THE EARTH OBSERVER

In this issue . . .

EDITOR'S CORNER

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Representatives from the CloudSat, PICASSO-CENA, PARASOL, Aura and Aqua science teams are beginning discussions of the afternoon satellite constellation. The intent is to coordinate orbits and resultant data acquisitions for more comprehensive and consistent monitoring of Earth processes from satellites. These discussions build on the morning constellation, which involves Terra, Landsat 7, EO-1 and SAC-C. These four spacecraft are currently in a common orbit plane and altitude, enabling cross-validation of data collections and multiplying the science returned from each mission. The afternoon constellation will further complement the inherent benefits of formation flying, and may eventually lead to combined data products.

Following the publication of Volume 2 of the EOS Data Products Handbook last year (describing science data products from ACRIMSAT, Aqua, Jason-1, Landsat 7, Meteor 3M/SAGE III, QuikScat, QuikTOMS, and VCL), Volume 1 (describing data products from TRMM, Terra and Data Assimilation) is being rewritten and updated. Many of the initial data products described in Volume 1 have now been revised due to new data handling capacities, processing algorithms, and metadata content. In addition, more detailed information on file specifications and processing frequency will be included. The publication date for Volume 1 of the Data Products Handbook will likely be later this year.

Technical brochures describing the ICESat and Aqua missions are being produced by the EOS Project Science Office, and are complemented by separate brochures produced for AIRS, AMSR-E and CERES. In addition, a new MODIS brochure describing the instrument on both Terra and Aqua is being produced. These brochures are intended to inform science professionals and other colleagues of the scientific objectives and capabilities of the missions and instruments. These and many other EOS mission and instrument publications are available from the EOS Project Science Office Web site at eos.nasa.gov.

Finally, I'm happy to report two new additions to the EOS Project Science Office staff. Chris Shuman has joined Goddard Space Flight Center and

will serve as the ICESat Deputy Project Scientist. Shuman received his Ph.D. in Geosciences from the Pennsylvania State University, and was previously a visiting research fellow with the Universities Space Research Association at Goddard, and an Assistant Research Scientist at the University of Maryland, College Park. Douglas Rabin has also been named the SORCE Deputy Project Scientist. Rabin is the Head of the Solar Physics Branch at Goddard, and will be a positive connection to the The Solar and Heliospheric Observatory mission, Living With a Star, and other solar missions.

Seal Pups trapped in the White Sea ▶ ▶ ▷ ▷ ▷

According to the Russian Polar Research Institute for Fisheries and Oceanography, between 250,000 and 300,000 Greenland seal pups face death by starvation over the next two months due to a cruel trick by mother nature. The seals, most of them less than two months old, are trapped on ice sheets that remain locked in the White Sea, located near Archangel in Northern Russia. Typically, during the spring thaw the ice sheets break up and flow with the currents northward into the Barents Sea, the seals' spring feeding grounds. The seal pups hitch a ride on the ice floes, living on food caught by their mothers until they arrive in the Barents Sea. Unfortunately, their mothers departed for the Barents Sea weeks ago leaving the pups with only their own individual stores of fat to sustain them.

In a normal year, the seal pups' trip from the White Sea out to the Barents takes about six weeks, and the seals have adapted to rely upon this mechanism of mother nature. During their yearly migration, the mother seals usually stay with their pups and feed them until their pelts turn from white to grey—a sign that the pups are mature enough to swim and feed themselves. Unfortunately, this year unusually strong northerly winds created a bottleneck of ice near the mouth of the White Sea, thus blocking the flow of ice and trapping the pups.

These images of the White Sea were acquired by the Moderate-resolution Imaging Spectroradiometer (MODIS), flying aboard NASA's Terra spacecraft. The top image, taken May 3, 2001, shows the large ice shelf still trapped in the White Sea. The bottom image was taken by MODIS almost this same time last year (April 23, 2000). Notice there was much less ice in the White Sea this time last year as most of it was enroute to the Barents Sea. (Images courtesy Jacques Descloitres, MODIS Land Rapid Response Team.)

May 3, 2001

April 23, 2000
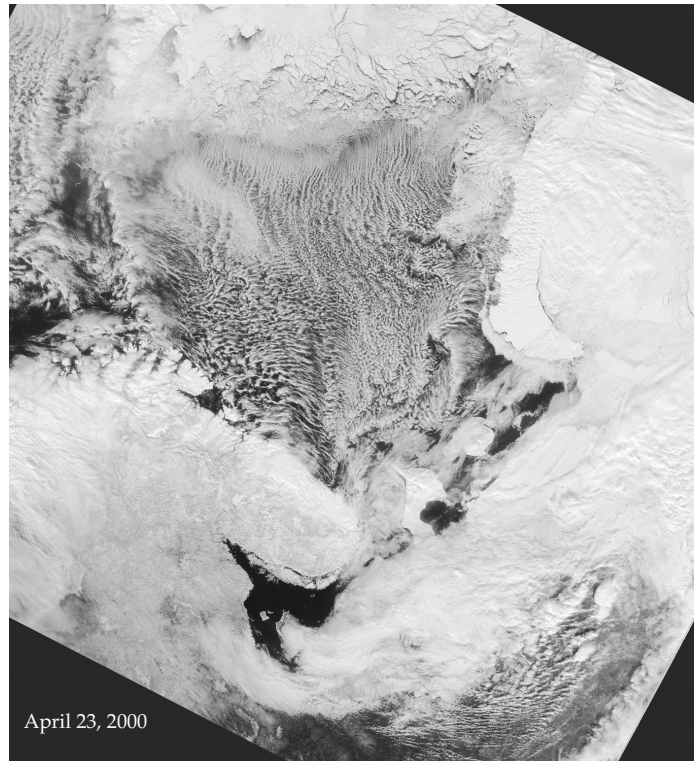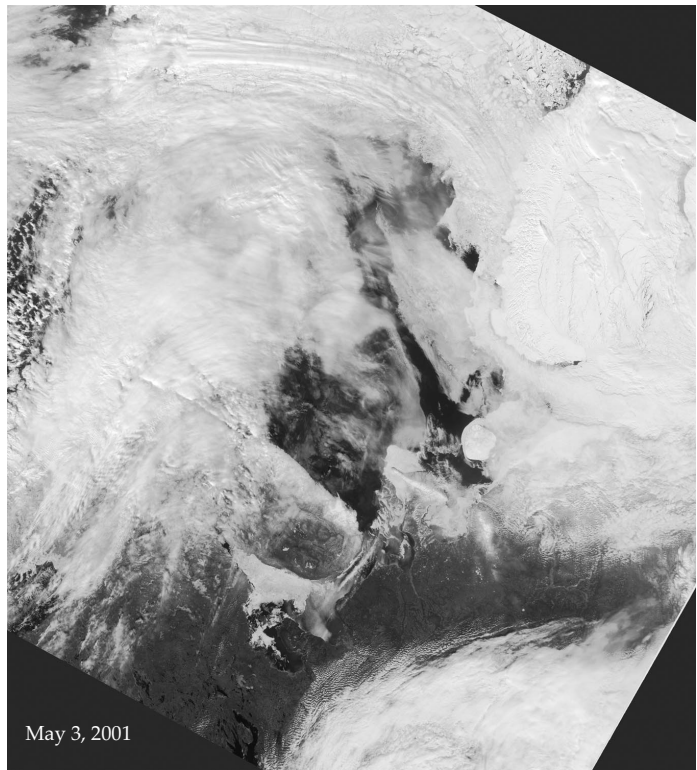
Minutes of the Aqua Science Working Group Meeting

— *Steve Graham (steven.graham@sesda.com), Aqua Outreach Coordinator*
— *Claire Parkinson (claire.parkinson@gsfc.nasa.gov), Aqua Project Scientist*
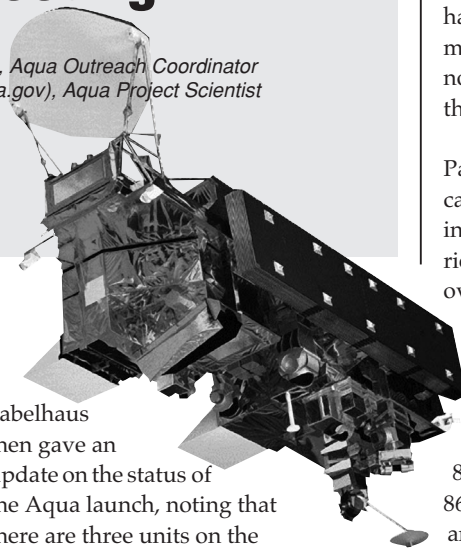
The Aqua Science Working Group met at the Goddard Space Flight Center (GSFC) on February 8, 2001, chaired by Claire Parkinson, the Aqua Project Scientist. Parkinson opened the meeting at 8:30 a.m. with a welcome and the announcement that George Morrow, the Aqua Project Manager, will be leaving the Aqua project on February 9 and will be replaced by Phil Sabelhaus. Parkinson elaborated on the critical work performed by Project Managers and thanked Morrow for all he has done to ensure that the mission will reach the objectives laid out by the scientists. Morrow then explained that he has greatly enjoyed working on the Aqua mission but has decided to take a job with Jackson and Tull, a private aerospace company, as Vice President for their Aerospace division. He thanked everyone for working with him and noted that he will be present at Vandenberg Air Force Base with many others to watch the launch of Aqua.

Morrow then introduced Phil Sabelhaus as the incoming Aqua Project Manager. Sabelhaus offered a brief history of his involvement with NASA Earth Science missions, including Project Manager of TOMS/EP, TOMS on ADEOS, GOES, Landsat, Aura, and VCL. He is happy to have the opportunity to be involved with the Aqua mission, especially at this critical and exciting stage, and is committed to the mission's success.

Sabelhaus then gave an update on the status of the Aqua launch, noting that there are three units on the spacecraft that are currently causing concerns: the Formatter Multiplexer Unit/Solid State Recorder (FMU/SSR), the transponder, and the transponder interface electronics (TIE). The Aqua TIE will be removed from the spacecraft and sent back to B. F. Goodrich for inspection, because a similar Aura TIE has recently failed vibration testing. The system Comprehensive Performance Test (CPT), scheduled to start February 8, was delayed to allow time to complete the procedure dry runs; the current estimated start date is February 14. [*Editors note: The Dry Run System CPT was successfully completed on March 6. No new significant hardware issues were identified.*] Additional problems include paint cracking on the Earth shade on AIRS and excess oil in the CERES deployment mechanisms. The latter problem is being addressed by placing the deployment mechanisms in a thermal chamber at an elevated temperature in order to bake out the excess oil.

Sabelhaus noted that the Delta Launch Manifest is filling up and is crowded in the June/July timeframe with Jason/TIMED, MAP, Genesis, Geolite, and GPS. The latest word is that the Flight Planning Board meets on February 8 and will likely slip Jason/TIMED to August. Meanwhile, a commercial Boeing launch called Earthwatch is sliding into the October slot. ICESat has a December slot and Iridium has moved to March 2002. If Aqua does not launch in September/October 2001, then it will likely be early 2002.

Parkinson thanked Sabelhaus and indicated that the Aqua mission is fortunate in having someone of Sabelhaus's experience and caliber available for taking over the Project Manager's job. She then mentioned that Volume 2 of the EOS Data Products Handbook is now available and copies can be obtained from lee_mcgrier@sesda.com or by phoning Lee McGrier at (301) 867-2037 or Steve Graham at (301) 867-2036. In addition, the AMSR-E logo and brochure have been printed and are being distributed.

Following Parkinson's comments, Ramesh Kakar, the Aqua Program Scientist at NASA Headquarters, spoke about the recompetition of the Terra and Aqua science teams. The present science team contracts run out on December 21, 2001, and Procurement may or may not allow contract extensions beyond that date. A new NASA Research Announcement (NRA) for recompeting the team efforts is under development, with Jim Dodge and Jack Kaye (both of NASA Headquarters) working on it. It is expected that the new NRA will recognize three broad categories: algorithm maintenance, science data analysis, and forward compatibility. Kakar noted that the sum of funding in the three categories would approximate the available funding in the science team funding line.

It is not clear at this time if separate NRAs will be needed for the two platforms or if one will suffice. It is possible that an NRA for Terra will be released this summer and the new NRA for Aqua (concentrating on AIRS/AMSU-A/HSB

and AMSR-E) could appear approximately one year after launch. Rather than going into more detail, Kakar deferred to Jack Kaye, who was at the afternoon session to expand upon these issues.

Next, Kakar offered an introduction to the NASA Earth Science Enterprise Research Strategy (2000-2010), noting that it should be a guiding strategy for the next decade and that it is based on the following five questions:

- How is the global Earth system changing?

- What are the primary forcings of the Earth system?

- How does the Earth system respond to natural and human-induced changes?

- What are the consequences of changes in the Earth system for human civilization?

- How well can we predict future changes in the Earth system?

Under these primary questions, there are 23 additional questions focusing on specific research areas. Kakar pointed out that 6 of the 23 questions concern the global water cycle. Lastly, Kakar reviewed the current missions and launch schedule.

"First Light Images" and Science Team Presentations

Next, Parkinson explained the importance for NASA public relations of getting good "first images" to show publicly a few months after launch and mentioned that Bruce Barkstrom and Vince Salomonson, the CERES and MODIS Team Leaders, respectively, have been through this process in 2000 with the Terra spacecraft.

CERES Team

Barkstrom then relayed his experience with first light images from Terra and offered thoughts on possible first light images from Aqua. Barkstrom noted that it is not premature to start now preparing for the first Aqua press conference. The audience to keep in mind when preparing images is the general public. Word charts and bar charts should be avoided, and the images should be kept simple.

The Aqua Working Group, or its spokesperson, needs to decide on the main Aqua story to present during the press conference. At the Terra press conference, the main story centered on atmospheric aerosols. It would be helpful to have movies and animations detailing the concepts, as opposed to still images.

Barkstrom noted that moderately acceptable formats are global images with recognizable features (geography) that are visually interesting. He posed the question of whether or not the U.S. should be in the center of the visuals. Also, Barkstrom praised the MISR team as having done the best preparations for the Terra press conference. Their work is a good model to follow for the Aqua press conference, with video sequences and well-rehearsed responses.

The Public Affairs Offices at NASA Headquarters and GSFC will have the primary responsibility for orchestrating the press conference. It is anticipated that we will use the services of the GSFC Scientific Visualization Studio and Earth Observatory team and should begin two to three months prior to the first press conference rehearsal in order to perfect the image formats and color scales. Based on the Terra experience, it will probably require about three iterations before the images are suitable. Also, the teams should expect to do a complete rehearsal at an IWG prior to the press conference.

MODIS Team

Parkinson then introduced Vince Salomonson, the MODIS Science Team Leader, to present initial results from the Terra MODIS and thoughts on possible first light images from Aqua. Salomonson noted that MODIS is performing well in terms of spatial, spectral, radiometric, geometric, and quantization performance. All major systems are working, the focal planes and bands are well registered and are performing (overall) better than specifications, and calibration looks good. Also, noise and other factors have been identified and reduced, leading to a useful state for scientific use. Finally, studies are continuing to further optimize Level 1B data. Salomonson also noted that there are 5 MODIS direct readout stations in the U.S., and 25 stations or more are expected to be in place worldwide soon.

Regarding Level 1B improvement areas, the following Terra MODIS characteristics have been fixed or improved on the Aqua MODIS:

- radiance versus scan-angle response for the thermal emissive bands;

- optical cross-talk from band 31 (11 μm) into bands 32 (12.0 μm) through 36 (14.3 μm);

- electronic cross-talk amongst bands 5-7 and bands 20-26; and

- non-uniform digital count bin-fill factors, particularly for bands 31-36.

Salomonson showed a chart summarizing the operational characteristics of the Terra MODIS since "first light" in February 2000. Several problems have been stabilized starting in the fall of 2000. The MODIS Characterization Support Team is now looking at making quantified estimates of the overall uncertainty in the Level 1 product. Preliminary estimates show that the uncertainty is being reduced with time and has reached planned levels for Bands 4 and 5. In

the thermal infrared bands (particularly the sea surface temperature bands at 11 and 12 μm) the performance has not reached adequate levels but is improving as more efforts continue to reduce the various uncertainty factors.

Commenting on the overall status of the science products, Salomonson said that ~40 products are currently in development. Most of the products have been released in Beta format for examination by the scientific community, starting in the fall of 2000. Work continues on all the products to get them to the point where they can be considered routinely useful for scientific or applications studies. It is suggested that anyone wishing to employ the MODIS products should communicate with the appropriate MODIS Science Team member to ascertain the utility of the product or, at least, should pay careful attention to the quality "flags" on the products. Additionally, the MODIS Web pages contain much useful material on quality assurance and validation efforts for the products. In general, use by the scientific community is encouraged so as to obtain feedback and hasten validation.

MODIS-associated data processing systems (i.e., the GSFC DAAC and the MODIS Adaptive Processing System [MODAPS]) reached stable global production in fall 2000 and are consistently ingesting, processing, archiving, and distributing data. The data systems are resource-constrained and efficiencies in hardware, systems, software, algorithms, and even products are being evaluated. While hopeful for additional resources, all avenues are being pursued for producing consistent, timely data sets. A goal is to produce a consistent, one-year data set starting sometime in 2001. This effort may begin in June 2001, using the best performing algorithms available at that time. It will cover the period from November 2000 to November 2001.

Regarding production status, EDOS is working well and reorders of Level 0

data by the GSFC DAAC are approximately 1%. The DAAC is processing Terra at 2X on Silicon Graphics Origin 2000s, and is expected to reach 3X with the addition of the remaining Aqua hardware and installation of the S4P on the Origins to support reprocessing. MODAPS is shipping 300 GB per day to the DAACs, and 167 TB of MODIS products have been archived at the GSFC, EROS Data Center, and National Snow and Ice Data Center DAACs.

A MODIS User Survey was conducted at the Fall 2000 AGU meeting. The goal of the survey was to address whether or not MODIS data distribution is lower than it should be. Roughly 350 people from fields ranging from education (K-12 and college introductory remote sensing courses) to atmospheric and oceanographic research participated in the survey. The reasons for not ordering MODIS data can be grouped into four categories:

1. Data Maturity - Several people indicated that they would wait for more mature data products because of resource limitations. (This is typical for new data products.)

2. Data Access - Several people had experienced difficulties with ordering data and have not tried again. (Information needs to be distributed regarding the improvements in data access.)

3. Data Subsetting (spatial, temporal and parameter) - The transfer of large data files is difficult. Several users would find the data more manageable if vertical profiles of selected parameters for specified geographical regions were available. (Subsetting/data mining efforts are taking place.)

4. Data Formats - Some users expressed concern about the data only being available in HDF-EOS format. (Use of data format translators is being considered.)

Salomonson commented on the near-term challenges facing the science team, including work to improve the Level 1B products, to optimize the use of the products by the scientific community, and to maximize the publication and oral presentation of recent results. The team is working to find and implement efficiencies in the processing, reprocessing, archiving, and distribution of the data.

Lastly, Salomonson commented on first light images from Aqua. The present understanding is that first light for MODIS will occur 39 days after launch, versus 68 days after the launch of Terra. In the Terra MODIS case, needed outgassing/purging did not occur sufficiently, and actions were necessary to eliminate icing on the radiative cooler in August 2000. The current perception is that the Aqua MODIS schedule is too fast, and MODIS first light should probably occur closer to 50 days after launch. However, the MODIS Science Team is ready to work with the Project to better understand the plans and trade-offs. Salomonson mentioned the importance of using common words rather than scientific terms at the "first light" press conference and of having a central theme.

