Earth Observing System

THE EARTH OBSERVER

A Bimonthly EOS Publication

November/December 1998 Vol. 10 No. 6

In this issue

EDITOR'S CORNER

Michael King
EOS Senior Project Scientist

On December 22, Dr. Ghassem Asrar, Associate Administrator of the Office of Earth Science, announced the selection of winning proposals for end-to-end small spacecraft missions known as Earth System Science Pathfinders (ESSPs). Under the terms of the competition, these ESSP mission proposals included not only instruments and data analysis, but also spacecraft, launch vehicle, and satellite command and control systems, and were cost capped at $90 M for the first mission and $120 M for the second mission. These principal investigator-led missions are to be developed from approval to launch in just three years (for the first mission) with little direct NASA oversight, and are expected to yield exciting new science that complements, but does not duplicate, the science from NASA's Earth Observing System (EOS). Furthermore, NASA policy precludes development of any mission that competes with or duplicates other capabilities available from foreign or commercial partners.

The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations–Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA), led by Dr. David Winker of NASA Langley Research Center, Hampton, VA, was selected as the primary second mission for full-scale development. It is designed to address the role of clouds and aerosol particles and their impact on the Earth's radiation budget—a balance of solar energy reaching the Earth, and lost to space, that ultimately controls the temperature of the Earth.

PICASSO-CENA will employ a dual-wavelength polarization-sensitive lidar to profile the vertical distribution of clouds and aerosol particles, along with a high-spectral-resolution oxygen A-band spectrometer, an imaging infrared radiometer, and a high-spatial-resolution wide-field camera. PICASSO-CENA, together with the Earth Observing System satellites, will establish the scientific basis for understanding the dynamics and energetics of the Earth's atmosphere in support of short-term weather and long-term climate forecasts. Its orbit is optimized to coincide closely with EOS PM-1 and especially the MODIS and CERES sensors onboard the spacecraft.

In addition to PICASSO-CENA, NASA has selected two additional ESSP missions, CloudSat and VOLCAM (the Volcanic Ash Mission), as alternate missions. CloudSat and VOLCAM will go through an extended development and technology assessment prior to the decision of which mission will be the primary and alternate. CloudSat is a mission focused on understanding the role of optically thick clouds on the Earth's radiation budget, and is led by Prof. Graeme Stephens of Colorado State University. CloudSat would use an advanced cloud-profiling radar to provide information on the vertical structure of highly dynamic tropical cloud systems. This new radar would enable measurements of cloud properties for the first time on a global basis, revolutionizing our understanding of cloud-related issues.

VOLCAM is a pathfinder mission for demonstrating the operational and scientific applications of monitoring volcanic clouds and aerosols from a geostationary orbit, and is led by Dr. Arlin Krueger of NASA Goddard Space Flight Center. Volcanic clouds are a potential hazard to jet aircraft, and have, on several occasions, damaged commercial airliners when volcanic ash has been injected into the airline engines. In addition to causing air traffic hazards, volcanic eruptions increase the amount of aerosol particles in the upper atmosphere that leads, in turn, to less solar radiation reaching the Earth's surface and subsequently cooler temperatures at the Earth's surface. The information provided by VOLCAM would provide data to better represent the transport of volcanic aerosols in global atmospheric-circulation models of the Earth's climate and weather.

The ESSP selections were made from a group of ten proposals that were evaluated in the second phase of a rigorous, two-phased selection process that began eight months ago with the April 1998 release of the second ESSP Announcement of Opportunity (AO). The original announcement generated 20 proposals that were subsequently evaluated on the basis of scientific merit. An initial ESSP AO resulted in the selection of two missions now under full-scale development for flight, namely the Vegetation Canopy Lidar (VCL) and the Gravity Recovery and Climate Experiment (GRACE). VCL will launch in 2000, while GRACE will be launched in 2001.

The estimated mission cost of PICASSO-CENA, including launch vehicle, is $173.5 million. NASA will provide $117.4 million, with France providing $56.1 million. The spacecraft will be launched in 2003. The provision by France of a PROTEUS spacecraft, the infrared imaging system, and science analysis support make this mission a true international partnership. The estimated mission cost of CloudSat would be $144.6 million, with NASA contributing $119.6 million. Collaboration with Canada is being explored for the provision of critical components for CloudSat's cloud-profiling radar. The estimated mission cost of VOLCAM would be $48 million, of which NASA would provide $45 million, and other U.S. government agencies would provide $3 million. The VOLCAM mission is intended to be launched using a "piggyback" approach involving one of several potential spacecraft of opportunity.

NASA plans to announce an opportunity for continuation as well as new research in the EOS Interdisciplinary Science (IDS) Program. This will involve a complete recompetition of research projects and will require a proposal from all PIs wishing to continue or initiate new research. This recompetition will include the original, long-term IDS grants, the more-recent three-year investigations, and the JGOFS Science investigations. The NRA should be released to the public around mid-May with proposals due in mid-August. Both mail and panel reviews are scheduled to be completed by the end of October, and the first six-month's worth of funding will begin approximately March 1, 2000. Subsequent yearly funding periods will begin on January 1 to minimize the uncosted carryover problem.

The scientific scope of this NASA Research Announcement (NRA) will cover the six areas of scientific emphasis in the forthcoming Earth Science Enterprise (ESE) Science Implementation Plan, namely the Global Carbon Cycle, the Global Energy and Water Cycle, Climate Variability and Prediction, Atmospheric Chemistry, Solid Earth Science, and other Interdisciplinary Science.

Finally, I am happy to report that Dr. Mark Schoeberl has once again agreed to serve as EOS Chemistry Project Scientist, replacing Dr. P. K. Bhartia, who has served effectively as Chemistry Project Scientist for the past two years. Dr. Schoeberl is a nationally recognized scientist with expertise in stratospheric dynamics, satellite instrumentation, and data analysis. He has extensive knowledge of issues of atmospheric chemistry, has previously served as EOS Chemistry and UARS Project Scientist as well as chair of the EOS Atmospheres Panel, and is Principal Investigator of an EOS Interdisciplinary Science Investigation. He is a senior scientist in the Laboratory for Atmospheres at Goddard Space Flight Center. Mark will have two deputy Project Scientists, Dr. Anne Douglass and Mr. Ernie Hilsenrath. The Chemistry Project Science Office has established six working groups to address the following specific issues: science, data systems, flight operations, education/outreach, algorithm development, and validation.

Joint Advanced Microwave Scanning Radiometer (AMSR) Science Team Meeting

— *Elena Lobl (elena.lobl@msfc.nasa.gov), AMSR-E Science Team Coordinator, Earth System Science Laboratory, University of Alabama, Huntsville, AL*

ADEOS-II AMSR homepage: se.eorc.nasda.go.jp/eorc/AMSR/amsr
EOS PM-1 AMSR-E homepage: wwwghcc.msfc.nasa.gov/AMSR

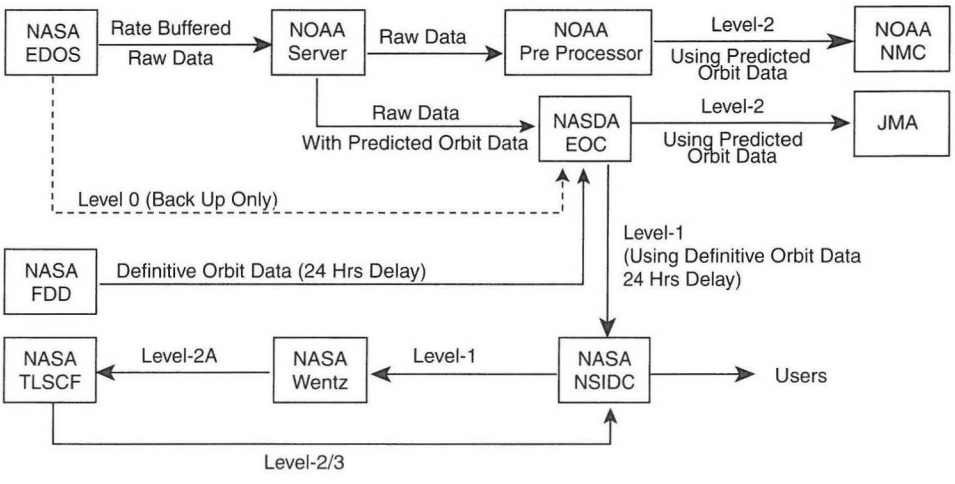
The joint AMSR Science Team had a meeting on November 12, 1998 at the Earth Observation Research Center (EORC), in Tokyo, Japan. This meeting followed the third ADEOS-II AMSR Workshop. The discussion topics were the AMSR Science Data Validation plan, the feasibility of the PM-1 spacecraft maneuver (requested by CERES and MODIS), AMSR-E data flow, early post-launch activities, and the reprocessing of data with the definitive navigation data. The two teams agreed to collaborate in public outreach activities regarding AMSR products.

Paul Hwang (EOS PM Project Office) gave the status of the project, including the status of the PM-1 Spacecraft and its instrument package. The integration and test of the instruments on the platform is scheduled to start June '99. All instruments are on schedule for delivery to TRW, the spacecraft contractor. The AMSR-E Memorandum of Understanding (MOU) is in negotiation and is expected to be ready for signature in January-February of 1999.

Some surprising results were found in the TRMM Microwave Imager (TMI) data when the TRMM spacecraft did a deep-space viewing maneuver: the temperature of deep space seen through the main reflector is higher than the temperature seen with the cold sky calibration target. The CERES and MODIS instruments requested that this maneuver be done with the PM-1 spacecraft. AMSR-E is interested in the maneuver, to see if the TRMM results will be reproduced, and ultimately help with the calibration of the instrument. Mitsubishi Electronics Company (MELCO), the AMSR-E manufacturer, has analyzed the stresses that the instrument will undergo during this maneuver and agreed that they are sustainable by the instrument in space. The AMSR-E data flow from the NASA EOS Data and Operations System (EDOS), where the data from the platform will be captured, to the eventual users of the AMSR-E standard products is outlined in the figure below. Using predicted versus definitive navigation data is still an issue for discussion. The AMSR-E team believes that the predicted navigation data will result in negligible errors in the Earth location; the AMSR team is studying this issue, and reprocessing will depend on the outcome of this analysis.

The AMSR-E Science Data Validation plan was briefly discussed. A large part of the ADEOS II Workshop was devoted to AMSR science data validation discussions, so, at the joint team meeting, it was quickly agreed to collaborate on a joint validation plan. NASDA will have its first draft of the plan in March, and then we will discuss merging the two plans.

Both AMSR Science Teams will be attending the 6th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment in Florence, Italy, March 16-18, 1999. Our next joint Science Team meeting will be held in Florence, immediately following this conference.



EOS AM-1 Control Center Implementation

— Dolly Perkins (dolly.perkins@gsfc.nasa.gov), Deputy Associate Director for EOS Operations, NASA Goddard Space Flight Center

Introduction

The EOS AM-1 spacecraft will provide valuable science data to the Earth science community. To ensure that maximum science return is achieved, the AM-1 spacecraft subsystems and science instruments will be scheduled, controlled, and monitored on a daily basis. These critical spacecraft and instrument operations will be performed primarily at the EOS Operations Center (EOC), located at NASA GSFC.

The AM-1 Flight Operations Team (FOT) is generally responsible for operating the spacecraft and instruments, which primarily include three main support functions: mission management; real-time command and control; and analysis of spacecraft and instrument performance and anomalies.

Mission management consists of planning and scheduling the onboard activities of the spacecraft subsystems and instruments, and constructing the associated command and memory loads for uplink. It also includes the management of onboard memory and of various ground system databases.

Real-time command and control involves monitoring the spacecraft and instrument health and safety, and dumping the recorded engineering and science data. It also includes issuing real-time commands needed to conduct planned operational activities and respond to anomalies, as well as uplinking the appropriate command and memory loads.

The analysis function is performed to trend and assess the overall performance of the spacecraft subsystems and instruments. Engineering data are gathered and analyzed to detect potential degradation of onboard components and to evaluate anomalies in greater detail.

History

The original EOC system was based on the Flight Operations Segment (FOS) architecture, which was developed under the EOSDIS Core System (ECS) contract by the Raytheon Systems Company and the Lockheed-Martin Corporation. A launch-ready system was originally scheduled to be delivered in September of 1997 to support a June 1998 AM-1 launch. However, NASA encountered major problems with the launch version, and decided to move the launch date to later in 1998. NASA and the ECS contractor agreed on a new FOS launch-ready delivery date of March 1998 to meet this change in launch schedule. The subsequent delivery in March contained many improvements, but still did not meet many of the launch critical requirements.

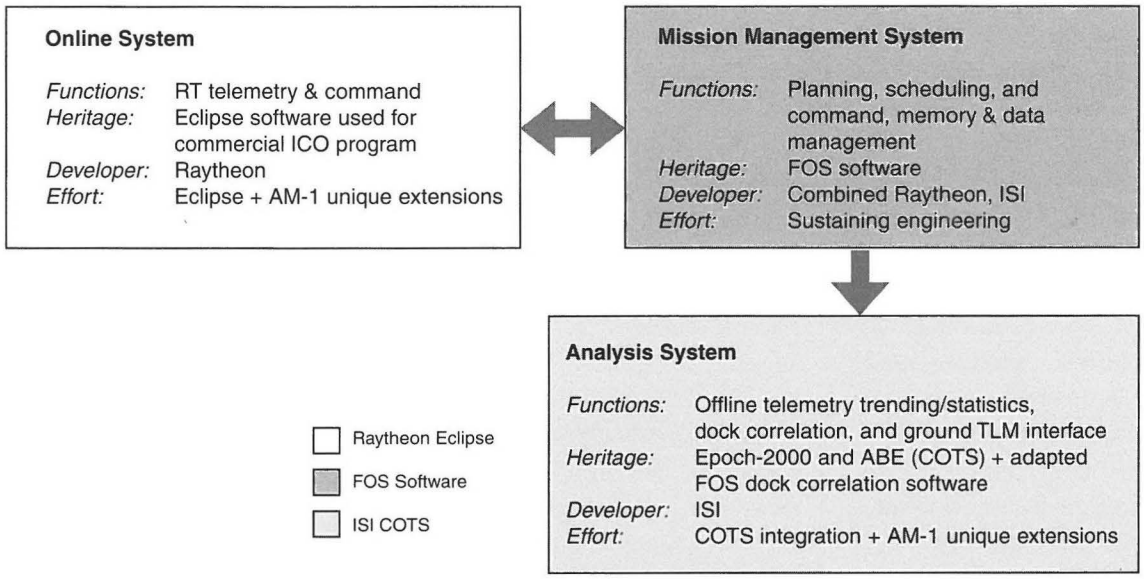
While the ECS contractor was again challenged to deliver a launch-ready FOS system, NASA GSFC also initiated a parallel effort to assess potential alternative architectures. This resulted in the implementation of an alternative control center prototype based primarily on the Epoch-2000 commercial command and control product developed by Integral Systems Incorporated (ISI). Based on the successful initial results of the alternative prototype, as well as the continued slow progress of the FOS recovery effort, Raytheon decided in September of 1998 to terminate efforts to complete the FOS. An alternative hybrid solution was chosen, utilizing a Raytheon commercially developed command and control product (Eclipse), the analysis component of the ISI Epoch-2000 product, and selected components of FOS. NASA and the ECS contractor developed a revised integrated schedule for completing the hybrid system and ensuring spacecraft and instrument operations team readiness. The revised plan calls for launch of the AM-1 spacecraft during the third quarter of 1999.

Hybrid Architecture

As shown in the figure, the revised hybrid architecture, known as the EOS Mission Operations System (EMOS), consists of three loosely coupled components. The components communicate via simple and clean interfaces, decreasing complexity of the overall system. The three components are the Online System, the Mission Management System, and the Analysis System.

The Online System supports the real-time command and control functions and utilizes the Raytheon Eclipse product. Eclipse evolved from control center software used by the Department of Defense in numerous classified programs and has significant heritage and maturity. Raytheon recently adapted the Eclipse product to the commercial ICO Global Communications program, resulting in a

EOS Mission Operations System (EMOS)



client/server architecture using DEC servers and Windows/NT PCs.

The Mission Management System reuses the planning & scheduling, command management, and data management components from FOS, which had reached an acceptable level of stability and maturity. Given the large amount of AM-1 -unique software in these areas, this approach avoided what otherwise would have been a major schedule impact. The new system is hosted on Sun/Unix workstations and utilizes the Sybase RDBMS to manage ground system data. A simple file interface is utilized to provide the various command and memory loads to the Online System for subsequent uplink. The system is being integrated by a combined Raytheon and ISI team.

The Analysis System provides all of the offline trending and statistics support. It is derived from the successful alternative architecture prototype, and is based on the ISI Epoch-2000 and Archive Browser Extracter (ABE) products. ISI is integrating this system as an ECS subcontractor to Raytheon.

Remote Instrument Operations

The concept of remote instrument operations has been maintained under the EMOS architecture, with the Instrument Support Toolkit (IST) still being used to provide the Instrument Operations Teams (IOT) with planning and scheduling, real-time monitoring, and analysis support. The Mission Management and Analysis Systems will be hosted on the IOT Sun workstations. For the Online System, the ECS contractor will provide each of the IOT's with one or more Windows/NT PC's to host the Eclipse software.

Status and Schedule

The EMOS build approach is based on multiple builds through the development cycle in order to provide initial functionality to support early interface testing with the AM-1 spacecraft, to expedite the development of operations procedures and display pages, and to initiate flight and instrument operations training and simulations.

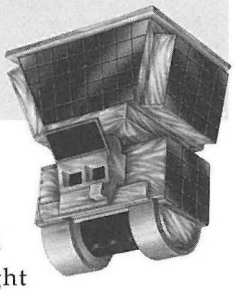
The first build was delivered in December 1998 and provides initial online functionality for real-time commanding, telemetry monitoring, and command procedure execution. It also provides nearly full functionality for the mission management and analysis components.

The second build will be delivered in March 1999 and will provide all functionality needed to support the launch and early orbit phase of the mission. Additional builds will be delivered through launch and early orbit in order to facilitate normal operations.

In summary, while the problems with implementing FOS caused major delays in AM-1 ground system readiness, NASA and the ECS contractor are confident that the new hybrid architecture addresses the fundamental architectural problems that existed. The new architecture and the addition of many new and talented players to the team have rejuvenated the effort and lead NASA to feel much more confident about achieving a launch-ready system on the new schedule.

CERES Science Team Meeting

— Gary G. Gibson, (g.g.gibson@larc.nasa.gov), NASA Langley Research Center
— Shashi K. Gupta (s.k.gupta@larc.nasa.gov), NASA Langley Research Center



The 18th Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held at the State University of New York at Stony Brook on September 15-17, 1998. The CERES Science Team reached a unanimous decision to archive the ERBE-like data products from CERES on the Tropical Rainfall Measuring Mission (TRMM). The ES8 (Level 2), ES9 (Level 3 monthly averages with the individual hourly observations), and ES4 (monthly averages only) will be fully available after October 1998.

Bruce Wielicki of the NASA Langley Research Center (LaRC), CERES Co-Principal Investigator, opened the meeting with an EOS program status report. The Earth Observing System morning satellite (EOS AM) launch is delayed until mid-to-late 1999 due to spacecraft control software problems. EOS PM is still on schedule for a December 2000 launch. For the EOS Follow-on, CERES is being proposed as part of three mission concepts: aerosol radiative forcing, cloud feedback, and climate variability. The climate variability mission would fill the time gap between EOS PM and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) to ensure a long time series of radiation budget measurements.

Instrument Status: TRMM and EOS AM/PM

Jack Cooper (LaRC) presented the instrument status report. A Tiger Team is investigating the cause of a voltage anomaly experienced by the Proto-Flight Model aboard the TRMM. The team has verified that the voltage fluctuations are a result of an anomalous voltage converter and not an improperly operating converter voltage monitor. Radiation damage testing performed on spare voltage converters has confirmed that radiation did not singularly cause the anomaly. Further tests are being conducted on spare voltage converters in order to determine the cause of this anomaly. The final outcome will include a recommendation for the operation of the instrument on TRMM and an assessment of the impact to the EOS AM-1 and EOS PM-1 instruments.

Robert B. Lee III (LaRC) showed that the CERES/TRMM calibration stability is excellent. The internal calibration module (ICM) ground-to-flight radiometric stability was ±0.2% for both the total and shortwave (SW) channels and ±0.4% for the window (WN) channel. The Instrument Team recommended using the ground count conversion coefficients to reduce CERES TRMM Earth radiance measurements.

Kory Priestley (LaRC) showed ground calibration results for the EOS AM/PM flight models. Flight Model 3 and 4 offset measurements are similar to those of the first three CERES instruments and are not expected to be a substantial concern in data analysis.

ERBE-like Data and Validation

The ERBE-like data will be validated and archived first. These data do not rely on coincident observations from the cloud imager. Richard Green (LaRC) showed large differences seen between the CERES and Earth Radiation Budget Experiment (ERBE) top-of-atmosphere (TOA) fluxes over the tropics (20S to 20N). CERES TOA longwave (LW) fluxes for the tropics range from 4 to 8 Wm^{-2} higher than ERBE. The TOA SW fluxes range from 0 to 3 Wm^{-2} lower than for ERBE. The large 1998 ENSO may help to explain the variation in LW flux differences from a peak of 8 Wm^{-2} in February to a minimum of 4 Wm^{-2} in July. The changes between ERBE and CERES are primarily in the total-sky fields (not clear-sky). Only about 1 Wm^{-2} of the LW change in July appears to be explainable by calibration differences. Comparisons of the long time series of Earth Radiation Budget Satellite (ERBS) nonscanner data which overlaps both ERBS and CERES scanner data support the change in LW flux between ERBE and CERES time periods (late 1980s to late 1990s). An increase of 3 to 4 Wm^{-2} in tropical mean LW flux also occurred in early 1991.

