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In this issue

EDITOR'S CORNER

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NASA selected 'Terra' as the winning name for the EOS AM-1 spacecraft after a competition to come up with a new, more descriptive, name for this flagship Earth Observing System mission to observe the entire planet from the unique vantage point of space. Terra will enable new research into ways the Earth's lands, oceans, atmosphere, ice, and biological ecosystems interact as a whole climate system. It is currently scheduled for launch on July 28 from Vandenberg Air Force Base, California (see article on page 10).

A small, low-cost Total Solar Irradiance Mission (TSIM) to study the Sun's solar radiation input to the Earth-atmosphere system has been selected as part of the second phase of the EOS program. The competitively selected science team will have full responsibility and authority to accomplish this mission, including acquiring a spacecraft, integrating the instruments and spacecraft together, integrating the spacecraft with a government provided launch vehicle, operating the spacecraft during the life of the mission, and analyzing the data. The TSIM, led by Dr. Gary Rottman of the Laboratory for Atmospheric and Space Physics, University of Colorado, seeks to learn more about global climate change through precise measurements of both the spectral and total irradiance from the sun. Solar radiation is the dominant energy input into the Earth's ecosystem, and even small changes in the sun's output can produce significant changes in the Earth's climate and environment. The possibility of combining the SOLSTICE (Solar Stellar Irradiance Comparison Experiment) instrument, also led by Dr. Rottman, with TSIM on one spacecraft, is currently under study. There is scientific synergy and programmatic benefit to combining these two instruments onto a single platform.

On March 2, Dr. Ghassem Asrar, Associate Administrator of the Office of Earth Science, announced the selection of four concepts for a six-month study as candidates for the Earth Observing 3 (EO-3) mission. One of these concepts will be selected as the third in a series of Earth Observation-focused New Millennium Program (NMP) technologies aimed at identifying, developing, and validating key instrument and spacecraft technologies that can lower cost and increase the performance of science missions in the 21st century.

The concepts selected for further study all focus on geostationary or geosynchronous orbits, and include: (i) Active large-aperture optical systems to provide high-resolution thermal imaging from geosynchronous orbit, proposed by Del Jenstrom, Goddard Space Flight Center; (ii) Geostationary synthetic-aperture microwave sounder, proposed by Dr. Bjorn Lambrigtsen, Jet Propulsion Laboratory; (iii) Geostationary imaging Fourier transforming spectrometer, proposed by Dr. William L. Smith, Langley Research Center; and (iv) Geostationary tropospheric trace-gas imager, proposed by Dr. Jack Fishman, Langley Research Center, who will work with Dr. James F. Gleason, Goddard Space Flight Center.

These NMP concepts were selected from 24 proposals submitted in response to a NASA Research Announcement released in September 1997. The selection process included evaluations of each proposal by external science and technology peer reviewers, along with two panel sessions with leading NASA scientists and technologists to categorize each proposal. The first New Millennium Program Earth-orbiting mission, Earth Observing-1 (EO-1), is scheduled for launch in December 1999. It will demonstrate an Advanced Land Imager (ALI) and hyperspectral imaging technologies (Hyperion) that may eventually replace the current measurement approach used by Landsat satellites. Earth Observing-2 will fly an infrared coherent Doppler lidar in the cargo bay of the Space Shuttle to demonstrate the capabilities of a space-based lidar to accurately measure tropospheric winds from the Earth's surface to a height of about 16 km. This flight, known as the Space-Readiness Coherent Lidar Experiment (SPARCLE), is scheduled for launch in early 2001.

The Geoscience Laser Altimeter System (GLAS), SOLSTICE, and EOS Chemistry science teams have developed Algorithm Theoretical Basis Documents (ATBDs) that are currently being reviewed by the international scientific community. Following these written evaluations, an oral review will be conducted on April 29 for GLAS, and May 18-19 for TES, HIRDLS, MLS, and SOLSTICE. A total of 7 ATBDs will be reviewed during the first week by a visiting committee chaired by Prof. Pat McCormick of Hampton University, and 9 ATBDs will be reviewed during the second week by a committee chaired by Mr. Larry Gordley of GATS, Inc. 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.

This peer review process is extraordinarily valuable to the science teams and engages the larger scientific community, both nationally and internationally, in the process of providing feedback on approaches to routine data analysis from EOS sensors. At present, 17 of the 19 algorithm teams of EOS have gone through at least one of these peer review processes, with only Jason-1 to follow at an appropriate point in the future. Landsat 7 Enhanced Thematic Mapper Plus (ETM+) does not have any standard data products and hence will not be required to develop any ATBDs in the future.

I am happy to report that AMSU-A (Advanced Microwave Sounding Unit-A) has been delivered to TRW, Inc., Redondo Beach, California, for integration on the EOS PM-1 spacecraft. This instrument provides atmospheric temperature measurements above the Earth's surface which, when combined with the Atmospheric Infrared Sounder (AIRS) and Humidity Sounder for Brazil (HSB), allow precise estimates of both temperature and moisture profiles from the Earth's surface to 100 hPa.

Finally, the table below lists the launches planned for Earth Science payloads throughout 1999. This looks to be a significant year for major satellite launches of interest to the Earth science research community as well as policy makers, applications specialists, and educators.

Date	Launch Site	Vehicle and Provider	Payload & Owner
April 15	Vandenberg Air Force Base, Calif.	Delta II, Boeing Co.	Landsat 7, NASA
May 16	Vandenberg Air Force Base, Calif.	Titan II, Lockheed Martin	QuikSCAT, NASA
July 28	Vandenberg Air Force Base, Calif.	Atlas IIAS, Lockheed Martin	Terra, NASA
September	Baikonur Cosmodrome, Kazakhstan	Zenit-2, Yuzhmash, Ukraine	Meteor-3M(1)*/ SAGE III, NASA
September 24	Vandenberg Air Force Base, Calif.	Taurus, Orbital Sciences Corp.	ACRIMSAT**, NASA
December 15	Vandenberg Air Force Base, Calif.	Delta II, Boeing Co.	EO-1***, NASA

* Russian meteorological spacecraft provided by Russian Space Agency
** Co-manifested with KOMPSAT (Korea)
*** Co-manifested with SAC-C (Argentina)

Multi-angle Imaging SpectroRadiometer (MISR) Science Team Meeting

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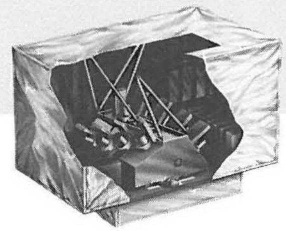


The MISR Science Team met in December 1998. The MISR Principal Investigator, Dave Diner of JPL, welcomed the meeting participants and outlined the meeting objectives, which were to review the status of the Terra spacecraft, MISR and AirMISR instruments, and MISR-2 Instrument Incubator efforts; review the status of the ground data-processing software; discuss product verification and quality assessment plans; discuss retrieval results obtained using AirMISR imagery; and demonstrate operational software and data analysis/visualization tools to the team.

The first session of the meeting was a discussion of AirMISR instrument and data-processing status. Carol Bruegge of JPL described the calibration and radiometric performance of the instrument, and Veljko Jovanovic of JPL described the georectification and geometric calibration of AirMISR data. Radiometrically, the instrument is meeting the established requirements. The primary issue with geometric calibration is the need to remove static offsets in the instrument orientation relative to the ER-2 navigation system. Bill Ledeboer of JPL talked about the software system that is used to process AirMISR imagery from raw flight data to calibrated, map-projected, and co-registered images. Jim Conel of JPL discussed flight plans for AirMISR for FY 1999, which include a vicarious calibration experiment that was conducted over Rogers Dry Lake in early December, for which an excellent field data set along with multiple AirMISR flight runs was obtained, plus planned flights over dark water (for aerosol studies), vegetation targets, and cloud fields later this year. Jeff Privette of GSFC gave an overview of plans for the EOS Validation Core Sites.

The next topic for discussion was MISR cloud mask techniques and a comparison with approaches used by other instruments, such as MODIS. MISR will use a variety of methods, including an automated, continuously updated histogram generation and analysis technique for establishing dynamic radiometric thresholds, plus stereoscopically-based cloud detection, and a multi-angle method for high-cloud detection. Using AVHRR as test data for the radiometric cloud-detection approach, Eugene Clothiaux of Pennsylvania State University and Larry Di Girolamo of the University of Illinois reported that discrepancies between MISR and MODIS algorithms were observed in 18-19% of the data. This needs to be followed up with actual data where longer time intervals will be available to improve the statistics used in developing the MISR thresholds, and more spectral bands will be available to MODIS. Over Greenland, where the radiometric thresholding technique is expected to have difficulties distinguishing snow from cloud, the MISR stereoscopic technique has been tested on Along Track Scanning Radiometer-2 (ATSR-2) data. Peter Muller of University College London reported a clear separability between the cloud layer and the underlying snow surface using this approach.

A discussion of aerosol retrievals followed. Ralph Kahn of JPL described sensitivity studies for MISR aerosol retrievals over ocean that indicate the ability to retrieve optical depth to an accuracy of 0.05 or 20% (whichever is larger), to distinguish among several size classes and compositional groups (characterized by refractive index), and to distinguish between spherical and nonspherical shapes. John Martonchik of JPL described his application of the heterogeneous land aerosol retrieval algorithm to AirMISR data acquired over Moffett Field, CA. Although optical depths that were similar to the ground truth values were retrieved, the data at high off-nadir angles in the blue and green bands appeared to require an unreasonable amount of absorption to be included in the aerosol model. The model results are sensitive to the pointing calibration at the oblique angles, and this is being investigated. Stu Pilorz of JPL then discussed the algorithmic approach he is using for building validation software that retrieves aerosol optical properties from field measurements. Wedad Abdou of JPL described lessons learned from a vicarious calibration experiment applied to AirMISR data. She also discussed the clear-sky anomalous absorption problem, in which certain observers have not been able to obtain consistency between direct field and diffuse field measurements of sunlight and skylight at the ground. She discussed the possibility of small particles as a possible explanation and follow-up studies are planned.

The next session focussed on surface retrievals. Bernard Pinty of the Joint Research Centre described the use of an algorithm based on the MISR surface retrieval approach that has been proposed for operational reprocessing of Meteosat data to retrieve surface albedo and aerosol optical depth simultaneously. Yuri Knyazikhin of Boston University discussed application of the MISR LAI/FPAR algorithm to POLDER data and the benefit of multi-angle viewing under LAI saturation. Peter Muller described a study examining the effect of surface albedo changes on climate forecasts with the UK Hadley Centre GCM, along with a comparison of POLDER-derived albedos with GCM 10-year mean forecasts.

The second day of the meeting began with a session on cloud stereo and albedos, in particular results from the AirMISR deployment over the SHEBA site in Alaska during FIRE III. Catherine Moroney of the University of Arizona first described several performance improvements that have recently been made to the MISR cloud-height stereo retrieval algorithms. Peter Muller then discussed application of the MISR stereo retrieval algorithms to ATSR-2 data. Using land surface topography for test purposes, differences between the stereo-derived elevations and an elevation map show the standard deviation of differences to be about 1.4 km for the ATSR-2 1-km nadir/1.6-km off-nadir data. (For MISR, stereo matching will be done at 275-m resolution.) Roger Marchand of Pennsylvania State University then presented results from the AirMISR Alaska deployment. Stereo retrievals over a cloud deck on June 3, 1998, show a mean cloud height of about 3 km, which agrees well with lidar results. Nadir radiances also agree well with the MODIS Airborne Simulator (MAS) radiances, but the radiances show a systematic offset from data acquired with the University of Washington Cloud Absorption Radiometer (CAR) on the CV-580 aircraft. Potential causes are under investigation. Tamas Varnai of the University of Arizona showed good agreement between cloud models and the AirMISR BRFs, however, the corresponding albedos are somewhat higher than expected. This is also being investigated.

Next, a discussion of the status of the MISR and the EOS Terra spacecraft was presented by Tom Livermore, the MISR Project Manager at JPL. Upgrades to the MISR flight software have been made to rectify several anomalies observed in earlier testing at Valley Forge. Susan Barry of JPL talked about MISR instrument operations and requested inputs from the Science Team on finalizing the Local Mode site list. Graham Bothwell of JPL discussed the status of the science data system along with the schedule for delivery, integration, and test of the at-launch version of the ground data-processing software.

Thomas Pagano of JPL presented the status of development of the MISR-2 prototype camera to be built under the Instrument Incubator Program. Plans for the MISR-2 cameras are to use a new optical design and chip-on-board electronics to reduce instrument size, while simultaneously including InGaAs detectors to extend the spectral coverage to 1.6 micrometers. Dave Diner informed the team of the status of NASA's post-2002 mission planning.

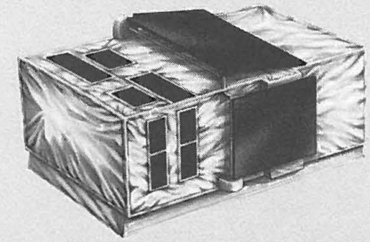
Amy Braverman of UCLA talked about the approach that MISR is planning for its Level 3 global products. Presently, two types of products are planned, component and joint. Component products result from the processing of individual Level 2 Product Generation Executables (PGEs), whereas joint products will combine results from multiple PGEs. For the latter, a technique known as Entropy Constrained Vector Quantization will be used to summarize the results into a global map, while retaining covariance information across parameters. Mike Smyth of JPL described some of the design considerations being addressed in generating the Level 3 products.

Next, a session on quality assessment (QA) and verification of data products was held. Bob Vargo of JPL gave an overview of the process, and Ralph Kahn described the team's approach to QA. Jia Zong described the verification approach for Level 1B2 products, and Larry Di Girolamo, Roger Davies of the University of Arizona, and John Martonchik discussed cloud mask, top-of-atmosphere/cloud product, and aerosol/surface product verification, respectively. Presentations by Scott Gluck and Carol Bruegge of JPL on Level 1A and 1B1 products were submitted for inclusion in the meeting notes but were not presented, in the interest of time. Earl Hansen of JPL led a discussion of the early mission data needs of the team.

The last day of the meeting focussed on demonstration of MISR operational software and visualization tools. Brian Chafin of JPL demonstrated the In-flight Radiometric Calibration and Characterization subsystem and Veljko Jovanovic, Mike Bull, Mike Smyth, Jia Zong, and Lisa Barge of JPL demonstrated the Geometric Calibration subsystem. Bill Ledeboer showed the AirMISR data processing system. Various visualization and analysis tools were demonstrated by Pranab Banerjee, Jeff Hall, Charles Thompson, Barbara Gaitley, and Robert Ando of JPL. Jim Galasso of the Langley DAAC demonstrated aspects of the EOSDIS Core System (ECS) processing, and Kyle Miller, Susan Paradise, and Kathleen Crean, assisted by Scott Gluck, Rick C. de Baca, David Nelson, Mark Apolinski, and Ruth Monarrez (all of JPL) demonstrated the Level 1 and Level 2 data-processing subsystems. A QA-based data query system being developed for MISR by the ECOlogic corporation was presented by Jennifer Carle, Renu Chaudhry, Guizhong Chen, and Scott Henderson of that company. Animations being developed in support of MISR outreach were presented by Eric de Jong and Shigeru Suzuki of JPL.

The meeting concluded with a presentation by Ralph Kahn on education and outreach, followed by a feedback and wrap-up discussion led by Dave Diner.

The Pre-launch MOPITT Validation Exercise (Pre-MOVE)



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— *Brad Gore, Paul Novelli, NOAA Climate Monitoring and Diagnostics Laboratory, Boulder, CO*
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Background and Introduction

The Measurements of Pollution in the Troposphere (MOPITT) is an eight-channel gas correlation radiometer to be launched on the EOS Terra spacecraft in 1999. The goal of the experiment is to support studies of the oxidizing capacity of the lower atmosphere on large scales by measuring the global distributions of carbon monoxide (CO) and methane (CH_4) and, thus, will represent a significant advancement in the application of space-based remote sensing to global tropospheric chemistry research. The primary measurement objectives of MOPITT are: (1) to obtain CO profiles with a resolution of 22 km by 22 km horizontally, 3-4 km vertically and with an accuracy of 10% throughout the troposphere; (2) to obtain total CO column amount measurements with a horizontal resolution of 22 km by 22 km and an accuracy of 10%; (3) to measure total CH_4 column to an accuracy of 1%, with a horizontal resolution similar to that of the CO measurement (Drummond 1992).

MOPITT Level 1 data products include: (1) eight calibrated and geo-located instrument difference radiances for each stare (~ 400 ms); and (2) eight calibrated and geo-located instrument average radiances for each stare (~ 400 ms). MOPITT Level 2 data products include: (1) tropospheric CO profiles, which are currently defined as average mixing ratios of five tropospheric layers (1000 – 700 mb, 700 – 500 mb, 500 – 400 mb, 400 – 300 mb, 300 – 200 mb) for each nominal 22-km-by-22-km pixel; (2) total CO for each atmospheric column over a nominal area of 22-km-by-22-km; (3) total CH_4 for each atmospheric column over a nominal area of 22-km-by-22-km. The column amount of CH_4 will only be available on the sunlit side of the orbit as a standard Level 2 MOPITT product.

In any remote-sensing experiment, validation of algorithms and data products is essential to ensure the quality of the data products for archiving and use by scientific communities. To complement the validation activities of each Terra instrument team, the EOS Project Science Office developed a NASA Research Announcement (NRA) that was issued in March 1997. As a result of this NRA, a number of investigators using different instruments and techniques were selected to provide correlative measurements for MOPITT data validation (Wang *et al.* 1998; http://eospso.gsfc.nasa.gov/validation/valinfo.html).

It is important to have confidence in the correlative data and associated data-processing algorithms before they are used to validate the MOPITT data products. It is also useful to test the intercomparison techniques that are to be used in post-launch MOPITT data validation. The Pre-launch MOPITT Validation Exercise (Pre-MOVE) was a validation campaign at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site of the Department of Energy Atmospheric Radiation Measurement (DOE/ARM) program (Stokes and Schwartz 1994) in Lamont, Oklahoma, March 2-6, 1998. The primary reasons for conducting Pre-MOVE at the CART site include: (1) it is a well instrumented site resulting in good characterization of the surface and the atmosphere column; (2) CART facility instruments SORTI (Solar Radiance Transmission Interferometer) (http://www.arm.gov/docs/instruments/static/sorti.html) and AERI (Atmospheric Emitted Radiance Interferometer) (Revercomb *et al.* 1995), lidars, and radiosondes are available to us; and (3) excellent logistic support at the ARM CART site.

