolia	SALSA, AZ & Mexico		Tapajos, Brazil	BOREAS SSA, Canada
ARM/CART, OK			Ji Parana, Brazil	Glacier National Park, MT
Altai, Russia				

Table 1. ACRONYMS: ARM/CART (Atmospheric Radiation Measurement/Cloud and Radiation Testbed), LTER (Long-Term Ecological Research), BOREAS (Boreal Ecosystem-Atmosphere Study), NSA (Northern Study Area), SSA (Southern Study Area), USDA-ARS (U.S. Department of Agriculture-Agricultural Research Service), SALSA (Semi-Arid Land-Surface-Atmosphere Program).

The sites are intended as a focus for land product validation over a range of biome types. However, they will also be useful for validation of some atmospheric products. The site list represents a consensus among the instrument teams and validation investigators, developed through a number of meetings and discussions. Most of the sites build on an existing program of long-term measurements and have an infrastructure to support *in situ* measurement. Each site has a point of contact responsible for overall validation coordination at the site (http://www-eosdis.ornl.gov/eos_land_val/list_sites.html). Although these sites are not intended to meet all EOS test site needs, they will, however, provide a focus for satellite, aircraft, and ground data collection for land product validation, and will provide sites for which scientists can readily access *in situ* and EOS instrument data sets. It is important to note that the EOS instrument vicarious calibration test-site needs will be coordinated by the EOS Calibration Working Group (Chair: Jim Butler, EOS Calibration Scientist - http://eospso.gsfc. nasa.gov/calibration/calpage.html) and are not included as part of the EOS Validation Core Test Sites.

Some products require special surface characteristics for validation. For example, the snow and ice products and the land surface temperature products will be validated at a number of product-specific test sites (Table 2a and 2b).

Table 2a. Primary Validation Sites for EOS Validation of Snow and Ice Products

Vatnajokull and Hofsjokull, Iceland	Juneau Icefields
Cordillera Real, Bolivia	Lake Mendota, WI, USA
Nevado Sajama, S. America	Mammoth Mt, CA, USA
Cordillera Blanca, S. America	Niwot Ridge, CO, USA
Keene, NH	ARM/Barrow, AK, USA
N.W. Minnesota	Greenland AWS; Various Sites
Glacier National Park, MT	Ross Sea, Antarctica
Central Alaska	
Malaspina Glacier	

Table 2b. Primary Validation Sites for EOS Validation of Land Surface Temperature Products

Railroad Valley, NV, USA	Amburla/Alice Springs, NT Australia
Death Valley, NV, USA	Tsukuba, Japan
Mammoth Lakes, CA, USA	Nam Co (Lake), Tibet
Lake Tahoe, CA, USA	Uyuni Salt Flats, Bolivia
Park Falls, WI, USA	La Crau, France
Salton Sea, CA, USA	Safawi, Jordan
Mauna Loa, HA, USA	Dunhuang Gansu, China
San Luis Obispo, CA, USA	Gobi Desert, China
Uardry Sheep Farm, Australia	Qinghai Lake, Qinghai, China
Broome, Australia	

Other products such as MODIS Land Cover Change will require validation at sites where rapid change is taking place and will include targets of opportunity selected during the EOS mission. Although there will be a large number of such land-cover sites, validation will rely primarily on the acquisition of high-resolution satellite data. An early example of global land-cover product validation is being supported by the NASA Land-Cover Land-Use Program (J. Estes University of California Santa Barbara P.I. - http://rsrunt.geog.uscb.edu/igbp.html). Similarly, a set of high-resolution satellite training and testing sites used for AVHRR land cover classification has also been developed by John Townshend and Ruth Defries (University of Maryland) (http://www.inform. umd.edu/landcover/mss-training-areas.html).