AIRS/AMSU-A/HSB Team

After a short break, George Aumann, the AIRS Project Scientist, offered a status update on the AIRS/AMSU-A/HSB program. The AIRS/AMSU-A/HSB instruments have been integrated on the Aqua satellite at TRW for the last six months, and many of the comprehensive performance tests (all with spectrometer and detectors at ambient temperature) have been completed. AMSU-A and HSB time code issues in the packets are currently being resolved. The pre-thermal vacuum scan mirror inspection is scheduled for February 18. The thermal vacuum test itself will allow testing of AIRS detectors at the in-orbit temperature of 60 K.

Regarding software status, AIRS Product Generation Software (PGS) version 2.1 has been delivered to the GSFC DAAC, and version 2.1.5 (the last pre-launch PGS delivery) will have the final interfaces frozen, plus additional Quality Assurance indicators. Level 1B software has been revised based on data from the Lockheed Martin thermal vacuum chamber and has been documented in the Level 1B Algorithm Theoretical Basis Document version 2.2i.

Global simulated software has been used for software development, incorporating real instrument noise and spectral characteristics. The global data field has been based on National Centers for Environmental Prediction (NCEP) Aviation forecasts including multi-layer clouds, liquid water, surface emissivity, and surface temperature. A "golden day" exercise was completed over the period January 22-25, 2001. This exercise involved testing the data flow, display, retrieval and analysis software. The team is currently analyzing the data.

Regarding validation activities, the AIRS team is working towards the original schedule of DAAC delivery of validated PGS by Launch + 12 months. Validation support teams will be integrated into the plan as soon as the teams are officially selected.

Aumann reiterated the challenge set forth by James Baker of NOAA and Dan Goldin of NASA to demonstrate AIRS data assimilation impact by Launch + 12 months. To that effect, a workshop was held on December 6, 2000, and was attended by representatives of NCEP, the European Centre for Medium-Range Weather Forecasts, the UK Met. Office, the Canadian Meteorological Center, and the GSFC Data Assimilation Office (DAO). The operational data link via NOAA's National Environmental Satellite Data and Information Service is in place and is currently producing daily AIRS/AMSU-A/HSB "data" using the NCEP Aviation forecast model. The current data assimilation uses only Level 1B, cloud-free data. The AIRS science team will assist with cloud-free identification, cloud-cleared radiance utilization, and the forward and tangent model. The next workshop is scheduled for May 2001.

Some initial thoughts on possible first light images from AIRS/AMSU-A/HSB presented by Aumann include:

- animation of a global map going from the top of the atmosphere to the surface to illustrate global temperature soundings;

- animation of global maps of several days of total water from AMSU to illustrate water transport; and

- animation of several days of global images from an upper tropospheric sounding channel to illustrate "water wind."

A special section in the Journal of Geophysical Research with first results from AIRS/AMSU-A/HSB is being planned, with refereed papers from each AIRS Science Team member. The papers would be submitted at Launch + 12 months, but will be in print no sooner than 10-12 months after submission.

AMSR-E Teams

Following Aumann, Elena Lobl presented on behalf of Roy Spencer, the U.S. AMSR-E Science Team Leader. Lobl noted that the AMSR-E Science Investigator-led Processing System (SIPS) should be ready for the Mission Operations Science Systems-2 test. Lobl then described a passive-microwave rainfall mystery, wherein various estimates of tropical ocean rainfall change during El Niño Southern Oscillation (ENSO) (+10% during the warm phase) are at least double those inferred from surface energy and atmospheric radiation balance considerations. Possible explanations for these differences include rainfall efficiency and changes in drop size distribution. The TRMM radar actually shows a rainfall decrease during the warm phase, perhaps due to changes in drop size distribution.

Regarding AMSR-E first light images, Lobl noted that AMSR-E has a strong heritage and thus the only new measurements to be highlighted are the highest spatial resolution passive-microwave data yet in the extratropics (the TRMM Microwave Imager has similar resolution in the tropics) and the highest 6 GHz resolution yet (50 km vs. SMMR's 120 km). Possible first light images include extratropical imagery of rain systems over the land and ocean, sea ice, soil moisture, snow cover, oceanic wind fields near deep low pressure systems, global imagery of sea surface temperature (even through clouds), and improved spatial sampling of rainfall.

After Lobl, Yasuyuki Ito, the ADEOS-II Science Project Manager at the Earth Observation Research Center (EORC) of the National Space Development Agency of Japan (NASDA), presented a status update on ADEOS-II and AMSR-E/Aqua, plus thoughts on possible first light images. Ito began with a brief overview of the Earth observation satellite programs of Japan, including a breakdown of the organization of the Office of Earth Observation Systems.

Next, Ito provided a status update on the ADEOS-II program. The ADEOS-II system Proto-Flight Test was completed in December 2000, and the satellite will be stored by the end of March 2001. Functional tests and additional tests on the satellite's sensors will be conducted, with a Post Qualification Review to be held by the end of March 2001, aiming towards a February 2002 launch target.

The AMSR-E flight instrument is undergoing a systems test aboard the Aqua spacecraft at TRW, while the Level 1 data processing system is undergoing its first mission simulation test. The second mission simulation test will be conducted from April to July 2001. Also, the Level 2 and 3 data processing system

is in the manufacturing and test phase.

Regarding data distribution for ADEOS-II and AMSR-E, the Earth Observation Center (EOC) will be the receiving, archiving, processing, and distributing center while the EORC will serve as the algorithm development and calibration/validation center. Validated Level 1 and Level 2 data will be available at the EOC 12 months after launch, but PI's will have access to the non-validated data before their public release. NASDA and NASA will implement catalog, browse, and order interoperability for the ADEOS-II phase.

Ito noted that geophysical products from the Global Imager (GLI) on ADEOS-II will include aerosol parameters, cloud parameters, chlorophyll-a, colored dissolved organic matter, suspended solid weight, sea surface temperature, vegetation index, and snow grain size and impurities. Additionally, the SeaWinds sensor will measure sea surface wind vectors, while the Polarization and Directionality of the Earth's Reflectances (POLDER) will measure clouds and aerosol parameters, and the Improved Limb Atmospheric Spectrometer II (ILAS-II) will measure ozone and HNO_3. The geophysical products from AMSR on ADEOS-II and AMSR-E on Aqua include cloud water, water vapor, precipitation, sea surface wind speed, sea surface temperature, sea ice, snow depth, and soil moisture.

There was an AMSR PI meeting in Kyoto, Japan from October 30 to November 1, 2000 and a joint U.S./Japan AMSR/AMSR-E, team meeting held in conjunction with an International Geoscience and Remote Sensing Symposium in Honolulu in July 2000. Currently, an AMSR/AMSR-E PI meeting is tentatively planned for the November 2001 to January 2002 time frame.

Ito suggested, as possible first light images from AMSR-E, a selection of high-resolution Level 1B images and Level 3 images on water vapor, sea surface temperature, and other variables, and, if feasible, animations using Level 1B and/or Level 2 data.

Discussion

Following Ito's presentation, Parkinson led a brief general discussion on Aqua first light images, including possibilities for highlighting, such as improved resolution, morning/afternoon contrasts, and the full hydrological cycle. Barkstrom noted that we need to move beyond highlighting high-resolution images and show how these data can affect people's lives. He also mentioned that it would be helpful to stress the combination of instruments and their technical differences. Bruce Wielicki of the CERES Team added that the images should focus on a common theme, such as the water cycle. Aumann mentioned that television weather forecasters are now claiming a 5-day accuracy and that there is a large public awareness of this, leading to the suggestion that maybe we should highlight the impact that Aqua will have on weather forecasting. It was also noted that many of the topics could be the same as those in the upcoming Aqua Science Writers' Guide.

Validation

Following the general discussion, Peter Hildebrand, the Aqua Deputy Project Scientist for Validation, presented a summary of the Aqua Validation Working Group meeting held at GSFC on February 7, 2001. In attendance at the February 7 meeting were approximately 20 participants from the MODIS, CERES, AIRS, and AMSR science teams. At the meeting, validation plans for each Aqua instrument were reported on by instrument team representatives. In summary:

- Vince Salomonson reported the MODIS Team's scheduled comparisons with other satellites, ground measurements and science campaigns, and models. Specific to MODIS-Land (see http://modarch.gsfc.nasa.gov/MODIS/), there will be a strong emphasis on piggyback validation activities with AERONET and FLUXNET. MODIS-Ocean will conduct an AVHRR pathfinder/MODIS comparison, conduct cruises with a marine interferometer, and utilize the MODIS Ocean Buoy. MODIS-Atmosphere will utilize land validation sites and field campaigns such as ARM, AERONET, FIRE-ACE, and SAFARI.

- Bruce Wielicki reported on the CERES Team's calibration and validation efforts for the Terra CERES and the TRMM CERES. Most CERES validation makes use of long-term validation sites such as ARM, BSRN, and AERONET sites for clouds, aerosols, and surface radiative fluxes. Current CERES field plans include the CERES ARM Validation Experiment (CAVE), the Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS), scheduled for July 12 - August 1, 2001, and the CERES Ocean Validation Experiment (COVE). The CERES field validation plans are detailed on the CERES Web site at http://www-cave.larc.nasa.gov/cave/.

- Eric Fetzer explained that on-orbit validations for the AIRS Team will focus strongly on operational rawinsondes and dedicated radiosondes at times of overpass, plus observations of the marine surface state from buoys. Soundings will come from ARM-CART validation sites, Brazil, and Australia. Fetzer noted that the full validation plan is on the AIRS Web site, http://www-airs.jpl.nasa.gov/.

- Elena Lobl noted the AMSR-E Web site at http://wwwghcc.msfc.nasa.gov/AMSR/. AMSR-E ocean product validation will utilize buoy, radiosonde, and satellite observations. Sea ice product validation will

use ship and aircraft campaigns, as well as MODIS and Landsat observations. Rainfall products will be validated through several field campaigns using a ground X-band radar and data from the Eureka and the Kwajelein radars, plus comparisons with the TRMM Precipitation Radar and the TRMM Microwave Imager. Snow products will be validated on 25-km grid, regional, and river basin scales using aircraft observations. Soil product validation will utilize many land surface hydrology experiments around the globe, modeling and data assimilation, and comparisons with AIRS and MODIS.

Hildebrand noted that common themes surrounding Aqua validation plans include the upcoming announcement concerning the pending Aqua validation proposals and the expected recompetition of the science team efforts. The next steps for the Aqua Validation Working Group will be to evaluate the common validation needs and to develop common calibration/validation venues. The next meeting will take place on August 1, 2001, the day before the next Aqua Science Working Group meeting.

During the validation discussion, Wielicki pointed out the need to sort out the definitions of beta versus provisional versus validated data products. Salomonson agreed, adding that it is probably an issue most appropriately addressed by the EOS Investigators' Working Group.

Formation Flying of the EOS Afternoon Satellites

After the lunch break, the meeting reconvened at 1:30 p.m. with Parkinson introducing the next set of three talks, all centered on the issue of formation flying of the afternoon satellites Aqua, PICASSO, CloudSat, PARASOL, and Aura. The first speaker in the group, Mark Schoeberl, the Aura Project Scientist, began by noting that there is con-

siderable interest in the formation-flying concept at NASA Headquarters and that his term for the afternoon satellite formation is the "A-Train", with Aqua at the lead and Aura at the tail. He showed an impressive animation of the A-Train in orbit and mentioned several important complementarities amongst the instruments on the five A-Train satellites.

Schoeberl then introduced Rich Macintosh and asked him to review formation flying requirements and the Aqua requirements for initial orbit phasing. Formation flying of Aqua with Aura requires that both spacecraft must maintain a ground track on the World Reference System (WRS) using frequent burns (once every three months) to counteract atmospheric drag. A ground track control of ±20 km results in minor variations in spacecraft separation of ±43 seconds along-track. The largest effect on the spacecraft separation over time is from the difference in ascending node mean local time (MLT) between the two orbit planes. While both spacecraft maintain their ground tracks, separation will change gradually as the MLT changes.

Both spacecraft must perform occasional inclination maneuvers to control MLT drift so minimum desired separation (on the order of 15 minutes) is not violated. The Aqua MLT is allowed to range from 1:30 p.m. to 1:45 p.m., while the Aura MLT is allowed to range from 1:30 p.m. to 2:00 p.m. Aqua and Aura must agree on desired MLT ranges to maintain separation; this implies an agreement on the frequency of inclination maneuvers. Smaller MLT range implies smaller, more frequent inclination burns—1 or 2 per year versus 1 or 2 over the lifetime of the mission.

Macintosh noted that, during the ascent phase, Aqua will perform maneuvers to synchronize with the WRS, and could normally synchronize with any WRS path since it is the first spacecraft in the afternoon constellation. However,

initial orbit phasing relative to the morning constellation must be considered to avoid ground station conflicts with those spacecraft. Aqua will need to time the ascent maneuvers so that after it reaches its final orbit position, it will not fly over the polar ground stations at the same time as other spacecraft. The preliminary Aqua ascent plan to 705 km consists of four maneuvers to be completed by day 14. The synodic period between spacecraft at 695 km and 705 km is 32 days; this is the maximum time we would have to wait for proper initial phasing before starting ascent maneuvers.

If Aqua is required to phase with the morning constellation, the time needed to perform the ascent to mission altitude could increase significantly depending on the initial phasing at launch. The best-case scenario has an initial phasing at launch that allows the final desired position to be achieved with no changes to the nominal maneuver plan. The worst-case scenario has an initial phasing at launch that requires a delay of one synodic period before starting the ascent. In the latter case, 32 days would be added to the 9-day maneuver period, for a total of 41 days. However, from the Terra experience, this would not necessarily preclude instrument operation during the ascent period.

Wayne Esaias, the MODIS-Ocean Group leader, offered the suggestion that in addition to formation flying of the A-Train we should look into the possibility of having the daytime path of the Aqua MODIS match the previous or next nighttime path of the Terra MODIS.

The next speaker, Bruce Wielicki from the CERES Team, continued with the formation-flying theme by elaborating on the synergisms of the train. Wielicki reiterated that the A-Train consists of Aqua, PICASSO, CloudSat, PARASOL, and Aura, with Aqua leading the train. The nominal plan for the others is to precess across the Aqua-MODIS scanning path.

Wielicki explained that together, PICASSO, CloudSat, and Aqua will allow studies of cloud feedbacks in the climate system in ways never before possible. These studies would involve processes in atmospheric state, cloud physics, cloud optics, and top of atmosphere, surface, and atmospheric radiative heating profiles. Additionally, formation flying will be useful for cloud validation with CloudSat and PICASSO. Variables include cloud amount, cloud top height, cloud physical thickness, cloud base, cloud visible optical depth, cloud infrared spectral emissivity, cloud liquid water path, cloud ice water path, cloud particle phase, and cloud particle size.

The A-Train will also facilitate aerosol validation. The vertical locations of aerosol layers are critical for source region back-trajectories, and the locations of cloud/aerosol in the same vertical layers are critical for indirect aerosol forcing. MODIS can obtain good aerosol data over dark surfaces, but the A-Train will allow us to obtain such data also over snow, ice, and all other surfaces. The optimal scenario is to combine PICASSO with MODIS and PARASOL. Wielicki noted that precession across the MODIS swath would help verify causes/physics of angle dependent aerosol cloud properties from passive imagers providing global climate data.

Next, Graeme Stephens of Colorado State University presented on CloudSat and the afternoon constellation. He reiterated that the combination of constellation observations well exceeds the sum of the individual parts and explained that part of his purpose in speaking at this meeting is to convince Aqua scientists of the importance of CloudSat contributions. The CloudSat team has developed optimized retrieval methods that combine heterogeneous (multi-sensor) information derived from the constellation. This, however, requires availability of the data. A critical issue thus becomes the exchange of data and how quickly and at what cost the CloudSat

researchers will be able to obtain appropriate subsets of Level 1 data from the other missions.

Stephens elaborated on how information from one sensor can enhance the products derived from others, with the possibility of development of new products and an opening of the possibilities for addressing new science.

Stephens then spoke briefly on the CloudSat mission, noting that it will include the first 94 GHz spaceborne radar system. A unique feature is that the radar is extremely sensitive and has a wide dynamic range. It sees the majority of clouds, from thin cirrus clouds to deep convective clouds producing heavy precipitation. The CloudSat science objectives are to:

- measure the vertical structure of clouds and quantify their ice and water content,

- predict clouds and precipitation,

- improve weather prediction and clarify climatic processes,

- improve cloud information from other satellite systems (particularly Aqua),

- investigate the effects of aerosols on clouds and precipitation, and

- investigate the utility of the 94 GHz radar for observing precipitation in the context of cloud properties from space.

Stephens then commented on two formation-flying scenarios. The original scenario involved CloudSat in formation with PICASSO-CENA (and more loosely with Aqua) to provide essentially instantaneous lidar/radar views of the atmosphere. The current scenario involves CloudSat flying in a tight formation with Aqua, aligning CloudSat radar with nadir pixels of MODIS. The combination of Aqua and CloudSat data

enhances the science of both missions.

Stephens then presented some examples of CloudSat synergy with MODIS, CERES, and AMSR. He noted that MODIS optical depth provides independent information that more tightly constrains the relation between the power returned from radar and the water and ice content of the radar volume, thus improving retrievals.

Finally, Stephens stressed the importance of coordinating CloudSat and Aqua validation efforts, noting also that the need exists to establish a data flow dialog and subsequent plan of action among members of the constellation instrument teams.

Recompetition

Following Stephens, Jack Kaye from NASA Headquarters spoke on the plans in development for dealing with the upcoming expiration of science team contracts. This will involve a separation of the science efforts into two main categories. First, the Core Instrument Team Activities, including algorithm maintenance and key aspects of data product validation, will be covered under an appropriate, somewhat restricted solicitation. This will maintain the continuity and heritage to insure high quality data products for release to the broad science community. It is expected that support for these activities will decrease over time as the processing algorithms stabilize and the initial validation studies prove successful. Both Terra and Aqua instrument team activities will likely be covered in one solicitation.

Second, an NRA will be released to solicit from the Earth sciences community long-term, multi-platform, multi-instrument Science Data Analysis investigations. Investigations will be sought that address questions relating to discipline areas and key science themes rather than addressing single instrument data sets. It is expected that support for these investigations will

increase over time as the data products from the EOS platforms reach appropriate stages of maturity. Researchers will be allowed to use alternative algorithms from those used in the standard products, although the funding here will not be for new algorithm development.

With these two types of solicitations, the goal is to fund activities that carry the EOS project through transitions from pre-launch initial algorithm development, to post-launch algorithm refinement and stability, to initial validation studies, and finally to broader validation studies and uses of the data products to address and answer important scientific questions. The intention is to shift funding dollars more and more from algorithm development and maintenance to scientific analysis.

Data Processing

Following Kaye, Bruce Barkstrom, representing Chris Justice and the Science Working Group on Data (SWGD), presented on Terra and Aqua data processing issues, beginning with an overview of a workshop held on June 1-2, 2000, at GSFC. The June 2000 workshop was called to evaluate how well the EOS Data and Information System (EOSDIS) supports current and upcoming EOS missions, to determine how requirements have changed, and to recommend solutions to meet evolving needs.

The participants at the June 2000 workshop discussed the then current operating status of EOSDIS, in particular the lower than expected throughput and how it should be addressed. They noted that the February 1996 baseline sizing used to implement EOSDIS is not adequate to support current science data needs. Because that baseline was established before the algorithms were developed and could be run in the production environment, it did not have a clear empirical basis. Terra instrument team representatives presented revised system sizing estimates based on current experience and improved understand-

ing of the EOS production environment.

Barkstrom noted that the instrument teams have made considerable improvements and efficiencies to codes and algorithms. However, increased hardware capacity is needed above the 1996 baseline to generate the higher-order geophysical data products already committed for Terra and planned Aqua science. Provisional cost estimates suggest that a much-desired three-fold increase in production capacity at the DAACs and SIPS could be obtained with a cost of approximately 7% of the annual ESDIS budget.