Goals of Pre-MOVE

The primary goals of Pre-MOVE were: (1) validate correlative measurement data-processing algorithms by comparing retrieved CO columns and tropospheric profiles from ground-based interferometers and spectrometers with *in situ* CO profile measurements by the NOAA/CMDL; and (2) test the MOPITT Airborne Test Radiometer (MATR) (Smith *et al.* 1998) and associated data-processing algorithm by comparing the retrieved CO profiles from MATR observations with aircraft *in situ* CO profile measurements by the NOAA/CMDL flask system; and (3) test intercomparison techniques and protocols and prepare for future validation experiments after the MOPITT launch in 1999.

Instruments and Measurements

All instruments or instrument types to be used for post-launch MOPITT data validation were part of the Pre-MOVE at the CART site, March 2-6, 1998. Each instrument and its measurements during Pre-MOVE are described in Table 1.

Data Analysis and Preliminary Results

Although the Pre-MOVE data analysis by the MOPITT correlative team is still in progress, preliminary results are very encouraging. Figure 1 shows the CO and CH_4 profiles measured by NOAA/CMDL using their aircraft sampling system on March 6, 1998 at the ARM site in Lamont,

Table 1. Summary of Pre-MOVE Activities.

Instruments	Measurements	Technique	Investigators	Obs. Dates
MATR	CO column and profiles	Airborne remote sensing	Smith & Shertz NCAR	March 2, 3, 6
Automated Sampler	CO, CH_4, CO_2 profiles	Airborne sampling	Novelli & Gore NOAA/CMDL	March 6
MAKS sampler	Surface CO, CH_4, CO_2	Sampling	Novelli & Gore NOAA/CMDL	March 3, 6, 9, 10
Grating Spectrometer	CO column	Ground-based remote sensing	Yurganov, Tolton, & McKernan U. of Toronto	March 3, 9, 10
Solar absorption FTIR (SORTI)	CO column and profiles	Ground-based remote sensing	Murcray, Stephen, & Pougatchev, DU, CNU	March 3
Thermal emission	Lower troposphere	Ground-based remote sensing	McMillan, Wang, UMBC, NCAR, U. of Wisconsin	March 2, 3, 4, 5, 6
Radiosondes	Temperature & H_2O profiles	*In situ*	Cress, Slater, & Sisterson DOE/ARM	March 2, 3, 4, 5, 6
Pre-MOVE Planning			Wang, Reichle & Cress NCAR, NCU, DOE/ARM	

Oklahoma. The NOAA/CMDL aircraft sampling unit is an automated package that collects samples of air using a small pump and 20 glass flasks. The samples are then returned to the NOAA/CMDL laboratory in Boulder, Colorado for analysis. Two successful sets of profiles for CO, CH_4, and CO_2 were obtained from 1-8 km with a vertical resolution of ~0.3 km. As shown in Figure 1, there are clearly elevated CO and CH_4 levels around 3 km in both morning and afternoon measurements, possibly as a result of convection. CO measurements made using the CMDL automated flask system have a typical precision of 1 ppbv (Novelli *et al.* 1994).

Ground-based remote sensing measurements were made with three instruments: AERI, SORTI, and a grating spectrometer from UT. Figure 2 shows the retrieved CO profile using ground-based solar absorption FTIR measurements (SORTI) on March 3, 1998 with a spectral resolution of 0.013 cm^{-1}. The retrieval was carried out by N. Jones of NIWA and N. Pougatchev of CNU (Pougatchev and Rinsland 1995). The agreement with the airborne *in situ* measurement is within about 10% in the middle troposphere, but the agreement is not satisfactory in the lower and upper troposphere. This could be due to the lack of coincidence (difference of three days) of both location and time for the interferometer observations and the *in situ* measurements. Therefore, the comparison here is more qualitative rather than quantitative. It could also mean that we need to further improve the algorithm and intercom-parison protocols, which is one of the goals of Pre-MOVE. All these issues are still being investigated.

Figure 3 shows the retrieved total CO column using the ground-based grating spectrometer (Yurganov *et al.* 1997) from UT during Pre-MOVE on March 3, 1998. As a comparison, the total CO column amounts retrieved from SORTI measurements on March 3, 1998 are also included in this figure. The total CO column retrieved from the grating spectrometer measurement using the nonlinear least square (NLLS) technique agrees fairly well with that from the SORTI measurement. Further analysis is in progress to understand the differences between the NLLS technique and the equivalent width (EQW) technique.

The top panel of Figure 4 summarizes the total CO column amounts retrieved from AERI spectra by Wallace McMillan and Hui He of UMBC during Pre-MOVE. AERI is a CART site facility instrument in autonomous operation acquiring an up-looking atmospheric emission spectrum roughly every 10 minutes. Gaps in retrieved CO column amounts occur where cloudy spectra have been removed (dot-dash lines in Figure 4). CO retrievals under cloudy conditions would underestimate the total column.

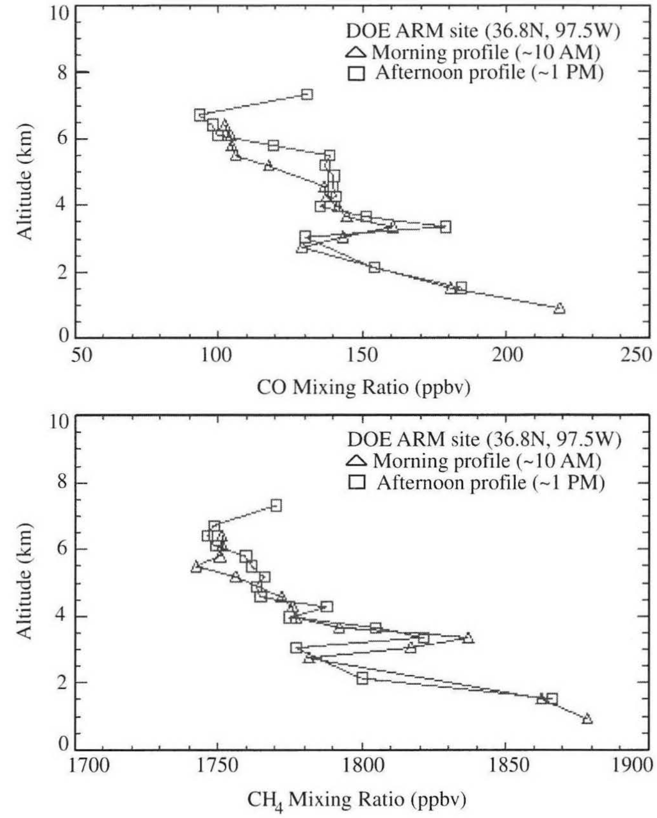

Figure 1. Aircraft *in situ* profiles of CO mixing ratio (top panel) and CH_4 mixing ratio (bottom panel). Triangles represent morning (~ 10:00 AM local time) profiles, and squares represent afternoon (~1:00 PM local time) profiles. All data were obtained on March 6, 1998 (Paul Navello and Brad Gore).

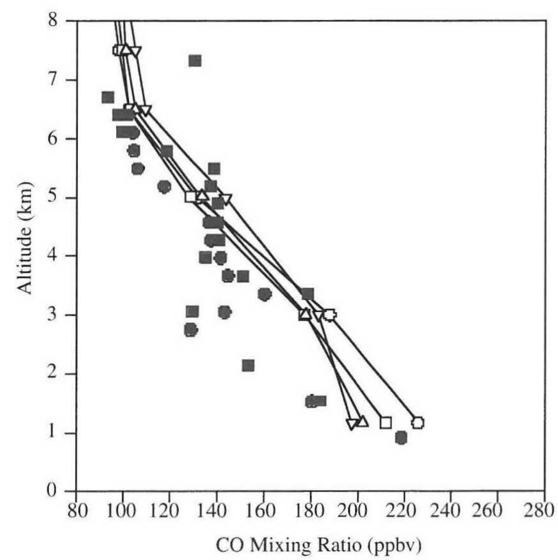

Figure 2. Retrieved CO profile using ground-based solar absorption FTIR measurement (SORTI) on March 3, 1998. Black circles (squares) are the *in situ* CO profile obtained during the morning (afternoon) of March 6, 1998. Open circles, squares, and triangles are the retrieved CO profile using SORTI data (Nikita Pougatchev and Nicholas Jones).

Likewise, retrieved CO columns close to cloudy periods could be cloud contaminated, and thus not representative of the CO column amounts retrieved during continuous cloud-free conditions (solid lines in Figure 4). Column CO retrievals were accomplished using a modified version of the prototype CO retrieval algorithm developed for the Atmospheric Infrared Sounder (AIRS) (McMillan *et al.* 1997). Although the retrieved quantity is total CO column, AERI measurements are most sensitive to CO in the boundary layer.

The bottom panel of Figure 4 zooms in on a particular time period of March 3 (GMT) when there were coincident measurements by the ground-based SORTI and UT grating spectrometer. The CO column amounts retrieved from measurements by the 3 different instruments are compared. We are encouraged by the initial general agreement of all these retrievals to +/-10%. Further improvements in algorithms and intercomparison approaches may lead to even better agreements. We note here that MOPITT is designed to provide tropospheric CO measurement with an accuracy of 10%.

Summary and Comments

A Pre-launch MOPITT validation exercise was successfully carried out at the DOE ARM site in Lamont, Oklahoma, March 2-6, 1998. Preliminary results are very encouraging. CO retrievals from ground-based interferometers and

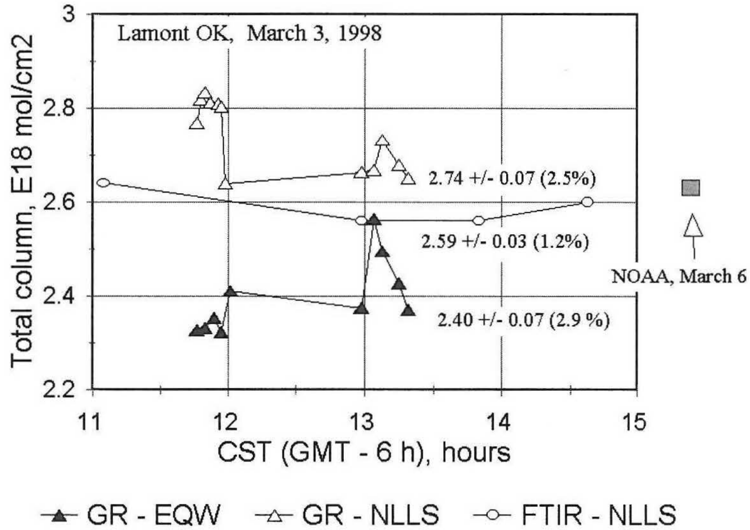

Figure 3. Retrieved total CO column using the ground-based grating spectrometer from the University of Toronto during Pre-MOVE on March 3, 1998 (triangles). Open triangles show the retrieved CO total column using the nonlinear least square (NLLS) technique. Filled triangles show the retrieved CO total column using the equivalent width (EQW) technique. As a comparison, the retrieved total CO column from the SORTI measurement on March 3, 1998 is shown (circles) (Leonid Yurganov, Eamonn Mckernan, and Boyd Tolton. SORTI spectra were processed by N. Pougatchev, C. Rinsland, B. Connor, and N. Jones using the NLLS technique).

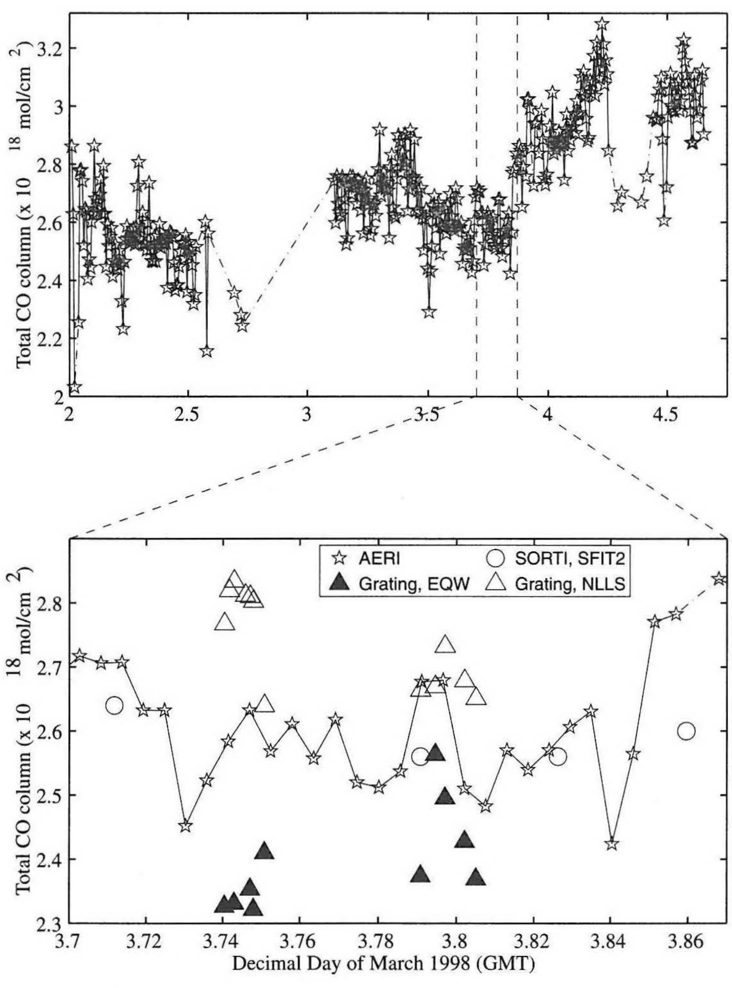

Figure 4. Total CO column densities retrieved from AERI spectra during Pre-MOVE, March 2-5, 1998, are presented in the upper panel. Dot-dash lines connect retrievals interrupted by cloudy sky scenes while solid lines connect continuous data points. AERI spectra were supplied by the ARM program. Temperature and water vapor profiles from AERI spectra were supplied by Bob Knuteson and Wayne Feltz, U. of Wisconsin. CO retrievals from the AERI spectra were performed by Wallace McMillan and Hui He, UMBC. The bottom panel shows an expanded view of the time period on March 3, 1998 (GMT) and compares the CO columns retrieved from AERI spectra to those retrieved from coincident ground-based SORTI and UT spectrometer measurements.

grating spectrometer measurements compare fairly well with measurements by the NOAA/CMDL automated sampler.

We have also started the planning of the second Pre-MOVE, Pre-MOVE II, to be conducted in the Boulder-Denver area in May 1999. The main objective is to further improve correlative measurement data quality and the data processing algorithm. We intend to conduct an end-to-end simulation of the validation process. By conducting the Pre-MOVE II in the Boulder-Denver area where the NOAA/CMDL is located, we expect to get more *in situ* CO profiles for comparison with remote-sensing measurements. We believe these two pre-launch validation exercises will prove to be very useful in the understanding and comparison of correlative measurements for post-launch MOPITT data validation.

There will be other MOPITT validation activities including development of an airborne simulator (MOPITT-A), which is being constructed in Canada at the Universities of Saskatchewan and Toronto. Initial test flights of that instrument are expected in the fall of 1999 on the ER-2 aircraft. These will be followed by validation flights for MOPITT and participation in field campaigns with other instrumentation.

Acknowledgment

We want to thank the DOE ARM program, especially Ted Cress, Doug Sisterson, and Donald Slater, for their help in the planning and execution of Pre-MOVE at the CART site in Lamont, Oklahoma. Their assistance and excellent logistics support were essential to the success of Pre-MOVE. MOPITT validation activities are funded by the Project Science Office at Goddard Space Flight Center (GSFC), the Canadian Space Agency (CSA), and the National Science and Engineering Research Council (NSERC) of Canada.

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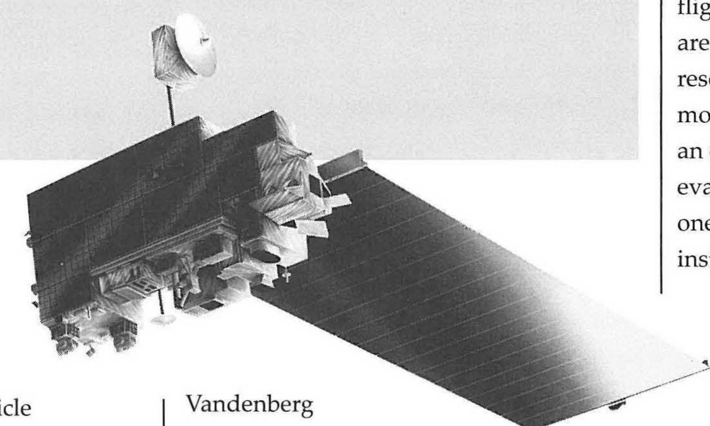
SWAMP Report to the IWG

—Yoram J. Kaufman (yoram.kaufman@gsfc.nasa.gov), Jon Ranson, Jim Collatz, Francesco Bordi, David Herring, David Starr; the Terra PIs: Bruce Barkstrom, Dave Diner, Jim Drummond, John Gille, Anne Kahle, Vince Salomonson, Hiroji Tsu, Bruce Wielicki, and Terra managers: Kevin Grady, Jack Leibee, and Chris Scolese



Introduction

EOS AM-1 (now renamed "Terra") is scheduled for launch July 28, 1999. This article summarizes the readiness of Terra for launch and the expectations for the data products in the first several months of the mission. With this article we want to start a close, well-informed collaboration with the Interdisciplinary Science (IDS) community. This article is based on presentations in the last Science Working group for the AM Platform (SWAMP) Meeting in Boulder, CO, held in February 1999, and is motivated by the EOS Science Executive Committee's call for providing more information to the community and a tighter link. Several events preceded this article and the very up-beat spirit of the last SWAMP meeting that we would like to convey to you.