David Young (LaRC) showed early validation results for ERBE-like monthly-averaged data. He compared tropical means of the first 7 months of CERES data with ERBS results. CERES had 11% more scenes identified as clear than ERBS observed for the same month from 1985-1989. This difference decreased as the El Niño event came to an end. CERES total-sky LW is 3% higher than ERBE, and the difference decreased as El Niño ended. The CERES values are consistent with ERBS non-scanner measurements for the same time period. Small clear-sky LW anomalies are consistent with model calculations. Total-sky SW is 2.7% lower

than ERBE, of which up to 2% is likely due to temporal sampling noise. The clear-sky SW is 2.9% lower than ERBE on average, but the deficit ranges from 1.8% for ocean to 6.1% for land and 8.7% for deserts. Young concluded that all CERES/ERBE differences are within the ERBE-like uncertainty limits and recommended archival of the ERBE-like monthly products.

Lou Smith (Virginia Tech) compared CERES scanner results with ERBE wide-field-of-view (WFOV) data. CERES total channel estimates of nighttime ERBE WFOV fluxes are biased less than 1%, comparable to the ERBS scanner-to-nonscanner comparisons. Daytime LW biases were less than 2%.

New CERES Data Products

There has been considerable progress on validating the CERES WN channel. Richard Green reported that both the Angular Distribution Models (ADM)s and Tropical Mean results show that the WN has more limb darkening than the broadband LW radiance. Fred Rose of Analytical Services and Materials, Inc. (AS&M) used MODTRAN to validate spectral correction coefficients for unfiltering the WN measurements. David Kratz (LaRC) used line-by-line models to establish the relationship between total and WN channel radiances for the case of high, cold clouds. Kory Priestley then performed a 3-channel intercomparison which implied an inconsistency between the SW channel and SW portion of the total channel at the 0.65% level.
Patrick Minnis (LaRC) briefed the team on new methods and algorithms for deriving CERES cloud products from the Visible-Infrared Scanner (VIRS) imager data. Cloud patterns from the current algorithm appear quite reasonable, but phase determination may overestimate water (liquid) clouds; heavy aerosols are missed; and a correction for viewing zenith and solar zenith angle dependence is needed. CERES-retrieved cirrus and daytime stratus cloud heights and temperatures agree well with surface measurements, but nighttime comparisons are not as close. Cloud emissivities and fractions are generally close to those from surface observations, but CERES-derived liquid water paths and effective droplet radii are, in general, larger than those from the surface. The optical depths from CERES agree well with surface observations during the daytime, but are much smaller at night. Future plans are to incorporate other Co-Investigator's algorithms, implement a tri-spectral nighttime retrieval algorithm, and use VIRS channel 2 for cloud mask, phase, and particle size calculations.

Norman Loeb (Hampton University) reported on the development of ADMs. He developed new CERES LW and WN ADMs for the ERBE scene types and noted significant differences from the ERBE ADMs. Details are given in the ADM Working Group report. He examined POLDER (Polarization and Directionality of the Earth's Reflectances) data to determine the influence of cloud properties on ADMs and albedo. Loeb determined that when all observations at all POLDER angles are considered, absolute ADM albedo bias errors are less than 0.03% compared to 0.3% for albedos derived using the independent pixel assumption.

Tom Charlock (LaRC) reported that the Surface and Atmospheric Radiation Budget (SARB) derived albedos for VIRS clouds are 0.07 higher than the CERES observations. The pre-launch albedos for Advanced Very High Resolution Radiometer (AVHRR) clouds had compared well to ERBE. CERES/ARM Validation Experiment (CAVE) results show that more SW absorption is needed in the atmosphere. The Fu-Liou radiative transfer code was modified in the LW to include explicit TRMM WN output and other spectral improvements. SARB has added the WN channel to the flux constrainment algorithm. SARB is considering switching from the Goddard Data Assimilation Office (DAO) to European Center for Medium-Range Weather Forecasts (ECMWF) data for their radiative transfer calculations.

Don Cahoon (LaRC) described the CERES helicopter field experiment conducted at the Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) site in August 1998. Spectral bidirectional reflectance distribution functions (BRDFs) were measured from helicopter-borne instruments over many types of cropland. The results of this experiment will be presented as CERES/ARM/GEWEX Experiment (CAGEX-3) and will be widely disseminated through a web site.

Data Systems

Robert Seals (LaRC) of the Langley Distributed Active Archive Center (DAAC) discussed the wide range of DAAC services for producing, archiving, and distributing Earth science data. Bruce Barkstrom (LaRC) cited a need for improving introductory information on CERES data products in the LaRC DAAC web ordering tool for CERES data. He showed an example of the ES-8 data product description and outlined the data quality summary pages needed for the ERBE-like Level 2 and Level 3 data products.

Jim Kibler (LaRC) presented the CERES Data Management System (DMS) status. All DMS subsystem deliveries to the DAAC are on schedule. Instrument and

ERBE-like subsystems are running at the DAAC using the LaRC TRMM Information System (LaTIS).

Education and Outreach

Lin Chambers (LaRC) gave an update on the CERES Students' Cloud Observations On-Line (S'COOL) Project. The S'COOL project successfully participated in a joint French/U.S. demonstration of science education cooperation during a May visit to France by Mrs. Clinton. Dan Goldin and Bruce Barkstrom were at a school in the Washington area. Schools in New York and France also participated. Currently S'COOL has 142 registered participants from 16 countries on 5 continents.

Working Group Reports

Instrument Working Group: Robert B. Lee III led the Instrument Working Group meeting in discussions of the accuracy of the CERES instrument on TRMM. Measurement accuracy and precision goals have been satisfied. The group is examining the instrument ground calibration data in an attempt to understand the 1% inconsistency in the ERBE-like 3-channel checks performed by Priestley for deep convective clouds (0.8%), and Richard Green on the Tropical Mean day/night check (1.2%). This inconsistency is within the CERES goal of 1% SW absolute calibration accuracy; calibration changes are not currently planned.

Cloud Working Group: Patrick Minnis led the discussion of cloud retrieval, archival, data dissemination, and validation issues. The team explored the possibility of using ECMWF data rather than DAO for constructing the Meteorology, Ozone, and Aerosol (MOA) data set. Man-Li Wu (GSFC) presented information about current and planned changes in DAO products that will address some of the concerns about DAO. The Langley cloud team will provide a summary of their work on differences between MOA skin temperatures and International Satellite Cloud Climatology Project (ISCCP) TOA temperatures for use in DAO validation.

There is an apparent overestimate of effective droplet radius in the water cloud retrievals. Accuracy of the 3.7 micron channel calibration and knowledge of the solar constant in this spectral interval were discussed as possible sources of errors. Also, team members discussed the inaccuracies inherent in using a bidirectional model as a possible source of the VIRS albedos being lower than other narrowband instruments.

Minnis presented a summary of both short- and long-term improvements planned for the cloud algorithm, including multi-layer retrievals. Larry Stowe (NOAA) noted that the Clouds from AVHRR (CLAVR) algorithm has a multi-layer flag that can be used for improving identification of multi-layer pixels. Ron Welch (U. Alabama – Huntsville) will tune his cloud mask to VIRS and develop improved masking techniques and multi-layer retrievals specific to VIRS. Stowe will investigate thresholds for application to the visible and near-infrared channels for the purpose of flagging aerosols in pixel data in the cloud algorithm. Team members were encouraged to visit the cloud working group's web site at Langley: http://lposun.larc.nasa.gov/~cwg/ for updates on algorithm changes and validation.

Welch showed recent results of classification studies using Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS) data from Alaska and smoke detection results from AVHRR data. He also presented results of his global detection of contrails from AVHRR imagery from October 1992 and discussed the impact of smoke aerosols on clear-sky SW fluxes in ERBE data using TOMS UV data for aerosol detection. He suggested visiting www.atmos.uah.edu/~sundar for further information.

Bing Lin (Hampton University) presented a study of the collocation of TRMM Microwave Imager (TMI) data with VIRS. After mapping VIRS data into the TMI fields of view, he identified a clear-sky temperature bias that implies that TRMM's recalibration was necessary.

Minnis presented a summary of contrail detection over the U.S. using NOAA-11 and NOAA-12 during April 1994. He also showed results from a LW anisotropy study that showed differences in clear-sky temperatures from GOES-8 and GOES-9 of as much as ±4 C when viewing the same area. Diurnal difference cycles were presented for various scene types and viewing conditions. Recent helicopter studies from the ARM SGP site confirmed the existence of such anisotropy.

Surface and Atmospheric Radiation Budget (SARB) Working Group: A joint meeting of the SARB and Surface-only Working Groups co-chaired by Tom Charlock (LaRC) and David Kratz addressed algorithm and validation issues.

Fred Rose discussed recent modifications to the Fu-Liou radiative transfer code made in cooperation with Qiang Fu (Dalhousie University) and David Kratz. The CKD (Clough, Kneizys, and Davies) continuum, which was limited to the window region in the original code, was extended to the 5-2200 cm^{-1} region. A new set of correlated-k's which accounts for the absorption of CFCs and weak bands of carbon dioxide was incorporated into the code, bringing the Fu-Liou results into

better agreement with line-by-line computations.

Shashi Gupta (AS&M) presented new scene-dependent global surface emissivity maps for the 12 spectral intervals of the Fu-Liou code, the CERES WN channel, and the broadband LW region. Use of the broadband emissivity map instead of the assumption of a black surface in net LW flux computations yielded differences of up to 6 Wm^{-2} over some regions. Emissivity maps are available to the science community at the following web address: http://tanalo.larc.nasa.gov:8080/surf_htmls/SARB_surf_html.

Shi-Keng Yang (Research and Data Systems Corporation) discussed the status of the Stratospheric Monitoring-group Ozone Blended Analysis (SMOBA) product which is the primary source of ozone data for CERES. SMOBA provides assimilated 3-D ozone fields based primarily on Solar Backscatter UltraViolet (SBUV/2) data from NOAA-14. Due to a malfunction of the grating on SBUV/2, the data stream was interrupted during parts of May and June 1998. The data stream was revived by shifting to a different wavelength, but the new data showed inconsistencies with prior data. A recalibration of the instrument on August 12 resulted in a decrease of 10-12 dobson units in the column ozone amount.

Man-Li Wu discussed DAO efforts toward improving the Goddard Earth Observing System (GEOS-2) meteorological fields. She compared clear-sky OLR fields from GEOS-2 and ECMWF. The differences over land areas were attributed to corresponding differences in ground temperature, and those over ocean areas to differences in moisture fields. The problems with the upper tropospheric humidity (UTH) in GEOS-2 were attributed to deficiencies in the model convection scheme.

Yaping Zhou (State University of New York at Stony Brook) compared results obtained from radiation modules of two versions of the Community Climate Model (CCM2 and CCM3) with data sets available from the CAGEX-1 web page. All models overestimated outgoing LW and underestimated downward LW flux; the Fu-Liou code provided the best agreement with observations and CCM2 provided the worst.

CERES ADM Working Group: Norman Loeb organized and led the first official ADM working group meeting in discussions of critical ADM/inversion research issues. These include spectral correction, definition of ADM scene types, and ways of consistently identifying scene types at all angles. The formation of this new working group is a reflection of the importance and complexity of this area of research.

Lin Chambers presented 2-D model results showing how incorrect scene identification due to 1D-cloud property retrieval errors can lead to ADM-derived albedo errors. Overall mean bias errors using the ADM approach were smaller than 1D approach at least by a factor of 2. She also showed the advantage of using multiple-view satellites (CERES rotating azimuth plane scanner; POLDER) to estimate albedo. Instantaneous rms errors in albedo were reduced by 50% when albedos inferred at multiple-view angles were averaged together and compared with truth as opposed to treating albedos in each view angle individually.

Richard Green led a discussion on how ADMs vary with height above the Earth's surface. He provided an example of an ADM for a Lambertian Earth and showed that neglect of the ADM dependence with height can lead to an error of about 1% in the derived TOA net flux.

Lou Smith showed recent LW and WN channel along-track measurements from ES-8. Overall, limb darkening in the WN channel was stronger than in the LW channel. The difference did not depend on scene type.

Norman Loeb compared new LW and WN ADMs derived from CERES SSF for ERBE scene types ("VIRS_12") with LW ERBE ADMs (Suttles et al.). VIRS_12 LW ADMs showed much more limb darkening than the Suttles LW models. He also found stronger limb darkening in the WN ADMs compared to the LW ADMs. Based on simulations from MODTRAN, Loeb argued that under clear-sky conditions, high tropical column water vapor and surface temperatures are the likely causes for the stronger limb darkening in the WN channel. However, in contrast to Smith's results, VIRS_12 LW and WN limb darkening showed a strong dependence on scene type—it tended to increase with cloud cover, particularly in the WN channel. The reason for the apparent discrepancy between the Smith and Loeb results may be because of differences between ERBE-like MLE (used in Smith's study) and VIRS imager scene identification (used in Loeb's study).

Yong Hu (Hampton University) showed some early statistics of cloud optical depth retrievals stratified by viewing geometry. In the fixed azimuth scan mode, VIRS mean optical depths show a 10% (relative) decrease between nadir and the most oblique VIRS viewing zenith angle (45 degrees). When VIRS mean optical depths are stratified by CERES viewing zenith in the rotating azimuth plane scan mode, no viewing zenith angle dependence is observed (since CERES viewing zenith angles are independent of VIRS viewing zenith angles). He also showed a systematic increase in cloud optical depth retrievals with solar zenith angle, confirm-

ing Loeb's earlier ERBS and AVHRR studies.

Time Interpolation and Spatial Averaging (TISA) Working Group: David Young led discussions of software development, current temporal and spatial averaging studies, and ongoing CERES ERBE-like validation efforts. Stephanie Weckmann (Virginia Tech) analyzed ERBE scanner and nonscanner data to show how the ERBE nonscanner data can be used to validate CERES results. Comparisons with Scanner for Radiation Budget (ScaRaB) data are also continuing. The team discussed several science issues that must be resolved. Can we define monthly mean errors for products that use geostationary data for temporal interpolation? Should we develop standard products which calculate monthly mean relationships between variables such as albedo and cloud particle size? Are there variables such as aerosols that require separate algorithms? How do we most effectively use cloud information from the geostationary satellites?

Investigator Presentation Highlights

Bruce Barkstrom (LaRC) gave a preview of the studies which he plans to undertake while on a 6-month sabbatical at the University of Illinois Urbana-Champaign. He will develop pattern recognition techniques for use in the characterization of cloud spatial structures.

Robert Cess (State University of New York at Stony Brook) analyzed measurements of direct, diffuse, and global SW radiation from eight stations in Canada, and the SGP/ARM site in Oklahoma. He noticed a very unusual feature in the data from one Canadian station and all data from the ARM site. Most of the afternoon data from these sites obtained during fall and winter showed diffuse radiation values less than the Rayleigh limit. The cause remains unexplained.

Jim Coakley (Oregon State University) presented results of a pixel-level cloud retrieval algorithm that incorporates information from adjacent pixels and regions. The algorithm retrieves information about pixels containing broken clouds rather than assuming that all non-clear pixels are totally filled with clouds.

Leo Donner (GFDL) presented results of a study of radiation and microphysics in the clouds of the Tropical Ocean Global Atmosphere Combined Ocean Atmosphere Response Experiment (TOGA-COARE) region. The objective of the study was to improve the cloud system model using observations from the TOGA-COARE region. Comparisons of modeled and observed surface and TOA radiation data showed that the ice sedimentation process in clouds has a significant impact on surface radiation.

Qingyuan Han (University of Alabama – Huntsville, representing Ron Welch) presented results on monitoring the indirect radiative forcing of aerosols using satellite data. Increased concentration of aerosols in the atmosphere leads to increased concentrations of cloud condensation nuclei (CCN) and cloud droplets, decreased droplet radius, and increased cloud optical thickness and albedo. The optical thickness of thin clouds was substantially affected by increased aerosol concentration while thick clouds were largely unaffected. The magnitude of the radiative forcing was estimated to be about 0.25 Wm^{-2} for the Southern Hemisphere (considered pristine), and about 0.77 Wm^{-2} for the Northern Hemisphere (considered polluted).

Patrick Minnis (LaRC) showed that azimuthal and viewing zenith angle dependence of skin temperature and surface emissivity were evident in both satellite and helicopter data sets. The magnitude of the variation is related to terrain roughness and possibly surface type. The anisotropic effects may be corrected for by using visible-channel BRDFs. The phenomenon will be examined more closely using GOES, VIRS, helicopter, and aircraft data sets.

V. Ramanathan (Scripps) presented observational data valuable for CERES related studies obtained during the Indian Ocean Experiment (INDOEX). These data consist of surface radiometric measurements, and retrievals of optical properties, vertical distributions, and chemical composition of ambient aerosols. Aerosol optical properties were derived from comparisons of site-measured and model-derived diffuse and global SW fluxes, and indicated that ambient aerosols were highly absorbing. These results can be used for developing models of aerosol radiative forcing for CERES.

David Randall (Colorado State University) presented the results of a numerical experiment on stratus cloud feedbacks in a coupled ocean-atmosphere model. It was primarily a study of the feedbacks between stratus clouds and the sea surface temperature (SST). The experiment was initiated by modifying the stratus parameterization in the model so as to increase the cloud optical depth (brighter clouds). Randall showed that while the response of an atmosphere GCM was a straight forward increase in the SW cloud radiative forcing (SWCRF) at the ocean surface, the response of the coupled ocean atmosphere GCM was far more complex because of the feedbacks. In the coupled model, increased cloud optical depth led to increased SWCRF, to lower SST, to increased atmospheric stability, to more stratus clouds, and to the whole cycle all over again, indicating a positive feedback.

Larry Stowe (NOAA) summarized his dark count corrections to VIRS 1.6 μm data to account for the 5 μm leak. He showed VIRS aerosol retrievals that utilized 1.6 μm data corrected with a 1.6 μm regression between night time 1.6 μm data and 10.8 μm temperatures and differences between 10.8 and 12 μm data. This correction is 0.6% to 1.2%. Stowe also found small errors of 0.1% to 0.2% in the visible data but did not determine the cause. He will do a similar regression for the full range of temperatures rather than just for the clear-sky temperature ranges that he used when checking for aerosols. He will check his regressions periodically now that the night time radiances are available.

Si-Chee Tsay (GSFC) summarized NASA's involvement in the South Africa Fire-Atmosphere Research Initiative (SAFARI), a project aimed at studying and establishing linkages between the physical, chemical, and biological processes in South African ecosystems. The approach is to develop synergies between remote sensing, modeling, and airborne and surface-based observational capabilities of the participating organizations. GSFC provides the surface-measured radiation data. Toward that end, SRB measurements are already being made, mostly using commercially available instruments. A limited number of specialized instruments, e.g., micropulse lidars, cimel sun photometers, MFRSR, NIP, and microwave radiometers will also be deployed. Pre-SAFARI experiments will be conducted in 1999 during February-March (the wet season) and August-September (the dry season). Several full-fledged coupled experiments will follow during the years 2000 onwards.

Shi-Keng Yang (representing Jim Miller, NOAA/NCEP) reviewed the status of the newest version of the radiation module of National Centers for Environmental Prediction (NCEP) data assimilation model. This model is being used for the second phase of the NCEP reanalysis and for the processing for the Atmospheric Model Intercomparison Project (AMIP II). An examination of the global mean energy budget of the model shows an imbalance. Comparisons of the TOA radiation fields with ERBE results, and of surface radiation fields with the Langley SRB data set show large differences.

David Young (LaRC) compared time-averaged fluxes from CERES crosstrack and rotating azimuth plane (RAP) scanners. He showed that the RAP and crosstrack-instantaneous SW fluxes agree to within 1%. The 6-month mean LW and SW fluxes are not biased by the inclusion of RAP data. He recommended that both RAP and crosstrack data be included in the CERES ERBE-like monthly mean products.

Science Team Logistics

The next CERES Science Team meeting is scheduled for April 27-29, 1999 at the NASA Langley Research Center. The focus will be twofold: the progress of validation for clouds, ADMs, SARB, and TISA, and new science results from the science team.

LETTER TO THE EDITOR

EOS SCIENCE POSTERS RELEASED IN THE CZECH REPUBLIC

During the XVII ISPRS Congress 1996 in Vienna, Austria, I was presented with a set of EOS science posters at the NASA booth. Their contents seemed to me to be very useful for geographical and ecological education in basic and secondary schools. Therefore, I got the idea to edit them in the Czech Republic. Due to the language barrier, it was necessary to publish the posters fully in the Czech language. For the first step, I contacted the EOS Project Science Office at NASA to provide me the permission to do it. With willingness, I obtained permission for translating the English text to Czech as well as the English contents of figures, if necessary. The EOS office supported me with all graphics files via ftp.