Aqua Integrated Mission Timeline

After Barkstrom, Fran Wasiak of the Aqua Instrument Planning Group presented an update on the Aqua Integrated Mission Timeline (IMT). The third IMT review was held on October 17, 2000, and was attended by representatives from the Aqua project, TRW, Instrument Operations Teams, and the Flight Operations Team (FOT). The current version of the IMT is based on all the IMT reviews (March, July, and October 2000). Some adjustments in the Aqua maneuver plan are to move the MODIS yaw maneuver from days 26-27 and 30-31 to days 32-33 and 37-38 and add a CERES yaw maneuver on day 41. One important maneuver that has not changed is the deep-space pitch maneuver scheduled for day 55. Plans call to baseline the IMT in March or April 2001.

Assumptions guiding the IMT team include:

- Activities, in general, are scheduled to occur during the FOT prime shift.

- Per FOT direction, only one EOS Polar Ground Network pass is used per orbit.

- Instruments use only Alaska and Svalbard ground stations. Spacecraft bus uses Alaska, Svalbard, and Wallops. McMurdo is not available for use.

- TDRSS is assumed to be available as scheduled. The Project has requested nearly continuous coverage for the first three hours after launch and two 20-minute TDRSS contacts per orbit thereafter.

- Timeline is based on the nominal plan and does not account for contingencies.

- Scheduling of the MODIS roll maneuver does not yet account for moon phase.

- Instrument scheduling is based on results of the last IMT review as well as continuing information exchange with Instrument Operations Teams and TRW, the Aqua spacecraft developer.

Issues surrounding instrument commanding during the first two weeks include the fact that spacecraft and AMSR-E RunUp activities occupy most of the first two weeks. Teams still have the option to schedule benign activities with their instruments during this period if they choose to do so, and MODIS may choose to perform transition to the ON state earlier than day 15 now that AMSR-E RunUp has been shortened.

It is the AIRS Team's preference not to perform deep-space constant pitch maneuvers, and the current IMT assumes no pitch maneuvers for the scheduling of AIRS activities, despite the planned pitch maneuver on day 55. Under some scenarios, AIRS would not complete its activation checkout until after the Launch-plus-90-days threshold. Hence, AIRS has provided a preliminary alternate plan of activities that needs to be implemented into the Baseline.

The slip in the MODIS yaw maneuvers is primarily because the MODIS Team has elected to wait until day 15 to begin the outgassing procedure and prefers 14 days of outgassing rather than the earlier scheduled 11 days. MODIS activities

remain in the same order, slipping the first set of yaw maneuvers to days 32-33. The second set of MODIS yaw maneuvers no longer needs to be delayed for CERES, and MODIS may opt to perform both sets of yaw maneuvers on four consecutive days.

The new review version of the IMT is to be released on March 30, while the Baseline IMT is to be released two weeks before Mission Rehearsal #1. Finally, the Product Development Tracking Tool has been proposed for IMT Change Request submittal.

Outreach

Steve Cole of the EOS Science News and Information Team at GSFC gave the last formal presentation of the day. The EOS Science News and Information Team supports media outreach efforts of all EOS missions and researchers. Cole noted that this is a critical time in the planning for media activities related to the launch of Aqua. Input from the Aqua Science Working Group on the key stories that the media and public should know about Aqua and its science needs to be given soon so it can be used to develop various media materials, including a "Science Writers' Guide to Aqua."

Science Writers' Guide topics should highlight key advantages of Aqua, either from its new instruments or from the usefulness of its data in combination with other data, including data from Terra. An initial list of possible Aqua research highlights was presented. Topics included: improvements in weather forecasting, sea-ice monitoring, snow-cover mapping and runoff estimates, complete ocean color coverage, diurnal cycles of clouds and solar radiation, surface heat budget of the ocean, acceleration of the hydrological cycle, insight into atmospheric water processes, mapping wildfire hazards, and soil moisture content. Comments on this list and suggestions of specific

MODIS Science Team Meeting

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MODIS SCIENCE TEAM MEETING, January 24 and 25, 2001
MODLAND Validation Workshop, January 22 and 23, 2001
MODIS Ocean Team Meeting, January 23 and 26, 2001
MODIS Characterization Support Team Meeting, January 23, 2001
MODIS Atmosphere Group Meeting, January 23, 2001
MODIS Land Group Meeting, January 26, 2001
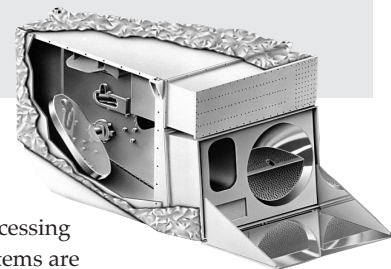
The MODIS Science Team Meeting and affiliated meetings convened in Columbia, MD, January 22-26, 2001. This article summarizes the activities of the two-day plenary session on January 24 and 25. Please see the "Meetings" section of the MODIS home page (http://modis.gsfc.nasa.gov) for the complete meeting minutes for this meeting, as well as other MODIS-related meetings for which minutes are available. Vincent Salomonson, MODIS Science Team leader, began the meeting by emphasizing the MODIS team's commitment to aligning its efforts with the Earth Science Enterprise's research strategy. He expressed his enthusiasm about the early results coming from the team. MODIS' major instrument systems work, the spectral bands are properly located, signal to noise ratios are good, and the gains appear to be stable. Data processing is stabilizing and products are being produced and archived. The calibration and characterization efforts overcame several challenges this first year after launch. Many of the MODIS products have been released including some Level 3 (L3) products from every discipline group, and the team is working toward improving product quality through instrument characterizations and validation.

Salomonson concluded the talk with a summary of challenges that the team would be addressing in the future: reaching a stable instrument characterization state, ensuring data

processing systems are efficient and that they are able to supply sufficient power to process and reprocess data, determining how to support MODIS Direct Readout users, and preparing for Aqua.

Terra Status

Paul Ondrus gave a brief history of Terra since launch. The high points are that all major systems are working within specs, the craft is producing enough power, it is collecting all science data, and it is satisfying pointing requirements. The biggest challenge has been managing the solid state recorder. Terra makes 4.8 TB of data each month; in one year, Terra has doubled the amount of Earth science data available to the scientific community. Ondrus reported that the deep space maneuver is still being negotiated with the Project and the other instrument teams.

MODIS Status

Bruce Guenther, MODIS Characterization Support Team Leader, gave a brief summary of instrument status, starting with the year's highlights, among them MODIS' successful activation and command operation. MODIS L1B data were the first Terra data to be publicly released; the solid-state recorder delivered 22.9 TB of data in 2000. The past

three months have been in a stable operation in the best configuration with respect to minimization of electronic cross talk, and signal-to-noise ratios are exceeding the team's best expectations. Guenther summarized areas that have been or are being studied for the Level 1B, including calibration of the reflected solar bands, testing of the solar diffuser stability monitor (SDSM), channel-to-channel and band-to-band co-registration, response versus scan angle differences, and mirror-side uncertainty. A history of code and Look-Up Table (LUT) changes is available on the MCST Web site.

MODIS Data: Acquisition, Production, and Distribution

Ed Masuoka, Science Data Support Team Leader, presented a status report on the data production system. Over 160 TB of MODIS data have been produced and stored at the three "MODIS" DAACs: National Snow & Ice Data Center (NSIDC), EROS Data Center (EDC), and Goddard Earth Science (GES). MODAPS delivers about 474 GB/day to the DAACs, and over 400 GB/day to the SCFs. Production of L2 through L4 science products is above the 2/96 baseline of 229GB/day but less than the 460GB/day that the Science Team has requested for MODIS in the SWAMP Working Group on Data (SWGD) report. Upcoming hardware and software changes to the MODAPS system should increase throughput to about 2X. SDST hopes to have Version 2 software in full production by the end of March. This should help MODAPS to begin to work off its backlog, which is about two months behind real time.

Steve Kempler, GES DAAC manager, reported that 167 TB of MODIS data have been archived; the average is about 21.2 TB per month, based on the last three months of steady production. With a compression level of 1.5 to 1, the total capacity for the three MODIS DAACs is about 1060 TB. Current distribution is below capacity. One reason for the low distribution is that the DAACs have a hard time filling large orders (they have received individual orders for all MODIS data). At the same time, they are not receiving enough small orders to distribute at their capacity. The results of an informal survey indicate that users are aware of MODIS data, but are concerned about data maturity, had difficulties with the ordering system, were unable to download the large files, or were unfamiliar with HDF. Kempler reported that the DAACs are currently working to resolve all of the issues within their control. The GES DAAC is preparing for MODIS reprocessing. Their current hardware capacity will allow 1X forward processing and 1X reprocessing. By April they will have 2X reprocessing from the installation of Aqua hardware, and they are pulling together all the necessary L0 and ancillary data they need.

Ocean Team Update

Wayne Esaias, MODIS Ocean Team Leader, began his ocean discipline group summary by saying that the team's progress this year has been substantial. All ocean parameters are in production through L4 and are approaching science quality, with near-daily, global, 1-km coverage. Provisional products will be released over the next few months. The fine structure seen in products such as the 443-nm water-leaving radiance and chlorophyll are quite impressive, and surpass the capabilities of SeaWiFS. The single outstanding issue for the team is understanding mirror-side uncertainty, a process that may take many months and almost certainly will require the deep space maneuver. It is possible that even with the deep space maneuver, the problem would not be solved, but the team feels that without the maneuver, there is no chance.

Mark Abbott gave an overview of the MODIS Ocean Color products and their use in studying biogeochemistry. Abbott showed examples of how the MODIS ocean color product could be used to track changes in the type and concentration of phytoplankton that correlate with changes in the polar front. These episodic changes may have a great impact on oceanic carbon flux. Estimates of carbon flux and Ocean Net Primary Productivity (NPP) vary widely, and MODIS' new fluorescence-detection capability may dramatically improve these estimates. Phytoplankton in nutrient-poor waters show increased fluorescence because their photosynthesis is limited. MODIS' ability to detect this physiology from space provides an unprecedented opportunity to refine estimates of NPP. Initial results indicate that the fluorescence capability on MODIS is outstanding.

Peter Minnett and Bob Evans summarized the status of the MODIS Sea Surface Temperature (SST) product. MODIS makes SST measurements in conventional thermal infrared bands as well as mid-wave infrared bands for the first time, providing unprecedented accuracy goals for measuring SST—to within 0.2 K. While characterization, calibration, and validation are still ongoing, preliminary results are encouraging. A MODIS map of the eastern Mediterranean Sea showed circulation patterns typical for the region and revealed eddy sub-structures not discernable with AVHRR data. In a practical application, the team used MODIS SST data to show that a fish kill in the Gulf of Oman was likely the result of a cold-water upwelling event that brought oxygen-poor waters to the surface, and not due to the release of ballast water from a U.S. ship.

The Ocean Team has introduced corrections for response-versus-scan angle differences, polarization, detector gains, sun glint, and aerosol radiance. Further insight will be gained by producing water-leaving radiance and chlorophyll fields separately for mirror sides 1 and 2. The group will use MOBY/MOCE & SeaWiFS data for validation of MODIS optical data, and they will use drifting buoys and M-AERI for validation of

thermal data. For Aqua, the Team can use Terra data to help in validation.

Atmosphere Team Update

Michael King, Atmosphere Team Leader, summarized the status of each of the team member's products, highlighting MODIS' new capabilities for remote sensing of the atmosphere, including CO_2 slicing at high spatial resolution, cirrus cloud detection over snow and ice, and aerosol retrieval over land. All MODIS atmosphere products have been released at this point, including L3 daily, eight-day, and monthly products, and they believe their product maturity will move from beta to provisional in April or May. King concluded by pointing out that the atmosphere discipline group Web site has many data tools available that were developed in house, including tools for subsetting and visualization.

A team of presenters led by Yoram Kaufman summarized the aerosol optical properties product suite. Presenters addressed the physical basis of the retrieval algorithms, including how the team had added a standard deviation threshold to refine the cloud mask to separate cloud and dust from aerosol. The team has developed an automatic procedure that pulls AERONET data for MODIS validation. The results show excellent agreement. MODIS aerosol optical thickness (AOT) retrievals over ocean show only a 2% deviation. The effective radius measurements are also quite good—within ± 0.1 mm. As with ocean retrievals, there is good correlation between MODIS and AERONET AOT measurements over land. As an example of how the aerosol products could be integrated into climate studies, Kaufman showed how MODIS top-of-the-atmosphere data combined with AERONET surface measurements allowed them to calculate the effect on atmospheric heating of smoke in Brazil.

Paul Menzel began his presentation on the cloud product suite by reporting

that comparison of MODIS data to the MODIS Airborne Simulator flown on ER-2 during September showed that IR calibration was quite good. MODIS sees more layers and structure of clouds than HIRS, and the 8.6, 11, and 12 mm channels are being used for an ice vs. water classification, which is a new capability of MODIS. Menzel expressed his excitement about the MODIS Direct Broadcast Receiving Station established at the University of Wisconsin-Madison's Cooperative Institute for Meteorological Satellite Studies. They have collected data from 500 Terra overpasses, and by the end of January they should be regularly making the most recent week of data available via ftp.

Bo-Cai Gao presented many examples of preliminary results from the MODIS near-IR water vapor and thin cirrus products. MODIS water vapor retrievals over Tibet, India, South Africa, and Spain all showed good detail and correlate well with reasonable expectations, e.g., high over vegetation and coastal margins. There is a 20% bias in water vapor measurements seen by MODIS, which may be due to line parameters compiled on HITRAN96, and which will be corrected with further validation. Quick-look images over South America, Canada, and the Arctic show that the 1.38 mm cirrus detection channel is providing excellent results. Cross-talk present in the 1.38 mm channel on Terra MODIS should be absent on Aqua. The water vapor and cirrus products should prove to be quite useful for hydrological and meteorological research.

Steve Platnick reported that the validation efforts include their cloud mask, cloudy skies, and clear skies data products. They compare MODIS data with existing satellites and algorithms or other MODIS products. They are also using data from fixed sites, e.g., AERONET, as well as field campaigns, e.g., PRIDE and SAFARI 2000. In PRIDE, the team deployed an array of ground-based, ship-based, and airborne sun photometers in order to increase its

opportunity to validate measurements of aerosol retrievals over the ocean. Chris Moeller reported on radiometric comparisons made during various field campaigns, including WISC-T2000, SAFARI 2000, and CLAP-T2000. MAS versus MODIS scatter plots show very good agreements for bands 20, 31, 32, and 35. The team is making small corrections for atmospheric window bands with high confidence and is validating these data to within 0.5°C.

Land Team Update

Chris Justice, Land Team Leader, reported that production of land products has been steady since August of 2000 and includes everything up to the monthly products, except the climate monthly grid (CMG) products. Among the most outstanding issues for the land team are cloud mask refinements, data processing and reprocessing resources, validation of global products, and availability of data subsetting and projection tools at the DAACs. Justice concluded by highlighting some of the team's achievements, among them developing new products, getting data out to the community in the year post launch, and developing new paradigms for quality assurance with the LDOPE facility and Land Product Validation.

Eric Vermote gave a presentation that covered energy balance and radiation budget products. MODIS surface reflectance is much improved over heritage instruments, and areas for improvement have been prioritized. The algorithm includes a "minimum blue" atmospheric correction plus a shadow filter, as well as a minimum view angle and maximum NDVI. Vermote then spoke about the BRDF/albedo product, which is a 16-day, 1-km gridded product that provides the albedo, surface reflectance, and surface anisotropy. This product is useful to climate modelers because it allows them to compute albedo and surface reflectance at any view angle or geometry.

The next products in the surface energy product suite were the snow products. The cryosphere team released snow products beginning in September, and they are providing special versions of these on a climate-modeling grid as well. The team is validating their products through fieldwork and ER-2 aircraft measurements, as well as through comparison with other snow maps, such as NOAA operational maps. The final product in the suite that Vermote discussed was the Land Surface Temperature and Emissivity product, the daily version of which has been released in beta version since late July 2000. The product has had quite a bit of validation, including comparison with ground-based measurements at grassland and rice field sites in California. Steve Running introduced the next group of land presentations, which focused on Land Biophysical Parameters. The first presenter in the group was Alfredo Huete who talked about the Vegetation Index products. MODIS produces two indices at 16-day and monthly intervals: Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI). The indices come in four resolutions: 250 m, 500 m, 1 km, and 25 km. Evaluation of MODIS data from several field campaigns both in the U.S. and abroad shows that agreement is quite good in many environments, especially those without aerosols. Huete showed examples of the products' application to regions in the Amazon. One significant issue for the team is determining the relationship between MODIS and the AVHRR time-series. MODIS is far more sensitive, and is not as subject to water vapor contamination in humid sites. So MODIS signals are much higher than AVHRR in those regions.

Ranga Myneni discussed the Leaf Area Index (LAI) and the Fraction of Photosynthetically Active Radiation (FPAR). The products were first released in August 2000, and they look quite good. Increasingly more complete coverage is available from the EDC DAAC. An

important consideration for the LAI product is the presence of cloud contamination, and the team encourages users to investigate QC bits two and four. In validation comparisons with Ikonos and the ETM+, MODIS appears to be doing well at most sites.

Running wrapped up the presentation by discussing the status of the Level 4, eight-day Photosynthesis/Annual Primary Productivity product. He prefaced his discussion by saying that he was sorry to have to report that he wouldn't have any results to show because numerous setbacks had hampered product development. Errors in the DAO meteorology inputs were the most serious problem. The DAO was aware of the problem, but the fix didn't go in until November. The team is now waiting for MODAPS to reach that date, and then they will make their next maps.

The final land discipline presentation was given by John Townshend, who summarized the Land Cover/Land Use Change Products. The Land Cover product provides a simple land-cover categorization for climate and carbon cycle models; it uses the IGBP-DIS scheme, and relies on more inputs than previous versions, including nadir-corrected surface reflectance, VI, snow cover, and LST. The classification uses both supervised and non-parametric approaches. The non-parametric approach is based on neural networks, and draws from databases from all over the globe. Townshend then discussed the Vegetation Continuous Fields (VCF) and Vegetative Cover Conversion (VCC). The VCF product seeks to overcome fixed boundaries between classification types, and thus to provide data on areas of vegetation transition. Compared to Landsat and AVHRR, MODIS maps are much richer. Validation will be conducted with high and very high-resolution data (from Ikonos) at locations in the U.S. and Zambia.

The VCC product identifies areas of particular concern for land use change,

many of which are anthropogenic. The product characterizes five types of land cover: forest, non-forest, bare, water, and burn scar. Townshend showed an example of the product's ability to detect floods in Cambodia and burn scars in the western U.S. this past summer. A case study of fires along the Montana/Idaho border addressed the question of whether roadless areas burned faster than areas with roads. Using the VCC product, they were able to show that the presence or absence of roads had no impact on whether an area burned.

The last products were the fire and burned area products. Townshend indicated that the switch to B-side in November has improved the performance of the fire bands, and calibration is still ongoing. Three of the six fire products are released: the active fire detection product (L2 swath); the Level 3, 1-km gridded product; and the Level 3, 5-km, daily global browse. The MODIS fire products successfully detected Australian fires in October, and the data can be correlated with the aerosol products to give an interdisciplinary view of the event. Product QA has included numerous field campaigns, including SAFARI 2000 and sites in the western U.S., and comparisons with other sensors, including AVHRR, ASTER, MAS, Landsat-7, and Ikonos. Dorothy Hall and Jeff Morisette discussed the MODLAND validation activities. Hall reported that the Data Assimilation Office and the modeling community are ready to use MODIS test data for the month of November, and she believes that the metrics will show significant improvement in the models' output. Morisette said that field data are being collected at a number of sites. The validation strategy includes collecting several layers of remote sensing data ranging from MODIS down to Ikonos resolution, and then complementing these with field data. Among the concerns raised at the Land Group's Validation workshop was the availability of stable MODIS products, and

the availability of coincident Terra data (MODIS, MISR, and ASTER) is a concern. There are reprocessing issues for validating data products to be used operationally. Reprocessing targets include four Bigfoot sites, LAI campaigns in Finland and Canada, and SAFARI 2000 wet and dry seasons.