Terra Launch and Flight Operations

Among the highlights at the SWAMP meeting were the reports by Chris Scolese (EOS Program Manager), Kevin Grady (Terra Project Manager), and Jack Leibee (Terra Mission Manager) concerning the readiness of the instruments, the spacecraft, the launch vehicle, and, yes, the flight operation software for launch. The launch is scheduled for July 28, 1999 from Vandenberg Air Force Base on the west coast, but is still subject to coordination with other, non-NASA missions. In the last few months there was a major breakthrough in the development of the flight operations software, our obstacle for launch in the last year. A highly experienced Raytheon team, under new (and highly experienced) NASA management, made a fast recovery and generated the EMOS software that will be used for the operation of Terra, as well as the subsequent EOS PM-1 mission (see Perkins, *The Earth Observer*, 1998, Vol. 10, No. 6).

An end-to-end test conducted in late January demonstrated the excellent capability of the system to the satisfaction of the Terra Flight Operations Team, headed by Bob Kozon, the Terra manager, and us, the Project Science Team. Jack Leibee is the new mission manager, with responsibility for integrating flight and ground segments and assuring overall readiness for flight. He has many years of experience in development and integration of flight software and flight operations in NASA. After the January test, Leibee anticipates no roadblocks that would prohibit a July launch. He emphasized that the success of EMOS was made possible, at least in part, by the excellent teamwork between the government and several industry groups involved in the project. Kevin Grady reported that the flight segment is in excellent shape. There are no major issues that need to be resolved. The launch delay was used to modify the MODIS electronics to reduce an electronics crosstalk issue, and to evaluate the impact of partial failure of one of the power supplies on the CERES instrument on TRMM. To be safe, new power supplies were ordered and will be installed on CERES. The ATLAS II AS launch vehicle was manufactured 2 years ago and is set for launch.

A New Name

EOS AM-1 was renamed through an international contest (conducted jointly by NASA and the American Geophysical Union) open to students in grades 8-12 (see press release on page 26). Further information on the Terra mission, the contest, and the winning contest essay and those of the other Top 10 finalists, may be found on the Terra Web site at: http://terra.nasa.gov

Terra Outreach Strategy

The Terra Project Science Office is spearheading creation of the Earth Observatory (EOb). David Herring is responsible for this activity. (The prototype URL is http://modarch.gsfc.nasa.gov/EO/eo_home.html; login and password are both "eob".) We hope this Web environment will become the NASA Web portal where the general public goes to learn about the Earth. As such, it will showcase new images and science results from EOS missions. The focus in its first year of operation (beginning April 15, 1999) will be on SeaWiFS, TRMM, Landsat 7, SeaWinds, and Terra. All resources produced for the EOb will be freely available for use by the scientific community, museums, educators, public media, regional "stakeholders," environmental awareness groups, and interested members of the general public.

To provide overarching guidance and review for Terra outreach activities, as well as to flag "mature" new science results ready for public release, an Executive Committee for Science Outreach (ECSO) was formed. This committee is chaired by Prof. V. Ramanathan, of the Center for Clouds, Chemistry, and Climate, Scripps Institution of Oceanography. The purpose of this committee is to "harvest" new Terra science results that are ready for public release, as well as to help temper the presentation of new results with respect to socio-political implications they may have.

To meet the public media's (primarily TV, newspapers, and our EOb Web site) requirements for quick access to satellite imagery of significant, newsworthy Earth events (e.g., severe storms, floods, El Niño, volcanic eruptions, wildfires), the Terra Project Science Office is forming a Rapid Response Network, to be headed by Jim Collatz, Associate Terra Project Scientist. After launch, this network will enable us to access and produce remote-sensing imagery of targets of interest within a matter of hours to days after acquisition.

Terra Mission Calendar of Events Before Launch

Following is the calendar of main events in preparation for launch:

Jan. 15
EMOS (the flight operation system) version 1.1 successfully delivered

Jan. 28
End-to-end test of EMOS 1.1 with the flight operations team and the instrument teams, which went very well

March 15
EMOS version 2.1 will be delivered

March 29
End-to-end test of EMOS by the flight operations team

April 6
Terra pre-ship review

April 15
Terra will be shipped from Valley Forge to Vandenberg Air Force Base

April 22
The Earth Observatory interactive web site released to the public. It will include presentation of early images, data products, and new science results to the general public

April 21/22
Science Data System end-to-end test

May 4
EMOS version 2.5 will be delivered

June 1
review of Terra readiness for launch

July 28
planned date for launch

Data Products

The following provides information on Terra Data Products and expected timing for release of these products. These dates are relative to the actual launch date. The actual dates of release of specific data products depend on the complexity of the product and successful calibration and validation. We anticipate two main stages in the release of each product: a Beta release based on preliminary calibration and quick validation, and a science data release once a first estimate of the accuracy of the products is established. We want to engage the science community in finding problems and validating the Beta release, to enable a timely release of the science data products. The Tables on pages 14-18 list the EOS measurements that will be derived from the Terra mission, together with names of specific data products, algorithm developers, and expected dates of product availability. For more details see the EOS Data Products Handbook at: http://eospso.gsfc.nasa.gov/eos_homepage/misc_html/data_prod.html.

The algorithms are documented on the EOS web site: http://eospso.gsfc.nasa.gov/atbd/pg1.html. For each algorithm the expected time frame after launch for delivery of the Beta data products is identified. The science quality data will be available as soon as validation of the product is conducted. The Beta data are basically the product of "at launch" algorithms with only gross errors removed: not yet validated to science quality. These are useful for the community to start getting a feel for formats and data and perhaps start thoughts on hypotheses, but not ready to test hypotheses with any quantitative rigor. Study of these data also may reveal problems that are missed in the initial team validation efforts. The assessment of the quality of the data needed for the scientific research will take anywhere between three months and two years to complete. A statement of the expected data quality will accompany the data when they are delivered to the DAACs, in both their Beta form and in science form.

The production level of Level 1 (radiometrically calibrated data with geolocation) is 100%. The production of Level 2 – 4 was set to 50% directly after launch increasing to 100% a year or two after launch. The teams have specific plans to select the data to be analyzed to the higher level:

MODIS Level 1- produce 100%. **Atmospheric products** - produce Level 2 every second day and all Level 3 using the time sub-sampled Level 2s. **Land products** - produce full-resolution Level 2-3 data for approximately half of the land masses, concentrating on regional subsets (including the U.S.), core validation sites and where NASA has intensive field experiments underway. **Oceanic products** - produce Level 2-3 globally by subsampling every second pixel.

MISR Level 1 radiometrically calibrated data: selected portions at launch, rising to 100% at launch + 3 months. Level 1 geometrically map-projected data: up to 100% beginning at launch + 4 months assuming the Langley DAAC is fully functional for MISR operations. Level 2 top-of-atmosphere albedo, cloud, aerosol, and surface data: global coverage but with reduced temporal sampling beginning at launch + 4 months (approximately 25% data throughput), rising to 100% after approximately 2 years.

MOPITT will process 25%-50% of the data into Level 2. It will be made up of 25% clear-sky cases, and 25% broken cloud over the oceans. Plans for Level 3 production are in process.

CERES ERBE-like data products are processed 100%. Cloud products are analyzed initially over the 3 DOE-ARM sites and Chesapeake Light, to compare directly to Terra and TRMM analysis. CERES Level 2 surface and atmosphere radiative flux product uses every third month for Beta processing tests.

ASTER Level 1 processing is done in Japan and is not subject to the U.S. production limitations (100% will be produced). The Level 2 processing is primarily on demand, and production will be done based on user requests and hardware availability.

Terra Mission Calendar of Events After Launch

Day 0-20
Spacecraft activation, orbit acquisition (in formation with Landsat 7), instrument activation

Day 21-39
Instrument check-out phase, first qualitative images from the instruments; images that demonstrate the unique capability of Terra to be released to the public

Day 30-45
Basic maneuvers of the spacecraft for MODIS and CERES calibration

Day 40-70
Continued instrument check-up and preparation for measurements

Day 71-90
360° spacecraft maneuvers (pitch) for instrument views of deep space and the moon

Day 90-120
Instrument calibrations in orbit, release of Beta version of Level 1 data (calibrated and georeferenced radiance at the instrument resolution)

Day 120-150
Release of first set of Beta version of Level 2 data (science data products, not gridded)

Day 150-180
Release of second set of Beta version of Level 2 data

Day 180-210
Release of first set of Beta version of Level 3 and Level 2 geolocated data

Day 180-1000
Release of validated science quality data. We anticipate that products with long heritage will be of science quality 3-6 months after the Beta delivery.

Newer products and CERES products that require the generation of the new angular models from CERES on Terra will take 3 years after the Beta version, which will use ERBE-type angular models.

The Terra Science Team wants to engage the science community in evaluating Terra measurements and the data products, in producing exciting science and applications using the data, and communicating new Terra images and science results to the general public.

The EOSDIS Archive System and Subscription

The EOSDIS archive system at the DAACs is sized to permit daily distribution of data approximately equal to the amount of data archived each day, including all Level 0 through Level 4 products. The users submit requests for data via the EOS Data Gateway (an enhanced version of the Version 0 EOSDIS interface). The requests are routed to the appropriate DAACs from which the data will be made available to the users via ftp or media shipment. The limit on sizing does not include the data distributed on a "subscription basis," i.e., standing orders for data that can be satisfied upon production before the data are archived. Subscription-based distribution is limited only by the available media and network bandwidth at each DAAC. Therefore EOS investigators that have routine use for Terra data can submit subscription requests, and the data will be automatically sent to them.

The subscription function will be available when the DAACs are ready to become operational for Terra, in June for EDC, GDAAC, and LDAAC, and around launch for NSIDC. Subscription submittal is an operator-assisted function. This means that users need to contact User Services at a DAAC to have a subscription submitted on their behalf.

Terra Validation Program — Year 1

The Terra Science Data Validation program will go into full swing shortly after launch. A wide range of activities are planned. Some are highlighted here. As yet, schedule details are not firm, given the very recent commitment to a July launch. The full scope of activities is described in plans and summaries available on the EOS Validation Page: http://eospso.gsfc.nasa.gov/validation/valpage.html where the validation contact person for each team or subteam is given, as are links to team pages. Besides the teams, the program includes more than 30 investigations focused on validation of Terra data products. Typically partnered with a specific team, these investigations are briefly summarized on the Validation Page. Correlative measurements include regular data collections from individual surface sites and networks of surface stations, and episodic intensive field experiments, some with airborne measurement components including airborne simulator versions of the Terra satellite instruments. Simulators include the MODIS Airborne Simulator (MAS), AirMISR, MASTER (MODIS-ASTER), and MOPITT-A. All are integrated on the NASA ER-2, though low-altitude platforms are typical for MASTER. MATR is an additional sensor used for MOPITT algorithm development and validation (10, 4)*.

Calibration and calibration validating activities will be an early focus, in addition to extensive artifact analysis and comparison of related satellite data products. Many vicarious calibration activities will occur intensively in October 1999. For example, ASTER and MODIS will use surface measurements at Railroad Valley (dry lakebed), sites in Australia, and surface temperature measurements from buoy arrays in Lake Tahoe and the Salton Sea for correlative measurements. Airborne measurements are also planned. In addition to Railroad Valley, MISR will make measurements at JPL in coordination with Terra and AirMISR overflights. Building on SeaWiFS heritage (9, 5)*, data from the Marine Optical Buoy (MOBY) anchored off Lanai and the monthly service cruises will be used by the MODIS-Ocean team. An initialization cruise into high-chlorophyll waters off southern California is planned for October. Other cruises will occur during the year including an Atlantic Meridional Transect cruise (Germany to Cape Town) in December that will also collect M-AERI (10, 3)* observations for SST validation.

Following on the heritage of SCAR-C, a focused field experiment on fires and their aerosol and gaseous effluents is presently being planned for the northwest U.S. in Fall 1999 and includes MAS and MOPITT-A overflights as well as surface and *in situ* data. Following on pre-MOVE (11, 1)*, MOPITT plans a validation exercise at the Department of Energy (DoE) ARM site in Oklahoma in Spring 2000. SAFARI-2000 is an international field experiment focused on land cover, biosphere, fires, aerosols, and gaseous effluent, that will be conducted in southern Africa in August-September 2000. SAFARI-2000 has a strong Terra validation focus (10, 6)*. Extensive surface and *in situ* atmospheric observations, and remote-sensing observations from MAS, AirMISR, MOPITT-A, and other sensors are planned. Observations will also be obtained for marine stratus cloud systems off the Namibian coast.

Observations from surface networks will play an integral part of the Terra validation effort. Data from AERONET (Holben *et al*., Remote Sens. Environ., **66**, 1-16, 1998) are key to validation of aerosol data products and atmospheric correction for many surface data products as well as characterization of surface bidirectional reflectance. These data will be heavily utilized. Networks of surface radiation sites will be used by CERES to validate surface radiation retrievals, especially in relationship to cloud conditions for sites specially instrumented with micropulse lidar. Detailed high-quality measurements of atmospheric structure and radiation from the DoE ARM site in Oklahoma, as well as ARM sites on the north slope of Alaska and in the tropical western Pacific will be used for validation of cloud data products produced by the teams. CERES has also developed surface radiation sites for mixed forest in Virginia and an ocean site off the mouth of the Chesapeake Bay. MOPITT will use analyses of FTIR and spectrometer measurements routinely collected at 18 Network for the Detection of Stratospheric Change (NDSC) stations and weekly airborne profile measurements (flask samples) at 5 sites obtained by NOAA Climate Monitoring and Diagnostics Laboratory (CMDL).

MODIS has developed a network of 24 core sites for validation of its land surface/ biosphere data products (10, 3 and 10, 6)*. This network is well integrated with AERONET and with various national and international programs, such as the LTER, GLCTS, FLUXNET, and BigFoot (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/), taking advantage of ongoing and planned field work, including major field experiments. There is a well-coordinated Terra data collection plan, i.e., ASTER scenes for the core sites, and collection of MODIS Quick Airborne Looks (MQUALS) data by light aircraft at selected sites (see page 22).

In summary, the first year of Terra will involve a very intensive effort at early validation of the science data products over a wide range of disciplines.

Editor's Note: * *The numbers in parentheses refer to volume and issue of The Earth Observer.*

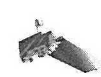
Measurement	Terra Instrument	Algorithm/Document	Authors	Expected ß-data delivery (days after launch)
INSTRUMENTAL				
Calibration / description of mission	ASTER	AST-01: Level 1B Data Processing	H. Tsu, H. Fujisada, K. Arai, K. Fukue, I. Sato, H. Watanabe, M. Kaku, A. Iwasaki, F. Sakuma	120
		AST-06: Decorre-lation Stretch	R. Alley	120
		AST-08: Digital Elevation Models	H. Lang, R. Welch	120
	CERES	CER-SYS-1.0: Subsystem 1.0: Instrument Geolocate and Calibrate Earth Radiances	R. Lee III, B. Childers, B. Barkstrom, G. Smith, D. Crommelynck, W. Bolden, J. Paden, D. Pandey, S. Thomas, R. Wilson, K. Bush, P. Hess, W. Weaver	120
	MISR	MISR-01: Level 1 Radiance Scaling and Conditioning	C. Bruegge, D. Diner R. Korechoff, M. Lee	90-120
		MISR-02: Level 1 In-Flight Radiometric Calibration and Characterization	C. Bruegge, N. Chrien, D. Diner, V. Duval, R. Korechoff, R. Woodhouse	90-120
		MISR-03: Level 1 Georectification and Registration	V. Jovanovic, S. Lewicki, M. Smyth J. Zong, R. Korechoff	120-150
		MISR-04: Level 1 In-Flight Geometric Calibration	V. Jovanovic	120-150
		MISR-05: Level 1 Ancillary Geographic Product	S. Lewicki	90-120
	MODIS	MOD-28: MODIS: Level 1A Earth Location	M. Nishihama, R. Wolfe, D. Solomon, F. Patt, J. Blanchette A. Fleig, E. Masuoka	90-120
		MODIS Level 1b- Geolocated and Calibrated Radiances	B. Guenther *et al.*	90-120
	MOPITT	MOP-01: MOPITT Calibrated and Geolocated Radiances	University of Toronto and NCAR MOPITT Team	90-120

Measurement	Terra Instrument	Algorithm/Document	Authors	Expected ß-data delivery (days after launch)
ATMOSPHERE				
Cloud Properties	MODIS	MOD-06: Discriminating Clear Sky from Cloud with MODIS	S. Ackerman, K. Strabala, P. Menzel, R. Frey, C. Moeller, L. Gumley, B. Baum, C. Schaaf, G. Riggs, R. Welch	120-150
		MODIS-04: Cloud Top Properties and Cloud Phase	P. Menzel, K. Strabala	120-180
		MOD-05: Cloud Retrieval Algorithms for MODIS: Optical Thickness, Effective Particle Radius, and Thermodynamic Phase	M. King, S-C. Tsay, S. Platnick, M. Wang, K-N. Liou	120-180
	MISR	MISR-06: Level 1 Cloud Detection	D. Diner, L. Di Girolamo, E. Clothiaux	120-150
		MISR-07: Level 2 Cloud Detection and Classification	D. Diner, R. Davies, L. Di Girolamo, A. Horvath, C. Moroney, J.-P. Muller, S. Paradise, D. Wenkert, J. Zong	150-180
	CERES	CER-SYS-4.1: Imager Clear-Sky Determination and Cloud Detection	B. Baum, R. Welch, P. Minnis, L. Stowe, V. Tovinkere, P. Heck, S. Gibson, Q. Trepte, D. Doelling, S. Mayor, S. Sun-Mack, T. Murray, T. Berendes, S. Christopher, K.S. Kuo, A. Logar, P. Davis	120-150
		CER-SYS-4.2: Imager Cloud Layer and Height Determination	B. Baum, P. Minnis, J. Coakley, B. Wielicki, P. Heck, V. Tovinkere, Q. Trepte, S. Mayor, T. Murray, S. Sun-Mack	150-180
		CER-SYS-4.3: Cloud Optical	P. Minnis, D. Young	150-180
Radiative Energy Fluxes	CERES	CER-SYS-2.0: ERBE-Like Inversion to Instantaneous TOA Fluxes	R. N. Green, J. Robbins, L. Chang	120-150
		CER-SYS-3.0 ERBE-Like Averaging to Monthly TOA Fluxes	D. Young, T. Wong, P. Minnis, M. Mitchum, D. Doelling, G. Gibson, L. Chang	150-180
		CER-SYS-4.5: Inversion to Instantaneous TOA Fluxes	R. N. Green, B. Wielicki, J. Coakley III, L. Stowe, P. Hinton	180-210

