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In this issue

EDITOR'S CORNER

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On October 6 and 7, the U.S. House of Representatives and Senate approved the Appropriations Conference Committee bill that provides funding to the Veterans Administration, Department of Housing and Urban Development, and Independent Agencies (including NASA) for FY99. The NASA budget was approved at $13.67 B, of which the Office of Earth Science was $1.413 B. Of this budget, $672.5 M is for the Earth Observing System (EOS), $268.2 M for EOSDIS, and $321.1 M for science, including both the research and analysis program and the EOS Interdisciplinary Science (IDS) investigations. The conference report includes $53 M of the Earth Science budget for earmarks, of which $41.8 M was provided by Congress. The earmarks include supporting the launch delay in the EOS AM-1 spacecraft resulting from the ground operations software problems; new centers at five universities for natural resource training, computers and remote sensing applications; funds for a regional applications center, and a consortium for the application of space data to education; and support for biodiversity programs at a museum.

An Investigators Working Group (IWG) meeting was held October 19-21 at the New England Conference Center, University of New Hampshire, Durham, New Hampshire. As in the past couple of years, the primary focus of this meeting was on scientific accomplishments obtained thus far by various EOS investigations. Participation was high, and included (i) a poster session on a wide variety of interdisciplinary investigations ranging from snow accumulation in the Greenland ice sheet to optical properties of Saharan dust and new particle formation in the upper troposphere, (ii) early science results and lessons learned in processing and distributing data from the Tropical Rainfall Measuring Mission (TRMM), (iii) anomalous absorption of clouds and regional aspects of global change, (iv) results from recently launched spacecraft and analysis projects, including the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and moderate-resolution scatterometer measurements over land and ice surfaces, and (v) climate change and public policy.

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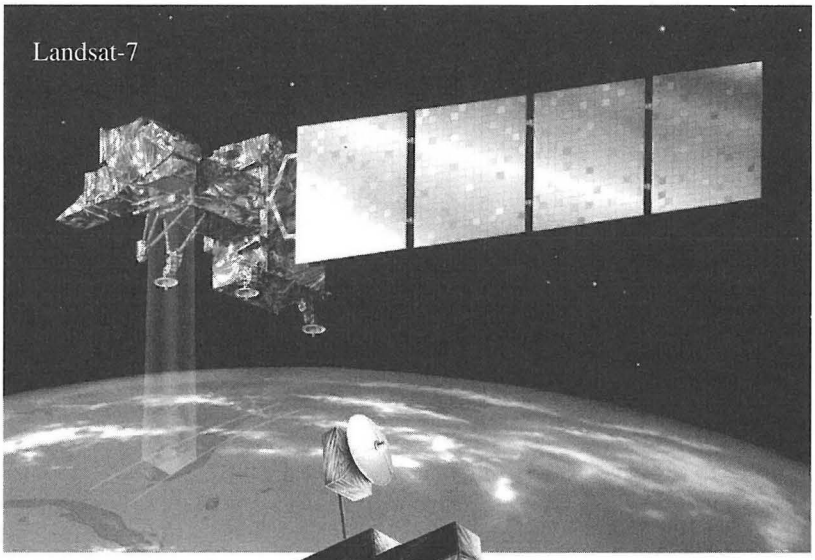
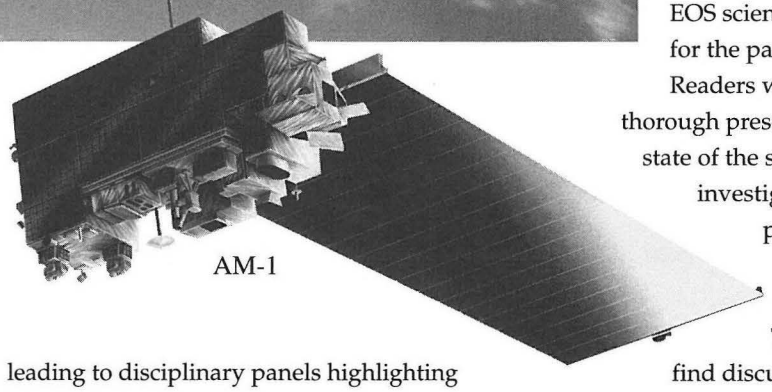




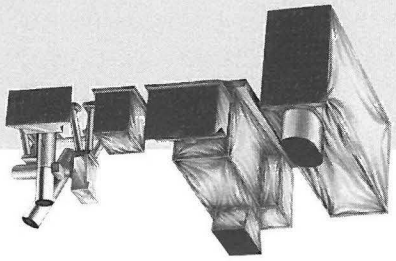
The EOS AM-1 satellite, originally scheduled for launch in June 1998, was delayed primarily because of inadequate flight operations segment (FOS) software required for command and control of the spacecraft. Lockheed Martin Space Mission Systems and Services, Seabrook, Md., developed the problematic software under subcontract to Raytheon Systems Co., the prime contractor for the EOS Data and Information System (EOSDIS). Due to these problems the real time command and control portion of the ground system will be replaced with the Raytheon developed Eclipse satellite control software package. The off-line portion of the control system will be provided by ISI and is based upon the original FOS design. A launch date for EOS AM-1 will be established following sufficient testing and performance of the new Eclipse ground control software later this year.

In May the Earth Science Enterprise began a strategic planning exercise to develop a notional concept for the second round of EOS missions to be initiated for the post-2002 time period. The intent of this exercise was, in part, to re-validate the linkage between overall scientific goals of EOS—expanding knowledge of the Earth system—and the existing EOS measurement strategy, and, secondly to identify emerging new research priorities that either were not possible with technology during the first round of EOS or are scientific priorities that have arisen in recent years. NASA began this process with a "Request for Information" to the scientific community that was later followed by 6 panel reviews of the 100 responses that were received, ultimately leading to disciplinary panels highlighting 23 mission concepts that were recommended for further technical and cost assessment. The final step in this process was a Post-2002 Mission Planning Workshop held in Easton, Md. on August 24-26 in which the nominal mission scenarios and underlying programmatic guidelines were presented to a representative group of RFI respondents and an Interdisciplinary Review Panel of independent scientific experts. This panel, chaired by Prof. Charles Kennel, Director of the Scripps Institution of Oceanography, was asked to evaluate various implementation scenarios that fell into three distinct categories of missions: (i) EOS follow-on missions for systematic measurements of critical parameters, (ii) Earth Probe missions for exploratory research or focussed process studies, and (iii) pre-operational instrument developments to provide new or more capable sensors for operational observing systems. The Interdisciplinary Panel has issued a report to NASA that can be found at ftp://eospso.gsfc.nasa.gov/docs/Kennel_Report.pdf.

In anticipation of the launch next year of the EOS AM-1, Landsat 7, QuikSCAT, and Meteor-3M/SAGE III spacecraft, the Project Science Office has completed the EOS Science Plan, under development by the broad EOS scientific community for the past 4 years. Readers will find a very thorough presentation of the state of the science being investigated by participants in the EOS program. They also will find discussions on how science investigations are conducted both before and after launch of the EOS satellites. This review of the state of the science, along with its extensive documentation of scientific references, should be of value to both working scientists and the graduate students who will take their place in the scientific endeavors of the next century. The plan consists of an overview chapter followed by seven topical science chapters that discuss, in considerable detail, all aspects of EOS science. The plan is published in two parts, an Executive Summary, consisting of summaries of all 8 chapters in the Science Plan, and a separate volume with the full text of each chapter. The plan is available in hard copy as well as on the web at http://eospso.gsfc.nasa.gov/sci_plan/chapters.html. A CD-ROM edition will also be published for use in classrooms, as it provides a very valuable teaching resource for students.

The 15th Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting

— Toru Kawakami (kawakami@ersdac.or.jp), ERSDAC (Earth Remote Sensing Data Analysis Center)



The 15th ASTER Science Team Meeting was held June 23-25, 1998, at the Tokyo International Forum in Yurakucho, Tokyo, Japan. There were approximately 90 participants representing the ASTER Science Team, Jet Propulsion Laboratory (JPL) ASTER Science Project, Goddard Space Flight Center (GSFC), Earth Remote Sensing Data Analysis Center (ERSDAC), Japan Resources Observation Systems Organization (JAROS), the ASTER Ground Data System (GDS) Project, the instrument vendors, and the Japanese algorithm development contractors. The three-day meeting was composed of a plenary session on June 24 and several individual Working Group meetings from June 23 to 25.

Plenary Session
Wednesday Afternoon, June 24

H. Tsu (Geological Survey of Japan [GSJ]), the ASTER Science Team Leader, welcomed the participants and opened the Plenary Session.

Y. Yamaguchi (Nagoya University) reported on recent Science Team activities and status. These included:

- The EOS AM-1 launch is postponed. The new launch date is still TBD.
- ASTER Instrument functionality and performance were confirmed by the Thermal Vacuum Tests at Lockheed Martin Missiles and Space (LMMS) in Valley Forge.

J. Cymerman (LMASD) reported on the EOS AM-1 Spacecraft status. He said that:

- Test performance (thermal vacuum test, functional test, etc.) of the spacecraft will be completed in early September.

- Spacecraft Readiness
  - ◊ Spacecraft will be ready for shipment preparation in mid-September.
  - ◊ Shipment preparation (approximately 3 weeks)
  - ◊ Launch operations (approximately 12 weeks)
  - ◊ Official launch date pending GSFC decisions

M. Kudoh (JAROS) reported on the ASTER and Spacecraft Status. The main topics were as follows.

- The postponement of the EOS AM-1 launch was reported to the SAC (Space Activities Committee; Japan Space Top Policy Management Organization) by Ministry of International Trade and Industry (MITI) on June 3, 1998.