To realize the idea, it was critical first of all to find a well-known publishing company and also a sponsor who would be able to cover the expenses of editing. Due to good long-term cooperation, I chose cartographic publisher Stiefel Eurocart. The printing fees for the posters were covered by the AUTOPAL Novy Jicin Company on the basis of a sponsor agreement. This fact allowed us to support all schools in Central Moravia, which was struck by heavy floods in 1997, with a set of posters free of charge.

The whole project was realized on the informal basis of collaboration, effort and readiness of NASA's EOS Office (USA), and three Czech institutions such as Palacky University of Olomouc, Stiefel Eurocart and Autopal Novy Jicin. The biggest reward for the author of Czech mutation is the fact that a set of posters was put in NASA's EOS library.

Assistant Professor Dr. Miroslave Vysoudil
Palacky University

Editor's Note:
The initiator of the project, Professor Vysoudil, is Head of the Department of Geography at Palacky University of Olomouc, Faculty of Science. The Department educates geography teachers for basic and secondary schools, and belongs among the important geographical workplaces in the Czech Republic.

Minutes Of The Fourteenth Earth Science Enterprise/Earth Observing System (ESE/EOS) Investigators Working Group Meeting

— Renny Greenstone (rgreenst@pop900.gsfc.nasa.gov), Raytheon ITSS

Note: Direct access to many of the presentations made at this meeting may be achieved by accessing the World Wide Web at the following URL: http://eospso.gsfc.nasa.gov/eos_homepage/misc_html/iwg_durham_98.html

The 14th meeting of the Investigators Working Group (IWG) of the Earth Science Enterprise/Earth Observing System (ESE/EOS) took place at the New England Conference Center in Durham, New Hampshire (the home of the University of New Hampshire), October 19-21, 1998.

Monday October 19

Morning Plenary Session (Earth Science Enterprise/EOS/EOSDIS Status)

Byron Tapley (University of Texas, Austin), chair of the IWG Science Executive Committee and session chair, opened the meeting and then gave the floor to Ghassem Asrar, NASA's Associate Administrator for Earth Science.

Ghassem Asrar (NASA Headquarters) reviewed the "long path from the beginnings of EOS to where we are now." He pointed to a major change from SeaWinds to QuikSCAT, calling it a "fantastic recovery," and then he went on to discuss two sets of challenges that face the EOS program for the next few years: 1) we need to establish the benefits of EOS science and educational activities that will come from the first series of EOS satellites, and 2) we need to establish the follow-on program for the post-2000 time frame. He pointed out that by accomplishing challenge number 1 we will build confidence in the achievements to be expected in meeting challenge number 2.

In any event we have learned that we cannot repeat the first EOS series as originally planned. Consequently, we have initiated a process on how to do the next series. The process began with a Request For Information (RFI) and a resulting workshop held recently in Easton, Maryland.

The first EOS series cannot be repeated because of the budget process. We had assumed that there would be 30% efficiencies thus setting aside funds for the second series, but that did not materialize. We wouldn't want to repeat the first series because we've learned new science, which has to be factored in. The old plan was too rigid—technology has moved on. Another factor is that we have an expanded community of Earth scientists with greater needs for exchange of Earth science data and information. Still another factor is the need to deal with practical problems—new customers are very vocal, acting through the Congress, in asking us to show that we are meeting their needs.

Our general philosophy calls for us to adopt two sets of principles for the next decade of EOS: 1) We must move from an observational paradigm to a science hypothesis/question paradigm. Instead of our current measurement strategy where observations are made in support of general scientific questions, we now think of NASA's responsibility as answering key and specific scientific questions. Our approach must not be just space-based but must also include suborbital flights and end-to-end modeling. 2) We need to achieve and maintain a balanced NASA Earth Science Program.

We will now have four program elements and we need to achieve a balanced investment portfolio among them:

- Science Research
- Applications, Commercialization, Education
- Advanced Technology
- Flight and Ground Systems

1. The Science Research Program

Asrar pointed out that NASA's Research and Analysis (R&A) program has been the foundation of its science activities. Lately, however, there has been concern over the health of R&A. Now, Headquarters is restoring support to the R&A program to rebuild it back to its 1994 level by the year 2000. At this time 18-20% of the $1.4 B ESE program goes to the R&A program. The intent is to build up R&A support to 25% of the ESE budget in the next 7-to-10 years. Along with this, the ESE Science Implementation Plan process will continue.

2. The Applications, Commercial, and Education Program

(This program element is now the basis for a new Division.) This Division consults users of ESE services and works with private practitioners as well as representatives of the States. Its mission is to bring out the practical benefits of ESE science, particularly in light of the current budget constraints. At this time 5% of the ESE budget goes into this area but there is a lack of focus. (Asrar wants to see it grow to 10% in the next several years.)

3. The Advanced Technology Program

In this program, ESE is trying to decrease mission development times to 2-to-3-year periods and at the same time to lower risk. We expect an overall cost reduction of at least 20% over the first EOS series. This involves improvements in spacecraft technology calling for industry investments. Also, there is a program to develop smaller/more efficient instruments. The "instrument incubator" program now has seven candidates under development. Two of the new instrument concepts are soil moisture and ocean salinity. We intend to increase our budget in this area from 6% to about 10% over the next several years, focusing on short-to-mid-term science objectives, with NASA-wide technology supporting long-term developments.

4. The Flight and Ground Program

This program deals with the use of EOSDIS on the ground and various elements of the space segment. First, Asrar focused on the DIS (*ground*) elements of the program.

ESE has a commitment to full use of the EOSDIS investment—there is no alternative—but possibly not making use of all the planned functionality, perhaps using about 80-90% of what had been planned. The first increment of EOSDIS is working to support the Landsat and AM-1 missions, but may not accommodate the further missions, PM-1 and CHEM. The Office of Earth Science (OES) is working to identify resources to support PM-1 and CHEM. There is also an internal NASA team studying what is to be done for the decade to come. (The PIs are expected to play a more-active role in the decision process for future developments.)

Asrar said that the EOSDIS Core System (ECS) will continue to perform the functions of data capture and initial processing to Level 0, and Level 1 processing would be performed either by the DAACs or by the PIs associated with the EOS instruments, this to be decided on a case-by-case basis. Generation of higher level data products will be performed principally by the PIs.

The *space* segment will undergo the most changes in order to avoid crises and the possible loss of support that might follow. Asrar noted that the first EOS series was general purpose, with technology innovation not a particular concern. Maintaining stability of observations between the first series and what follows is an obstacle to innovation. Asrar feels that we must separate our goals and presented five dimensions to be taken into account:

1) Determine what data are really needed. The initial program had a 15-year data-accumulation effort, but suffered from unnecessary constraints. (At the RFI review there was an attempt to identify what was really needed for 15 years and, possibly, beyond.) Systematic measurements in this vein must be continued. They may continue measurements from the first EOS series or they may begin systematic measurements of other variables, based on the growth of our scientific understanding, e.g., precipitation.

2) Experimental objectives must include short-term demonstrations of new capabilities. These may be carried out through the Earth Probes program.

3) There must be a transition from research experimental to operational. (At present there is no formal process to make this transition; we tend to follow an *ad hoc* approach.) The OES is now working with the Integrated Program Office (IPO) of NPOESS to define a bridge between AM, CHEM, and NPOESS for the period 15-to-20 years from now.

Asrar pointed to the development of the next Landsat instrument (ALI), which has already been built and is now in thermal vacuum test. It is 3-4-times better than ETM+ and is slated to be launched late next year. For ocean-related systems there is planning to effect the transition from experimental to operational going on right now, but at this time there is no mature system available. TOPEX, NSCAT, and SeaWinds should be transitioning to operational systems. NASA can't continue to support systems like these for the long run and, to this end, there are dialogues with the Navy, NOAA, and international organizations to have them take over operational support. If this doesn't happen, NASA may have to drop out of these activities. Asrar pointed out that NPOESS can serve as the "venue" for transitioning ocean studies into the operational world.

4) There must be major support to University-developed missions. Asrar referred to a University-based Education Earth System Science (UNESS) micro/small-satellite

program intended to engage graduate students and their advisors in NASA's Earth Science program.

5) The New Millennium small-satellite program is intended to demonstrate key enabling technologies and their associated risks, prior to their integration in science missions.

In what he called "side remarks," Asrar congratulated TRMM and TOPEX/Poseidon for their remarkable successes in articulating the benefits of NASA missions to society at large. They have been of tremendous help in overcoming budget cycle difficulties relating to EOSDIS and AM-1 problems. In contrast, he said that the EOS community is falling behind in its outreach activities.

On December 6 at the AGU meeting, Dan Goldin is to articulate his vision statement for Earth Science. This will be the first official NASA commitment to the Earth Science program. Asrar invited all the participants in EOS to help in guiding the EOS process for the next decade.

There is an issue with uncosted commitments. Congress says that this problem must be fixed or "they will do it for us." Right now, $550 M is being held as uncosted commitments. EOS stands to lose $150 M if the money is not spent by September 1999. It is urgent that university billing be on time.

In regard to the new Commercial Space Act, we will show clearly that we will not do something that industry states it can do.

Other comments made by Asrar were these:

1) The PI-led mission will be the preferred approach for mission management.

2) There is no national strategy for transitioning experimental scientific observations into the operational weather-monitoring system, and, in the absence of such a strategy, we are working very closely with the IPO to see that NPOESS flies at least the following instruments: an advanced Earth surface imager, an atmospheric temperature and humidity sounding package, an ozone column profile monitor, and a total solar irradiance monitor. We are also interested in seeing that ocean altimetry and scatterometry are transitioned into the converged operational system.

3) We are investing in the area of ocean data assimilation, seasonal-to-interannual prediction modeling, and state-of-the art supercomputer capability toward meeting this objective.

Asrar ended his talk by saying that he is committed to making this new Enterprise strategy happen, and that he is looking forward to working with all those present to ensure our continuing success.

Berrien Moore (University of New Hampshire) described the current status of the "National Academy of Sciences (NAS) Pathways Report." The report is the product of the NAS Committee on Global Change Research, Board on Sustainable Development, Policy Division. Moore said that the "overview" document for the report is now available from National Academy Press. (The overview carries the title: "Global Environmental Change: Research Pathways for the Next Decade." The full report is still not ready for distribution.) He urged "careful" reading of the Pathways Report—every word in the report was debated. He said that we must examine the "lessons learned" and added that it stressed the criticality of observations. In the science arena the report presents six areas of focused research: biology, two climate studies, paleoclimate, chemistry, and human dimensions. Then there are five "themes" for each of the six focused research areas. Finally, each of the five themes has five science questions. There is a recommendation to focus efforts on key science questions.

Overarching in the report were recommendations to the USGCRP that it should work on the carbon cycle and the hydrologic cycle to understand and document them; that it should work on modeling the climate system (there is a need to understand 30-to-50-year changes—the climate system *transient* response, and not just the equilibrium response, must be understood); and that it should work on radiative forcing and chemical changes, particularly involving the roles of aerosols and methane. Another recommendation was to strengthen the technology for *in situ* observations, which are falling apart around the world.

The following recommendations cited by Moore were not in the short "Overview" report , but will appear in the main document, due to be released in an on-line version in early November:

1) There should be a long-term (more than 15 years) coherent measuring system, e.g., the Keeling records of CO_2. NASA cannot do these long-term measurements, which must transition to NOAA.

2) The Data and Information System (DIS) needs to be more flexible in its response to new technology. The Committee says that it will be watching the progress of NASA's "federated" approach.

3) The report notes that the U.S. is not

the lead country in modeling, but it is good that other countries are taking the lead. The report also takes note of the progress made at the Hadley Center in modeling the atmosphere with full chemistry.

Moore cautioned that the overview report has very little to say about the critical issue of clouds and radiation, but that the full report has extensive information on this.

Moore stated that the Academy will be trying to establish its role in seeing that the Pathways report recommendations are carried out. Asrar added that there will be a new committee to push implementation of the recommendations, and that there may be Congressional hearings related to this.

Pierre Morel (NASA Headquarters) presented the latest information on the "EOS Second Series: Status and Plans." He said that NASA wants to operate with all "due process." His talk would focus on flight mission planning. There is a need to re-validate the linkage between Earth Science questions and research priorities and measurement priorities that will lead to the most essential measurements. He referred to the RFI review session held in Easton, Maryland (August 24-26) that was previously mentioned by Ghassem Asrar as the occasion where the plans for the second series were reviewed.

The RFI had been issued in May 1998. Six discipline panels reviewed the proposals that had been received in response to the RFI. 23 flight mission concepts came from the review, and they can be found on the World Wide Web. The second step in the process was to review the mission concepts using an industrial "cost model." A "nominal mission scenario" was developed and reviewed by a panel of 33 "distinguished scientists" headed by Charles Kennel. (The report of the RFI review is available at URL: http://eospso.gsfc.nasa.gov/eos_homepage/misc_html/intro_kennel.html.

The outcome of the RFI process was the conclusion that there is a need to identify the key systematic measurements required for the next decade. Three specialized mission types were identified: 1) EOS systematic follow-on measurements leading to operational systems as appropriate; 2) Earth Probes (also referred to as Discovery missions); and 3) New Millennium Program missions bringing in new technology. It was also stressed that it is essential to transition measurements to NPOESS, and that NPOESS should develop research-grade measurements programs.

Morel gave what he called "Priorities at a Glance":

1) *Atmospheric Chemistry*
   - Monitor ozone, both total column and profiles
   - Make systematic high-precision measurements of key species in the stratosphere ("thin monitoring")
   - Perform tropospheric "Discovery" missions with high vertical resolution

2) *Atmospheric Physics and Radiation*
   - Earth Probe missions on clouds and aerosols
   - Systematic measurements of atmospheric temperature and water vapor
   - Total Solar Irradiance (TSI) monitoring

3) *Hydrology and Mesoscale Weather Processes*
   - Systematic measurements of global precipitation—first and foremost!
   - Develop soil moisture remote sensing technique
   - Develop pre-operational geostationary observation systems
   - Provide for other experimental observations, e.g., rivers and lakes, cold land properties

4) *Oceans and Ice*
   - Systematic observations of ocean surface topography and winds
   - Systematic observations of ice sheet mass balance
   - Systematic monitoring of ocean primary productivity
   - Develop pre-operational geostationary imager
   - Add other experimental observations, e.g., surface salinity

5) *Land Cover and Terrestrial Ecosystems*
   - Provide systematic measurements of land cover using Landsat and MODIS follow-ons
   - Provide Discovery missions to study ecosystems recovery from disturbed states

6) *Geodynamics and Natural Hazards*
   - Provide systematic observations of dynamic topography and related geography using SAR interferometers and precision altimeters
   - Develop time-dependent gravity field mapping
   - Develop time-dependent magnetic field mapping
   - Develop various pre-operational geostationary observing systems

Morel showed the response to the panel recommendations in the form of "Timelines for Systematic Measurements" for the period 1999 to 2011. In his charts he showed the flow from EOS measurements into NPOESS via "bridging" measurements. He noted that performing stratospheric chemistry measurements will

bring the International Space Station into play. There is a hope to be able to buy radar imaging commercially. TRMM's measurements will become part of the International Precipitation Mission in 2003 under Japanese leadership and then become global in 2009.

There are to be eight Discovery missions (Earth Probes) starting in 2001, with the possibility of supporting three such missions in the course of two-year intervals. Morel listed seven such missions saying, however, that there is no commitment to carry them out:

- tropospheric chemistry with high vertical resolution using DIAL;
- aerosol radiative forcing with high vertical resolution using lidar;
- cloud radiative feedback using multiple sensors in the same atmospheric column (lidars, radar);
- soil moisture and sea surface salinity using low microwave frequencies;
- vegetation recovery using a steerable lidar altimeter;
- cold-land processes research using radiometric SAR with high calibration; and
- time-dependent gravity using satellite-to-satellite tracking.

Skip Reber expressed concern that through the Discovery missions with their single objectives we are losing out on the simultaneity that is often wanted by the IDS investigators. Morel responded that the models can serve the function of integrating non-simultaneous measurements.

Berrien Moore called attention to the ill-defined geostationary observing missions. Morel responded that we are aware of this and working on it.

Following the morning break, **Chris Scolese** (Goddard Space Flight Center) reported on the "Status of the GSFC EOS Missions." He said that recovery activities are under way to deal with the one-year delay of the AM-1 launch that has been imposed by difficulties with the Flight Operations System (FOS). The spacecraft hardware will basically be ready in January, and it is expected that a launch date will be set in two months. CERES may replace its voltage converters, depending on the outcome of the TRMM instrument study. MODIS is going to fix the crosstalk between detectors in the readout electronics and is deciding whether to go back and do thermal vacuum testing and re-calibrate with the new electronics. There have been budget impacts affecting both ICESat and EOSDIS.

Scolese listed major issues, which include developing a control center for AM-1, providing the necessary funding for ICESat and EOSDIS, and establishing working agreements for Landsat 7 operations and data processing. He referred to reorganizing activities taking place at both GSFC and OES. Both algorithms and instruments are the responsibility of GSFC.

Landsat 7 has been assigned a launch date of April 15, 1999, and this is being tracked. AM-1 is to be launched in the third quarter of 1999, but this awaits finalizing of the FOS recovery plan.

Scolese showed pictures of the AM-1 spacecraft and the instruments and showed the launch vehicle on its stand at the launch site. There are still some problems affecting the status of the AM-1 launch.

The PM-1 launch is affected by the lack of instrument contingency funds. The spacecraft I & T is to begin in June of next year.

Regarding ICESat, Scolese said that the GLAS instrument is in good shape. GSFC has total responsibility for the mission. The launch vehicle has yet to be selected—as a matter of preference it could be either Athena II or Taurus XL. Unfortunately, there is a $15 M cut in the FY 99 budget threatening the ICESat schedule.

On a happy note, he said that CHEM-1 is "moving along."

Summarizing, Scolese said that considerable progress has been made overall in the last year. The FOS is still the pacing item for the AM-1 launch date. An agreement on a specific launch date is to be worked out in the next few months. The spacecraft must be ready for launch early in 1999 to maintain its place on the launch schedule.

Dolly Perkins (Goddard Space Flight Center) reported on EOSDIS. She referred to the EOS Polar Ground Network, the EOS Data and Operations System (EDOS), and the associated networks.

Concerning the Science Data Processing Segment, she said that, by launch date, all Landsat 7 and AM-1 data will be provided though Level 1. The Emergency Back-up System (EBS) is ready for use as needed.

Since 1997 the ECS contractor (formerly Hughes and now Raytheon) has been having problems, partly due to heavy attrition (greater than 35 percent). Some of the ECS functions are now being carried out by other elements of EOSDIS. The instrument teams are now taking on more of the instrument data processing, and budget problems await us in the out years.

Since March there has continued to be slippage of the Flight Operations System (FOS). As a result the command execution system is being replaced by a new commercial system called ECLIPSE.

Facing a budgetary challenge beyond the AM-1 launch time, ESDIS has considered four alternatives. The selected "option A+" minimizes the 1999 budget impact and relaxes some of the requirements. It calls for adding capabilities incrementally over four releases occurring in FY 1999 and 2000. The requirements that were dropped can be restored at a later date, provided that the budget permits this. Generally, the system is becoming more adaptable over time, permitting the use of new technologies and processing approaches.

Three times processing of the data is now being considered. "One-stop shopping" is still in place.

In answer to a question, Michael King replied that there has been some full-load testing with MODIS, and full end-to-end testing will start in November.

Asrar said, if the PIs can do the data processing job within their budgets, they will be permitted to do it. Jim Dodge commented that archiving and distribution of the data are still to be carried out by the DAACs.

Byron Tapley was concerned that network bandwidths might be constricting. Perkins replied that we are considering bandwidth for data entering the system and have yet to look at the bandwidth for data coming out of the system. Asrar said that we never intended to provide full data access to the outside community. He stressed that any requirements from the outside community with budgetary impacts must be sent to Headquarters for resolution.

Afternoon Plenary Session (TRMM Early Results and Lessons Learned). The session was chaired by Chris Kummerow (Goddard Space Flight Center)

John Wilding (Goddard Space Flight Center) was the leadoff speaker. Wilding's topic was "SeaWiFS Data System Experiences and Lessons Learned." Chuck McClain made a few introductory remarks before Wilding gave his presentation. McClain said that mid-September was the first anniversary of routine SeaWiFS operations, and they are now able to provide real-time products. There are four tightly coupled elements to the SeaWiFS ability to deliver products: data capture, mission operations, calibration/validation, and core processing. McClain suggested that this mission approach might serve as a prototype for other missions to come. The system is adaptable to multi-systems. He explained that Wilding has been in charge of keeping the processing system going, from capture through to the DAAC.

Wilding explained that the system requirements were to have high automation, high flexibility, and be able to do reprocessing readily. The main elements of the system are the scheduler and the visual database cookbook (VDC). They use a relational database.

Among the key system features listed by Wilding were its ability to serve as a MODIS emergency back-up. The system offers high adaptability, scalable architecture—it was adapted to OCTS in just two weeks, and it was possible to create a fully functional prototype for MODIS in less than a month.

The primary lesson learned was the value of having ***all*** project elements in a collaborative working environment. In summary, Wilding stated that SeaWiFS is now a complete end-to-end system. McClain added that the great asset of SeaWiFS is its ability to provide a system for users of other platforms. Users of the SeaWiFS system can specify run corrections. They just submit them as "special recipes."