MODIS Geolocation Status

Robert Wolfe reported that they have met the geolocation accuracy specification of 150 m (1 sigma) and are making progress toward the accuracy goal of 50 m (1 sigma). The Land Group's 250-m resolution products drive the goal. In March, SDST reduced geolocation error from 1.7 km to 500 m RMS, and then further reduced the error to within 100 m RMS in June 2000. Further correction that will bring MODIS to its goal is expected in February 2001. SDST's next steps include examining a possible confusion between time and pitch biases and looking at time-dependent trends in the data.

MODIS Direct Broadcast

Jim Dodge reported that there is now complete coverage of the United States in real time with five operational direct broadcast receiving stations. The cost to build a MODIS DB station is currently around $300,000. The U.S. receiving stations keep full swaths of MODIS data available online for up to one month after acquisition, and the sites have the capability to decode raw data for a full swath as well, calibrate and navigate the data, and generate selected data products. The network of receiving stations is providing reasonable amounts of raw data to requesting scientists and other users.

Earth Science Enterprise

Diane Wickland spoke about the Earth Science Enterprise's overarching objective, which is to answer the question how is Earth changing and what are the consequences for life on Earth?

Wickland summarized the Enterprise's approach for determining priority of projects. Wickland also discussed priorities for research and field campaigns.

Interagency Use of MODIS Data

Bruce Ramsay explained that NOAA's decision to use MODIS data for operational and evaluation was based on the desire to reduce the risk in the transition from POES AVHRR to the NPOESS VIIRS era at NOAA. Ramsay said there is a NOAA-NESDIS server at NASA GSFC Building 32. With this system, NOAA is processing a subset of MODIS data within a 3-hour window. In the summer of 2001, they expect to be able to distribute MODIS subsets of products to the NOAA community. NOAA has now laid the groundwork for processing and distributing data in this experimental mode for use in NOAA operational purposes.

Teruyuki Nakajima and Takashi Nakajima spoke about MODIS data use in the Global Land Imager (GLI) project. NASDA has developed a command and control script for converting MODIS Level 1B data to GLI format. They used rapid MODIS data analysis for campaign support, using aerosol and cloud properties products. Takashi Nakajima noted that data visualizations were made within 18 hours after acquisition.

Aqua Processing Readiness & Terra Reprocessing

Mike Moore reported that ESDIS completed its first Aqua end-to-end test, which was successful. Moore said that almost all ECS Aqua elements are in place at the DAACs. Given the delay in the Aqua launch, Moore agreed with the team that there is some room for exploiting Aqua processing resources to help expedite reprocessing of Terra data. With respect to Terra reprocessing, the archive sizing assumptions are that when a reprocessed version of a given product is created, the older version

will be kept for six months and deleted thereafter. This assumption is for sizing purposes only and the instrument teams can negotiate with the DAACs on what data are stored versus deleted. In addition, for budgeting purposes, the following "rolling archive" strategy is assumed in sizing the archive:

- Level 0 data are retained indefinitely;

- Level 1A data are deleted 6 months after processing to Level 1B (except that ASTER Level 1A data is retained indefinitely and AMSR-E and GLAS Level 1A data is treated as if it were Level 1B);

- Level 1B data are deleted 6 months after being superseded by reprocessed Level 1B data;

- Level 2 data are deleted 6 months after Level 3 processing (except that MISR, GLAS, and MLS Level 2 data is treated as if it were Level 3); and

- Level 3 data is deleted 6 months after being superseded by reprocessed Level 3 data.

The need for deletion arises in practice only if the capacity is exceeded by the data to be archived. This depends on various factors including the actual cost of hardware and the actual data compression ratios that are achieved. Current observations indicate that the above rolling archive strategy need not be followed for MODIS data at Goddard and NSIDC DAACs. For the MODIS data at the EDC DAAC, no deletions need to occur until late 2003. It may be unnecessary to delete the data at the EDC DAAC if larger compression ratios are observed or the hardware costs go down faster than currently assumed."

Aqua Launch Readiness Report

Claire Parkinson reported on Aqua launch readiness, indicating that the official Aqua launch date is currently July 12, 2001, but there is a high probability that the mission will launch

MODIS Land Team Annual Validation Review Meeting

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Overview

The objective of this meeting was to bring together validation investigators and EOS sensor team members to exchange information and findings to optimize existing and planned validation activities (URL 1, listed at the end of the article). The meeting was well attended by members of the MODIS Land Discipline Team (MODLAND) and EOS Investigators involved with MODLAND. David Starr of the EOS validation office provided the context for the meeting with a brief update of current EOS validation activities and future plans.

Chris Justice, MODLAND Team leader, started the meeting with an overview of the importance of validation activities for global land products. For the land community, global product validation is an emerging and challenging research area. Existing products are largely unvalidated. As the generation of global products becomes increasingly easier and the number of products multiplies, their use is becoming more widespread. Therefore, it is important to provide statements as to the accuracy of the products. Standard procedures for data collection, analysis and reporting will make these statements easier to provide. MODLAND validation activities are contributing to the development of these standards.

Since there is common interest in validation activities from the various data providers and space agencies, MODLAND is working with international partners to establish a forum for developing global validation procedures. This is being done primarily through the CEOS: Working Group on Cal/Val – Land Product Validation subgroup (WGCV-LPV) – with an initial focus on products from the "Global Observation of Forest Cover" program: LAI/FPAR/NPP, Land Cover (LC) and LC Change and Fire (URL 2).

Bruce Guenther provided an overview on the performance of the MODIS instrument. The main issue for validation science was the switch to "B-Side" electronics and changes in the calibration look-up table in early November 2000. This action significantly reduced noise in several bands; however, because of this switch, data collected before November 1 will not be consistent with data collected after. Validation activities using data collected prior to November 1 are still useful with respect to assessing the general agreement between validation data sets and the MODIS products, but any quantitative accuracy statements from these studies cannot be applied directly to the post-November products.

Nazmi El Saleous presented information on the MODLAND product production system. The algorithm used for production of a MODLAND product can be tracked by the Product Generation Executive (PGE) version, which is embedded in the product metadata. However, the version of input data used is not included in the product metadata. To help track the history of both the input data and the software version, the MODLAND production homepage contains tables summarizing the change history of land and upstream PGEs. The tables can either display the overall change history since the nadir door was opened or gives more details for a time period of interest (URL 3). David Roy noted that the MODLAND QA team publishes updates to the "science quality flag" for all released products (URL 4). This is a general statement on the product's overall quality. Both the PGE version and the science quality flag can help with interpretation of possible nuances of the products and thus help temper validation results.

One of the issues brought up by validation investigators during the first year of MODIS data collection was difficulty in dealing with projection of MODLAND products. The Level 3 and 4 MODLAND products are projected into the Intergerized Sinusoidal Grid (ISIN). ISIN was selected in the mid-1990s for the overall MODIS grid as a compromise between land, ocean and atmosphere requirements. A primary advantage to ISIN is that it is a global, non-interrupted projection that may be aligned at any meridian by sliding rows. In addition, it is continuous across the ends of rows. The disadvantage is that it is not currently supported by most image processing software packages or HDF-EOS tools. EDC DAAC has contracted the South Dakota School of Mines to develop a map projection conversion tool. Version 1.0 is currently available (URL 5). This tool can help validation investigators reproject MODLAND products into a projection recognized by the image processing software they are using.

Validation investigations

Both EOS Validation investigators and MODLAND PIs made presentations. There were also presentations from MISR (Brugge), the Scientific Data purchase (Pagnuti), and NASDA's GLI team (Honda). Presentations are available on-line (URL 1). Based on the presentations and discussions from break-out sessions, the meeting arrived at several conclusions. In general, there is no set definition for what it means for a product to be "validated." That is, validation activities are incremental, with incremental stages including:

- exploring products at a few well-instrumented sites;

- incorporating multiple sites with similar measurements;

- developing a globally representative network and incremental goals;

- checking and refining products to be on target – "unbiased";

- estimating product uncertainty at pilot sites;

- comparing initial results with theoretical error bars;

- estimating product uncertainty with global representation, and

- inferring the impact of uncertainty on products' use.

The ultimate driver should be the utility of products for addressing science and application questions. Current activities are addressing the early stages in this incremental structure.

From the experience gained during the first year of MODIS data collection, there is a clear need for a close coupling between external validation investigators and the science team. This interaction between several investigators and the science team could provide expanded opportunities for validation activities including:

1. additional sites with the same investigators;

2. additional sites with additional investigators (using protocols and methods already developed);

3. network of sites with global representation; and

4. integration with end user feedback.

Summary

Validation campaigns have been undertaken for each of the MODLAND products. They represent a significant amount of work and dedicated resources. Results are starting to come in. Validation activities in 2001 will benefit from stable MODIS data. As activities continue, emphasis will be placed on standardizing measurement techniques through protocols. MODLAND will continue to focus on the EOS Land Validation Core Sites and to interact with international partners through the CEOS, WGCV-LPV.

Acknowledgments

Related URLs:
1. MODIS Land Team Validation Annual Review Meeting, 2000: http://modis-land.gsfc.nasa.gov/val/modland_val_mtg_2001.html

2. CEOS Working Group on Cal/Val – Land Product Validation subgroup: http://modis-land.gsfc.nasa.gov/val/modland_val_mtg_2001.html

3. MODLAND Production http://modland.nascom.nasa.gov/prod/

4. MODLAND Science Quality Flag http://modland.nascom.nasa.gov/QA_WWW/release.html

5. EDC DAAC's MODIS Reprojection Tool: http://edc.usgs.gov/programs/sddm/modisdist/index.shtml

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Minutes of the Aqua Science Working Group Meeting

researchers active in these areas were requested of all meeting attendees.

Lastly, Parkinson led a brief discussion on whether to attempt to produce a special Aqua issue of a professional journal. Salomonson commented that the Terra special issue of the IEEE Transactions on Geoscience and Remote Sensing was useful and a corresponding issue could be equally useful for Aqua. One suggestion was to emphasize AIRS/AMSU-A/HSB and AMSR-E, with briefer discussions regarding MODIS and CERES, both of which are included in the IEEE special issue on Terra. It was decided that a special Aqua issue should be pursued.

The date for the next meeting of the Aqua Science Working Group was set for Thursday, August 2, 2001 at GSFC.

Aura Science Team Meeting

— Anne Douglass (douglass@persephone.gsfc.nasa.gov), Chair, Aura Science Working Group, NASA Goddard Space Flight Center
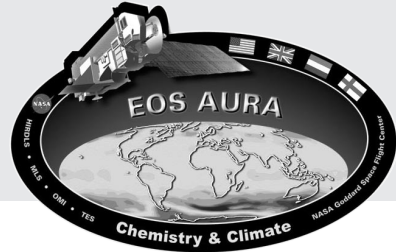
An EOS Aura Science Team Meeting was hosted by the MLS and TES teams April 4-5, 2001 at the Pasadena Convention Center, Pasadena, CA. Mark Schoeberl (project scientist) opened the meeting. Phil deCola (program scientist at NASA HQ), spoke briefly about uncertainties at NASA Headquarters due to the new administration. Mark Schoeberl, representing Aura Project Manager Peg Luce, presented the overall status of the project. Most of the six-month launch delay to June 2003 has been consumed by delays in the instrument delivery dates, and there is very little slack in the schedule. Tom Nosak, Spacecraft Manager for TRW, reported on challenges to integration of the Aura platform presented by the delay in the Aqua launch. He assured us that integration of the Aura spacecraft will be completed before the Aura instruments are delivered.

Mark Schoeberl described formation flying of the Aqua, CloudSat, Picasso, PARASOL and Aura satellites. He used an animation to illustrate how the satellites follow each other in similar orbits. Aqua is followed within a few minutes by CloudSat, Picasso and PARASOL; the separation between Aura and Aqua is only 15 minutes. Formation flying will make it possible to combine aerosol information from all satellites with the water vapor measurements made by MLS, thus enhancing the scientific value of individual data sets. Rich McIntosh presented some of the technical challenges of formation flying. Bob Jones responded to questions about the impact of frequent use of thrusters to maintain the orbit formation.

The Aura instrument principal investigators presented information about the present status of their instruments, the algorithm, and data processing preparations. John Gille and John Barnett (Co-PIs, HIRDLS) report that most subsystems have been delivered. Joe Waters (PI, MLS) showed a pamphlet describing technical aspects and science goals which has been developed by MLS. The MLS instrument schedule has little slack but the team is committed to on-time delivery. Reinhard Beer reported that integration of TES is nearly complete, although there have been some delays due to a problem with detectors. Exercises of the TES nadir algorithm with input data from sonde measurements and from a model simulation are promising. Bert van den Oord (Deputy PI OMI) reported on the progress of the instrument, and preparation for the ATDB review that will take place at the end of the summer.

There are seven working groups associated with Aura. The Science Group (chair, A. Douglass) organizes the annual Science Team Meeting. The Mission Operations group (chair, A. Kelly) did not make a report at this meeting since an Aura Ground System review will be held at GSFC in late April. The Education and Public Outreach Group met in January and E. Hilsenrath (chair) presented its progress at this meeting. Outreach activities are planned in collaboration with three partners: the American Chemical Society through their publication *Chem Matters* that is aimed at high school teachers and their students; the GLOBE project that involves students in measurement programs; and the Smithsonian, which is developing an exhibit for the Smithsonian and for other museums. The other four groups met on Tuesday April 3. The Algorithm Working Group (chair, N. Livesey) reported on progress in an intercomparison exercise involving all of the instruments using a single orbit through a constituent field simulated by the MOZART model. The Data Systems Group (S. Lewicki, acting chair) reported on approval of the Aura Level 2 guidelines, and the need to develop guidelines for the mapped data to be produced in Level 3. The Aerosol Group (S. Massie, chair) reported on the need for a computer code that can be adapted to general use for the Aura instruments to evaluate the impact of aerosols and clouds on the constituent retrievals. The Validation Working Group (L. Froidevaux and A. Douglass, co-chairs) reported on the status of the Aura Science and Validation document. The working document will be upgraded to Version 1.0 and made available outside the validation team pending consensus on the validation priorities and the executive summary. All additional inputs to the document are due May 1.

Science presentations completed the meeting agenda. Several presentations concerned topics related to instrument and algorithm development. The TES retrieval team gave presentations on preliminary results with the single orbit test (H. Worden), the capability of TES retrievals to capture ozone temporal variability (K. Bowman), and ways to account for aerosols and clouds in TES measurements (A. Eldering). B. van den Oord presented results with the OMI development model. A statistical method of calculating radiative transfer for HIRDLS was shown to be superior to other methods in accuracy and speed

of computation (T. Heinemann). A presentation on OH column measurements over JPL's Table Mountain Facility (F. Mills) was followed by a discussion of non-LTE effects on OH mesospheric measurements (H. Pickett).

Various approaches to validation of satellite observations were presented. P. Novelli showed observations made at NOAA/CMDL for validation of MOPITT observations of CO and CH_4. R. Rood demonstrated the potential of ozone assimilation to monitor instrument performance and stability. R. Salawitch gave an overview of the SOLVE mission and the dual purposes of validation and addressing science goals through a combination of aircraft and satellite observations.

Much discussion was prompted by presentations concerning the role of cirrus clouds in the tropics. J. Holton showed sub-visible cirrus above convective anvils with tops above about 14 km, producing cooling that can offset the heating due to subsidence, and discussed the implications of such processes on stratospheric water. However, UARS HALOE observations show that sub-visible cirrus clouds often occur in the tropics away from regions of deep convection (S. Massie). These two papers are relevant to the objectives of The Tropical Composition and Climate Coupling Experiment, a mission proposed to provide validation for the Aura platform while addressing science questions as those posed by Holton and Massie.

A three-dimensional chemistry and transport model (CTM), driven by winds from the Goddard Earth Observing System Data Assimilation System, is being used to interpret tropospheric measurements from the GOME instrument. R. Martin showed comparisons of a simulation from the Harvard chemistry and transport model (CTM) with calculations of tropospheric column NO_2 from GOME measurements of the total column. P. Palmer also used the Har-

vard CTM and GOME observations of formaldehyde to evaluate the emissions of isoprene used in the model.

Several presentations concerned current issues in atmospheric chemistry. M. Schoeberl showed estimates of ozone loss during the SOLVE period using data from ozonesondes, the lidars aboard the DC-8, *in situ* ozone measurements from the ER-2, and satellite ozone measurements from Polar Ozone and Aerosol Measurement III (POAM). A. Tabazadeh discussed issues of detection of denitrification in UARS MLS observations of HNO_3 that will be useful in analysis of Aura MLS HNO_3; such issues are also relevant to present and future northern hemisphere ozone loss. H. Pumphrey showed the importance of mesospheric measurements that are possible with EOS MLS. UARS MLS observations of CH3CN show an enhancement in August 1992 that may be related to mid-latitude injection of tropospheric air from a forest fire into the stratosphere (N. Livesey).

A number of presentations concerned atmospheric dynamics. Topics included the following: the Whole Air Community Climate Model, an atmospheric general circulation model with interactive chemistry for the lower and middle atmosphere (B. Boville); improvements in the data assimilation product of the NASA GSFC Data Assimilation Office DAO) by utilization of a general circulation model being developed jointly by NCAR and DAO, and validation of the stratospheric dynamics and constituent transport using that system (S. Pawson); analysis of stratospheric warmings during the 2000-2001 northern winter (G. Manney); theoretical analysis of the gravity waves likely to contribute to the quasi-biennial oscillation, and how such waves are likely to be seen in HIRDLS data (J. Alexander).

The next Aura science team meeting will be held in Spring, 2002, probably in the Netherlands.

MODIS Science Team Meeting

much later in the year. The full system comprehensive performance test still remains, as does the thermal vacuum test. They will also need to reinstall the solar array prior to shipment to Vandenberg Air Force Base. The Aqua Project is now exploring formation flying of NASA's afternoon satellites, i.e., Aqua, PICASSO-CENA, CloudSat, PARASOL, and Aura. Wayne Esaias asked how Aqua's flight track lines up with Terra's each day, saying that there might be some benefits for looking at track relationships for MODIS science. Parkinson announced that the EOS Data Products Handbook, Vol. 2, is out now in hardcopy.

VIIRS

The final presenter, Robert Murphy, MODIS Project Scientist, presented an overview of the planned specifications for the Visible Infrared Imaging Radiometer Suite (VIIRS), which will be built by Raytheon SBRS. It will be a single sensor covering the spectral region from 0.4 to 12 μm. It will have 22 spectral bands, including one broadband "day-night" band. VIIRS will have a rotating telescope design, an onboard solar diffuser, and a Solar Diffuser Stability Monitor. Its first flight will be on NPP in 2005, and all subsequent NPOESS missions will carry a copy of VIIRS. In the design of VIIRS, NASA incorporated many lessons that were learned from MODIS.

Before the meeting adjourned, Salomonson indicated that the MODIS Team will have most products out in steady production fashion soon for folks to look at, including complete data months, like December 2000. He indicated that he now would like the Team to work toward producing a consistent data year. He concluded by saying that plans will be developed to have a results symposium at the end of 2001 or the beginning of 2002.

