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Michael King
EOS Senior Project Scientist

In the past month, the *1999 EOS Reference Handbook* was completed and is now being printed. The purpose of this *Reference Handbook* is to provide a broad overview of the Earth Observing System (EOS) program to both the science community and others interested in NASA's Earth Science Enterprise (ESE). This edition includes a brief history of EOS from its inception, science objectives, mission elements, planned launch schedules, descriptions of each instrument and interdisciplinary science investigation, background information on team members and investigators, international and interagency cooperative efforts, and information on the EOS Data and Information System (EOSDIS). A number of figures and tables are included to enhance the reader's understanding of the EOS and ESE programs. It is available electronically from http://eospso.gsfc.nasa.gov/ eos_homepage/misc_html/ refbook.html, and will be available in hard copy by September 30. Copies may be obtained by sending e-mail to Lee McGrier at lmcgrier@pop900.gsfc.nasa.gov.

The EOS Project Science Office has completed an Educational CD-ROM entitled *Welcome to NASA's Earth Science Enterprise*, which provides educators, students, and the general public with an overview of the latest research related to our global environment, while providing the necessary background material to comprehend these studies. The CD-ROM is divided into four main sections: Land, Sea, Ice, and Air. In addition, there are overviews of EOS spacecraft and instruments, remote sensing, a description of what EOS will measure (the EOS 24 measurements), and a description of why and how we will study the Earth. Accompanying this CD-ROM is an *Activity Supplement* (Teacher's Guide) which, together with the CD-ROM, enables students and teachers to further their comprehension of seven topics highlighted on the CD-ROM, including ozone, clouds, volcanoes, El Niño, sea level, sea ice, and deforestation. Copies of the CD-ROM and accompanying Activity Supplement can be obtained by sending e-mail to Lee McGrier at lmcgrier@pop900.gsfc.nasa.gov.

The SeaWinds scatterometer began global observing mode from the QuikScat satellite on July 15. Initial calibration analyses have resulted in global back-

scatter accuracies of ~0.3 dB and ocean vector wind accuracies of <2 m s^{-1} in wind speed and <20° in wind direction with respect to operational global surface wind analyses. SeaWinds maps winds over ~93% of the ice-free oceans daily. Following intensive, detailed validation by the science team, it is expected that SeaWinds global backscatter and ocean vector wind measurements will be available to the operational and research communities in November 1999, with a fully reprocessed data set available in January 2000 through PODAAC at http://podaac.jpl.nasa.gov. NOAA has the responsibility for distributing near real-time data to operational weather prediction centers.

The SeaWinds global backscatter measurements allow all-weather, moderate resolution monitoring of land and ice-covered regions as well. As one example, SeaWinds data have already been used to monitor iceberg B10A in the southern ocean near Antarctica. The iceberg is the size of Rhode Island and broke off from the Thwaites Ice Tongue in Antarctica in 1992. Iceberg B10A measures 38 by 77 km, and has also been imaged by the Enhanced Thematic Mapper Plus (ETM+) on Landsat 7 (http://landsat7.usgs.gov/browse/iceberg.html). On September 7 the U.S. Geological Survey announced the availability of Landsat 7 ETM+ data to the general public. Full scenes that have been corrected for sensor effects and spacecraft geometry (Level One processing) are available from the EROS Data Center in Sioux Falls, South Dakota(http://edcwww.cr.usgs.gov/landdaac/landsat7), at a price not to exceed $600 each.

The AIRS/AMSU-A/HSB, AMSR-E, SAGE III, ACRIM III, SIM, Jason-1, and Data Assimilation science teams are currently preparing Algorithm Theoretical Basis Documents (ATBDs) that will be reviewed by the international scientific community. These teams are expected to deliver their ATBDs to the Project Science Office by December 15. Following these written evaluations, an oral portion of this review will be conducted in February. These documents, developed for each data product, consist of a detailed physical and mathematical description of the algorithm, variance or uncertainty estimates, and practical considerations, such as calibration and validation, exception handling, quality assessments and diagnostics.

These documents will be posted on the World Wide Web following revisions that result from the written reviews as well as panel report recommendations. All of these missions, (with the exception of SIM, recently selected as part of the SORCE mission, and Jason-1, a joint mission between NASA and CNES), have previously developed ATBDs and have had them reviewed and posted on the EOS Project Science Office Web site at http://eospso.gsfc.nasa.gov/atbd/pg1. html.

In the process of updating the *EOS Reference Handbook*, the Earth science mission profile was redesigned so that it now has a new look (see http://eospso.gsfc. nasa.gov/eos_homepage/missions.html). All of the Earth science missions have been reorganized by launch date in chronological order, with the actual date of launch for missions already in orbit. All missions contain descriptions of the spacecraft name, launch date, altitude, orbital inclination, and equator crossing time (for sun-synchronous orbits), as well as the instrument complement onboard the spacecraft. Spacecraft and/or instruments not provided by NASA are clearly indicated on the chart. This is quite common, as our program is international in scope with many valuable international partners.

Landsat 7 Team Receives The American Institute Of Aeronautics Space System Award

— Lynn Chandler (Lynn.Chandler.1@gsfc.nasa.gov), Goddard Space Flight Center

The Landsat Project Government-Industry Team has been selected to receive the American Institute of Aeronautics Space Systems Award for 1999. The award will be presented on Tuesday, Sept. 28 at the AIAA Space Technology Conference and Exposition in Albuquerque, N.M.

The award recognizes outstanding achievements in the architecture, analysis, design and implementation of space systems. Receiving the award will be team leaders from Goddard Space Flight Center (Greenbelt, Md.), Lockheed Martin Missiles and Space, SBRS/Raytheon Systems Company and the US Geological Survey. Goddard managed development of the Landsat 7 project.

The Landsat 7 team received the award for outstanding teamwork and accomplishments in developing the latest and most advanced satellite in the Landsat series of Earth remote sensing spacecraft. "Landsat 7 truly was an outstanding team effort and we are very honored to receive this award," said Phil Sabelhaus, Landsat 7 Project Manager at Goddard.

Landsat 7 is the latest in a series that began in 1972. These data will provide scientists with new information on deforestation, receding glaciers, and crop monitoring. The data also will be available commercially for land-use planning and urban development issues. Landsat 7 is part of the Earth Observing System, the major component of NASA's Earth Science Enterprise, a long-term program that is studying changes in Earth's global environment. The goal of the Earth Science Enterprise is to provide people a better understanding of natural changes. Enterprise data are essential to people making informed decisions about their environment.

Status of NASA's Earth Science Enterprise: A presentation by Dr. Ghassem Asrar, Associate Administrator for Earth Science, NASA Heaquarters

I am pleased to be able to address the Earth Science community at Goddard during our most exciting and productive year yet. I'd like to take this opportunity to lay out the big picture of the Earth Science Enterprise, and enlist your continued support to achieve our goals. Let me start by updating you on recent events, which include some good news and some, well, other news.

So far this year we are three for three in successfully launching satellite missions. The February launch of SUNSAT and Oersted, Dutch/South African Earth remote-sensing satellites, adds two of a five-star constellation of GPS receivers in orbit. Landsat 7 continues to perform beautifully, and NASA and USGS hope to declare it operational in a matter of days. The first images from QuikScat data are now available, and they look very good.

We continue to have difficulties with getting rides to orbit. Our next mission, the Shuttle Radar Topography Mission, will be delayed about a month to fix a wiring problem on the Shuttle orbiter, and we hope not to run afoul of other time-critical missions in the Shuttle queue. Terra, our EOS flagship mission has, along with GOES, been delayed by problems with the RL-10 engine on the launch vehicle. We are hopeful of an October launch if the RL-10 certification is accomplished in the next week or so. Langley's SAGE III instrument, slated for ride on a Russian spacecraft and launch vehicle, is being delayed while Russia studies adding another instrument. TOMS has fallen off the Russian table, but Goddard is stepping up to define a QuikTOMS mission as a free-flyer, much as we did for the QuikScat mission, and still plan to launch in 2000. This will be another validation of Goddard's resilience and ability to fulfill Enterprise commitments. So, where we started 1999 with a plan for 10 launches, we will probably end with 6 or 7, with the others sliding to early 2000. But that's the space business!

You have probably heard that the Congress, in deliberating on the FY 2000 budget, is considering a $305-million reduction for Earth Science at NASA. The problem stems from the future budget caps that were agreed to as part of the 1997 budget agreement. NASA is not alone in this dilemma; all the agencies in the discretionary spending "pot" face similar challenges. The tack the Congress has taken is to preserve the missions in development and allocate the cuts against future missions. In reality, such a cut will hurt both the present and the future. It cancels the ESSP program and cuts algorithm and EOSDIS funding to the point where we will not be able to realize the full return on our investment in data collection. But this is by no means a foregone conclusion yet. September often brings cooler weather and "cooler" heads.

So, we've had some successes and some setbacks this year. But if it wasn't hard, it likely wouldn't be worth doing, and the Earth Science Enterprise is absolutely worth doing.

Outside our community, every audience Mr. Goldin or I speak to is genuinely excited to hear how NASA is using space technology to study our own planet, and how the results of our research are addressing issues they care about. Inside our Earth Science community, we are making the transition from a data-poor research effort to a data-rich one. Our crude pictures of ocean winds and rainfall, of atmospheric aerosols and tropospheric chemistry, of ice-sheet topography, and of land cover and biomass are about to become detailed, dynamic panoramas.

Let me now lay out for you a portrait of the Earth Science Enterprise along content and time dimensions. Along the ***content*** dimension, the Enterprise comprises four major elements. The most fundamental, of course, is *Research*. Our research and analysis activities, including model development and mission science teams, are the intellectual capital of the Enterprise. We are committed to peer-reviewed, cutting-edge research to identify and answer key questions about the Earth system. Chief among these are:

- Ecosystems & Global Carbon Cycle – How do changes in terrestrial and marine ecosystems affect primary productivity and the global carbon budget?
- Global Water & Energy Cycle – In what way are atmospheric and hydrological processes that produce severe weather, cause floods, and

control water resources related to climate changes?
- Climate Variability & Change – Are the changes we observe in the Earth climate associated with mechanisms we can understand, model, and predict?
- Atmospheric Chemistry – Is stratospheric ozone recovering as a result of the Montreal Protocol? Can long-distance transport cause significant global tropospheric pollution?
- Solid Earth & Natural Hazards – Can we understand the dynamics of the Earth interior, and use this knowledge to prepare for natural hazards such as volcanoes and earthquakes?

We are working to increase the portion of investment in Research to 25% of the Enterprise budget.

The second element is *Applications, Commercialization, and Education*. It is no longer possible to justify the Earth Science Enterprise on the basis of science alone. We must demonstrate the value of our research in the economy and in the broader society. This requires us to work with commercial firms, local governments, and others to translate science data into practical solutions. We are moving to achieve a 10% level of investment in this area.

The third element is *Mission Implementation and Operations*, in which we fund our satellite and information systems development. As we have developed the first series of EOS missions, this has consumed about 65% of the Enterprise budget. By applying the Administrator's better, faster, cheaper principles, we plan to reduce this to about 55%.

The key to doing so is *Advanced Technology*, which is the fourth element. We have a three-pronged investment strategy for technology—instruments, platforms, and information systems. The New Millennium and Instrument Incubator programs are perhaps the most visible parts of this effort today. Our advanced technology program leverages off several others, including the Space Science core-technology program. We plan a 10% level of investment in technology, which will yield as much as a 50% reduction in per-mission costs for future missions.

Let me now take you along the ***time*** dimension. In the near-term, from now through 2002, we are launching the EOS first series. Our priority is to safely and successfully launch 22 instruments and spacecraft during that time period. Some of these are multi-instrument satellites like Terra and PM-1; others are single instruments provided for launch on foreign platforms, like SAGE III and SeaWinds. Our second priority is to implement a data and information system that is capable of operating these missions and receiving, processing, archiving, and distributing their data. As we do so, we will be laboring to demonstrate the broad scientific and applications value of the data from this first series of missions.

For the mid-term, from 2003-2010, we have begun to define a set of national mission concepts of three types. One is a set of systematic measurements that will carry on those EOS measurements that are required to build a data set useful for global-change studies. Many of these are planned for transition to the NPOESS, and the missions now being considered will bridge the EOS and NPOESS eras.

A second set are exploratory missions similar to the Earth System Science Pathfinders that are already underway. These missions will explore Earth system processes that are not well understood and, as such, employ innovative technical approaches.

The third set are prototype operational missions that satisfy requirements of other agencies, and are co-sponsored by them.

We have also just released an Announcement of Opportunity for small University Earth System Science (UNESS) missions to help train the next generation of Earth scientists and engineers.

For the long-term, beyond 2010, our intent is that NPOESS and related operational systems will assume the responsibility for long-term climate observations. Meanwhile, NASA will move on to conceive a new generation of remote-sensing tools which will enable the environmental prediction systems of the future.

Much of the work of envisioning this future is being done right here at Goddard. Beyond the first decade of the next century, we plan to take full advantage of scientific discoveries and technological innovations that will enable national and international proactive environmental prediction systems. Here are a couple of examples:

The current suite of operational weather satellites allows a 5-day forecast of regional weather. Over the next 20 years, we would like to push that out to 14 days. The benefits to such industries as agriculture and construction, not to mention vacation planning, would be enormous. What is required to achieve a 14-day forecast capability?

First, we need improved observations. The most important new scientific observation required is tropospheric winds measured with an accuracy in the range of 1-3 m/s, with a resolution of 1 km vertically and 100 km horizontally. That leads to a new technology requirement: tunable lidar systems. We are just approaching the beginning phases of work

with space-based lidars. This is part of a broader push to expand from passive to active remote-sensing capabilities.

Another example is soil-moisture measurement. Accurate regional measurements of soil moisture would be a great boon for agriculture, and also aid in assessing flood-damage potential. We plan to fly an aircraft instrument to demonstrate one approach to this in 2001.

One shortcoming present in all LEO–based observing systems is revisit time. Landsat, for example, has a 16-day revisit time. To address the problem of revisit time for these and other measurements, we want to move toward constellations of smart spacecraft, and to the use of orbits beyond LEO and GEO, such as L1 and L2, to achieve continuous views of the Earth. Such systems might be:

- Low and mid-level Earth orbit-based sensor webs and reconfigurable satellite constellations.
- GEO-based large-aperture imagers and sounders, and event monitors
- L1 and L2 Earth and Space weather outposts

With these, we need on-orbit advanced information systems with high-bandwidth communication to produce direct-to-the-user data products.

Second, we need fundamental research.
I described our science themes and questions earlier.

Third, we need modeling and data analysis capabilities.
A 14-day prediction capability also leads to new requirements for computing power for modeling and visualization. This includes capabilities for high-volume distribution and storage as well as processing speed.

The key to turning all these new data into useful information products is data visualization; transforming data into running 3-D images representative of real processes such as storm development or El Niño evolution or aerosol transport.

Currently, visualizations are limited to sites with limited time on advanced supercomputing capabilities. Data volumes are such that visualization products cannot be easily shared electronically. But with advances in computing power and research targeted on visualization techniques, we can make progress toward an era where visualizations can be World Wide Web-based and user driven. One outcome of this will be that non-scientists will be able to gain an immediate appreciation of the power and scale of Earth-system processes, because they will be able to view them as they would an animation.

Summary:

As we move into the next decade, we will be reaping the science and applications rewards of the last ten years of planning the Earth Observing System. We are already doing so for the pre-EOS missions launched since 1991.

But this is only the beginning. Our understanding of the Earth System is growing rapidly, as is our technological capability to make new observations and turn them into useful information products.

The next 20 years will be an exciting time for Earth Science, and will witness the evolution of a global environmental monitoring capability that will enable regional- and local-scale decision-making for a whole host of economic and societal endeavors.

But in order to have these opportunities in the future, we need to deliver on our promises in the present. This means successfully launching the missions we now have in development. It means realizing the full scientific return from our investment in those missions. And it means working with people and organizations outside the research community to translate our scientific knowledge into solutions to practical problems in the economy and the broader society.

And that is going to require all of us to work together toward these goals. While many nations are involved in Earth Science, the U.S. is the only nation, and NASA is the only Agency, with the breadth of expertise to establish the vision and framework for Earth System Science. And Goddard Space Flight Center is the largest portion of this capability.

It is my hope, and my expectation, that the civil service and contractor science and engineering community here will embrace this vision as its own and work to see it fulfilled. We must rise to the challenge of making good on our current promises to deliver quality data sets to the climate-change science community and demonstrate practical applications of these data. If we are successful, we will build confidence in our sponsors that the future we envision is possible.

The Earth Science Enterprise is here to stay. With your help, we can ensure NASA will be there to help the nation and the world meet the challenges of proactive environmental prediction for the new century.

Minutes of The Fifteenth Earth Science Enterprise/Earth Observing System (ESE/EOS) Investigators Working Group (IWG) Meeting

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

The 15th meeting of the Investigators Working Group (IWG) of the Earth Science Enterprise/Earth Observing System (ESE/EOS) took place at Manor Vail Lodge in Vail, Colorado, June 15-18, 1999.

Tuesday, June 15
Morning Plenary Session (Earth Science Enterprise/EOS Status)

Michael King, EOS Senior Project Scientist, Chair.

In the absence of Ghassem Asrar, NASA's Associate Administrator for Earth Science, **Jack Kaye** (Director of the Research Division, Office of Earth Science [OES], NASA Headquarters) gave an update on "Earth Science Enterprise, Status and Future." Kaye, noted that the number of EOS Interdisciplinary Science Investigations (IDS) has grown by a factor of three since the initiation of EOS. Kaye showed an OES organization chart and pointed out that Michael Luther is now the Deputy Associate Administrator of OES.

He presented a list of near-term challenges. These included: Developing the first series of EOS and selected Earth Probe missions, with ten launches planned for CY 99 followed by 25 launches through CY 02; delivery of a functioning Data and Information System (DIS) to support these missions; implementation of scheduled aircraft and field campaigns; collection and analysis of data from operating missions such as TRMM; and establishing joint applications projects with other Federal, State, and local agencies. Kaye also listed planned EOS and "other" Earth-science-related missions for 1999, 2000, and 2001.

ESE now has five *science* themes:

- Ecosystems and Global Carbon Cycle
- Global Water and Energy Cycle
- Climate Variability and Change
- Atmospheric Chemistry
- Solid Earth and Natural Hazards

Kaye pointed out that there are differences between these ESE themes and those adopted by the USGCRP.

ESE also has six *applications* themes:

- Food and Fiber
- Natural Resources
- Disaster Management
- Environmental Quality
- Urban Infrastructure
- Human Health and Safety

Kaye said that there are two cross-cutting themes: land use/land cover and weather and climate.