Measurement	Terra Instrument	Algorithm/Document	Authors	Expected ß-data delivery (days after launch)
Radiative Energy Fluxes	CERES	CER-SYS-4.6: Empirical Estimates of Shortwave and Longwave Surface Radiation Budget Involving CERES Measurements	B. Barkstrom, D. Kratz, R. Cess, Z. Li, A. Inamdar, V. Ramanathan, S. Gupta	180-210
		CER-SYS-5.0: Compute Surface and Atmospheric Fluxes	T. Charlock, F. Rose, D. Rutan, T. Alberta, L. Coleman, G. Smith, N. Manolo-Smith, T. Bess	180-210
		CER-SYS-6.0: Grid Single Satellite Fluxes and Clouds and Compute Spatial Averages	G. L. Smith, T. Wong, N. McKoy, K. Bush, R. Hazra, N. Manalo-Smith, D. Rutan, M. Mitchum	180-210
		CER-SYS-10.0: Monthly Regional TOA and Surface Radiation Budget	T. Wong, D. Young, P. Minnis, R. Cess, V. Ramanathan, M. Mitchum, D. Doelling, G. Gibson, S. Sullivan	180-210
		CER-SYS-12.0: Regrid Humidity and Temperature Fields	S. Gupta, A. Wilber, N. Richey, F. Rose, T. Alberta, T. Charlock, L. Coleman	180-210
	MISR	MISR-08: Level 2 Top-of-Atmosphere Albedo	D. Diner, R. Davies, T. Varnai, C. Moroney, C. Borel, S. Gerstl	150-210
Tropospheric Chemistry	MOPITT	MOP-02: Retrieved Carbon Monoxide Profiles and Column Amounts of Carbon Monoxide and Methane	J. Gille, J. Wang, M. Deeter, D. Edwards, J. Warner, D. Ziskin, and the NCAR MOPITT Team	150-210
Aerosol Properties	MISR	MISR-09: Level 2 Aerosol Retrieval	D. Diner, W. Abdou, T. Ackerman, K. Crean, H. Gordon, R. Kahn, J. Martonchik, S. McMuldroch, S. Paradise, B. Pinty, M. Verstraete, M. Wang, R. West	150-210
		MISR-11: Level 2 Ancillary Products and Datasets	D. Diner, W. Abdou, H. Gordon, R. Kahn, Y. Knyazikhin, J. Martonchik, S. McMuldroch, R. Myneni, R. West	150-210
	MODIS	MOD-02: Remote Sensing of Tropospheric Aerosol from MODIS: Optical thickness over land and ocean and aerosol size distribution over the ocean	Y. Kaufman, D. Tanré, L. Remer, A. Chu, S. Mattoo, C. Ichoku	150-210

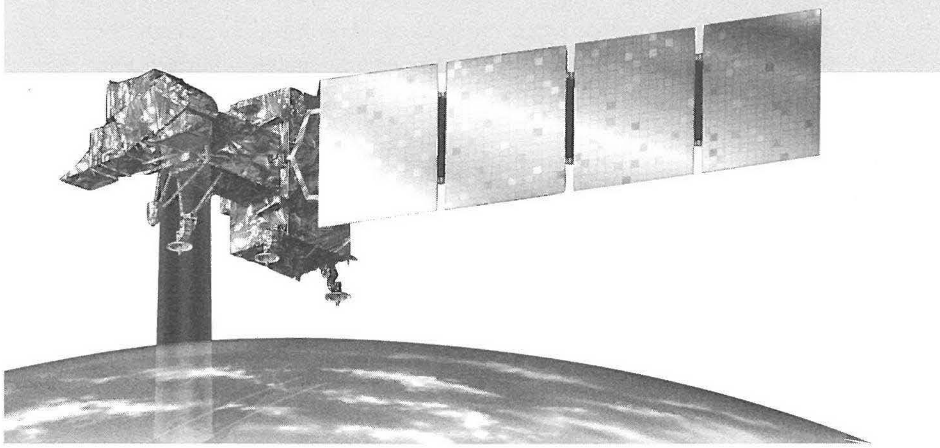
Measurement	Terra Instrument	Algorithm/Document	Authors	Expected ß-data delivery (days after launch)
Atmospheric Temperature	MODIS	MOD-07: MODIS: Atmospheric Profile Retrieval	P. Menzel, L. Gumley	120-150
Atmospheric Humidity	MODIS	MOD-03: MODIS: Near-IR Water Vapor Algorithm	B-C. Gao, Y. Kaufman	150-180
LAND				
Land Cover & Land Use Change	MODIS	MOD-08: Atmospheric Correction Algorithm Spectral Reflectances	E. Vermote	150-210
Vegetation dynamics		MOD-09: BRDF/Albedo	A. Strahler, X. Li, S. Liang, J.-P. Muller, M. Barnsley, P. Lewis	
		MOD-12: Land Cover	A. Strahler, J. Townshend, J. Borak, A. Hyman, E. Lambin, A. Moody, D. Muchoney	150-210
		MOD-13: Vegetation	A. Huete, C. Justice, W. van Leeuwen	150-210
		MOD-15: LAI (leaf area index) and FPAR (fraction photosynthetically active radiation)	S. Running, R. Myneni, R. Nemani, J. Glassy	210-360
		MOD-16: PSN (daily photosynthesis) and ANPP (annual net primary production)	S. Running, R. Nemani, J. Glassy	210-360
	MISR	MISR-10: Level 2 Surface Retrieval	D. Diner, J. Martonchik, C. Borel, S. Gerstl, H. Gordon, Y. Knyazikhin, R. Myneni, B. Pinty, M. Verstraete	150-210
	ASTER	AST-04: Level 2B1- Surface Radiance and Level 2B5 - Surface Reflectance	K. Thome, S. Biggar, P. Slater	150-210
Surface Temperature	MODIS	MOD-11: Land Surface Temperature	Z. Wan, W. Snyder	150-210
	ASTER	AST-02: Brightness Temperature	R. Alley	150-210
		AST-03: Temperature/ Emissivity Separation	A. R. Gillespie, S. Rokugawa S. J. Hook, T. Matsunage, A. Kahle	180-210
		AST-05: Atmospheric Correction Method for ASTER Thermal Radiometry Over Land	F. Palluconi, G. Hoover, R. Alley, M. Jentoft-Nilsen, T. Thompson	150-210

Measurement	Terra Instrument	Algorithm/Document	Authors	Expected ß-data delivery (days after launch)
Fire Products	MODIS	MOD-14: MODIS: Fire Products	Y. Kaufman, C. Justice	150-210
OCEAN				
Surface Temperature	MODIS	MOD-25: MODIS: Infrared Sea Surface Temperature Algorithm	O. Brown	150-210
Phytoplankton & Dissolved Organic Matter		MOD-17: Normalized Water Leaving Radiance	H. Gordon	150-210
		MOD-18: Bio-Optical Algorithms: Case 1 Waters	D. Clark	150-210
		MOD-19: Case 2 Chlorophyll_a Algorithm and Case 2 Absorption Coefficient Algorithm	K. Carder, S. Hawes, Z. Lee	150-210
		MOD-20: Algorithm for Surface PAR and IPAR	K. Carder, S. Hawes, R.F. Chen	180-210
		MOD-21: Algorithm for Clear Water Epsilons	K. Carder, C. Cattrall, R.F. Chen	150-210
		MOD-22: Chlorophyll Fluorescence	M. Abbott	150-210
		MOD-23: Detached Coccolith Concentration	H. Gordon, W. Balch	150-210
		MOD-24: Annual Ocean Primary Productivity Algorithm	W. Esaias	150-210
		MOD-27: Phycoerythrin Pigment Concentration	F. Hoge	150-210
CRYOSPHERE				
Sea Ice and Snow	MODIS	MOD-10: MODIS: Snow Mapping Algorithm and the Sea Ice Mapping Algorithm	D. Hall, A. Tait, G. Riggs, V. Salomonson	150-210
	ASTER	AST-13 Polar Surface and Cloud Classification	R. Welch	730



Report on the Landsat 7 Science Team Meeting

— Darrel Williams (darrel@ltpsun.gsfc.nasa.gov) Landsat 7 Project Scientist
— Samuel Goward and Jeffrey Masek, Landsat Science Team Office, University of Maryland



The Landsat 7 Science Team held their semi-annual team meeting December 1-3 at the NASA Goddard Space Flight Center (GSFC). Participants from the 14 research teams, as well as NASA, NOAA, and USGS, attended the meeting, which was co-chaired by Landsat 7 Science Team Leader, Samuel Goward, and Landsat Project Scientist, Darrel Williams.

Following welcoming and farewell remarks from Tony Janetos (NASA HQ Landsat Program Scientist), briefings were given on the status of the Landsat platform and ETM+ instrument by the Landsat Project Manager, Phil Sabelhaus (GSFC), and on the Landsat Ground System by Deputy Project Scientist, Jim Irons (GSFC). Sabelhaus announced that a launch date of April 15, 1999 had been set, but there was a chance that the date might be pushed ahead to March 31, 1999. Although the original delivery of the ETM+ instrument was delayed due to faulty power supplies, the problem has now been corrected, and work was on schedule for either the late-March or mid-April launch date. Sabelhaus did note some minor problems that emerged during radiometric and geometric testing, and indicated that these issues would be addressed during the next few months. Irons reported that the Landsat 7 Ground System is nearing completion and is on schedule for the launch and the subsequent transition to nominal operations. The Landsat Mission Operations Center (MOC) at Goddard Space Flight Center is launch ready. The Flight Operations Team (FOT) and the Flight Support Team (FST) are preparing for launch by participating in a series of "launch and on-orbit activation" simulations in the MOC. The Landsat Data Handling Facility (DHF) is in place at the U.S. Geological Survey's (USGS) EROS Data Center (EDC) at Sioux Falls, SD. The components of the DHF (the Landsat Ground Station, Landsat Processing System, and the Image Assessment System) are undergoing final tests in preparation for launch. The ETM+ data received and processed to Level 0R by the DHF will be sent to the EDC Distributed Active Archive Center (DAAC) for archiving, processing to Level 1 data products, and distribution to ETM+ data users. Delays in the development of the EOSDIS Science and Data Processing Segment remain a concern, but recent EDC DAAC tests indicate that the Segment will be sufficiently developed to support the on-orbit check-out of the ETM+ during the first 60 days following launch.

Shortly before the Science Team meeting, representatives of NASA, NOAA, and the USGS agreed to transfer responsibility for Landsat 7 operations from NOAA to USGS. Thus, the Landsat program will effectively become a two-agency partnership between NASA and USGS beginning in 1999. James Ellickson (NOAA) and R.J. Thompson (USGS/EDC) discussed this transition. Following the 60-day spacecraft checkout period, USGS will be responsible for ground data systems support, data acquisition, and interactions with International Ground Stations (IGS). NASA will continue to be responsible for flight operations until October 2000, at which time that responsibility will be transitioned to the USGS as well. Thompson stressed that USGS will build on satellite operations expertise of both NASA and NOAA, and that USGS was committed to making Landsat 7 a success. Thompson also mentioned that the current pricing structure for Landsat 7 data may be reviewed, to explore a more favorable pricing policy for either data consumers or the IGS network.

Brian Markham, John Barker, and Jeff Pedelty (GSFC) presented a brief summary of ETM+ radiometric and geometric test data. Although the ETM+ instrument performance has generally met specifications, some anomalies did emerge during testing. These include:

◊ Althcugh the modulation transfer function (MTF) for the panchromatic band is expected to meet specifications during the first year of orbit, model analyses indicate that the outgassing of water molecules from the epoxy graphite housing will result in a reduction of the effective resolution of the panchromatic band from 15 to ~18 – 21 m by the end of the mission.

◊ Coherent noise in the panchromatic band at a frequency of 91 kHz using the "B" side configuration of the ETM+. (Note: After the meeting, this effect was traced to a bad capacitor in one of the spacecraft power supplies. This power supply controls the ETM+ baffle heaters, and is not part of the ETM+ instrument power supplies that were repaired earlier. The faulty capacitor has now been replaced.)

◊ Excess coherent noise in two detectors of band 5 at a frequency of 27 kHz.

◊ Continued instability in the internal calibrator (IC), which has drifted since early testing at Valley Forge.

These results were discussed more thoroughly during an evening breakout session presented by Markham, Barker, and Pedelty, and attended by nearly all team members. ***It should be stressed that none of these anomalies in instrument performance is serious enough to warrant a delay in launch, and, in nearly all respects, the radiometric and geometric performance of ETM+ appears to be superior to any other Thematic Mapper instrument from the Landsat series.***

The second day commenced with a discussion of follow-on options for Landsat 7. Stephen Ungar (GSFC) presented an update on the New Millennium Program (NMP) Earth Observing 1 (EO-1), a technology demonstration targeted for launch in December 1999. The mission seeks to exploit new technology to acquire improved high-resolution observations at reduced cost. EO-1 will include a pushbroom multispectral/panchromatic array (the Advanced Land Imager – ALI), a hyperspectral imager built by TRW (Hyperion), and an atmospheric corrector sensitive to water vapor and clouds. Ungar presented test data for the ALI indicating a substantial improvement in the signal-to-noise ratio compared to the Landsat 7 ETM+ due to the greater dwell time associated with a pushbroom instrument approach.

This presentation led to a discussion of the "Landsat-Next" proposal, submitted by Darrel Williams and Jim Irons from the Landsat Project Science Office (LPSO), and Samuel Goward and Jeff Masek from the Landsat Science Team in response to last summer's EOS Request for Information (RFI) call. Recall that in early 1998, NASA HQ solicited input via the EOS RFI to select a set of measurements for the next generation of EOS sensors. To ensure that Landsat-type measurements would continue to be a priority, the "Landsat-Next" proposal articulated the science rationale for high-resolution, seasonally acquired, multispectral observations, and outlined future measurement goals. These measurement goals include improved ground navigation of IFOVs, 12-bit radiometry, and extra spectral bands for atmospheric correction. Goward stressed that the objective of the proposal was to offer the science rationale and requirements for future high-resolution missions, but that the technical design of such missions was still open.

The afternoon of the second day revolved around a proposal from the University of Maryland to build a Landsat Science Team computing facility (REALM - Research Environment for Advanced Landsat Monitoring). Such a facility would enable science users to submit analysis tasks to a database of preprocessed Landsat data. Thus, rather than dealing with individual scenes, users could apply algorithms to arbitrary regions around the globe, allowing automated, continental-scale analyses. Goward (UMCP) noted that it had taken the Landsat Pathfinder project nearly five years to process 3000 scenes into maps of tropical deforestation. In contrast, Landsat 7 would return the same volume of data every 12 days. Such volumes of data require a drastic improvement in the way researchers handle Landsat analysis. Following Goward's introduction, technical presentations were delivered on atmospheric correction (Guyong Wen, GSFC), automated image co-registration (Jacqueline LeMoigne, GSFC; Jim Storey, EDC), and cloud detection (Rich Irish, SSAI/GSFC). The science team agreed that such a capability would substantially benefit the Landsat science mission, and agreed to investigate options for implementation.

The day concluded with a presentation by David Herring (SSAI/GSFC), representing the EOS Project Science Office, on the new EOS Earth Observatory web site. This web site, currently under development by the EOS Project Science Office, gives the public an in-depth look at Earth System Science, and the role of satellite remote sensing. The site includes a number of innovative features, including on-line geophysical models and interactive data visualizations. Herring noted that Landsat 7 would play a major role in EOS public outreach, since it would be the first major land-imaging mission in the EOS series.

The final day of the team meeting began with a summary of the science team review of the Landsat Long-Term Acquisition Plan (LTAP) by Samuel Goward (UMCP) and Terry Arvidson (Lockheed-Martin). The LTAP provides a set of algorithms for scheduling Landsat 7 image acquisitions, with the overall goal of building a substantially cloud-free archive of global imagery documenting the seasonal cycles of Earth's vegetation. On August 31, 1998, a one-day review of the LTAP was held at GSFC to give the Landsat Science Team a detailed view of the algorithms and their implementation. The review was successful, and all participants agreed that the LTAP represented a major contribution to the success of the Landsat 7 mission. Several minor issues were highlighted by science team members, and most of these were addressed during the December team meeting. A written summary of the LTAP is being prepared for submission to *EOS Transactions*, the newsletter of the American Geophysical Union.

Terry Arvidson discussed post-launch operations of Landsat 7. The first 60 days after launch will be dedicated to spacecraft health and safety, orbit stabilization, and instrument calibration. Following 18 days of outgassing, the ETM+ instrument will start acquiring test data. Concurrently, a series of burns will adjust the spacecraft orbit to meet the Landsat Worldwide Reference System (WRS) grid. This orbital drift will allow a 30-orbit underfly of Landsat-5, during which time imagery will be acquired from both platforms to aid instrument characterization. During the checkout period, the Landsat Project Science Office (LPSO) will be the sole customer for ETM+ data. Normal operations and data distribution to other users will begin after the checkout period. Richard Irish (SSAI/NASA GSFC) also presented a short overview of the data formats selected for Landsat 7 data distribution. Formats for the Level 1-G product include HDF, GeoTiff, and the EOSAT FAST format.

The meeting concluded with two presentations highlighting the use of ETM+ data for land-cover applications. Science team member James Vogelmann (Raytheon ITSS/EROS Data Center) presented an overview of the proposed More Refined Land Cover (MRLC) 2000 project. This project, a joint effort of USGS, NOAA, and the EPA, seeks to produce accurate, consistent land-cover products for the United States from Landsat TM and ETM+ imagery. MRLC 2000 would extend the current work by adding more refined land-cover classes and land-cover-change products. Jeff Morisette then gave a report on EOS Calibration/Validation activities, many of which require Landsat 7 imagery.

The meeting also included presentations from all team members on their research activities during the last six months. Readers interested in specific science team investigations should consult the article on the October 1997 Landsat Team meeting in the February/March 1998 issue of *The Earth Observer*. The next team meeting will be held in Solvang, California, coordinated to occur with the launch at nearby Vandenberg Air Force Base (tentative dates are April 13-14, 1999). Interested parties should contact Jeffrey Masek (jmasek@geog.umd.edu) for further information.