EOS Aura Ground System Review

— Angelita C. Kelly (angie.kelly@gsfc.nasa.gov), NASA Goddard Space Flight Center, Greenbelt, MD.

Note: Many of the presentations made at this meeting have been posted on the World Wide Web at: http://www.qssmeds.com/aura/docs/GSR_042401/index.htm
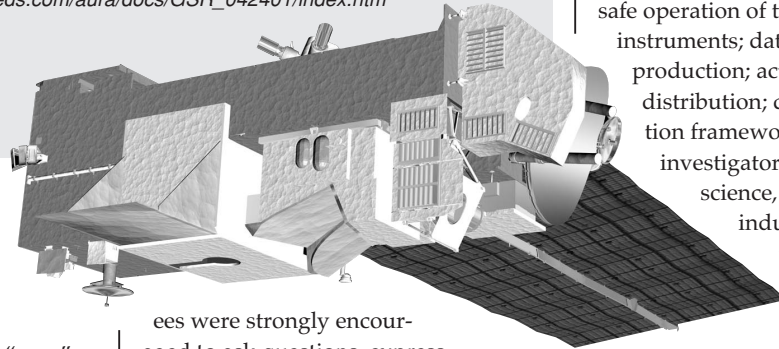
The EOS Aura Ground System Review was held at the Goddard Space Flight Center (GSFC) on April 24-26, 2001. The review board for this "peer" review was chaired by Dennis Dillman, Code 300/Office of Quality Assurance with the following team members: Candace Carlisle, ESDIS Systems Manager; Carolyn Dent, Aqua Mission Manager; Robert Jones, Aura Systems Manager; Ludie Kidd, System Integration and Engineering Branch; Ed Masuoka, Chief, Terrestrial Information Systems Branch; Paul Ondrus, Chief, Earth Science Mission Operations Office; and Bert van den Oord, Deputy Principal Investigator for the Ozone Monitoring Instrument (OMI). Attendees included personnel from all segments of the Aura mission, i.e., scientists, spacecraft, all instrument teams, the Aura Project, and ground system personnel. The review was deemed a success.

The purpose of the review was to present the end-to-end ground system for the Aura mission to Aura personnel. The emphasis was on having the Aura personnel review the Aura-unique requirements that will be implemented within the existing EOS Ground System, most of which is currently in use for Terra, and is in testing for supporting the Aqua mission later this year. The goal was to identify any additional requirements, and any issues/concerns that impact the ground system. The attend-

ees were strongly encouraged to ask questions, express concern, and document them via Request for Action forms (RFAs), to help in clearly defining requirements for the ground system.

Splinter meetings with the TES, OMI, and HIRDLS teams were held on the afternoon of April 26, all day April 27 and half a day April 30 with the OMI team.

Day 1, April 24

Aura Science Mission

After Dolly Perkins, ESDIS Project Manager, welcomed the attendees, Mark Schoeberl, Aura Project Scientist, presented the science objectives and the science strategy for the Aura mission. He stated that Aura will enable us to get important measurements of the chemistry and dynamics of the stratosphere. Aura's four instruments, High Resolution Dynamics Limb Sounder (HIRDLS), Microwave Limb Sounder (MLS), Ozone Monitoring Instrument (OMI), and Tropospheric Emissions Spectrometer (TES), will provide new chemical measurements of the troposphere, and important climate measurements. He also discussed his concept for formation flying with the Aqua spacecraft to achieve near-coincident measurements.

Aura Ground System Overview

Angelita (Angie) Kelly, Aura Mission Operations Manager, stated that Aura will be supported by the same ground system configuration that will support Aqua and ICESat. She reviewed the basic requirements and functions of the EOS Ground System which are: the safe operation of the spacecraft and instruments; data capture and data production; active data archive and distribution; distributed information framework for supporting EOS investigators and other users in science, government, industry, education, and policy; and interoperability with other data centers worldwide. Kelly identified the lead personnel for each of the ground system elements and described the various organizational and matrixed personnel interfaces within GSFC in support of the Aura mission. Most of the Aura ground system team members also support, and are gaining experience on Aqua.

Kelly discussed the Aura Ground System architecture, functions, and data flow, highlighting the ground system elements needing Aura-specific modifications. She addressed the functions associated with each of the system elements, starting with the science downlink flow from the spacecraft to the ground stations, the flow of the data at a reduced rate to GSFC for Level 0 processing, the higher level processing at the individual instrument Science-Investigator-led Processing Systems (SIPSs), and the archive and distribution of the standard data products at the Distributed Active Archive Centers (DAACs) at GSFC (for HIRDLS, OMI, and MLS) and at the LaRC (for TES). The command uplink was described, starting with the input from the instrument operations team via the GSFC-provided Instrument Support Toolkits (ISTs), the integrated command upload from the EOS Operations Center (EOC), and the monitoring

of command execution, and health and safety status using the real time housekeeping telemetry data. An Aura-specific entity, the Direct Broadcast Finland Ground Station, was also noted.

Highlights of the Aura ground system development schedule, the requirements definition process, the requirements documentation process and hierarchy, and the risk management processes for the Aura and ESDIS Projects were addressed. Kelly emphasized the need for feedback on the material presented at the review, especially the requirements documents, the Mission-Specific Requirements document (MSRD) by May 14, and the EOS Mission Operations System (EMOS) Level 4 requirements, (presented on Day 2) by May 4 .

Instrument Operations

Debbie Ramey, Aura Instrument Planning Group (IPG) lead, gave the following summary of instrument design features or operations which drive ground system requirements.

MLS, a passive microwave radiometer/spectrometer, measures thermal emissions from the atmospheric limb, makes continuous global measurements day and night, scanning vertically in +x direction of flight. MLS will require numerous microprocessor loads during activation, and Inertial Reference Unit (IRU) gyro angle data from the spacecraft will be used in science processing.

OMI, a nadir-viewing imaging spectrograph with a large field-of-view and two optical channels, will make global measurements of a number of trace gases in the troposphere and stratosphere, and will obtain almost full coverage of the globe within a day. OMI will perform solar calibration every orbit. The Aura flight software stored command sequences have been resized to handle the daily OMI system stored commands.

TES views in both limb and nadir direc-

tions and can target within 45 degrees of local vertical. The standard product will be a global survey (two orbits of pre-calibration and 16 orbits of survey). Nadir targets will include volcanoes, industrial catastrophes, etc. TES has a command timing constraint of at least 500 ms between commands. Cooler telemetry may replace normal housekeeping data for a few packets on S-band.

HIRDLS, a multi-channel infrared radiometer designed to scan the stratosphere and mesosphere in the anti-flight (-X) direction, will obtain profiles over the entire globe both day and night. A two-axis tilting mirror provides scanning in altitude and azimuth. Instrument control routines (SAIL) minimize the need for large numbers of spacecraft stored commands; however, there will be a need to update SAIL parameters through microprocessor loads. HIRDLS has a moveable sunshield door. Some quick processing of science data will be required.

Flight Dynamics

Felipe Flores-Amaya described the basic orbital requirements (frozen, sun-synchronous, 98.2 degree inclination, 16-36 degree Solar beta angle constraint, repeat cycle of 233 revolutions per 16 days). The basic flight dynamics functions for Aura were presented, i.e., tracking, attitude determination, maneuver planning, planning and scheduling, including the generation of planning products for the instrument teams.

The Aqua Flight Dynamics System software will be modified to accommodate Aura-unique requirements. Examples of new Aura requirements that Flight dynamics will have to provide are: predicted Sun entrance/exit times into the OMI calibration field-of-view, predicted sun azimuth and elevation angle in HIRDLS defined frame at one-minute intervals, predicted lunar ephemeris in the spacecraft frame at one-minute intervals for MLS, and predicted TES global survey start events.

Some of the Flight Dynamics issues that are being worked are: the 24-hour time span for definitive ephemeris currently spans from 00:00 to 00:00 GMT; Aura teams have requested a change to have the time span go from 12:00 to 12:00 GMT, to keep the data as current as possible for science processing. This change will be made. Another concern is the need for realistic X-Band GBAD data for pre-mission testing.

EOS Data and Operations System (EDOS)

Stephanie Nickens, Deputy EDOS Project Manager, presented an overview of EDOS functions and capabilities. EDOS performs data capture at its Ground Station Interface Facility, which is physically located at the ground sites in White Sands (used for EOS Terra), Alaska, and Norway. EDOS products are generated at the Level 0 Processing Facility at GSFC and include time-ordered Level 0 production data sets (PDS), expedited data sets (EDS), and rate buffered (raw) data (RBD) files. The EDOS C4.1 Aqua version is currently undergoing testing. This is designed to be for multi-mission support, including Aura. It includes a system upgrade for data flushing that will enable the TES SIPS to receive PDSs in a timely manner in spite of TES's on-off mode of operation. There are no known Aura-unique requirements. The database will need to be updated for Aura.

There was an extended discussion regarding data latency, especially for the rate buffered data. Both the OMI and HIRDLS team desire to have rate buffered data available in less than three hours from observation time to give them sufficient time to process to Level 2 within three hours. This is a capability which is not currently provided and a Request for Action (RFA) was written to investigate what can be done to improve data latency.

Aura Test Coordination Activities

Vic Buczkowski, Aura Test Coordinator, presented the overall Aura testing road map. This includes the different phases and categories of testing leading to launch, starting with element level testing, then interface testing, system testing, and operations testing. Project-specific tests are conducted by the Mission Operations Manager and Flight Operations Team (FOT); they include spacecraft to ground interface tests, mission tests, and mission rehearsals. Mission readiness tests will be conducted by the Mission Readiness Manager and will exercise Aura ground system elements from a mission operations perspective prior to interface tests with the spacecraft. Science data flow testing through the DAACs and the SIPS will be conducted by the Science Systems Test Group.

Buczkowski described the science data collection process. A Science Test Data Collection and Validation Plan will be developed and worked with the Project, TRW, instrument teams, and the science testing team.

A draft integrated testing schedule was provided for review by Aura personnel. Buczkowski took an action to identify which of the test activities involve the instrument teams and/or TRW.

Science Systems

Stan Scott, ESDIS Aura Science Interface Manager, provided an overview of the science systems that will support Aura. He showed a draft data flow chart, taking the Level 0 data sets produced by EDOS to the Distributed Active Archive Systems (DAACs) from which the individual Science Investigator-led Processing Systems (SIPSs) will access the data. The input data to the SIPS also include ancillary/auxiliary data, some of which are still to be defined. The SIPS will process the data to Level 1 and Level 2, generating standard products which will be sent to

the GSFC DAAC for HIRDLS, OMI, and MLS, and to the Langley Research Center (LaRC) DAAC for archive and distribution. The chart also showed interfaces for the various Team Leader (TL)/Principal Investigator (PI) Science Computing Facilities (SCF) at JPL, Oxford University, National Center for Atmospheric Research (NCAR) in Boulder, and the Netherlands.

Scott summarized the new/potentially new Aura requirements for science processing. Following are some of them: ESDIS to provide data in HDF 5/HDF-EOS 5 format, provide Linux support, etc. A potential new requirement which still needs further evaluation is the need to provide 8 Hz attitude data.

Open items include: OMI standard data product generation from the integrated Dutch/U.S. Science Team.

Science Systems Development and Testing

Glenn Iona, Science Systems Integration and Test Manager, discussed the schedule for future releases of the EOSDIS Core System (ECS) Science Data Processing System (SDPS) and the EOS Data Gateway (EDG). ECS Release 6B plus any patches (to be determined) is projected as the version that will support Aura; it is scheduled for 2002. Iona stated that baseline Interface Control Documents (ICDs) for ECS interfaces with EDOS, EMOS, FDS, and the SIPSs will be updated. He also expressed his concern regarding a source for GBAD data with sufficient fidelity to support science processing.

Iona described the three phases of science system testing for each SDPS release, namely engineering tests, formal interface confidence tests (ICTs), and end-to-end tests to demonstrate the readiness of the system to process data to Level 2/3. The presentation included a draft detailed schedule and information regarding test activities, duration, and level of effort for science team participation.

Goddard Earth Sciences (GES) DAAC

Steve Kempler, the Goddard Earth Science (GES) DAAC Manager, discussed the operations concept and the Aura data flows at the DAAC and for HIRDLS, MLS, and OMI. He also presented current status and performance to date. The DAAC produces 331 GB/day of MODIS Terra Level 1 data, executing 2.2 times faster than real time, at the same time sustaining a 24-to-48 hour lag behind the leading edge of data capture. The archives are filling up fast, handling 20.8 TB/month. More archive resources are being procured to handle Aqua and Aura data. To date, there are ~190 TB in the archive. There are currently no problems distributing the data. There are plans to augment the current hardware and staff to handle new mission data requirements.

LaRC DAAC

Richard McGinnis, the LaRC DAAC Manager, presented the plan for handling the TES requirements. TES data is currently estimated to be equivalent to MISR data for which the LaRC DAAC does production, archive, and distribution. TES will require additional staff and additional hardware for ingest, archive, and distribution. Open items include: definition of standard data products need to be finalized to provide a better estimate of data volume, and whether the Data Preparation (DPREP) process will be at the GES DAAC (as currently directed by the ESDIS Project) or at the LaRC DAAC (as preferred by the JPL TES team).

HIRDLS Ground System Status and Plans

Ken Stone, HIRDLS U.S. Data Manager, presented an overview and status of the PI SCF and the SIPS in Boulder, CO. SCF hardware is in place to support engineering version software development and testing, and the local area network has been upgraded to 100

Mbits/sec. The SCF enhancement schedule through FY 2004 was also presented. Ken presented the L1 and L2 Science Software processing flow and methodology. This included a listing of the software units and status.

The SIPS is still in a requirements gathering and definition phase. Derived requirements are being developed for each of the four subsystems. Currently, 30% of proposed staffing is in place. Additional software developers will start this year. Issues and concerns include: funding for continued processing during I&T, funding for hardware in post-launch period, attracting and keeping qualified people, and the impact of launch delays.

MLS Ground System Status and Plans

David Cuddy, JPL, presented the SIPS and SCF overview. The SIPS, which is being implemented by Raytheon ITSS in Pasadena, will process the data and generate Level 1B, 2, and 3 products. Level 1 and Level 2 production will be daily. Level 3 production will be daily/monthly maps and zonal means. The science software development is on schedule, with the engineering model completed in the first quarter of CY 2001. The launch ready model is scheduled for the end of CY 2002 and will support end-to-end testing. All the code is new (no direct heritage from UARS MLS).

The SIPS development has inherited design and code from Vegetation Canopy LIDAR, which in turn was inherited from GSFC DAAC V0. Approximately 65% is reusable for MLS SIPS.

Open items include: 8 Hz attitude data are needed for science processing (TBR); and a security concern regarding FTP interface between SIPS and DAAC.

OMI Ground System Status and Plans

Albert Fleig, Deputy U.S. OMI Team Leader, presented a brief history of the joint OMI activities, Team Leader Science Computing Facility (TLSCF) and SIPS status and interfaces, SIPS development status, and the proposed OMI SIPS (OSIPS) architecture. The software algorithm was also presented. OMI investigators did not propose individual SCFs. The TL SCF was established similar to the SIPS. The OSIPS is based on existing MODIS SIPS (MODAPS). MODAPS is currently running and producing 8x the OMI data rate. OMI hardware is based on just-in-time procurement of commodity Linux/Intel chip boxes, disks, tape storage, and networks. The total ozone algorithm is scheduled for implementation and test in FY2001. All algorithms for at launch processing will be complete in FY2003.

Open items include: science team ability to support the algorithm delivery schedule, difficulty in getting additional staff, timely delivery of definitive attitude and ephemeris data.

TES Ground System Status and Plans

Robert Toaz, the TES Ground System Manager at JPL, presented the TES SIPS and SCF overview and status. SIPS development and operations will be performed by Raytheon ITSS (RITSS) in Pasadena. Level 1, 2, and 3 data products will be generated. The TES SIPS is based on software developed by RITSS for the Goddard V0 DAAC. Most of the support software was ported without change. The core software scheduling will be restructured for distributed resources management. New software includes planning functions for starting TES jobs and the tracking database. The SIPS schedule is on track with the first delivery in April currently undergoing I&T. The SIPS software status was also presented. There are no signifi-

cant issues; there is a concern regarding funding for remaining algorithm and science software development activities.

Day 2

EOS Mission Operations Segment (EMOS)

Kevin Klem, Ann Habeger, and John Diubaldo (all from Raytheon) presented the requirements for the EOS Mission Operations Segment. This included a broad discussion of all requirements for the Mission Management, Online, and Analysis Subsystems. New requirements identified to support the four Aura instruments were discussed.

Topics included a review of many database capabilities, stored command processing, and handling of instrument microprocessor loads. Earlier this year, the commanding flexibility afforded by the OMI instrument precipitated a review of the allocations for stored command sequences within the spacecraft bus instrument support computer. So, at the GSR, the EMOS developers recognized new requirements to rework the allocations for quantities and sizes of stored command sequences.

EMOS developers acknowledged a few other new ground system requirements which were driven by the design and operations of the four Aura instruments. In particular, new flight dynamics products will be needed by Aura. The ability to handle some unique command subfields was recognized as needed. The ability to handle TES cooler telemetry is also new to EMOS. A few minor open items were itemized at the conclusion of the day due to the fact that the instruments have not yet been fully integrated. The day was highly successful in presenting the requirements for Aura.

Space Network

Ed Dembowczyk provided the current Space Network configuration, including the fleet of eight Tracking and Data

Relay satellites (TDRS) that provide 85 % coverage per orbit for low Earth orbiting spacecraft, including EOS Terra high rate and low rate support. The addition of the Guam remote ground terminal in 1998 further increased coverage to 100% for all customers by providing closure to the TDRSS zone of exclusion.

During Aura launch and early orbit (LEO), the SN provides the initial support for low rate command, telemetry and tracking. It will provide near-continuous coverage from separation to approximately launch-plus-3 hours. During the spacecraft activation phase, 10 to 15 20-minute contacts per day are anticipated and will be scheduled as needed for real time command and telemetry support. The SN will be used in conjunction with GN support.

During the operational phase, the SN will support an average of two 10-minute contacts per day for tracking and clock correlation support. Additional support will be scheduled to support maneuvers, as needed. During all mission phases (except pre-launch), contingency support will be provided.

The SN can meet Aura requirements without additional changes.

Networks/Communications

Clayton Sigman and Jerry Zgonc provided the current communications network topology, including the links between GSFC and the ground stations in Alaska and Norway. The Aura pre-launch requirements at the spacecraft integration and test facility (TRW) and at the Vandenberg Air Force Base (VAFB) are the same as those for Aqua. The links with Alaska and Norway are planned to be upgraded from 52 Mbps to 75 Mbps 8 months prior to Aura launch to handle both Aqua and Aura. Mission voice requirements with U.S. facilities are planned.

Specific links for each of the instruments showing the ISTs, EOC, DAAC, EDOS,

SIPS, and SCFs were addressed. An RFA was written to correct some of the information for OMI. It was stressed that the international partner bears the responsibility and cost for connectivity, as stated in the international agreement/joint implementation documents. An RFA was written to investigate the cost and feasibility of voice links between the EOC and the instrument operations facilities in the UK and the Netherlands.

As the ESDIS Security official, Sigman also mentioned the need to comply with the NASA Policy and Guidelines document, NPG 2810.1, Security of Information Technology. The ESDIS Project will work with the Aura teams to ensure 2810.1 compliance.