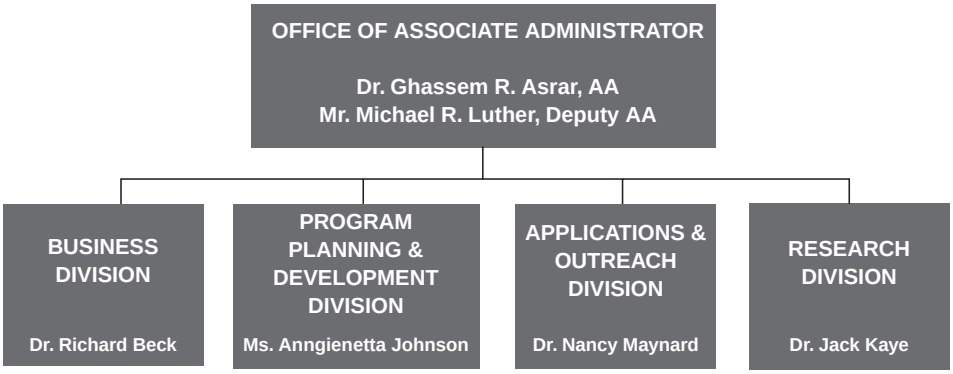
Regarding applications, initially there is an emphasis on the land surface and its ties to agricultural issues. The Stennis Space Center focuses on the commercial area. There is a concern that the science and commercial applications groups need to have improved interactions.

Commenting on the New Millennium Program (NMP) missions, Kaye reported that EO-1 is "on track," Sparcle is having cost and schedule difficulties, and EO-3 definition is progressing. Commenting on Earth Probes status, Kaye said that there has been a House bill that would kill Triana, but there is still hope for the mission.

An ESE Technology Strategy has been approved and it is now in printing. Included are Instrument Incubator, Advanced Information Systems Technology (AIST), and Core and Cross-cutting Technologies.

The NPOESS Preparatory Project (NPP) now includes an Advanced Technology

Office of Earth Science Organization



Microwave Sounder (ATMS). There is a very important issue about how research missions transition to operational missions. Neal Lane, the President's science advisor and head of the Office of Science and Technology Policy (OSTP), has authorized drafting of a policy statement on this issue. Operational missions must support research mission needs. This is an *urgent* policy requirement. Kaye showed a chart giving current schedule assumptions. It showed the dates for which NPP would provide coverage, leading into the launch of NPOESS C1 between July and December 2008.

ESE is now supporting a New Investigator Program. There have been 17 selections out of 84 proposals, and there is an intent to have solicitations every 18 months with 30 awards each time.

NASA's outreach strategy is based on the concept that it is necessary to communicate to the public that "Earth science at NASA is truly science in the public interest."

A National Research Council (NRC) report has been issued assessing the ESE post-2002 mission scenario. The report says that ESE needs a fully integrated science plan and embraces NASA's call for a national policy discussion on the transition from research to operations.

Among ESE's long-term "challenges" is to change the budget investment balance to increase emphasis on research, advanced technology, and commercialization/applications. ESE is challenged to adopt the Science=>Technology=>Mission paradigm, with an aggressive instrument technology development program. ESE should increase science data purchases from commercial suppliers and should form new partnerships and test pilot applications with regional users.

ESE planning for the next decade includes completion of Version 2.0 of the ESE Science Implementation Plan. The Science Implementation Plan has 13 overarching questions covering the five thematic areas of ESE. EOS scientists should be looking into these 13 questions. A Strategic Enterprise Plan is in development and is to be reviewed with ESSAAC in September. Kaye said that the OMB is looking for a coherent exposition of ESE's post-2002 strategy in support of the FY 01 budget request. This is a very strong OMB concern.

Kaye concluded his formal presentation with a chart labeled "Tasks for the EOS-IWG." The key thought for the IWG was that "EOS IWG members should play a leading role in promotion of EOS data use outside the traditional EOS community and in recruiting/welcoming new members of the Earth science community to bring new ideas and measurement concepts."

Tasks for the EOS-IWG

EOS 1st series plan and budget is firmly in place.

- Priorities should shift toward effective implementation
  - Calibration/validation of new instruments as they come on line
  - Production of promised data sets & scientific progress
  - Organized, regular reporting of science results
- EOS-IWG members should play a leading role in:
  - Promotion of EOS data use outside the traditional EOS community
  - Recruiting/welcoming new members of the Earth science community to bring new ideas and measurement concepts

Addressing a question from the audience, Kaye said that there is soon to be an EOS IDS follow-on announcement that will be very important. The current set of IDS investigations will generally come to an end in December 1999. The earliest due date for new proposals is the second week of September.

In answer to a question from Ricky Rood, Kaye said that it is essential to show that we have a Science plan that leads to a Mission Plan.

Phil Sabelhaus (Goddard Space Flight Center), Deputy Director for Development, gave the talk entitled "EOS Flight Program Status." He said that there has been considerable progress since the last IWG, which was held last fall in Durham, New Hampshire. Notable was the highly successful launch of Landsat 7 on April 15. The unfortunate failure of the RL-10 engine on the Centaur upper-stage rocket has led to a delay of at least one month to not earlier than August 27, 1999 for the Terra launch. TOMS is to be a free flyer and not part of the PM-1 mission. CHEM integration has begun. ICESat is now co-manifested with CATSAT (The Co-operative Astrophysics and Technology Satellite).

The FY 99 budget is OK but tight. Contingency has been restored to PM-1. The Terra science-processing software has been delivered. Additional resources have been requested to support CHEM. Priorities are to assure spacecraft safety, provide resources for the launch of Terra, and to establish a stable baseline for ESDIS to proceed.

Landsat has now provided more than 6000 scenes. Appropriate spacing of Landsats 5 and 7 on orbit allows an eight-day repeat cycle instead of the standard 16 as long as they are both functioning. USGS is to take

over management and funding as of October 2000. Sabelhaus showed the first Landsat 7 image.

Terra is now in a stand-down mode awaiting the solution of the launch-vehicle problem. In the meantime there have been three successful ground system to TDRSS tests.

The PM observatory is now entering the integration and test phase. Instrument development activities are at or near completion. There is adequate schedule slack to December 22, 2000. ICESat will have a Delta II launch vehicle. Its control center will be supplied by Ball and the Laboratory for Atmospheric and Space Physics (LASP).

CHEM instruments are making good progress. The Algorithm Theoretical Basis Document (ATBD) reviews for MLS, HIRDLS, and TES were successful. The SOlar Radiation and Climate Experiment (SORCE) is to combine SOLSTICE and TSIM. It now has a July 2002 launch date. Sabelhaus said that significant progress has been made in the EOSDIS arena.

Mission systems tests for Terra have shown that the flight operations system is getting better with successive trials. 85% of the segments have been verified as of June 4. Connectivity tests have been successful. Sabelhaus also listed areas where improvements are still needed.

Landsat 7 is functioning routinely but there are "stability" problems—correctable problems with the software and with the operational people who are still learning their roles. Terra End-to-end Science System Tests (TESS) have revealed some problems with ASTER and CERES—everything else is fine.

As a result of a joint NASA-Integrated Program Office (IPO) feasibility study, a work split between the two organizations has been agreed upon.

Sabelhaus ended his presentation saying that Landsat data operations are stable, and that the Terra control center is able to support operations.

Mark Schoeberl (Goddard Space Flight Center) addressed "Earth Science Visions for the Next Millennium." He asked: "What should NASA be doing for Earth Science in the 2020 time frame?" In the 2020 era Schoeberl feels that such factors as possible changes in climate, population growth, biodiversity, and land use all will impact habitability of Earth and quality of life and have economic consequences. Things that NASA can do include:

- Enable accurate 14-day weather predictions with 12-hour severe storm forecasts.
- Enable accurate short-range climate/environmental prediction (mostly seasonal to interannual).
- Enable long-range climate/environmental prediction (decadal).
- Enable prediction of global air and water quality.
- Enable prediction of natural hazards.
- Enable efficient management of natural resources.

Schoeberl said that Science and Discovery are the stepping stones to discovery. The goal is to answer: "What can we do to make people's lives better."

The basic requirements for prediction include: robust scientific research activities focused on understanding the Earth System; a stable, calibrated global observing system; and an integrated information and data-management system. (There must be the ability to present and communicate scientific results to the public.) On the way to achieving improved environmental prediction it is essential that we drive sensor costs down. NASA *technology* is the key to achieving our national goals.

We look to our Agency partners: NOAA for weather prediction, EPA for air/water quality, and DOI and USDA for land management.

Looking to the future of space observations, Schoeberl sees the need for NASA to go to smaller sensor systems at lower costs. He envisions a *sensor web* where multitudes of sensors are spaceborne at the same time.

One of Schoeberl's charts had the message: "NASA must achieve the goal of enabling proactive environmental prediction."

Looking to new technologies, he illustrated the value of dense networks of space-based wind observations leading, for example, to improved storm locations. He showed the value of improved SST observations, and said that adding a soil-moisture capability would also lead to significant improvements. The successful forecasting of the 97/98 El Niño season was an example of what can be achieved with the added spaceborne capability.

Schoeberl has a vision of "nano spinners." These might have 10-kg mass with no propulsion systems (using magnetic torque to maintain their attitudes). He called attention to the ever-increasing need for computer power. If grid sizes for forecast models are to decrease from 10 km to half that size, then 8 times the computer power will be required. In 10-to-15 years ECMWF will be able to use data at the AIRS pixel size.

New approaches to software development call for open-model architectures and automatic parallelization schemes.

In situ sensors will have to be improved. They often serve as prototypes for space-based sensors.

Rosenzweig cautioned that, despite the successes with recent El Niño forecasting, serious errors were made affecting the agricultural community.

Jim Dodge (NASA Headquarters) described "EOS Direct Broadcast (DB) Activities." MODIS will be the first EOS source of DB broadcasts (NOAA's AVHRR is the prototype). DB is now available for both Terra and the PM satellite, but only MODIS will use it on Terra, whereas all PM instruments will use it. The DB data are expected to be most useful for regional systems, considering the ~$0.5 M cost of the receiving system. Data are downloaded using an X-band link. DB data will serve as primary sources for flight operations devoted to calibration/validation activities. They will assure that the aircraft get to the right places at the right times.

About 100 users for DB have been identified internationally. (He listed the likely sites.) Any Landsat site could use DB by performing a simple conversion of their equipment. A 4-m program track antenna system is required. Data can go directly into the ground-computer hard drive. Level 1B data and product images would be available in just one hour. (This capability is good for locating storms, volcano plumes, and fires.)

Dodge showed the coverage to be provided by the three U.S. stations and noted that there is no station planned for Sioux Falls, although it would be feasible to have one. The Australian CSIRO will also have regional coverage with three sites. Dodge and Michael King are working to establish DB stations for Africa.

Potential real-time MODIS products include regional ocean color and chlorophyll. MOSIX is a free software package that provides a way of parallel processing the DB data. The University of Wisconsin will provide packets of information on how to work with the DB system.

Afternoon Plenary Session, Part 1 (Earth Science Enterprise/EOS Status, continued)

First speaker of the afternoon was **Bob Murphy** (Goddard Space Flight Center) on the subject of "NPOESS Preparatory Project (NPP)." (NPP is a joint NASA/DoD/NOAA activity.) Murphy began his talk with a listing of the NPP mission objectives, which are to provide *NASA* with continuous global-change parameters after Terra and EOS PM, and to provide NPOESS with pseudo-operational risk-reduction demonstration and validation for three of the four critical NPOESS instruments and algorithms. The three instruments in question are Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-Track Infrared Sounder (CrIS), and Advanced Technology Microwave Sounder (ATMS).

Murphy listed the key NPP personnel, led at Goddard by Raynor Taylor as Project Formulation Manager. The launch readiness date is set at 2005, and a five-year mission life is planned. The orbit will be at 833 km with a sun-synchronous 10:30 a.m. descending node. Data will go directly to polar ground stations, bypassing TDRSS. There will also be direct broadcast (DB) of real-time data.

NPP will be the primary source for 13 of the 24 EOS measurements in the period between EOS PM and NPOESS (planned for 2009). NPP will contribute to NPOESS through sensor risk reduction, ground-system risk reduction, and early user evaluation of the NPOESS algorithms.

The current status of NPP is this: There is an agreement between NASA Headquarters and the Integrated Program Office (IPO); results of a feasibility study were presented to Ghassem Asrar (NASA) and Bob Winokur (NOAA/NESDIS) on April 8, 1999. It was noted that NPP meets the requirements that were established for EOS-2 and EOS-3 at last year's ESE/EOS meeting in Easton, Maryland. Competitive phase B studies are now under way for CrIS and VIIRS. Selections are to be made for CrIS by August 1999 and for VIIRS by mid 2000. (*Ed. Note: ITT, Fort Wayne, Indiana, was selected to provide CrIS*.). A phase B study for ATMS is to begin in the fall of 1999 with completion due in ten months. Contractors for these instruments are to provide both the sensors and the algorithms. Operational Algorithm Teams (OATs) will provide governmental oversight.

An Integrated Operational Requirements Document (IORD) sets the requirements for the sensors based on an interagency study.

NASA requirements have been merged into the IPO requirements. The OATs provide science guidance to the IPO on specific measurement suites. VIIRS imaging requirements were based on MODIS but have been updated. CrIS extends the measurement series of AIRS, and ATMS extends the measurement series of AMSU-A and HSB.

VIIRS could be several instruments making up the "suite." There is a requirement (from the Air Force) that VIIRS have a constant ground resolution of about 400 meters. It should match MODIS for selected long-term measurements such as SST and land-cover determinations. It omits ocean-fluorescence determinations. VIIRS resolution for surface albedo is enhanced from 4 km to 1 km, and accuracy is increased from 0.05 to 0.03. Land-

surface temperature resolution is also enhanced from 4 km to 1 km.

Bob Atlas (Goddard Space Flight Center, acting head of the Data Assimilation Office [DAO]) gave an update on "Improvements in Data Assimilation for Terra and PM-1." He said that the mission of the DAO is to provide a Data Assimilation System (DAS) that makes the best use of satellite data. He listed the differences between the DAO's operations and Numerical Weather Prediction (NWP): DAO produces more diagnostics; DAO's model starts with the surface of land and sea and extends through the stratosphere to the mesosphere; the DAO's time scale is finer; the DAO has more data types; and the final DAO result is an analysis, not a forecast. Additional DAO products are parallel analyses, offline analyses, and R&D products. The GEOS-2 model now being developed is superior to GEOS-1 in representations of zonal winds and temperatures plus sea-level pressure. It is also superior in its representation of integrated eddy fluxes.

Half-degree resolution has been shown to bring out fronts sharply even in situations where they do not appear in the NCEP or ECMWF analyses.

Atlas said that the Physical Space Statistical Analysis Scheme (PSAS) permits direct implementation in physical space. He listed the innovative features of PSAS. The NASA/NCAR model now being developed has the goal of providing global data assimilation of both physical and chemical features of the atmosphere. The model is capable of bringing out fronts in the isobar patterns and also wind fields. DAS will produce $1^{o} \times 1^{o} \times 36$-pressure-level assimilated products.

The model runs with 1-degree resolution in near real time—just one day late. Reprocessing will go back to at least the earliest satellite observations, but this cannot be done with existing computer capabilities.

The SSM/I product is used for sea ice. Ground temperatures are represented by the 2-meter product. Half-degree resolution is not used for long-term climate prediction. Stratospheric chemistry is being assimilated offline, and there are no plans to do chemistry directly with the GEOS model.

Afternoon Plenary Session, Part 2, Global Water Cycle

This session was chaired by **Eric Wood**, NASA Headquarters.

Randall Koster (Goddard Space Flight Center) gave some insights into "The Influence of the Land Surface on the Predictability of Precipitation at Seasonal Time Scales." Koster's work is in connection with NASA's Seasonal-to-Interannual Prediction Project (NSIPP). The question to be resolved is: "How predictable is precipitation?" Related to that question is the question: "How predictable is soil moisture?" Another question is: "If soil moisture can be predicted, how useful is that prediction for the prediction of precipitation?"

Koster has a model called MOSAIC. Using the model for simulation, a correlation was found between observed precipitation and SST.

Koster chose to address the question of how much the prediction of precipitation is affected by the prediction of soil moisture. In a run called ensemble 1 he used prescribed SST, and in ensemble 2 he used prescribed SST plus land-surface moisture. He found that with both SST and land-surface moisture prescribed, there was high predictability of precipitation. Predictability was greatest in wet/dry transition zones. It was not good in very wet or very dry regions.

Koster made runs with 16 different ensembles and found that response of soil moisture to initial conditions was very strong in some regions but not in others. His overall conclusions were that land-surface moisture initialization can contribute to the predictability of precipitation. Predictability is best in transition regions. Large evaporation is needed to have an effect, and this is typical of summer-time conditions. Roger Barry commented that Koster's work points to the need for in situ measurements, and Eric Wood said that the Soil Conservation Service is currently doing more of this. Wood added that the Europeans are considering making satellite-based soil-moisture measurements.

Steve Running (University of Montana) addressed "Cold Season Processes and Links to Continental Land Surface Processes." Running led off with an animation showing day-to-day variations in Net Primary Production (NPP) across the continental United States that followed the west-to-east movements of the air masses, illustrating tight daily coupling of the biosphere with the atmosphere. Another animation of the daily global surface freeze/thaw cycle clearly illustrated both synoptic and seasonal dynamics in the areal extent of frozen land surface. This suggests the valuable contributions that a high-repeat-cycle SAR system could make to land-surface monitoring. At high latitudes the impact of regular monitoring of freeze/thaw and snow cover is of major importance to carbon- and hydrologic-cycle processes as well as weather forecasting.

Running went on to make a presentation

on a proposed mission dubbed "Cold Land Processes Research Mission (EX-7)." According to Running, high latitudes are where land-surface monitoring is most needed. The earliest signs of global warming are expected to be found at high latitudes, but this is where the ground stations are rarest due to sparse population. Freeze/thaw and snow-cover-change observations are needed because both the ecosystem and land-surface energy exchange respond sharply to these transitions. Since so much of the land is subjected to cloud cover and seasonal darkness, it is natural to think of using radar to detect surface changes. Running showed an example in which NSCAT data picked up the freeze/thaw cycle. This was due to the change in dielectric constant of the surface that occurs as the water changes phase in going from freeze to thaw.

For an EX-7 baseline mission there would be two SARs, one in L band for freeze/thaw detection, and one in X band for snow-melt detection. Thus there would be dual frequencies. The radars could be on one platform or two smaller platforms flown in formation. They would give good transition-time determinations. The freeze/thaw cycle could be followed on a daily-to-seasonal basis. This suggests the valuable contributions that a SAR system could make. At high latitudes the impact of freeze/thaw and snow cover is of major importance to NPP.