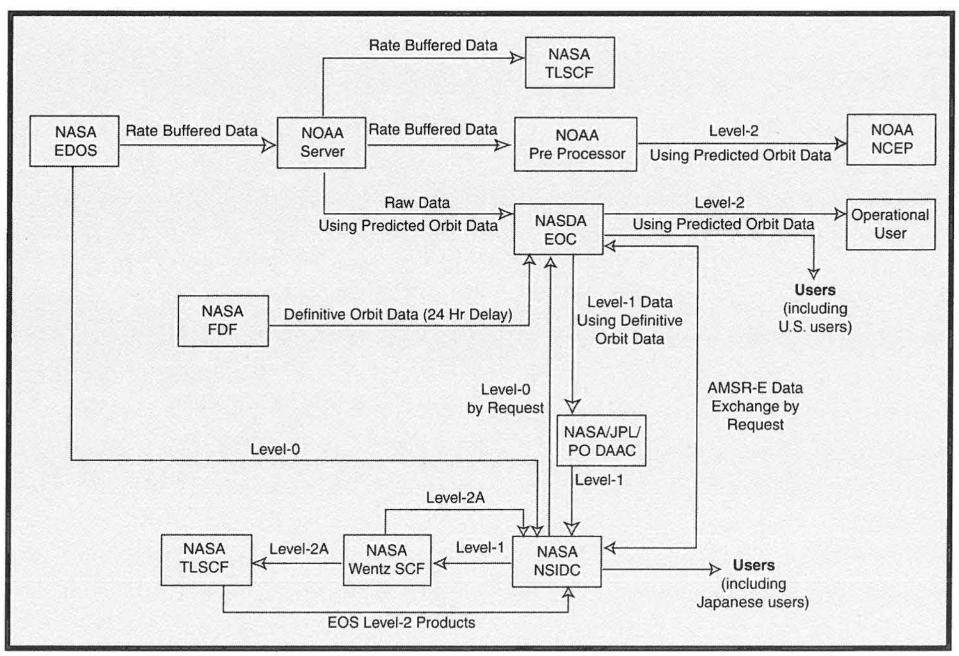
Corrections

The figure on the right replaces the figure on page 3 of the November/December 1998 issue, Vol. 10, No. 6, in the article titled—Joint Advanced Microwave Scanning Radiometer (AMSR) Science Team Meeting.

The SAFARI 2000 article in the November/December issue of The Earth Observer should have been titled "SAFARI 2000: a Southern African Regional Science Initiative."

The Earth Observer staff regrets these errors.

—Ed.



A Light Aircraft Radiometric Package for MODLAND Quick Airborne Looks (MQUALS)

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The 'MODLAND Quick Airborne Looks' (MQUALS) is an airborne radiometric system (instruments and protocol) for rapid and low-cost land product validation over a range of terrestrial biome types. The package can be flown 'below the atmosphere' at altitudes of 150 to 300 m AGL for accurate and independent characterization of surface reflectances. The package can be flown at higher altitudes (500-1000 m AGL) for scaling or large area studies. In this article we describe the MQUALS system and its application in characterizing the wide range of vegetation canopies represented by the Earth Observing System (EOS) Land Validation Core Sites. The basic package consists of calibrated and traceable "transfer radiometers," digital spectral cameras, an infrared thermometer and a set of albedometers, all connected to a laptop computer for synchronized measurements. The package is easily shipped and mounted on a variety of light airplanes. The flying costs for a 3-5 day deployment with transect measurements at various sun angles would be approximately $5 K. A key feature of MQUALS is the rapid processing "turn-around" of the measured results to within 7 - 10 days.

Background

The MODIS Land (MODLAND) group has the task of validating a series of Geophysical and Radiometric products over a diverse range of terrestrial biomes. As a result of the wide array of lifeforms (species, physiology, and structure) found over land surfaces, with their spatial heterogeneity and temporal dynamics, we have found it desirable to deploy a light, aircraft-based radiometric/imaging package with simple instrumentation for rapid and extensive 'ground truth' data collection to aid *in situ* comparisons with MODIS sensor products. This mobile package will be utilized at various validation sites, especially the EOS Land Validation Core Sites (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/core_sites.html). Through MQUALS, these sites will be characterized and geolocated with GPS in a consistent manner with an identical and 'traceable' radiometric package. In conjunction with simultaneous field sampling, MQUALS will allow us to collect a self-contained set of biophysical and radiometric data from the same ground pixels, which can be correlated and compared with ASTER, Landsat ETM+, and MODIS/MISR pixel values.

Objectives

The main goal is to provide a 'ground truth' characterization of land-cover surface types to aid in EOS product validation, support linkages between radiometric accuracies and scientific goals, and accurately tie satellite products to measurements on the ground. MQUALS has the following primary objectives in support of land-product validation:

◊ a land surface optical characterization, including measurement of multispectral radiances, spectral vegetation indexes, and albedo over transects up to 10-20 kilometers,

◊□ a consistent, well-calibrated and "traceable" instrument package, coupled to EOS vicarious calibration activities, for radiometric accuracy analysis,

◊ analysis of dependencies of MODIS data on sampling geometry, target scene, sun angle, and atmosphere,

◊ extension, correlation, and scaling of ground-based vegetation biophysical (leaf area index, % cover, biomass) and radiometric (fraction of absorbed photosynthetically active radiation) measurements to MODIS pixel sizes (250 m, 500 m and 1 km),

◊ documentation of surface conditions and sampling of landscape variability with high-resolution, spectral-digital camera imagery, providing qualitative and semi-quantitative checks of MODIS data.

In addition, MQUALS can provide quality assessments, uncertainty analyses, and generation of error bars with respect to product performance. MQUALS can also provide feedback on calibrated radiance (Level 1B) processing differences and their impacts on land products and provide for systematic assessments of long-term stability for monitoring studies.

System Design

The basic sensor package consists of a digital, multi-camera array, a nadir-looking Exotech radiometer with MODIS filters, two albedometers, an infrared thermometer (optional), and a laptop computer with Labview software for programmed and coordinated data acquisition. The sensor package can be mounted on a variety of small aircraft. The mounted setup is illustrated in Fig. 1. The ground component of MQUALS consists of a Spectralon reference panel with a second Exotech mounted for continuous measurements of site irradiance.

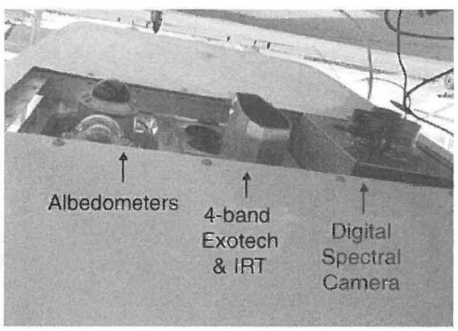

Figure 1. Mounted setup of the MQUALS radiometric package.

Exotech Radiometer (Model 100 BX) with 4 Filter Set

The Exotech radiometer is a stable, durable, and calibrated radiometer with four spectral MODIS bands (Table 1). The four channels are co-aligned to within ±0.5°.

The field-of-view can be varied from 1° square field, 15° circular field and 2π steradians. We currently are conducting flights with 15° field-of-view lenses,

Table 1. Spectral characteristics of MQUALS components.

Filter/Sensor	MODIS Sensor	Exotech Radiometer	Digital Camera
Channel 1, red	620 - 670 nm	623 - 670 nm	635 - 667 nm
Channel 2, NIR	841 - 876	838 - 876	835 - 870
Channel 3, blue	459 - 479	456 - 475	455 - 465
Channel 4, green	545 - 565	544 - 564	- - - -

Table 2. Measurement swaths for the Exotech radiometer and digital camera system at different aircraft altitudes.

Aircraft AGL	Exotech 1° FOV	Exotech 15° FOV	Camera HFOV	Camera VFOV	Camera pixel resolution
100 m	1.7 m	26 m	60 m	45 m	0.10 m
150	2.6	39	90	67	0.15
300	5.2	78	180	135	0.29
500	8.7	132	300	225	0.50
1000	17.5	264	600	450	1.0

although this differs substantially from the very narrow IFOVs of satellite sensors. However, this setting is an unavoidable compromise between the need to sample representative areas and approximating the IFOV of the satellite. With a 1° field of view, the ground pixel size of the Exotech is approximately 2 m (at 100 m AGL) resulting in highly variable, narrow swath measurements. Table 2 shows the swaths of the Exotech radiometer as a function of aircraft altitude.

We will fly the aircraft on multiple transects (3-to-10 km in length) over a selected site. The flight lines are designed on a case-by-case basis but will generally: (1) traverse uniform areas of the dominant land-cover type, and (2) span the land-cover heterogeneity, including land cover subtypes and gradients to encompass the range of variability in site parameters. Typical flight transects would occur at an altitude (150 m AGL) corresponding to Exotech 'pixel' resolutions of 40 m. Pixel size could be increased to 100 m or more by flying at higher altitudes. At a speed of 150 km/hr, the aircraft can traverse a 10 km length transect in approximately 4 minutes, collecting approximately 240 Exotech samples at a nearly constant sun angle-target-sensor geometry (Fig. 2).

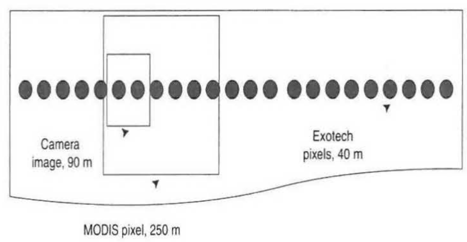

Figure 2. Diagram of Exotech and camera airborne data acquisitions in relation to a MODIS pixel for 150 m AGL and 15° field-of-view Exotech.

Dycam ADC Modular 4 Camera System

This multi-camera array consists of three cameras, upgradable to a fourth camera, with an optical mount and parallel port software. The spectral characteristics of the cameras are summarized in Table 1. The total field-of-view for the 1/4 inch detector array (640 x 480 pixels) in combination with a 6 mm focal-length lens is 33° (horizontal) by 25° (vertical). The swath width and dimensions of the imagery are presented in Table 2. At 150 m AGL, a 90 m swath is imaged while at 1000 m AGL a 600 m swath is imaged. The camera system and software are also designed to be able to measure 'reference' panels for derivation of reflectance-based imagery and computation of vegetation indexes. Figure 3 is an example of a 3-band composite image acquired at 250 m AGL.

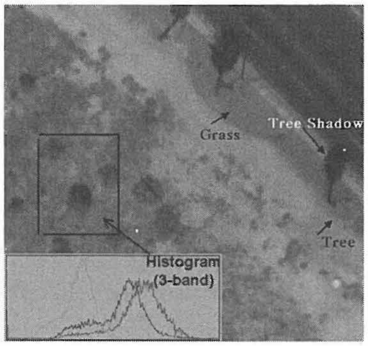

Figure 3. Example of 3-band (blue, red, and near-infrared) airborne image acquired at 250 m AGL over a desert shrubland (bottom) adjacent to a well-watered roadside planted with trees and grass (top). The image is approximately 120 m by 90 m with a pixel resolution of 0.20 m.

Spectralon Diffuse Reflectance Target

Field and low-altitude airborne measurements of radiance reflected from a surface require an assessment of the irradiance in order to derive the reflectance factor (RF). One can approximate irradiance by sampling radiance reflected from a Spectralon panel that is calibrated to account for its inherent nonlambertian properties. A commercially produced Spectralon diffuse reference panel (Labsphere) is utilized on the ground in combination with a second Exotech radiometer to measure irradiance conditions at the site continuously. They have an anodized aluminum frame covered with a specially formulated white reflectance coating (Spectraflect) with a reflectivity of 99% over an effective spectral range of 300 to 2400 nm and a thermal stability of 100°C. An 18-inch-by-18-inch panel constructed from four, 9-inch panels is used for MQUALS. These plates are weather-resistant and washable.

Kipp and Zonen albedometers

MQUALS will use two airborne and one ground-based pyranometers/ albedometers from Kipp and Zonen. The clear-dome albedometer provides short-wave broadband albedo in the range of 305 - 2800 nm and the red dome albedometer provides NIR broadband albedo in the range of 695 - 2800 nm. An upward looking, clear-dome pyranometer is mounted on top of the airplane for irradiance measurements. Another set of albedometers is mounted on the ground.

Laptop computer for data logging

A Gateway 233 MHz laptop computer is used as a data-logger and instrument controller. Data logging frequency for all of the on-board instruments and start and stop times are programmed prior to the flight transects. The computer logs the data from all instruments simultaneously. Special purpose software (LabView) is used to synchronize these activities.

LabVIEW Instrument Control Software with PC cards (Version 4.0)

This software is an icon-based graphical programming and data acquisition tool with front-panel user interface for control and data visualization. Complex acquisition, analysis, and presentation applications can be generated in real time using a graphical methodology. Different data acquisition systems such as the Exotech, digital camera, and albedometers can be controlled using this software, and data acquired from these instruments can be checked visually for problems. PC cards, including those for signal conditioning, voltage modulation accessories, and data acquisition, are used to connect the computer with the instruments.

GPS system (from aircraft):

Geo-positioning of the air transects is accomplished using the GPS receiver onboard the aircraft. Plans are being made to acquire a differential GPS and connect it directly to the laptop computer.
Calibration and Traceability

The Exotech radiometers are stable and durable optical instruments that are easily calibrated in the laboratory and can be cross-calibrated with similar instrumentation used in the field as well as on other airborne platforms. These "transfer radiometers" can also be cross-calibrated with the radiometric equipment utilized by MODIS Calibration Support Team (MCST) activities, including simultaneous on-site measurements at vicarious calibration field sites. The MQUALS package is currently being calibrated by the Remote Sensing Group within the Optical Sciences (OSC) Department at the University of Arizona. There are three aspects to the calibration of the Exotech radiometers used as part of MQUALS. One aspect is to calibrate radiometers in flight using "vicarious calibration" techniques similar to those used for Landsat-5 Thematic Mapper. These methods rely heavily upon collecting ground-based data from a well-understood radiometer (an ASD FieldSpec FR in this case) with reference to a field reflectance standard (Spectralon in this case). The field reference is calibrated in the Optical Sciences laboratory prior to the field experiment to determine its bi-directional reflectance with reference to a NIST-traceable standard of reflectance. Differences in the spectral response of the Exotech radiometer relative to MODIS are taken into account by measuring the Exotech spectral response using the

Optical Sciences monochromator. An additional tool for the vicarious calibration of the Exotech radiometer, and the digital cameras as well, are a set of calibrated tarps (7 m on a side) that are setup at the calibration sites to be viewed by the airborne camera. This enables characterization of the spectral response and linearity of the camera array system.

A similar technique to the vicarious calibration approach is to cross-calibrate the Exotech radiometer to the ground-based radiometer using the field reflectance standard to transfer the calibration from one instrument to the other. Since the ASD spectroradiometer is hyperspectral, effects due to band differences in the two radiometers are minimized. This method can either rely on an absolute calibration of the ASD spectroradiometer to obtain the absolute calibration of the Exotech, or one can simply do the cross-calibration in terms of reflectance. The latter has the advantage of "reducing" the uncertainty by not relying on the absolute calibration of one of the radiometers but a relative calibration of the reflectance standard. A similar calibration can be done in the lab, but the field-based approach has the advantage of using the same spectral source that the MQUALS data set uses.

The third aspect of the MQUALS calibration is to provide a "traceable" link to the MODIS Instrument (Fig. 4). This is accomplished through the use of ultrastable laboratory radiometers that took part in a calibration round-robin to characterize the Santa Barbara Remote Sensing (SBRS) primary standard source (a large spherical integrating source) used in the pre-launch calibration of the MODIS instrument. These radiometers have also been used to calibrate the Optical Science's sources and reference panels. Thus, any instrument calibrated using Optical Science's laboratory will have traceability to the MODIS sensor.

Note that at this point, we do not know of the radiometric stability of the multispectral digital camera system, however we will make efforts to calibrate this instrument if possible. If not, this instrument will primarily be used for characterization of scene heterogeneity and qualitative variability of component optical properties.

MQUALS Schedule for 1999

Site	Dates	Land Cover	Other
Railroad Playa, NV	Late April-early May	Barren, vicarious calibration	Landsat ETM+
La Jornada, NM	Late May & September	Semi-arid grass/shrub	LTER site
*Bondville, IL	July - August	Cropland	BigFoot site
ARM-CART or Konza	July - August	Grassland/agriculture	Possible MAS/ AirMISR overflight
BOREAS NSA	August - September	Boreal Forest	BigFoot site

* tentative

Testing of the MQUALS package is ongoing and has occurred mostly in the vicinity of the Semi-Arid Land-Surface-Atmosphere (SALSA) area in southeast Arizona (http://www.tucson.ars.ag.gov/salsa/salsahome.html), over a fairly uniform dry grassland. We also are testing and calibrating the system in a barren uniform area near the Tucson International Airport. The current schedule for 1999 MQUALS deployments is listed in the table above.

The Railroad Playa calibration experiment is expected in late April – early May, following the April 15 launch of Landsat ETM+. In this experiment we aim to: (1) cross calibrate the MQUALS package with the MODIS vicarious calibration team; (2) register MQUALS data with Landsat ETM+ for a homogeneous site with no vegetation; and (3) establish a zero baseline condition for vegetation indexes. The Jornada Experimental Range (La Jornada) near Las Cruces, New Mexico will be flown in late May (dry season) and September (wet season) time frames. This is a semi-arid validation Core Site with desert shrub, grassland, and mixed grass/shrub subsites located in a protected area which is part of the NSF's Long Term Ecological Research (LTER) site network. The Bondville, IL and BOREAS NSA (Canada) overflights will occur in conjunction with BigFoot vegetation validation work in the July-September time frame. The objective of the BigFoot program is to provide ground validation of MODIS land cover, LAI, and FPAR, with special consideration of multiple scaling issues

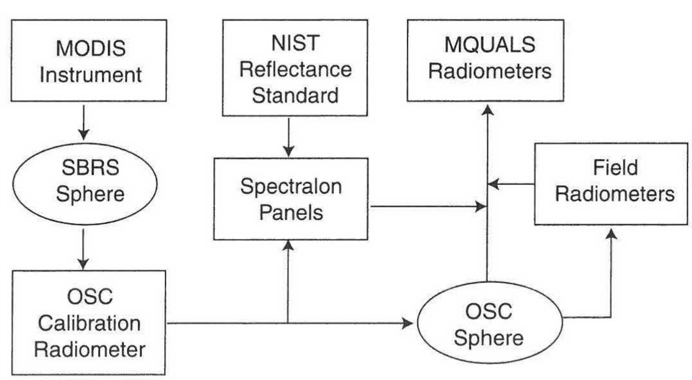

Figure 4. Diagram of the traceability of field validation measurements to the MODIS instrument.