Aircraft Coordination

The validation program will include the collection of aircraft data. MISR and ASTER will be relying heavily on airborne simulator data from AirMISR (http://www-misr.jpl.nasa.gov/armain.html) and the MASTER (http://asterweb.jpl.nasa.gov/master/) instruments. The large cost of aircraft flights makes coordination between flight mission, instrument, and validation investigators highly desirable. The tentative program of planned flights for 1999 provides opportunities for test site over-flights and piggy-back missions. Those interested in more information on flight itineraries and schedules should contact the individual flight mission principal investigators listed at http://eospso.gsfc.nasa.gov/eos_homepage/airborne.html.

Data Management

Bill Emanuel (University of Virginia) and Dick Olson of the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) co-chaired the validation data management group. A validation data policy has been clearly specified by the EOS Validation Office (http://eospso.gsfc.nasa.gov/validation/policy.html). Efficient data management will be critical for validation of land products combining satellite and *in situ* data. Timely feedback on algorithm performance will be needed for early algorithm refinement and prior to product reprocessing. Those undertaking product validation will require rapid access to coincident *in situ* and EOS instrument data. It was agreed that validation investigators would make their validation data available through the World Wide Web as soon as possible following data collection and at least within 6 months after acquisition. The ORNL DAAC has taken the charge to coordinate *in situ* data management. A central Web Site for EOS *in situ* data validation coordination will be established at the ORNL DAAC, providing metadata of the various investigator validation data holdings and pointers to investigator Web sites. Most of the higher order land products from the AM-1 platform will be available from EOSDIS via the Land DAAC at the EROS Data Center (EDC). The usefulness of a single Web page, with links to relevant *in situ*, aircraft and satellite sensor data sets, for each Core Validation Site was noted.

Recent Progress In Land Validation Coordination

Since the December meeting there have been a number of developments with respect to validation. Efforts have been made through SWAMP to ensure that data acquisition from MISR, ASTER, MODIS and Landsat 7 will be made for the EOS Core Test Sites, as soon as possible following launch. ASTER and Landsat 7 have included the Core Test Sites in their acquisition strategies.

The individual validation investigators and the instrument teams are developing their own Web sites for validation data distribution. The ORNL DAAC has developed an EOS Validation Data Management Web site (http://www-eosdis.ornl.gov/eos_land_val/valid.html) and is testing a 'search tool' called 'Mercury', which will search each of the validation investigators and instrument team member Web sites for validation metadata and provide a catalogue of validation data. The ORNL DAAC is also developing a Web site for the FLUXNET program (http://cdiac.esd.ornl.gov/programs/NIGEC/fluxnet/). FLUXNET is a network of ground stations measuring carbon and energy fluxes and will be used to validate various primary production data sets. Carbon dioxide and energy flux data sets from two AMERIFLUX sites are currently being transferred to ORNL to prototype coordination of that network with EOS validation.

EDC DAAC representatives took the charge from the December meeting to develop plans to facilitate satellite data access in support of EOS validation. The EDC DAAC is currently exploring possibilities for packaging satellite data for the EOS Core Validation Sites, to facilitate data access and analysis by validation investigators. This data packaging will hopefully be a value-added activity by the DAAC which will speed up the validation process. As a precursor to EOS data collection and management, the NASA Landsat Pathfinder Global Land Cover Test Sites (GLCTS) program being implemented at EDC (P.I.: Ken McGwire, Desert Research Institute) is compiling land cover, Landsat, AVHRR and Digital Elevation Model (DEM) data sets for the EOS Core Validation Sites (http://edcwww.cr.usgs.gov/landdaac/pathfinder/pathpage.html).

Cooperation between EOS Validation and the NASA regional intensive field campaigns has always been part of the MODIS land validation strategy. The NASA component of the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is now underway and the LBA tower sites have been selected and will provide an opportunity for EOS validation. The Southern African Fires and Atmosphere Research Initiative (SAFARI 2000) will provide a continuation of the SCAR (Smoke/Sulfate Clouds and Radiation) class of ground and airborne campaigns during the early years of the AM-1 mission and an opportunity for EOS data product validation and early science results. The NASA contribution to the GEWEX Continental-scale International Project (GCIP) will provide a regional framework activity for the U.S., within which to validate and exploit EOS land products.