Chris Kummerow (Goddard Space Flight Center, TRMM Project Scientist) was the enthusiastic lead-off speaker for "TRMM Overview of Early Science Results: Hot Gems." He explained that the three precipitation sensors were the TRMM Microwave Imager (TMI), the Precipitation Radar (PR), and the Visible and Infrared Sensor (VIRS, like AVHRR). LIS and CERES are also on the spacecraft. The first TRMM images were available on-line on December 8, 1997. He showed some images from VIRS over Florida and a comparison of PR images with ground radar over a squall line. Using TMI, brought out the amount of graupel to be found in oceanic storms. The 10-GHz TMI channel was used to study sea-surface temperatures during the recent El Niño. The greatest differences among the TRMM algorithms occur in the deep tropics, and were found notably in the February 1998 data.

There have already been tremendous improvements in the algorithms since the first TRMM data became available. Now the Science Team is working very hard to build strong consensus algorithms to ensure the TRMM legacy. The Science Team is hoping to get down to 10% anomalies between rain estimates, but further research will be needed to do better than that. Planning for TRMM science communications has really paid off, making data readily available not only from the regular data stream, but from a new "real-time" stream as well.

The Science Team has been checking out the algorithms that were applied to warm rain over land and found no glaring errors. The topographic errors occurring in mountainous areas have been "cleaned out."

Bruce Wielicki (Langley Research Center) discussed "CERES on TRMM Early Science Results." He noted that the first CERES data from the TRMM spacecraft became available on December 27, 1997. He said that the calibration accuracy and stability of the CERES radiometers exceed the specifications. Navigation accuracy is about 1 km, and CERES calibration is 2-to-10 times better than the ERBE calibration. Over the first 8 months, no change in instrument gain was found within 95% confidence limits of between 0.1 to 0.3%, depending on the channel, an unprecedented level of stability for Earth-viewing radiometer data. Level 1b CERES radiance data (calibrated and navigated) have been in the archives since July 1998, roughly a factor of 4 faster than was done for ERBE.

The CERES-archived "ERBE-like" TOA flux data currently appear to have better accuracies than ERBE. The data for January through August 1998 are available in the Langley DAAC.

It appears that there could be a real climate change of 4 W m^{-2} in outgoing longwave (LW) flux for the +/- 20° latitude zone as measured by ERBE and CERES, from the ERBS period (1985-1989) to the present. Unfortunately, there is an observational gap of 8 years between the current CERES data and the previous ERBE scanning radiometer data from NOAA and ERBS missions, but the ERBE wide-field-of-view (WFOV) instrument on the ERBS spacecraft is still functioning after 14 years. The ERBS WFOV data indicate that this change occurred in early 1991, before the Pinatubo eruption. The SCARAB data from 1994 are also consistent with such a change.

Early CERES data have shown that the maximum albedo of deep convective clouds is roughly 0.74, and the albedo of precipitating deep convective clouds (identified by the TRMM radar) is about 0.66. Theory for small ice particles predicts a maximum of about 0.79. The drop in albedo for precipitating clouds may be due to an increase in particle size for the precipitating clouds or may be due to lightning production of SO_2 in the upper cloud.

As of September 1 there was a CERES voltage-converter anomaly which caused one of the voltage converters to be sensitive to temperature. The CERES instrument has been shut down for an investigation of the impact of this sensitivity on instrument lifetime. Results of the investigation should be available by late November, with a decision then on future operations of the instrument.

Hugh Christian (Marshall Space Flight Center) discussed "LIS on TRMM Early Science Results." He explained the physics of lightning-causing clouds. In order to have lightning there must be graupel particles plus ice crystals plus supercooled water and 7-8 m/s updraft velocities in the cloud. Also, there most be some mass above the zero-degree isotherm. In the updraft the ice particles become positively charged and the graupel become negatively charged. As they separate the potential difference leads to lightning. Thus, lightning is well correlated with updraft intensity and with cold-process rain. Lightning can be seen to be a measure of how energetic cloud cells may be.

The Optical Transient Detector (OTD) is a precursor of LIS and is still flying after three years in orbit. LIS is a more-sensitive instrument than OTD.

Using OTD and LIS it has been shown that equatorial Africa is the hottest lightning spot on Earth. OTD observations have shown lightning occurrences at latitudes higher than 70 degrees north. The preponderance of lightning occurs over northern hemisphere land. The global flash rate has been found to be about 40 flashes per second, and this is just about half of the old estimate. This lower flash rate thus implies lower NO_x and thus lower ozone production. Intracloud lightning dominates. An interesting finding is that continuing-current discharges may be a warning signal for forest fires.

After an afternoon break the TRMM session continued with a presentation by **Arthur Hou** (Goddard Space Flight Center) on the "Impact of TRMM Precipitation and Moisture Observations on DAO's Assimilated Global Data Sets." He stated that the Data Assimilation Office (DAO) is the first among the global data producers to attain rainfall and total precipitable water (TPW) assimilation capabilities. Assimilating TMI (from TRMM) and SSM/I rain rates and TPW data is effective in improving the hydrological cycle and atmospheric energetics in the Goddard Earth Observing System (GEOS) model analysis. Errors in the outgoing longwave radiation (OLR) in the GEOS analysis are reduced by approximately 20% in bias and 25% in rms error between 20°S and 20°N. As a result of adding TRMM data, the GEOS Data Assimilation System (DAS) now gives better tropical precipitation forecasts beyond one day.

The last speaker for the first day of the IWG meeting was **Erich Stocker** (Goddard Space Flight Center) presenting "TSDIS Experiences and Lessons Learned." Like SeaWiFS, the TRMM Science Data and Information System (TSDIS) is database driven. Even more than in SeaWiFS, commercial software systems are used. Errors are viewed through a system called OVERVIEW. TSDIS has used a commercial

database called SYBASE and has found some problems with it in the form of page "lockups." TSDIS has no responsibility to provide data to the general public.

Among management lessons brought out by Stocker were these:

- Management authority must follow management responsibility.
- Science processing systems must be managed from a *science* organization and *not* from a *computer* organization.

Stocker said that in the world of TRMM "real time" refers to data that are less than three hours old at the time the user gets ftp access. In fact, at least 80 percent of the time the data are less than two hours old at the ftp site.

TSDIS now includes four government people and 26 full-time equivalent (FTE) contractor people.

Tuesday October 20

Morning Plenary Session (Anomalous Absorption of Clouds and Regional Aspects of Global Change). The session was chaired by Michael D. King (Goddard Space Flight Center).

Robert Cahalan (Goddard Space Flight Center) dealt with the question: "Is the Sun's Heating of Earth's Atmosphere Excessive?" He began by referring to an FY 96 Report to Congress which referred to three papers in a 1995 issue of *Science,* by Cess *et al.*, Ramanathan *et al.*, and Pilewskie and Valero, dealing with atmospheric absorption of solar radiation. He then defined such terms as total absorption, cloud forcing, cloud forcing ratio, and "excessive."

Various other studies in the period 1975 to 1997 found solar absorption by the atmosphere to be typically near 65 W m^{-2}, but Cahalan showed a second group of four previous studies that found results closer to 85 W m^{-2}. So there was a bimodal distribution of results, with most finding approximately 20-percent absorption by the atmosphere (~65/340), but a second group 20 W m^{-2} higher, or about 25-percent absorption (~85/340).

When plane-parallel theory was applied to absorption by clouds, the results appeared to be insensitive to cloud amount or aerosol, and there was a negligible excess absorption in the visible. Cahalan said that there had been studies by Li and colleagues showing variations of absorption with latitude, with a large excess near the equator, little or no excess at mid-latitudes, and a deficit in absorptance at high latitudes. Work by King and colleagues, using the Cloud Absorption Radiometer (CAR), did show some excess absorptance in water vapor window regions in the near infrared, but the amount was not comparable to the very large numbers reported in the 1995 *Science* articles. These CAR measurements apply to absorptance deep inside thick clouds, in the so-called "diffusion regime" of radiative transfer. While these in-cloud diffuse measurements found no large excess, significant excesses in diffuse radiation at the surface have been reported. The explanation for the excess diffuse radiation at the surface is still being debated.

Cahalan went on to mention a two-aircraft experiment that was conducted at the DoE/ARM Southern Great Plains site to check directly on the excess absorptance problem in clouds. Two aircraft flew simultaneously, one above and the other below the cloud. There was a problem in keeping the two aircraft and their radiometers level. This was important because the flux determinations are very sensitive to the radiometer view angle. However, corrections were made to determine what the flux would have been in level flight, and the results show an excess that increases with cloud amount, with the largest absorptance exceeding 35% during a flight on October 30, 1995.

Cahalan also mentioned the 3D errors that affect theoretical calculations. These are large enough to often make local absorptances appear to be negative, due to net downward radiation from cloud sides. However, Cahalan said that these effects have been carefully simulated and can be effectively removed. After 3D errors are removed from the observations, there remains a real 3D correction to absorptance, but such corrections are typically only on the order of 1%. Also, 3D effects have characteristic signatures which depend on cloud type and sun angle, and in some cases 3D effects can *decrease* the all-sky absorption when compared to clear sky, as well as increase it. By contrast, the 1995 *Science* studies found no spatial or spectral signatures, and some later satellite studies also find no dependence of excess absorptance on latitude or season. Cahalan reported that no physical hypothesis is known to explain this lack of spatial or spectral signatures found in many of the empirical studies. Cahalan feels that there is a need to quantify expected signatures of absorption due to various 3D cloud effects, aerosols, drizzle, and the radiative continuum, as well as to examine a wide variety of 3D cloud situations, in combination with aerosols and drizzle.

Cahalan's conclusion was that there is a likely excess absorptance of about 5% (10-to-15 W m^{-2}) with an unknown impact on climate sensitivity, and that future studies will need accuracies of 1% (~3 W m^{-2}) in order to distinguish the various physical mechanisms which might be responsible for the solar absorption excess in the cloudy atmosphere.

Stephen Schwartz (Brookhaven National Laboratory) reviewed experimental work on "Atmospheric Absorption Inferred from Sun and Sky Photometry." He began by saying that he was concerned with possible aerosol effects on the solar irradiance budget. Working mainly with surface measurements at the DOE Southern Great Plains ARM site in North Central Oklahoma, his group found that direct normal solar irradiance (DNSI) at the surface is most sensitive to aerosol optical thickness, t. Sun photometry with "Langley plots" was used to determine values of t, permitting comparisons of measured and modeled DNSI. The findings were that it is necessary to know aerosol optical depth with great accuracy in order to model DNSI accurately, and that there is *no* unrecognized atmospheric absorption.

In part II of his talk Schwartz presented work on the diffuse downwelling irradiance (DDI), measured with a shaded pyranometer. The finding was that "measured" equals "modeled" at high-altitude sites but not at low-level sites such as the Southern Great Plains ARM site or Saskatchewan. At low altitudes the model results were systematically higher than the measured results. He stated that "something" seems to remove the power from the diffuse radiation! He suggested that this absorption masquerades as an "enhanced" aerosol optical depth, and further that such absorption is inconsistent with typical properties of tropospheric aerosols and with measurements of aerosol single scattering albedo made at the Oklahoma site. Something other than aerosols is responsible for this atmospheric absorption, of magnitude about 0.02 optical depth. AERONET results from 80,000 measurements indicate that such a magnitude of minimum extinction is widespread.

[An overview kindly provided by Bruce Wielicki gave these insights into the Schwartz talk: Diffuse radiation in clear skies appears to be off by an equivalent aerosol optical depth of 0.02, or an equivalent global mean clear-sky flux of 17 W m^{-2}. The difference does not appear to correlate with aerosol optical depth, as it should, if it is explainable by an uncertainty in aerosol single scatter albedo. The difference also did not appear to correlate with column water vapor.]

Jim Hansen suggested that perhaps the single scattering albedo value could be changed, and Schwartz agreed that this should be considered, especially in instances of high aerosol optical depth.

Tom Charlock (Langley Research Center) addressed a "Comparison of Computed Shortwave Fluxes with Observations from Surface Radiometers, CERES, and GOES over ARM SGP (Oklahoma and Kansas)."

Charlock began by saying that we lack information on shortwave forcing of anthropogenic aerosols and changes in land use. The CERES ARM GEWEX (CAGEX) experiment was a web-based exercise conducted "pre-launch" with access to input data, computed fluxes, and measurements. Charlock showed data from October 11, 1995 on surface insolation vs. time. The diffuse radiation exhibited large errors (it was not well calibrated). The measured diffuse radiation was low whereas the calculated radiation was high. The measured diffuse radiation did not correlate well with the measured precipitable water. Clear-sky measurements and calculations for October 11 showed no discrepancies, but huge discrepancies were found for cloudy-sky conditions.

The CAGEX ARM Enhanced SW Experiment (ARESE) was conducted in the period September 25 to November 1, 1995. Generally, large cloud absorption was found in this experiment. October 30, 1995 was a cloudy day. Good agreement was found between the measured and the calculated radiation at the top of the atmosphere (TOA). However, the mean radiation calculated for the surface was much too high ~100 W m^{-2}.

Cloud profiles were obtained using radar, microwave radiometers, and lidars for different cloud conditions, but still discrepancies of ~100 W m^{-2} were found.

Charlock reported on CERES data from January to June of 1998 and compared the data with results from the CERES ARM Validation Experiment (CAVE) with the conclusion that ERBE data have an uncertainty of about 5-to-10 W m^{-2}. The surface measurements are generally not consistent with the model calculations.

Charlock pointed out that the sorts of disagreements found at the ARM site were apparently not applicable to data taken at high altitude at Mauna Loa. There seems to be the need for better calibration of surface solar insolation measurements. Direct-beam solar insolation measurements seem to be well calibrated, but diffuse radiation measurements are still a concern.

Steve Wofsy (Harvard University) asked "Are Forests Really Important Sinks for Atmospheric CO_2?" He showed the trends for CO_2, for 1998 to 1990, and pointed out that the atmospheric anomaly was low. In the period 1980 to 1990 there has been a source of 6.3 to 7.3 Gt C/yr from fuel consumption and deforestation, which, taking atmospheric uptake into account, leads to a missing sink of 1-to-2 Gt C/yr. Keeling and coworkers have been measuring oxygen concentrations over the Pacific and find that oxygen concentrations are changing more rapidly than CO_2

concentrations are changing. They find that land and ocean uptakes are about equal.

In the period between 1800 and 1950 the biospheric addition of CO_2 to the atmosphere has been significant. (This finding is based on an analysis of the amount of ^{13}C present in the atmosphere.) In more-recent years it appears that the biosphere has been taking up carbon.

Wofsy referred to a *Science* article by Tans (the next speaker) in which there is this quote: "North America sops up 1.7 petagrams C/yr." He then quoted from the "Birdsey Forest Inventory Plots," which showed that in 1950 U.S. forests had an increase in carbon. He commented that there are widely differing numbers as to the rate of increase of forest carbon intake.

Wofsy has looked at data from two very different sites, one is in Manitoba (a boreal site with trees about 75-90 years old) and the other is the Harvard Forest (with trees about 60 years old). Some comparisons between the two tree stands were these:

- Harvard intake has increased by about two over five years.
- Harvard has had a varying intake in recent years, with no such effect in the boreal forest.
- The boreal forest is affected by an underlying peat surface.

Factors affecting the sequestration of carbon differ at the two sites because of their different surfaces. Warming over the last 30 years has affected the two sites differently.

Wofsy concluded that terrestrial land-use history is most significant in determining the role of forests in carbon sequestration. Climate warming is a very important factor for midlatitudes. It is important to get more information on the ecosystems.

Steve Running commented that this work shows the importance of vegetation disturbances. We need more satellite data to learn more about this. He pointed out that the tower sites are giving reasonable magnitudes for carbon release. Bob Dickinson added that land-use change should be put in models along with trace-gas histories for the past century.

Pieter Tans (NOAA) had for his subject "Keeping Track of Atmospheric Trace Gas Budgets." His group (CMDL) has the assignment to keep track of the greenhouse gas budgets. He displayed a chart giving the current CMDL flask sites and towers along with the aircraft used for monitoring of trace gases. They have enhanced coverage for marine boundaries and are now branching out to get more land measurements. The CO_2 program goes back to 1976.

A recent *Nature* article reports on methane measurements for the period 1984-1986 and shows a declining growth rate. New global measurements of fossil fuel-derived CO_2 in 1992 and 1993 show large uptake in midlatitudes, mostly terrestrial. It is very difficult to distinguish biospheric from oceanic uptake of CO_2 using the $^{13}C/^{12}C$ ratio. (An accuracy of 0.01/mil would be required.)

CMDL uses a 2D transport model to go from concentrations to identification of sources and sinks. In another chart he showed that, omitting fossil fuels, there is a net uptake of CO_2 in the northern hemisphere for mid- to high-latitudes. CMDL has also used a 3D transport model and applied it to 14 "source regions." They run the model in monthly time steps. Using the model brings out the sparsity of data. They have used an estimated marine boundary layer time series to fill in data missing from other records, but there are problems with this method in some parts of the world. Tans has concluded that column-averaged CO_2 should be used in CMDL calculations.

Tans has now formulated a desired data-gathering program. There should be 3 x 3-degree grid cells with monthly means. Accuracy per column should be 0.1 ppm. Aircraft should be used to obtain *in situ* profiles along with satellite laser measurements at 1.58 micrometers using DIAL. Steve Wofsy commented that diurnal measurements are needed from the satellites, and Tans replied that perhaps the satellites would only provide night measurements but that aircraft could be used to determine the bias associated with missing daytime observations.

Dave Skole (Michigan State University) undertook a review of "Pattern to Process: Linking Satellite Observations and Socioeconomic Variables for Regional Land Cover Analysis." Skole said that the key question was the nature of the carbon cycle on an interannual basis. The human dimension is hard to incorporate in models with the land-use/land-cover change information that is needed in order to establish a true understanding of interannual effects. His work begins with Amazonia where he has used data at ten-year intervals. Regrowth rates there are not well quantified. There is an "asynchrony" between deforestation and regrowth. 1995 was a peak year for deforestation in Amazonia.

Research issues he posed were: distinguishing between interannual and decadal rates of change and how to use socioeconomic data and satellite data to better understand the dynamics of deforestation. We must understand how farmers make decisions. "Big" farmers are not a big

factor in deforestation but they are important in establishing the regrowth rate.

Skole has used a Markov approach in what he called short -run models. This work involved interviews with individual farmers. Skole presented a hypothesis of his work which is: Deforestation events depend on site accessibility, life cycle stage of a family, and family wealth. He noted the regular grid pattern that prevails for farm plots.

Eric Davidson (Woods Hole Research Center) presented "A Conceptual and Empirical Basis for Estimating Nitrogen Oxide Emissions from Soils at Regional and Global Scales." Davidson explained that he uses nitrogen oxide to mean both NO and N_2O since the same organisms, under different circumstances, produce both. He said that nitrifying bacteria, denitrifying bacteria , and biological reactions must all be taken into account. The supply of nitrogen is important—it comes from both fertilizers and from nitric acid-acid rain deposition.

Soil moisture affects the N_2O/NO ratio, with dry soil causing an increase in NO and wet soil favoring N_2O. Davidson has studied NO emissions from soils. For the southeast U.S. he has found that heavy use of fertilizers has led to high NO emissions. Soils are a moderate source of NO_x in general, but may dominate in some areas leading to local increases in ozone. For four tropical locations he has found a positive correlation between the amount of NO_x flux and the amount of water-filled space in the soil. He found the same sort of correlation with the Tragnet database, which includes sites all over the world. Litter fall also leads to increases in NO_x flux.

In his final chart Davidson showed predicted NO_x based on litter fall for six sites around the world. Two sites with high acid rain were way off the curve. The presence of leguminous trees was another reason for falling off the curve.

Afternoon Plenary Session, Tuesday (Results from Recently Launched Spacecraft and Analysis Projects). This session was chaired by Michael Freilich (Oregon State University).

Dixon Butler (The GLOBE Program) introduced GLOBE as a project involving children from all over the world. There now over 6100 participating schools and 72 partner countries. GLOBE requires that there be at least one teacher trained by GLOBE in each participating school, and there are more than 75 U.S. GLOBE "training franchisees."

Butler listed some of the types of measurements being taken by the GLOBE students. Student data have been validated against "agency" sources, and some significant differences have been found in some instances. Elissa Levine of Goddard has reported that the soil moisture measurements are very good and helpful in her work.

Butler introduced **Russell Congalton** (University of New Hampshire) as the GLOBE PI for land cover and related biological measurements. Congalton said that the objective of the program is to obtain data of *genuine* value. In one instance, wetlands validation was needed. The work entails using the Modified UNESCO Classification system (MUC). MUC has over 150 land-cover classes. Each school involved was given Landsat TM imagery for its area. Then the students classified areas on the map, recorded biometry, made land-cover determinations, and made accuracy assessments. The next step will be to establish protocols to detect future changes. This activity was found to very acceptable when it was applied to state parklands. High schools have to buy a $600 instrument kit to particiate in the program.

Congalton said that this program is an incredible resource for environmental science and education.

Mick Follows (Massachusetts Institute of Technology) presented "Models of Seasonal and Interannual Variability in North Atlantic Biogeochemical Cycles." Follows uses SeaWiFS colors to study interannual variability. He begins with process-oriented models. He has found that some biogeochemical variations correlate with meteorological indices—but the observations are local and not basin wide. He is looking for underlying mechanisms that might explain the variability and listed three causes: 1) meteorological forcing leading to modulation of the nutrient supply, 2) biophysical interactions, and 3) internal variability of the ecosystem, e.g., predator/prey relations.