- Recent S/C major activities (thermal vacuum test, thermal balance test, spacecrafts comprehensive test etc.) from February 1 to end of July, 1998

- Effects of launch delay on ASTER
  - ◊ Though JAROS/ASTER sensor committee specified some marginal requirements for launch delay (one year or so) in the ASTER developmental specifications from the beginning, strict storage conditions should be maintained and specified.
  - ◊ For more than a one-year delay, ASTER needs to check detailed items on reliability for each subsystem, especially for the cryocooler systems.
  - ◊ Frequent operations in the clean room are preferable for the ASTER instrument

A. Unger (GSFC) reported on the launch and EOSDIS Core System (ECS) status. He said that:

- Development schedule of Flight Operation Segment and launch date will be decided and announced by GSFC around the middle of July.

- Flight Operations Segment (FOS) completion date and EOS AM-1 launch date are dependent on stabilizing system and exhaustive testing to discover and correct all remaining problems.

- EOS Data and Operations System (EDOS) acceptance testing will be completed in late June.

- ECS Science Information System:
  - ◊ Level-1 Production Rule patch released to DAACs on May 14, as scheduled.

◊ Supported successful Landsat-7 system test (I&T4c.3) at EROS Data Center (EDC).
◊ Completed initial multi-user system stability testing.

H. Watanabe (ERSDAC) presented the current status of ASTER GDS. He reported on the major milestones of U.S.-Japan meetings during FY 1995 and 1997 and talked about the schedule of prelaunch activities. He also presented the status of Level-1A & 1B generation and Data Processing Requests (DPRs) & auto-processing of Level-1B generation by GDS.

A. Maruyama (ERSDAC) also presented a status report on the CMS (Customer Management System).

Activity/Summary Reports

Y. Yamaguchi reviewed the discussions that took place at the April SWAMP and he also summarized the ASTER Operation and Mission Planning Working Group (OMPWG) *ad hoc* meeting that was held April 8-10 at ERSDAC in Tokyo. The OMPWG topics included the status of:

- a joint pre-launch mission preparation plan;
- IST development and schedule;
- scheduler development;
- ASTER Mission Simulator (AMS) development;
- Mission Analysis Tool (MAT) development; and
- xAR development plan.

He also reviewed the SSSG (Science Scheduling Support Group) technical meeting. M. Pniel reported on the action items of the OMPWG *ad hoc* meeting.

T. Kawakami reported on the 11th GDS/EOSDIS I/F meeting that was held June 8-11,1998 at the EDC DAAC in Sioux Falls including the plan for ASTER science operations for ASTER Level-1 processing during the ICO (Initial Check-Out) period Other discussion topics included:

- Japan and U.S. science teams jointly defined the data acquisition requirements for the ICO period, which include approximately 210 target sites.
- Data acquisition between L+1 and L+40 will be based on requests collected by the Instrument Team, JAROS, and (between L+41 and L+105) by the Science Team.
- Comparison between GDS products and Science Products: Science Team is responsible for data validation.

Y. Yamaguchi reported on the Science Team Acquisition Request (STAR) Review Committee meeting held June 23. The summary of this meeting is as follows:

A draft STAR Guideline document, prepared by H. Sekine, was reviewed by the Committee members. This document defines STAR types, proposal guidelines, parameters, and so on.

The Committee decided that, with the exception of two special cases, up to 400,000 km^2 of each STAR proposal may be classified as high priority, and the rest must be low priority. The special cases are the Global Land and Ice Monitoring From Space (GLIMS) Glacial Monitoring STAR and the AST/IDS Volcano Monitoring STAR, which are allowed to have up to 400,000 km^2 classified as high priority and the remainder must be medium priority. Local STARs are limited to only a few specified purposes such as instrument calibration and emergency observations, and will be 1-2 scenes with very high priority. The ICO STARs were finalized with a few minor changes. Concerning the at-launch post-ICO STARs, the STAR proposals and parameters will be reviewed and revised by STAR submitters in order to meet the new guidelines by September 1998. New post-ICO STAR proposals can be submitted any time.
H. Sekine (Mitsubishi Research Institute) presented the STAR collection status. The main topics included:

- Status of Japanese STARs
  ◊ Japanese ICO STAR parameter files were almost all collected from each WG (121 STAR targets)
  ◊ 30 post-ICO STAR proposals with 2504 STARs were accepted by the Japanese STAR Committee
  ◊ All ICO & post-ICO STARs have been sent back to each WG to review the targets and parameters (due date is the end of July).
- Launch slip impact on:
  ◊ STAR Target
  ◊ STAR Parameters
- STAR Collection Schedule (Japan)
  ◊ Collect revised ICO & Post-ICO STAR parameter files from each WG by the end of July 1998
  ◊ Collect revised ICO & Post-ICO STAR proposals by the end of July 1998
  ◊ Evaluate/approve new STAR proposals by September 1998 (TBD)

R. Molloy (JPL) presented the U.S. STAR Collection status.

- All approved ICO STARs were transferred to H. Sekine as of June 18, 1998
  ◊ 166 STARs consistent with summer Northern Hemisphere ICO phase
  ◊ ICO STAR list "tweak" expected as result of STAR Committee analysis

I. Sato (Chair of Higher Level Data Product WG, GSJ) reported on the status of the ASTER User's Guide. Topics were as follows:

- Progress after the last Science Team meeting
  - ◊ Update HTML version documents
  - ◊ Make the updated version available at the ASTER Science Server (ERSDAC)
- Current work and future plans
  - ◊ Prepare to release PDF version
- Schedule
  - ◊ Parts of General and Level-1 data product of this Guide will be prepared by the end of March 1999.

K. Arai (Saga University) and K. Thome (U. of Arizona) reported on the results of the field campaign in Tsukuba, December 1997, and in Nevada, June 1998.

Issues for Discussions:

Y. Yamaguchi asked each working group to discuss the following issues:

- Launch Slip Effect
  - ◊ Each WG is requested to discuss the launch slip effect
  - ◊ Parameter change of the already submitted STARs; due the end of July 1998
- Algorithm Validation Plan in both ICO and after ICO phases
  - ◊ Let us take advantage of the launch slip to consolidate the validation plans
- STAR Collection
  - ◊ STAR guideline is being prepared by OMPWG by September 1998
- Outreach Plan
  - ◊ ASTER AO has been issued from the Japanese side
  - ◊ ASTER websites in the U.S. and Japan have been opened
  - ◊ What do we need to do in addition to these?
- Research Activities
  - ◊ We look forward to obtaining the real ASTER data.

The next ASTER Science Team meeting will be held January 1999, in Pasadena, California.

Summary Report of each Working Group

The *Ecosystems Working Group meeting*, Chairs H. Kayanne (University of Tokyo) and T. Schmugge (USDA Hydrology Lab), was held on Tuesday, June 23, 1998 in Tokyo. The agenda for the meeting was brief with only three presentations.

- H. Kayanne started with a brief presentation on the status of the special product algorithms being developed by the Japanese team: wetland, agricultural land, aridland, coral reefs and forest. At present, most of the test sites are situated in Japan. Japan Ecosystems WG intends to expand monitoring sites by ASTER with many targets in Asia.
- T. Schmugge gave a presentation describing the TIMS data acquired during the summer of 1997 over the Southern Great Plains experiment (SGP-97) site in Oklahoma and the JORNEX experiment site in New Mexico. The TIMS data acquired are of good quality and should be adequate for estimating surface fluxes. The spatial scales of a portion of the data acquired over the SGP-97 site were studied using wavelet techniques with interesting results. A ground based TIR radiometer recently acquired by the Hydrology Lab with ASTER TIR bands was described. An approach for using remotely sensed surface temperatures to estimate surface fluxes was presented. M. Ramsey of Arizona State University described the planned use of ASTER data at the Phoenix urban LTER site.
- These presentations were followed by a discussion of the proposed STAR sites from this working group. It was concluded that more collaboration between H. Kayanne and T. Schmugge was needed.

A *Geology Working Group meeting*, Chairs M. Urai and L. Rowan (USGS), was held on June 23. We discussed Higher Level Products and STAR status. M. Ramsey presented 'Aleutian/Kamchatcan volcanic hazards studies'. M. Jinguuji (NIRE) presented 'Quantitative estimation of erupted volcanic ash by using satellite data'. Y. Yamaguchi and C. Naito (Nagoya University) presented 'Spectral indices for lithologic discrimination using the ASTER SWIR data'. S. Hook (JPL) reported on the MASTER status and B. Raup (USGS) reported on GLIMS progress. We found some redundancies in the Volcano STAR. A new Action Item was assigned to D. Pieri (JPL) and M. Urai (GSJ) to eliminate the redundancies from Volcano STAR.

The *Temperature-Emissivity Separation (TES) Working Group meeting*, Chair S. Rokugawa, was held on June 23. Both Japanese and U.S. TES code status were reported, and the TES code update scenario was then discussed for the initial checkout phase. The results of field campaigns in Tsukuba '97 and in Railroad Valley '98 were also reported by the participants. Finally the current status and future flight plan of MASTER (MODIS and ASTER simulator) were presented.

The *Level-1/Geometric Working Group meeting*, Chairs H. Fujisada (Science University of Tokyo) and G. Geller (JPL), was held on June 24. The topics addressed included:

- Level-1 related operation overview during initial checkout period;
- Level-1 algorithm update;
- Japan's geometric validation plan update;
- U.S. geometric validation plan update; and
- development status of geometric validation tools.

The *OMPWG (Operation and Mission Planning Working Group)*, Chairs Y. Yamaguchi and M. Pniel (JPL), met on June 25. The summary of this meeting is as follows.

T. Kawakami (ERSDAC) showed the ASTER AO status update. AO is open to anyone at http://astweb.ersdac. or.jp/ao/. H. Sekine (Mitsubishi Research Institute) and R. Molloy (JPL) discussed xAR collection status and transfer strategy to ASTER Ground Data System (GDS). Updates of the operation and mission planning tool development were reported: ASTER Instrument Support Terminal (IST) by T. Narita (Japex Geoscience Institute: JGI), the scheduler by T. Ohno (JGI), ASTER Mission Simulator (AMS) by R. Cohen (JPL), and Mission Analysis Tool (MAT) by H. Muraoka (Dowa Engineering). R. Molloy reported the discussion results by the Science Scheduling Support Group (SSSG) on the previous day. The issues include the new schedule of the Operation Procedure Document (OPD) development, software fix for the scheduler, user category format for AMS input, and so on. N. Doi (ERSDAC) presented the SSSG training plan and D. Wenkert (JPL) updated the status of Mission Guidelines for ASTER Operations.