Day 3

Ground Network

Michael Condon presented an overview of the Ground Network configuration that will support Aura and a summary of the GN requirements. The GN components that will provide both high rate (X-Band) and low rate (S-band) support are the Alaska Ground Station (AGS) and the Norway Svalbard Ground Station. The Space Operations Management Office (SOMO)/Consolidated Space Operations Contract (CSOC) have made arrangements to supplement AGS and SGS with commercial services from Honeywell DataLynx antenna in Alaska (PF1) and the Svalbard Data Services Antenna in Norway. The GN currently supports Landsat-7, QuikScat, and EO-1. It provides tape back-up for Terra in case of Space Network (SN) unavailability. Terra weekly proficiency passes are performed. Future mission support includes Aqua, ICESat, and Aura.

Aura support requirements are similar to those for Aqua. The Aqua GN enhancements are currently in testing and are planned to provide Aura support. The GN will provide primary S-Band realtime telemetry, tracking, and command support. The AGS and SGS

will capture the 150 Mbps science data downlink via X-band. The WGS will provide S-Band support only. The GN will schedule Aura passes in accordance with the schedule constraints provided by the Flight Operations Team. The schedule will include at least one Direct Broadcast pass per day for the Finland Ground Station (FGS). The Aura contacts will be scheduled to minimize contention with Aqua for the network communication resources, that is, contacts for Aura and Aqua for the same orbit might be scheduled at two different stations (AGS and SGS), except in cases where only the Norway stations can view the spacecraft.

In response to current concerns regarding poor GN performance during the past few months, Condon shared the data from an ongoing investigation being conducted by CSOC to determine the causes of the downward trend in GN performance. He cited recent operations staff turnover, lack of experience, and system automation deficiencies resulting in operator errors. Engineering activities are underway to improve 11-meter antenna proficiency, including software enhancements. A Systems test engineer has also been assigned to WGS (where testing is conducted prior to deployment at Alaska and Norway) to perform independent validation of software and system changes. There is also ongoing discussion with CSOC to improve the current antenna turnaround time of 18 minutes.

Mission Readiness Testing

Ken Lehtonen, ESDIS Mission Systems Readiness Manager, described the activities to ensure that the ground system mission element are ready prior to Aura launch. He explained the roles and responsibilities, readiness testing philosophy, and how the readiness tests fit within the overall testing road map presented on Day 1. Descriptions of the different test, test tools, and the schedule were also provided. Involvement of the instrument teams was discussed.

Aura EOC to Spacecraft Interface Testing (SCIF), Mission Tests (MT), and Mission Rehearsals

Vic Gehr described the five specific tests to verify the interface and functionality of the ground system with the spacecraft. These tests are conducted after the spacecraft has gone through comprehensive performance testing. SCIF #1 will check out basic interface functionality and will focus on bus operations, including commanding of the four controllers on the spacecraft, and if integrated, command to each instrument. The subsequent SCIFs will verify additional functionality, such as Solid State Recorder (SSR) operations, interfaces with the GN and SN, command loads, receipt and processing of housekeeping data, etc. Instrument and spacecraft contractor (TRW) participation at the EOC and TRW will be required, starting with SCIF #2 through SCIF #5.

Mission tests (MTs) will exercise the ground system using day-in-the-life activities including normal operations procedures/loads, stored commanding for instruments, pre-defined command scripts, stored command sequences, etc. They will demonstrate the capabilities for receipt and processing of all data collected as well as the execution of normal operations activities. Two mission tests are planned.

The schedule for both the SCIFs and mission tests will be coordinated very closely with TRW integration and test activities and the instrument teams. SCIFs and MTs are performed with the real spacecraft. All commands and procedures will be verified/approved by TRW and the instrument teams prior to each test.

Mission rehearsals (MRs), also referred to as simulations or readiness exercises, will be conducted starting after thermal vacuum testing to establish/demonstrate the overall readiness of the entire Flight Team, i.e., the personnel that will be supporting launch and early orbit

(LEO). The primary objective of mission rehearsals is to get everyone familiar with their console position and surroundings, the tools/products that they will be using, handling nominal and contingency operations, and most importantly, working together as a team. The goal of MRs is to create a simulated environment as close as possible to the actual LEO operations, exercise portions of the LEO timeline, and demonstrate Flight Team readiness. The Aura Mission Rehearsal Plan will include the type of simulations to be performed, the number, duration, and schedule for each type, the overall process by which simulations will be conducted, from initial simulation script/product development through execution and debrief (simulation critique/problem tracking). Simulations will use the spacecraft simulator and the EOSDIS Multimode Portable Simulator (MPS). A RFA was assigned to document the guidelines for the various users, e.g., the Flight Operations Team, for sharing the simulator resources to support both Aura and Aqua.

EOSDIS Test System (ETS) Multimode Portable Simulator (MPS)

Willie Fuller, ETS Manager, and Ernest Quentin presented the capabilities of MPS and the planned capabilities to support Aura. The ESDIS MPS provides a low to medium fidelity simulator for testing the forward and return links. It simulates the spacecraft data across the interfaces. The Aura MPS is based on the Aqua MPS. It will be enhanced to provide instrument simulation capability to supplement functionality that is not provided in the spacecraft simulator. The MPS is used primarily for early testing of EMOS deliveries prior to SCIF tests. It will also be used in Aura prelaunch simulations/mission rehearsals. The Aura MPS is planned for September 2001.

A concern was raised regarding the time sharing of the spacecraft simulator pro-

vided by TRW between the Aqua and Aura missions.

Aura Flight Software (FSW) Maintenance

Don Glenn presented for Tom Clement on the activities pertaining to maintenance of the Aura flight software. Flight software refers to all the software residing on the four spacecraft 1750A processors and the FSW development and validation environment. The GSFC FSW maintenance team performs pre-launch project-level verification and validation (PVV) of the Aura flight software and post-launch maintenance of the software.

TRW has responsibility for the flight software until launch plus 90 days. The GSFC FSW team will assume responsibility after launch plus 90 days. The team also provides maintenance for the Terra and Aqua FSW. Strict configuration management procedures will be followed for any changes to the FSW. The FSW maintenance team will be responsible for creating, testing, and delivering FSW loads to the Flight Operations Team. A problem resolution procedure for investing, analyzing, and resolving spacecraft problems will be documented in the Aqua/Aura FSW Maintenance and Configuration Management Plan.

Flight Operations Presentations

John Teter, Aura Flight Systems Engineering Manager, provided a high level description of flight operations at the EOC.

Dan Muleady, TRW Aura Flight Operations Manager, showed the preliminary Launch and Early Orbit timeline. He discussed the plan for generating the integrated mission timeline (IMT) and provided a CD of the draft IMT to each of the instrument teams. The plan is to have a Mission Operations Working Group in the fall to focus on updated

Using Landsat Thematic Mapper Images to Detect Land Cover Change in South Africa

— Brent McCusker (mccuske1@msu.edu), Department of Geography, Michigan State University

Introduction[1]

Land is a contested issue in South Africa. After three-hundred years of land alienation and exploitation, South Africa's black majority has finally achieved some redress for the grossly imbalanced land distribution. The national land reform program has undertaken to transfer land from individual whites to black communities via a willing-buyer, willing-seller program. After the transfer of land, one could expect to see an intensification, or increased usage, of the land. The usefulness of Landsat Thematic Mapper Images in identifying land cover change is documented here.

Methods and Scene Properties

To assess the scope of land cover change on the redistributed farms, six Thematic Mapper satellite images were obtained for the Northern Province, specifically scene numbers 169077, 169076, and 170076 for the years 1989 and 2000[2]. These image footprints encompassed all but one of the study areas. Images were collected that would represent the study areas before and after the transfer of land from white to black owners.

Each scene was geo-rectified to latitude/longitude coordinates and the geo-rectification was verified across the two time periods to ensure accurate representation of change. All scenes were classified using the unsupervised isodata clustering method. Supervised classification was also undertaken. These classifications provided a map of land cover at a broad scale. Land cover classes included forest, grassland, water, the built environment, and barren land. However, change in the study areas was anticipated to be largely fluctuation between agriculture, grazing, and fallowed or abandoned land. As such, spectral separation was difficult to achieve and proved to be inadequate. In dryland Africa, small scale subsistence farming can be identified more readily by the pattern it leaves on the Earth's surface rather than its reflectance value.

To overcome the inadequacy of the spectral classifiers, a subset of the most relevant areas of each scene was digitized manually using on-screen digitizing. This procedure entails displaying the image on the computer screen and then creating polygons with the mouse rather than using a paper map and a digitizing tablet. Each area was divided into land use classes, namely: agriculture, grassland, forested, residential, and other. Figure 1 shows the spatial-
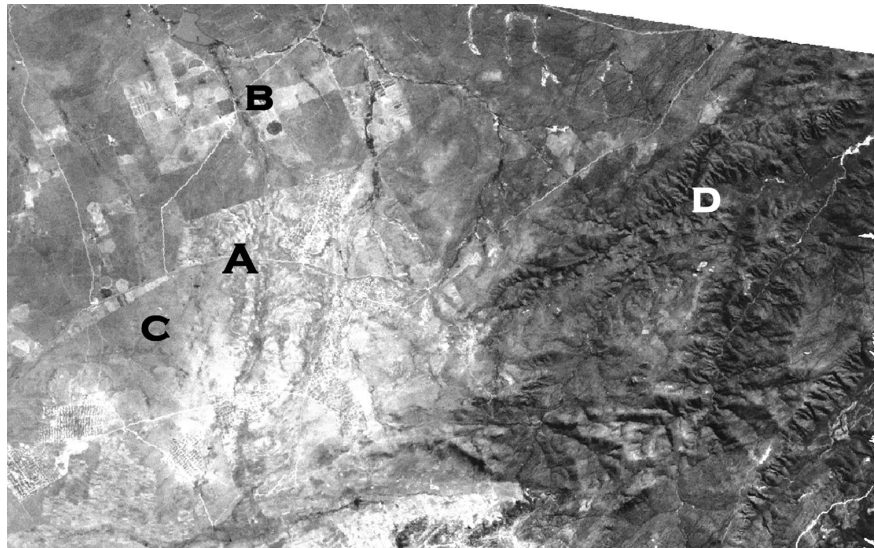

Figure 1. 2000 TM Image of Monyamane Communal Property Association (CPA) Area.

[2] One of the scenes in the earlier period was from 1989 due to limited availability.

spectral properties of the Monyamane study site. Note that some agricultural lands in the study areas are not rectilinear. African agriculture is quite different spatially from commercial or white agriculture, as evidenced in Figure 1, letter "A". While white/commercial agriculture is largely a collection of rectangular and square fields with an occasional center-pivot irrigation circle (letter "B"), African agriculture is spatially manifest as a patchwork of small fields, often following contours, without definitive boundaries. Grazing land (letter "C") lies between and beyond farmed areas, however, because of the need for a priori knowledge of the area to determine which areas are actual grazing lands and which are simply open grasslands, the category was called "grassland." Forests (letter "D") are not widespread in the study areas. For the other study sites, forested areas are those in inaccessible areas such as gullies or high peaks, where farming or grazing is minimal.

The land use change maps were created using Arc/Info, Arc/View, and Erdas Imagine. Once digitized, each polygon was coded in the database to correspond with the visually interpreted land use on the underlying image. Next, the two coverages were merged using the "union" command in Arc/Info with the "nojoin" option at the minimum fuzzy tolerance. The "union-ed" coverage contained the unique identifiers for each polygon from the two original coverages, but also assigned new unique identifiers in a separate variable column in the dataset as many of the land use polygons overlapped creating "slivers." Because the unique identifiers for each original coverage remained in the new "union-ed" coverage, the new polygons for land use were manually coded. In order to generate a 'land use change' variable, the land-use codes for the two original coverages had to be added together. To do this, "land use" variables for the 1988/89 scenes were recoded from single digits to tens. For instance, the code for grassland was

changed from "2" to "20" and so on. This would allow for unique codes to be generated in the final "land use change" variable for the "union-ed" data set. Had one of the 'land use' codes from the two original variables not been recoded, the 'land use change' variable would not have had distinguishable change classes.

Notice that in Table 1 a change from agriculture (1) to grasslands (2) yields a land use change code of "3". However, so does a change from grassland (2) to agriculture (1). To prevent duplication and create unique change codes, the simplest procedure is simply to add "10" to the 1988/89 land-use codes (Table 1). All land use change codes are then unique to each particular class of change. The variable "land use change" could then be mapped in Arc/View (Table 2). For this paper the various change categories have been combined into three categories representing intensification, extensification, and conversion to residential.

Table 1. Rationale for Recode: Without Recoding

Land Use Code 1988	Land Use Code 2000	Land Use Change
1	2	3
2	1	3
3	2	5
2	3	5
1	3	4
4	4	8
4	1	3

Table 2: Rationale for Recode: With a Recode

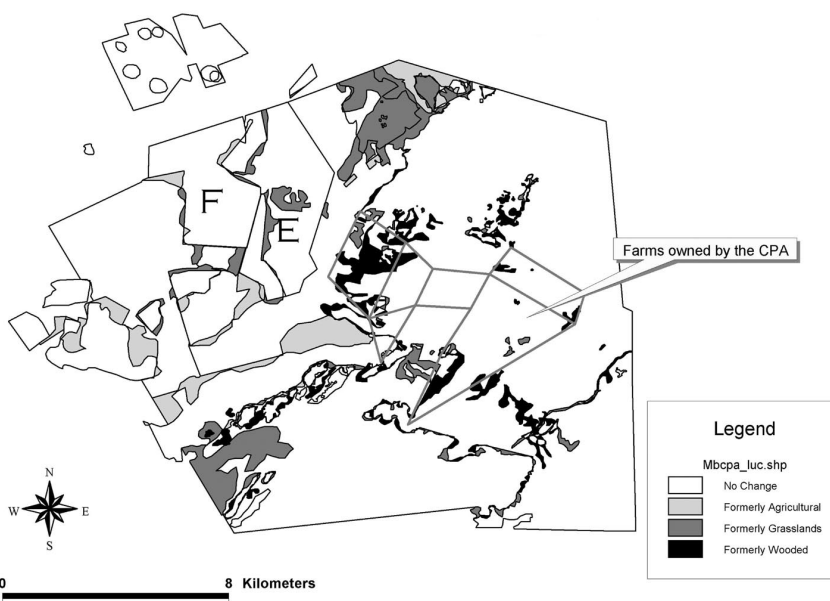| Land Use Code 1988/89	Land Use Code 2000	Land Use Change
10	2	12
20	1	21
30	2	32
20	3	23
10	3	13
40	4	44
40	1	41

Figure 2. Land Use Change 1988-2000 Monyamane CPA and Environs.

Land Use Change on the Study Site

The scope of land use change on the farms under study was minimal and the change that did occur tended to be extensification, from agriculture to grassland or wooded areas. Figure 2 shows the expansion of rural townships (letter "E") and some fluctuation of agricultural lands. Polygon "F" is the land on which the town's residents farm crops such as corn and vegetables. Large areas of farmland and grassland have been converted to other uses.

Figure 3 details land uses in 2000. Note the large areas of conversion to grassland in the center of the map at letter "G". Respondents reported out-migration from the area leading to a lack of labor to farm as intensively as they had in 1988. The apparent conversion to grassland on the transferred farmland (letter "H") was a result of fuel wood collection rather than to raise cattle or crops.

All maps created in this study were "ground-truthed" in early 2001. The border areas between the different land cover classes was found to be particularly problematic. Satellite images of dryland areas are not acquired any differently than over tropical areas, however, the scope of human use and change and the representation of this on the images is very different. In tropical areas, clearing of the land is easily detected. Forested areas contrast well against cleared land and therefore are readily identified. In dryland Africa, the scope of change is often between grassland, farmland, and abandoned or fallowed land. These classes are much more difficult to distinguish as their spectral properties are very similar. Simple classification and change analysis becomes difficult. The isodata method employed in the initial classification did not prove successful for the scope of change investigated. The method distinguished the forested from non-forested areas well, but the distinction between other classes (such as farmland and grassland) was weak.

While other computer-aided methods of classification may have proved more useful (such as NDVI indices), for these purposes the on-screen digitizing method was most useful. The spatial properties of the land cover classes make them more readily identified. With knowledge of the spatial manifestation of the cover types, the land cover and subsequent land use classes were delineated. The spectral information was not discarded, however. The spectral data combined with the spatial data helped discern areas that were visually confusing. Thus, in this study, it was the combination of the spectral and spatial data that made the Landsat data useful in understanding change in the South African landscape.

Conclusion

This paper has shown the usefulness of Landsat Thematic Mapper data in creating land use change maps for dryland areas of South Africa. By utilizing both the spectral and spatial data, the land use change analysis was enhanced from one that would have simply presented forest/non-forest to one where agricultural, grassland, residential, and wooded/forested areas are distinquishable. Experience on the "ground" is important for studies in areas such as this due to spectral confusion of land cover in dryland scenes. Understanding the spatial manifestation of land cover and land use will help analysts gain a deeper understanding of change.
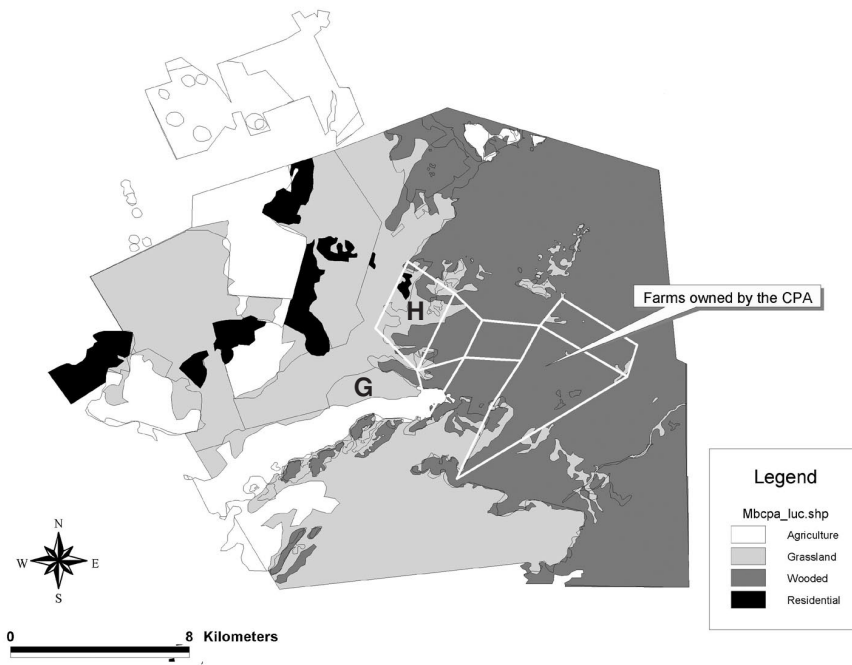

Figure 3: Land Use in 2000 Monyamane CPA and Enviirons

Science Working Group on Data: A Data Distribution Workshop

— Graham Bothwell, Chairman of the EOS Science Working Group on Data, Jet Propulsion Laboratory

The EOS Science Working Group on Data (SWGD) arose from an initiative at the March 2000 meeting of the Science Working Group for the AM Platform (SWAMP) for an on-going evaluation of how well the current EOS data system can support the Terra, Aqua, and Aura missions for which it was designed. Information about the SWGD, including reports of workshops, can be found on the recently created SWGD Web site, at http://swgd.gsfc.nasa.gov.

As reported in the November/December 2000 issue of *The Earth Observer*, the inaugural SWGD workshop was held on June 1-2, 2000, at the Goddard Space Flight Center (GSFC). Although that event concentrated primarily on data processing requirements for NASA's Terra mission, it also concluded that innovative approaches would be needed to meet data distribution needs. It was recommended "that there be a meeting about six months from now to address data distribution status and archive access needs." This meeting took the form of a Data Distribution Workshop, which was held on February 1, 2001, at Fort Lauderdale, Florida, in conjunction with the EOS Investigators Working Group (IWG) meeting.