Dennis Lettenmaier (University of Washington) spoke on "Global Monitoring of Large River and Surface Water Bodies." Lettenmaier was proposing a new mission he called HYDRA-SAT for HYDrological Radar Altimetry SATellite. The goal of this mission would be to monitor the water bodies in real time and thus to study the effects of variations in water storage and discharge. The rationale for the mission is that river flow is a major component of the global water cycle and that stream flow is important, but is not well observed worldwide. Monitoring in the U.S. is adequate, but it is not so good globally. The number of reporting stations worldwide peaked in 1970 and then dropped rapidly. Another problem is the large lag in getting the data into databases at the appropriate data-processing facilities. Some countries are unwilling to disseminate their data.

Lettenmaier offered two scenarios for his mission. Scenario A uses radar altimetry, but will not get river widths. Overpass times must be on the order of three days to capture important surface water dynamics—e.g., TOPEX/Poseidon.

Scenario B calls for an innovative low-cost radar altimeter with doppler processing. Over land it is possible to take advantage of fixed land topography. A large antenna will be needed to get the cross-track width of the rivers. River widths should be estimated to 10-m accuracy. There should be 5-cm rms altimetry. Rivers would have to be >250-m wide. River crossings should be repeatable to ±125 m cross-track. SAR could be used to determine areal extent changes and thus volume changes in lakes.

Eric Wood noted that there has been some research in the Amazon for measuring wetlands. Dave Emmitt pointed out that, with 10-m lidar footprints, clouds would not be much of an obstacle to the measurements.

Wednesday, June 16
Morning Plenary Session (Polar Missions, Science Results, and Data Products)

Claire Parkinson, PM-1 Project Scientist, chaired this session.

First speaker of the morning was **Bob Bindschadler** (Goddard Space Flight Center) giving "New Understandings of Ice Sheet Dynamics." Bindschadler said that he would give "a whirlwind tour of ice dynamics research in the 90s." His focus was on ice streams and principally those of West Antarctica. Satellite sensing has revolutionized the study of ice sheets.

He showed a reconstruction of Antarctica at the time of the last glacial maximum (20,000 years ago). In its current form, the West Antarctic sheet has lost about two-thirds of its mass. The significance of such changes lies in their possible effect on global sea level. He showed an illustration of the rise in sea level around the world if the sheet were to melt completely and noted that one-third to one-half of the world population lives within the "coastal zone." The cost to the U.S. of a one-meter rise is estimated to run from about $270 B to about $475 B.

Early milestones in ice-sheet research go back to the 1970s when airborne radar revealed the existence of cravassed margins of the ice streams. AVHRR was the first satellite-sensor system to map ice-stream locations.

Bindschadler discussed the ice-stream characteristics: width 50 to 80 km, length 300 to 400 km, thickness 1000 m, speed 100 to 700 m/yr. Fast motions are explained by the fact that the streams are underlain by marine sediments and supported by pressurized water so that the ice sheets float. The streams are slowed by basal and lateral resistance.

Mid-decade milestones included the use of Landsat to map ice-stream velocity patterns and the demonstration of shear-margin development.

New milestones include Radarsat interferometry measurements of velocity inland

and the discovery of tributary networks feeding the ice streams. The discovery of non-uniform flow of ice sheets was "stunning."

Future milestones include: ICESat elevation measurements, which will highlight areas undergoing change; Radarsat measurements, which will carry out a second mapping of Antarctic ice-stream velocities; and Landsat 7 determinations of ice-stream motion.

In concluding remarks, Bob said that satellite remote sensing has revolutionized ice-sheet research. ICESat will make the measurements to detect change in mass balance. Zwally added that ICESat will make 0.1 mm/yr sea-level equivalent measurements. Bob stated that we don't think of ice-sheet "collapse" any more.

Hugh Kieffer (U.S. Geological Survey Astrogeology Branch) discussed "Viewing Glaciers from ASTER." Kieffer said that we're here (in Vail, Colorado) because glaciers shaped the valleys allowing Interstate 70 to bring us here from Denver.

Kieffer said that Global Land Ice Measurements from Space (GLIMS) is an international organization. The GLIMS coordination center is located at USGS, Flagstaff, and the GLIMS World Data Archive is at NSIDC. GLIMS is much concerned with distinguishing clouds from the surface in polar regions.

Kieffer pointed out that glaciers are "natural integrators" of climate. They represent the balance between precipitation and temperature/insolation. Many glaciers including Glacier National Park are disappearing rapidly. The Alps lose about nine glaciers per year. Worldwide, glaciers are disappearing at the rate of 2 or 3 per week. The glacier connection to climate is not simple. Oerlemans (1994) mapped glacier change, but there is no general digital database of glacier sizes and extent. (At the conclusion of the talk Roger Barry pointed out that there is no world map of land ice at the current resolution of climate models, and Michael King suggested that MODIS cloud masking could help.)

Recognizing the above shortcomings, Kieffer proposed a program of space-based applications with these objectives:

1. Measure all glaciers within a 5-year period.
2. Develop a comprehensive uniform image record.
3. Establish a GIS database with these objectives:
   a. provide lateral extent and surface velocities;
   b. provide surface topography where practical;
   c. determine rates of change; and
   d. provide periodic global assessment.

Kieffer would use three types of information: imaging, SAR, and altimetry. Comparing SAR with imaging, Kieffer said that, to first order, each is best where the other is poorest. ASTER is almost ideal for a glacier survey. It has high spatial resolution, provides stereo, SWIR bands distinguish ice from snow, pointing ability allows more-frequent coverage of surges.

Kieffer said that steps still to be taken are: more algorithm development, database implementation, and acquiring formal support. A final comment, from Jim Hansen, was that the Earth is getting warmer and that the best confirmation of this is the retreat of the glaciers.

Seelye Martin (University of Washington) reported on "Recent Changes in the Arctic." Along with changes in the atmosphere and oceans there have been changes in pack-ice thickness and extent. Martin showed Manabe's model results for CO_2 doubling, leading to 10° C warming in "autumn." The *observed* warmest northern land-surface temperatures only occurred in the *spring*! Warming was *not* observed in the autumn.

In observing the Arctic Oscillation, Martin cited investigators who find strong warming over the Asian landmass. They also find a warming trend in the Alaskan permafrost temperatures for the period 1983 to 1995.

Cavalieri and others have found decreases in pack ice of about 3 percent per decade over the last 20 years for polar regions.

SCISEX is an oceanographic project that has been using a nuclear submarine called USS Pargo since 1993. SCISEX data show about a 2° C warming in the upper ocean since 1993 as compared to an earlier U.S.-Russian "Atlas" data assembly. Near-surface salinity has also increased, leading to decreased stability in the surface layers.

Drew Rothrock has analyzed changes in ice thickness and found that it has decreased by 1.5-to-2 meters in the Eastern Arctic.

Martin described changes observed over the last decade that may be related to changes in the Arctic Oscillation, and he stressed that the observed changes are big compared to climatology. Remaining questions are these: Will this trend continue? What are the feedbacks? What are the effects on the ecosystem?

Judy Curry (University of Colorado) gave "An Overview of the FIRE Arctic Clouds Experiment." The experiment was motivated by uncertainties in satellite (ISCCP) cloud retrievals in the Arctic and also by the large discrepancies in simula-

tion of arctic cloud and radiation fields by climate models.

Curry pointed out that satellite retrievals of Arctic cloudiness and surface characteristics are hampered by many factors, including the frequent presence of thin multiple cloud layers and mixed-phase clouds. She then described aircraft experiments conducted April to July 1997 that used ER-2 and in situ (low-level) aircraft overflights of surface-based measurements at ice station SHEBA. The biggest challenge to remote sensing of clouds lies in separating the cloud signal from the bright, heterogeneous underlying surface.

Curry believes that the FIRE Arctic Clouds Experiment will lead to improvement of cloud retrievals and determination of radiation fluxes from EOS. Active sensors (radar, lidar) will provide considerable improvement to the satellite retrieval of Arctic clouds, shedding light on their complex vertical structure. (Joe Waters commented that MLS can provide cirrus cloud coverage that is unaffected by surface characteristics.)

Taneil Uttal (NOAA Environmental Technology Laboratory [ETL]) described "Atmospheric Measurements over the SHEBA Ice Camp." (SHEBA is the acronym for Surface Heat Budget of the Arctic Ocean.) Taneil said that her talk would complement the FIRE ice talk given by Judy Curry. SHEBA constituted the largest ice camp in history. A Canadian ship frozen in the ice served as the power station for the project, which ran for a full annual cycle.

Measurements were intended to cover an entire atmospheric column and go down to 300 meters in the ocean. Surface-based sensors included lidar from ETL to look at clouds. The lidar gave heights vs. time up to 8 km and discriminated cloud particle phases. Plots of water-, mixed-, and pure-ice clouds vs. time were obtained as were rawinsonde data.

A meteorological tower was 20-m tall from top to bottom and instrumented all the way. A "miracle" of SHEBA was that it worked all the time and didn't need repositioning throughout the duration of the project. The average surface temperatures during SHEBA under cloudy skies were -24° C and they were -17° C under clear skies. SHEBA summers were almost 100% cloudy.

Four Portable Automated Metnet (PAM) stations supplied by NCAR operated throughout the year, providing coverage from October 1997 to September 1998. A NOAA ETL cloud-sensing radar at 35 GHz picked up light precipitation, recorded doppler winds, and classified cloud types. Also recorded were cloud boundaries and bases and tops of multilayer cloud systems. Cloud thickness determinations were very accurate. Determinations of ice/water contents based on radars and radiometers were used to establish profiles of particle characteristics. Problems arose in certain situations when there were alternating layers of ice- and liquid-particle clouds. Uttal said that her group will be doing surface validation for CERES at Barrow, Alaska.

Terry Tucker (U.S. Army Cold Regions Research and Engineering Laboratory) described "SHEBA Snow and Ice Studies." Tucker said that the object of his research is to better understand the processes governing surface-energy balance, particularly looking at ice-albedo feedback. At SHEBA the surface changed dramatically from month to month. Although soot from the ship's generator could be detected at up to 0.8 km from the ship, it was not a problem.

Tucker found that snow depth has a large spatial variability. It increases slowly and then decreases rapidly. The average depth in spring was 34 cm. It took eight months to build up and just one month to melt. At any time the amount of snow cover was determined by independent storms. Melt ponds grew ~50 cm deeper and ~2 m wider during SHEBA. Lateral melting was significant. During ice melt the albedo decreases and spatial variability increases. The formation of melt ponds leads to a sharp drop in albedo. Ice permeability rose during the melt process.

In summary, the average albedo changed from 0.9 to 0.4. There was a net mass loss during the SHEBA year. The ice thinning was specific to the latitude of the study. The warmth of the underlying ocean water was probably the cause.

Afternoon Plenary Session (A Selection of Results from Recently Launched Spacecraft and Analysis Results)

This session was chaired by **Daniel Jacob** (Harvard University).

Darrel Williams (Goddard Space Flight Center) gave a very enthusiastic review of "Landsat 7 Early On-orbit Performance and Science Goals." The spectacular launch took place on April 15, and the first image came on Sunday April 18—it included EDC! The project is now carrying out its normal post-launch on-orbit independent verification plan (OIVP). The satellite is currently flying lower and faster than would be normal because of a planned underflight with Landsat 5. The two satellites are actually 20 minutes apart along track. Having coverage from two satellites permits 8-day repeat coverage.

Williams reported that Landsat 7 pixel locations are good to ~ 100 meters.

There are some performance issues: ETM+ has suffered loss of scan-mirror phase lock, and there is a problem with onboard calibrator stability—temperature variability is excessive. Landsat 7 offers two new noteworthy components: image assessment system and long-term data acquisition plan (LTAP).

In summary, Williams said that everything is performing well and the system will be operational by July 15.

Gary Rottman (University of Colorado) described "The Solar Radiation and Climate Experiment (SORCE)." He discussed the evolution of the project going back to the selection of SOLSTICE through the original EOS Announcement of Opportunity (AO) process. The National Academy of Sciences has recommended that there be both a total and a spectral irradiance project.

The TIM instrument on SORCE is expected to measure Total Solar Irradiance (TSI) with an accuracy of 100 ppm. Early data have shown than TSI varies by about 0.1%. There has been a spread in measurements of TSI between previous instruments of about 0.5%. SIM on SORCE will measure solar spectral irradiance. The overall objective of SORCE is to determine how our variable Sun affects Earth's atmosphere and climate.

The Laboratory for Astronomy and Solar Physics (LASP) (operating in the PI mode) will manage the entire SORCE program, including the building of the four instruments: TIM, SIM, SOLSTICE, and XPS. Orbital Sciences is to provide the spacecraft and launch (set for July 2002). SORCE is to operate for five years at 600-km orbital altitude.

Frank Wentz (Remote Sensing Systems) reported on "Early SST Results from TRMM." He said that this work is sponsored by ESIPs and the AMSR and TRMM science teams.

Wentz pointed out that the TRMM antenna aperture is about 70 cm in diameter. The atmosphere is nearly transparent to clouds at the TRMM frequencies below 30 GHz. He can correct "out" water vapor effects to leave about 0.3 K error and he can correct out cloud optical thickness to leave about 0.06 K error. Surface roughness remains the primary source of error. To correct for surface wind speed, Wentz uses both the H and the V polarization signals. Winds greater than 15 m/s are not computed.

Wentz found that SST determined by the TRMM TMI instrument compared well with the Reynolds SST that is based on AVHRR and buoys. Buoy temperatures correspond to about 1 meter, and microwave temperatures correspond to about 1 mm. Wentz said that sun glitter can interfere with TRMM SSTs. Aerosols are not a problem for microwave retrievals but they are a big problem for infrared. TMI doesn't give SST in rain, and AVHRR doesn't give SST in the presence of clouds.

A 3-day map of SST from TRMM brings out the circulation features of the ocean such as upwelling regions. In a time series of Hurricane Bonnie, areas of cooling indicated the hurricane's strength.

TMI has a calibration problem, as indicated by a 10-degree offset from cold space. Apparently, the problem occurred because a coating was sanded and should not have been!

In the future, ADEOS 2 with SeaWinds will provide both speed and directions of the winds. AMSR with a 2-m antenna will have improved area resolution. Wentz expects to see 0.2 K accuracy with 3-day averaging.

Pat McCormick (Hampton University) gave an "Overview of PICASSO-CENA." The acronym spelled out is Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations-Climatologie Etendue des Nuages et des Aerosols. This is an ESSP mission. LITE is regarded as a predecessor experiment. PI is Dave Winker (Langley Research Center [LaRC]).

Four scientific instruments will be flying on the platform in close formation with the PM-1 platform. The instruments are: a 3-channel lidar, an oxygen A-band spectrometer (ABS), an imaging infrared radiometer (IIR), and a wide-field camera (WFC). Launch is to take place in 2003. The mission will provide aerosol and cloud vertical structures and have improved longwave radiative fluxes.

Mission partners are as follows: LaRC is the lead; the French will provide the PROTEUS spacecraft plus the IIR instrument; Hampton University leads the algorithm implementation plus the educational outreach; and Ball will develop the lidar, the ABS, and the WFC.

Science objectives include developing a global suite of measurements to give observations of direct aerosol forcing.

PICASSO-CENA is to be co-manifested with CloudSat for a Delta II launch. It is to fly in formation with EOS PM at ± 60 seconds for cloud observations. The lidar footprint will be have a 70.5-m diameter. Estimates of *direct* aerosol forcing will make use of MODIS, CERES, and AIRS data.

PICASSO-CENA will be able to handle multilayered clouds—AMSR-E data will fill in for optically thick low-level clouds.

"The Latest TOMS Results" were reported by **P. K. Bhartia** (Goddard Space Flight Center) who started by showing the ozone

hole as determined from TOMS for September 30, 1998.

TOMS primary products are reflectivity (380/340 nm), total column ozone, and volcanic columnar SO_2. Derived products are tropospheric column ozone, aerosol optical thickness and back scatter coefficient, and surface UV flux.

Bhartia noted that surface UV reflectivity for July, climatologically, varies from 4% to 8% percent over the globe, with little difference between land and ocean. The TOMS ozone record for 1980 to 1999 is in good agreement with ground measurements. The spring maximum of ozone at midlatitudes is about the same as it was in 1979. Northern hemisphere polar ozone has been decreasing until the last two years. Comparing 2-D model results for total ozone in the south polar region shows fairly good agreement. A 3-D chemistry and transport model also shows good agreement with observations. Shifts in the region of minimum ozone show the effects of El Niño and biomass burning.

Bhartia reported on ozone studies with TOMS. Sulfate effects on UV reflectivity are different from those of absorbing aerosols such as smoke and dust. The effects of aerosol attenuation on UV flux at the surface can be as much as 50%.

The Triana mission is to have an EPIC camera with TOMS and MODIS channels. An image will be available once each hour with 8-km resolution.

Steve Ghan (Battelle Pacific Northwest Laboratory) reviewed the "Use of Satellite Measurements to Evaluate Physically-Based Models of Aerosol Radiative Forcing." He began by presenting the requirements to reduce the uncertainties: treat all radiatively important aerosol particles; treat all important components of cloud condensation nuclei; treat water uptake; and treat cloud/aerosol interactions.

Ghan then discussed MIRAGE—the Model for Integrated Research in Atmosphere Global Exchanges. The model has four modes of internally mixed aerosols. Chemical processes in the model are relatively simple. There is some agreement, but not everywhere, between MIRAGE and AVHRR on global optical depths. (He used data for August 1994.) He has found that anthropogenic sulfur forcing is greatest at northern midlatitudes.

In future work with MIRAGE, Ghan will be looking at additional sensitivity experiments, correcting relative humidity bias, correcting droplet number bias, and taking into account the effects of biomass burning.

Graeme Stephens (Colorado State University) presented "CloudSat Science Objectives." CloudSat is a mission of opportunity that will provide "A new dimension in the global observations of clouds." This is a USAF partnering mission with DOE's ARM heavily involved with the validation aspects.

Stephens stressed that cloud feedback is one of the largest areas of uncertainty in climate prediction. He showed a feedback loop from circulation to cloud properties to heating to circulation.

The project includes numerical weather prediction (NWP) and field observations. Stephens noted that progress in modeling is now surpassing the ability to validate the models.

Cloud processes are *fast*. CloudSat is to provide the information needed to improve the physics that is used in models for NWP. It is critical to have profiles of clouds, radiative fluxes, and heating. The link between cloud physics and cloud optics is missing, and this project is trying to bridge this gap.

CloudSat is a multi-sensor mission to quantatively evaluate the representation of clouds and cloud processes in global models, and is co-manifested with PICASSO-CENA for a March 2003 launch. It requires tight formation with PICASSO-CENA (~ 30 sec). It will carry an advanced millimeter cloud-profiling radar that can see through thin and thick clouds plus precipitation. It will measure both Liquid Water Content (LWC) and Ice Water Content (IWC) profiles. The radar will operate at 94 GHz with 500-m vertical resolution. There will also be an oxygen A-band spectrometer to determine atmospheric scattering. It will serve as a particle sounder to give profiles of both cloud and aerosol layers. Combining the data from the radar (active) and the spectrometer (passive) will give determinations of both the liquid water path and the particle sizes.