The MODIS land group (Lead: Alfredo Huete) is developing plans for a light-aircraft-based validation package, which will be used to extend point and ground-based reflectance measurements to larger footprints (1-5 km) at the Core Validation Sites. Simple and stable instrumentation with transfer radiometers coupled to MODIS Level 1b calibration activities would provide a consistent and mobile radiometric package. This versatile, low cost, rapid deployment would be made in conjunction with, and coupled to, ground-based fAPAR and LAI validation to characterize canopy reflectance over 1-km footprints at various view and sun angles. An open meeting to develop protocols for LAI/fAPAR validation measurement is planned for early this summer and is being organized by Jeff Privette (NASA/Goddard).

The NASA EOS Validation Program provides an important foundation for the development of international collaboration with respect to instrument calibration and product validation. The Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation is an obvious forum to further develop the international data requirements and cooperation for product validation. Similarly EOS land validation can both benefit from and contribute to the emerging Global Observing System Network (http://wwww.geog.umd.edu/landcover/bvs), which is creating a network of existing networks and sites making land measurements relevant to the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS). International cooperation and coordination of land satellite product validation holds much promise, but is something that has yet to be fully developed.

NASA Atmospheric Researchers Focus on Mexican Fires

— David E. Steitz, NASA Headquarters, Washington, DC. (Phone: 202/358-1730)
— Allen Kenitzer (nkhazeni@pop100.gsfc.nasa.gov), NASA Goddard Space Flight Center, Greenbelt, MD.

Since the beginning of the Mexican fires in late March and early April of this year, atmospheric researchers at NASA using the Total Ozone Mapping Spectrometer (TOMS), have been closely monitoring the fires and the smoke aerosols emitted by the fires. TOMS obtains daily images of the amount of smoke present in the atmosphere anywhere in the world.

Scientists have a keen interest in smoke aerosols generated by fires like those in Mexico because smoke contributes to the overall global air-pollution levels that can impact the quality of air that humans breathe. Residents of Texas have been issued warnings to remain indoors to avoid adverse health impacts, such as asthma, from the smoke. Increased smoke concentration from human-induced fires could contribute to global climate change.

The fires started in southern Mexico and northern Guatemala near the end of March 1998. Though most of the fires were started as part of the annual clearing of agricultural fields, some started naturally because of the extremely dry conditions. The dry conditions are associated with the El Niño weather patterns similar to those that caused the fires in Indonesia earlier this year.

The small particles, called aerosols, that comprise smoke can affect the amount of energy reaching the Earth's surface by reflecting and/or absorbing sunlight. Smoke aerosols also can act as small particles upon which clouds can form. Clouds containing smoke aerosols are believed to reflect and absorb energy in different ways than clouds formed from natural particles such as dust or sea salt.

"Shortly after the fires started, we noticed the increased amount of aerosols (in this case smoke) in the region," said Dr. Jay R. Herman, an atmospheric scientist at NASA's Goddard Space Flight Center, Greenbelt, MD. "By mid-April large amounts of smoke were covering parts of Mexico with plumes extending into Florida, Texas, New Mexico, California and Wisconsin.

The smoke was sufficiently thick that it was easily visible on the ground and resembled a light haze to medium fog in parts of Texas, Georgia and Florida, Herman said. On May 16 the smoke plume extended across the Eastern U.S., passing through Ohio, and into Southern Canada.

Because of the difficulties in extinguishing the fires, the large smoke plumes are still present in Mexico. The smoke tends to extend from the ground up to an altitude of about three kilometers (1.8 miles) and follow the prevailing winds. Due to wind shear in this altitude range, there is frequently more than one plume, with smoke blowing from west to east and from south to north. With prospects of rain slim due to the El Niño-driven drought, scientists believe the smoke may linger for a long time.

Meanwhile, space observations can document such events as the highly unusual transport of large amounts of dust from China (Gobi desert) across the Pacific Ocean and striking parts of the Western U.S., and the smoke from Canadian fires in the Pacific Northwest.