The Atmospheric Correction Working Group meeting, Chairs T. Takashima (EORC) and F. Palluconi (JPL), was held on June 25. The topics were as follows:

- Present status of IR algorithm
  - ◊ The algorithm was delivered in April 1998
- Present status of VIS algorithm (U.S. and Japan)
  - ◊ Junge-based look-up table is completed and is comparable with MISR's (U.S.).
  - ◊ Adjacency effect algorithm (Ver. 1) is almost ready (perhaps end of August 1998) (Japan)
- Field campaign at Tsukuba and Railroad Valley
- Cloud masking
- Polar-cloud masking and contrails on at least 130 validation sites in the world demonstrated by AVHRR (R. Welch, University of Alabama)
- Publication
  - ◊ K. Thome (U. of Arizona), 1998: Atmospheric Correction of ASTER, *IEEE TGARS*, **36**, 1199-1211.

The *Radiometric Calibration Working Group (CAL WG) meeting*, Chair K. Arai (Saga University), was held on June 25. The summary of the meeting is as follows:

One of the major concerns for us is the radiometric calibration coefficient determination method with three types of different sources, onboard calibration lamps and blackbody, vicarious calibration, and cross calibration. K. Arai proposed his algorithm as a current baseline for that. Although we could not reach a conclusion, a careful trend analysis for the aforementioned three different sources during the initial checkout period as well as the prelaunch calibration phase is highly recommended.

The vendors for VNIR and SWIR presented the test results acquired at Valley Forge during the T/V test, in particular, onboard calibration lamps.

There will be an additional test with an external lamp for SWIR.

A careful analysis will be made for calibration output for VNIR.

K. Thome briefly reported the activities at the previous field campaign in Railroad Playa, Nevada in June 1998. We made a successful observation with Landsat, SPOT, SeaWiFS, and NOAA as well as aircraft-based MODIS/ASTER Simulator, MODIS Airborne Simulator (MAS) flights. Also, we discussed the next field campaign plan for the Pasadena area in January 1999 in conjunction with the next ASTER Science Team meeting.

Summary of the Atmospheres Panel Meeting

— *Mark Schoeberl (schom@zephyr.gsfc.nasa.gov), Code 910, NASA Goddard Space Flight Center*

The Atmospheres Panel met October 19, 1998 during the EOS IWG in Durham, NH. The current Panel Chair, Daniel Jacob, was unable to attend the meeting so a previous Panel Chair, Mark Schoeberl, conducted the meeting. The Panel discussed an assortment of issues which are summarized below.

NPOESS—The converged National Polar-orbiting Operational Environmental Satellite System (NPOESS) is scheduled to take over many measurements being made by the AM and PM platforms. However, NPOESS requirements are primarily operational, and it isn't clear that the data will be of high enough quality for the needs of the research community. The Panel expressed frustration that the NPOESS requirements were defined without clear input from the research community at large. As an example, Gary Rottman noted that the solar UV measurements proposed for NPOESS were totally inadequate for any kind of monitoring. One Panel member responded that the UV monitoring requirements emerged as a compromise on the total solar irradiance measurements. This example indicates how some of the NPOESS requirements have come about and may now be inadequate for the research community. The Panel urged that since many NASA researchers would be depending heavily on NPOESS data after EOS AM, PM and CHEM, NASA HQ should have a more proactive input into the NPOESS instrument selection and definition process.

EOS-2—The panel was confused by the EOS-2 process presented by Pierre Morel. It wasn't clear in the presentation where we are in the definition of the EOS-2 process. Even though Morel showed STEP 1 charts, he kept referring to STEP 2. It also wasn't clear what is happening beyond STEP 2 and what kind of community input will be possible.

Validation of EOS instruments—There was some discussion of a stronger coupling between EOS instrument calibration/validation programs and the Research and Analysis Program. For example, the upcoming Sage III Ozone Loss and Validation Experiment combines validation of SAGE III with a major R & A mission—a combination that benefits both. The Panel discussed how the calibration of several instruments could be aligned with science questions. For example, a field mission exploring aerosol properties might combine MODIS, MISR, and TOMS data along with aircraft lidars and aerosol *in situ* measurements. Chuck Kolb raised the issue whether the proper instrumentation for the validation missions was being developed and whether NASA aircraft resources would be sufficient for such validation missions. The Panel agreed that there was a need for clear communication between the EOS validation efforts and the R and A program.

Data Assimilation—The issue of data assimilation was raised by the Panel. The CERES team has noted that the Data Assimilation Office (DAO) GEOS-2 surface temperature and profile moisture data were not as high quality as the European Center for Medium-Range Weather Forecasts (ECMWF) data. They have asked NASA HQ if they could obtain ECMWF data for processing CERES data. The TES team has also noted that ECMWF surface pressure would be better for their algorithm. This has created some questions on whether the DAO development cycle can meet the needs of the EOS investigators. The Panel further noted that ECMWF data would not be adequate for investigations needing stratospheric information so that using ECMWF data could not be a universal solution. The Panel Chairman explained that the DAO had computer processing issues and was also looking at a different GCM model for the core system. The Panel expressed confidence that the DAO probably could meet EOS needs downstream, but the individual investigators also need to use the best meteorological data products available to generate research quality data.

PI Processing—A number of PIs complained that the PI Processing option under EOSDIS is being exercised in a confusing way. In two cases, the Instrument PIs were given 24 hours to estimate how much it would cost for them to set up their own data processing system. (This is a very short amount of time.) When they responded, EOSDIS replied that DIS could do it cheaper. However, when the PIs asked what assumptions were going into the DIS calculation, they couldn't get a clear answer. Thus, they were concerned that DIS hadn't performed the cost calculation the same way that the PIs had and perhaps had left out some crucial steps. The Panel recommends that the DIS and the PIs work together to iterate the computing requirements.

A Review of EOS Quality Assessment (QA) Methodology and EOSDIS Support for QA

— Bob Lutz (rlutz@ltpmail.gsfc.nasa.gov), Raytheon ITSS, Code 423, Goddard Space Flight Center, Greenbelt. Maryland 20771

INTRODUCTION

One of the main objectives of any scientific data processing system is that suspect and bad data be identified and flagged before release to the user community. This is a challenging task within EOS[1] due to the large volume of data produced (one terabyte per day), the near-real-time mode between data production and distribution, and the numerous error sources that may affect data quality. Quality control measures applied to the data before release to the general public are referred to as Quality Assurance or Quality Assessment (QA) within EOS. QA is one of three components of quality control, with Calibration and Validation being the other two processes[2].

The AM–1 spacecraft will be the first comprehensive satellite of the EOS program. The spacecraft supports five instruments: ASTER, CERES, MISR, MODIS, and MOPITT. There is an associated instrument team (IT) for each instrument developing the science algorithms and processing software. MODIS, producing more data than the four other instruments combined, has its instrument team split into three disciplines: atmosphere, ocean, and land. The instrument teams and their programming staff use one or more science computing facilities (SCFs) to develop and test the science algorithm software and to support IT quality control analyses.

EOSDIS[3] has been under development to support the AM–1 spacecraft and future EOS missions. EOSDIS provides the computing and network facilities to support the generation, archiving, and distribution of geophysical data products from the data sensed by the EOS instruments. EOS AM-1 data are archived at four operational DAACs: Goddard Space Flight Center (GSFC)—MODIS; Langley Research Center (LaRC)—CERES, MISR, MOPITT; EROS Data Center (EDC)—MODIS, ASTER; and the National Snow and Ice Data Center (NSIDC)—MODIS. EOSDIS's infrastructure, the EOSDIS Core System (ECS), provides the instrument team scientists the computing architecture needed to quality assess their data (i.e., the Client—the EOSDIS search and order tool).

QA is defined within EOS as the process that identifies and flags data products that obviously and significantly do not conform to the expected accuracies for the particular product type.[3] The QA process is performed primarily at the granule or smaller level, where a granule is defined as the smallest entity of a data set that is tracked and managed by the system. The instrument teams realized that it would be necessary to incorporate automated QA within the Product Generation Executives (PGEs—science software executives) to ensure at least the minimum needed quality control of all the data. Some limited QA would also be performed manually on subsets of the data products by staff at the DAACs and the SCFs. A further complexity in the planning of EOS QA was that EOSDIS and the science algorithms have been developed simultaneously. This necessitated that the resulting QA methodology be sufficiently flexible to respond to changing requirements from both a science and information system perspective.

The various types of archived QA parameters will be useful to several types of users. Instrument teams can use QA parameters for monitoring the "health" of their data products. They may be more concerned with sub-granule (e.g., pixel) level QA data, rather than granule-level QA data. The general science community may utilize QA parameters quite differently from the instrument teams, in that these parameters may be used to screen data for potential usefulness. Here granule level QA parameters are the most important elements, since these attributes are used to search and order data. The organization and storage of QA parameters within EOSDIS must be able to satisfy the requirements of both of these types of users.

In consideration of the above points, a successful EOS QA methodology must be able to integrate: a) the automated flagging of suspect data by the algorithm software, b) the capability of EOSDIS to alert the ITs and the DAACs to suspect data, c) the extraction of suspect data out of the archives for QA purposes and the subsequent storage of QA results within EOSDIS, and d) the organization, archiving, and display of all of these QA results (automated and human) in a user-friendly format for the scientific community.