The workshop was designed to assess the current status of Terra data distribution and identify immediate and fore-seeable obstacles to meeting user data needs, and to identify critical needs and areas for improvement and approaches for new development.

Stakeholder status and feedback

The first part of the workshop was a gathering of status and feedback from all the parties participating in EOS data distribution, including NASA Head-quarters; the EOS Program Office and ESDIS Project at GSFC; the DAAC User Working Groups (UWGs); and DAAC management.

All of the EOS DAACs have User Working Groups (UWGs). Besides facilitating the requirements and issues of the user community, the UWGs have a vital role assisting the DAACs to determine user needs, interface requirements, and priorities. Reports from the UWGs to the workshop indicated that the ordering system works well (within its inherent limitations), that data are easy to select, and that user services support is generally good. There are also numerous issues still being worked or remaining to be worked such as, to list but a few, difficulties in ordering collocated data from multiple sensors; concern about limits to the volume of distributed products; and the lack of similar file naming conventions between instruments.

The immediate data distribution needs at the DAAC-based distribution systems are highly individual. While distribution capabilities at the JPL DAAC are adequate, the larger DAACs at GSFC, NASA Langley, and the EROS Data Center (EDC) have not yet fully achieved their potential due to a range of issues, most of which arise from the newness of the Terra mission. The more critical issues are in the process of being addressed, such as problems with high-volume orders. There are also long-term capacity issues.

Selected issues and recommendations

The second part of the workshop involved discussing the process towards resolving the various issues in data distribution, and making specific recommendations. To facilitate this, the meeting divided into three discussion groups to address selected priority issues.

A. Software tools to facilitate distribution and early use of data

The EOS data products are not always regarded as easy to read and handle, and current tools to assist with this are limited in capability. The range of tool requirements includes data product search-and-order tools; format conversion tools; and data manipulation tools, e.g., reprojection. A three-step process was recommended for providing tools that offer essential basic capabilities, namely: (1) a survey of available tools, including those available from commercial software packages; (2) a commitment by the DAACs to support selected tools; and (3) development of new tools where capabilities do not already exist.

The group concluded that, because the provision and support of software tools will fall ultimately to the DAACs, responsibility for tool definition and advocacy should reside with them, in conjunction with their UWGs, with funding for tool development by the community sought through budget augmentation.

B. User modeling

The primary application of user modeling is in prioritizing and making resource allocations at the DAACs more effective, such as to aid in identifying current and future stress points; to develop mitigation strategies; and to help users and DAACs become more efficient. Without a successful modeling technique, systems can be wrongly sized and funding mistakes can readily occur. There is currently no model used to forecast system evolution. Steps to overcome this include: (1) better use of existing available metrics; (2) development of a suitable range of alternative modeling techniques, including the extensive model developed by and described to the workshop by Bruce Barkstrom; (3) discussion based on presentations to the various UWGs; and (4) development of profiles for different kinds of users.

C. Creative solutions to current and projected distribution obstacles

This topic was designed to suggest techniques for resolving issues in data distribution not addressed by current plans or developments. The different classes of solutions that could be investigated include:

- Contributions from groups other than the DAACs might include value added products; helping to distribute standard products, e.g., partial or full mirror sites.

- Direct broadcasting might be facilitated more, along with software tools to use the data received, and the data recipients encouraged to redistribute their data.

- Greater distribution efficiency may be achieved through new technological mechanisms such as data pools, data mining, coincident data searches, and various other ways.

- Not-for-profit organizations may be able to assist with creative financing.

- Braking mechanisms may be useful, such as sliding scales of data availability depending on the size of data sets ordered.

- Certain products might be developed in a more innovative manner.

- Improved data user tools were discussed above.

- Anticipation of needs through better user models was discussed above.

Along with these ideas were the following suggestions for encouraging creative solutions:

- It was felt that the DAACs should take the lead in better defining existing and future needs of the users, using the UWGs and other mechanisms.

- A full spectrum of organizations and groups needs to be involved in carrying foward the momentum of ideas initiated by the workshop.

- There needs to be a mechanism to ensure a continued supply of data sets from non-traditional suppliers.

- A programmatic mechanism should decide what resources are needed to maintain the data holdings and ensure long-term archiving.

- It is important to allow for innovative solutions, including unconventional ideas.

- The capabilities of the non-NASA community can be engaged when relevant.

In many instances, the realization of creative solutions will be part of the evolution of NewDISS, the system that is planned to handle NASA's Earth Science data processing in the future. It is a concept for a distributed, flexible, responsive system that allows for a spectrum of heterogeneous approaches, utilizing key standard interfaces to facilitate a workable across-the-board infrastructure. NewDISS is still in the formulation stage, but evolution towards it is already emerging.

Conclusion and next steps

The success of the SWGD depends upon a genuine interaction between the instrument and science teams represented by the SWGD and the program and project management, so that issues relating to success of the respective EOS missions are resolved effectively. The prospects for this are promising, based on the senior level of participation in the workshop by representatives from NASA Headquarters and the GSFC Program and Project Offices.

The core of future SWGD activities is embodied especially in the above-reported discussion on creative solutions. The discussions at the current workshop represent only a first step, and are primarily at the level of potential possibilities that will require ongoing elaboration and review to ensure a successful evolution of progress. A future meeting on creative solutions is therefore recommended, possibly in conjunction with the next IWG meeting.

There is also scope to continue the exploration of topics at future workshops. Typical topics include: EOS user models, software tools, and Terra data archiving.

In conclusion, the SWGD seeks to work with the existing organizational, developmental, and operational structures to assist the EOS missions. In doing this, it is necessary to work for a community consensus and to assist in communicating that consensus and its related proposals. It is important that no opportunities be left unutilized or underutilized. This workshop made a good start toward addressing the many issues associated with data distribution.

The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA): new research results start to form building blocks for integration

— *Janice Wiles (janice.wiles@gsfc.nasa.gov), SSAI, Outreach and Education Officer for NASA's LBA Projects in Amazonia, GSFC Ecology and Hydrometeorology Project Office*
— *Michael Keller (michael@kaos.sr.unh.edu), Project Scientist LBA-Ecology, Complex Systems Research Center, University of New Hampshire*

Introduction and Background

The Amazon Basin contains the largest extent of tropical forest on Earth, over 5×10^6 km^2, and accounts for a large proportion of the planet's animal and plant species. However, over the past 25 years, rapid development has led to the deforestation of over 500,000 km^2 in Brazil alone. A small number of field studies carried out over the last 15 years show local changes in the water, energy, carbon and nutrient cycling, and atmospheric composition caused by deforestation and biomass burning. This research has raised concerns about the region and how these changes might affect the global atmosphere and climate.

Almost a decade has passed since the Brazilian scientific community, joined by an international team of scientists which included investigations funded by NASA's Earth Science Enterprise, began to plan a continental scale experiment to understand the impact of this rapid development. This group developed a research strategy that would provide new understanding of how Amazonia currently functions as a regional entity in the Earth system and how changes in land use and climate affect the biological, physical and chemical functioning of the region's ecosystems. The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is one of the largest coordinated scientific endeavors in the humid tropics. The project's implementation began in 1998 and has advanced rapidly since. Today LBA studies comprise over 100 well-coordinated research groups involving about 600 scientists from South and North America, Europe and Japan. LBA studies are organized within seven themes that cut across the realm of Earth System Science: physical climate, atmospheric chemistry, carbon storage and exchange, biogeochemistry, hydrology and surface water chemistry, land use and land cover change, and the human dimension of Amazonian development.

LBA's research strategy is multi-dimensional as the project works to understand the spatial and temporal characteristics and interactions. Study plots and flight paths lie along two ecological transects that cross the basin, each with different climatic and land use intensity gradients (Figure 1). These process-based studies are scaled up using aircraft measurements, remote sensing data and models (Figure 2). Using this strategy, LBA will produce an integrated analysis of the complex biological, chemical, and atmospheric processes that drive the extensive ecosystem of the Amazon Region. Research will range from scales of one-meter plots to the

Figure 1. LBA research sites are found along two major transects which span gradients of land use intensity and annual rainfall variability.

LBA SCALING / INTEGRATION

SeaWIFS AVHRR   GOES   SSM/I   ENVISAT   TRMM
SPOT   LANDSAT   CBERS   Radarsat   JERS-1   VCL
MODIS   ASTER   MISR   SRTM
ALI   HYPERION

Optical Studies
Models

Radar Studies
Radiation Fluxes

Regional Scale
100 -10,000 km²

IKONOS

AVIRIS
AirMISR
MAS
Models

CO₂ and Trace Gas
Flux Measurements
Lidar Profiler

CO_2 and Trace Gas
Flux Measurements
Lidar Profiler

Study Area Scale
10 -100 km²

Fluxes
Towers
Chambers
Models

Optical Studies
Field Spectrometers
Ceptometers
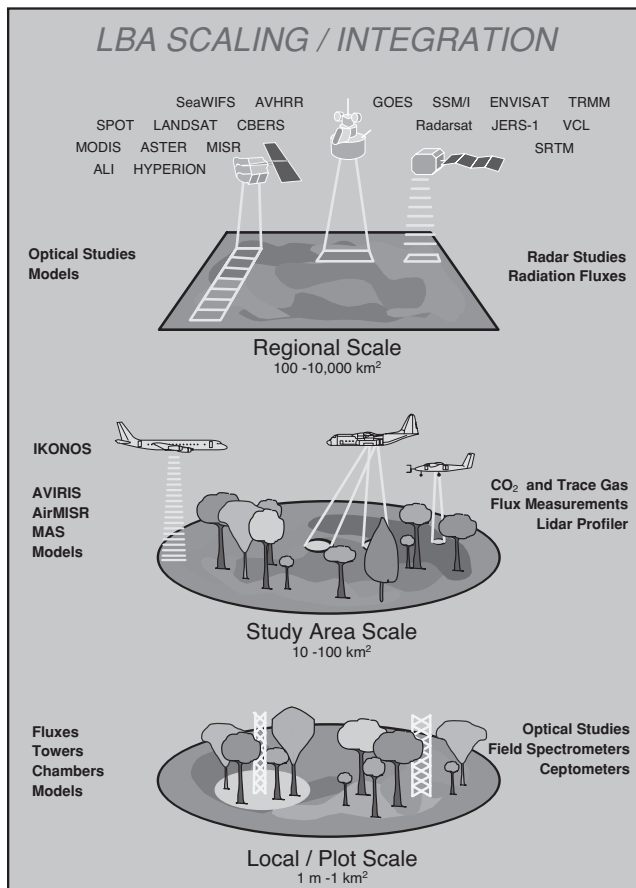
Local / Plot Scale
1 m -1 km²

Figure 2. Research teams collect data on the ground, and from instruments that are mounted upon towers, in air balloons, on aircraft and on orbiting satellites. Scientists use sophisticated computer models to describe current climate conditions, and to predict changes. Such models must account for the Amazon Basin's characteristics and natural cyclic phenomena that change rainfall frequency, intensity and distribution (La Niña and El Niño) and modifications to landscape and atmospheric gas concentrations.

entire Amazon region and will demonstrate how changes in land use modify the quantity and quality of the Earth system's essential components.

From its early planning, LBA has been concerned about capacity building in the region. LBA leaders and collaborators place a strong emphasis on building a cadre of trained scientists in Amazonia able to carry on after LBA has completed its research mission. To date, through the efforts of the LBA Training and Education Committee, the project has supported field and laboratory training for over 200 individuals who are actively making contributions to answer LBA's research questions. In the future, these well-trained scientists and future leaders in the project's several disciplines will certainly prove to be LBA's greatest legacy.

Results

Following are some of the research results to date that contribute to understanding how the Amazon functions and how deforestation, fire, conversion to pasture and agricultural fields, highway and urban construction change the region's natural function, affect sustainable land use, and affect the global climate.

- One of the biggest questions that LBA faces is whether the Amazon region is a net source or sink of carbon, and how the carbon flux changes interannually. Observations by Greg Asner and models by Hangin Tian and their colleagues indicate that vegetation responds to rainfall variation during wet years with both greater productivity and carbon storage. Jeff Richey and others are using AVHRR data from 1980-2000 to understand the variability in precipitation and how it might affect carbon cycling.

- Accurate biomass estimates are key to understanding the impact of loss through burning, cutting or logging on nutrient and carbon cycling through the atmospheric and biospheric systems. LBA is attempting to estimate biomass through field study and remotely sensed imagery. Researchers have found that soil type influences secondary succession rate and, therefore, biomass estimates for secondary forests. Studies on terra firma forests near Manaus (along the northern transect, see Figure 1) show that soil fertility is important for tree and liana biomass. Rainforest fragmentation results in a substantial loss of forest biomass, mainly due to elevated tree mortality.

- Loss of biomass through burning and cutting tropical landscapes is a significant source of greenhouse emissions. Chris Potter and colleagues used a combination of satellite observations of fire occurrence from the IGBP DIS global fire product combined with biomass and productivity estimates from the CASA ecosystem model to evaluate the carbon budget for the Amazon region. They found the region acted as a net source for carbon in a range of .2-1.2 Pg/year between 1992 and 1993.

- The greatest uncertainty in determining carbon flux for 1989-1998 is quantifying biomass lost to deforestation. Biomass, rates of deforestion and rates of decay uncertainties accounted for about 60, 25, and 15%, respectively, of the range of estimates of flux (R. Houghton *et al.*, 2000).

- Root metabolism, decay and soil microbial processes generate gases which are released at the soil surface. The type of gas released and the rates of emission are important in understanding global trace gas budgets. Whendee Silver and colleagues use sequential coring techniques to show that live roots appear to turn over carbon in approximately one year. Susan Trumbore, Plinio Camargo and colleagues

In situ field measurements in the Santarem region: a) measuring wind direction and speed, air temperature and precipitation, b) field laboratory, c) CO_2 flux and profiles, d) solar panels provide energy for continuous field measurements, e) tower flux measurements above the canopy of the Tapajos National Forest.

found that fine root structural material was 6-19 years old. Can these two results be reconciled?

- Eric Davidson and others are looking at land-use change and biogeochemical controls on methane fluxes in soils in the Eastern Amazon. Methane flux into tropical soils accounts for approximately 10-20% of atmospheric methane consumed annually by all soils. Tropical deforestation could be changing this important methane sink. In all land uses, uptake rates of atmospheric CH_4 were greater in the dry season than in the wet season, indicating that soil water content and gas transport are important factors for methane flux.

- The future flora of Amazonia will include significant areas of secondary forest as degraded pastures are abandoned and secondary succes-

sion proceeds. Plinio Camargo and colleagues study recovery of carbon stocks and carbon fluxes within a secondary forest and compare these measurements to those for a primary forest, degraded pasture and productive pasture. Moving along a transect from a 23-year-old degraded pasture to a 7-year-old secondary forest to a 17-year-old secondary forest indicate that the soil organic matter from C3 forest plants was quickly re-established after cutting. The degraded pasture also had significant carbon from carbon and C3 plants. Radiocarbon data showed that most of the carbon in the top 10 cm of soil had been fixed by plants during the past 30 years. Differences in soil carbon among land-use types were relatively small. Root inputs were almost identical to pri-

mary and secondary forests. Litterfall in the secondary forest was 88% that of the rate in the primary forest. But, by contrast, the secondary forest had only 17% of the above-ground biomass when compared to the primary forest. The researchers found belowground carbon in the secondary forest nearly identical with that of the unaltered forest, due to the rapid cycling rates of soil carbon and rapid recovery rates of carbon fluxes to and from the soil.

- Along the southern transect in the Brazilian state of Rondonia where streamside riparian buffers are either cut or thinned, Reinaldo Victoria, Linda Deegan and colleagues found differences in the chemistry of surface waters and an increase in dissolved inorganic and organic nitrogen in rivers.

- Fire is becoming an increasingly important tool for managing pasture and agricultural fields in the Amazon Basin. Studies on the effects of fire show changes in soil chemistry. In Rondonia, acidic soils are formed from basic rocks. Fire used to clear land elevates the pH of sur-

face soils rendering it more basic. At depth, these same soils continue to be acidic indicating that fire alters surface soil pH. Farmers prefer soils that are formed on basic rocks because they tend to be more fertile. Therefore, greater changes of soil chemistry are observed on basic rock compared to acid rock. LBA researchers Getulio Batista and Karen Holmes continue to collect and utilize soil survey data to look at the interaction between soil chemistry and land use.

- Mark Cochrane, Carlos Souza, Daniel Nepstad and Heloisa Miranda have researched the present and future effects of ground fires on forest carbon stocks, metabolism, hydrology, and economics. Many of these fires occur at ground level and are not easily visible from the air or satellite platforms. After each ground fire, it becomes much easier for the forest to be reignited so that after two fires, the probability of the forest burning altogether is very high. The investigators have found significant impoverishment of Amazonian forests by logging and fire. Selective logging opens new forest areas and leads to an increased probability of fire spreading unintentionally into the forest. The project, through the work of Urbano Lopez at IPAM, has developed an Amazon-wide model to predict forest susceptibility to fire. The need for this model became clear during the 1997-98 ENSO event and the model was successful, even in its preliminary form, at predicting areas most at risk of accidental fires.

- Fire changes atmospheric composition and concentration of trace gases.

LBA atmospheric chemists Liane Guild and Lucianna Gatti are modeling and measuring (respectively) the effects of fire, which include large releases of carbon monoxide, nitrogen oxides, and particulates during the dry season. According to one model the dominant emissions come from those intentional fires set to clear the land where forests have been felled. Sun-photometers spread across the Amazon Basin for LBA and the AERONET projects show that there can be up to 25% reduction in photosynthetically active radiation during times of heavy smoke.

- Differences in soil type prove to be a key factor for choosing land use and crop type. Land use and land change studies show that credit rates, inflation and access to markets determine the magnitude of agricultural expansion. Jeff Cardille and colleagues have used a mid-1990s land cover map, agricultural census data from all Amazon region countries and regression tree analysis to produce a map of agricultural land use for the basin.

- Paulo Artaxo and colleagues have explored the relationship between atmospheric aerosols, radiation and clouds during wet and dry season sampling campaigns over the last three years, combining extensive *in situ* measurements with remote sensing techniques. During the wet season Amazonia demonstrates cloud and precipitation features which resemble those over open ocean, and not those over a continental land mass as one would expect; hence, Amazonia has been referred to as the "Green Ocean." The cloud droplets are large, clouds are shallow (2-3 kilometers high) and warm precipitation is frequently observed. Cloud condensation nuclei concentration is very low on the order of 300-500 particles/cc. Burning vegetation during the dry season in the Amazon Basin raises biogenic aerosol concentrations by as much as seventy-fold. Air with a greater density of aerosol particles generally forms clouds much higher (10-15 km), cloud droplets are small and scatter light and reflect it back to space, reducing the light useful for plant photosynthesis by 40%. Lightning is very active. The NASA TRMM satellite shows that skies which are dense with aerosol particles form large clouds that produce only half the expected rainfall. Human-produced emissions have already changed cloud and precipitation properties in Amazonia. Similar changes could be occuring in Africa and Southeast Asia.

- By some estimates, 20% of the basin can be considered alluvial or hydric in nature. Using SMMR and videography John Melack and Evlyn Novo found that during the "wet" season the Central Basin's surface water expands from 20,000 km^2 to cover 60,000-90,000 km^2. Enormous quantities of matter and energy are transported along flow paths that are part of the drainage network of this basin.