Follows has been researching the North Atlantic Oscillation (NAO). The NAO has been strong in the period from 1987 to 1997 leading to tight gradients. His model shows that the convective index for the Labrador Sea has been high during this same NAO period leading to transport of nitrogen through the north Atlantic basin.

Follows wants to model chlorophyll a and compare his results with measurements from SeaWiFS. He showed his model results for chlorophyll concentration for the spring periods of 1988 (low concentration), 1992 (high concentration), and 1994 (high concentration) in the period that the NAO went from low to high.

Summarizing, Follows said that the simplest nutrient cycle shows interannual variability in export production. The

variability is dominated by the convective contribution.

Mark Abbott pointed out that as the NAO changes, the wind stress curl will also change. He asked if Follows will use QuikSCAT wind field data. Follows replied that winds will be important, but his results are not strongly sensitive to them. He is doing large-time-step averaging.

John Walsh (University of South Florida) gave some insights into "Regional Models of Carbon/Nitrogen Cycling: Minimum Levels of Ecological Complexity." He started his remarks with a comment that grid models tend to miss near-coastal waters, and these are the places where most of the production takes place.

Walsh gave his findings for three regions: 1) Southern Caribbean Sea: Cariaco Basin and Barbados, 2) Antarctic waters: circumpolar current and Bransfield Strait spring blooms, and 3) Gulf of Mexico: Loop Current and the West Florida Shelf annual cycles.

Southern Caribbean Sea: Cariaco Basin: Walsh said that on a yearly basis the Basin may be a weak source of CO_2 to the atmosphere. He said that his springtime case matches observations quite well, but the summertime case was not as good. Some problems are due to missing trichodesmium, missing iron, and missing phosphorous in the model. He pointed out that the source of iron is the Saharan desert plume.

Concerning production in the *Antarctic* he said that three phytoplankton variables are needed, and, in his model, they were subjected to four types of herbivores to explore the relative importance of grazing pressure and light limitation on annual carbon cycling within both iron-replete waters around the Antarctic Peninsula and putative iron-poor offshore regimes.

Gulf of Mexico: Loop Current and the West Florida Shelf Annual Cycles: A model of the food web affecting red tides, inherent optical properties, and biogeochemical cycles on the West Florida shelf is now being constructed for five types of phytoplankton. All the parameters in his model are measured except for the ciliates. Silicon must be added as an explicit state variable to effect competitive disadvantages for the fast-growing diatoms.

Chuck McClain (Goddard Space Flight Center) discussed "Ocean Applications of the SeaWiFS Sensor." He began with some highlights of the first SeaWiFS year ending with September 18, 1998:

- There were no serious anomalies (all systems were healthy).
- After the first reprocessing was completed, it was determined from the lunar calibration data that the two near-infrared bands were degrading. A correction scheme was implemented, and a second reprocessing was initiated in August and completed in September.
- The Marine Optical Buoy (MOBY) has been operational since July 1989.
- Members of the MODIS Oceans Team (D. Clark and H. Gordon) conducted a post-launch initialization cruise out of Hawaii in February.
- There have been more than 850 authorized data users (via the DAAC).

McClain showed some SeaWiFS seasonal composites and pointed out that this was the first time that such data were available. Polar projections show the large contrasts between opposite polar regions. This is the effect of having more iron in the North. The Northern Hemisphere also has more seasonal variations.

McClain also showed some high pigment concentrations that appeared in the equatorial region by August 1998, as we entered the La Niña phase. In the Indian Ocean SeaWiFS observed seasonal variations and phytoplankton blooms in July and August as the summer monsoon regime began to take over. Large coccolithoporid blooms were observed in the Bering Sea during the summer and fall of 1997 and in April 1998. SeaWiFS provided some of the observations of this phenomenon in the Bering Sea. This bloom will impact fisheries such as salmon because the salmon are unable to swim through the bloom to spawn in the Alaskan rivers. SeaWiFS also provided observations of "red tide" in the Bahai Sea off the China Coast in September 1998.

McClain said that SeaWiFS was the first ocean color project with an organized calibration/validation (cal/val) program. They do their cal/val in coordination with the MODIS science team. An on-orbit vicarious calibration methodology for the NIR bands of SeaWiFS is needed even though the sensor was well calibrated before launch. Thus, the prelaunch calibration of these two bands is being used even though the visible bands are being adjusted based on simultaneous *in situ* SeaWiFS comparisons with MOBY. The solar and lunar calibrations only provide calibration stability relative to the initial on-orbit solar and lunar calibration data. The SeaWiFS project is providing real-time data to several field experiments at any given time.

McClain ended his talk by showing global NDVI results, which they produce routinely, observations of fires in 1998 for Mexico and Florida, and cloud optical thickness measurements.

Following the afternoon break the first speaker was **Eric Vermote** on the subject

of "Prototype Land Surface Reflectance, Vegetation Index, and Aerosol Products from SeaWiFS Data." Vermote addressed four products: 1) Level 3 monthly surface reflectance (minimum blue composite), 2) seasonal variations in RGB, 3) aerosols over land/ocean based on AVHRR/SeaWiFS fusion, and 4) MODIS prototype vegetation indices.

The SeaWiFS Level 3 monthly surface reflectance uses minimum blue that has the advantage of minimizing atmosphere and cloud perturbations. Using the seasonal variation in RGB it was possible to compare April 1998 to September 1998 and note the disappearance of snow cover and the development of vegetation for North America. Over Africa the development of vegetation in the sahelian zone was observed in the northern part, and the seasonal variation was observed in the southern part.

Data from AVHRR were used to detect targets of low reflectance in conjunction with SeaWiFS, thus enabling the derivation of aerosols over land in the SeaWiFS blue and red channels. The Enhanced Vegetation Index (EVI) is being examined as a prototype for MODIS products. The new EVI algorithm tends to minimize aerosol contamination. EVI does better than NDVI for broadleaf vegetation in Brazil.

Vermote concluded that his work with SeaWiFS has generally been successful but that cloud screening needs some improvement.

David Long (Brigham Young University) reviewed "Tropical and Cryosphere Applications of High Resolution Scatterometer Data." He was addressing Ku-band observations at 14 Ghz. While SAR systems can achieve very high resolution, they have limited temporal and spatial coverage. Scatterometers have low (50 km) resolution, but rapid, global coverage. Long used the Scatterometer Image Reconstructive Filtering (SIRF) algorithm to enhance the scatterometer resolution. Referring to tropical rainforest mapping, he said that classification is performed according to values of the A (sigma-0 at 40 degrees incidence angle) and B (sigma-0 slope vs. incidence angle) coefficients. Accuracy of 94 percent has been achieved using the A and B coefficients along with polarization data. Comparisons of Seasat-A Satellite Scatterometer (SASS) data from 1978 with NSCAT data from 1996 have permitted identifying new highways and new settlements in Brazil from the change images. Scatterometer images are particularly useful in the polar regions. Scatterometer images of the polar regions are useful in monitoring seasonal melt cycles and tracking ice motion.

Long summarized the advantages of scatterometers as follows: They are able to provide wide-area coverage; they offer frequent observations; they have high radiometric accuracy; they provide multiple incidence angles; and they also have multiple azimuthal angles. As such, they complement both high-resolution SAR sensors and low-resolution passive radiometers.

Mark Drinkwater (Jet Propulsion Laboratory) described "Land Ice and Sea Ice Studies with Radar Data." The European scatterometers have now been operating from 1991 to the present day, giving us valuable C-band microwave radar time series data. Scatterometers have high sensitivity to the presence of liquid water along with ice and are less sensitive to meteorological conditions than passive microwave instruments. Drinkwater showed images of surface melting in Greenland for the period 1992 to 1996. Knowledge from Greenland observations has been applied to the study of Antarctic ice.

Drinkwater mentioned that sea-surface scatterometry goes back to the Seasat-A Satellite Scatterometer (SASS) flown in 1978. ERS Scatterometer data for Palmer and Marie Bird Land showed strong trends in snow accumulation over land, whereas SSM/I appears less sensitive to the changes. Differences between NSCAT and SASS images indicate significant regional decadal variability, which reinforces the ERS Scatterometer observations.

Drinkwater made some concluding observations about scatterometry and sea ice: Sea-ice snow-surface melt causes large reductions in the backscatter signal. Surface salt-water flooding, which is also particularly prevalent in Antarctica in summer, can be distinguished from surface melt on snow-covered sea ice. Observations indicate considerable interannual variability in surface melting. Scatterometry is able to distinguish the onset of Antarctic sea-ice melt, and how widespread the effects of summer flooding are in the Antarctic.

Melting indicates situations in which atmospherically delivered heat contributes to removal of the sea-ice cover; whereas flooding only occurs under special conditions in which the ice is buffered from the atmosphere by snow cover. Flooding is significant, as it results in upward growth of meteoric ice, and a summer survival mechanism for Antarctic ice. Meteoric ice (possibly better referred to as snow ice) comprises a significant component of the mass of Southern Ocean sea ice.

Antony Liu (Goddard Space Flight Center) reviewed "Sea Ice Motion from

Wavelet Analysis of Satellite Data." Liu began with a presentation of the mathematics of the approach he used. The technique involves a 2D gaussian wavelet—the Mexican hat wavelet.

He described an analysis of SSM/I, SMMR, and NSCAT images merged with buoy data. He then illustrated the international arctic buoy program and showed a good match between buoy drift speeds and NSCAT and SSM/I wind speeds and angles. He noted that ice-motion streamlines tended to match atmospheric pressure fields. He was able to discern a reversal of the ice motion that occurred in just four days.

Liu concluded his presentation with the statement that he has shown that it is possible to merge sea-ice motion data from NSCAT, SSM/I, and buoys, but that there is still a problem to do this tracking in the summer melt season.

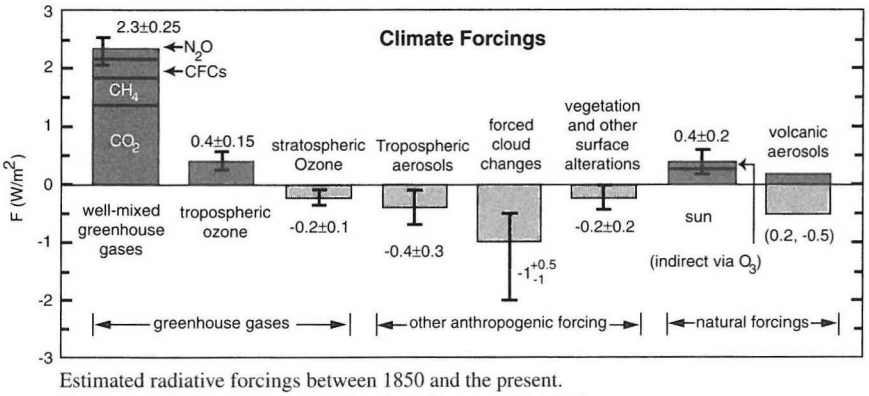
Wednesday October 21

Morning Plenary Session (Climate Change and Public Policy). **John Melack** (University of California Santa Barbara) chaired this final session.

Jim Hansen (Goddard Institute for Space Studies) led off with a review of "Climate Forcings and Climate Change: Relevance of Global Observations to Kyoto Protocol." The Kyoto protocol attempts to minimize greenhouse gas emissions, but there are two problems: 1) the opponents assert the likelihood of significant economic damage from constraints on greenhouse emissions; and 2) the proponents think that scientific understanding is so good that no more research is needed!

Hansen said that we need better understanding in order to adopt the most cost-effective policies. He referred to a *Science* paper (August 21, 1998) on energy resources. He noted that it now looks as if global production of oil and gas will peak during the next few decades, raising the issue of what sources of energy should be developed to follow oil and gas.

He went on to review the estimated climate forcings for the roughly 100 years between 1850 and the present (see the figure). He divided up the types of forcing into three classes: greenhouse gases, other anthropogenic forcings, and natural forcings. Well-mixed greenhouse gases were the largest source of positive greenhouse forcings, and aerosols and related "forced cloud changes" led to the greatest negative forcing. The imputed tropospheric aerosol cooling is quite uncertain. Three types of aerosols were included in the calculation: sulfates, organics, and soil dust. The much larger uncertainty in forced cloud changes is due to the indirect effect of aerosols on clouds. A microphysics model was used to determine this. The net forcing due to all the factors considered in the figure is + 1 W m^{-2}.



Estimated radiative forcings between 1850 and the present.
Hansen, J., M. Sato, A. Lacis, R. Ruedy, I. Tegan and E. Matthews. Climate forcing in the industrial era. *Proc. Nat. Acad. Sci.*, **95**, 12753-12758, 1998

Hansen said that the rate of increase of greenhouse gas forcing has been decreasing over the last 20 years. Apparently, the CO_2 sink has been increasing for the last 20 years along with the increases in emissions.

The present growth rate of the greenhouse climate forcing is only half of that in the most common IPCC scenarios, mainly because of reduced growth of methane, chlorofluorocarbons, and carbon dioxide. A key issue is to understand better the sources and sinks for methane and carbon dioxide so that we can estimate future climate forcings and the effectiveness of different policy options.

Frank Wentz (Remote Sensing Systems) reported on an analysis of "Decadal Time Series for Tropospheric Climate State Variables." He reviewed the recent findings of tropospheric cooling that have been reported, based on the Microwave Sounding Unit (MSU), and said that when an orbit-decay correction was made, the reported cooling became warming. The debate has to do with the global climate record for the period 1979 to 1995. The accepted surface thermometer value has shown warming of +0.15 K/decade, whereas the MSU results were -0.05 K/decade. In the same period the accepted tropical SST trend was +0.10 K/decade whereas MSU results were -0.11 K/decade. After applying the orbit-decay correction, the MSU trend becomes +0.07 K/decade, in better agreement with the surface data. Another comparison for the period 1987 to 1997 showed warming for both SST as measured by AVHRR and water vapor as measured by

SSM/I. Wentz explained some of the differences between MSU determinations and ground-based as due to the channel 2 weighting functions of the MSU sensor. The MSU weighting function peaks in the mid-troposphere. It is important to realize that the shape of the function is dependent on scan angle. The cooling that is computed is an artifact of the procedure that is used to get the near-surface temperature by taking into account T_{nadir} and T_{limb}. The orbital decay affects the value of T_{limb}. When appropriate corrections are made, MSU gives reasonable temperature profiles.

Wentz compared MSU, AVHRR, and SSM/I results and concluded that we must look at data from many different approaches based on the work of many different groups. It is important to have better-calibrated radiometers with better-known responses to instrument temperatures. We need plenty of overlap between successive space platforms, and they should have fixed ascending nodes. There should be a focus on measuring climate with low-cost systems that will be good for establishing the long-term record.

Wentz feels that NPOESS requirements are getting too complex for long-term sustainability of the mission.

Mark Abbott (Oregon State University) discussed "The Oceans and Climate Change: Impacts and Feedbacks." He said that the oceans play a critical role in Earth's climate. There are links between the large time- and space-scale patterns of ocean circulation and very small-scale responses in the ocean ecosystem. Broecker has assumed that nitrogen is the key variable in limiting net primary productivity in the ocean. John Martin sees not nitrogen but iron abundance as the limiting factor for ocean productivity. He is quoted as saying "give me enough iron and I can create an ice age."

Abbott described the relation between the microbiological loop and iron. Low iron favors small phytoplankton, and they are grazed by very small grazers, leading to rapid and efficient recycling of iron and nitrogen. This is the *baseline* ecosystem for much of the world ocean. There is a tight balance between grazers and phytoplankton. The grazers keep nutrients in the upper layer.

Abbott then discussed "non-equilibrium strategies" and asked what would happen if we added iron in the Southern Ocean. Landry has said that adding iron to the ocean would change the types of phytoplankton that were present. Pulses of iron favor diatom blooms (large species). Small forms don't grow. Non-equilibrium communities dominate ocean fluxes, thus supporting many fisheries.

Abbott showed the weekly position of the Antarctic polar front. He said that drifters in a polar front meander indicate the patterns of iron increase and decrease. He showed observations of intense spring blooms of chlorophyll obtained from moorings located around Antarctica. Strong blooms are associated with topography and iron present in the meanders. The appearance of fluorescence is an indication that the phytop!ankton are not using nutrients efficiently.

Reviewing the record for the Central North Pacific, Abbott commented that this is the locale of one of the largest, most ancient ecosystems. ENSO events led to more-stable stratification and more phosphorous-limited communities. Changes in variability are being observed in the northern Pacific. The paleologic record could provide evidence for a strong drawdown of atmospheric carbon dioxide, but the record is incomplete and contradictory. More ENSO events could mean more shifts in oceanic regime, but the number of possible oceanic states is limited.

In summary, Abbott said that a long time series of consistent observations is critical—both satellite and *in situ* observations are needed. Better models of mesoscale phenomena are needed. Present ecosystem models are too limited, and multiple "species" and multiple nutrients must be included in the models. Physiological processes such as nitrogen and iron fixation need to be parameterized. Response to environmental transients must be included in the models.

Ken Hawker (MITRE Corporation), as final speaker, addressed "The Roles of Uncertainty and Error in the Functioning of the Kyoto Protocol." Hawker called attention to the polarization that stands between the public's policy views and the Kyoto implications. He raised questions such as: What about inadvertent errors in achieving compliance? Can we stick to mean values?

He said that the treaty is a "greenhouse gas" treaty intended to control the rate of use of certain stocks. (The treaty sets a target of cutting emissions worldwide by an average of 5.2 percent from 1990 levels, between 2008 and 2012. The U.S. target, as a developed nation, is 7 percent, but the U.S. Congress is not likely put this into law.) There are direct economic stakes in emissions trades. The treaty fails to define what is meant by "emission reduction units." "Transparency" is the key feature of the treaty—each nation has to report what it's doing.

There are complexities in the treaty that must be dealt with. The use of a "market basket" of gases requires the use of Global Warming Potentials (GWPs). The basic

equation used for oil, gas, coal, deforestation, rice farming (methane production) is: Resource Use × Emissions Factor × GWP = Equivalent CO_2 emissions.

Net emissions must account for tropical deforestation. The treaty is not a self-contained instrument. The protocol incorporates the 1996 IPCC methodologies, e.g., the IPCC prescribes the method to be used to calculate methane emissions from rice paddies.

Nations are responsible for treaty-defined quantities. Every nation could be in compliance, and still the overall objectives of the treaty would not be achieved.

Hawker commented on errors and uncertainties. We don't know the absolute errors in national fossil fuel consumption estimates, not even for the Organization for Economic Cooperation and Development (OECD) countries. There are great differences between the UN and the International Energy Agency compilations of emissions. The greatest uncertainties lie in the estimates of land use change forestry (LUCF).

The estimated uncertainty for fossil fuel emissions is still too large: two different current estimates differ by 12 percent for the 48 largest emitting countries, 26 percent for the medium emitters, and 60 percent for the smallest emitters. Combining uncertainties leads to a total uncertainty in CO_2 of 10 percent, this despite the fact that the global goal is a reduction of five percent! There is also uncertainty resulting from the permissible trading of CO_2 emissions between countries.

The contrast between the Kyoto treaty and the Montreal protocol is that the latter *forbids* things. This is easier to enforce than setting limits that must be adhered to.

(Continued on Pg. 43)

CD-ROM Version Of An Interdisciplinary Climatology For Global Change Climate Studies Is Now Available

http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/FTP_SITE/inter_disc.html

This climatology study consists of over 70 physically different, multiyear, monthly-mean global climate parameters, which summarize 25 data sets dealing with land, ocean, cryosphere, biosphere, atmosphere, and solar sciences. This collection was compiled to facilitate both basic research and teaching on the subject of interannual climate variability and global change. Twelve of the data sets are over ten years in length, and four of these cover more than 100 years. The data are formatted to facilitate the comparison of the different data sets, and User's Guides accompany each data set. The collection was started in 1995 by the Goddard Distributed Active Archive Center (GDAAC) at the Goddard Space Flight Center. It has since grown considerably and is available free by electronic transfer (anonymous ftp). The CD-ROM version was produced in collaboration with the Center for Earth Observing and Space Research (CEOSR), Institute for Computational Sciences and Informatics (CSI), George Mason University.

The CD-ROM version has a number of interesting features. It was written using modified ISO 9660 standards, which permit file names longer than eight characters. In addition to the data and documentation available on the ftp site, it also contains the Grid Analysis and Display System, GrADS (copyright 1988-1996 by Brian Doty), and three climate scenarios on global warming, monsoons, and El Niño. Compiled read programs, which can output the data in ASCII format, are available for a number of computer platforms, including Macintosh and PCs. The CD is designed to be handled by a Web browser and the included documents contain links to additional data and information sources on the Internet. Text versions of the documents are also available. Additional information may be obtained from James McManus, mcmanus@daac.gsfc.nasa.gov, phone (301-614-5262). The free CD may be ordered by Internet (URL above), by e-mail , phone, or fax:

E-mail: daacuso@daac.gsfc.nasa.gov
Phone: (voice) 301-614-5224, or 1-800-257-6151
Fax: 301-614-5268

NASA Earth Science Enterprise Education Program Update

1999 NASA EARTH SYSTEM SCIENCE FELLOWSHIP PROGRAM Proposals Due March 15, 1999

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

NASA announces 1999 graduate student training fellowships for persons pursuing Master of Science (M.Sc.) or Doctoral (Ph.D.) degrees in Earth System Science. The purpose is to ensure continued training of interdisciplinary scientists to support the study of the Earth as a system. These fellowships will be available for the 1999/2000 academic year. Over 400 Ph.D. and M.Sc. fellowships have been awarded since the inception of the program in 1990.