DEVELOPMENT OF A STRATEGIC EOS QA PLAN

Introduction

Initial scoping of the effort was led by the EOSDIS Project Scientist and then transitioned to the Earth Science Data and Information System (ESDIS) Project's Science Office, under the coordination of a QA Scientist. The development of an EOS QA plan has entailed an interactive and iterative process, involving the ITs, the DAACs, and the developers of ECS. The EOS QA plan has also evolved over the course of several years, as ITs' ideas matured as to how they planned to perform their QA analyses and as the design of EOSDIS passed from a conceptual phase to implementation. An initial strategy was developed, documented, and published for review by the EOS science community[4].

Instrument team and DAAC participation

The ESDIS Science Office requested that the instrument teams develop and submit Draft IT QA Plans to ESDIS several years prior to launch, so that EOSDIS (which was under concurrent development) could support the needs of the ITs. These draft plans contained operational scenarios of the IT QA methodology, including QA data flows and the QA-related functionality of EOSDIS, and description of the content and format of QA parameters stored in the products[5]. Also included in the IT QA plans were descriptions of the expected roles and responsibilities of the DAACs in the QA process. Although science QA is the responsibility of the instrument teams, some monitoring of the data (for example, visual inspection) could take place at the DAACs under agreements between the respective ITs and DAACs. Early specification of the responsibilities of the DAACs and ITs should help in the allocation of appropriate resources required to carry out the QA functions.

EOSDIS design evolution

A fundamental aspect of the EOSDIS design is the incorporation of sufficient flexibility to accommodate new and evolving IT and DAAC QA requirements. EOSDIS provided for generalized support for QA functionality when the specifics were unknown, and provided "hooks" within the system to allow additional functionality to be added at a later date.

EOSDIS was designed to present QA information to the user at several levels, with summary QA information provided at the granule level and more-specific QA information provided at the sub-granule level. This hierarchical format was intended to meet both the needs of instrument team scientists and the user population.

It was also recognized by the ECS developers that they would need to develop enhanced system functionality within EOSDIS to allow the instrument teams to access the data in a highly efficient manner. Special tools would be needed for the instrument teams to incorporate their QA analyses back into the system.

Coordination of the instrument teams, the DAACs, and the developers of EOSDIS

To provide a forum for an exchange of ideas, a series of workshops was held under the auspices of the ESDIS Science Office. A QA Working Group (QAWG) was formed with representatives from each AM-1 instrument team, their associated DAACs, and ECS contractor staff. In addition, SAGE III and the Data Assimilation System (DAS) teams were represented, and interested members from the EOS Interdisciplinary Science Teams were invited to participate. The QAWG generates and works action items and acts as a liaison to the ITs and DAACs on all QA issues. Through these meetings the ITs and DAACs learned of each others' needs through a discussion of their individual QA plans; the strengths and weaknesses of EOSDIS were identified by discussing QA scenarios; and guidance was gathered from the user community in regard to the resulting EOS QA methodology.

DISCUSSION OF EOS QA METHODOLOGY

Introduction—dissemination of information

The ITs were provided a "generic" QA Plan[6] by the ESDIS Science Office to provide guidance and some commonalty as to what elements should be covered in their respective plans. Draft QA Plans[7-15] were submitted to the ESDIS Science Office and, in turn, were distributed among the members of the QAWG. This included QA plans from each AM-1 instrument and SAGE III. Many of these draft plans are now outdated and reflect only the team's QA methodology at the time of submission. Final QA Plans are due several months before the AM-1 launch. In addition, Kahn[16,17] presented the early QA thoughts of the MISR team to the general science community via two articles in *The Earth Observer*. Three QA Workshops were also held in conjunction with this effort: November, 1996, July, 1997, and January, 1998.

The resulting EOS QA methodology that evolved from the QAWG peer review of the Draft QA Plans and from sessions at the workshops is presented through discussions of: a) Archived QA (how QA results are stored), b) Operational QA (how QA is done), and c) User QA (how QA results will be used). The final part of this section discusses the special requirements that were specified for EOSDIS by the QAWG, to support IT and DAAC QA needs.

Archived QA

QA parameters are archived within EOSDIS at several levels:

- Granule level QA data (the smallest data entity that may be tracked in EOSDIS).
- Sub-granule level QA data (within the granule).
- External QA granules (linked with the data product granule).

These three types of QA parameters are described below.

Granule level

At the granule level, QA parameters are stored in the metadata (Table 1). QA metadata consist of core (all products) and non-core (product specific) metadata[18].

A) Core QA Metadata—Core metadata, being common to all EOS products, allow the user to utilize global search criteria for browsing and searching the EOSDIS database. There are two components of QA core metadata: QACollectionStats and QAStats.

1) QACollectionStats—A set of three general QA flags is used to indicate the overall quality assessment level of the granule. Text comment fields are available to supplement these flags.

a) AutomaticQualityFlag —This flag is set by the algorithm processing software within the PGE. The valid values are Passed, Failed, and Suspect. Criteria for setting this flag (e.g., What constitutes "Passed"?) are determined by the ITs. There is no default valid for this flag and it must be set in the PGE.

b) OperationalQualityFlag—This flag may be set by DAAC personnel and indicates the results of non-science QA (i.e., data are not corrupted in the transfer, archiving and retrieval process). The valid values are Passed, Failed, Suspect, Being Investigated, Not Investigated, Inferred Passed, and Inferred Failed. Not Investigated is the default value assigned by the system, if non-science QA is not performed.

c) ScienceQualityFlag—This flag is set by the IT scientists or their designees (e.g., personnel at the DAAC) indicating the results of science QA. The valid values are the same as the OperationalQualityFlag, with the addition of "Validated"—the granule has been validated by an expert (e.g., the granule has been compared to *in situ* data). The default value is Not Investigated.

2) QAStats—A set of generic numerically based flags is associated with each granule. These flags are:

—QAPercentMissingData
—QAPercentOutofBoundsData
—QAPercentInterpolatedData
—QAPercentCloudCover

These parameters are generated within the PGEs, with values that range from 0 to 100 or a default null value. Again, criteria are determined by the instrument team scientists writing the algorithm software. Some teams are opting not to populate all of these parameters where they believe the parameters are not meaningful for their specific products (e.g., the MISR team does not populate the QAPercentOutofBoundsData or QAPercentCloudCover parameters). In addition, some of these flags may not be informative for all levels of data (e.g., all Level 3 data are interpolated data).

B) Non-core QA Metadata—To indicate individual product QA information, specific granule-level QA parameters are established by the ITs. These parameters are assigned values within the PGEs and are known as QA product specific attributes (QA PSAs). Being part of the non-core metadata, these parameters may also be utilized, in addition to the core metadata, by the user for data

Table 1: Granule level QA metadata

Granule Level Metadata	
Core (common to all products)	QACollectionStats — AutomaticQualityFlag — OperationalQualityFlag — ScienceQualityFlag QAStats — QAPercentMissingData — QAPercentOutofBoundsData — QAPercentInterpolatedData — QAPercentCloudCover
Non-core (Product specific attributes [PSAs])	QA PSAs — defined by ITs

searches within EOSDIS. Many of the QA PSAs defined for the granule may be summary statistics of the sub-granule (e.g., pixel level) QA parameters. For example, for the MODIS Atmospheric Aerosol product, two of the defined QA PSAs are "percent success rate of retrieval—land" and "percent success rate of retrieval—ocean."

Sub-granule metadata

Data products may also contain QA parameters within the product itself rather than in the metadata. Generally, but not necessarily, these are at the same resolution as the data product. For example, several teams (e.g., ASTER) are including QA data planes within all their products that contain QA information for each pixel. This approach allows the user to visualize per pixel QA information in a common format for the entire team's data products. It provides a consistent format for interpretation by casual and sophisticated users and is useful for data screening at the pixel level.

External QA products

External QA products may be generated as the data products are produced and contain QA information at the granule level primarily used by the ITs at the SCFs. These include QA log files (MODIS Land), exception logs (MOPITT), or QA reports (CERES). These QA products are, in essence, QA granules, which are searchable and orderable within the EOSDIS system. The QA granules may correspond one-to-one with the data granule (MODIS Land, MISR) or may be a QA summary file of many granules (MOPITT). They may be permanently stored or temporarily created for the instrument team's needs. For example, MOPITT is creating QA summary logs for their QA analyses. These files have a short archival lifetime, on the order of days. To support analysis of these QA granules at the SCFs, several teams (e.g., MISR, MODIS Land) are developing external databases from EOSDIS. Within these databases, they copy, store, and analyze these external QA products.

Operational QA

This section presents a description of the three general components of Operational QA.

Components of operational QA

Though the specifics may vary for each IT's QA scenario, there are three general operational components of EOS QA:

- By the algorithm software, the PGEs (PGE analysis).
- By personnel or software at the DAAC facility (DAAC analysis).
- By IT scientists or their designees at the Science Computing Facility (SCF analysis).

A) **PGE QA Analysis**—Within this component, the data products are produced (generally at a DAAC) from science algorithms supplied by the instrument science teams. Numerous QA parameters (operational and product-related) are generated by these algorithms. These generated QA parameters may be at the granule or sub-granule level, and possibly summarized or subsetted. These QA parameters are then sorted and subdivided among the product metadata, the data product, and any external QA products. From criteria specified by the instrument teams, the core metadata field—the AutomaticQualityFlag (flag and text)—is set within the PGEs. In addition, some teams (e.g., ASTER) are making extensive use of alerts or alarms in their processing software to warn them of anomalous conditions that occur during production. These alerts may be: a) automatically sent to DAAC operations staff, who forward these messages to the instrument team, or b) sent to processing logs, which later can be downloaded from the system and be analyzed.

B) **DAAC QA Analysis**—The DAACs are responsible for monitoring non-science QA aspects of data production. They are to check the integrity of the data at the file level, to ensure that the data are not corrupted in the transfer, archiving, or retrieval processes. This analysis may include checking that the file can be opened and that the file size is correct. In addition, some DAACs may perform limited science QA functions, in agreement with their ITs. This may involve monitoring summary QA statistics and alerts generated from the PGE QA analysis or visually displaying data to detect gross problems. The results from non-science QA analyses performed at the DAAC are summarized in the core metadata OperationalQualityFlag, and text field by DAAC staff.