CloudSat validation makes use of multi-agency, multi-platform internationally integrated programs. Finally, Stephens said that CloudSat "is the opportunity to test new ideas that will lead to new and important information."

The final speaker of the second day of the IWG meeting was **Chris Bretherton** (University of Washington) on "Current Understanding of Stratus Clouds." Bretherton discussed the effects of cold advection vs. warm advection. Warm advection can lead to fog. Many types of boundary-layer clouds are observed. He showed a chart of annual stratus cloud amounts over the globe and another chart of boundary-layer cumulus cloud amounts.

Radiative effects of boundary-layer stratus include albedo enhancement and cooling of the atmosphere. Where there is more sun, stratus cools the surface; where there is less sun (as in polar regions), stratus warms the surface. The presence of boundary-layer clouds is correlated with lower tropospheric stability. Many processes are at work in cloud-topped boundary layers.

Bretherton reviewed problems with models. There are differences of factors of two between ISCCP data and CCM3 cloud-cover fractions. The CCM3 model optimizes the land boundary layer, but does not take all conditions into account over water. Coupled models in particular have problems. The 26° C isotherm goes too far eastward in the Pacific. In an experiment wherein aircraft followed a column of air, 2-D eddy-resolving models tended to agree with observations.

Important process uncertainties include: entrainment—this is not well agreed upon; 3-D radiative transfer is not well reported; microphysics is inadequate, and aerosol feedbacks need better representation.

Finally, there is a need to know more about aerosols and drop radii over the globe and their relation to shallow cloud precipitation.

Thursday, June 17
Morning Plenary Session (Terrestrial Carbon Science Program)

This session was chaired by **Steve Running** (University of Montana)

Ruth Defries (University of Maryland) described "Deriving Continuous Fields of Global Vegetation Properties and Implementation for Biospheric Modeling." Defries said that biospheric models need accurate land cover, and actual land cover is more heterogeneous than the models can use. She went on to give the U. of Maryland approach to meeting this problem.

As background she noted that a vegetation map from AVHRR shows thirteen different vegetation classes, but most pixels in reality have mixtures of vegetation types. There are many disagreements among models as to the vegetation types. Maps are static and do not respond to changes.

In the Maryland approach each pixel has proportional coverage for each vegetation type. Leaf forms, leaf type, and leaf longevity are described in continuous fields for each pixel. DeFries uses a linear-mixture model approach to set proportions for each type. Prototypes for continuous fields require global multispectral, multitemporal data, which currently come from AVHRR. The model includes percentages for three growth forms: woody, herbaceous, and bare ground. Leaf longevity percentages are given for evergreen and for deciduous trees. Leaf type percentages are for needleleaf and broadleaf.

DeFries said that her approach has applications to the Kyoto treaty where it is necessary to establish carbon stocks for a baseline year. It is necessary to set the spatial extent of forests despite the different definitions.

Following her discussion of the method, she gave several examples of its application. Examples included: percent tree cover globally, independent of forest type, and a comparison of this result with a Landsat image—it looked good; an area of dramatic deforestation where there was fair comparison with Landsat—the comparison was made difficult because she used 8-km AVHRR data.

DeFries gave examples of potential improvements for the continuous field method and pointed out its applicability to biogeochemical models such as Steve Running's BIOME-BGC and CASA. She showed how the continuous field can be used to derive NPP from Running's model. In CASA, NPP can be allocated to wood, leaf, and root. (Running commented that this approach could improve GCM representations.)

The talk by **Ranga Myneni** (Boston University) was concerned with "Global Products of Leaf Area and Absorbed Photosynthetic Radiation of Vegetation from Terra." Myneni said that his group does algorithm development. His purpose in this talk was to inform the IWG members about his group's activities regarding LAI and FPAR data, both from MODIS (1-km daily coverage) and MISR (16-day coverage). His algorithm assumes six structural vegetation types.

He pointed out that determinations of LAI can be ambiguous when they are based on pairing of NIR and red signals. However, with more bands or look angles the uncertainties can be resolved. He has an algorithm that gives the distribution of LAI with specified uncertainties. The addition of MISR angular measurements improves the retrieval. Myneni showed some SeaWiFs data that indicated the capability of his method. He noted that Tucker's values of NDVI have paralleled Hansen's ground temperatures for 18 years of springtime data. He ended by showing the LAI/FPAR validation sites organized by biome.

The scheduled talk by C. David Keeling (Scripps Institution of Oceanography) "Evidence of Interannual Variability in Terrestrial Carbon Fluxes Deduced from Atmospheric Isotopes of CO_2" was given by Steve Running from Keeling's notes as

Keeling was unable to attend the meeting. Keeling has looked at global trends in CO_2 fluxes from 1978 to the present. Measurements are based on $^{13}C/^{12}C$ ratios.

Keeling's look at the fluxes for 20 years vs. latitude has shown that latitudes above 47° are biosphere sources of carbon; latitudes from 23° to 47° N are a biosphere sink; and latitudes between 23° S and 23° N are a tremendous biosphere source. Over the last five years the global biospheric flux has risen sharply.

Keeling has data for La Selva, Costa Rica, a tropical zone that is a CO_2 source. He reports on a flux increase vs. tree-growth anomaly, wherein a growth reduction implies an increase in CO_2 respiration. He also finds that increases in biospheric flux correlate with temperature rises, but the flux increases when the rain decreases. Keeling's summation of this research is that the tropics are the key source of the global CO_2 rise.

Dave Schimel (NCAR) reported on the "Interannual Variability of Terrestrial CO_2 Exchange: A New Inverse Approach." He showed records of continuous fluxes from 1980 to 1995 with the trends removed and pointed out the influences of the El Niño and the El Chichón and Mt. Pinatubo volcanoes.

The standard inverse modeling approach for CO_2 fluxes gives estimates of the magnitudes and spatial distribution of the fluxes. Schimel's new k-model approach looks only at interannual variability. The output gives the global relation between changes in temperatures and changes in CO_2 fluxes. The model takes into account the role of nitrogen uptake in plant growth.

Residuals from the model of ecosystem physiology (k-model) suggest anomalous uptake early in El Niño periods followed by losses. Ocean uptake followed by high tropical biomass burning may cause this pattern.

Schimel's key finding is that a warming trend in high latitudes leads to increases in primary productivity. He remarked that the temperature sensitivity of respiration is greater than that of primary productivity. The temperature changes can trigger ecosystem responses on multiple lagged time scales. The temporal structure of the lags is consistent with feedbacks through the nitrogen cycle.

Schimel said that there are challenges for the remote-sensing community:

- inability to directly observe from space respiration or nitrogen-cycling changes;
- detection of year-to-year changes in phenology is possible—MODIS will help, but simple inferences about links between climate and observed phenology may be unwarranted because of lag or carry-over effects;
- large residual fluxes may be associated with year-to-year changes in land-use practices.

Other comments were that the effect of temperature changes does depend on the time in the growing season, and that the nitrogen cycle may not be the sole reason for the lags in CO_2 flux release after the initial temperature response. In fact, in the k-model, the principal lagged effects arise through plant metabolism of nitrogen (which fertilizer studies show to persist for several years) and not from the 'ecosystem' nitrogen cycle.

Dave Hollinger (University of Montana) and **Steve Running** (University of Montana) addressed "The Role of FLUXNET and AmeriFlux in EOS Validation and Biospheric Monitoring." Hollinger said that he is the director of the AmeriFlux project. As indicated on the Web, AmeriFlux is the Carbon Dioxide Flux Measurement Network of North, South, and Central America. It is a program of long-term CO_2 flux measurements using the eddy-covariance technique. Measurements come from different ecosystems and include carbon dioxide, water vapor, and energy exchange. AmeriFlux assesses fluxes at spatial scales up to square kilometers in area, continuously.

FLUXNET is a "partnership of partnerships," formed by linking existing sites and networks of which AmeriFlux is one. Accordingly, it "provides researchers access to consistent and integrated measurements of carbon dioxide, water vapor, and energy fluxes and associated site vegetation, edaphic, hydrologic, and meteorological characteristics. Fluxes and ancillary information are unified into consistent, quality-assured, documented, readily accessible data sets via the World Wide Web."

Hollinger gave the advantages of the eddy-covariance technique:

- minimal impact—simply requires putting up a tower;
- high time resolution;
- gives net exchange;
- provides area averaging;
- operates automatically; and
- some ability to partition flux into soil respiration and canopy uptake

Hollinger gave several examples of net ecosystem exchange (NEE) measurements. Some of these were hourly measurements for July and others were daily measurements. They indicated a peak summer uptake.

Characteristic scales of tower measurements are 10^4 to 10^6 m^2. A large gap at 10^{10} to 10^{12} m^2 is related to political boundaries, and this is where remote sensing could bridge the gap.

FLUXNET has both a science component and a data and information system (DIS) component. The science component sees to the intercalibration of the flux measurement sites, and the DIS component maintains a long-term archive at the Oak Ridge DAAC. EUROFLUX has all managed forests. Some of the NASA Aeronet sites are at the FLUXNET sites.

Steve Running said that the AmeriFlux net allows the study of geographical and seasonal patterns of carbon fluxes and will be used for validation of MODIS land data including both gross primary productivity (GPP) (effectively photosynthesis) and NPP. There is an attempt to get tower sites to deliver their micrometeorology data weekly. With those data, Running could compute MODIS values of GPP and compare them with DAO values. The tower data would be used to eliminate DAO errors. In effect, he would be able to test the MODIS algorithms independent of the DAO.

Many of the towers will have soil moisture in addition to their regular data. There are five ongoing studies of the possibility of making doppler lidar measurements of CO_2 flux from space. NASA is now considering the technology that would be necessary to bring down the costs of the tower sites and thus expand their coverage.

Final speaker of the session was **Chris Field** (Carnegie Institute of Washington) reporting on the "Integration of the Global Carbon Cycle and Challenges for Implementing Kyoto Protocols." Field outlined

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SOlar Radiation and Climate Experiment (SORCE) Science Team Meeting

— Robert F. Cahalan (Robert.Cahalan@gsfc.nasa.gov), NASA Goddard Space Flight Center, Greenbelt, MD.

Gary Rottman (U. Colorado-LASP), Thomas Woods (U. Colorado), George Lawrence (U. Colorado), Jerold Harder (U. Colorado), William McClintock (U. Colorado), Julius London (U. Colorado), Oran White (NCAR), Peter Fox (NCAR), Ray Roble (NCAR), Peter Pilewskie (NASA/Ames), Judith Lean (NRL), Dominique Crommelynck (Inst. for Meteorology), Belgium Paul Simon (Inst. for Aeronomy, Belgium), Claus Fróhlich (PMOD, Switzerland)

Goddard has been authorized to proceed with the implementation of SORCE by memo from the Associate Administrator of Earth Science on August 31, 1999. A cost cap of $112M has been specified, which includes science data processing. July 2002 is the baselined launch readiness date.

The first SORCE Science Team meeting was held August 26-27 in Taos, New Mexico. Gary Rottman, the SORCE PI from University of Colorado-LASP gave an overview of the mission, followed by presentations by each of the LASP instrument scientists - George Lawrence (TIM), Jerry Harder (SIM), Bill McClintock (SOLSTICE), and Tom Woods (XPS). Dominique Crommelynck of the Royal Met. Inst of Belgium described instrument intercomparison efforts, and Claus Fróelich of PMOD, Switzerland discussed the past record of TSI (Total Solar Irradiance).

Judith Lean of NRL talked about detection of long-term solar variations, and implications for SORCE. Dick White and Peter Fox of NCAR described algorithms for computing TSI and solar spectral variations from magnetograms and other solar image data.

Goddard Project Scientist Bob Cahalan discussed dependence of Earth's albedo and atmospheric absorption on TSI and solar spectra, and Peter Pilewskie of Ames Research Center described measurements of solar spectra within Earth's atmosphere.

Rottman has formally requested that Crommelynck, Frohlich, Lean and Pilewskie be added to the SORCE Science Team which, together with previous members from SOLSTICE and TSIM, brings the team to 13 members, 10 from the USA, 2 from Belgium and 1 from Switzerland.

A series of Space Shuttle flights, approximately one per year beginning in 2000, is being explored to intercompare TSI measurements by TIM with similar ones by ACRIM and SOLCON, to narrow the uncertainty in absolute calibration of TSI. A working group is being formed to handle the implementation and science objectives of the intercomparison, organized by Bill Ochs and Bob Cahalan of Goddard.

CEOS Working Group on Calibration and Validation Meeting on Digital Elevation Models and Terrain Parameters

— Ian Dowman (idowman@ge.ucl.ac.uk, University College London)
— Jeff Morisette (jeff.morisette@gsfc.nasa.gov, University of Maryland)
— Chris Justice (justice@maddux.evsc.virginia.edu, University of Virginia)
— Alan Belward (alan.belward@jrc.it, Joint research Centre, European Commission)

Introduction

On May 26 and 27, 1999 the Committee on Earth Observing Satellites' (CEOS) Working Group on Calibration and Validation held a meeting at University College, London. The WGCV provides an international forum for calibration and validation information exchange, co-ordination, and co-operative activities. The working group promotes the exchange of technical information and documentation, joint experiments, and the sharing of facilities, expertise, and resources among its members as appropriate. This pooling of international effort helps the CEOS WGCV to promote standards and allows all to benefit from hard-won experience. It helps avoid duplication and overlap, while encouraging synergy.

The focus of the May meeting was on production and validation of both Digital Elevation Models (DEMs) and terrain parameters, as derived from spaceborne sensors. These two major components are summarized below. For more information on the meeting see http://wgcv.ceos.org.

DEMs

The DEM sessions covered a variety of topics, but with an emphasis on using Synthetic Aperture Radar (SAR) data. Andy Sowter discussed the automatic generation of DEMs from Stereo SAR and noted that a key issue is to produce an affordable product that satisfies user needs and minimizes use of ground control. He also stressed the need for calibration/validation of orbit data. Laurent Polidori gave a paper on accuracy considerations for DEMs over equatorial forests where well-planned collaborative projects, which make use of all available information, can give a very wide range of information. Christian Staetter emphasized this point in discussing high fidelity DEM generation using PAN and multispectral image data. Wolfgang Noack reported on the use of X-SAR on SRTM and gave a number of examples of the quality that can be obtained and how cartographic techniques such as hill-shading can aid visualization. Other papers discussed DEMs for hydrological modeling (Alec Walker), the comparison of slope estimates from low resolution DEMs (Nick Drake), and segmentation of multitemporal SAR (Douglas Corr). A general paper by Polidori asked a number of fundamental questions on the use of SAR data: What is the most useful new research needed for SAR? Can we trust the technical literature concerning the operational status of SAR algorithms? Why are there no clear standards for SAR image quality at the user level?

In the course of the papers and discussion a number of issues were raised that suggest action at the level of the CEOS Plenary. One pressing problem resulting from the acquisition of global data sets, such as from SRTM, is how to obtain a well-distributed coherent set of ground control points. It was also noted that more international collaboration was required in the area of data fusion and synergistic use of sensors, the development of test sites and control data, and on an agreed statement of sources of error and quality requirements.

A number of actions were agreed for the Terrain Mapping subgroup to take forward:

- prepare recommendations for the establishment of a global GCP network;
- consider how orbit validation could be developed;
- update current status of sensors;
- produce a statement of DEMs available; and
- produce a DEM requirements document with a science rationale, taking into account the output from SRTM.

Terrain Parameters

The review and exchange of calibration and validation information for terrain parameters covered a broad spectrum of issues, ranging from reviewing established land cover accuracy assessment results (Alan Belward on IGBP landcover validation and John Taylor's results from the MARS project), to current plans for validation of higher order biophysical products (EOS/MODIS validation plans by Chris Justice and Jeff Morisette and validation activities in Australia presented

by Fred Prata). In addition to specific validation activities there were presentations related to planned missions (IKONOS by Nick Kladian and Envisat by Yves-Louis Desons) and sampling strategies with various global tessellations (Tim Richards). The Global Observations of Forest Cover (GOFC), presented by Frank Ahern in the context of the Integrated Global Observing Strategy (IGOS), emphasized the importance of the global perspective in thematic product validation. CEOS GOFC provides an operational pilot activity for the provision of spaceborne data for various aspects of forest cover monitoring (http://www.gofc.org/gofc). One important focus for the GOFC project is to secure the provision of data sets needed to quantify forest cover extent and rates of change to address outstanding questions of the global carbon cycle.

Through the presentations and related discussions on terrain parameters, the WGCV reached the conclusions that WGCV should initiate a Validation Sub-Group within CEOS WGCV, which would focus on validation of land products. The primary goals of the sub-group would include:

- promoting the quantification and characterization of satellite land product accuracy;
- sharing land product validation past experience and lessons learned;
- moving towards the generation of 'standardized products with known accuracy' from similar sensing systems in the context of data continuity;
- establishing relationships between like products - e.g. V.I.s;
- developing traceable *in situ* validation measurement standards and protocols;
- coordinating international validation activities; and
- improving access to validation data sets.

There is an opportunity to use the CEOS GOFC project as a test-bed for developing improved land product validation coordination. This would not only contribute to the credence of the GOFC products but also allow the WGCV to assess gaps, overlap, and redundancy in observation requirements arising from the validation implications of the developing IGOS. This opportunity could be addressed by a CEOS calibration/validation initiative on product validation for selected GOFC products, e.g.:

- Leaf Area Index (LAI);
- Fraction Absorbed Photosynthetically Active Radiation (fAPAR);
- Active Fire, Burned Area;
- Land Cover Type and Characteristics (continuous fields, land cover change);
- Forest Biomass; and
- Net Primary Productivity.

This would build on current and planned land product validation initiatives.

Spring 2000 was set as a target date for a first meeting of the Validation Sub-group. The focus will be on validation of products associated with GOFC. The meeting would include a generic session of invited papers on validation concepts/approaches and presentations on the GOFC product suite (with a focus on standardizing products and product validation). It was also recommended that the meeting include break-out sessions to discuss: a) *in situ* measurement protocols, b) validation sites, and c) data access for various product suites (such as the selected products listed above). Invitees should represent the different moderate and high resolution, as well as SAR, instruments contributing to GOFC. Appropriate linkages would be made with other related international coordination such as the Global NPP activity of the Terrestrial Observation Panel for Climate (TOPC).

(Note: Following the meeting Jeffrey Privette, EOS MODIS Land Validation Program, NASA Goddard Space Flight Center, and Stefan Dech, German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Oberpfaffenhofen, agreed to co-chair the new WGCV sub-group. NASA and DLR have kindly agreed to support them in their roles as joint co-chairs.)