(http://www.fsl.orst.edu/larse/bigfoot/plan.html). The MQUALS data will provide insight for scaling from field data to 250 m spatial resolution. Finally, we would like to underfly the ER-2, with MAS/ AirMISR, over some of the ARM-CART or Konza grassland sites.

Product Validation Issues

We propose to characterize the optical properties of the validation sites and at various times of the season. These validation, 'ground truth' sites will be both optically and biophysically characterized, and atmospheric effects will be simultaneously measured with sunphotometers. Precise measurements will include both the heterogeneity and uniformity of the sites and measurements will be conducted at high resolution as well as scales equivalent to that of the MODIS pixel (250 m to 1km). We will initially focus on the surface reflectance, vegetation indexes, albedo, LAI, FPAR and landcover products from MODIS. MQUALS could also be useful for the snow and land surface temperature products.

The Level 3 and 4, composited products result in cloud-free maps at 16-day intervals. These products possess a wide range of view and sun angles and 'residual' atmospheric and cloud effects. Ground truth measurements are necessary to assess how well the composited, as well as daily, MODIS products represent actual surface conditions. For example, with an independent determination of nadir-based, 'true' surface reflectance, we can analyze where the uncertainties in the MODIS products lie and identify systematic errors. Errors associated with MODIS sensor calibration, instrument noise, atmosphere correction, BRDF correction, and the cloud mask algorithm will

(continued on page 39)

Student Names NASA Earth Observing Satellite; NASA Sets Launch Date

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In a student contest to name the first in its series of Earth Observing System satellites, NASA chose 'Terra' — in honor of our planet's mythical Mother Earth — as the winning name. The Terra spacecraft will enable scientists to study, with unprecedented clarity, global climatic and environmental changes going into the new millennium.

In setting a launch date of July 28, 1999, for the spacecraft formerly known as "EOS AM-1," NASA's Associate Administrator for Earth Science, Dr. Ghassem Asrar, announced the new name after reviewing the top ten finalist essays from a contest jointly sponsored by NASA and the American Geophysical Union (AGU).

"The concept of 'Terra' uniquely conveys the themes and objectives of this important Earth science mission," Asrar said. "I congratulate Ms. Sasha Jones, a student in St. Louis, MO, for submitting the winning name and essay." Sasha's school will receive a computer and software that will enable students and teachers there to access Terra satellite imagery on the World Wide Web.

Informed that she had won the grand prize, Sasha, 17, said, "That's cool; I never won anything in my life." A senior at Brentwood High School in St. Louis, she plans to attend Western University and major in English. Her parents, Mr. and Mrs. Barry Jones, will accompany Sasha to Terra's launch, and she hopes her brother Brandon, 15, and sister Kristine, 12, can make the trip too.

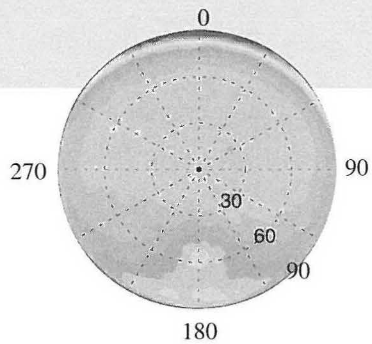
In all, the international contest drew more than 1,100 entries from all 50 states and more than a dozen other countries. Members of the selection committee included top NASA and AGU officials, as well as Earth scientists and science teachers.

Terra is the flagship of NASA's Earth Observing System, a series of satellites designed to observe the Earth from the unique vantage point of space. Focused on key measurements identified by a consensus of U.S. and international scientists, Terra will enable new research into the ways that our planet's lands, oceans, air, ice, and life interact as a whole climate system.

Terra is managed by NASA's Goddard Space Flight Center, Greenbelt, MD, for NASA's Office of Earth Science, Washington, DC. The AGU is an international organization of more than 35,000 scientists dedicated to advancing the understanding of Earth and its environment in space, and making the results of their research available to the public.

Summary of the International Forum on BRDF

— Shunlin Liang (sliang@geog.umd.edu), University of Maryland, College Park, MD
— Alan H. Strahler (alan@crsa.bu.edu), Boston University, Boston, MA



The International Forum on BRDF (IFB) was held at the Argent Hotel in San Francisco on December 11-12, 1998. More than sixty people from nine countries attended this event. BRDF stands for bidirectional reflectance distribution function, and it generally refers to multi-angle remote sensing. The objectives of the IFB were to summarize recent research progress, to identify important future research topics, and to determine their priorities. The IFB was structured in a panel discussion format. Eight panels were organized, and each panel consisted of a series of themes. Theme chairs organized a group of researchers charged with writing a white paper on the theme and preparing a panel presentation(s). The set of white papers will be published in a special issue of *Remote Sensing Reviews*.

The meeting identified five primary courses of action for the BRDF community:

- Identify a set of key scientific questions to which multi-angle data and modeling provide qualitative and quantitative advances over more traditional approaches. Organize case studies based on actual data or simulations to show the value added by multi-angle data and to define the multi-angle measurement requirements that are driven by critical science objectives.
- Explore different inversion techniques to retrieve geophysical, biophysical, or radiation parameters that are relevant to climate, environmental, and ecological sciences along with the requisite accuracies. Data fusion and assimilation from multiple sources with different spectral, spatial, temporal, and angular characteristics should be emphasized.
- Continue development of simpler BRDF models, simplified from sophisticated physical models or semiempirical statistical models, that are suitable for kilometer-scale satellite observations over both homogeneous and heterogeneous landscape types.
- Develop a benchmark validation database that may be created from well-designed field campaigns, laboratory measurements, or model simulations.
- Strengthen graduate education programs emphasizing BRDF modeling and applications. Processing and analysis of EOS multi-angle remote-sensing data will require many people with strong quantitative skills.

The IFB began with a welcome by the organizer, Shunlin Liang of the University of Maryland. After a brief overview of the IFB objectives, meeting formats and logistics, he presented his views on some of the BRDF top issues. The IFB's purpose is twofold. First, it provides an assessment of the status and future problems of multi-angle-sensing science after a decade of directed research. Secondly, it prepares the way for the Second International Workshop on Multi-angular Measurements and Models, in Ispra, Italy, September 15-17, 1999.

Alan Strahler of Boston University reviewed BRDF historical developments, including previous meetings and prior research issues as they have evolved over the years. BRDF researchers began meeting informally as early as 1990, at the BRDF specialist workshop in Tempe, Arizona, which was sponsored by the Canada Centre for Remote Sensing. Concerns at first largely centered on field and aircraft directional reflectance measurements and models. With subsequent meetings in Columbia, Maryland (1992); Beijing, China (1996); and College Park, Maryland (1997), attention became more focused on spaceborne applications of multi-angle sensing and on the information content of the multi-angle signal. As we begin to enter the second decade of BRDF research, our most important mission is to translate the gains in understanding the physics of complex surface scattering into retrieval of physical and biophysical parameters that support global-change assessment activities.

Science Drivers for BRDF Studies

Panel 1 on "Science Drivers for BRDF Studies" was chaired by Mike Barnsley of the University of Wales Swansea, UK. He first overviewed the scope and content of the panel. After discussing various science drivers and the `products' of BRDF models/data that may be appropriate, he organized this panel into two sessions. The first session was to identify the science drivers including two themes: Earth radiation budget and ecological applications. The second session was to address the science drivers, including data normalization using angular information and estimation of biophysical properties directly from directional reflectance/ emittance measurements.

There were several presentations in the theme of "Angular corrections to satellite data for estimating Earth radiation budget." Alan Strahler of Boston University first provided an overview of this topic and discussed its relevance to global-change studies. Shunlin Liang of the University of Maryland reviewed different angular models that convert radiance to flux and discussed the uncertainties in converting narrowband albedos to broadband albedos. Since surface broadband albedos also depend on atmospheric conditions, he raised the issue of providing broadband albedo products derived from one atmospheric condition to users who may need albedo for many different atmospheric conditions. Fred Prata of CSIRO, Australia introduced their ground measurement network in Australia and demonstrated the long-term trends and variations of the measured broadband albedos.

In the theme of "Ecological and biogeochemical benefits of multi-angle satellite observations: concepts and realization," Greg Asner of Stanford University first analyzed the major sources of uncertainty in large-scale ecological /biogeochemical research, and then discussed how multi-angle approaches can realize benefits for ecological/biogeochemical research.

In the theme of "Remote sensing data standardization using BRDF models: view and sun angle effects on vegetation indices (VI), leaf area index (LAI), and land-cover classification," Wim van Leeuwen of the University of Arizona reviewed different sensors that will provide off-nadir observing capabilities and focused on remote-sensing data standardization applications, including the use of BRDF models in global VI compositing, standardization of global VIs to constant sun and view angles, LAI derivation from standardized reflectances, and nadir equivalent reflectance values as input to land-cover classification.

In the theme of "Biophysical parameter retrieval from multi-angle remote sensing," Jing Chen of Canada Centre for Remote Sensing reviewed different approaches for deriving biophysical parameters from remotely sensed data.

Panel 1 discussions are summarized below:

(1) The BRDF community needs to be more aware of the broader environmental science (ES) drivers that underpin and justify BRDF research and development. We have, to varying degrees, lost sight of this point: much of the current debate in the BRDF literature is focused on the fine detail of model variants, inversion schemes, etc., which, while important, is effectively unconstrained. We need to define our goals (and hence the methods required to reach these) in terms of specific (ES) user requirements.

(2) The BRDF community needs to develop better links with its (current and potential future) 'user' communities. We must re-cast our research in terms of specific ES questions and requirements, but it is critical that they must be questions posed by the ES community, not ones that we think that the ES community is interested in or necessarily just the ones that BRDF methods can easily address. Otherwise there is a danger that we might concentrate on issues that are considered "old hat" by the target communities (e.g., focusing on above-ground biodiversity, just as soil microbial biodiversity becomes the hot topic; or "missing carbon," just as the global nitrogen cycle is seen as more critical). If we are serious about this, we should invite more ecologists, climate modelers, etc., to the next and future BRDF meetings.

(3) We need to clarify the role/significance/value of data normalization/ standardization methods. It could be that this approach is seen as inherently inferior to the derivation of biophysical properties directly by BRDF model inversion, or that the approach is widely accepted and hence does not require further debate. The truth may lie somewhere in between these two extremes, but we did not manage to tease this out during the meeting. Further discussions reached the following consensus. The angle-normalized vegetation indices are the simplest ways of inversion to obtain biophysical parameters. These simple inversion methods are empirical, region and species specific. They therefore require field data to support the algorithm development. These methods are surely valid as long as they are calibrated with field data and therefore have been widely used in climate and ecological studies and will continue to be so. More sophisticated BRDF inversion methods have the potential to be general and reduce the requirements for field measurement data. However, the methods are far from mature, and more research is still needed.

(4) Do we need to show that BRDF

approaches offer unique information about Earth surface materials, or is it sufficient to demonstrate that the information provided by BRDF data is complementary to the multispectral signal and provides added value? That there is a need to show that BRDF approaches provide unique information about Earth surface materials was accepted in the general debate without a critical discussion.

The point is probably more important than it at first seems because our response to this question defines the way that we should direct our research activities. Taken at face value, we must show not only that the BRDF hot-spot, bowl-shape, etc., relate directly to certain key biophysical properties that cannot be derived by other means, but also that these can routinely and unambiguously be retrieved from directional reflectance measurements.

Three-dimensional (3D) Modeling and Simulations

Panel 2 on "Three-dimensional (3D) modeling and simulations" was chaired by Chris Borel of the Los Alamos National Laboratory. In the theme of "Mathematical aspects of BRDF modeling: adjoint problem and Green's function," Yuri Knyazikhin of Boston University and Alexander Marshak of NASA / Goddard Space Flight Center (GSFC) reviewed the adjoint formulation of 3D radiative transfer and the Green's function concept in neutron transport and then discussed their applications in 3D radiation transport in vegetation canopies.

In the theme of "Monte-Carlo ray-tracing simulations," Roger Davies of the University of Arizona reviewed the historical developments of ray-tracing techniques particularly in the cloud community. Philip Lewis of University College London, UK, discussed the progress and issues in the land surface environmental applications.

In the theme of "Radiosity simulations," Chris Borel of the Los Alamos National Laboratory reviewed the historical developments of radiosity simulation techniques and applications in the areas of vegetation canopy modeling, atmospheric correction, and terrain modeling. (Radiosity techniques, invented by thermal engineers in the 1950s, explicitly create a global system of equations to describe the interreflection of light in a scene, and automatically take into account the effect of multiple reflections.) Wenhan Qin of the University of Maryland presented applications of combining L-systems and radiosity simulation techniques for vegetation canopies. (L-systems stand for Lindenmayer systems, which are parallel rewriting systems introduced by Lindenmayer for describing the development and growth of living systems.)

In the theme of "Recent advances in geometrical optical modeling and its applications," Jing Chen of the Canada Centre for Remote Sensing reviewed different geometric optical models and discussed his four-scale geometric optical model and applications. Xiaowen Li of the Chinese Academy of Sciences and Boston University discussed scaling issues in geometric optical models and pointed out that the reciprocity principle and Planck laws are not always valid at different spatial scales.

The discussions from Panel 2 are summarized below:

(1) In the mathematical aspects of BRDF modeling, use of energy-conserving techniques is important. Adjoint and Green's function methods are new powerful tools in the modeling of land surface scattering processes but need more development.

(2) Monte Carlo simulations are mature and are sufficiently powerful to simulate novel sensors such as cloud-probing lidars. Due to computational complexity their use has been mainly as a benchmark for analytic radiative transfer.

(3) In radiosity simulations, the powerful combination of L-systems and radiosity allows studies of canopy structure effects in vegetative canopies in the near infrared, where multiple scattering is important. The question of the need for spatial detail in modeling the scattering in vegetation is still unresolved.

(4) Geometric optical modeling has many practical applications for homogeneous surfaces but needs further development to model heterogeneous environments. The question of whether the Helmholtz reciprocity theorem is valid should be further investigated.

Simplified Radiative Transfer and Semiempirical Modeling

Panel 3 on "Simplified radiative transfer and semiempirical modeling" was chaired by Shunlin Liang of the University of Maryland. After a brief introduction by the chair giving the panel composition and its rationale, Wenhan Qin of the University of Maryland presented the theme of "simplified canopy radiative transfer modeling." He started with an introduction to radiative transfer (RT) formulation in both leaf and canopy levels, and then reviewed recent progress in the following five areas: finite-size medium theory; hot spot effect consideration; role of non-leaf organs (e.g., stems in crops and branches / trunks in forests); coupled atmosphere-canopy RT models; and RT model inversion and applications.

Qin finally discussed a series of research- and application-related issues.

In the theme of "Progress in surface particulate medium bidirectional reflectance modeling and applications," Shunlin Liang of the University of Maryland first demonstrated the need for estimating soil properties from remote sensing that are currently mapped from conventional techniques. He then reviewed the formulation and progress of radiative transfer and geometric optical modeling of particulate media and applications (e.g., soil and snow). He presented the research results on detectable depth of soils from visible and near-infrared spectra. Different research issues were also discussed.

There were a series of presentations on the theme of "Inversion methods for physically-based models" led by Dan Kimes of GSFC. After Kimes gave the brief introduction to the scientific rationale for using physically-based models, general description of the inversion problem, and current methods of inversion, Jeff Privette of GSFC focused on the traditional inversion methods. He discussed the mathematical formalism, different components of the classical inversion problem, different optimization algorithms and many research issues, such as speed vs. accuracy, model/parameter choice, data set quality effects etc. Yuri Knjazikhin of Boston University focused on table look-up methods. He demonstrated that retrieval of vegetation parameters is an ill-posed problem. Regularization techniques need development in order to provide convergence of the retrieval algorithm; that is, the more measured and accurate information available will generate more accurate outputs. He also discussed the law of energy conservation as a basis for regularization and presented examples of global LAI and FPAR (Fractional Photosynthetically Active Radiation) fields derived from SeaWiFS (Sea-viewing Wide Field-of view Sensor), POLDER (Polarization and Directionality of Earth's Reflectances), Landsat (Land Remote-Sensing Satellite) and Land Surface Reflectance (LASUR) data. (LASUR is a data set of atmospherically corrected AVHRR surface reflectances at global scales [1/7-, 1-, and 5- degree resolution; one-week temporal resolution] for 1989 and 1990.) Abdelgadir Abuelgasim of GSFC focused on neural network methods. After describing the approach, he compared the advantages and disadvantages of the neural network methods with other inversion approaches and discussed research issues. Alex Lyapustin of GSFC presented his research on the land surface albedo retrieval scheme. Finally, Dan Kimes of GSFC summarized this theme and pointed out the need for rigorous comparisons of the various inversion methods, future sensor studies, and development of new methods for handling ancillary information (e.g., topographic data, high spectral and spatial resolution data, temporal and spatial BRDF data).

In the theme of "Bidirectional reflectance and albedo from semiempirical models: approaches, models, and issues," Wolfgang Lucht of Boston University briefly reviewed different semiempirical models and their applications. He also discussed research issues in modeling, inversion, practical considerations, and albedo derivations. Jean-Louis Roujean of CNRM, France, added more critical issues in semiempirical modeling and applications. Bernard Pinty of the EC Joint Research Centre, Italy, provided a historical review of the Rahman-Pinty-Verstraete model and its recent applications.

In the theme of "Directional variance of remote-sensing images", Wenge Ni of Raytheon ITSS in Lanham, Maryland, reviewed a new concept, the bidirectional reflectance variance function (BRVF). She summarized applications of contextual information using nadir-view remote-sensing imagery and then discussed the BRVF modeling using a geometric-optical approach and presented several examples of BRVF analysis using airborne and spaceborne remotely sensed data. Further research issues were also discussed.