C) **SCF QA Analysis**—The ITs ultimately are responsible for the science QA of their data products. Each instrument team has developed a different strategy and set of procedures to accomplish this objective. There are two general types of QA analyses performed by instrument team scientists: 1) those of an investigative nature and principally analyzing suspect data, and 2) those of a routine nature involving regular screening of the data product. Many teams are estimating that they can routinely examine 10% of the daily averaged data production. It is

expected that, during the first year, a greater emphasis will be placed on analyzing suspect data. Maturity in the understanding of the behavior of the instruments and revised science algorithms, should see a gradual change from investigative QA to routine QA screening in later years. A subset, or the entire data product stream for instruments with low data rates, may be examined by scientists at the SCF. For most AM-1 instrument teams it is impractical to transfer the full set of data products from the DAAC to the SCF because of prohibitively large network requirements. Therefore, over a given time period, most teams intend to order only statistical samples and samples of those data with quality problems indicated by their QA metadata. Some teams will receive all the external QA products associated with their products and infer from these which products should be ordered for QA purposes.

The results of science QA analyses performed at the SCF are summarized in the core metadata ScienceQualityFlag and text field by the instrument team scientists.

User support for QA

The science community is provided with some tools within EOSDIS to enable them to access the generated QA parameters efficiently. Although two of the topics (the EOSDIS Client and Subscription) presented in this section were not developed specifically for QA purposes, these may be used to exploit QA information associated with the data products. The User Comment Document and DAAC User Services Groups are also discussed here. These latter features may aid the user in interpreting and describing (for other users and the ITs) information related to the quality of the data.

EOSDIS Client

The EOSDIS Client is the tool that the science community will use to search, browse, and order AM–1 data. Users are able to search on granule-level core and product specific attributes to define the granules that they wish to order. For example, a search initiated with "ScienceQualityFlag = Passed" in the search criteria field will return only granules that have passed IT QA analyses.

Within the Client, the user will be able to display all QA-related metadata (core and product specific) for the product. This allows a user to see the product QA parameters as a group, helping the user decide which data to order.

EOS policy states that all AM–1 data, regardless of the quality, be visible, searchable, and orderable from EOSDIS. Based on a QAWG recommendation, the Client manually requires users to acknowledge that they are ordering poor quality data (e.g., when any of the Automatic, Operational, or Science Quality flags is set to "Failed"). This occurs even though the user may or may not have searched on these attributes.

Subscription

The Subscription functionality within EOSDIS allows the user community to place standing orders on future EOS data. Users specify to have the data either automatically sent to their facility ("pushed"), or to be sent a notification that the data are ready to be extracted or "pulled" from the system. Again, users can specify QA core and product specific attributes as qualifiers within their subscriptions, enabling them optionally to filter poor-quality data. It should be noted that in the case of poor-quality data being automatically pushed to the user, EOSDIS does not warn the data receiver, as is done within the Client. In this push scenario, as well as an order using the Client, the user will be provided all related QA core and product-specific metadata with the data product.

User Comment Document

To enable users to communicate their quality concerns back into EOSDIS, a User Comment Document is associated with each data product. The User Comment Document is for users to provide scientific comments about specific granules or the entire data set. Comments will be reviewed by DAAC staff for appropriateness and may be forwarded to the instrument teams for investigative action.

User Services

In addition, users may communicate directly with the DAAC User Services Groups, established at every DAAC, with quality-related questions. Staff employed in these positions will investigate the nature of these user concerns. If necessary, they will consult with instrument team personnel for guidance and resolution of the question.

Specific requirements of operational QA

Within discussions of the QA scenarios at the workshops, several new requirements were specified for EOSDIS to support the needs of operational QA. EOSDIS had been designed to be flexible in adapting to evolving requirements.

A) The ITs and the DAACs were anticipating performing a large number of updates to the Operational and Science Quality Flags. An ECS-supplied tool was required to perform these "batch" updates. At a QAWG meeting, the ITs and the DAACs proposed a conceptual design for the tool, which was then developed by the ECS contractor into a prototype—

the QA Metadata Update Tool (QA MUT)[19]. The QA MUT works with the EOSDIS Client to provide an efficient and user-friendly process to update the QA metadata. A demostration was provided to the QAWG in a subsequent meeting, which led to further enhancements concerning security, access, and control privileges. The QA MUT is scheduled to be available for use by the ITs and the DAACs shortly after launch.

B) The ITs needed to have their processing logs become searchable and orderable entities within EOSDIS. This functionality would facilitate their QA analyses and support related error analyses of crashed or unsuccessful production runs. This requirement was satisfied, in that these logs are now orderable and searchable system-type granules.

C) Initially, the at-launch functionality of Subscription did not include the ability to subscribe against non-core metadata. Instrument team QA representatives strongly urged that this additional functionality be ready by launch, to support their intended QA scenarios (i.e., subscribing only on core metadata QA would be too restrictive). ECS developers have taken this into consideration and gave this functionality higher priority. At-launch Subscription now includes this feature to support instrument team QA analyses.

D) To reflect evolving instrument team QA scenarios and processes, the number of valid values for the Operational and Science Quality flags was increased to include Inferred Passed and Inferred Failed.

E) Another EOSDIS requirement surfaced within the January 1998 QAWG meeting. The GSFC DAAC has decided to automate a large portion of non-science QA that would have previously been undertaken manually. This entails running GSFC DAAC-supplied software immediately after the data product is created and before the product is archived. This additional software would be encapsulated with, though not part of, the PGE. This feature resulted in the need to have the OperationalQAFlag (which previously had been designed to be updated only by the QA MUT after archiving) updatable within the PGE environment. This requirement was successfully implemented by the ECS contractor to support automated at-launch DAAC QA analyses.

CONCLUSIONS AND FUTURE QA ENHANCEMENTS WITHIN EOSDIS

Currently, EOS policy states that all data products are to be made available to the general science community. As a consequence, the importance of mechanisms to ensure the quality of the products prior to their distribution has been recognized, and an end-to-end QA approach has been developed. This paper has described the different elements of the EOS QA approach from data production through archiving that have been adopted by the AM–1 science teams and the data producers at the DAACs.

The design of EOSDIS has proven to be adaptive to the new QA requirements described in this paper. Future enhancements to EOSDIS may include granule-level data visibility and access controls that will allow developers (science teams) and producers (DAACs) to temporarily hold specific data sets that require more detailed QA analysis. Another requirement recently advocated is the need for an automated method to update the QA metadata outside of the production software. This requirement was born out of the realization that QA procedures may be automated through post-launch experience and characterization of the spaceborne instruments and of the science software used to produce the products.

QA is an evolving element within EOS. Communication is continuing among all entities (the instrument teams, the DAACs, and the developers of EOSDIS) in order to ensure that the quality of the large volume of EOS products is defined and documented. The user community will be involved in this process after launch by providing feedback from their experiences in trying to use the data. It is expected that user feedback will be important for the instrument teams to identify problems with their products and to fine tune their QA methodologies.

Many of the standard EOS products are new and without heritage, and may contain questionable data in the early post-launch period. Users of EOS data must now be made aware of the QA information associated with the products to encourage their proper utility. This information will be made available in a timely manner prior to launch within EOSDIS.

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EOS Scientists in the News

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† "North America Soaking Up Carbon from Atmosphere," Associated Press (Oct. 16). **Pieter Tans** (NOAA) and colleagues published a paper in *Science* (Oct. 16) arguing that North America is acting as a massive carbon sink. **David Schimel** (NCAR) disagrees with the research and voices concern that the results may be misinterpreted.

† "Thin Ice," *Boston Globe* (Sept. 28) by David Chandler. **Robert Bindschadler** (NASA GSFC) and **Charles Bentley** (U. Wisconsin) discuss West Antarctic Ice Sheet stability and possible sea-level rise as a result of melting at an American Geophysical Union Chapman Conference. **Richard Alley** (Penn State) discusses rapid climate changes seen in ice-core records. Bentley and Alley were also featured in National Public Radio's "Morning Edition" (Sept. 17) broadcast on the Chapman Conference by Richard Harris.

† "NASA Learns That Faster and Cheaper Isn't Always So," *New York Times* (Sept. 14) by Warren E. Leary. This article discusses NASA's shift to less-expensive programs and the unsuccessful Lewis and Clark missions. **Ghassem Asrar** (NASA) comments on lessons learned from the two failed missions.

† "NASA Charts Earth Observation Strategy," *Nature* (Sept. 10). A news article by Tony Reichhardt covers a recent meeting where researchers discussed the next generation of EOS spacecraft and their proposed payloads. **Mark Abbott** (Oregon State) comments on progress made by the group toward focusing on science questions.

EOS researchers please send notices of recent media coverage in which you have been involved to:
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SeaWiFS Completes A Year Of Remarkable Earth Observations

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Excerpts from RELEASE: 98-170

For the first time in history, NASA is releasing dramatic images documenting the Earth's changing biology, both on land and in the oceans, as observed from space for one continuous year.

The changing seasons of life, the "pulse of the planet," are being monitored by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), which was launched on August 1, 1997, and has continuously produced data since September 18, 1997. The SeaWiFS mission is the first NASA Earth Science data purchase in which industry led the development of the full mission.

"Although originally designed to observe the oceans, SeaWiFS provides a unique capability to study the land and atmospheric processes as well," said Dr. Gene Feldman, oceanographer, who heads SeaWiFS' data processing team at NASA's Goddard Space Flight Center, Greenbelt, MD. "As a result, we can monitor changes in the global biosphere with a single sensor over land and ocean."

Among the highlights of SeaWiFS' first continuous year of observation were new insights into the impact of the El Niño climate anomaly on ocean life. Further, SeaWiFS was able to monitor a variety of natural disasters, including fires in Florida, Mexico, Canada, Indonesia, and Russia; floods in China; dust storms in the Sahara and Gobi Deserts; and the progress of hurricanes, such as Bonnie and Danielle.