WGCV has made important contributions to the process of international co-operation ensuring long-term confidence in the accuracy and quality of Earth Observation data and products. Users benefit from better quality data, better documentation and sustained commitments to provide calibration updates. Developments such as IGOS (and the GOFC pilot project) raise the stakes even higher. A forum for progress review, for verifying the quality of terrestrial products, for proposals for future developments and to optimize exploitation of the products is needed, and meetings such as that proposed for spring 2000 represent excellent opportunities to strengthen the international co-operation on which global scale activities so clearly call.

Conclusion

As the land remote sensing community starts to pay increased attention to data quality and accuracy through product validation, an international validation coordination mechanism has considerable appeal. The space agencies and land remote sensing community will benefit from sharing experience and resources associated with the collection and sharing

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NASA EOS Validation via SAFARI 2000: Preparing the Way

— Michael King (king@climate.gsfc.nasa.gov), NASA Goddard Space Flight Center
— Tim Suttles (tim.suttles@gsfc.nasa.gov), Raytheon ITSS Corporation

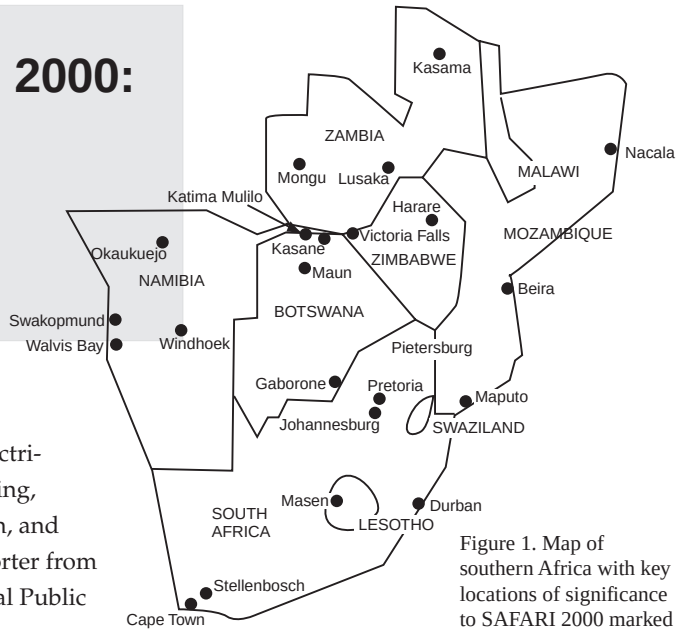

Figure 1. Map of southern Africa with key locations of significance to SAFARI 2000 marked

During July 8-24, 1999, a team of U.S. and South African scientists visited southern Africa as part of preparatory work leading up to the Southern Africa Regional Science Initiative 2000 (SAFARI 2000). SAFARI 2000 is an international regional science initiative being developed to explore, study, and address linkages between land-atmosphere processes and the relationship of biogenic, pyrogenic, or anthropogenic emissions and the consequences of their deposition to the functioning of the biogeophysical and biogeochemical systems of southern Africa. This initiative is being built around a number of on-going, already funded activities by NASA, the international community, and African nations in the southern African region. The largest component of SAFARI 2000 is a regional field experiment to be conducted in southern Africa from August-September 2000.

Figure 1 shows the locations of principal activities during SAFARI 2000, many of which were visited during a tour of the region in July 1999 by U.S. and South African scientists.

a. Cape Town and Stellenbosch, Republic of South Africa (RSA) (July 8-9)

During July 8-9, Michael King and Tim Suttles visited (i) the Department of Oceanography, University of Cape Town, (ii) the Department of Electrical & Electronic Engineering, University of Stellenbosch, and (iii) met with a radio reporter from the South African National Public Radio.

Figure 2. Table Mountain towering over Cape Town, South Africa.

Meetings were held at the University of Cape Town with Profs. Chris Reason and Mathieu Rouault. Prof. Reason is an oceanographic modeler interested in the retroreflection of the Agulhas Current and its interaction with the Benguela Current off the Namibian coast. Michael King demonstrated the QuikScat Web page showing how to obtain SeaWinds measurements from NASA's recently launched satellite to validate the winds produced by Reason's model. Reason was also interested in sea surface temperatures, presently produced by AVHRR and to be produced later this year by MODIS, and ocean altimetry that is produced by TOPEX/Poseidon. Mathieu Rouault described his interests in rainfall variability, convective systems embedded in southern Africa, and validation of regional atmospheric models. Rouault and his team are interested in and are currently working with TRMM data.

A special visit was made to the University of Stellenbosch to get an update on results from South Africa's first satellite (SUNSAT), designed and built by students at the University of Stellenbosch and

launched by NASA earlier this year. On the day of the visit, the University managed to acquire their first image from the satellite, and they provided a high quality print of it to take back to Dr. Ghassem Asrar. They are having communication problems with the satellite, so they are only able to bring down low-data-rate, quick-look images of a small portion of a scene from any given orbit. If they like the scene that was acquired, they can download the entire scene (60 × 60 km), but this can only be accomplished over a 7-day period! From an educational point of view, however, this was a good project for Stellenbosch. Ninety-six staff members and students worked on the project and 46 M.S. theses were written on SUNSAT. What is lacking is onboard or preflight calibration, which is a major impediment to achieving quantitative science from the mission.

Finally, while in Cape Town, King and Suttles met with John Richards, a reporter from South Africa's National Public Radio. They discussed NASA's Earth Observing System, global change, ship tracks, the Earth's radiation balance, and finally NASA's interest in southern Africa (i.e., SAFARI 2000). Richards taped interviews with King and Suttles separately, which were subsequently broadcast throughout South Africa.

b. Johannesburg and Pretoria (July 12-13)

During July 12-13, King and Suttles visited Johannesburg and Pretoria, and had a busy schedule that included:

Visit to the University of Witwatersrand (WITS), in Johannesburg

- Met with Prof. Harold Annegarn and Stuart Piketh on aircraft and landing facilities in Kruger National Park and Pietersburg, South Africa; inspection tour details for Botswana, Zimbabwe, Zambia, and Namibia; and the planned Gaborone SAFARI 2000 implementation workshop.

- Met with the Prof. Leila Patel, Deputy Vice Chancellor of WITS, along with senior faculty and staff.

- Discussion with WITS faculty and students involved in SAFARI 2000, including Prof. Charlie Mather (Geography; image processing), Prof. Spike McCarthy (Geology; expert on Okavango Delta), and Juliao Cumbane, Coleman Dube, and Abel Sakhau (students).

- Lunch at Hofmeyer House staff club with Profs. Mary Scholes (Life Sciences), Helda Marks (Chemistry and Deputy Dean of Science), June Meeuwis and Peets Wolvaardt (Geography & Environmental Sciences, Rand Afrikaans University), Dr. Gerhard Held (Eskom TRI–research labs of electric utility), and Luanne Otter (CSIR).

Visit to St. John's College

- Michael King and Tim Suttles gave lectures to the faculty and students of St. John's College, a prestigious all-boys private high school in Johannesburg (see Figure 3). The lectures described EOS, global change (land cover and land use change, ozone depletion, global warming), and SAFARI 2000.

Visit to U. S. Embassy of South Africa

- Meeting with Atim Ogunba (Environmental Science & Technology Officer, U. S. Embassy), Luanne Otter and Ike Lombard (scientists and international coordinators from CSIR), Ferdi van der Walt (International Officer, National Research Foundation), Nico Kroese (South African Weather Bureau), Bob Swap (University of Virginia and U. S. Coordinator of SAFARI 2000), and Prof. Harold Annegarn (WITS and RSA coordinator of SAFARI 2000).

- Discussed aircraft overflight clearance, customs waivers and use of Carnet de Passage, shipping of consumables to RSA (radiosonde balloons), and current schedule.

Visit to Department of Transport

- Meeting with Johann Bierman (Section Manager, Air Transport Regulation) who is responsible for all bilaterals and licensing of foreign aircraft operations over RSA.

- Bierman expressed willingness to facilitate aircraft flight operations of the NASA ER-2, Proteus, and University of Washington CV-580 over RSA, and support of SAFARI 2000 in general.

Visit to Satellite Applications Centre (SAC), CSIR Mikomtek

- Visited the SAC outside Pretoria, to get a better understanding of the role of this organization within RSA, which now includes receiving, archiving, and distributing data from Earth observation satellites throughout southern

Figure 3. Michael King, Tim Suttles, Sandy Heather, and Lorraine Tandt at St. John's College following lecture to faculty and students.

Africa. The SAC has a large satellite tracking dish, which could be used for direct broadcast of Terra and PM data, and has in the past been used to receive Landsat 4 and 5 TM data. The Pretoria station has been used for global launch support and tracking for NASA, ESA, CNES, DLR, and Russian Space Agency spacecraft. SAC has an extensive archive of data from Meteosat (1977-1995), NOAA (1984-), Landsat MSS (1989-), Landsat TM (1989-), Spot (1989-) and ERS-1 and -2 (1994-).

c. Gaborone, Botswana (July 14-15)

On July 14, King, Suttles, and Bob Swap traveled from Johannesburg to Gaborone via the South Africa Weather Bureau (SAWB) Aerocommander 690A aircraft. The group was met at the airport by a Professor of Physics at the University of Botswana (UB) and driver, and immediately transported to UB for a scheduled seminar. King and Suttles gave a combined seminar entitled 'New Remote Sensing Data Coverage for Southern Africa—The SAFARI 2000 Experience,' with King describing EOS and global change science while Suttles followed with a description of SAFARI 2000 and current plans for southern Africa. The seminar was attended by 60 students and faculty members, and was hosted by Prof. Susan Ringrose of UB.

Additional meetings held in Gaborone included:

- Visit with Mr. Masego Mphathi, Director of the Department of Crop Production and Forestry, Ministry of Agriculture.

- Dinner with Prof. Sharon Siverts, Vice Chancellor of the University of Botswana, and senior administrative staff of UB.

U. S. Embassy

- Met with Robert Krueger (U. S. Ambassador to Botswana), Scott DeLisi (Deputy Chief of Mission), and David Franz (Political-Economic Officer), to discuss SAFARI 2000 and requirements for ground-based measurements, data processing, and airborne operations in Botswana.

U. S. Agency for International Development (USAID)

- Met with Ed Spriggs (Director), Anthony Vance (Deputy Director), Candace Buzzard (Project Manager, Natural Resources Management Project), Raymond Morton (Chief, Agriculture & Natural Resources), and Robert Buzzard (Program Management Specialist), to discuss SAFARI 2000 and ways in which USAID could contribute immeasurably to the success of SAFARI if they (i) supported a data center and training center for the southern Africa region at UB, and (ii) supported scientists from southern Africa north of South Africa who want to participate in SAFARI 2000 but who have no financial support to participate.

- Visit with Mr. A. V. Lionjanga, Permanent Secretary, Ministry of Works, Transport and Communications, who suggested the University of Washington might prefer to operate its aircraft from Maun, Botswana, rather than Victoria Falls, Zimbabwe; his ministry approves overflight and operation of foreign aircraft in Botswana.

- Visit Mr. I. Muzila, Principal Hydrological Engineer, Department of Water Affairs, Ministry of Minerals, Energy, and Water Affairs, to brief him on goals of SAFARI 2000.

d. Maun and Okavango Delta, Botswana (July 16-17)

On July 16, Michael King, Tim Suttles, Harold Annegarn, Bob Swap, and Steve Platnick departed Gaborone via the SAWB Aerocommander 690A on a tour of proposed SAFARI 2000 measurement sites. En route to Maun, Botswana, the group overflew the Makgadikgadi Salt Pan of Botswana. At Maun, a meeting was held with the assistant aircraft manager to assess the feasibility of operating the CV-580 from this airport; though feasible, it was later determined that it was too far from the primary sampling sites near Mongu, Zambia. A trip was made via 4-wheel drive vehicle to the Maun tower (cf. Fig. 4), which is operated by the Max Planck Institute in Germany on real estate owned by the University of Botswana. This is a possible site for locating an AERONET sunphotometer as well as additional solar radiation measuring equipment.

Figure 4. Tower in Maun, Botswana.

Over the weekend a visit was made to the Okavango Delta, the largest inland delta in the world, to experience the wildlife of southern Africa (Bob Swap and Tim Suttles were charged by a hippopotamus, which fortunately turned back at the last moment).

e. Victoria Falls, Zimbabwe and nearby Zambesi River, Zambia (July 18-19)

After briefly landing in Victoria Falls and clearing customs, King, Suttles, Annegarn, and Platnick flew on the Aerocommander over Victoria Falls and along the Zambesi River to Mongu, the site of one of the EOS flux towers (Jeff Privette, Goddard Space Flight Center, is principal investigator). The environment includes the miombo woodland of Mongu, nearby grassland, and riverbed of the nearby Zambesi. This site will be overflown quite often by the ER-2 and the CV-580, and will be coordinated with many Terra overflights during SAFARI 2000. Many, many fires were observed en route to Mongu, along with a well-mixed boundary layer with a uniform, plane-parallel, haze layer overlying essentially all of western Zambia. Before departing Zimbabwe, a meeting was held with Jerry Ndlovu, Director of the Victoria Falls airport. Although Ndlovu was quite enthusiastic about SAFARI 2000 and hosting the CV-580 for two weeks during the experiment (September 2000), the group felt that Zimbabwe was not a good area to operate any U.S. aircraft. This opinion is based on the following considerations:

- There is a $30 (U.S.) entry visa required to enter Zimbabwe, and a $20 departure tax.

- The hotel charges in Zimbabwe were based on the country the guest was from, and U.S. guests were charged an extremely high amount ($283 for a single).

- Phones did not work for most of the day we were at Victoria Falls, and it took over an hour to use a Visa card to get $20 U.S. converted to Zimbabwe dollars; the use of phones, faxes, and e-mail would more than likely be difficult to use reliably in Zimbabwe.

f. Kasane, Botswana and Katima Mulilo, Namibia (July 20)

With the realization that Maun was too far from Mongu to effectively operate the CV-580 during the central part of SAFARI 2000 (cf. Fig. 1), and with the additional difficulties in Zimbabwe associated with excessively high per diem rates, poor phone lines, and an unwelcoming government to foreign visitors, the SAWB Aerocommander pilots recommended two alternative locations for the CV-580 (Kasane, Botswana and Katima Mulilo, Namibia).

A flight was made from Victoria Falls to Kasane to check out the airport facilities. Unfortunately this visit occurred on a Botswana holiday and the airport manager was not available. Nevertheless airport facilities appeared to be quite adequate, only 50 km or so west of Victoria Falls, and much cheaper to operate from than Victoria Falls. In addition, this is a most interesting location next to the Chobe River and Chobe National Park, which has the largest elephant herds on Earth. The Botswana government, including the U.S. Embassy, is more than willing to host activities in Botswana, and the landing fees and parking fees are $50 in Botswana, compared to $80 in Zimbabwe and $40 in Namibia. The disadvantage is that there is really no office space available at the airport, unlike Maun and Victoria Falls, and the parking area is small and would have to be set aside for the CV-580 to have clear rights to a regular parking space on the tarmac. This is being pursued.
Due to a tight schedule, a visit was not made to Katima Mulilo. However, it was learned later from the airport manager of Walvis Bay, Namibia, who is Director of all regional airports in Namibia, that it may be a good operating base for the CV-580. The Director indicated he could guarantee a hangar and office space, and that the runway was quite long and the town very nice. It is located on the Zambesi River across from Zambia and due south of Mongu. Hence, it is also a practical place to operate from. Unfortunately, a couple of weeks after this visit, there was a separatist uprising in Katima Mulilo, which is located in the Caprivi Strip of Namibia between Botswana and Zambia, and 16 people were killed. Before operating from this location, the political situation would need to be re-evaluated.

g. Namibia (July 20-22)

After leaving Kasane, the group flew to Ondangwa, Namibia (near the Angola border) to clear customs, and then flew to Etosha National Park. Enroute the aircraft overflew the Etosha Pan, the largest salt pan in Africa (110×60 km), to assess its uniformity as a ground calibration target for MODIS and MISR and as a uniform ecosystem for making measurements of the bidirectional reflectance factor from the CV-580. An AERONET sunphotometer will be located at Namutoni on the eastern edge of the pan during the experiment, along with a sodar from the University of Virginia (Mike Garstang).

Wilfred Versfeld, Director of the Etosha Ecological Institute, met the group at Okaukuejo, the largest guest camp at Etosha, which means 'Great White Place'. The next day (July 21), a meeting was held

with Johann le Roux, who is the satellite remote sensing expert at Etosha. He has long been collecting AVHRR 1-km data over northern Namibia, and showed the seasonal variability of reflectance of the pan, which is much brighter in the west (near Okaukuejo) than in the east (near Namutoni). In addition to the biomass burning smoke that is well mixed in the boundary layer and which originates from the north (Angola and western Zambia), there is a persistent low-level wind from the east during the day that picks up dust from the pan and blows it west over the Atlantic Ocean. King expressed an interest in setting up an AERONET site at this location in the west, as well as placing Si-Chee Tsay's surface radiation network at this location.

In the afternoon, a trip was made to the pan itself, where it was observed that the pan is nonuniform, and has most unusual reflectance characteristics. It was generally quite dark looking in the direction of the sun (no sunglint or Fresnel reflection), and quite bright looking away from the sun (especially bright in the backscattered direction). None of the group had ever seen any natural surface with these characteristics, and hence collected samples of the pan and returned them to Goddard so that Jim Butler could make measurements of the BRDF in his state-of-the-art diffuser laboratory.

The tour continued with a flight from Etosha to Windhoek for a meeting at the U. S. Embassy with Harmony Caton, Third Secretary/Vice Consul and Major Nichols, Air Attaché. They were very supportive of SAFARI 2000 and likely to be of much value in helping to work out the aircraft overflight and basing permissions in Namibia and in helping to execute a letter agreement to operate the CV-580 in Namibia.