Applications will be considered for research in atmospheric chemistry and physics, ocean biology and physics, ecosystem dynamics, hydrology, cryospheric processes, geology, geophysics, and information science and engineering, provided that the specific research topic is relevant to NASA's Earth remote sensing science, process studies, modeling, and analysis in support of the U.S. Global Change Research Program (USGCRP). NASA discourages submission of paleoclimate-related applications to this program.

Additional information about the Earth Science Enterprise (ESE) and the Earth Observing System (EOS) scientific priorities can be obtained from the ESE Strategic Plan, http://www.earth.nasa.gov/, and EOS science publications http://eospso.gsfc.nasa. gov/eos_homepage/scipubs.html.

Awards are made initially for one year and may be renewed annually, no more than two additional years for a total of three years, based on satisfactory progress as reflected in academic performance and evaluations by the faculty advisor. Three years is the maximum support a student may receive in pursuing M.Sc. and/or Ph.D. degree(s). The amount of award is $22,000/annum, which may be used to defray student's stipend, living and educational expenses, travel expenses to scientific conferences, tuition, and fees.

Students admitted to or already enrolled in a full-time M.Sc. and/or Ph.D. program at accredited U.S. universities are eligible to apply. United States citizens and resident aliens will be given preference, although the program is not restricted to them. Students with disabilities and from underrepresented minority groups are urged to apply. No applicant shall be denied consideration or appointment as a NASA Earth System Science Fellow on grounds of race, creed, color, national origin, age, or sex.

For more information, see http://www.earth.nasa.gov/education/ess99/index.html.

Global Change Education Resources Under Development

The Institute for Global Environmental Strategies (IGES) is leading an effort for NASA and the U.S. Global Change Research Program to develop a series of educational resources to promote the teaching of climate change. This effort involves three main tasks:

1. the identification of existing climate-change-related education resources;
2. the development of ten, in-depth articles discussing the potential impacts of climate change by region (based on the national assessment); and
3. the development of K-12 learning activities that will enable educators to introduce the topic of climate change into classrooms by examining the impacts on specific sectors such as agriculture, forestry, coastal issues, human health, and water resources.

The list of existing climate-change-related education resources has been developed and the regional articles are progressing through a rigorous review and editorial process.

The development of K-12 learning activities is just beginning and will include the participation of several leading science education experts. For more information, please contact Nancy Colleton, IGES, at ncolleton@aol.com.

NASA-Sponsored Series Premieres In April On PBS — Free Educational Materials Available

Premiering Tuesday, April 6, 1999, at 10:00 p.m. ET, JOURNEY TO PLANET EARTH explores the fragile relationship between people and the world they inhabit. Produced by Emmy Award-winning

filmmakers, Marilyn and Hal Weiner, and presented on PBS by South Carolina ETV, this three-part series examines the intense pressures being placed upon the world's rivers, farmlands, and mega cities.

"Rivers of Destiny" kicks off the series with a close look at four of the world's great waterways, the Mississippi, Amazon, Jordan, and Mekong. Audiences will meet the people whose lives and livelihoods are intertwined with these rivers.

"Land of Plenty, Land of Want," airing Tuesday, April 13, at 10:00 p.m., examines the social, economic, and political factors that determine how farmers and communities around the world can work the land and grow food for their rapidly increasing populations without destroying their natural resources.

"The Urban Explosion," airing Tuesday, April 20, at 10:00 p.m., brings the first season of programs to a conclusion with a look at the scientific, historic, and economic dilemmas of the mega cities. "The Urban Explosion" takes a close look at the history, growth, and future of four major cities, New York City, Mexico City, Istanbul, and Shanghai.

JOURNEY TO PLANET EARTH is made possible by funding from NASA, the Rockefeller Foundation, the Kellogg Foundation, the Arthur Vining Davis Foundation, the American Honda Foundation, and the U.S. Department of Agriculture.

For further information, contact: Michele Reap, South Carolina ETV Outreach, (803) 737-3394; e-mail: <mreap@scetv.org>

NSIP Includes New Earth Science Competitions

The NASA Student Involvement Program (NSIP) is a national program of investigations and design challenges for students in grades 3-12. NSIP links students directly with NASA's diverse and exciting missions of research exploration and discovery. Two new Earth science competitions have been developed for this year's program:

Watching Earth Change, with categories for grades 5-8 and 9-12 — Students will use images of Earth (from satellites, astronaut photos, or aerial photography) to identify and illustrate ways that the Earth changes.

Earth Systems in My Neighborhood for grades 3-4 — Students will select, observe, and describe a local study site, focusing on how the parts (land, water, air, and life) are connected.

The other two competition categories are **Design a Mission to Mars, and Aeronautics and Space Science Journalism**— students select any topic of interest, including the Earth system.

The entry deadline for this year is February 23, 1999. Submissions will be judged at NASA Centers; winners will be notified by April 20, 1999.

The NSIP program and materials are developed in collaboration with NASA by TERC's Center for Earth and Space Science Education, Institute for Global Environmental Strategies, and WT Chen & Company, Inc. For more information about NSIP see the project website at http://www.nsip.net.

Worlds Of The Pacific Exhibit

The exhibit "Worlds of the Pacific," which is on display at the California Science Center, continues to be a great success. The exhibit consists of elements from NASA TOPEX-funded projects at Oregon State University, Oregon Museum of Science and Industry, and Colorado Center for Space Research, along with NASA JPL's Earth Sciences Flight Projects, Earth Science Flight Instruments, and SeaWinds. It is expected that over 1.5 million visitors will see this exhibit.

Resources On The Web

Investigation of Sulfur Chemistry in the Antarctic Troposphere (ISCAT)
http://www.acd.ucar.edu/spole.

Students from around the world join in the excitement of a six-week field study at the South Pole's new Clean Air Facility.

El Niño Poster
http://podaac.jpl.nasa.gov/newedu.html

A new El Niño poster as viewed by TOPEX/Poseidon is available at this site.

Ocean World
http://oceanworld.tamu.edu/

Developed by Texas A&M through support from the NASA/JPL TOPEX/Poseidon Education Project.

Global Viewer
http://farside.gsfc.nasa.gov/ISTO/dro/global/page1.html

This site uses data from existing satellites to create a multi-layered representation of Earth in near real time.

NASA, Central American Nations Sign Earth Sciences Pact

— David E. Steitz (dsteitz@mail.hq.nasa.gov), NASA Headquarters, Washington, DC

NASA and the Central American Commission on the Environment and Development (CCAD) will use existing satellite data to develop land-use maps of Central America.

NASA Administrator Daniel S. Goldin and the President of the Central American Commission on the Environment and Development, and Minister of Environment and Natural Resources of El Salvador, Miguel Eduardo Araujo Padilla, signed a Memorandum of Understanding (MOU), establishing cooperation between the CCAD and NASA in support of the Mesoamerican Biological Corridor.

Under the terms of the agreement, NASA Centers as well as NASA-funded investigators and Central American researchers will use satellite data to develop maps classifying the land cover of the Central American isthmus according to life zones, land-use types, geological structure, hydrology, and other Earth Science factors. NASA also will support the development of the CCAD's environmental data and information system by making available optical, radar, and topographic remote-sensing data to the CCAD. The agreement will initiate a new partnership between NASA and the countries of Central America and will demonstrate the utility of NASA Earth science data and information for both biodiversity conservation and sustainable-development planning.

The membership of the CCAD consists of the Governments of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, which have all agreed to work together within the CCAD framework to promote the sustainable development of the entire Central American region. In 1997 the Presidents of the seven Central American countries endorsed the concept of a Mesoamerican Biological Corridor, running throughout the Central American isthmus with the goal of integrating conservation and the sustainable use of the region's biodiversity into a framework for long-term economic development.

NASA's Marshall Space Flight Center, Huntsville, AL, and Jet Propulsion Laboratory, Pasadena, CA, will participate in the implementation of the agreement in support of NASA's Earth Science Enterprise, Washington, DC.

Goddard Scientist Receives Nordberg Award For His Contribution To Understanding Polar Ozone Depletion

Dr. Mark R. Schoeberl, NASA Goddard Space Flight Center, is the 1998 recipient of the William Nordberg Memorial Award for his Earth science research. Schoeberl is the fifth recipient since the Goddard honor was first introduced in 1994, and is recognized for his development of a powerful new analysis method that allows the estimation of stratospheric ozone loss using a limited amounts of data.

Nordberg, who was the Director of Space Applications at Goddard, was a pioneer in using remote sensing to investigate Earth and its environment. The William Nordberg Memorial Award for Earth Science is presented annually to a Goddard employee who best exhibits qualities of broad scientific perspective, enthusiastic programmatic and technical leadership on the national and international levels, wide recognition by peers, and substantial research accomplishments in understanding Earth System processes.

Schoeberl is a fellow of the American Geophysical Union, American Association for the Advancement of Science, and the American Meteorological Society. He is the current President of the Atmospheric Sciences Section of the American Geophysical Union and the EOS Chemistry Project Scientist and Project Scientist for Goddard's highly successful Upper Atmosphere Research Satellite.

The Earth Observer and the EOS community wish to congratulate Dr. Schoeberl on this outstanding achievement.

SAFARI 2000: a Southern African Fire/ Atmosphere Regional Science Initiative

— *Bob Swap (rjs8g@virginia.edu), University of Virginia, USA*
— *Jeff Privette (jeff.privette@gsfc.nasa.gov), NASA/Goddard Space Flight Center*
— *Michael King (king@climate.gsfc.nasa.gov), NASA/Goddard Space Flight Center*
— *David Starr (starr@climate.gsfc.nasa.gov), NASA/Goddard Space Flight Center*
— *Tim Suttles (tim.suttles@gsfc.nasa.gov), Raytheon ITSS Corporation*
— *Harold Annegarn (annegarn@global.co.za), University of the Witwatersrand, RSA*
— *Mary Scholes (mary@gecko.biol.wits.ac.za), University of the Witwatersrand, RSA*
— *Chris Justice (justice@kratmos.gsfc.nasa.gov), University of Virginia*

Overview

The Southern African Fire-Atmosphere Research Science Initiative 2000 (SAFARI 2000) is an interdisciplinary science activity designed to increase our understanding of the southern African ecological and climate system as a whole, as well as its relationship to hemispheric and global climate. The project involves a confederation of national, regional, and global environmental research activities. NASA, through its EOS, Land Cover and Land Use Change, and Terrestrial Ecology Programs, is supporting several efforts that will contribute to SAFARI 2000. These include an extensive validation component associated with the launch of the EOS AM-1, and Landsat 7 platforms in 1999-2000.

SAFARI 2000 will address the key linkages between the physical, chemical, and biological processes, including human impacts, essential to the functioning of the regional biogeophysical system. More specifically, it will help characterize and quantify the biogenic, pyrogenic, and anthropogenic aerosol and trace gas sources and sinks; validate the understanding of these processes using atmospheric transport and chemistry models, ground-based, airborne, and satellite-based observations; and determine the climatic, hydrological, and ecosystem consequences of these biogeochemical processes.

Interest in the southern African region by the EOS validation community stems from two basic reasons: 1) unique and compelling scientific processes highly relevant to understanding climate and global change and 2) ongoing scientific investigations funded by southern African, European, and U.S. sponsors. The latter create the opportunity for leveraging off existing investigations, thereby providing maximum scientific return on limited resources.

The Region

The boundaries of the study region are defined by the atmospheric environment and the geography of Africa south of the Equator. These permit a reasonably discrete study region, which in turn permits mass-balance calculations to be performed. The semi-closed atmospheric circulation, shown in Figure 1, provides both a context and integrating mechanism between the biological and physical systems. This is especially the case during austral winter when anticyclonic circulation and associated clear sky conditions favorable for satellite and airborne remote sensing, dominate the region on as many as four out of every five days.

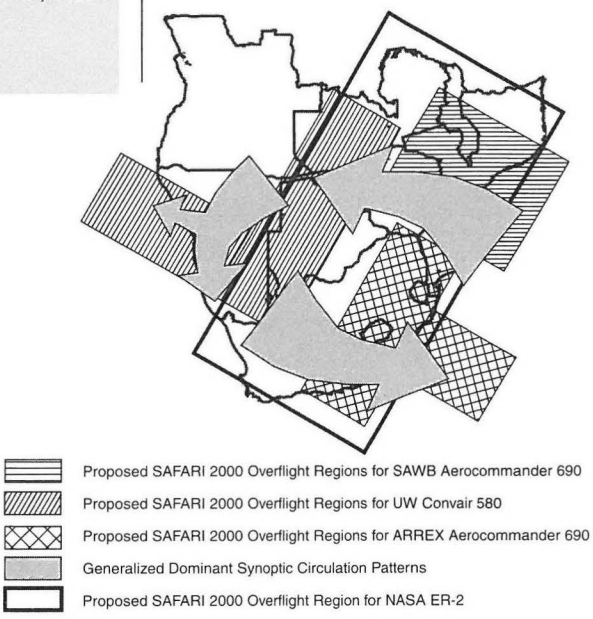


Figure 1. Southern African Recirculation Patterns and Potential Airborne Sampling Areas.

Marked biogeophysical gradients in vegetation type and structure, rainfall, and biogeochemistry characterize much of the study region. These gradients occur over spatial extents of thousands of kilometers both meridionally, as in the case of the Kalahari sands, and zonally, as is the case of the Miombo woodlands. The latter, which represent the largest tropical dry forest system in the world, occupies approximately 2.8 million km^2 in Africa. Both rainfall, which varies annually across the region from <100 mm to >1200 mm, and fire occurrence and frequency demonstrate a strongly seasonal, generally

temporally consistent, spatial progression across the study region. The wet season extends from November through May. Fire frequency peaks in August/September, coincident with the peak of the dry season (Figure 2).

Background

Southern Africa is a highly sensitive region due to its increasing population and population migration, rain-fed subsistence agriculture, limited water and food availability, and relatively low industrial development. However, recent political and social stability has led to more rapid though sporadic economic and industrial development. Energy generation to support mining and metallurgical industries, as well as the industries themselves, has contributed to high levels of aerosol and trace gas emissions. Additionally, the region is subject to some of the most extensive biomass burning in the world, most of which is associated with human population pressures on regional ecosystems. These anthropogenic forces, along with a strong source of biogenic emissions and a large natural variability in both regional climate and ecosystem processes, combine to effect changes in the biogeochemical cycling of the region. Moreover, these forces serve as strong catalysts for large-scale changes in land cover and use.

These threats to the regional ecology and climate have led the Intergovernmental Panel on Climate Change (IPCC) and the International Geosphere-Biosphere Program (IGBP) to designate southern Africa as a focus for scientific assessment. Specifically, the IGBP and START (SysTem for Analysis, Research, and Training) have facilitated collaborative research efforts through their Kalahari, Miombo, and Subsistence Rangelands programs. Other national and international agencies such as the NOAA Climate Prediction Forum and Regional Applications Program have likewise targeted the region.

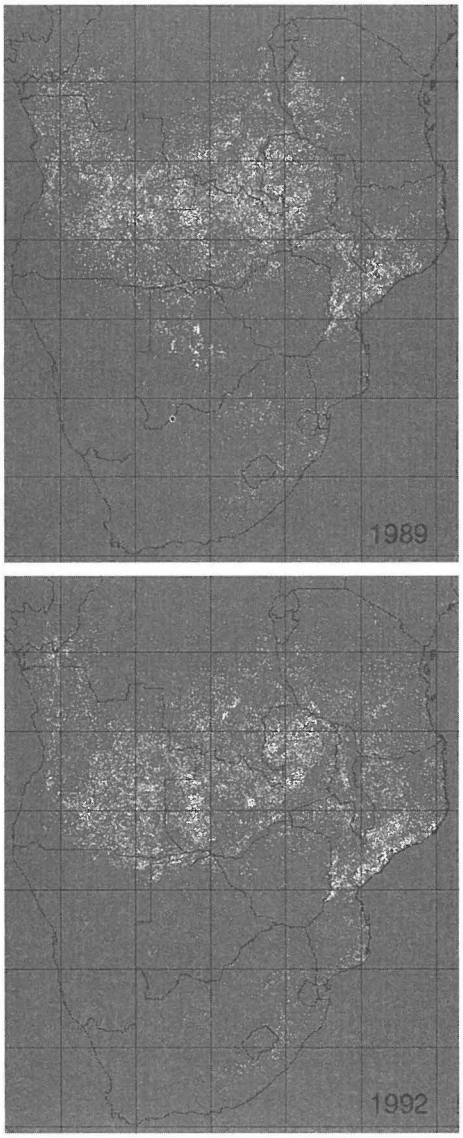


Figure 2. Southern African Biomass Burning during August/September, 1992 with SAFARI 2000 core sites indicated.

The international science community has mounted a concerted response. The Southern African Fire-Atmosphere Research Initiative 1992 (SAFARI 92) was organized under the IGAC (International Global Atmospheric Chemistry) Biomass Burning in the Global Environment (BIBEX) program. The activity involved more than 150 scientists from 14 countries and focused on biomass burning and its atmospheric effects in the Southern Hemisphere. It particularly addressed factors controlling the process and distribution of subtropical savanna fires as well as the chemistry, transport and source strength of their products. The successful program contributed substantially to our current understanding of these processes, although SAFARI 92 revealed little on their consequences.

The Southern African Atmosphere Research Initiative 1994 (SAFARI 94), a joint South African-German flying campaign, followed SAFARI 92 and focused on the *in situ* chemical sampling of aerosols and trace gases across the region during the non-biomass burning season.

These initiatives, together with others addressing independent ecological and climate issues, have contributed much to our understanding of discipline-specific objectives. However, linkages between the controlling and impacted processes were given less attention. In particular, past scientific accomplishments have led to the formulation of questions that require more synthetic, integrated and interdisciplinary research. It is on this foundation that SAFARI 2000 is being developed.

The initial motivation for SAFARI 2000 evolved from several IGBP/START regional workshops that identified the global-change science priorities for the region. This led to a series of stakeholder workshops held in the summer of 1998. At a National Science Foundation (NSF)-sponsored workshop on Southern African Land-Atmosphere-Biosphere Interactions, held at Blydepoort, South Africa in July, 1998, more than 70 participants from 12 countries met to begin shaping the core elements of SAFARI 2000. Specific

questions about aerosols and trace gases were developed with the following progression in mind: sources; transformations; patterns; responses; and interactive processes.

Presently, a number of precursor activities set the stage for SAFARI 2000. These include: ARREX (South Africa's Aerosol Recirculation and Rainfall Experiment); INDOEX (Indian Ocean Experiment); AERONET (NASA's Aerosol Robotic Network); SHADOZ (NASA's Southern Hemisphere ADditional OZonesondes Project) and IDAF (IGAC DEBITS (Deposition of Biogeochemically Important Trace Species) Africa project). The IGBP LUCC/START Miombo Network is helping coordinate efforts that concern the miombo woodlands in the northern half of the study region. The NASA Land-Cover/Land-Use Change and Ecology programs have a number of studies currently underway in southern and central Africa.

SAFARI 2000

SAFARI 2000 will be conducted over a three-year period starting in the second half of 1999, with major field campaigns during 1999 and 2000. It will focus on the following science components: terrestrial ecosystems and biogeochemical transformations, land-cover and land-use change, fire disturbance, pyrogenic, biogenic and industrial emissions and their transport, aerosol and cloud characterization and interactions both over land and oceans, and atmospheric chemistry and deposition.

Multiple tools will be used to achieve the Initiative's goals. The existing scientific database and regional infrastructure will be exploited, and be augmented by new *in situ* and remote measurements and comprehensive modeling efforts. In situ measurements will be largely clustered around core field sites that are representative of major regional land-cover variants, have a scientific heritage, and are subject to long-term preservation. Field sites near Mongu, Zambia, and Skukuza, South Africa, will anchor the ground network. These two sites are currently part of NASA's Global Land Cover Test Sites, EOS Land Validation Core Sites, and AERONET programs. A walk-up tower at each site will allow above-canopy access to investigators (Figure 3). Several other scientific towers in the region will also be employed.

Both periodic and large episodic aircraft campaigns will complement the ground measurements. The SAFARI Core sites will be overflown periodically by light aircraft hosting a small set of remote sensing instruments. More intensive aircraft measurements will occur during Intensive Field Campaigns (IFC) scheduled for August/September 1999, and February 2000, and August/September 2000. The strategy is to integrate a comprehensive wet season assessment with dry season assessments. At least two aircraft featuring extensive aerosol, trace gas, and ground observation sensors will be used during these periods. In addition, the NASA ER-2 will carry a range of simulation sensors, including MAS, AirMISR, CLS, SSFR, S-HIS, and MOPITT-A during the IFC in August/September of 2000. A full suite of satellite land and atmosphere products from the AM, Landsat 7, SeaWiFS, NOAA/AVHRR, and other satellites will be employed.