SeaWiFS enabled scientists to witness the ocean transition from El Niño to La Niña conditions in the Equatorial Pacific, specifically around the Galapagos Island. The instrument also allowed researchers to observe the striking speed with which the ocean returned to its pre-El Niño state. While El Niño essentially shut down the highly productive Equatorial Pacific ecosystem, the subsequent La Niña resulted in unprecedented phytoplankton blooms, which stretched across the entire basin from the South American coast to the Western Pacific warm pool.

Phytoplankton are microscopic marine plants that remove carbon dioxide from the atmosphere for internal use. Scientists are eager to understand this exchange of carbon dioxide and the role it plays in the global climate.

"One of the most fascinating events witnessed in the global ocean was the spring bloom in the North Atlantic," said Dr. Charles McClain, SeaWiFS project scientist. "While many regions of the ocean experience a spring bloom, the event in the North Atlantic was the most dramatic."

During the winter, storms and surface cooling mix the surface waters of the Atlantic, replenishing the nutrient supply from the deep, cold, nutrient-rich waters. Once sunlight is sufficient to support plant growth, phytoplankton populations explode and persist for nearly three months until nutrients are depleted. This bloom migrates northward following the Sun throughout the spring and summer.

Unexpected phenomena observed by SeaWiFS, according to McClain, were the massive blooms of coccolithophores, a unique type of phytoplankton in the Bering Sea. These blooms may have a significant impact on fish populations in this area, one of the most productive fishery regions in the global ocean.

During the summer-fall of 1997 and spring of 1998, expansive blooms of coccolithophores occurred along the Alaskan shelf. These were the first observations of blooms of this magnitude in the Bering Sea. Coccolithophores shed vast numbers of white carbonate platelets which cloud the water. "The net result was fish that normally spawn in the adjacent rivers could not traverse the bloom in order to enter the rivers to spawn. In addition, local bird and marine mammal populations had high mortality rates due to starvation because the fish migrated to other waters," said McClain.

NASA is leading an international collaboration using SeaWiFS data. More than 800 scientists representing 35 countries already have registered to use the data. There are over 50 ground stations throughout the world which receive data from the OrbView-2 spacecraft. In addition, the unique government-industry partnership with ORBIMAGE, Dulles VA, represents a new way of doing business for NASA. Images from this mission are available at http://seawifs.gsfc.nasa.gov/SEAWIFS.html.

AGU Chapman Conference: West Antarctic Ice Sheet

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For the past decade, scientists have scrambled over the vast, remote West Antarctic Ice Sheet hoping to discover if or when the giant ice mass will slide into the ocean and send sea level swiftly upward, submerging coastal communities. Rapid changes in sea level have happened in the past, according to Robert A. Bindschadler, a glaciologist at NASA's Goddard Space Flight Center. But the important question for scientists is what is going to happen in the future.

The world's leading experts on the West Antarctic Ice Sheet met for the first time to discuss the latest findings on the stability of the Earth's most precariously perched ice sheet. On September 13-18, 1998, at the University of Maine, Orono, scientists reported on all aspects of the ice sheet, from deep ice cores offering clues of past climates to satellite views of flowing ice streams. The Chapman Conference on the West Antarctic Ice Sheet was sponsored and organized by the American Geophysical Union and co-sponsored by the International Glaciological Society.

"For the last 4,000 to 5,000 years there haven't been any major jumps in sea level. Now about half the world's population lives near the coast. We've set ourselves up to be vulnerable," said conference organizer Bindschadler. Sea level is currently increasing very slowly—just a few millimeters each year—but if the ice streams moving toward the sea start speeding up, sea level could rise several inches a year. According to Bindschadler, the entire West Antarctic Ice Sheet has enough mass to raise sea level more than 15 feet.

The West Antarctic Ice Sheet lies mainly in the South Pacific Ocean and contains over 3 million cubic kilometers of ice covering about ten percent of the total Antarctic area. It is the globe's only ice sheet that could possibly collapse and slide into the ocean, said Bindschadler, because it sits atop slippery marine sediments below sea level.

Charles R. Bentley, a glaciologist from the University of Wisconsin, said it is important to keep in mind how long such a collapse may take. If the collapse takes place over 5,000 years, the change in sea level would only be about 1 millimeter per year, about half as fast as the current rise. "That sort of thing could hardly be considered a disaster," he said. However, Bentley added, if it takes only 100 years, sea levels could rise 50 millimeters (2 inches) per year.

To understand the behavior of the West Antarctic Ice Sheet, scientists must understand how the ice moves. Ice streams—currents of fast flowing ice—are the ice sheet's superhighways, swiftly transporting ice from land into the sea. Ice streams are different from glaciers in that they are bordered by ice instead of rock. The ice streams flow 10-to-100 times faster than the ice surrounding them, with speeds between 500 and 1000 meters (1500-3000 feet) per year. Ice streams average about 80 kilometers (50 miles) across and 100 kilometers (62 miles) long. Each stream dumps 15-30 cubic kilometers (3.5-7 cubic miles) of ice into the ocean each year.

Measuring the flow of these vast ice streams from the ground can be treacherous, so many researchers rely on satellite observations. Bindschadler compared satellite images of ice streams taken over the last 35 years, which included recently declassified U. S. intelligence data. He found that ice streams once thought to flow at a constant rate are actually slowing down, making the question of whether the West Antarctic Ice Sheet as a whole is wasting away much more complicated. Ted A. Scambos, a University of Colorado glaciologist, and Mark A. Fahnestock of the University of Maryland found the same slow-down in more recent satellite images. "We wanted these things to be like normal glaciers," said Scambos who added that the movement of mountain glaciers is fairly easy to understand. "It's becoming clear that's not the case. What you have is a system of ice streams and runaway glaciers that switch on and off and change position and mass flux." So, if the rivers of ice are speeding up and slowing down and in some cases even stopping, how much ice is lost to the sea becomes difficult to determine.

Bentley and Mark D. Stenoien, also from the University of Wisconsin, used radar data from the European Space Agency ERS-1 and ERS-2 satellites to study the Pine Island Glacier, a vast river of ice that flows from the West Antarctic Ice Sheet directly into the sea. They found that the glacier is actually fed by many different tributaries. This also challenges current views of ice streams, which assume that

streams have a single starting point where the ice starts to speed up.

Eric R. Rignot, a glaciologist at NASA's Jet Propulsion Laboratory, used satellite radar data to study the Pine Island Glacier and several ice streams flowing onto the Ronne Ice Shelf, a massive slab of floating ice attached to the West Antarctic Ice Sheet. Satellites can help determine where glaciers and ice streams leave land and hit the ocean because the floating ice bobs on the tides, straining the ice where it is attached to land. Rignot found that the ice streams flowing onto the Ronne Ice Shelf were not retreating and are very stable. "There is as much ice in as there is ice out," he said. But the point where the Pine Island Glacier hits the ocean is retreating very quickly, moving back over three miles in just a few years. Rignot, who recently published his findings in *Science*, said that Pine Island Glacier's swift retreat is like a fire alarm. "It provides some very strong incentive to study this area. If that's where the action takes place, we better not miss it," he said. Digging deep into the ice sheet is another way scientists study the icy continent. Richard B. Alley, a glaciologist from Pennsylvania State University, reads the West Antarctic Ice Sheet's history in tiny air bubbles trapped in ice cores. "The climate is capable of making changes in much less than a generation," he said. "The interesting thing is why do these big changes happen?" Alley will present a new hypothesis on these frantic climate changes at the conference.

Laurence Gray from the Canada Centre for Remote Sensing is looking at ice-sheet features in remote regions using new data from Radarsat, a Canadian satellite launched by NASA in 1995. Data from Radarsat is being used to create the first

(Continued on Page 18)

Earth Science Public Education on the Radio

— Cindy Howell (chowell@pop100.gsfc.gov), Earth Science Enterprise, Public Affairs, Goddard Space Flight Center, Greenbelt, MD 20771

The Earth & Sky (E&S) radio series and the NASA Earth Science Enterprise forged a strategic partnership in the summer of 1998 in order to create a fellowship for radio broadcast. Radio fellow Beverly Wachtel was sent by Earth & Sky to NASA's Goddard Space Flight Center in Greenbelt, MD to produce a series of radio shows on current research in the Earth sciences.

The series of twenty, 90-second radio pieces will air on approximately 700 radio stations in the U.S. — and more throughout the world — in late 1998 and early 1999. Covering topics ranging from algae to volcanoes, these shows stress the study of Earth as an interconnected system as well as new approaches to studying changes in global climate.

The first batch of 90-second radio features on NASA Earth Sciences will air this fall. The programs are produced by the Earth & Sky (E&S) radio series for a measured audience of 3.8 million listeners weekly. In the Washington area, the programs can be heard on WETA at 8:15 am weekdays, 90.9 on the FM dial. Other stations carrying the program are listed on the E&S web site. For more information and advertised links to NASA sites as the programs are aired, please look to the E&S web site: http://www.earthsky.com

Earth & Sky NASA Fall Play List

1998

October 1	Sea Ice (featuring Claire Parkinson)
October 29	Satellite to the Rescue (featuring Dennis Chesters)
October 30	Satellite Limits (featuring Claire Parkinson)
November 9	Tropical Rainfall (featuring Marshall Shepherd)
November 17	Cloud Cores (featuring Marshall Shepherd)
November 25	Snow (featuring Jim Foster)
November 26	Snow White (featuring Jim Foster)
December 7	Ride to Earth Orbit (featuring Mary Cleave)
December 8	View From Earth Orbit (featuring Mary Cleave)
December 9	Small World (featuring Mary Cleave)
December 18	Landsat (featuring Jim Irons)

1999

January 6	Burning Concerns (featuring Anne Thompson)
January 13	Water Planet (featuring Gene Feldman)
January 14	Surf and Turf (featuring Gene Feldman)
January 15	Carbon Cycle (featuring Gene Feldman)
January 28	Cratered Moon, Cratered Earth (featuring Susan Sakimoto)

Another six shows will be scheduled for February.