TOMS is part of NASA's Earth Science strategic enterprise, a long-term, coordinated research effort to study the Earth as a global system. The TOMS program is managed by the Goddard Space Flight Center for NASA's Office of Earth Science, Washington, DC. TOMS images of the smoke plumes are available at URL: http://jwocky.gsfc.nasa.gov.

EDUCATION HIGHLIGHT

NASA Earth Science Enterprise Education Program Update

— Nahid Khazenie (nkhazeni@pop900.gsfc.nasa.gov)
Earth Science System Program Office, NASA Goddard Space Flight Center

EARTH SCIENCE ENTERPRISE AT THE NATIONAL SCIENCE TEACHERS ASSOCIATION (NSTA) CONVENTION

At the April 16-1998, NSTA Convention in Las Vegas Nevada the NASA Earth Science Enterprise (ESE) showed a strong, unified presence with representatives participating from NASA Centers and NASA-sponsored organizations from across the country. In addition to the thousands of classroom materials, posters, fact sheets, and CD-ROMs that were distributed at the ESE booth, almost 600 teachers attended NASA Earth Science sessions at the conference, which ranged from 15-minute demonstrations to 1-hour hands-on workshops. The conference had a record turnout with almost 20,000 participants.

NASA-SPONSORED CD-ROM WINS CODIE AWARD

The Software Publishers Association (SPA) announced the 1998 Excellence in Software Awards winners on Monday, March 23, during the 1998 Spring Symposium in San Jose, Calif. SPA's annual Excellence in Software Awards, known as the Codie Awards, are peer-recognition awards granted for excellence in today's software industry marketplace.

"Ocean Expeditions: El Niño," developed by Planet Earth Science and distributed by Tom Snyder Productions received an award for Best Curriculum Software for Secondary/Post-Secondary Schools. "Ocean Expeditions" received support from NASA's Earth Science Enterprise.

FIELD TEST VERSION OF EARTH SYSTEM SCIENCE CD-ROM AVAILABLE

Project Earth System Science (eSS), a cooperative activity between Norfolk State University and NASA Langley Research Center, has developed a CD-ROM for middle and high school science teachers. A field-test version is available for review either in CD-ROM or over the Web at <http://vigyan.nsu.edu/DAACess/>.

Project eSS emphasizes the use of satellite data as content for curriculum development. The project facilitates access by educators and scientists to remote sensing data gathered by the Earth Observing System (EOS) and stored at the Langley Research Center Distributed Active Archive Center (DAAC).

For more information, please contact Dr. S. Raj Chaudhury or Dr. Gae Golembiewski, Co-Directors, NEB 122, Norfolk State University, 2401 Corprew Avenue, Norfolk, VA 23504; Phone: (757) 683-8730; FAX: (757) 683-9054

RESOURCES ON THE INTERNET

NASA EDUCATION PROGRAM BROCHURE AVAILABLE ON-LINE

http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Accessing.NASA.Education.Brochure/

The newly updated "How to Access Information on NASA's Education Program, Materials, and Services" brochure is now available on NASA Spacelink.

This publication is a guide to various educational resources such as: NASA Field Centers and Precollege Contacts, on-line resources (NASA Education Home Page, NASA Spacelink, Quest, NASA Television, and FEDIX), Central Operation of Resources for Educators (CORE), NASA Educator Resource Center Network, and Space Grant College and Fellowship Program/Experimental Program to Stimulate Competitive Research (EPSCOR)

LIFTOFF TO LEARNING PROGRAM GUIDE

http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Lift off.to.Learning. Brochure

The Liftoff To Learning Program Guide provides a brief description of each of the Liftoff to Learning videotapes and accompanying resource guides. The Guide includes a subject matrix identifying which programs relate to various subject areas and grade levels.