The group then flew from Windhoek to Walvis Bay, Namibia overflying the red sand dunes of the Namib Desert (the tallest sand dunes on Earth, at 1000 feet), at a height of 100 to 200 feet above the dunes. At Walvis Bay, a meeting was held with the airport manager, Mr. D. F. Booysen, who was exceedingly supportive of the CV-580 operating from this field. He is the one who pointed out the virtues of Katima Mulilo as well, which would simplify the letter agreement from NASA to Namibia if the UW aircraft were to operate at two bases in Namibia as well as Pietersburg, RSA. The airfield was quite long, and there were adequate facilities for operation for the final component of SAFARI 2000, which involves overflights of the Namibian stratus clouds that occur over the Benguela Current off the Namibian coast in September.

h. Johannesburg (July 23-24)

On July 23, the group flew from Walvis Bay to Johannesburg. That evening Michael King gave an invited Prestige Lecture at the National Awards Ceremony of the Associated Scientific and Technical Societies (AS&TS) of South Africa, an amalgamation of 94 professional societies of science and engineering throughout South Africa, consisting of some 40,000 members. The lecture was entitled 'NASA Earth Observation Programs: Past, Present, and Future.' For this formal black tie and highly publicized event in RSA, King used the electronic theater developed by Fritz Hasler, manager of the Visualization & Analysis Laboratory (VAL), at NASA Goddard. Staff of the VAL, including Jesse Allen, Barbara Summey, Mike Manyin, and Reto Stockili, supported this activity and prepared the following animation sequences:

- Meteosat colorized still (Merit Jentoft-Nilsen, VAL).
- Terra launch and deploy (with Australia background, rather than Vandenberg; Reto Stockili, VAL).
- Landsat band combination illustration with San Francisco, including digital elevation of the mountains in the Bay area (Jesse Allen, VAL).
- Landsat 7 ETM+ flyover of Cape Town, RSA (Jesse Allen, VAL, based on data and animation work done at the Science Visualization Studio [SVS]).
- Africa 1 km land use classification still (Yuhong Tian and Ranga Myneni, Boston University).
- Global 1 km AVHRR imagery for both ocean and land (National Geographic and JPL).
- NDVI seasonal coverage of the U.S. (left screen) and Africa (right screen) animated over a 1 (U.S.) and 2 (Africa) year period, showing similarity in greening up and drying out of both continents in series (Mike Manyin, VAL).
- 17 years of monthly NDVI averages for Africa (Jesse Allen, VAL, based on data and animation work done at the SVS).
- TRMM miracle swath containing Precipitation Radar (PR) data over 4 hurricanes (Greg Shirah, SVS).
- El Niño with SST, surface topography, and vector winds (Greg Shirah, SVS).
- MODIS Airborne Simulator (MAS) cycling of 50 bands over a biomass burning fire in Brazil, comparable to what is expected during SAFARI 2000 in Zambia (Rob Simmon, Earth Observatory/GSFC DAAC).

- MAS flyover of fire in Brazil (Barbara Summey, VAL).

This 50-minute lecture was extremely powerful, and had a very significant impact on the diverse audience of engineers, scientists, and spouses, and was very well received. Credit goes to Jesse Allen, Fritz Hasler, and Barbara Summey for pulling this material together for presentation in a forceful and effective manner.

The following day, prior to returning to the U.S., Michael King was invited to give one more lecture, this time for 1.5 hours and to 500 public high school teachers from Gauteng province (particularly Soweto, Johannesburg, and Pretoria). Much of the animation from the previous evening was used (cf. Figure 5), eliminating only the MAS flybys of Brazil as too technical. This was followed with presentations on ocean processes (SST, vector winds, ocean color, and topography) and land processes (especially hydrology) from the EOS poster series using vugraphs, and concluded with a description of ship tracks as observed by AVHRR and visualized by the RC-10 camera on the NASA ER-2 aircraft.

NASA Earth Science Enterprise educational materials were distributed to the teachers for use in the classroom. The educational materials included copies of each of the EOS science theme posters (7 in the series), along with fact sheets and other science brochures. The EOS posters, first produced in 1994, are still being requested today over the Web at a rate of 400 per day! The EOS Project Science Office has just completed an educational CD-ROM based, at least in part, on the poster series but much expanded, with an accompanying teacher's guide. This will be sent over to South Africa shortly.

After returning from the visit, Michael King received the following message from Prof. Rosemary Falcon, president of AS&TS, the society that hosted the event in Johannesburg:

'I must tell you that you left a trail of enormously excited people here, many of whom cannot wait until you get back! You had such a marvelous manner of presentation, delivered with such skill, conviction and obvious enjoyment. For this may I now thank you so very much, and also for all the trouble that was taken to mount the special lecture and the Electronic Theatre, including the presence of Jesse Allen. Please would you pass this on to the powers-that-be that took all the trouble to make this all happen?

It may interest you and your colleagues to know that your lecture kicked off a wonderful initiative. In other words, the importance of it provided the occasion for many different people to meet who would never normally do so, and, from that occasion, to realize that there is so much to do in this country - but altogether, and for a major common cause - namely, the use of science, engineering and technology in the study and improvement of the environment for the betterment of all mankind. The repercussions for this country were and are continuing to be many fold, and not just in the technical aspects! I hope to be able to report to you more on this in the near future. All in all, your lecture was indeed a major step, in many directions.'

In conclusion, this was a most effective trip to southern Africa in many regards, and leads to the expectation that the experiment being planned for southern Africa next year will be a great success. The region is poised to work with NASA and the international scientific community.

Figure 5. Michael King showing El Niño animation during lecture to 500 public school teachers in Johannesburg (photo courtesy of Antony Cowey, Editor, Information and Communications Division, Mintek.)

SHADOZ (Southern Hemisphere ADditional OZonesondes): A New Ozonesonde Data Set for the Earth Science Community

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1. Why and What is SHADOZ?

In the past 5 years, new tropical tropospheric ozone data products have been developed from TOMS and other satellites [Fishman and Brackett 1997; Hudson and Thompson 1998; Ziemke et al. 1998]. Also, during this period, many global chemical-transport models have been developed for interpretation of satellite data and to predict future ozone levels in the troposphere and stratosphere.

The lack of independent ozone profile measurements for evaluation of satellite data and models is critical in some regions. At least a dozen southern hemisphere tropical sites have operated balloon-borne ozone instrumentation (ozone sondes) in the past decade, but sampling frequencies vary and operational periods are often sporadic. When Earth-Probe TOMS was launched in mid-1996, only four of these sites were operational.

In 1998, the Goddard Space Flight Center with its Wallops Flight Facility and NOAA/CMDL (Climate Monitoring and Diagnostics Laboratory), began a 2-year project to collect a consistent set of measurements by augmenting ozonesonde launch frequencies at southern hemisphere tropical sites and making the data available to the scientific community at a single electronic location - the SHADOZ website in the Atmospheric Chemistry and Dynamics Branch at Goddard: http://code916.gsfc. nasa.gov/Data_services/Shadoz/shadoz_hmpg2.html

2. Where are SHADOZ sites?

Stations in SHADOZ include four islands in the Pacific: Fiji, Tahiti, Galapagos and American Samoa. Two sites are at and in the Atlantic: Natal (Brazil) and Ascension Island. Three other sites span Africa (Nairobi and Irene, near Pretoria, South Africa) and the Indian Ocean (Réunion Island and Watukosek in Java, Indonesia). Table 1 lists coordinates and the SHADOZ Co-Investigator responsible for each site. Figure 1 shows the clickable map that appears on the SHADOZ website. All SHADOZ sites were operational at the initiation of the project. A guiding principle is to enhance sonde launches and data at facilities on a cost-share basis with an international partner. It is hoped that wider dissemination of data and interaction with users and field projects will leverage local funding to maintain

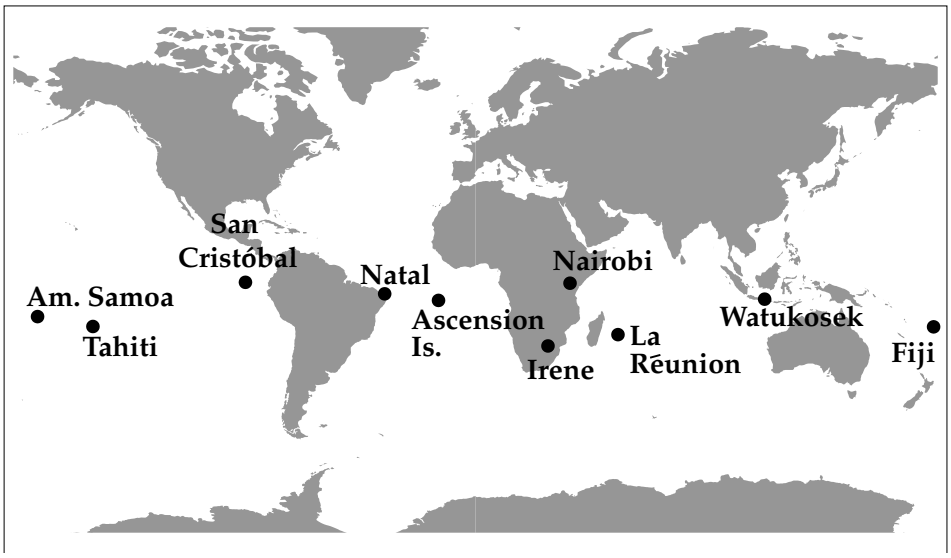

Figure 1. SHADOZ stations as they appear on the website.

The SHADOZ homepage gives technical information for each station, a clickable site map, addresses and email for Co-Investigators. Co-Investigators are responsible for original data processing and should be consulted for details of method and appropriate references to their work. The website is: http://code916.gsfc.nasa.gov/Data_services/Shadoz/shadoz_hmpg2.html.

Questions about data should be directed to the datakeeper and webmaster: Jacqueyn Witte: witte@gavial.gsfc.nasa.gov. Questions about SHADOZ should be directed to Anne Thompson: thompson@gator1.gsfc.nasa.gov

SHADOZ Sites	Lat./Long. (deg)		Co-I
Pago Pago, A. Samoa	-14.23	-170.56	Samuel Oltmans (NOAA/CMDL)
Papete, Tahiti	-18.00	-149.00	Samuel Oltmans (NOAA/CMDL)
San Cristóbal, Galapagos	-0.92	-89.60	Samuel Oltmans (NOAA/CMDL)
Natal, Brazil	-5.42	-35.38	Volker Kirchhoff (INPE)
Ascension Island	-7.98	-14.42	Francis Schmidlin (NASA/WFF)
Irene, South Africa	-25.25	28.22	Gerrie Coetzee (SAWB)
Nairobi, Kenya	-1.27	36.80	Bruno Hoegger (Aer. Sta., Payerne)
La Réunion	-21.06	55.48	Jean Leveau (Univ. Réunion)
Watukosek, Indonesia	-7.50	112.60	Toshihiro Ogawa (NASDA/EORC)
Suva, Fiji	-18.13	178.40	Samuel Oltmans (NOAA/CMDL)

Table 1.

infrastructure and operations. Originally planned for the 1998-1999 period, most sites will contribute SHADOZ data through 2000.

Note:
SHADOZ data sets are products of evolving research by the site Co-Investigators and ongoing community collaboration. As you work with the data, please keep us and site Co-Is posted on issues that will help us improve the value of the data. In 2000, the 1998-1999 SHADOZ data will be available on a compact disc.

Current sampling at all stations is once-per-week or twice monthly, usually, but not always, mid-week. Balloon-borne ozonesondes are coupled with a meteorological radiosonde for data telemetry, transmitting air pressure, air and pump temperatures, relative humidity, and ozone to a ground receiving station at 1-second intervals. Figure 2 gives an example of a typical sounding from Ascension Island (8°S, 14°W), which was taken by the US Air Force and processed by Dawn Holdren and Tom Northam (SESI) at Wallops Fight Facility.

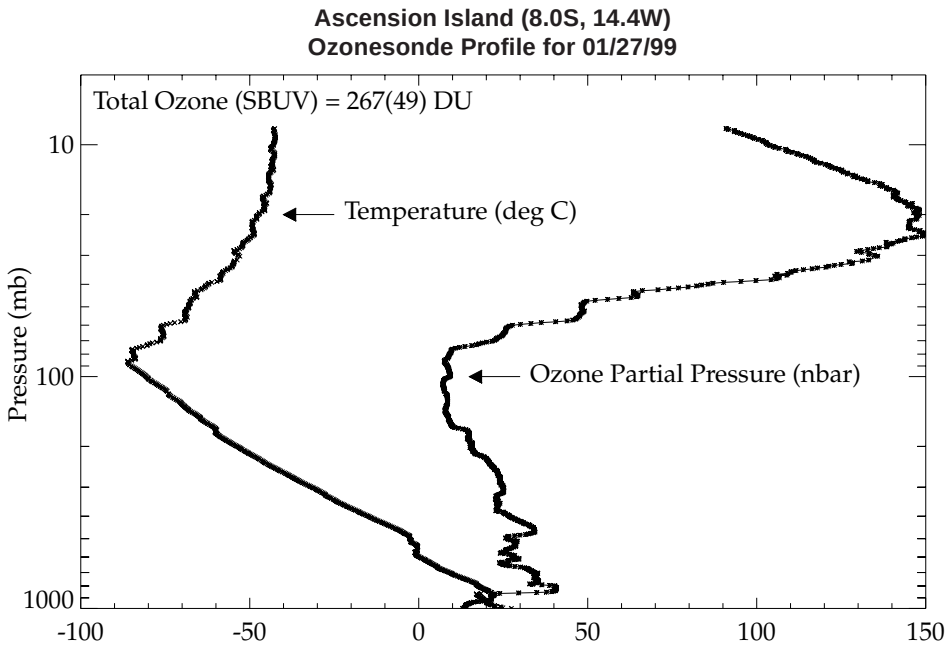

Figure 2. Typical ozonesonde profile viewable on SHADOZ website shows ozone and temperature profiles from the surface to 7 mb. Ozone is measured by the electrochemical concentration cell (ECC) method.

3. Multiple Applications for SHADOZ Observation

SHADOZ observations are already being used by modelers and researchers preparing satellite ozone data sets (Figure 3). SHADOZ is designed to meet other needs of the Earth science community as well:

(1) Provide the first climatology of tropical ozone along the equatorial zone for the study of atmospheric processes like the wave-one pattern in total ozone [Shiotani 1992; Kim et al. 1996]. Until SHADOZ, no comparable data set existed with extensive coverage through the Pacific, Indian and Atlantic regions.

(2) Supplement field project observations. For example, the 1998-1999 sondes at American Samoa, Fiji and Tahiti came from the GTE/PEM -Tropics (Global Tropospheric Experiment/Pacific Exploratory Mission) experiment. The Irene site will launch sondes more frequently than usual as a SAVE (Southern African Validation for EOS) component during SAFARI-2000.

(3) Improve ozone profile climatologies for TOMS, SBUV and SAGE II satellite retrievals. The current tropical data are based on a very limited number of soundings. SHADOZ will also guide algorithm development for future satellite instruments, e.g., SAGE III, QuikTOMS, OMI, SCHIAMACHY, HIRDLS, TES.

(4) Serve as a resource for scientists and educators in southern hemisphere tropical locations, some of which are developing more scientific research capacity.

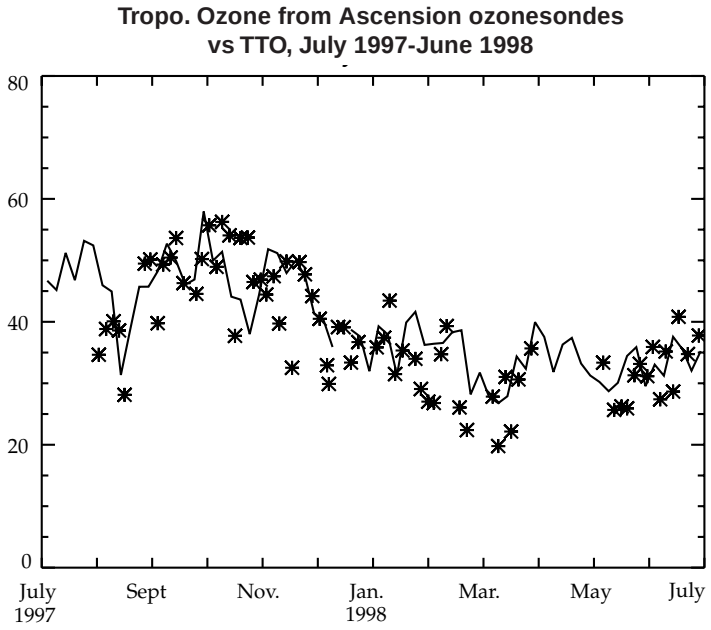

Figure 3. Ascension Island integrated tropospheric column ozone (stars) with tropospheric ozone derived from TOMS by the modified-residual method. Column-integrals in Dobson Units (DU). Adapted from Thompson and Hudson [JGR, in press, 1999]. Real-time maps of tropical tropospheric ozone by the modified-residual method appear on http://metosrv2.umd.edu/~tropo. At the same website, twice-monthly maps of tropospheric ozone (20N-20S, 1x2 degrees) for 1979-1992 are available in digital form.

4. Additional SHADOZ Data Sets - Experiments of Opportunity

From time to time, intensive tropical campaigns are making data available to SHADOZ. The first half of 1999 added data from several special field projects. GSFC supplied some of the ozonesondes launched daily in the Maldives (5N, 73E) during the INDOEX (Indian Ocean Experiment) in January through March 1999. The data will become part of the SHADOZ archive, as will half a dozen sondes launched by SOWER (Stratospheric Ozone and Water in the Equatorial Region) at Christmas Island in the Pacific (2N, 157W) during the NASA PEM-Tropics experiment in February and March 1999. Perhaps the most unusual augmentation of a SHADOZ data set is from the NOAA Research Vessel Ronald H. Brown, on which 22 sondes were launched by SHADOZ Principal Investigator Anne Thompson between Norfolk, Virginia, and Cape Town, South Africa, in January and February 1999 (see Figure 4 and 5). Ozonesondes aboard ship have been launched between Europe and South America and Africa, but SHADOZ data are taken from the first North America to Africa cruise with ozonesondes. James Johnson of the NOAA/Pacific Marine Environmental Lab in Seattle added five soundings between Cape Town and Mauritius, as the Ronald Brown continued eastward from Africa on its way around the world.

5. Summary

SHADOZ attempts to set an example for timely public distribution of much needed radiosonde and ozonesonde data, foster further interaction amoung modelers, satellite investigators, SHADOZ Co-Investigators, students and educators. By demonstrating the value and desire for ozone data among the Earth science community, SHADOZ hopes to inspire participant countries and agencies to maintain their sites for scientific research, monitoring, and education. At the conclusion of the SHADOZ project, the sonde data will become part of the WOUDC (World Ozone and Ultraviolet Data Center) archive in Toronto.

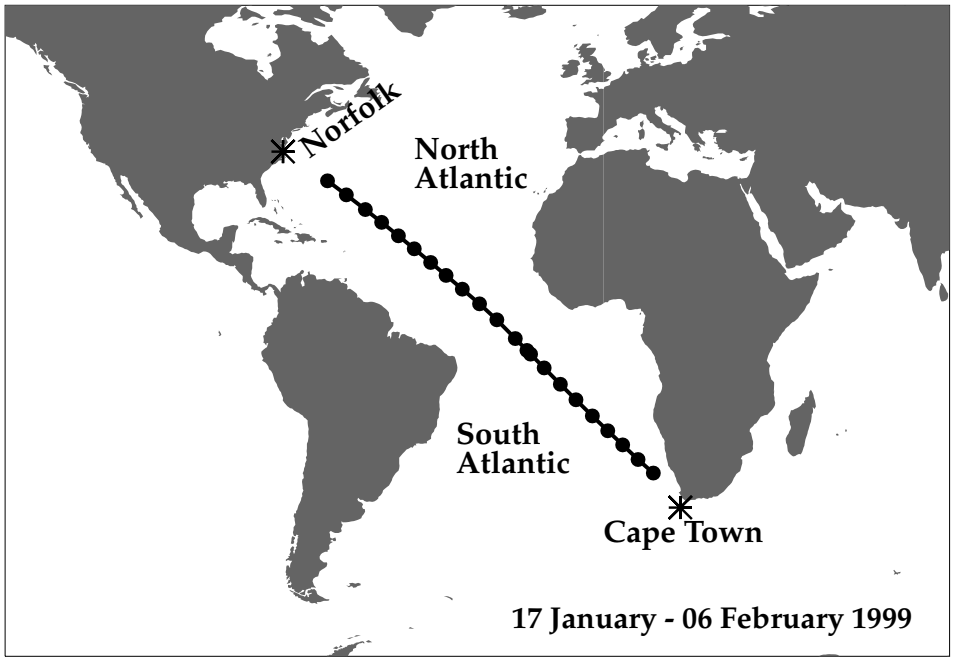

Figure 4. The Atlantic segment of the R. H. Brown ship track. The solid circles show the location of each of the 22 ozonesonde launches.