In the last presentation of this panel, Gail Anderson of the U.S. Air Force Geophysics Laboratory, discussed the requirements and recent implementations of the surface BRDF in the MODTRAN code that has been widely used in various remote-sensing applications.

The issues from Panel 3 are summarized below:

(1) Develop simplified radiative transfer models suitable for heterogeneous landscapes. There have been interesting debates on the roles of semiempirical models and simplified radiative transfer models in various applications. By examining four major applications (boundary conditions, surface BRDF retrieval, angular normalization of remotely sensed data, and biophysical parameter retrieval), we can see that currently semiempirical models are most suitable for the first three types of applications, while the simplified radiative transfer models are better suitable for the last application. A consensus strategy is to retrieve surface BRDF from the remotely sensed data, first using semiempirical models, and then retrieve biophysical parameters later using simplified canopy models. To effectively retrieve biophysical parameters directly from remotely sensed data, particularly with kilometer-scale resolutions, simple models are needed to account for surface heterogeneity. Studies are needed to focus on linkages of "effective" parameters in simple models

with spatial distributions of the corresponding surface parameters. Decent calibration/validation datasets are highly needed.

(2) Apply advanced inversion algorithms to retrieve important biophysical / geophysical parameters required by different ecological applications and surface modeling. Most current inversion algorithms are compromises between inversion accuracy and computational speed, such as searching look-up tables that are created from more sophisticated canopy models or inverting simplified radiative transfer models. Advanced inversion algorithms (e.g., neural networks, regression trees, etc.) may enable us to retrieve important biophysical parameters from more sophisticated models without further model simplifications, which may enable us to investigate the model invertability and sensitivity more realistically. Most current inversion algorithms rely on specific satellite sensors. New inversion algorithms should take advantage of information from multiple sources and produce more information by developing data fusion and data assimilation techniques.

(3) Explore high-order statistical moments of the surface radiation field and their linkages with surface structural information. Many inversion algorithms assume observations at different angles are independent, while they are actually highly correlated. It is practically impossible to monitor the Earth surface from every angle, and it is actually unnecessary to do so because of its high correlation. High-order statistical moments are also sensitive to surface structural information. Studies on statistical characterization of the surface radiation field will allow us to determine the best viewing angles at different bands and help retrieve surface structural information that is highly needed in the ecological applications.

(4) Develop semiempirical models whose coefficients have explicit physical meanings suitable for surface modeling and various ecological applications. Semi-empirical model parameters are not necessarily fully physically based, but may contribute to representing a physical process and/or may appear as a grouping of physical parameters.

Hotspot Research and Applications

Panel 4 on "Hotspot research and applications" was chaired by Siegfried Gerstl of the Los Alamos National Laboratory. He first recognized and stressed that the hotspot region in BRDFs of vegetated land surfaces is the most information-rich subregion within a BRDF distribution so that we may truly talk about a "hotspot signature" for all three-dimensional structured surfaces. Especially for vegetation canopies it has been shown by many model calculations, some recent measurements with airborne Advanced Solid-State Array Spectroradiometer (ASAS), CAR, MAS, AirPOLDER, and AirMISR) and spaceborne sensors (POLDER), that the hotspot effect is indeed diagnostic for canopy structure and may allow the retrieval of such canopy structural parameters as leaf size and shape, tree crown size, and canopy height for low-LAI stands.

The present state-of-the-art in hotspot modeling and canopy architecture retrieval was reviewed by Wenhan Qin of the University of Maryland and Jing Chen of the Canada Centre For Remote Sensing. Data from airborne POLDER calibration measurements in the hotspot region were reviewed by Jean-Louis Roujean of CNRM, France, who also showed that the hotspot angular signature yields similar features when airborne and spaceborne data are compared, ranging from a few meters to several kilometers spatial resolution.

Hotspot data from the MODIS (Moderate-Resolution Imaging Spectroradiometer) Airborne Simulator (MAS) were discussed by Sig Gerstl of the Los Alamos National Laboratory and show very remarkable detail in the BRDF distribution in the hotspot region, even without the application of atmospheric corrections. Gerstl discussed also the newly approved NASA satellite project Triana that will place a high-resolution multispectral imager at the Earth/sun (gravity-neutral) Lagrange Point L-1 to provide continuous well-calibrated images of the full Earth disk with spatial resolution of ~8 km. Due to its distance from the Earth (about 4 times the Earth-moon distance) and its location along the line-of-sight between the Sun and Earth, Triana will image the entire Earth in the hotspot direction all the time, while the Earth rotates under it. The hotspot angular distribution will be measured out to +15 degrees by slow measurement around the L-1 point. Thus, Triana is truly a 'global hotspot imager' and is expected to deliver these data by early 2001. To quantitatively analyze and understand Triana data will require the acceleration and focusing of ongoing hotspot research with the hope that a global hotspot ecology may be developed with Triana data.

The following top research/action priorities were identified for hotspot R&D within the next few years:

(1) Simplified 3D hotspot models need to be developed that are capable of representing the three-dimensional aspects of realistic heterogeneous, km-size scenes. These models should allow the derivation of quantitative correlations of hotspot signature parameters to canopy structural

parameters, and their scaling for different fields of view.

(2) Build an experimental database for hotspot BRDF signatures from airborne measurements, like those from the MODIS Airborne Simulator, for solar zenith angles between zero and 90 degrees, covering the hotspot distribution function to at least +/ -30 degrees. This database should allow look-up tables to be built for terrestrial hotspot signatures by latitude, longitude, biomes, and season.

(3) Develop rigorous atmospheric correction algorithms for hotspot angular signatures that include absorption and multiple scattering effects by Rayleigh and Mie scattering from gaseous and aerosol atmospheric constituents.

BRDF Retrieval from Remotely Sensed Data

Panel 5 on "BRDF retrieval from remotely sensed data" was chaired by David Diner of NASA/JPL. He started with a set of questions about multi-angle/BRDF remote sensing: Why should we do it? What does it mean? How should it be implemented technically? How do we insure its place in future missions?

In the theme of "BRDF retrieval from sequential multi-angle observations," Mike Barnsley of the University of Wales Swansea, UK reviewed BRDF retrieval from different sensors that provide off-nadir observations one at a time (i.e., sequential multi-angle observations), such as MODIS, AVHRR (Advanced Very High-Resolution Radiometer), SeaWiFS, SPOT-vegetation, CHRIS (Compact High Resolution Imaging Spectrometer), etc. Advantages and limitations were also discussed.

In the theme of "BRDF retrieval from simultaneous multi-angle observations," Marc Leroy of CESBIO, France, compared different inversion methods for those sensors that provide multi-angle observations simultaneously (i.e., simultaneous multi-angle observations), such as MISR (Multiangle Imaging SpectroRadiometer), POLDER, ATSR-2 and ASAS. Some common features and examples were also presented.

Diner then outlined a set of key scientific questions ("silver bullets") to which multi-angle data and modeling provide critical and unique input, and organized the participants into groups to focus on key questions. He charged them to: 1) identify the geophysical, biophysical, or radiation parameters that must be measured along with the requisite accuracies. Be able to state the consequences of not achieving these accuracies; 2) identify the angular sampling and coverage requirements; 3) identify spatial, spectral, temporal, and supplementary model requirements; 4) put together case studies based on actual data or simulations to show the value added by multi-angle data. The detailed summary of these discussions will be described in an article to be submitted to the *Bulletin of the American Meteorological Society* (see BRDF Future).

Modeling and Measurement of Thermal Angular Effects

Panel 6 on "Modeling and measurement of thermal angular effects" was chaired by Fred Prata of CSIRO, Australia. Chris Borel of the Los Alamos National Laboratory first outlined different modeling efforts, including vegetation models by J. Smith, Lee Balick, J. Norman, etc., DIRSIG modeling at RIT, hyperspectral scene thermal modeling at LANL, and directional modeling of emissivity for sea surfaces by P. Villeneuve and F. Prata. Borel then presented some recent results in temperature/emissivity retrievals. In the second talk in this panel, Fred Prata of CSIRO, Australia first clarified the meanings of parameters like land surface temperature (LST), emissivity, thermal BRDF and Bidirectional Emittance Distribution Function (BEDF). He then discussed field and laboratory measurements in thermal IR and temperature/emissivity separation algorithms. He pointed out that there remain many problems with surface temperature retrieval (particularly over the land) and some of these do relate to directional effects. He suggested looking at the state-of-the-science for LST retrieval and figuring out how much of the problem is due to directional effects, how much is poor experimental design (e.g., calibration/validation), how much is due to the atmosphere and how much is due to inadequate sensor performance. Prata also commented that while sensors like AVHRR, ATSR-2, Landsat, TIMS, Daedalus, and others have been studied in detail, the new sensors (such as MODIS, ASTER, AATSR, GLI) will be the challenge for the future. Prata was followed by Julienne Stroeve of the University of Colorado at Boulder who presented some interesting results that demonstrate the effects of snow/ice angular corrections on thermal energy balance studies. Since this panel was quite small, they decided not to identify research issues and priorities on behalf of their community.

Measurements and Validation

Panel 7 on "Measurements and validation" was chaired by Charles Walthall of USDA/ARS at Beltsville. After brief panel charges by the chair, Stefan Sandmeier of GSFC reviewed different BRDF laboratory measurements for both vegetated and non-vegetated surfaces and major goniometer laboratories around the world. The advantages and disadvantages of laboratory BRDF measurements compared to field measurements were also discussed.

In the theme of "Measurements for biophysical and BRDF products: defining appropriate resolutions for validation," Charles Walthall gave a comprehensive discussion on a variety of issues related to field BRDF measurements, including objectives for BRDF research data collection, examination of field campaign models, brief history of major BRDF-friendly field campaigns, evolution trends of data collection on the surface, evolution of methods, outstanding issues and problems, and future activities.

Research priorities from this panel are summarized below:

(1) Conduct fusion experiments (with multispectral and multi-angle measurements) to address the uniqueness of multiple-view-angle (MVA) data relative to spectral nadir-only data. Parameterize the landscape and the atmosphere for use in models as an integral part of the effort. Few data sets exist that can be used to address MVA data values using both empirical and model-based approaches. There is also a lack of knowledge about the spectral variability of directional reflectance of the Earth's surface. A critical element of this includes specifying minimum parameters for models to address cause and effect and parameter retrieval. New parameters describing ecological systems and structures may result from this effort. Protocols for measurements are needed to insure high-quality data and to direct instrumentation development. Specification of surrogate measurements when optimum instrumentation is unavailable will increase the amount and quality of data. Recommended approaches include pairing investigators with modeling expertise with those having measurement expertise and/or ecological applications expertise.

(2) Conduct experiments with measurements from a range of temporal and spatial scales that address the changes of information accompanying different spatial and temporal resolutions. There is a concern that our understanding of the Earth's surface is limited by our ability to sample only small areas and short time scales with a reasonable level of confidence. It is therefore necessary to understand how information content changes as a function of the spatial dimension and as a function of time. This will increase our knowledge of Earth systems and yield insights for selection of optimum spatial and temporal resolutions for Earth observations.

(3) Identify levels of aggregation/clumping and heterogeneity of canopy and landscape elements and determine their significance. There appear to be levels of aggregation of Earth surface features affecting radiant energy interactions. These structures are assumed to be ecologically significant. It is necessary to understand what canopy and landscape elements exhibit levels of aggregation, determine the dimensions of the aggregations, and understand their ecological significance. This is a relatively recent finding that strongly questions assumptions about the degree of randomness in nature. Better knowledge of these issues will improve our understanding of Earth systems, result in better models, optimize measurement strategies, and provide additional foundations for specifying Earth observation system resolutions.

BRDF Future

Panel 8 on "BRDF Future" was chaired by Alan Strahler of Boston University. In a theme of education and outreach, Mike Barnsley of the University of Wales Swansea, UK, stressed the importance of BRDF education and outreach and demonstrated a Web-based interface for running the Scattering by Arbitrarily Inclined Leaves (SAIL) canopy model that can be essentially used for both undergraduate and graduate education. Charlie Walthall of USDA/ARC at Beltsville discussed a variety of issues, such as how we can increase awareness of BRDF research findings, how we can infuse BRDF into remote-sensing applications, and how we can improve/expand remote-sensing education so that BRDF research is an integral part.

Group discussion on BRDF future centered on short-term issues of promoting the value of multi-angle remote sensing to the broader Earth system science community, especially in the context of NASA's plans for future missions centered around science themes. No new mission specifically utilizing multi-angle sensing except Triana is planned after the launch of MISR on the Terra platform. The group expressed concern and decided to work harder to promote the contributions of multi-angle sensing to retrieval of surface parameters essential to Earth system science. It was agreed that an article be drafted and submitted to the *Bulletin of the American Meteorological Society* that would provide case studies and arguments for multi-angle sensing, following the lead of Panel 5. Dave Diner agreed to lead the effort to draft the article with inputs from discussion leaders. It was also agreed that a summary of the meeting would be submitted to *The Earth Observer*. Continuing discussion confirmed five priority issues for future BRDF research, which were stated at the beginning of this meeting summary.

(continued on page 37)

Earth Science Enterprise Educational Update

Augmented Learning Environment For Renewable Teaching—Project Alert

— Nahid Khazenie (nkhazeni@pop100.gsfc.nasa.gov), NASA Headquarters, Earth Science Enterprise, Washington, DC

Project ALERT is a cooperative California-based program with two main partners, the California State University (CSU) geoscience and education disciplines and NASA centers at Ames Research Center (ARC) and the Jet Propulsion Laboratory (JPL). It is a three-year initiative that began in the spring of 1998 with funding from NASA and nine CSU campuses; several additional campuses are being recruited for the coming year. The shared goals are to build strong bridges between NASA scientists, engineers, and science information technologists at ARC and JPL, and university educators and scientists at CSU. A primary emphasis of ALERT is to create, improve, and/or infuse interdisciplinary Earth science course materials into the core science curriculum of pre-service teachers.

ALERT projects include repackaging Earth science information generated by NASA missions for educational uses, effecting simpler transfers of NASA technology to education, and reassessing and augmenting university-level Earth science course content.

For more information, see the ALERT WWW site <http://www.projectalert.nasa.gov> or contact J. W. Skiles, SETI, NASA Ames Research Center, <jskiles@mail.arc.nasa.gov>, or Ellen Metzger, Geology, San Jose State University, <metzger@geosun1.sjsu.edu>.

Conference On Remote Sensing Education For The Next Millennium, July 6-9, 1999, University Of Colorado At Boulder

The Conference on Remote Sensing Education (CORSE) is sponsored by NASA, the American Society for Photogrammetry and Remote Sensing (ASPRS), the International Center for Remote Sensing of Environment (ICRSE), and the IEEE-Geoscience and Remote Sensing Society (IGARSS). The objective of CORSE 1999 is to provide K-12 educators with a comprehensive overview and hands-on experience with Earth science applications. Information will be posted on the CORSE web site as it becomes available: http://www.asprs.org/CORSE.

Event-Based Science Project Needs Teachers To Test Remote-Sensing Activities

Are you already using Event-Based Science modules? Would you like to help the Event-Based Science Project by testing NASA-funded, remote-sensing activities for one or more of these EBS units: Flood, Oil Spill, Fire, Volcano, Blight, Gold Rush, Hurricane, and Earthquake? Contact The Event-Based Science Project for details:

Event-Based Science Project
Montgomery County Public Schools
850 Hungerford Drive
Rockville, MD 20850
tel. 1-800-327-7252; fax: (301) 279-3153
email: russ_wright@fc.mcps.k12.md.us
Website: http://mcps.k12.md.us/departments/eventscience>

Our Earth—Opportunities for Undergraduates

The Washington NASA Space Grant Consortium is offering a hands-on research opportunity for undergraduate students during the summer of 1999. Opportunities for Undergraduate Research in Earth System Science (OUR Earth) is an eight-week, NASA-funded program that matches talented undergraduates from around the country with University of Washington (UW) faculty and researchers engaged in cutting-edge, Summer 1999 projects including the following:

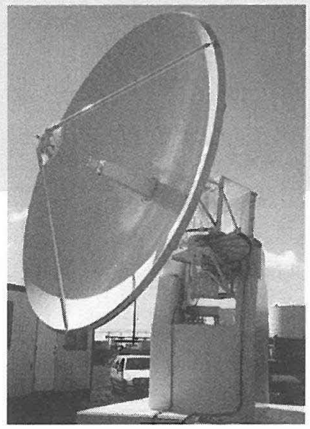
- probing remotely for life in icy environments,
- building virtual worlds that help people understand the environment,
- studying marine storms,
- analyzing the interaction of oceans, ice, and atmosphere; and
- predicting the effects of forest clearcutting on a large river basin.

Complete program information, including a downloadable application form, can be found at <http://weber.u.washington.edu/~nasauw/ourearth.html>.

Summary of EOS Direct Broadcast Meeting

Canberra, Australia, December 1998

— *Ian Barton (ian.barton@marine.csiro.au) CSIRO Marine Research, Hobart, Australia*
— *Jim Dodge (jdodge@hq.nasa.gov) NASA Headquarters*



Torben Nielsen's 5 meter antenna at the Univ. of Hawaii.

Following previous successful meetings on the direct broadcast (DB) of data from EOS platforms to national and foreign ground stations, a meeting jointly arranged by Australia and NASA was held at CSIRO Headquarters in Canberra, Australia, during December 1998. The Australian organizing committee was formed by members of the Tasmanian Earth Resources Satellite Station (TERSS), which operates an X-Band station in Hobart, Tasmania.

The delegates were welcomed by David Jupp, Head of CSIRO's Office of Space Science and Applications (COSSA). David commented on the timeliness of the meeting and the value of real-time data in many different applications, especially for countries with large, sparsely-populated areas and/or large marine Extended Economic Zones.