The various data sets derived from this array will help provide the initialization and validation sets required for various modeling activities. The research will incorporate models of ecosystem processes such as biophysical energy and water exchanges with the atmosphere, biogeochemical cycling, and plant demographics, as well as mesoscale atmospheric models. The observations and modeling will extend across spatial scales from plot to landscape and region scales and across time scales from hours to weeks to years.

Based on lessons learned from previous campaigns, data integration and archiving are actively being planned. A fully open data distribution policy is envisioned, with incentives for rapid data reduction and turnaround. Information from SAFARI 2000 activities will be disseminated regionally and internationally via the Internet as well as through the distribution of CD-ROMs. A mirror World Wide Web site with SAFARI-only data will likely be set up in the region. These efforts will help scientists achieve the goal of results synthesis by 2001.

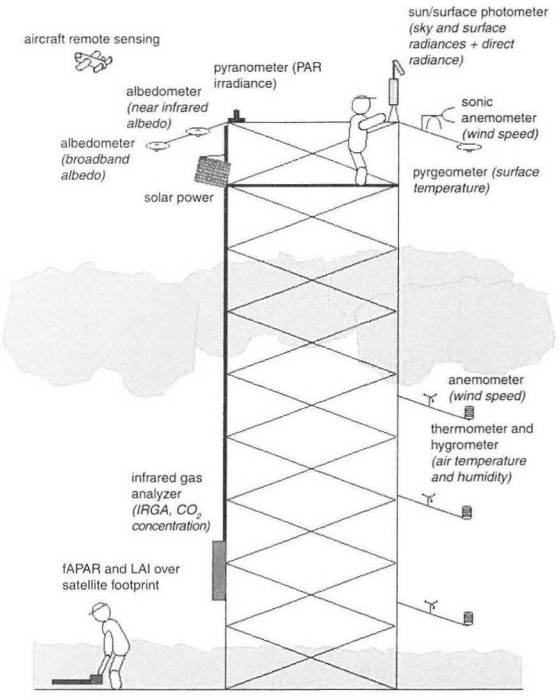


Figure 3. Schematic of EOS validation tower set up that will be deployed at Mongu, Zambia, and Kruger National Park, South Africa.

SAFARI 2000 provides northern and southern hemisphere researchers opportunities for capacity recognition as well as the transfer of technology and expertise from North to South and perhaps, more importantly, from South to North. An important component of the SAFARI 2000 objectives is model and satellite product evaluation by local experts, as well as the promotion of informed use of these models and data by regional scientists.

Earth Observing System Synthesis

The ambitious goals of SAFARI 2000 will be achieved with the help of the comprehensive data sets expected from the new generation of EOS sensors. High-spatial-resolution sensors such as ASTER on AM-1 and ETM+ on Landsat 7 will detect fine-scale land-cover change and use, and facilitate the scaling of point and short-transect measurements over much larger areas. Likewise, MODIS, SeaWiFS, and AVHRR will be used for full regional views and retrospective analysis. Particularly encouraging is the anticipated ability of MODIS to more accurately detect thin cirrus clouds, fire temperature, areal extent, and thermal energy, and detect surface features through the occasionally pervasive smoke layers. The highly variable aerosol forcing problem will largely be attacked with the accurate aerosol and 3-D cloud products expected from MISR. This sensor may also help resolve savanna and woodland variability through its bidirectional sampling capabilities. Finally, MOPITT will help resolve large-scale source, sink, and transport questions associated with carbon monoxide and methane emissions.
In return, a significant contribution to EOS validation will be made by SAFARI 2000. In addition to planned regional activities by members of the MODIS, MISR, ASTER, and MOPITT instrument teams, three AM-1 validation investigations are funded in the region. These three activities include: Southern African Validation of EOS (SAVE): Coordinated Augmentation of Existing Networks, J. L. Privette (PI); Vertical Profiles of Carbon Monoxide and Other Gases in the Troposphere, P. C. Novelli (PI); Biomass Burning and Emission of Trace Gases and Aerosols: Validation of EOS Biomass Burning Products, W. M. Hao/D. E. Ward (PIs). The AERONET program will capture aerosol information with a relatively dense deployment of sunphotometers. Together, these groups will coordinate ground and air measurements around the Core Sites to validate both atmospheric and surface satellite products. When possible, investigators will leverage their analyses on independently gathered data sets. Standing acquisition requests have been negotiated with the respective instrument teams for products at each of the Core Sites. An extensive set of airborne *in situ* measurements will be made over the various surface sites and coordinated with the EOS satellite overpasses. In addition to the NASA ER-2, the U.S. will support the University of Washington CV-580 for *in situ* measurements of clouds, aerosols, trace gases, and radiation. This large range of measurements combines to make SAFARI 2000 the largest coordinated validation activity planned for AM-1.

The Next Steps

SAFARI was chosen as a rallying acronym for the Initiative, centered on the millennium, and with a heritage of international collaboration within the region. It is envisaged that through open participation in SAFARI 2000, new *in situ* data collection combined with advances in the modeling of the biogeophysical systems and improvements in satellite monitoring, will lead to an improved understanding of regional and global environmental change in southern Africa.

Government and scientific agencies from the U.S., Europe and Southern Africa have been briefed on the plans for SAFARI 2000. The SAFARI 2000 Science Plan is under development and should be ready for open distribution in early 1999. The outline of the Science Plan, developed at the Blydepoort planning meeting, received preliminary endorsement at the BIBEX Meeting held in Seattle, Washington, USA, in August, 1998, and will be presented to the IGAC steering committee in late spring of 1999.

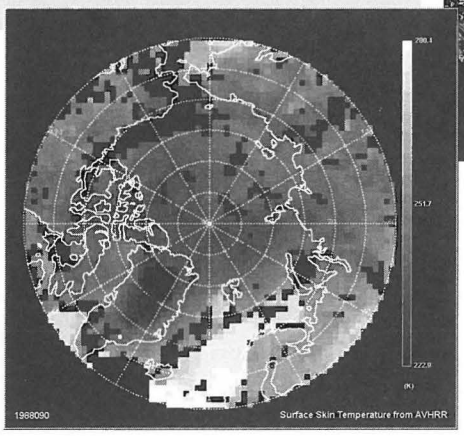
The anticipated schedule of SAFARI 2000 milestone events is as follows:

February 1999: Science Plan distribution
July 1999: Second SAFARI 2000 workshop in Gaborone, Botswana—completion of the Implementation Plan of SAFARI 2000
August/September 1999: First Intensive Flying /Ground Campaign (dry season)
February/March 2000: Second Intensive Flying /Ground Campaign (wet season)
April 2000: Third SAFARI 2000 workshop, location TBD
August/September 2000: Third Intensive Flying/Ground Campaign (dry season)

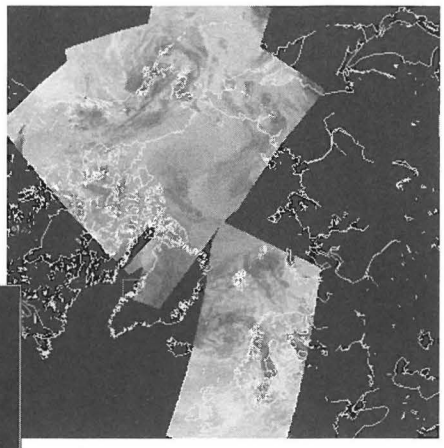
The SAFARI 2000 initiative is open to international participation. Although no explicit core funding is available to U.S. investigators, various funding programs have expressed interest in entertaining SAFARI 2000 proposals submitted through normal funding channels. For further information on SAFARI 2000, please contact the authors and/or visit the SAFARI 2000 World Wide Web page - http://safari.gecp.virginia.edu

New Polar Pathfinder Sampler Addresses Data Inter-use Concept

— *R. Hauser (avarani@kryos.colorado.edu), University of Colorado, Boulder, CO*



An image of the precipitable water between the Earth's surface and 850 mb is derived from the TOVS sensor for the P-Cube data set. The highest values, indicated by lighter grey shades, can be identified over the open water regions. Lower values are seen over the Arctic's central ice pack. No data are available over the higher elevations of Greenland but low amounts of precipitable water are observed over land. A good example of this occurs over north central Russia.



Surface temperatures poleward of 60 degreees N are provided by the P-Cube data set for day 90 (March 30) 1988. These temperatures were derived from the AVHRR sensor at a spatial resolution of 100 km. Higher temperatures, indicated by lighter shades of grey, predominate over the open ocean areas of the North Atlantic and Barents Sea, as well as in the Davis Strait between southern Greenland and Canada and over portions of the Bering Sea in the North Pacific. The coldest temperatures are seen over Greenland and the central Arctic ice pack.

While the science world eagerly awaits NASA's Earth Observing satellite launches, the EOSDIS Distributed Active Archive Centers (DAACs) have been hard at work to ensure availability of high-quality heritage data that enhance the anticipated EOS data streams. For instance, in 1990 when NASA and NOAA teamed to create the Pathfinder Program to generate long time series from existing satellite data sets, it was decided to make Pathfinder data available through the DAACs because, along the way to providing data relevant to global-change research, the Pathfinder investigators were to provide prototype methods for processing and handling large data sets.

The Pathfinder process underscored technical difficulties impeding interdisciplinary data use. Integrating data from different sensors for study is typically awkward because data come in different formats. Reconciling information from multiple sensors can require considerable preparation before data become useful for research purposes. With data inter-use in mind, the Pathfinder program encouraged teams to take a comprehensive approach.

In January 1999, members of three Polar Pathfinder Projects and the National Snow and Ice Data Center (NSIDC) DAAC will bring a groundbreaking example of this idea to fruition. To maximize Polar Pathfinder utility and address the needs of the cryospheric research community, the Special Sensor Microwave/Imager (SSM/I), Advanced Very High Resolution Radiometer (AVHRR), and TIROS-N Operational Vertical Sounder (TOVS) Pathfinder teams coordinated processing activities to create a Polar Pathfinder Sampler that provides a means of studying Arctic ocean, land, ice, and atmosphere interactions at one time.

The Polar Pathfinder data have synchronized file formats and naming conventions, and all data have been projected to the NSIDC Equal-Area Scalable Earth-Grid (EASE-Grid). The fundamental concept of the EASE-Grid is that it provides a basis for a standard, flexible system for working with remote sensing data, independent of the satellite sensor or data type.

The new Polar Pathfinder CD-ROM contains both samples of daily composites of 100-km merged Pathfinder data sets and full-resolution samples of each Polar Pathfinder product. The Sampler features selected animations for previewing large-scale atmospheric and surface-condition changes. In addition, the CD-ROM provides a merged data set from three Pathfinder projects within a low-resolution, multidimensional structure known as the "P-Cube". Containing 16 atmospheric

and surface variables, the P-Cube provides data for a range of polar climate research applications, but will be of special interest to investigators dealing with large-scale atmospheric changes, surface heat and mass balance studies, and sea ice modeling.

"P-Cube is a superset of variables from the three sensors," says Drew Rothrock, principal investigator of the NASA EOS interdisciplinary research project, Polar Exchange at the Sea Surface (POLES). "Data can now be compared between instruments and with *in situ* data. These P-Cube data will be used initially for validation of existing data until they have passed review by the polar science community. Their greatest strength, though, is in providing the beginning of a climatology of interrelated polar variables."

"It's essential to understand the relationships between individual variables," Rothrock says. "For instance, understanding how albedo changes with surface temperature over sea ice becomes trivial using this data set because the information is in a form conducive to climatological analyses."

Numerical models of the planet's general circulation indicate that polar regions are anything but insignificant climatologically. Climate-change projections show polar regions warming faster than lower latitudes. The long-term record indicates that glacial areas have evolved quite differently than tropical climates.

Polar regions respond quickly to changes in climate conditions. Leads, channels of open water within sea ice, and the open ocean at the fluctuating ice margin, respond to incoming solar energy, inducing moisture fluxes that lead to cloud formation and precipitation which ultimately feed back into global atmospheric and oceanic circulation. Earth's ice and snow shape daily weather and human activities around the world. The extent and volume of snow and ice change radically season-to-season and over hundreds of thousands of years, effecting substantial changes in the planet's albedo, weather patterns, water resources, and sea level. But in spite of its climatological significance, "very little data on the three-dimensional state of the Arctic exist — by that I mean ice cover and the atmosphere above it," says Greg Flato, a research scientist at the Canadian Centre for Climate Modeling and Analysis. "It's hard to assess, for example, the way clouds behave, or the way clouds and radiation interact in the Arctic. These interactions may be quite different from the way they occur elsewhere."

The instruments selected to provide Polar Pathfinder data sets provide different and complementary information, Flato points out. "AVHRR provides surface-level imagery in visible and thermal-infrared wavelengths, providing quantitative information on sea ice types. AVHRR suffers because it can't see through clouds."

"The SSM/I provides lower resolution images but it can penetrate cloud cover and, therefore, provides information on sea ice concentration, large-scale surface temperatures and large-scale ice motion. The main purpose of TOVS is to supply information on the atmospheric column above the ice," he says.

"This a rich data set that's going to see a lot of use," he says. "The next step is to make the full data sets available allowing researchers to see how things are evolving over longer periods." NSIDC already distributes SSM/I Pathfinder data. The other Polar Pathfinder data sets are still in production with distribution slated for 1999.

"The primary goal of the Pathfinder Program was to turn out common data sets," Rothrock says. "The Polar Pathfinder Sampler demonstrates the usefulness of doing this with historical data. And, using data from more than one sensor means that a range of variables-cloud fraction, temperature, and albedo-are available over varying times," he says. "One of the most significant outcomes of this project is that people with experience with particular sensors are successfully working with researchers skilled in completely different sensors," Rothrock says. "It is a good multi-sensor data production model for EOS."

The Polar Pathfinder Sampler will be distributed (free) at the January meeting of the American Meteorological Society. To order a copy, please send your postal mailing address, phone, and e-mail address to:

NSIDC User Services
Attn: Polar Pathfinder Sampler
nsidc@kryos.colorado.edu
Campus Box 449
University of Colorado
Boulder, CO 80309-0449 USA
Fax: +1 303-492-2468

Status Report on the Data Processing Portion of EOSDIS

— Carl A. Reber (reber@skip.gsfc.nasa.gov), EOSDIS Project Scientist, NASA/Goddard Space Flight Center

There has been strong concern voiced since the October IWG meeting related to several aspects of the ESDIS Project approach to meeting the challenge of maximizing the benefits that can be achieved within the restricted resources anticipated over the next few years. Much of the concern is apparently based on an incomplete understanding of what has been proposed, including the amount of latitude anticipated in negotiations with instrument teams.

"Option A+," presented to the EOS Investigators Working Group (IWG), is the name given to the compromise solution negotiated between Goddard and the Office of Earth Science (Code Y at HQ) balancing the "Option A," which was within budgetary guidelines, and "Option C," which implemented all the EOSDIS goals and requirements but was unaffordable. The data processing and distribution allotment works out to a bit more than one third of the EOSDIS budget, with the remainder taken by flight operations activities, getting data to the ground and between ground sites, and DAAC operations. The budget concerns relate to the fiscal years from 1999 to 2003, with the next two years requiring immediate attention. ESDIS is now focusing on putting together a viable system that supports getting data to the users as soon as possible, without overly reducing functionality. Some planned hardware capacity has been reduced, but the system architecture provides for expansion; if resources become available in the future, hardware will be less expensive to augment than functionality. Nearly $30 million (out of $138 million total savings through FY '03) has been identified in capacity reductions, including lowering processing and distribution capability, and archiving Levels 1 and 2 data for only six months. The "six month rolling archive" has caused quite a bit of the concern mentioned above, along with the process of involving PI teams in data production activities.

We have been holding meetings (euphemistically called "1-on-1's) with individual instrument teams since early November to address these concerns and to explore the impact of the A+ option on the teams' operations. These generally involve representation from ESDIS, ECS, the instrument team, the appropriate DAAC(s), and the mission project scientist(s), and give us the opportunity to understand the instrument teams' data use so decisions can be tailored to their needs. For example, while the "rolling archive" was used across the board by ESDIS for costing purposes, the actual implementation is negotiable if a team can come up with other ways to save comparable money, or if the implementation is not viable. (The suggestion for the six-months limit was originally made because many folks thought that the prime interest in much of the data would be at Level 3.) Another major goal related to PI processing is for both sides to understand the other's assumptions used in preparing estimates for data processing, and to ensure that both the instrument teams and ESDIS are using the same assumptions and ground rules. The teams are shown detailed plans for purchasing equipment to meet their needs by year, as well as a detailed description of the hardware that is available today at each site for their use. At this point, it appears that none of the A+ reductions impact AM-1 instruments in the first year after a July launch. Several teams expressed a desire to see more detailed information on which to base their data processing proposal, and ESDIS has either given this to them, or is in the process of preparing it.

Based on these and other discussions, the status for the missions/ instruments is as follows:

- Landsat 7 has not been affected by the A+ budget option.

- ASTER has no Level 3 products; the Level 1 is processed in Japan, and most of Level 2 is produced on demand. Therefore, ESDIS plans to keep all the ASTER data. ASTER data will be processed and archived at the EDC DAAC.

- MISR has no defined Level 3 products as yet, and ESDIS plans to keep all MISR data. MISR data will be produced and archived at the Langley DAAC.

- MODIS has at least two versions of Level 1 data; one of these will be maintained. Level 2 is still under discussion. MODIS Level 1 data will be produced at the Goddard DAAC,

and the MODIS team will produce Levels 2 and above. The data will be made available through the Goddard, EDC, and NSIDC DAACs.

- The CERES Instrument Team will produce their data using the TRMM system at the Langley DAAC, and their data will be archived at the DAAC using ECS. We have not yet held a "1-on-1" with the CERES team.

- MOPITT plans to process outside of ECS for six-to-twelve months after launch, then migrate their processing into the ECS at the Langley DAAC. Their data will be available through the Langley DAAC under both modes.

- The AIRS team is studying the possibility of doing their own data processing and will be preparing a proposal. Archiving and distribution will be done via the GSFC DAAC.

- AMSR is preparing a proposal for doing their processing outside of ECS. Archiving and distribution will be done via the NSIDC DAAC

- The GLAS Instrument Team plans to process outside of ECS. Their data will be available through the NSDIC DAAC.

We plan to complete this round of "1-on-1's with the instrument teams for AM, PM, and CHEM early in the new year. The Data Panel, under the lead of Dave Emmitt, is contacting EOS IDS investigators to discuss the impacts of the A+ option from their perspective. Comments and thoughts from the DAAC user working groups are being solicited by Bruce Barkstrom through the offices of Lin Chambers of the Langley DAAC User Working Group.

EOS Scientists in the News

"The El Niño Factor," *Discover* (Jan.) by Carl Zimmer. Mark Cane (Columbia Univ.), Chet Ropelewski (NOAA/NWS), Tony Busalacchi (NASA GSFC), and Kevin Trenberth (NCAR) are working to isolate the factors that have the greatest impact on El Niño to better predict future events.

"Warming Reasons Elusive," *The Christian Science Monitor* (Dec. 14) by Robert C. Cowen. R. Steven Nerem (U. Texas-Austin) discusses how change in sea-level rise is a short-term result of El Niño based on the data from the TOPEX/Poseidon satellite.

"Satellites to Monitor Volcanoes," *San Francisco Chronicle* (Dec. 10) by David Perlman. Luke P. Flynn and Peter Mouginis-Mark (U. Hawaii) are using the infrared sensors on Geostationary Environmental Satellites (GOES) as thermometers to find "hot spots" on active volcanoes in North and South America. Flynn and Mouginis-Mark were also featured in *Discovery* Channel Online (Dec. 10), Reuters (Dec. 9), and *The London Times* (Dec. 8).

"Glacial Ice is Slip-sliding Away," *Christian Science Monitor* (Dec. 10) by Colin Woodward. Robert Bindschadler (NASA GSFC) and David Vaughan (British Antarctic Survey) monitor the melting of the West Antarctic Ice Sheet.

"Study Looks at Landscape Changes," *Associated Press* (Dec. 9) by Joseph B. Verrengia. Jonathan Foley (U. Wisconsin), Roger Pielke (Colorado State), and Elfatih Eltahir (MIT) are examining how landscape changes affect regional climate and how these changes have influenced climate shifts throughout history.

"Will Humans Overwhelm the Earth?," *New York Times* (Dec. 8) by Malcolm W. Browne. Compton Tucker (NASA GSFC) analyzes the images of Earth taken by Landsat to look at anthropogenic changes.

"Humans Not to Blame for Sahara," *Reuters* (Nov. 24). Compton Tucker (NASA GSFC) noticed, by observing satellite data, that drought conditions (not human activity) were to blame for the environmental change in the Sahara between 1980 and 1997.

"Satellite Limits," *Earth & Sky radio program* (Oct. 30). Claire Parkinson (NASA GSFC) explains how satellites receive data by measuring the amount of radiation the object gives off.