NASA CORE CATALOG

http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/NASA.CORE.Catalog/
An Adobe Acrobat PDF version of the NASA Central Operation of Resources for Educators (CORE) Educational

Materials Catalog has been released. The NASA CORE catalog has more than 200 NASA-produced videocassette, slide, and CD-ROM titles available for a minimal charge.

NEW ONE-STOP WEB SITE FOR TEACHING AND LEARNING

http://www.ed.gov/free

A new one-stop web site for teaching and learning resources was announced on April 8 by Education Secretary Riley. The web site, "Federal Resources for Educational Excellence," (FREE) offers:

√ quick access to hundreds of teaching and learning resources across the federal government;

√ a place where teachers, federal agencies, and other organizations can begin forming partnerships to develop new resources for teaching and learning; and

√ information about an effort to support partnerships of federal agencies and teachers, as well as other organizations, to develop Internet-based learning resources and Internet-based learning communities.

NASA UNVEILS NEW INTERNET SITE FOR FIRE MONITORING BY SATELLITE

— David E. Steitz, Headquarters, Washington, DC. (Phone: 202/358-1730)
— Lynn Chandler, Goddard Space Flight Center, Greenbelt, MD. (Phone: 301/286-9016)

In an effort to provide up-to-date information about current fire situations around the globe to the public and scientific communities, NASA today unveiled a new presence on the World Wide Web that provides an up-to-date synopsis of current information about fires and their effect on global climate change. This web site features revealing animation depicting wildfires across the globe.

The new Web site at URL http://modarch.gsfc.nasa.gov/fire_atlas/fires.html provides recent imagery, analysis of data from the early and mid-1990s, and a synthesis of a range of satellite information resources that are currently available about terrestrial fires and future global fire monitoring capabilities. The Web site draws upon satellite resources from several U.S. agencies and international partners and is intended to serve the needs of the scientific community and the general public.

The recent fires in Mexico and Brazil, and last summer's fires in Indonesia, have heightened public awareness of the importance of natural and human-induced wildfire as a contributor both to regional pollution and global change. Nearly 175 million acres of forest and grasslands are burned each year worldwide. Using data from satellite sensors, aircraft, and ground-based initiatives, scientists are working to develop a new global fire-monitoring program that will enable them to better understand the many implications of this growing problem.

Specifically, efforts are underway to quantify the total area of forests and grasslands burned each year and to more accurately estimate the amount of resulting emission products. These newer and better data will facilitate development of more robust computer models that will enhance scientists' abilities to predict how biomass burning will impact climate, the environment and air quality.

Since no single satellite or instrument provides optimal characteristics for fire monitoring, data are currently used from several satellite systems. Each system has different capabilities in terms of spatial resolution, sensitivity/saturation level, spectral frequency, overpass time and repeat frequency.

Among the agencies and programs represented on this web page are:

√ The International Geosphere Biosphere Program using Advanced Very High Resolution Radiometer (AVHRR) data for 1992/3 from international ground stations.

√ The NOAA-National Geophysical Data Center global fire database for 1994/5 using U.S. Air Force Defense Meteorological Satellite Program - Operational Linescan System data.

√ A near real-time multi-source fire monitoring system being developed for the U.S. to support the Interagency Fire Center in Boise, ID.

√ A near real-time multi-source active fire monitoring system currently being developed at NOAA-National Geophysical Data Center in Boulder, CO, for the current burning season as part of its Significant Event Imagery activity.

√ Satellite fire-monitoring systems from Brazil, Russia and Senegal using the countries' own regional AVHRR systems.

√ Regional examples of trace gas and particulate emissions from fires in Brazil, Southern Africa and Alaska provided by various research groups.

√ Field and aircraft measurements of fires and emissions for satellite data validation as well as new sensing systems and algorithms being developed by various research groups.

EOS Science Calendar

September 29 - October 1
Landsat Science Team, Patuxent Wildlife Visitor's Center and NASA/GSFC, Greenbelt, MD. Contact Jeff Masek, tel. (301) 405-8233, e-mail: jmasek@geog.umd.edu.