Acknowledgments

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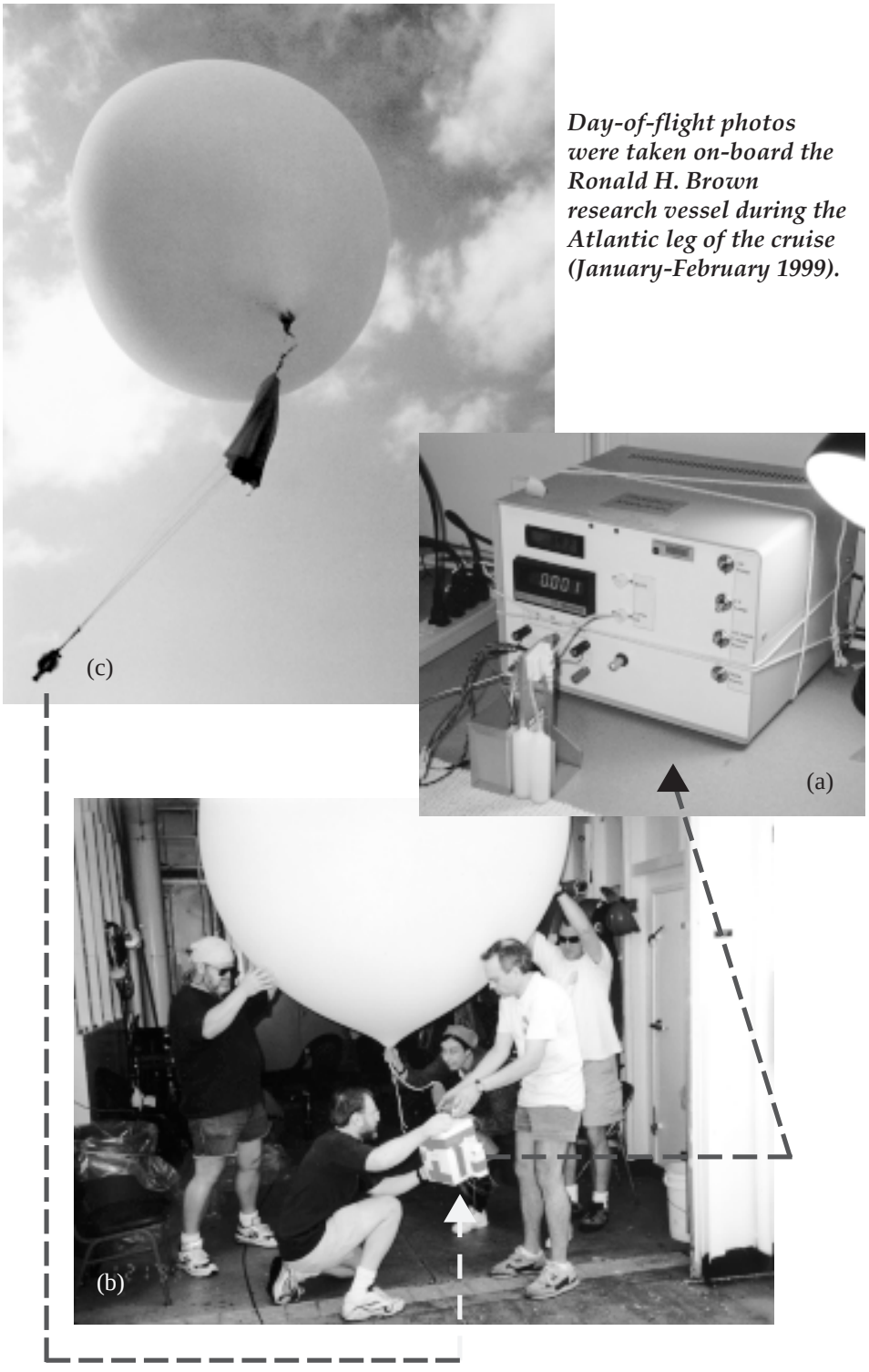

Day-of-flight photos were taken on-board the Ronald H. Brown research vessel during the Atlantic leg of the cruise (January-February 1999).

Figure 5.
(a) The electrochemical concentration cell (ECC) ozonesonde is connected to the ozone test unit to condition it, check response times, and record an average background value of ozone.
(b-c) Before launching, the ozonesonde is sealed inside a weatherproof polystyrene box. A radiosonde is then attached to the outside of the box for data telemetry transmitting meteorological parameters and ozone to a ground receiving station on-board the ship.
(c) The final launch set-up shows a small parachute and payout reel connecting the ozonesonde box to the balloon.

Pre-Launch Validation Activities for the MODIS Snow and Sea Ice Algorithms

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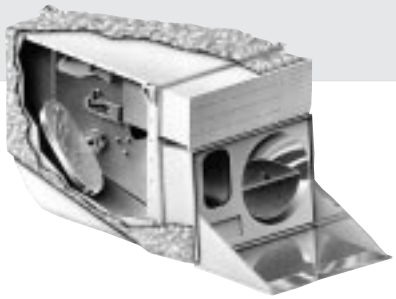

Introduction

Pre-launch validation efforts have been conducted for the at-launch Moderate Resolution Imaging Spectroradiometer (MODIS) snow and ice products. Daily and 8-day composite snow-cover and sea ice products will be produced at 500-m and 1-km spatial resolution, respectively, following the launch of Terra. A post-launch, daily, global snow albedo product will also be produced, and is still under development.

It is anticipated that the MODIS at-launch snow-cover maps will be used, along with other data, by hydrological modelers to make predictions of water supply and flooding, and by general circulation modelers and climatologists to study the Earth's energy balance and climate. In addition, the MODIS snow and ice products will be used as input to other MODIS algorithms to produce other products, e.g., the MODIS cloud mask.

Pre-launch validation activities are being conducted by the MODIS snow and ice team at Goddard, as well as by the University of Alaska, the University of Colorado, and the University of California at Santa Barbara (UCSB). The University of Alaska project is responsible for validation of the MODIS sea ice products, and the UCSB and University of Colorado teams are conducting validation activities for the at-launch snow cover, and post-launch snow albedo products, respectively.

Numerous field programs have already been conducted in support of validation efforts for the snow and ice products (Hall et al. 1993, 1998a and b; Klein et al. 1998a; Li et al. 1999; Nolin and Stroeve 1999a and b; Zhou and Li 1999).

Four field programs are planned for 2000. The first is a cruise in the Southern Ocean during which the University of Alaska will perform field validation with concurrent Terra overflights, and is scheduled for February and March 2000. Another Southern Ocean cruise is proposed to NSF for the austral spring in September and October 2000. These sea ice cruises will be conducted in concert with other work funded by NSF. Also in February 2000, there will be a field program in Wisconsin and Minnesota for validation of the snow-cover and snow albedo algorithms conducted by researchers at Goddard and the University of Colorado. In March 2000, UCSB will carry out snow-mapping validation with Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) flights at King's river basin, California.

Snow-cover products validation

Validation activities in the MODIS snow and ice team at NASA/GSFC.

Field and aircraft experiments have been conducted in order to assess the accuracy of snow-cover mapping using the MODIS snow-mapping algorithm. Experiments conducted in Alaska, Saskatchewan, and the mid-western United States in continuous snow cover, and New York and New Hampshire in patchy snow cover, have provided a framework for determination of expected, global snow-cover mapping errors with MODIS. Using the EROS Data Center (EDC) land-cover maps of North America and Eurasia (Loveland and Belward 1997), the Earth's land surface has been classified into seven different classes as follows: forest, mixed agriculture and forest, barren/sparsely vegetated, tundra, grassland/shrublands, wetlands, and snow/ice (Hall et al. 1998a). Snow-mapping errors, derived using MODIS prototype algorithms for most of the seven classes, were determined from previous field, aircraft and satellite studies (Hall et al. 1993, 1998a; Klein et al. 1998b).

Average monthly snowline positions for the Northern Hemisphere were obtained from the NOAA National Environmental Satellite, Data and Information Service (NESDIS) (Matson et al. 1986). The snowline positions were registered to land-cover maps, and the percent of each of the seven land covers north of the continental snowline was calculated monthly for North America and Eurasia. Using the information on snowline

position and snow-mapping error estimates in the various land covers, hemispheric snow-mapping errors were calculated for each land-cover type. It was assumed that errors are uniform within each class. While this is not always a valid assumption, it allows us to make a preliminary estimate of Northern Hemisphere snow-cover mapping accuracy.

Snow-mapping errors are expected to be greatest in forested areas. In forested areas, even where snow cover on the ground is reported to be 100%, snow cover observed from space may not be seen as complete because the area covered by tree stems, branches and canopies is often non-snow covered. In addition, less snow in forests will be mapped at off-nadir view angles than at nadir. When viewed from an angle, the tree stems, branches and trunks block the view of the snow more than when the forest is viewed from nadir. When viewing a snow-covered forest from the air, little or no snow cover may be seen, especially if there is no snow in the tree canopy.

The greatest monthly errors in snow mapping can be expected from about November through April (9-10%) as shown in Table 1. It is at these times that snow covers most or all of the boreal forests and many of the forests located in the mid-continent regions. The expected, aggregated Northern Hemisphere snow-mapping error is about 7.5%. Error estimates will be refined after we acquire the first year of MODIS global snow-cover data.

Month	North America	Eurasia
January	9	9
February	9	9
March	9	10
April	9	10
May	6	8
June	5	6
July	5	5
August	5	5
September	5	5
October	6	7
November	9	8
December	9	8

Table 1. Maximum expected errors (in %), by month, in Northern Hemisphere snow mapping using EOS/MODIS data.

Other efforts by the MODIS snow and ice team have focused on determining relative accuracy of snow cover products derived from different sensors (Hall et al. in press; Tait et al. submitted), and on the development of a snow-cover product using both visible/near-infrared and passive-microwave data. The spatial resolution and bands of the sensor are key to accurate snow mapping; however, the ability to map snow through cloud cover and darkness is also important. A combination of visible, near-infrared and passive-microwave sensors can provide a snow-cover product that takes advantage of good spatial resolution, and also has the ability to map snow through clouds and darkness. Algorithms that will combine MODIS and Advanced Microwave Scanning Radiometer (AMSR) data, following the launch of the PM-1 platform in 2000, are under development in collaboration with Al Chang, NASA GSFC, of the AMSR team.

Activities for snow-cover product validation at UCSB.

Progress has been made in testing the MODIS snow cover mapping algorithm under the most difficult circumstances – patchy snow cover in mountainous areas.

The focus of the UCSB investigation has thus far been on alpine watersheds. For validation of the MODIS snow-cover algorithm, digitized, high resolution (1-4 m) VNIR color photos taken simultaneously on the ER-2 (Shi and Li 1998; Li and Shi 1998), have been used. Thus, a large amount of the ground truth for snow covered areas can be used to validate the accuracy of the snow mapping algorithm under a variety of viewing and illumination conditions, and land cover, atmospheric and terrain conditions. The greatest possible error of the MODIS algorithm is expected to occur in rugged alpine and forest regions, especially under patchy-snow conditions. In the pre-launch time frame, validation has been performed using 67 AVIRIS scenes (10×12 km) for which the VNIR color photos are available. These data are mainly from the Sierra Nevada and South Cascades Mountain Ranges from April to July, during snow melt season from 1994-1997.

The validation was performed in two ways: 1) total snow fraction at the AVIRIS scene scale - about 10×12 km, and 2) pixel-based validation. The former represents the case for climatic studies where we are only interested in the snow fraction information at a grid but do not care where they are inside the grid, such as GCM input. The latter represents the case for hydrological studies, especially at the drainage basin scale, where we need information, not only on the total snow-covered area, but also on locations within the grid. In terms of estimating the total snow-covered area (SCA) fraction from an AVIRIS scene, the MODIS algorithm has a slightly larger error in the large fraction range, with over-estimation in most cases, than its estimation at the small fraction range. The overall accuracy for the fraction cover in a scene is 12.1% with a maximum error of 31.6%. For a grid of GCM models at the regional to global scale, it is generally at a scale coarser than the AVIRIS coverage. The error is much less than the current techniques that are used to generate the snow extent as the GCM input, such as that obtained from

passive microwave sensors. Therefore, this work shows that MODIS will significantly improve the accuracy of the snow extent input data for climatic and regional or global hydrological studies.

For pixel-based validation, however, the overall RMSE from all scenes is 25.1%. When a binary classifier is used, the probability that a "mixed" pixel will be classified as snow is related to the fraction of snow in a pixel. The spatial distribution of snow cover in a mountain area depends upon elevation, surface orientation, and the intensity and direction of wind. It is, in general, characterized as full, large fraction, and small fraction at high, middle, and low elevation zones, respectively. A common problem with a binary classifier is that its estimation will over estimate or under estimate the snow extent in different elevation zones. Because the snow melting rate differs at the different elevation zone, the sensitivity of the snow-melt prediction to snow mapping accuracy differs at each elevation zone. Either high resolution image data (i.e. ASTER or ETM+) or a more sophisticated snow mapping technique (such as estimating snow fraction at each pixel) may be required for hydrological applications at the drainage basin scale, in mountainous areas.

For post-launch validation, we have investigated the feasibility of using high-resolution image data—ASTER and ETM+—to derive ground truth using 1) existing binary classification algorithms, and 2) the spectral linear unmixing technique. The latter can provide very accurate snow mapping (Shi et al. 1999a and b). In addition, the data from AVIRIS, MAS, and EO-1 will be used to obtain ground truth data to validate the MODIS algorithm under different conditions.

Activities for the future snow albedo product validation at the University of Colorado.

Snow surface albedo will be one of the post-launch products to be generated from data acquired by the MODIS instrument. In particular, the angular reflectance characteristics over snow are needed to convert satellite measurements of bidirectional reflectance to albedo. MISR also requires characterization of the angular reflectance characteristics over snow, and thus this work will be useful for characterizing the surface albedo needed for MISR Top-of-Atmosphere products. This validation effort has a three-pronged approach consisting of:

- validation of a model to convert from surface reflectance measurements to surface albedo;
- development and validation of a scheme for converting narrowband to broadband albedo; and
- sensitivity analyses to determine how atmospheric components, especially aerosols, affect the accuracy of the albedo retrievals.

The DISORT (DIScrete Ordinates Radiative Transfer) model is used as the basis for converting spectral reflectance to spectral albedo. Data from a pre-launch validation campaign (held in March 1998 at a site near Mono Lake, California) have confirmed the efficacy of this model for characterizing the bidirectional reflectance distribution function (BRDF) of snow. With extensive support from JPL scientists James Conel and Mark Helmlinger of the MISR validation team, the University of Colorado team was able to collect a unique data set of snow bidirectional reflectance using a continually rotating radiometer known as PARABOLA. Data from this instrument have now been calibrated and are in close agreement with DISORT results. Additional measurements included atmospheric optical depth, diffuse and total irradiance, and snow physical properties. Ground-based snow spectral reflectance measurements were made using an Analytical Spectral Devices FieldSpec FR field spectrometer. Airborne data were successfully acquired on March 10, 1998. MAS data were collected over the study site, concurrent with the ground-based measurements of atmospheric and snow properties. The MAS data have now been calibrated and agree well with ground-based snow reflectance measurements. Now that the BRDF conversion scheme has been validated, anisotropic reflectance factors have been derived for MODIS (channels 1-19 and 26) at an angular resolution of 5 degrees. The same will be done for MISR channels in the near future.

A critical concern is the current lack of an aerosol retrieval method that provides accurate estimates over snow-covered surfaces. This prevents accurate atmospheric correction of MODIS and MISR data over snow. Through a combination of model simulations and field validation experiments (both pre-launch and post-launch), this research will validate an existing scheme for converting measurements of snow bidirectional reflectance to snow albedo for both MODIS and MISR. To date, all the modeling sensitivity analyses have been completed. These runs were made using the 6S model, which was modified by adding a snow spectrum for surface reflectance. Snow BRDF data have now been added to the 6S model so that anisotropic effects are considered. Results from the 6S runs show that reflectance for all channels decreases as aerosol optical depth increases. Snow is brighter than path radiance and aerosols have a net darkening effect, which is roughly linearly a function of aerosol optical depth. Urban aerosols have the greatest effect and maritime aerosols the least effect. In post-

launch efforts, we will quantify how different estimates of atmospheric aerosols change our estimates of albedo from MODIS and MISR.

The University of Colorado team is currently using ASD field data and DISORT model output (convolved to the MODIS and MISR channels) to derive relationships between narrowband and broadband albedos. Such a scheme will allow intercomparison of broadband albedo retrievals between MODIS and MISR. While still in the preliminary stage, this work will be a focus of efforts in the upcoming year. Plans are also being made for a post-launch validation campaign in February 2000 at Lake Mendota, Wisconsin.

Sea ice products validation

Activities for the sea ice cover and ice-surface temperature validation at the University of Alaska.

The University of Alaska Fairbanks (UAF) group is responsible for validation of MODIS ice product in the Southern Ocean. An independent validation in the Southern Ocean is necessary for two main reasons.

First, sea ice in the Southern Ocean is more dynamic than that in the Arctic in terms of the annual variability in its spatial coverage. In the Arctic, sea ice coverage varies from a March maximum of approximately 15×10^6 km^2, to a September minimum of about 8×10^6 km^2. In the Antarctic, a maximum extent of approximately 20×10^6 km^2 occurs in September while a minimum of 4×10^6 km^2 occurs in February (Parkinson and Gloersen 1993). In addition, the more stormy condition of the Southern Ocean creates a vast marginal ice zone where the main sea ice types are pancake ice and cake ice. The former has a size of <1 m and the latter has a diameter of 20-30 m. The mixture of ice and water with various ice concentrations in the marginal ice zone may pose difficulties for mapping ice coverage and estimating ice concentrations using conventional satellite optical sensors that only have a small number of wavelength channels, Riggs et al. (1999) have successfully used the MODIS Airborne Simulator (MAS) to map sea ice extent and classify sea ice type in the marginal ice zone in the Bering Sea in April. The Southern Ocean would be ideal for further demonstration of the usefulness of the sophisticated MODIS sensor for mapping sea ice, especially for mapping the vast marginal ice zone in the region.