The meeting kicked-off with a presentation from Jim Dodge, who provided information on the status of NASA's EOS Program including plans for the direct broadcast of data to ground reception stations. For the Terra (formerly AM-1) platform, only data from the MODIS instrument would be available, but for the PM-1 satellite, Earth observation data from all instruments would be available via direct broadcast. Currently NASA is planning four national reception sites – Hawaii, University of South Florida, University of Wisconsin, and GSFC. Software packages to assist in the preliminary analysis of the DB data are under development at GSFC and Wisconsin. Many foreign stations, including those in Europe, Asia, South America, and Australia, are also planning direct reception of these data. The importance and value of blending EOS data with those from other sources (including other satellites) was stressed. Finally Jim stated that NASA is committed to the concept of an international user community that shares information on data reception, processing algorithms, calibration, and validation. Also, NASA's policy is to support free exchange of EOS data for approved research, operational public-good activities, and educational applications.

The introductory talk was followed by five presentations, each giving examples of the importance of real-time data in different applications. Richard Smith of the Western Australian Department of Land Administration (DOLA) gave examples of the use of AVHRR data in the management of agricultural areas with special emphasis on the detection of areas affected by salinity and by grass fires. DOLA currently operates an automated near-real-time fire-monitoring program for northern Australia based on NOAA AVHRR data. Richard also stated that a consortium in Western Australia was planning to develop Australia's third X-band reception station in Perth over the next year. This would ensure that a range of new data, including possibly real-time EOS DB data could be made available to applications in Western Australia.

Rob Lees of SPOT Services Australia described the new VEGETATION instrument on the French SPOT-4 satellite. Data are transmitted to European ground stations on both X-band (global data) and S-band (local data). Global data processing is undertaken in Belgium while S-band stations are able to process their data in near real time. Data products include ten-day composites of vegetation indices with cloudy areas removed. The data products are finding wide applications in the management of agriculture, land use, and environmental studies.

Ian Barton of CSIRO Marine Research described the many benefits of the use of real-time satellite data in the management and research of Australia's Marine Exclusive Economic Zone—an area that is larger than the Australian land mass. Currently, data from many different satellites are used, and these will be augmented by those from the EOS program in the coming years. Australia also maintains a comprehensive network of satellite data validation sites, both on the land and over the oceans. These data will be made available to satellite operators to assist in the continuing monitoring of instrument performance. Barton also stressed the need for the development of a suitable processing package which would allow foreign DB reception stations to obtain Level 1B data products (geo-located geophysical quantities) from the raw DB data stream.

Graham Harris of CSIRO Land and Water Division gave the fourth presentation in this group, and talked about a new program to address and reverse salinity and erosion problems in one of Australia's main agricultural areas—the Murray-Darling Basin. Over the past years poor land management, deforestation, and over-grazing have led to a large increase in non-productive land. A major program of reforestation was planned to address these issues, and accurate and timely remote sensing techniques for monitoring the reclamation process were essential. Discussions are being held between CSIRO and NASA on the potential for this major undertaking to be an international focus of Earth-observing activities.

The last presentation was from Jim Simpson of Scripps Institution of Oceanography, UCSD. Simpson described plans to collect satellite data for an area of 1000 km by 1000 km centered on Hawaii. By collecting data from all available satellite instruments (EOS, AVHRR, SeaWiFS, etc.) as well as ground-based data, the experiment would show the value of combining these data in the derivation of geophysical parameters. Improved techniques for cloud clearing over the oceans and the determination of cloud heights over land were described. Using MODIS data it should be possible to derive cloud heights with an accuracy of 200 m. Finally Simpson commented that the extra channels of data available with MODIS should lead to an improved detection of volcanic ash clouds for increased aviation safety. The DB of MODIS data to foreign stations would be essential if the aviation industry was to benefit from this application in the time frame it needs.

Peter Bayliss of the University of Dundee, Scotland, delivered the first of four talks on the development of X-band stations for the reception of DB from environmental satellites. The University of Dundee has been receiving AVHRR data for many years and is now planning to install an X-band station. They have obtained a 3.7-m antenna and have developed a novel movable feed to overcome the key-hole problem. The university has also developed a signal simulator for testing the new system.

Bertil Gransberg of the University of Karlstad, Sweden, described the development of a similar system for the DB reception of data from the Terra and EOS PM platforms. He also has a 3.7-m Cassegrain antenna and gave detailed information on the complete system. Data applications will include vegetation, snow, and ice monitoring as well as weather forecasting.

The third presentation was jointly delivered by Woolner and Longhorn of the Australian Centre for Remote Sensing (ACRES). Woolner described the two Australian X-band receiving stations at Alice Springs and Hobart. These stations are both managed by ACRES, with the former being operational for almost twenty years. Both stations are currently undergoing a full upgrade and Longhorn presented details of the improvements. The upgrades will provide full automatic operation, with on-line browse products being available within one hour of reception. ACRES was also investigating the distribution of selected, small-area products over the Internet in near real time. Both Australian stations are potentially available to receive DB data from the EOS satellites for specific real-time applications, and ACRES is very interested in progress on the development of these applications.

Torben Neilsen of the University of Hawaii described the Hawaii satellite reception system, which is based on a 5-m antenna. The design philosophy is to concentrate on using software whenever possible. Currently, the system is capable of receiving data from Landsat 5 and ERS-2, and is ready to receive data from the Landsat 7, Terra, and PM-1 satellites when they are launched. The full system was developed "in-house," and basic design details are available. Torben also stressed the need for a good orbit model for a system that does not have an auto-track facility.

The use of data from the EOS program in weather forecasting was the topic of a further three presentations. For the weather services the most useful satellite data products are from the sounding channels of satellite instruments that give vertical profiles of temperature and water vapor over remote areas. MODIS on both EOS platforms would be able to provide this information with an improved horizontal spatial resolution, while the AIRS instrument on the PM-1 platform would give an improved vertical resolution through the provision of high-spectral-resolution data at the appropriate wavelengths. John Le Marshall of the Australian Bureau of Meteorology described these two instruments as the "new generation" for weather forecasting. The world's weather services are eagerly awaiting these data—but to ensure that the real-time products are fully exploited will require the reception of DB data and the provision of an analysis package to quickly and easily interpret the data. In the past much has been gained from an early release of appropriate software, and Le Marshall suggested that this would also be true for the EOS era. Finally, he gave some impressive examples showing the value of real-time cloud-drift winds in the successful forecasting of the tracks of tropical cyclones (hurricanes).

Paul Hwang and Gene Shaffer of GSFC described the development of a Level 1b software package for the interpretation of data from the instruments on the PM-1 satellite, including AIRS. They also presented details of the status and schedule of PM-1. NASA has plans for an Internet site for potential users of data from the satellite, which would also address DB issues.

Bjorn Lambrigsten of JPL gave a full description of the AIRS instrument, including the development of a full processing system. He stated that JPL will support DB activities as far as funding and time would permit. A preliminary release of software is expected by mid-1999. The AIRS Science Team is also working closely with the International TOVS Working Group (ITWG). This group of representatives from international weather services has been extremely successful in the exploitation of data from the vertical sounding instruments on the NOAA operational meteorological satellites.

The one remaining presentation was from Liam Gumley of the University of Wisconsin-Madison. He described the development of one of NASA's EOS ground stations and the parallel development of a processing package that would provide Level 1b products from the EOS DB data stream. Both activities are receiving funding support from NASA. The processing package would eventually be widely available to ground stations capable of receiving the DB data stream. Wisconsin is hoping to involve the international community in the development and evaluation in this project. The main goal of the Wisconsin group is to exploit MODIS data to provide improved satellite data products for clouds and the atmosphere.

Prior to the final discussion session Fritz Hasler (GSFC) and his colleagues gave an animated 3-D presentation of Earth observation data. A sequence of geostationary satellite data at 1-minute intervals gave an impressive visualization of a tropical hurricane. The demonstration included close-up and cross-sectional views of the eye of the hurricane, as well as over-laid wind vectors. Several other examples demonstrated the power of these techniques for interpretation, research, and educational applications.

In the closing session Ian Barton provided a summary of the meeting and also suggested several points for further discussion. Following the summary there was wide-ranging debate about intellectual property issues relating to processing software and the distribution of data products. Jim Dodge reconfirmed that NASA operates under a policy of free exchange of data for approved research, operational public-good activities, and educational applications. However, use of DB data for commercial outcomes would need to be negotiated with NASA. Generally also, DB applications would use real-time data with data for less time-critical applications being obtained from EOSDIS. During the meeting it became evident that there is now a depth of international knowledge to assist in the development of international networks of national X-band reception stations. This is well complemented by a set of documents, available from NASA, to assist with the development of effective reception facilities for DB data from NASA's EOS satellites. The meeting attendees noted the absence of delegates from ESA, Japan, and some other countries (due to a number of reasons), and a wider international attendance at the next meeting would be encouraged.

There were three technical tours associated with the meeting. Two of these were completed during the meeting in Canberra—the first to the ACRES facility where delegates experienced, first hand, the production of satellite data products from data received at the Australian X-band stations. The second tour was to NASA's Deep Space Tracking Station at Tidbinbilla near Canberra. This is one of three global stations used for NASA's interplanetary missions. The third technical tour to Hobart followed the meeting. This tour included visits to the Hobart X-band station, the CSIRO Marine Laboratories, the University of Tasmania, and the Australian Antarctic Division.

A more complete report of the meeting is available at http://www.eoc.csiro.au/ under the heading "Direct Broadcast Meeting Reports."

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BRDF

In January, 1999 a proposal to defray publication and distribution costs for the special issue of *Remote Sensing Reviews* was approved by Dr. Diane Wickland, Program Manager of NASA's Terrestrial Ecology Program. The organizers gratefully acknowledge her contribution, as well as that of the Center for Remote Sensing of Boston University, which contributed substantially to help cover meeting costs. We would like to thank all panel chairs for their contributions of the panel summaries to this report.

EOS Scientists in the News

"El Niño Observed from Start to Finish," *Environmental News Network* (Jan. 6). **Antonio Busalacchi** (NASA GSFC) and **Ants Leetmaa** (NOAA) discuss how the 1997-98 El Niño event was the "event of the century." This event was the best monitored, the first El Niño observed globally from start to finish, and the first one ever predicted. Busalacchi's and Leetmaa's discussion was also featured in *Christian Science Monitor* (Jan. 8).

"Global Warming is for Real, NASA Says," *Environmental News Network* (Jan. 7). **James Hansen** (NASA GISS) explains there is no longer a question about whether global warming is occurring. The real questions now are determining the rate, significance, and identifying possible solutions of global warming.

"1998 Was Hottest Year on Record; '90's Hottest Decade,"*Knight Ridder Newspapers* (Jan. 12) by Seth Borenstein. **James Hansen** (NASA GISS) and **Kevin Trenberth** (NCAR) report that 1998's 0.34° Fahrenheit reading departure from long-term annual averages makes 1998 the warmest year on record. This information has sparked concern and debate over the Kyoto, Japan agreement to reduce greenhouse gas emissions Hansen and Trenberth were also featured in *Associated Press* (Jan. 12), *Reuters* (Jan. 11) and *Science News* (Jan. 2).

"Warming Affects Ocean Algae," *Reuters* (Jan. 14). **Kevin Arrigo** (NASA GSFC) led a study on the ocean surrounding Antarctica. These oceans make up 10% of the world's oceans and soak up carbon dioxide.

"Lessons from El Niño," *Dallas Morning News* (Jan. 18) by Alexandra Witze. **Antonio Busalacchi** (NASA GSFC), **Mark Cane** (Columbia Univ.), and **Kevin Trenberth** (NCAR) are sifting through the flood of information from the 1997-1998 El Niño in the hopes of predicting the effects of future El Niño events.

"NASA Animates 20,000 Years of Antarctic Ice History," *CNN* (Feb. 3). **Robert Bindschadler** (NASA GSFC) explains the 3-D computer animation showing the shrinking of the West Antarctic Ice Sheet. The image emphasizes that over the last 20,000 years that the ice sheet has lost two-thirds of its mass and raised sea level 10 meters.

"Ancient Egypt Helps Modern Science," *Associated Press* (Feb. 5) by Randolph E. Schmid. **Elfatih Eltahir** (MIT) examines Nile flood records dating back to A.D. 650 to estimate El Niño events. Eltahir found two periods of frequent El Niño events but could not find a link between the two periods. Eltahir's research was also featured in *ABC News* (Feb. 5), *Los Angeles Times* (Feb. 5), *and Seattle Times* (Feb. 5).

"Climate-observing Systems Inadequate," *USA Today* (Feb. 12). **Kevin Trenberth** (NCAR) comments on the National Research Council's study that raises questions about the confidence of climate research data. He says that the subtle trends in climate are difficult to detect with existing data. Trenberth proposes the idea that a climate-observing system should be established. Trenberth's discussion was also featured in *Associated Press* (Feb. 4) and *Los Angeles Times* (Feb. 4).

"Bacteria Under Ice: Some Don't Like It Hot," *Science News* (Feb. 13) by Richard Monastersky. **Richard B. Alley** (Penn State) discusses the discovery of bacteria living underneath glaciers in Switzerland that are growing at a temperature of zero degrees Celsius. This finding is causing scientists to question assumptions made about life in cold environments on Earth and other planets.

"Sea Change in the Arctic," *Science News* (Feb. 13) by Richard Monastersky. **Michael Steele** (Univ. of Washington) and **John M.Wallace** (Univ. of Washington) have returned from the Surface Heat Budget of the Arctic (SHEBA) project and have found that they need to question preconceived ideas about the Arctic. Increases in greenhouse warming, changes of the ice pack, and strong winds above the atmosphere, are predicted to have a dramatic effect on climate.

"Icy Clues to Earth's Future," *The Washington Post* (Feb. 21) by Curt Suplee. **Robert Bindschadler** (NASA GSFC) reveals that Antarctica is actually three different parts in terms of climate response: the East Antarctic Mass, the Antarctic Peninsula, and the West Antarctic Ice Sheet. Bindschadler has done extensive work observing the shrinking of the West Antarctic Ice Sheet and the effects it will have on world sea levels. Bindschadler admits he is uncertain if the ice sheet will continue to shrink.

"Study Shows No Long-Term Growth of Sahara Desert," *Space News* (Feb. 22) by Leonard David. **Compton Tucker** (NASA GSFC) reports on his Advanced Very High Resolution Radiometer (AVHRR) data collected from 1980-1998 over the Sahara desert and reveals that the Saharan-Sahelian boundary moves south in dry years and north in wet years.

"Early Warning," *Discover* (March). **Luke Flynn** (Univ. of Hawaii) explains his use of satellite data in predicting volcanic eruptions and says that a system of six to eight satellites is needed to accurately observe volcanoes around the world

"El Niño, La Niña: Nature's Vicious Cycle," National Geographic (March). **Ants Leetmaa** (NOAA) and **Kevin Trenberth** (NCAR) discuss how climate models for the first time accurately predicted the 1997-98 El Niño event better than statistical models. These climate models also predicted the event a year in advance. **Fritz Hasler** (NASA GSFC) did the image processing for the article and for the front cover.

EOS researchers please send notices of recent media coverage in which you have been involved to:
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Goddard Space Flight Center, Greenbelt, MD 20771
Tel. (301) 286-5347; fax: (301) 286-0329
Email: scole@pop900.gsfc.nasa.gov

EOS Scientists in the News

EOS Science Calendar

April 27-29
CERES Science Team Meeting, Williamsburg, VA. Contact Joella Hanlon, e-mail: j.p.hanlon @larc.nasa.gov.

May 4-6
MODIS Science Team Meeting, University of Maryland, College Park, MD. Contact Barbara Conboy, e-mail: bconboy@pop900.gsfc. nasa.gov.

May 11-12
ORNL DAAC User Working Group Meeting, Arlington, VA. Contact Robert B. Cook tel. (423) 574-7319, e-mail: cookrb@ornl.gov.

May 25-27
The Land Processes DAAC Science Advisory Panel, EROS Data Center. Contact Bryan Bailey, e-mail: G.gbbailey@edcmail.cr.usgs.gov.

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

July 14-16
AIRS Science Team Meeting, Pasadena, CA. Contact Dr. H.H. Aumann, e-mail: aumann@ jpl.nasa.gov, tel. (818) 354-6865.

Global Change Calendar

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

May 17-21
American Society for Photogrammetry & Remote Sensing (ASPRS), Portland, OR. Contact: 5410 Grosvenor Lane, Suite 210, Bethesda, MD. 20814-2160, tel. (201) 493-0290; e-mail: meetings@asprs.org; URL: http://www.asprs-portland99.com

June 15-17
Joint Fire Science Conf. & Workshop, Boise, Idaho. Call for Papers. Contact Jon Ranson, tel. (202) 358-0276, Fax: (202) 358-2771, e-mail: jranson@hq.nasa.gov.

June 23-25
ATSR Workshop, ESRIN, Frascati, Italy. Contact jfyall@esrin.esa.it, fax: +39 06 94180362, URL: http://www.esrin.esa.it/ atsrconf/.

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

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

July 11-16
29th Conference on Radar Meteorology, Montreal. Contact Monica Tolson, e-mail: tolson@smtpgw.dc.ametsoc.org.

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

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

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

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

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

September 15-17
Second International Workshop on Multi-angular Measurements and Models, ISPRA, Italy. Contact Michel Verstraete, e-mail: michel.verstraete@jrc.it, URL: http:// www.enamors.org.

September 20-24
Conference on Sensors, Systems and Next Generation Satellites V, University of Florence, Italy. Call for Papers. Contact Steve Neeck, email: steve.neeck@gsfc.nasa.gov.

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MQUALS

propagate into the final product. However, MQUALS measurements will similarly be affected by calibration, bidirectional reflectance, spectral sensitivity, and diffuse / direct irradiance effects. Thus, independent measures acquired for product validation will always differ somewhat from MODIS. Surface heterogeneity also presents difficulties in the measurement of biophysical parameters over MODIS pixel sizes. The error and lack of reproducibility in field measurements may exceed those from the satellite.

We are currently drafting field validation methods and protocol documentation as a guide in the standardization of EOS field-collected validation data. MQUALS flights, for example, will generally be made at multiple times of the day in order to bracket a range of sun angles and allow for extrapolation of the radiometric data to specific solar zenith angles for standardization purposes. A single MODIS scene or composited product may contain solar zenith angles that vary by 20°, along with sensor view angles that vary ±55°. End-to-end validation examples involving MQUALS prior to the launch of the Terra EOS satellite will be the subject of a forthcoming article. The URL address for MQUALS is http: / / gaia.fcr.arizona.edu / newmqual.html.

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