1999 USRA/GSFC Graduate Student Summer Program In Earth System Science

— *GSSP Program Coordinator (GSSP@gvsp.usra.edu), Universities Space Research Association*

The Universities Space Research Association, in collaboration with the NASA Goddard Space Flight Center's Earth Sciences Directorate, is offering a limited number of graduate student research opportunities for the summer of 1999. The Program is scheduled for June 7 to August 13, 1999.

The aim of this program is to attract and introduce promising students to Earth system science career options through hands-on research experiences in the Earth sciences at NASA. Each student will be teamed with a NASA scientist mentor with similar scientific interests to jointly develop and carry out an intensive research project at GSFC over a ten-week period. Mentors will be drawn from within the three participating Earth Science laboratories at NASA Goddard: The Laboratory for Atmospheres, The Laboratory for Hydrospheric Processes, and The Laboratory for Terrestrial Physics.

During the first full week (June 7-11) the students will attend a concentrated public lecture series that will provide an overview of important scientific problems and investigations in Earth system science. The title and theme of the 1999 lecture series is "Action at the interfaces of the Earth Sciences." In addition, students will participate in informal weekly lunch discussions with GSFC researchers and have the opportunity to tour key NASA facilities and meet with NASA and industry scientific managers.

The program is open to students enrolled in, or accepted to, a U.S. accredited graduate program in the Earth, physical or biological sciences, mathematics, or engineering disciplines. Students will be selected on the basis of academic record, demonstrated motivation and qualification to pursue multidisciplinary research in the Earth sciences, clarity and relevance of stated research interests to NASA programs, and letters of recommendation. Preference will be given to students who have completed at least one year of graduate study. Minorities and women are encouraged to apply.

Students must commit for the full ten-week period (June 7-August 13, 1999). Because of NASA/GSFC security regulations, citizens of certain proscribed nations may be ineligible. If in doubt, please inquire.

Details and a formal application may be obtained by contacting the GSSP Program Coordinator at the email address above, or downloaded from http://www.usra.edu/gssp. The deadline for applications is February 10, 1999.

(Continued from Pg. 17)

AGU Chapman Conference: West Antarctic Ice Sheet

complete satellite image of Antarctica by researchers at the Byrd Polar Research Center. The complete mosaic will be finished in a year, according to Kenneth Jezek, principal investigator for the Antarctic Mapping Mission. For the first time, satellite elevation measurements of the West Antarctic Ice Sheet are being planned using a laser instead of radar. ICESat, a NASA satellite set for launch in 2001, will use the Geoscience Laser Altimeter System (GLAS) to gather very accurate elevation measurements on the ice sheet. Bentley said that radar-derived elevation measurements are sometimes suspect because radar sees a wide area and is not very accurate on steep slopes. "The big benefit of using the laser is that it can be highly focused like a laser pointer," said Bentley, who discussed the ICESat mission and its plans for studying the West Antarctic Ice Sheet.

NASA Earth Science Enterprise Education Program Update

Earth System Science Education Workshop Held In Mexico

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

Earth System Science Education: Building Capacity within the Inter-American Institute (IAI) for Global Change Research was the theme of a workshop held in Ensenada, Mexico at the Universidad Autónoma de Baja California (UABC) from September 7 - 18. Fifteen participants representing institutions in Brazil, Chile, Colombia, the Dominican Republic, Honduras, Mexico, and Uruguay learned about Earth system science concepts from lectures and field trips presented by the UABC Faculty of Marine Science. Coastal processes provided the central theme around which Earth system and global change science topics were presented. Workshop participants also offered lectures describing their own work relevant to Earth systems education, as did invited speakers from JPL and InterNetwork Media. NASA/Universities Space Research Association (USRA) Earth System Science Education (ESSE) program participants from the University of Oklahoma and the University of Michigan also offered lectures and a hands-on tutorial of Earth system modeling using the STELLA software package.

GSFC Earth Space Science Education Project (GESSEP)

The GSFC Education Office is charged with providing materials that support both national standards and state curricular frameworks, as well as incorporating the knowledge being generated through NASA's science and technology programs. One activity for meeting this objective is GESSEP which, during FY 1997-98, developed a repository of over 60 internet-based, Earth and space science investigations for grades 5-8 and 9-12. A key requirement in the design of the investigations is that they are all self-explanatory. Pilot testing of the investigations will occur during the 1998-1999 school year. For more information about GESSEP, please contact the project co-investigators: Stephen Gilligan, e-mail: charles1@mail.ameritel.net or Vern Smith, e-mail: vern@aesp.nasa.okstate.edu

National Park Service Liaison To NASA

Two years ago, the staff at NASA GSFC contacted the National Park Service (NPS) because they recognized the need to share their resources and gain a broader audience. In April, 1997, GSFC signed a Memorandum of Understanding with the NPS that acknowledges the mutual interest of both agencies in promoting math and science literacy through technology. This connection will benefit the Service's visitor services and resource management programs by establishing links through the World Wide Web, access to field experts, access to a tremendous library of images, and tie the outreach/education centers of the agencies. If you are currently working on an Earth science education curriculum project or research that you think has significance to the National Park Service, please contact Ms. Dufficy at phone (301) 286-0535 or e-mail: Toni_Dufficy@nps.gov.

Remote Sensing Education And Training Initiative At Stennis

Stennis Space Center has launched the Commercial Remote Sensing Workforce Development Education and Training Initiative (WDETI) to establish a trained work force that will ensure Mississippi's ability to remain competitive in the growing remote-sensing job market. The goal of the initiative is to establish world-class remote-sensing education and research centers in Mississippi that will address the shortage of trained personnel in the area of remote sensing.

The work force initiative is part of the Mississippi Space Commerce Initiative, a collaboration among the state of Mississippi, NASA, private space-related businesses, and four research universities. Stennis Space Center, Mississippi State University, Jackson State University, the University of Mississippi Medical Center, and the University of Southern Mississippi will serve as Centers of Excellence for Geospatial Studies. These four universities will establish and support research assistantships and work-study programs, which will require students seeking remote-sensing-related degrees to spend several months working at Stennis with the Commercial Remote Sensing Program or the Mississippi Space Commerce Initiative Research Institute. Several of Mississippi's community colleges are also being used as prototype training and education centers.

Recently the Mississippi Department of Education and WDETI initiated a pilot program to introduce remote-sensing education in Mississippi schools from the kindergarten level to college. When fully implemented, this program will place remote-sensing training within reach of all Mississippi students by the year 2002.

New GLOBE Measurements

Based on the recent recommendations of a National Science Foundation (NSF) peer review panel, Global Observations to Benefit the Environment (GLOBE) students will add several new measurements to their core study over the next few years. These include:

- Under the supervision of Dr. Jack Fishman of NASA Langley Research Center, GLOBE students will undertake study of surface ozone concentrations.

- Dr. Paul Ruscher of Florida State University is developing a new protocol for students to measure relative humidity. Dr. Ruscher is also assuming responsibility for student cloud observations.

- Also, in the field of atmospheric science, Dr. David Brooks from Drexel University in Pennsylvania is seeking GLOBE student support in his studies of atmospheric haze.

- In the hydrology field, Dr. Roger Bales and his colleagues at the University of Arizona are developing an aquatic macroinvertaebrates protocol. Students will use this protocol to determine the diversity of bottom-dwelling macroinvertaebrates at their hydrology site.

- Expanding their current land-cover studies, GLOBE students will help researchers track seasonal changes. Dr. David Verbyla of the University of Alaska at Fairbanks will use GLOBE student data to improve understanding of changes in growing seasons, a major potential indicator of climate change.

For more information on GLOBE, visit: ***http://www.globe.gov***

Students Go Back To School With NASA Computers

In just one year, NASA has donated over 36,000 excess computer items with an original cost of $75 million to public, private and parochial schools serving students in pre-kindergarten through 12th grade. Working with the federal Computers for Learning program, established by Vice President Al Gore in 1997, Federal agencies can now streamline the transfer of excess computer equipment to those U.S. schools with the greatest need.

A new website funded by the U.S. Department of Energy has made it even quicker and easier for schools to request and obtain free equipment that includes shipping by private companies. The web address is: www.computers.fed.gov. U.S. schools or educational nonprofit organizations seeking additional information or assistance in accessing the computer upgrades should visit the website. A toll-free Computers for Learning hotline, 1-888/362-7870, is available from 1-5 p.m. EDT, Monday through Friday.

GSFC Project Engages Student Scientists

A new Earth science education initiative sponsored by the Earth Observing System (EOS) PM Project is challenging students in over a dozen test schools to work as scientists, processing raw, real-time satellite data from Earth-observing satellites.

Middle and high school students participating in "Exploring Technology with Satellite Imagery," receive and process data covering the entire Western hemisphere from Geostationary Operational Environmental Satellites (GOES).

They also use data products, which others have developed and made available via the Internet, as ground truth for their research. Students enhance their own raw data from the same time and place, to bring out features such as ocean currents, wildfires, hurricanes, rain, snow, fog, etc., and correlate their data products with the ground truth images.

Each school is encouraged to electronically communicate with other participating schools, challenging each other to provide specific data products and to answer questions about the imagery they are handling.

Participating schools are also writing their own activity modules to be used in their fall classes.

Check the project website for current information about the program: http://coolspace.gsfc.nasa.gov/outreach. For more information, contact: Michael Comberiate, GSFC, e-mail: michael.comberiate@ gsfc.nasa.gov; Tel: (301) 286 9828; or the project's teacher developer, Rob Theriaque, e-mail: SpcShuttle@aol.com.

Resources On The Internet

Fundamentals Of Remote Sensing Tutorial
http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

Landsat-7 — A Global View Of The Earth
http://ltpwww.gsfc.nasa.gov/landsat7

PUMAS — The On-Line Journal Of Math And Science Examples For Pre-College Education
http://pumas.jpl.nasa.gov

NASA Selects Regional Earth Science Applications Centers

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

NASA's Office of Earth Science has selected nine public/private consortia throughout the U. S. to form seven Regional Earth Science Applications Centers (RESACs). The RESAC program will use NASA's Earth science results, technologies, and data products to help resolve issues with regional economic and policy significance and to support regional assessments supporting the U.S. Global Change Research Program.