Second, the Terra satellite instruments will map the Southern Ocean in a solar illumination condition considerably different from that for the Arctic Ocean. Because the snow and ice surface reflectance is anisotropic, lower solar illumination angles can introduce a major error source in spring and autumn when the solar illumination angles in the region are low at local solar time. This situation requires collection of field data in the Southern Hemisphere to assess the performance of the MODIS snow and ice product in the region.

With support from both NASA and the National Science Foundation (NSF), the UAF group has conducted two pre-launch field campaigns in the Ross Sea aboard the U.S. Research Vessel Nathaniel B. Palmer, with one in the austral winter in May and June 1998, and one in the austral summer in January and February 1999. The group was able to calibrate field remote sensing instruments and to obtain field data sets during the cruises. The field remote sensing instruments tested in the cruises include a fine resolution spectroradiometer for measurement of surface spectral reflectance, two precision spectral pyranometers for the derivation of surface total albedo, two broad band thermal IR radiometers and 20 automatic data logging thermisters for measurement of surface temperature and brightness temperature, and a sun photometer for estimation of the atmospheric water vapor content and correction of atmospheric effects on spaceborne remote sensing data. Future cruises in the region have been planned for field validation with concurrent Terra satellite flights, with one scheduled for February and March 2000, and the other proposed to NSF for an austral spring season in September and October 2000.

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(Continued from page 18)

Minutes of The Fifteenth Earth Science Enterprise/ Earth Observing System (ESE/EOS) Investigators Working Group (IWG) Meeting

his talk which would cover the requirements posed by the protocol; "sticky" issues involving both technology and biogeochemistry; contributions of EOS-type data; and enhancing the relevance of EOS data.

The FCC is the Framework Convention on Climate Change, dated June 19, 1993. The "Protocol" is a document still under development. The ultimate objective of the protocol is to stabilize greenhouse gases within an 'appropriate' time frame. The protocol is based on the 'precautionary' principle.

Article 3 of the protocol says that greenhouse gas emissions must be five percent below those of the 1990 base period. The change in carbon stocks from 1990 is a key measure. Article 5 has provisions for monitoring and trading emissions. There can be various agreements among countries to accomplish 'clean' development.

Field listed "sticky" technical issues:

- leakage problem;
- many sources problem—there are thousands of power plants worldwide;
- delayed responses problem; and
- finite commitment periods.

"Sticky" scientific issues include accuracy, presentation of relevant processes, spatial resolution, etc. Assessing of Kyoto sinks requires looking at inventories, a book-keeping land-use model, biogeochemical models, and inversions and eddy flux. The real "crux" is land-use/land-cover change.

In the characterization of 1990, sinks are assessed only in relation to the 1990 baseline. EOS data will improve the understanding of earlier AVHRR/Landsat data

Field said that long-wavelength SAR can be used to determine carbon stocks, and he deplored the dropping of such instrumentation early in the EOS program. He stressed the need to develop a way to sense soil carbon remotely. Enforcement is the key to success of Kyoto, but it is not spelled out.

Lively discussion followed this presentation with opposing sides saying that EOS would or would not be able to play a role in the necessary science to carry out Kyoto.

Earth Science Education Program Update

— *Nahid Khazenie (nkhazeni@hq.nasa.gov), Education Program Manager, Office of Earth Science, NASA Headquarters*
— *Steve Graham (steve.m.graham.2@gsfc.nasa.gov), EOS Project Science Office, Raytheon ITSS*

The Institute for Global Environmental Strategies (IGES) in Arlington, VA, announces an opportunity to participate in the Earth System Science Education Alliance (ESSEA), an innovative professional development program.

ESSEA is a partnership among IGES, the Center for Educational Technologies (CET) at Wheeling Jesuit University, and sponsored by NASA's Earth Science Enterprise. ESSEA has the following objectives:

- promote the growth of knowledgeable and well-equipped K-12 Earth system science educators through on-line professional development courses;
- demonstrate the effectiveness of the World Wide Web in the promotion of professional development of K-12 Earth system science educators; and
- respond directly to the need to prepare more teachers to meet the demand of a growing U.S. student population.

To meet these objectives, ESSEA will support universities, colleges, and science education organizations in offering K-12 Earth system science (ESS) on-line graduate courses that have been developed within the CET at Wheeling Jesuit University for NASA's Earth Science Enterprise. The Earth system science courses use an innovative instructional design model, are delivered over the Internet, and feature student-centered, knowledge-building virtual communities. Successful proposers will participate in an intensive four-day training workshop to learn how to deliver the courses.

The ESSEA program, with the on-line Earth system science courses as it's centerpiece, will not only include training teachers but will develop an active and long-term mechanism for delivering professional development on a national scale.

IGES intends to award three-year grants to entities with unique and innovative proposals to facilitate and offer the Earth system science on-line courses developed and tested by CET. It is anticipated that each grant will be in the range of a total of $45,000 over a three year period. Plans are to issue up to six grants in 1999; up to eight new grants in 2000; and an additional eight new grants in 2001.

A copy of the full announcement and proposal guidelines is available at http://www.strategies.org/essea.html

Earth Science Education Forum Program

The preliminary program for the first NASA Earth Science Education Forum is available on the conference WWW site at http://www.strategies.org/conference.html. The conference will be held November 14-17, 1999 in Austin, Texas, and is a first—bringing together the principals from NASA Earth science education programs from across the country. Over 140 participants have registered for the conference from programs targeted at all levels and audiences.

NASA Student Involvement Program (NSIP) 2000

NSIP is a national competition for students in grades 3-12 that links student research and projects to NASA's strategic enterprises. Two of the areas of competition are related to NASA's Earth Science Enterprise: Watching Earth Change (for grades 5-8 and 9-12) and Earth Systems in my Neighborhood (for grades 3-4). Entries for this year's competition are due February 1, 2000, and the National Symposium will be held in Washington, DC May 6-10, 2000. For more information about NSIP, including the 1999-2000 Program Announcement and copies of Educators' Guides for each competition, see the project website at http://www.nsip.net.

University Earth System Science (UNESS) Project

Solicitation Number: AO-99-OES-02
Response Date: Dec 01, 1999

The National Aeronautics and Space Administration (NASA) Office of Earth Science announces the opportunity to conduct innovative spaceborne Earth system investigations in the form of complete spaceflight missions or secondary payload instruments through the University Earth System Science (UnESS) Project. This Announcement of Opportunity (AO) is intended to foster the devel-

opment of the next generation of Earth system scientists, engineers, managers, educators, and entrepreneurs through significant and meaningful hands-on student involvement in Earth observation space missions at the university level. The hands-on student involvement should include helping prepare the proposal through analysis and distribution of the data to the scientific community. This AO will give equal weight to the scientific and student/applications involvement aspects of the proposal.

The AO is at the Earth Science Enterprise Home Page: http://www.earth.nasa.gov/ under "Research Opportunities" or via anonymous ftp at ftp.hq.nasa.gov/pub/ese.

This announcement will be open for the period from August 2, 1999, through December 1, 1999, and proposals may be submitted at any time throughout that period.

Point of Contact:
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UnESS Project Executive
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E-mail: gjohnsto@mail.hq.nasa.gov
http://nais.nasa.gov/EPS/HQ/date.html#AO-99-OES-02

EOS Scientists in the News

— Emilie Lorditch (elorditc@pop900.gsfc.nasa.gov), Raytheon ITSS

"Acclimating to a Warmer World," *Science News* (Aug. 28) by Richard Monastersky. **Cynthia Rosenzweig** (NASA GISS) says that the study seeks to analyze how climate change will affect the 19.6 million people living in the New York metropolitan area. Rosenzweig is part of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change and leads the New York study.

"Sunspots May Play Role in Global Warming," *Christian Science Monitor* (Aug. 26) by Robert C. Cowen. **James Hansen** (NASA GISS) discusses the possibility that aerosols and dust in the atmosphere, generated partly by human activity, have substantially counteracted expected greenhouse warming.

"Getting to the Roots of Carbon Loss," *Science* (Aug. 20) by Jocelyn Kaiser. **Chris Field** (Carnegie Institute of Washington) **Ruth DeFries** (Univ. of Md.), and **Steven Running** (Univ. of Mont.) aim to sum up all the carbon added to the atmosphere since humans began to leave a significant mark on the Earth.

"Research to Benefit from Cheaper Landsat Images," *Nature* (Aug. 19) by Tony Reichardt. **Samuel Goward** (Univ. of Md.) explains how even a modest land use study can result in expensive bills for images. The cost of a Landsat image is $475 a scene, which make the images much more affordable than most satellite images.

"Carbon Dioxide In Air Can Stem Soil Erosion," *Reuters* (Aug. 11). **Chris Field** (Carnegie Institution of Washington.) has found that atmospheric carbon dioxide helps bind soil particles together, which can help in places vulnerable to soil erosion. Field discovered that carbon dioxide stimulates changes in soil structure making conditions perfect for the soil to stick together.

"La Niña Keeps Hanging Around," *Environmental News Network* (Aug. 10). **William Patzert** (NASA JPL) examines La Niña's impact on North America's climate this fall. Using data from the TOPEX/Poseidon mission, Patzert observed how La Niña caused contrasting ocean levels and temperatures on opposite sides of the north Pacific Ocean.

"Case Grows for Climate Change," *Chemical & Engineering News* (Aug. 9) by Bette Hileman. **James Hansen** (NASA GISS), **Stephen Wofsy** (Harvard Univ.), **V. Ramanathan** (Scripps), and **Kevin Trenberth** (NCAR) are searching for evidence that proves a human influence on the global climate and the connection between greenhouse gas emissions and global climate change.

"Carbon Dioxide Shakes Off Its Pursuers," *Science News (July 24)* by Richard Monastersky. **Inez Fung** (Univ. of Calif. Berkley) challenges a team led by Princeton University researchers that reported that the forests and fields in the

United States are acting as a carbon dioxide sink with her own study. Fung says the biggest problem with the study is that North America appeared to absorb tons of carbon dioxide while Europe and Asia absorbed next to nothing.

"Flood Cooled Atmosphere in Ice Age," *Los Angeles Times* (July 22) by Chris Kahn. **Richard Alley** (Penn State Univ.) explains how a giant flood can trigger a worldwide freeze in a matter of decades.

"Ocean Fever Heralds African Epidemics," *Science News* (July 17) by Richard Monastersky. **Kenneth J. Lithicum** (Walter Reed Army Inst. of Research**)** and **Assaf Anyamba** (NASA Goddard) discuss their research about the 1997 Rift Valley Fever epidemic that killed tens of thousands of livestock and hundreds of people in Kenya. Lithicum and Anyamba's research also appeared in the Associated Press and *Science*.

"Does a Globe-Girdling Disturbance Jigger El Niño?," *Science* (July 16) by Richard Kerr. **Michael McPhaden** (NOAA) and **Compton Tucker** (NASA Goddard) explain the unpredictable atmospheric oscillation that may help transform an ordinary El Niño into a monster for forecasters.

"Rift Valley Fever," *National Public Radio, Science Friday* (July 16). **Compton Tucker** (NASA GSFC) reports on the Rift Valley fever outbreaks in East Africa from 1950-1998 and how these outbreaks followed periods of abnormally high rainfall.

"New Evidence Heats Up Climate Debate," *Christian Science Monitor* (July 15) by Robert C. Cowen. **James Hansen** (NASA GISS), **V. Ramanathan** (Scripps), and **Charles Kennel** (Scripps) discuss the decline by 25 percent of heat-trapping greenhouse gases although there has not been a decline in carbon dioxide emissions. This finding suggests that the atmospheric carbon dioxide won't double by 2050 as previously thought, giving humanity more time to cope with global climate change.

"Global Warming —Turning Up the Heat," *ABC's World News Now* (July 15). As the heat index soars, 25 deaths have been blamed on the heat. **Cynthia Rosenzweig** (NASA GISS) says that developing nations appear to be more vulnerable to global warming.

"Flights Could Be Helping Make Earth's Skies More Unfriendly," *Dallas Morning News* (July 12) by Alexandra Witze. **Patrick Minnis** (NASA Langley) has studied how contrails can thin into cirrus-like clouds that trap more of the sun's heat. Scientists think the situation will get worse and predict that by 2050 the United States will have nearly three times more contrail coverage than in 1999.

"Purer Air May Bring More Heat / Sulfates Now Block Some of Sun's Rays," *Houston Chronicle* (July 1) by Seth Borenstein. **James Hansen** (NASA GISS) cautions that determining how sulfur, clouds, and other variables factor into climate change is too complicated to predict outcomes confidently.

"A Better View of Earth," *Popular Science* (July 1999) by Mariette DiChristina. NASA's first Earth-observing satellite, **Terra**, will capture a better view of the complex processes that govern the Earth's climate. Terra will look for changes in long-term land-use patterns, snow and ice cover, and climate variations.

EOS researchers: Please send notices of recent media coverage in which you have been involved to: Emilie Lorditch, EOS Project Science Office, Code 900, Goddard Space Flight Center, Greenbelt, MD 20771, Tel. (301) 441-4031; fax: (301) 441-2432; e-mail: elorditc@pop900.gsfc.nasa.gov.

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CEOS Working Group on Calibration and Validation Meeting on Digital Elevation Models and Terrain Parameters

of *in situ* validation data. In the next few years there will be an increase in the availability of moderate resolution (c. 1 km) sensing systems and a proliferation in data products. With the high cost of *in situ* data collection relative to the resources available for the non-space segment of most observation programs, the potential benefits from international coordination are considerable. The May 1999 CEOS WGCV meeting and its recommendations provide a point of departure for such international coordination and an expanded role for the CEOS Calibration and Validation Working Group.

EOS Science Calendar

Oct. 12-14
Landsat Science Team Meeting, NASA/GSFC. Contact Darrel Williams, e-mail: darrel@ltpmail.gsfc.nasa.gov.

October 19-21
AIRS Science Team Meeting, University of Maryland, Baltimore County. Contact H.H. Aumann, e-mail: aumann@jpl.nasa.gov.

October 25-27
Joint TOPEX/POSEIDON-Jason Science Working Team Meeting, St. Raphael, France. Contact Yves Menard, e-mail: menard@imhotep.cst.cnes.fr, or Lee-Lueng Fu, e-mail: llf@pacific.jpl.nasa.gov.

Global Change Calendar

October 24-28
Geological Society of America. Denver, CO. Contact Tammy White, e-mail: twhite@geosociety.org, website at http://www.geosociety.org.

November 2-5
The CEOS Global Observation of Forest Cover (GOFC) Meeting on Fire Mapping and Monitoring, the Joint Research Center, Ispra, Italy. Contact Frank Ahern, e-mail: Frank.Ahern@CCRS.NRCan .gc.ca.

December 6-10
The Fourteenth William T. Pecora Memorial Remote Sensing Symposium & the Land Satellite Information in the Next Decade III Conference & Exhibition, Doubletree Hotel, Denver, Colorado. Contact: ASPRS, The Imaging & Geospatial Information Society, 5410 Grosvenor Lane, Suite 210, Bethesda, MD 20814-2160; e-mail: asprs@asprs.org; website at http://www.asprs.org.

December 13-17
The 1999 American Geophysical Union (AGU) Fall Meeting, Moscone Center, San Francisco, CA. Contact: AGU, 2000 Florida Avenue, N.W. Washington, D.C. 20009. Tel. (202) 462-6910; Fax: (202) 939-3229.

— 2000 —

January 9-14
American Meteorological Society 2000, Long Beach Convention Center, Long Beach, CA. Call (202) 682-9006; Fax: (202) 682-9298; e-mail: ams@ametsoc.org.

February 17-22
American Association for Advancement of Science (AAAS), Washington, DC. Call (202) 326-6736, website at http://www.aaas.org.

March 7-10
Oceanology International 2000. Call for Papers. Contact Christine Rose, Conference Executive, Oceanology International 2000, Spearhead Exhibitions Ltd, Ocean House, 50 Kingston Road, New Malden, Surrey KT3 3LZ, UK. Tel. +44 (0) 20 8949 9222; Fax: +44 (0) 20 8949 8186/8193; e-mail: christine.rose@spearhead.co.uk; website at http://www.spearhead.co.uk.

March 14-15
Adaptive Sensor Array Processing Workshop, MIT Lincoln Laboratory. Call for Papers. Contact Edward J. Baranoski, e-mail: kballos@ll.mit.edu, website at http://sam2000.uconn.edu.

March 16-17
IEEE Sensor Array and Multichannel (SAM) Signal Processing Workshop, Cambridge, MA. Call for Papers. Contact Edward J. Baranoski, e-mail kballos@ll.mit.edu, website at http://sam2000.uconn.edu.

March 27-31
28th International Symposium on Remote Sensing of Environment, Cape Town, South Africa. Call for Papers. For abstracts submission: abstracts@mikom.csir.co.za, or see website at http://www.isrse.co.za, Fax: +27 21 883 8177; tel. +27 21 886 4496 (ask for Deidré Cloete); postal: The 28th ISRSE Technical Committee, P.O. Box 452, Stellenbosch, 7599, South Africa.

May 22-26
ASPRS: The Imaging and Geospatial Information Society, 2000 Annual Conference, May 22-26, 2000. Washington, DC. Call for Papers. For abstracts submission see website at http://www.asprs.org/dc2000; tel. (410) 208-2855; Fax: (410) 641-8341; e-mail: wboge@aol.com.

June 12-14
Sixth Circumpolar Symposium on Remote Sensing of Polar Environments, Yellowknife, Northwest Territories, Canada. E-mail: circumpolar2000@gov.nt.ca, tel. (867) 920-3329, website at http://www.gov.nt.ca/RWED/rs/circumpolar2000.

July 16-23
International Society for Photogrammetry & Remote Sensing (ISPRS) 2000, Amsterdam. Call for Abstracts. Contact organizing secretariat, tel. +31 20 50 40 203; Fax: +31 20 50 40 225; e-mail: isprs@congrex.nl

July 24-28
IGARSS 2000 International Geoscience and Remote Sensing Symposium, 20th Anniversary, Hilton Hawaiian Village, Honolulu, Hawaii. Call for Papers. Website at http://www.igarss.org.

July 24-29
International Radiation Symposium (IRS-2000), Saint Petersburg State University, St. Petersburg, Russia. Contact conference coordinator, Evgenia M. Shulgina, St. Petersburg State University, Research Institute of Physics, 1 Ulyanovskaya, 198904, St. Petersburg, Russia; Fax: +7 (812) 428-72-40; e-mail: Evgenia.Shulgina@ pobox.spbu.ru; or shulg@troll.phys.spbu.ru.

Publications Available

EOS/AM-1 Digital Elevation Model (DEM) Data Sets:
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