EOS researchers please send notices of recent media coverage in which you have been involved to:
Steve Cole
EOS Project Science Office, Code 900
Goddard Space Flight Center,
Greenbelt, MD 20771
Tel. (301) 441-4146; fax: (301) 441-2432

Global Validation of EOS LAI and FPAR Products

— *Jeff Privette (jeff.privette@gsfc.nasa.gov), NASA's Goddard Space Flight Center*
— *Ranga Myneni (rmyneni@crsa.bu.edu), Boston University*
— *Jeff Morisette (jmoriset@chaco.gsfc.nasa.gov), University of Maryland*
— *Chris Justice (justice@kratmos.gsfc.nasa.gov), University of Virginia*

On October 10-11, 1998, approximately 30 scientists met at Boston University to further plans for validating the EOS-AM LAI, FPAR, and NPP products. The group included members of the MODIS Land (MODLAND), Interdisciplinary Science (IDS), and AM-1 Validation teams, as well as community experts. The goal was to develop both a focused 1-year implementation plan as well as a longer term ramp-up strategy. Five key topics were discussed, including: 1) general needs and responsibilities, 2) ancillary *in situ* parameters, 3) validation sites, 4) scaling up field data, and 5) dissemination of validation data and information. Below is a brief background, followed by a summary of the presentations, discussions and conclusions of this meeting.

Background

Leaf area index (LAI) and the fraction of photosynthetic radiation absorbed by vegetation (FPAR) are important land characteristics used to parameterize and validate models of ecosystem functioning, surface-atmosphere transfer, agricultural yield, net primary production (NPP), and other environmental processes (Sellers and Schimel, 1993, Global and Planetary Change, 7:279-297). The international community has, therefore, deemed these parameters important for climate research (see GCOS and GTOS URLs in Table 3 for reference information), and endorse their operational long term monitoring (see GOFC URL in Table 3). Consequently, these parameters are a high priority for the EOS AM-1 platform. Upon AM launch, LAI and FPAR data will be produced, at relatively high temporal resolution (daily through yearly), through both the MODIS and MISR product chains independently. NPP will be produced by MODIS. Later, single LAI and FPAR products from the AM platform will be produced once the most beneficial approach for fusing the data streams becomes clear.

To date, end-users of satellite data have had to rely on unvalidated LAI and FPAR products. The EOS Project, however, is supporting validation through its instrument teams and validation investigators (see URL in Table 3). In addition to quantifying the accuracy of EOS algorithms, this will greatly benefit modelers by providing uncertainty estimates alongside the EOS products. As with the design of the products themselves, a close dialogue is now needed between the field data collectors, the EOS algorithm developers, and the end-user community to ensure that the validation data are collected and packaged appropriately for greatest effectiveness. A significant step in this direction occurred with the SWAMP Validation Workshop (December, 1997), which exposed critical issues for global LAI/FPAR/NPP validation (Justice et al., 1998, *The Earth Observer*, **10**(3):55-60). The present meeting used recommendations from the SWAMP meeting as a starting point.

LAI/FPAR Product Description and Field Data Network

Recent advances in the MODLAND LAI/FPAR algorithm, led by Ranga Myneni (see URL in Table 3), translate uncertainty in the input fields (e.g., land-cover class, surface bidirectional reflectance) into a probability distribution solution. This approach accounts for the likelihood of multiple solutions to the inverse problem given "perfect" input reflectances, then assumes additional estimation error resulting from true uncertainties in input reflectances. This approach both bounds the accuracy with which field validation data need be collected (and hence the collection method itself), and provides new measures for algorithm performance during validation.

At the meeting, Myneni proposed that two levels of validation occur: scale-independent validation of the stand-alone algorithm and scale-dependent validation of the LAI/FPAR product. This strategy allows confidence to develop in the algorithm using multiple fine-scale sample points at a single geographical test site, in addition to the more limited ability to validate the coarser-scale products at that site. Both point value and value distribution tests were proposed.

Responsibility for this validation will be shared between the MODIS and MISR instrument teams and the AM-1 Validation Investigators. However, for global validation, it is recognized that greater resources and coordination are required

than are currently recruited. Thus, MODLAND is applying significant effort to developing EOS-wide validation protocols and encouraging participation by community data collectors and product users. Meeting participants extensively discussed potential synergy with existing measurement networks, including FLUXNET and Long Term Ecological Research (LTER) sites (see URLs in Table 3). This synergy may involve both post-launch measurements and historical data sets.

A possible model for assimilating data from such varied sources was outlined by Leonard Brown of the Canadian Centre for Remote Sensing, who is helping coordinate a federated LAI collection network in Canada. Brown reported that although significant effort was required to coordinate and maintain the network, most researchers were willing to collect data as part of their perceived scientific obligations. Further, Brown suggested that the Canadian data, available for roughly 10 sites for 1-2 years, could be made available to the EOS Validation Program. MODLAND validation personnel will pursue this collaboration in the coming year.

Validation Sites

Global validation requires field data from a range of sites representing a logical subset of the Earth's land covers. Meeting participants agreed that the EOS Land Validation Core Sites should be emphasized for this purpose (see URL in Table 3). These sites are foci for EOS AM-1 and Landsat 7 land validation activities, and are high priority data acquisition and product generation targets. They are expected to facilitate both validation and early EOS science. The sites typically have a history of *in situ* and remote observations, and can expect long-term preservation. Centralized WWW-based archiving of ASTER, MISR, MODIS, and Landsat 7 ETM+ products in relatively easy-to-use formats are planned for these sites.

Because the Core Site network is in its infancy, meeting participants agreed that LAI and FPAR validation should be planned only at sites for which firm commitments to data collection have been secured. However, several participants volunteered to collect data at non-Core sites. These "collaborating" sites, together with the participating Core sites, are listed in Table 1. The list provides at least two representatives from each of the six vegetated biome types recognized by the MODLAND LAI algorithm. Participants agreed that initially at least seasonal (4 times/yr) *in situ* LAI/FPAR assessments were required for product validation.

Ancillary Measurements

Although product validation can be conducted with only LAI and FPAR field data, a prioritized list of ancillary measurements needed for algorithm valida-

Table 1. LAI/FPAR validation sites for Year 1 of EOS AM

Name	Country	Biome	EOS Core Site	Investigator
USDA BARC, MD	U.S.	broadleaf cropland	X	Liang
Bondville, IL	U.S.	broadleaf cropland	X	BigFoot
Gainesville, FL	U.S.	broadleaf cropland		Craig
Tapajos	Brazil	broadleaf forest	X	Asner
Hawaii	U.S.	broadleaf forest		Asner
Harvard Forest, MA	U.S.	broadleaf forest	X	BigFoot
Park Falls, WI	U.S.	broadleaf forest	X	Gower
Uardry	Australia	grassland	X	Hook
Osage, OK	U.S.	grassland		Walter-Shea
Konza, KS	U.S.	grassland	X	BigFoot
East Anglia	England	grassland	X	Barnsley
Vernon,TX	U.S.	grassland		Asner
BOREAS NSA	Canada	needleleaf forest	X	BigFoot
Cascades, OR	U.S.	needleleaf forest	X	Law
EMATREF	France	needleleaf forest		Roujean
Yaqui Valley	Mexico	shrubland		Asner
San Pedro Basin/SALSA, AZ	U.S.	shrubland	X	Qi
Skukuza	South Africa	shrubland/woodland	X	Privette
New Zealand Network	New Zealand	various		Brown
Canada LAI Network	Canada	various		Chen
Mongu	Zambia	woodland	X	Privette
Cerrado	Brazil	woodland		Asner

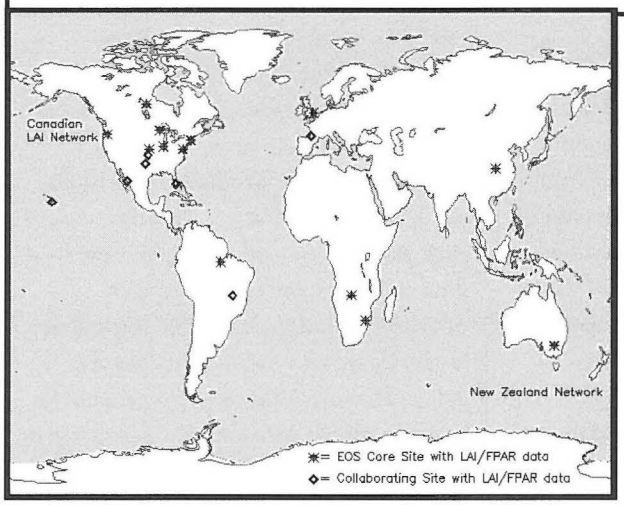


Fig. 1. EOS Land Validation Core Sites and collaborating sites being used for Year 1 LAI/FPAR product validation.

tion was developed under Myneni's lead. Myneni emphasized that not all listed variables are necessary for this task; however, any such measurements would be useful. The measurements are shown in Table 2 in order of decreasing importance.

Scaling

A consistent and troubling problem for land-product validation is the appropriate scaling of point field measurements to the coarse resolution of satellite products. Several presentations addressed this topic. Among the most encouraging was the newly formed BigFoot initiative (formerly MODLERS; see URL in Table 3). Warren Cohen and Dave Turner outlined BigFoot's plans to provide MODLAND validation data, as well as develop 5 km x 5 km gridded models (25-m and 1-km grids) around FLUXNET tower sites. BigFoot will initially focus efforts at four EOS Core Sites (BOREAS NSA, Harvard Forest, Bondville, and Konza). BigFoot will measure and scale up LAI, FPAR, NPP, and land-cover maps to appropriate resolutions for EOS validation. A combined program of field data collection, aircraft overflights and fine-resolution satellite image acquisitions will be used. BigFoot will also attempt to characterize and parameterize the relationship between the measured NEE values and the MODLAND NPP product. This pathfinding activity will test various scaling methodologies and work with MODLAND to develop a WWW site outlining a suggested strategy.

In addition, Alfredo Huete described a light-aircraft remote sensing package developed for MODLAND Quick Airborne Looks (MQUALS). The package includes three aligned digital cameras (red, blue, and near-infrared, 640x480 pixels), an albedometer, a 4-band calibrated radiometer, and a GPS receiver. All data are stored in near-real time on a laptop computer. Initial NDVI images from the prototype camera showed expected patterns. The package was designed to be shipped to local small-aircraft operators near validation sites for low-cost site and reflectance characterization. The complete MQUALS system is designed to provide validation assessments within seven days of data collection. MODLAND personnel agreed to develop and prototype a data collection plan around the initial LAI/FPAR validation sites. Particular emphasis will be placed on: 1) assessing radiometric qualities of the instruments, 2) overflying BigFoot sites in the early post-launch timeframe, and 3) developing appropriate flight strategies for fast and useful scaling.

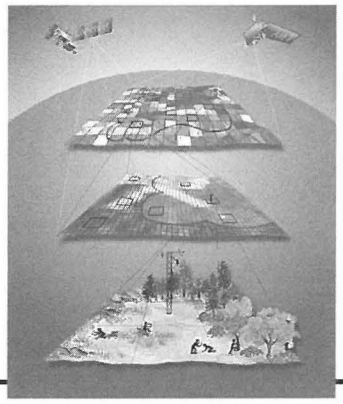


Fig. 2. Conceptual design for scaling in the BigFoot project. See URL in Table 3.

Table 2. Additional data useful for algorithm validation

Land Cover Variable or Characteristic
• canopy multispectral reflectance (nadir or bidirectional)
• leaf spectra (reflectance and transmittance)
• background nadir spectral reflectance (soil + litter)
• fraction of areal vegetation cover
• vegetation crown allometry (height, width, gap)
• phenology (green-up, mature, senescent stage)
• vegetation composition (either by species or structural type)
• wet or dry status
• fraction of non-photosynthesizing vegetation (at min. photosynthetic activity stage)
• meteorological data (minimum set)

Historical Data Mining

Because initial AM validation sites are relatively few, it was suggested that historical LAI/FPAR data (e.g., from FIFE, BOREAS) be analyzed and used to provide expected values and ranges for EOS product values. A number of extended data sources, such as the LTER network, were suggested. Possible roles for the EOS DAACs for archiving and distribution were also considered. Bill Emanuel and Jeff Privette agreed to bring this possible service to the attention of the Oak Ridge National Laboratory (ORNL) DAAC.

Protocols and Data Dissemination

Finally, data and communication protocols were discussed. In particular, the respective roles of the ORNL and EDC DAACs, the EOS instrument teams, and the validation investigators in the coordinated validation system are under development. Representatives of the ORNL User Working Group and the EDC Scientific Advisory Panel (SAP) at the meeting agreed to address roles and responsibilities with their respective DAAC personnel. Moreover, pathways for educating the product user community on how to interpret validation results have yet to be developed. Participants briefly discussed possibilities including peer-reviewed publications, product metadata codes, and rasterized uncertainties for gridded products. This topic, together with

timeliness issues, will be discussed in further communications. To further facilitate community access and involvement, the publication of a CD-ROM containing early Core Site validation data was also suggested.

EOS land-product validation is being planned as part of a long-term implementation plan. Initial validation efforts will both estimate product accuracy and prototype validation scheme components. It is hoped the components currently planned, upon successful post-launch evaluation, will be substantially extended to provide more rigorous and comprehensive product evaluation.

We anticipate that the validation procedures started by the EOS instrument teams and validation investigators will act as a catalyst for broader involvement by the research community in product evaluation. Clear protocols for data collection and WWW archiving and access will give all researchers a simple mechanism for participation. With the recent increase and planned launch of new moderate-resolution sensors (e.g., VEGETATION, MODIS AM/PM, GLI, NPP, NPOESS) by different space agencies and the increased availability of higher order standard products, the benefits of standard measurement protocols and validation-site data sharing are considerable. The Committee on Earth Observation Satellites(CEOS) Calibration/Validation Working Group is an obvious mechanism to expand the early developments and lessons learned in EOS land validation into a truly global validation initiative.

Table 3. WWW Site Addresses

Site	URL
BigFoot	www.fsl.orst.edu/spacers/bigfoot/plan.html
Committee for Earth Observation Satellites	ceos.esrin.esa.it
EOS Validation Program	eospso.gsfc.nasa.gov/validation/valpage.html
FLUXNET	daacl.ESD.ORNL.gov/FLUXNET
Global Climate Observing System	www.wmo.ch/web/gcos/gcoshome.html
Global Observations of Forest Cover	www.ccrs.nrcan.gc.ca/ccrs/tekrd/internet/gofc/gofce.html
Global Terrestrial Observing System	www.fao.org/gtos/Home.htm
Long Term Ecological Research	lternet.edu
EOS Land Validation Core Sites	modarch.gsfc.nasa.gov/MODIS/LAND/VAL/core_sites.html
MODLAND Validation	modarch.gsfc.nasa.gov/MODIS/LAND/VAL
Myneni's LAI/FPAR Site	cybele.bu.edu/research/modismisr/
ORNL DAAC Validation Site	www-eosdis.ornl.gov/eos_land_val/valid.html

Earth and Sky
Earth and Sky
Earth and Sky
Earth and Sky
Earth and Sky

These are the air dates for the last batch of 90-second radio features on NASA Earth Sciences. The programs are produced by the Earth & Sky (E&S) radio series for a measured audience of more than 3.8 million listeners (weekly).

SCHEDULED RADIO PROGRAMS

February 4	Ocean Color (featuring Dr. Chuck McClain)
February 5	Signs of Change (featuring Dr. Chuck McClain)
February 25	Ice Sheet (featuring Dr. Bob Bindschadler)
March 7	Bucket of Ozone (featuring Dr. Rich Stolarski)
March 25	The Stuff of Clouds (featuring Dr. Michael King)
March 26	Volcanoes and Climate (featuring Dr. Michael King)

In the Washington area, the programs can be heard on WETA at 8:15 am weekdays, 90.9 on the FM dial. Other stations carrying the program are listed on the E&S web site.

For more information, and advertised links to NASA sites as the programs are aired, please look to the E&S web site: http://www.earthsky.com

EOS Science Calendar

February 24 - 26
AIRS Science Team Meeting, Santa Barbara, CA. Contact: H. H. Aumann, tel. (818) 354-6865, e-mail: aumann@jpl.nasa.gov.

February 25-26
SAGE III Science Team Meeting, Tucson, Arizona. Contact: M.P. McCormick, tel. (757) 728-6867, e-mail: mcc@cs.hamptonu.edu or W.P. Chu, tel. (757) 864-2675, e-mail: w.p.chu@larc.nasa.gov.

March 16-18
AMSR Science Team Meeting, Florence, Italy. Contact: Elena Lobl, tel. (205) 922-5788, e-mail: elena.lobl@msfc.nasa.gov.

April 12-14
EOS-Chem Science Team Meeting, Pasadena, CA. Contact: Ernest Hilsenrath, tel. (301) 286-6051, e-mail: hilsen@ssbuv.gsfc.nasa.gov.

April 12-14
GLAS Science Team Meeting, Madison, WI. Contact: Bob Schutz, tel. (512) 471-4267, e-mail: schutz@csr.utexas.edu.

April 27-29
CERES Science Team Meeting, NASA Langley. Contact: Joella Hanlon, e-mail: J.P.HANLON@LaRC.NASA.GOV.

June 15-17
EOS Investigators Working Group Meeting, Manor Vail Lodge, Vail, CO. Contact Mary Floyd, tel. (301) 345-3211, e-mail: mfloyd@westover-gb.com.

Global Change Calendar

February 8-11
AVIRIS Earth Science and Applications Workshop, Jet Propulsion Laboratory. Contact Robert Green, e-mail: org@gomez.jpl.nasa.gov. or URL: http://makalu.jpl.nasa.gov.

March 1-3
Thirteenth International Conference and Workshops on Applied Geologic Remote Sensing, Vancouver. Contact Marilyn Dehring, tel. (734) 994-1200, ext. 3350, e-mail: dehring@erim-int.com.

March 23-26
Progress in Electromagnetics Research Symposium (PIERS 1999), Taipei International Convention Center, Taipei, Taiwan. 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. or contact Ms. Mei Yuan Lai, tel. (886) 3-425-7232; fax: (886) 3-425-5535, e-mail: maylai@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.

May 17-21
American Society for Photogrammetry & Remote Sensing (ASPRS), Portland, OR. Contact: 5410 Grosvenor Lane, Suite 210, Bethesda, MD 20814-2160, tel. (201) 493-0290; e-mail: meetings@asprs.org; URL: http://www.asprs-portand99.com

June 28-July 2
1999 Coherent Laser Radar Conference, Mt. Hood, Oregon. Contact Michael Kavaya, e-mail: Michael.Kavaya@msfc.nasa.gov, URL: http://space.hsv.usra.edu/tenth_biennial_coherent_laser.html.

June 28-July 2
IGARSS, Hamburg, Germany. Contact Tammy Stein, e-mail: stein@phoenix.net, URL: http://www.igarss.org.

July 18-30
The 22nd General Assembly of International Union of Geodesy and Geophysics, University of Birmingham, UK. Contact: IUGG99, Beacon House, Long Acre, Birmingham B7 5JJ, UK. tel. +44 (0)121 322 2722; Fax: +44 (0)121 322 2240, URL: http://www.bham.ac.uk/IUGG99/.

August 2-6
18th Congress of the International Commission for Optics, San Francisco, CA. Contact ICO XVIII Conference Manager, SPIE, 1000-20th Street, P.O. Box 10, Bellingham, WA 98225, tel. (1) 360 676 3290; Fax: (1) 360 647 1445; e-mail: ico18@spie.org.

September 8-10
Non-CO_2 Greenhouse Gases (NCGG-12) Scientific understanding, control and implementation, Noordwijkerhout, The Netherlands. Call for Papers. Contact Joop van Ham, e-mail j.vanham@plant.nl, FAX: +31-15-261 3186.

Sept. 13-15
IEEE International Workshop on Multimedia Signal Processing, Copenhagen. Contact Jenq-Neng Hwang, e-mail: hwang@ee.washington.edu; URL: http://eivind.imm.dtu.dk/mmsp99/

September 13-17
Sixth Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC), Bologna, Italy. Call for papers. URL: http://www.fisbat.bo.cnr.it/IGAC99/.

(Continued from Pg. 27)

Minutes Of The Fourteenth Earth Science Enterprise/ Earth Observing System (ESE/EOS) Investigators Working Group Meeting

Hawker suggested that EOS could help reduce uncertainties by showing compliance if it obtained regional granularity.

At the end of Hawker's presentation Steve Schwartz noted a concern, based on experience in the case of demonstrating reductions of sulfur emissions to comply with acid deposition limitations, that some nations presented artificially high emissions in the years that had been used to determine the base emissions from which reductions would be calculated; by having thus inflated their emissions, they readily achieved apparent reductions without reducing a thing. He said that such a concern should be noted in the case of carbon reductions as well.

The fourteenth meeting of the EOS IWG adjourned at 11:30 on October 21, 1998.

Code 900
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Official Business
Penalty For Private Use, $300.00

Bulk Rate Mail
Postage and Fees Paid
National Aeronautics and
Space Administration
Permit G27

The Earth Observer

The Earth Observer is published by the EOS Project Science Office, Code 900, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5559, FAX (301) 614-5620, and is available on the World Wide Web at http://eospso.gsfc.nasa.gov/ or by writing to the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the Global Change meeting calendar should contain location, person to contact, telephone number, and e-mail address. To subscribe to *The Earth Observer*, or to change your mailing address, please call (301) 614-5561, or write to the address above.

The Earth Observer Staff:

Executive Editor:	Charlotte Griner (charlotte.griner@gsfc.nasa.gov)
Technical Editors:	Bill Bandeen (bill.bandeen@gsfc.nasa.gov)
	Renny Greenstone (renny.greenstone@gsfc.nasa.gov)
Design and Production:	Winnie Humberson (winnie.humberson@gsfc.nasa.gov)
Distribution:	Hannelore Parrish (hannelore.parrish@gsfc.nasa.gov)

Printed on Recycled Paper