October 13-15
Joint TOPEX/POSEIDON-Jason-1 Science Working Team Meeting, Keystone, Colorado. Contact Shannon Andrews, e-mail: Shannon_Andrew@qgate.ucar.edu.

October 19-21
EOS Investigators Working Group Meeting, New England Center, Durham, NH. Contact Mary Floyd, tel. (301) 220-1707, e-mail: mfloyd@pop200.gsfc.nasa.gov

Global Science Calendar

July 19-24
SPIE International Symposium, Optical Science, Engineering, and Instrumentation, San Diego, CA. Contact William L. Barnes, e-mail: wbarnes@NEPTUNE.GSFC.NASA.GOV, URL: http://www.spie.org/info/sd/.

August 17-21
International Conference on Satellites, Oceanography & Society, Lisbon, Portugal. Contact David Halpern, e-mail: halpern@pacific.jpl.nasa.gov, or URL: http://www.unesco.org/ioc/iyo/icsos/.

September 1-4
ECO BP '98 International Symposium on Resource & Environmental Monitoring, Budapest. Contact Dr. Gabor Remetey Fulopp, tel. (+36) 1-301-4052, fax: (+36) 1-301-4691, e-mail: gabor.remetey@ f-m.x400gw.itb.hu, or URL: http://www.heqyi.com/isprsc7.

September 12-17
National States Geographic Information Council, Annapolis, MD. Contact Kate Barrell, tel. (603) 643-1600, e-mail: nsgic@aol.com.

September 14-17
SPIE's First International Asia-Pacific Symposium on Remote Sensing of the Atmosphere, Environment & Space, Beijing, China. Contact Jinxue Wang, e-mail: jwang@eos.ucar.edu.

September 21-25
The European Symposium on Remote Sensing, Barcelona, Spain. Contact Steve Neeck, e-mail: steve.neeck@gsfc.nasa.gov, URL: http://www.europto.org/.

September 27-October 2
13th AIP International Congress, Fremantle, Western Australia. Contact Prof. Brian O'Connor, e-mail: promaco@promaco.com.au, URL: http://www.promaco.com.au.

October 5-7
Fifth International Conference on Remote Sensing for the Marine and Coastal Environments, San Diego. Contact Robert Rogers, tel: (313) 994-1200, ext. 3234, fax: (313) 994-5123, e-mail: marine@erim-int.com, URL: http://www.erim-int.com/CONF/conf.html.

October 25-28
Geological Society of America, Toronto. Call (303) 447-2020, fax: (303) 447-0648.

Oct. 29-Nov. 1
First International Conference on GIS Education, Ypsilanti, MI. Contact Jay Morgan, tel. (410) 830-2964, e-mail: jmorgan@towson.edu.

November 16-19
Ocean Community Conference '98, Baltimore, MD. Contact Pete Allen, e-mail: mts-occ98@ieee.org.

December 6-10
American Geophysical Union (AGU), San Francisco, CA. Contact Karol Snyder, tel. (202) 939-3205.

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January 10-15
American Meteorological Society, Dallas, TX. Contact Richard Hallgren, tel. (617) 227-2426, ext. 201, e-mail: hallgrew@ametsoc.com.

March 23-26
Progress in Electromagnetics Research Symposium (PIERS 1999), Taipei International Convention Center, Taipei, Taiwan. Call for papers. One-page abstract submission deadline is September 1, 1998. For further information, contact: Prof. Kun Shan Chen, PIERS 1999, Center for Space and Remote Sensing Research, National Central University, Chung-Li, Taiwan, tel. (886) 3-425-7232; fax: (886) 3-425-5535, e-mail: dkschen@csrsr.ncu.edu.tw, URL: http://piers1999.csrsr.ncu.edu.tw/.

April 27-29
Oceanology International Pacific Rim 99, Singapore. Call for papers. Contact Versha Carter, tel. +44 (0) 1818 949 9222, e-mail: carter@spearhead.co.uk, URL: http://www.spearhead.co.uk.

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