- Selective logging is a growing land use in the Amazon Basin. In forests subject to selective logging, approximately 1-6 marketable trees are removed per hectare. Over several years, loggers intensity harvests so that the area affected can be as large as the area clear-cut. This leads to damage in the forest and may lead to long term losses of timber productivity. Identifying logged areas with remote sensors has failed. Greg Asner, Natalino Silva (EMBRAPA-Belem), and colleagues indicated that identification of selective logging extent or intensity is limited when using Landsat ETM+ or SPOT imagery. They showed that selective logging can, at best, be detected 1.5 years after disturbance. In 2002, NASA will support research using the airborne visible infrared imaging spectrometer (AVIRIS) instrument to characterize and differentiate spectral signatures of selectively logged forest, as well as primary and secondary forest.

Summary of NASA's contribution to LBA

NASA supports LBA through its LBA-Ecology and LBA-Hydrometeorology Projects. These efforts concentrate research on the ecological and hydrometeorological processes in Amazonia and how land cover change affects these processes. NASA's Terrestrial Ecology and Land Use/Land Change Programs support the Ecology Project, and Land Surface Hydrology Program (LSHP) sup-

ports the Hydrometeorology Project.

NASA's LBA Ecology Project has 46 individual studies, each with its own research question that will contribute to answering the question: How do tropical forest conversion, regrowth, and selective logging influence carbon storage, nutrient dynamics, trace gas fluxes, and the prospect for sustainable land use in Amazonia? These three-year long studies will continue through 2001. Some will seek renewal through an upcoming NRA for LBA Ecology to be released in 2001. NASA's Airborne Science will contribute to LBA through an airborne remote sensing campaign in 2002, and six individual research projects have been selected to "scale up" information and scientific understanding relevant to the terrestrial ecology and land-cover change objectives of LBA-Ecology. These observations will help to fill key data gaps and reduce major scientific uncertainties in the understanding of regional carbon balance and trace gas fluxes.

NASA's LBA Hydrometeorology Project has 11 individual studies each with its own focus in the areas of physical climate and land surface hydrology. In summary these projects study convection and precipitation at various spatial scales and seasonal-to-interannual differences in land and atmospheric processes and cycles, both within sub-basins and across the region. Models are used to assess and project climatic trends and relationships to land and ocean processes. This research will quantify the regional water budget, contributing to a more accurate understanding of the affect of land cover and other surface changes upon the land-atmosphere hydrological cycle, regional and global climate.

Conclusion

In June 2000, LBA held a Scientific Conference in Belém, Pará, Brazil, where over 350 participants met to present their findings in open meetings and on

283 posters that covered the full range of LBA's scientific themes. While there is still much to understand about how the Amazon region functions, the conference showed progress in many areas including a greater understanding of the relationships among the seven research themes.

Many challenges lie ahead for LBA science. Greater scientific involvement of the research communities of all of the Amazonian countries is needed. Also, to answer the overarching questions, LBA needs to effectively integrate, coordinate and synthesize a wealth of thematic research results and this perhaps presents, in itself, the greatest challenge for Earth System Science.
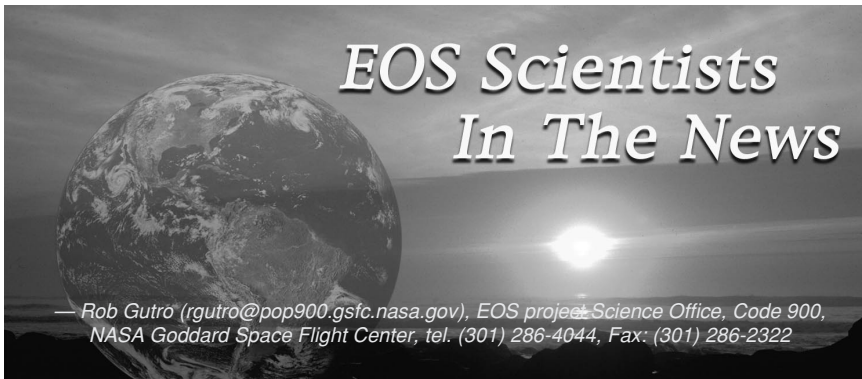
LBA will focus its future efforts on synthesizing site-based process studies to understand the interaction of the Amazon Region with the global system. The research includes building on process studies of trace gases, nutrients and land use changes and incorporating the human dimension into those processes for the entire Amazon Basin. Airborne and space-based measurements over the entire Amazon region will be used to check regional models of carbon and trace gas budgets.

Ultimately, in addition to augmenting our understanding of the importance of Amazonia for the planet, LBA must enhance the scientific understanding needed to guide the sustainable use of the Amazonian forests.

References

References can be found at the following website: lba-ecology.gsfc.nasa.gov/lbaeco/News_Events/publications.htm.

EOS Scientists In The News

— Rob Gutro (rgutro@pop900.gsfc.nasa.gov), EOS project Science Office, Code 900, NASA Goddard Space Flight Center, tel. (301) 286-4044, Fax: (301) 286-2322

"McCain Critical of Global Warming" (May 1) *Associated Press*
Senator John McCain's Commerce Committee held a hearing on the new Intergovernmental Panel of Climate Change report, and heard testimony from **James Hansen** (NASA/GISS) among others.

"Bush Calls In Experts to Help Set Course on Climate," (April 28) *New York Times*
The Bush Administration called on several climate experts, including **James Hansen** (NASA/GISS), for advice in the wake of the decision to abandon the Kyoto Protocol.

"Shrinking African Lake Offers Lessons on Resources," (February 28, March 27, April 26) *USA Today, New York Times*, NationalGeographic.com
Mike Coe and **Jon Foley** (Univ. of Wisconsin-Madison) used satellite data to confirm that Lake Chad, once one of Africa's largest freshwater lakes, has shrunk dramatically over the last 40 years.

"Mongolian Dust Cloud Moves Across America," (April 25) ENN.com, CBSnews.com
Gene Carl Feldman (NASA Goddard) was interviewed about how the Sea-WiFS satellite tracked a cloud of pollution and dust from Mongolia that spread across 25 percent of the United States in late April.

"Deforestation Caused Global Cooling," (April 25) Weather.com
Ken Caldeira (Lawrence Livermore National Lab) and other researchers suggest that forests replaced by fields of grass and crops may have cooled the globe between 1000 and 1900 A.D. because lighter color vegetation reflects more sunlight back into space.

"Less Pollution May Boost Global Warming," (April 20) SeattleTimes.com
Research by **Michael Prather** (Univ. of California-Irvine) indicates that reducing nitrogen oxide without reducing carbon monoxide would lead to a long-term increase in atmospheric methane and boost global warming.

"Wet Stratosphere May Delay Ozone Recovery," (April 18) USAToday.com, Space.com
Drew Shindell (NASA/GISS) says greenhouse gases have increased the amount of water vapor in the stratosphere, which may delay ozone recovery and accelerate climate change.

"Climate Change Inspires Extreme Acts of Science at North Pole," (April 17) *New York Times*
John Michael Wallace (Univ. of Washington) commented on a project where scientists at the North Pole Environmental Observatory are gathering climate data to fine-tune computer models that simulate global climate in hopes of better understanding climate change in the Arctic.

"Two Studies Affirm Greenhouse Gases' Effects," (April 13) *Washington Post*
William Patzert (NASA/JPL) commented on natural variability in oceans, in regard to two climate models' agreement on the connection of rising ocean temperatures and increasing atmospheric carbon dioxide.

"Watching the Sea Grass Grow…From Space," (April 5) *Christian Science Monitor*, ScientificAmerican.com
Gene Carl Feldman (NASA/GSFC) and **Jorge Sarmiento** (Princeton Univ.) discussed SeaWiFS data showing that ocean phytoplankton have increased their carbon uptake over the last three years from 111 billion tons to 117 billion tons.

"Ozone-Eating Clouds Form in Cold Polar Rings," (March 30) Space.com
Azadeh Tabazadeh (NASA/Ames) explained new research that indicates bands of frigid air in the stratosphere are creating [more?] ozone-depleting polar clouds.

"NASA Satellite Finds Massive New Antarctic Iceberg," (March 22) CNN cable, MSNBC cable, *ABC National News*, **Weather Channel**
Robert Bindschadler (NASA/GSFC) reported that NASA's Landsat 7 satellite detected a 15-mile crack in the Antarctic's Pine Island Glacier that will lead to the formation of a new iceberg.

"Ice Probe Explores Glacier's Secrets," (March 19) BBC News online
Frank Carsey (NASA/JPL) noted that the ice probe into the West Antarctic Ice Sheet could be the forerunner of probes designed to look for life anywhere in the solar system.

"Satellite Tracks Plumes of Pollution," (March 19) ScientificAmerican.com
Anne Thompson (NASA/GSFC) used the Total Ozone Mapping Spectrometer to find a key difference in the way smoke and smog move in the atmosphere.

Earth Science Education Program Update

— *Blanche Meeson (bmeeson@see.gsfc.nasa.gov), NASA Goddard Space Flight Center*
— *Theresa Schwerin (theresa_schwerin@strategies.org), IGES*

NASA Earth and Space Science Education Seminar: The Space Place

On April 11, Nancy Leon of NASA's Jet Propulsion Laboratory presented "The Space Place" at an Earth and Space Science Education Seminar at NASA GSFC. The Space Place is an education outreach effort that uses various media to reach students in the classroom, home, and community. Traditionally underrepresented audiences, such as African-Americans, Hispanics, girls, and rural populations are the target groups.

The foundation of The Space Place is its Internet site: spaceplace.jpl.nasa.gov/. Here students, teachers, parents, and other educators are provided with scientific information, applications, and activities. Written for the student, these activities do not require special equipment and, therefore, can be conducted at home or in an informal education setting.

By providing monthly columns to newspapers and specialty magazines, information and activities are passed on to additional students, parents, and classrooms some of which may not have Internet access. These columns provide exciting information and activities and direct the reader to where additional information can be found. Lastly, The Space Place reaches museums, libraries, planetariums, zoos, aquariums, Boys & Girls Clubs of America, and YMCA

chapters across the country. Through a quarterly "Club Space Place" distribution, organizations not traditionally reached by this type of product obtain displays, activity ideas, and supplemental materials.

Because of its design, The Space Place has the potential to include all NASA missions. For more information contact: Nancy Leon, Education and Public Outreach Lead, NASA New Millennium Program, NASA JPL 4800 Oak Grove Drive, Mailstop 301-235, Pasadena, CA 91109. Tel: (818) 354-1067, nleon@jpl.nasa.gov.

NSIP Regional Winners To Be Honored At National Symposium

Over 3,000 students developed and submitted entries to the 2000-2001 NASA Student Involvement Program (NSIP) -- NASA's national competition for students – in five competition areas: My Planet Earth, Watching Earth Change, Design a Mission to Mars, Aeronautics and Space Science Journalism, and Space Flight Opportunities. A list of all winning entries can be found on the NSIP WWW site at http://www.education.nasa.gov/nsip.

The Center winners (regional winners selected at seven NASA Centers) of the high school Watching Earth Change competition were honored at the NSIP National Symposium, May 5-9, at Kennedy Space Center, Florida. Each year,

a Thacher Scholarship is awarded, in cooperation with NSIP, to the Center high school winner of the Watching Earth Change competition who displays the best use of satellite remote sensing in understanding the changing planet. $4,000 is provided to the student for educational expenses.

Other NSIP prizes include a trip to Space Camp for the national middle school winners; a trip to Space Flight Opportunity Week at GSFC Wallops Flight Facility for students whose experiments are selected for flight; school programs by NASA representatives for Center first place winners; medals for all second and third place winners; and a certificate of participation for all on-time, qualified entries.

Science@NASA Receives International Award

On April 3, the Science@NASA family of web sites received a prestigious international honor, the 2000 Pirelli INTERNETional Award, which recognizes excellence in science communications and "the spread of science culture" using the Internet.

Science@NASA is operated by NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, and received more than 330 million "hits" from Internet users in 2000. The sites feature a broad range of science and space news. Science@NASA also received the Webby Award in 1999 for the "Best Science Site on the Internet" from the International Academy of Digital Arts and Sciences. It is the only U.S. government Web site to win both these awards. The full story is at http://science.nasa.gov/headlines/y2001 ast04apr_1.htm?list474867

What is ECHO?

In response to feedback indicating the need for more flexibility in user access to data, ESDIS Project is developing the EOS ClearingHOuse (ECHO). ECHO is based on a new strategy that reflects the realities of diverse sub-community needs. The original and current user interface (EOS Data Gateway - EDG), based on the old strategy, has evolved to adequately support many users. However, the diverse nature of scientists, instrument specialists and the public drives the need for different methods of finding data. We have adopted a new approach of putting EOSDIS metadata into a clearinghouse and providing interfaces for plugging in alternative user interfaces and data services developed outside of ESDIS.

ECHO provides a common, well-defined message level interface to the metadata. With ECHO's focus on supporting various searches of the metadata and brokering the subsequent orders for data, individual communities can tailor a user interface design to their own needs and access methods. This approach enables the community to participate in defining their interface without having to focus on the potentially nasty details of the underlying infrastructure. New systems that are customized to the needs of a community can be developed to use either the native or any of several other protocols to communicate with ECHO's repository of current information. All of this is accomplished by building a flexible clearinghouse and service broker infrastructure based on XML and Java Beans.

The Workshop, August 22-24, 2001 at Goddard

The purpose of this workshop is to provide preliminary training on ECHO and Client APIs so that developers can start prototyping alternative user interfaces. This early activity serves three purposes:

1. We can flesh out system requirements before the system goes fully operational.
2. You and your community (defined by you) can have early access via alternative data access paths to EOSDIS data.
3. This workshop will provide you the opportunity to voice your ideas and input on the capabilities to be exposed through ECHO APIs.

If you are serious about writing your own user interface for EOS data access and would like to attend this workshop, please contact Robin Pfister (robin.pfister@gsfc.nasa.gov) and provide the following information:
Name
Citizenship
Institution Affiliation
Science Team Affiliation (if applicable)
e-mail address
phone number

Space is extremely limited so send your information in early.

EOS Aura Ground System Review

and more detailed instrument input to the IMT.

Wrap-up

Peg Luce, Aura Project Manager, thanked the ground system team, especially the presenters, for a very good and comprehensive review.

The review generated many good questions and detailed technical discussions that clarified or brought up several requirements-related items. The Requests for Actions (RFAs) were reviewed and assigned at the end of each day. The Aura MOM and the ESDIS Systems Manager will track RFA progress and disposition.

Earth Scientist On News

"Satellite Data Proves Greenhouse Effect," (March 14) CNN.com
Drew Shindell (NASA/GISS) commented that a new study based on 27 years of satellite observations should end the debate over greenhouse gas effects.

"Clouds Above the Pacific Could Release Trapped Heat," (March 7) BBC News Online
New research by **Arthur Hou** and **Ming-Dah Chou** (NASA/GSFC) suggests the tropical Pacific Ocean may open a "cirrus cloud heat vent" that may diminish warming caused by greenhouse gases.

"Scientists Report Gains in Protecting Ozone Layer," (March 4) *Newsday*
Charles Kolb (Aerodyne) reported that the level of chlorine has peaked in the upper atmosphere, and that international agreements limiting the amount of ozone-eating gases are effective.

Science Calendar

June 4-6
MISR Science Team Meeting, Pasadena, CA. Contact: David Diner, tel. (818) 354-6319, e-mail: David.j.Diner@jpl.nasa.gov.

June 18-20
OMI International Science Team Meeting, Royal Netherlands Meteorological Institute (KNMI), DeBilt, The Netherlands. Contact: Ernest Hilsenrath, hilsen@ventus.gsfc.nasa.gov

June 19-21
AIRS Science Team Meeting, Pasadena, CA. Contact: George Aumann, e-mail: aumann@jpl.nasa.gov.

July 24-26
Federation of Earth Science Information Partners, University of North Dakota in Grand Forks. Contact: George Seielstad, e-mail: gseielst@aero.und.edu.

July 31
ORNL DAAC User Working Group Meeting, Baltimore, Maryland
Contact: Bob Cook, cookrb@ornl.gov, 865 574 7319

August 2
Aqua Science Working Group Meeting, NASA Goddard Space Flight Center, Greenbelt, MD, Bldg. 33, Rm. H114. Contact: Claire Parkinson, tel. (301) 614-5715; e-mail: claire.parkinson@gsfc.nasa.gov.

September 10-21
HDF/HDF-EOS Workshop, Champaign, IL. Contact George Schwenke, e-mail: george_schwenke@sesda.com, URL: http://hdfeos.gsfc.nasa.gov/hdfeos/call5.html.

September 18-20
CERES Science Team Meeting, Brussels, Belgium. Contact: Jennifer Hubble, NASA Langley, 757-864-8333, e-mail: j.m.hubble@larc.nasa.gov

October 29-November 1
U.S. TRMM Science Team meeting, Fort Collins, CO. Contact: Robert Adler, e-mail: Robert.Adler@gsfc.nasa.gov

Global Change Calendar

April 23-27
ASPRS: The Imaging and Geospatial Information Society, St. Louis. tel. (410) 208-4855; Fax: (410) 641-8341; e-mail: wboge@aol.com; URL: www.asprs.org.

May 7-10
14th Annual Geographic Information Sciences Conferences, Baltimore, MD. Contact Towson University, tel. (410) 830-3887; e-mail: jmorgan@towson.edu; URL: www.towson.edu/cgis/tugis2001.

May 14-18
Environmental Risks & the Global Community, Argonne, IL. Contact Joan Brunsvold, tel. (630) 252-5585; e-mail: jbrunsvold@anl.gov.

May 29-June 2
2001 Spring AGU (American Geophysical Union) Meeting, Boston, Massachusetts. tel. 1 (800) 966-2481 or 1(202) 462-6900; Fax: 1 (202) 328-0566; e-mail: meetinginfo@agu.org; URL: www.agu.org

July 9-13
International Geoscience and Remote Sensing Symposium, Sydney, Australia. tel. 61.2.6257.3299; Fax: 61.2.6257.3256; e-mail: igarss@ausconvervices.com.au; URL: www.IGARSS2001.org/.

July 10-13
Global Change Open Science Conference "Challenges of a Changing Earth," Amsterdam. Contact Will Steffen, e-mail: sec@igbp.kva.se; URL: www.sciconf.igbp. kva.se.

July 10-18
International Association of Meteorology and Atmospheric Sciences 2001 Conference, Innsbruck, Austria. For more informaiton see URL: meteo.uibk.ac.at/IAMAS2001.

Septemper 2-7
International Association of Geodesy Scientific Assembly, Budapest, Hungary. Contact Viktor Richter, e-mail:

richter@sztaki.hu, tel. 361-209-6001; Fax: 361-386-9378; URL: www.sztaki.hu/conferences/iag2001.

October 7-10
2001 International Conference on Image Processing, Thessaloniki, Greece. Call for Papers. Contact Diastasi, tel. +30 31 938 203, Fax: +30 31 909 269, e-mail diastasi@spark.net.gr.

December 10-14
2001 AGU Fall Meeting, San Francisco, CA. For more infomation, tel. 1 (800) 966-2481 or 1(202) 462-6900; Fax: 1 (202) 328-0566; e-mail: meetinginfo@agu.org; URL: www.agu.org.

January 21-23, 2002
Non-CO$_2$ Greenhouse Gases (NCGG-3) scientific understanding, control options and policy aspects, Maastricht, The Netherlands. Contact Dr. Joop van Ham. e-mail: j.vanham@plant.nl; tel. 31-15-285-2558; Fax: 31-15-261-3186; URL: www.et.ic.ac.uk/Dept/LocalNews/greenhouse.htm.

July 9-12, 2002
2002 Joint International Symposium on GeoSpatial Theory, Processing and Applications, Ottawa, Canada. Call for Papers. For details, tel. +1 613 224-9851; Fax: +1 613 224-9577; e-mail: exdircig@netrover.com; URL: www.geomatics2002.org.

The Earth Observer

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