The centers selected will comprise "end-to-end" consortia (from user needs definition to product delivery) and will include members from the research community, private industry, public agencies, and other potential information users in the public and private sectors. The selected consortia involve over 20 private companies, about ten state and local government agencies, 20 Federal agency regional offices, and 15 universities.

The RESACs will apply state-of-the-art NASA Earth science research results to such diverse areas as precision farm management; monitoring of forest growth and health; regional water resources and hydrology; assessment of the impact of long-term climate variability and change; land-cover and land-use mapping; agricultural crop disease and infestation detection; management of fire hazards; watershed and coastal management; environmental monitoring; and primary and secondary science education.

For example, one RESAC will address water-management problems in the arid Southwestern U. S. Using hydrologic models derived from NASA-sponsored research, the RESAC will use spaceborne and airborne instruments to provide improved information on water resource availability. This information will assist planners in developing strategies for resource allocation among competing economic and environmental uses in a rapidly evolving global economy.

"Regional-scale problems are well-suited to NASA's Earth science data and technology; no other system of observation is available for analyzing such large-scale issues," said Dr. Ghassem Asrar, Associate Administrator for Earth Science, NASA Headquarters, Washington, DC. "This program will capitalize on the science and technology developed over the past decade by NASA's Earth Science enterprise to provide solutions to practical and societal problems that exist today and help in mitigating them in the future."

"The selection of the RESACs is the first of a number of planned NASA initiatives to develop new methods for bringing together the research, service, and user communities to apply NASA's research results to practical, near-term problems," added Alex Tuyahov, Manager, Earth Science Applications Research Program, NASA Headquarters.

The selected consortia are:

Northern Great Plains RESAC, led by George A. Seielstad of the University of North Dakota

Northeast Applications of Usable Technology In Land Planning for Urban Sprawl RESAC, led by Chester Arnold of the University of Connecticut

NASA Southwest Earth Science Applications Center, led by Roger C. Bales of the University of Arizona

Upper Great Lakes RESAC, led by Marvin E. Bauer of the University of Minnesota, St. Paul

Midwest Center for Natural Resource Management, led by George R. Diak of the University of Wisconsin, Madison

Wildlands Fire Hazard Center, led by Christopher Lee of the California State University, Dominguez Hills

Great Plains RESAC, led by Edward A. Martinko of the University of Kansas

California Water Resources Research and Applications Center, led by Norman L. Miller of the Lawrence Berkeley National Laboratory

Mid-Atlantic RESAC Consortium, led by Stephen D. Prince of the University of Maryland, College Park

NASA is investing approximately $14 million in these seven new RESACs in FY99. The three-year grants will take advantage of NASA's extensive Earth Science program, a long-term effort to study human-induced and natural changes in the whole Earth system.

Triana Mission Selected

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

After a rigorous peer-review evaluation of nine competing proposals, NASA has selected a proposal from the Scripps Institution of Oceanography in La Jolla, CA, to implement the Triana mission with NASA's Goddard Space Flight Center, Greenbelt, MD.

Named for the sailor on Columbus' voyage who first saw the New World, Triana is a satellite mission to L1 (the Lagrange libration, or neutral gravity point between the Earth and the Sun). From L1, Triana will have a continuous, full disk, sunlit view of the Earth. The mission will provide this view of the Earth for distribution over the Internet at the beginning of the new millennium.

Dr. Francisco P.J. Valero of the Scripps Institution of Oceanography, a part of the University of California at San Diego, has been selected as Principal Investigator to lead development of the Triana mission. Dr. Valero's mission concept includes two scientific instruments: the Earth Polychromatic Imaging Camera (EPIC), to be built by Lockheed-Martin Advanced Technology Center of Palo Alto, CA, and an advanced radiometer, from a source to be selected later this fall. Triana also will include a small, next-generation space-weather monitoring instrument to contribute to our understanding of how solar events affect Earth-orbiting spacecraft, such as communications satellites.

"An advanced radiometer at L1 will provide, by looking at the whole sunlit side of the Earth at once, the first direct measurements of the radiant power reflected by the planet, and thereby contribute to our knowledge of how much of the Sun's energy is absorbed in the Earth's atmosphere," said Dr. Valero. "The EPIC instrument will observe the Earth's vegetation canopy structure and evolution by taking advantage of the retro-reflectance, or 'hot spot,' view that will be available by being in-line between the Earth and the Sun. The EPIC also will observe clouds and aerosols."

"The L1 vantage point, with its full-disk view of the Earth, offers unique scientific advantages," said Dr. Ghassem Asrar, NASA's Associate Administrator for Earth Science. "The full-disk view of the Earth enables retrieval of global quantities at once, whereas measurements from low Earth orbit or geostationary Earth orbit must be 'stitched' together, requiring concerted efforts to 'process out' differences due to viewing times and revisit intervals.

"L1 will be a prime vantage point for the next generation of Earth remote-sensing instruments. Triana will serve as a pathfinder for those future missions, providing scientific and operating experience in the L1 environment," said Asrar.

The Triana mission also will invite participation from the educational community. "We hope and expect to have widespread participation by students in every phase of this inspirational project. Students will benefit from 'hands-on' participation in Triana via the Internet and NASA's educational outreach efforts," Asrar said. NASA plans to solicit proposals for educational applications of Triana data next year.

Commercial participation also is possible for the Triana mission. Commercial enterprises have expressed an interest in contributing financially to Triana development in exchange for commercial rights to data. NASA will consider commercial partnerships for the Triana mission over the coming months.

NASA plans to proceed expeditiously on mission development. Goddard will provide a Small Explorer-lite spacecraft and ground system for Triana, as well as program integration and management support. Triana is a $75 million mission to be launched by December 2000 from the Space Shuttle cargo bay. Triana will be the latest in the Earth Probe series of missions in NASA's Earth Science enterprise, which seeks to understand the total Earth system and the effects of natural and human-induced changes on the global environment.

NASA Helps "HOT" Cities Cool Down

— David E. Steitz (dsteitz@mail.hq.nasa.gov), NASA Headquarters, Washington, DC.
— Tim Tyson, NASA Marshall Space Flight Center, Huntsville, AL.

Environmental planning for the 2002 Olympic games, strategies to reduce ozone levels, focused tree-planting programs, and identification of cool roofs are early spinoffs from a NASA urban study just concluding in three U.S. cities.

Researchers from NASA's Marshall Space Flight Center, Huntsville, AL, flew a thermal camera mounted on a NASA aircraft over Baton Rouge, LA; Sacramento, CA; and Salt Lake City, UT. The thermal camera took each city's temperature and produced an image that pinpoints the cities' "hot spots."

The researchers are using the images to study which city surfaces contribute to bubble-like accumulations of hot air, called urban heat islands. The bubbles of hot air develop over cities as naturally vegetated surfaces are replaced with asphalt, concrete, rooftops, and other man-made materials.

Salt Lake City is using the early results to help plan sites for the 2002 Olympic Games and develop strategies to reduce ground-level ozone concentrations in the Salt Lake City valley. Though at high altitudes ozone protects the Earth from ultraviolet rays, at ground level it is a powerful and dangerous respiratory irritant found in cities during the summer's hottest months.

In Sacramento and Baton Rouge, city planners and tree-planting organizations are using the study to focus their tree-planting programs.

The science team will continue to analyze the thermal heat information and work with the cities to incorporate future results into the cities' plans. The team plans to disseminate its findings nationally so other cities can incorporate what the team has learned into their long-range growth plans.

Global Change Calendar

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

January 18-22
International Symposium "Aerosols, clouds and radiation, land surfaces, ocean color: the contribution of POLDER and new generation spaceborne sensors to global changes studies," Meribel, France. Contact Gerard Dedieu, e-mail: Gerard.Dedieu@CESBIO.CNES.FR URL: http://www.cnes.fr/actualities/ALPS99.

January 19-21
NASA, FEMA, and the GW University are sponsoring the 2nd Conference on "The Applications of Remote Sensing and GIS for Disaster Management," Washington, DC. Abstracts and papers are requested. Contact Greg Shaw, tel. (703) 729-8271; e-mail: glshaw@gwu.edu
URL: http://www.gwu.edu/~cms/gis/.

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

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

March 23-26
Progress in Electromagnetics Research Symposium (PIERS 1999), Taipei International Convention Center, Taipei, Taiwan. Contact: Prof. Kun Shan Chen, PIERS 1999, Center for Space and Remote Sensing Research, National Central University, Chung-Li, Taiwan. tel. (886) 3-425-7232; Fax: (886) 3-425-5535, e-mail: dkschen@csrsr.ncu.edu.tw.

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

EOS Science Calendar

December 14-16
MISR Science Team Meeting, Pasadena, CA. Contact: Dave Diner, tel. (818) 354-6319; e-mail: djd@jord.jpl.nasa.gov

December 15-16
MODIS Science Team Meeting, University of Maryland Conference Center, College Park, MD. Contact Barbara Conboy, tel. (301) 286-5411; email: barbara.conboy@gsfc.nasa.gov

January 12-14, 1999
ASTER Science Team Meeting, Pasadena, CA. Contact Anne Kahle, tel. (818) 354-7165; email: anne@aster.jpl.nasa.gov, or Hiroji Tsu, tel. 011-81-298-54-3533; email: tsu@gsj.go.jp

February 4-6, 1999
Project ATLANTA Team Science meeting, San Jose, CA. Contact: Dale Quattrochi, tel. (256) 922-5887; email: dale.quattrochi@msfc.nasa.gov

February 25 - 27, 1999
AIRS Science Team Meeting, Santa Barbara, CA. Contact: H. H. Aumann, tel. (818) 354-6865; email: aumann@jpl.nasa.gov

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