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1989 • 2009 CELEBRATING TWENTY YEARS

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Editor's Corner

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On June 22-24 the Earth Science Division of NASA's Science Mission Directorate and the National Academy of Sciences hosted a symposium called *NASA Earth System Science at 20: Accomplishments, Plans, and Challenges* (ESS@20) that took place at the National Academy of Sciences building in Washington, DC. This event was a chance to focus on the past, present, and future of Earth System Science. The meeting featured a retrospective on the twenty-year history of the Earth Observing System (EOS) Program that began with the publication of the landmark *Bretherton* report in 1988. It also included a look ahead to the future of Earth System Science, with particular emphasis on the importance of maintaining satellite data continuity in the coming years. In his closing remarks, **Ralph Cicerone**, President of the National Academy, noted the importance of interagency collaborations in addressing climate and other Earth Science issues, and stressed that effective outreach and communication are key complements to all Earth Science research. A summary of the symposium is being planned for an upcoming issue.

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Rising above the two lightning towers around the launchpad at Cape Canaveral, a *Delta IV* rocket races into the sky carrying the GOES-O satellite into orbit. **Photo credit:** NASA/ Kim Shiflett.

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In This Issue

Our ongoing *Perspectives on EOS* series has endeavored to chronicle the history of EOS, including personal accounts by those involved in its early implementation. In this issue, we continue our series with the first of two articles from **H. K. "Rama" Ramapriyan** from the Goddard Space Flight Center (GSFC) that describe the evolution of the Earth Observing System Data and Information System (EOSDIS). Rama has been involved with EOSDIS since its inception and thus is well qualified to reflect on the history of the program. As you might imagine, creating a system that successfully distributes over 150 million data product files each year wasn't without its hiccups and Rama shares some of that rocky road. He tells us about how EOSDIS was conceived and the ongoing struggle between engineers (designers) and scientists (users) to seek out what Rama calls the *Goldilocks compromise*—i.e., the data system that was "just right" for all involved. We hope you enjoy this article about the design and implementation of a world-class data and information system. (Look for the conclusion of Rama's article in our September–October issue.)

Two more EOS milestones were recently achieved. June 19 marked the 10th anniversary of the launch of the Quick Scatterometer (QuikSCAT) mission. QuikSCAT carried a SeaWinds instrument into orbit and was designed to be a "quick recovery," to fill in the data gap that occurred when the Japanese Midori [also called the Advanced Earth Observing Satellite (ADEOS)] satellite, on which the NASA Scatterometer (NSCAT) flew, lost power suddenly in June 1997. QuikSCAT was designed to have a three-year lifespan, but ten years after launch, the vector wind data that QuikSCAT gathers over the oceans in all-weather conditions continue to be used by the National Oceanic and Atmospheric Administration (NOAA) and the European Centre for Medium-Range Weather Forecasts (ECMWF) for operational use.

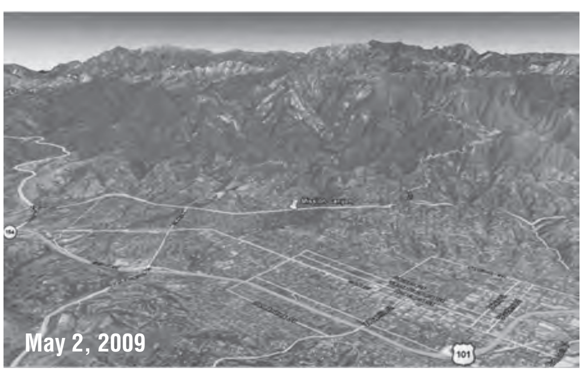
Also, July 15 marked the 5th anniversary of the launch of Aura. The high vertical resolution profiles of the atmosphere that Aura makes have been critical to understanding ozone, air quality, atmospheric chemistry, and climate change. In October 2007, a change in orbit was initiated, moving Aura closer to Aqua in the Afternoon Satellite "A-Train" Constellation. To read about some of Aura's notable science highlights, visit: *aura.gsfc.nasa.gov/science/auratop10.html*. You can also read a summary of the last Aura Science Team meeting in our January-February 2009 [**Volume 21, Issue 1**, pp. 41-42] issue. The next meeting is planned for September 2009. Congratulations to both the QuikSCAT and Aura Teams on their achievements!

On June 27 at 6:51 PM, the latest Geostationary Operational Environmental Satellite, GOES-O, was launched into space from Cape Canaveral Air Force Station in Florida aboard a *Delta IV* rocket. GOES-O is the second in the GOES-N series of geostationary environmental weather satellites launched by NASA for NOAA. NOAA manages the GOES program which provides severe weather information for meteorologists and the public. GSFC procures the spacecraft and manages their design, development and launch. (Upon reaching geosynchronous orbit at 89.5° W longitude on July 8, 2009 NASA transferred operations to NOAA and GOES-O name was changed to GOES 14.) Congratulations to the NASA/NOAA team on another successful launch!

On the education and outreach front, as it has for the past eight years, the Earth Observing System Project Science Office (EOSPSO) sponsored an Odyssey of the Mind (OM) long-term problem. Students examined environmental change in this *Earth Trek* problem by building a "vehicle" that changed as it traveled to four locations. EOSPSO staff members "trekked" to Iowa State University in Ames, Iowa for this year's OM World Finals. More details on the competition and NASA's presence there are featured in an article on page 22 of this issue.

I'd like to mention two multimedia-related items of interest. To gather information for an upcoming video on NASA's Airborne Science Program, **Chris Chrissotimos** made the long journey to Greenland to observe an aircraft field experiment called *Operation Ice Bridge* (OIB). His experience, entitled *Operation Ice Bridge: A Journal of My Expedition to Greenland*, is on page 12 of this issue. This journal complements blogs featured in past issues, such as **Lora Koenig**'s stay at Summit Camp, Greenland [**Volume 21, Issues 2** and **3**] and the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) campaign [**Volume 20, Issues 4** and **6**]. These firsthand accounts of research in the Arctic not only give unique (and often entertaining) perspectives on the challenges of doing science research in remote environments, but they also highlight the importance of studying the polar regions, where the impacts of climate change are expected to be the most significant.

Finally, I'm pleased to announce the recently released video production, *The Dynamic Earth: NASA Observes Our Ever-Changing Planet*. This 17–minute video provides a brief introduction to Earth System Science and NASA's role in observing and studying our changing planet. The video is available for viewing on the EOSPSO website (*eospso.gsfc.nasa.gov/*) or can be downloaded from: *eospso.gsfc.nasa.gov/eos_homepage/for_educators/educational_dvd.php*. At the latter link, you'll also find links to the video's acronym and glossary lists, and video weblinks to other NASA Earth Science sites.



In Santa Barbara County, a wildfire, called the Jesusita fire, ignited on May 5, 2009, in the Cathedral Peak area northwest of Mission Canyon. As of midday May 8, the fire, which was 10% contained, had scorched 3,500 acres, damaged or destroyed 75 structures, and had forced the evacuation of tens of thousands of residents.

The images above show soil moisture change in the top soil layer (2-in deep) on May 2–3, 2009, as measured by the NASA QuikSCAT satellite scatterometer (radar). On May 2, rainwater increased the amount of moisture in the soil by a modest 4%. However, by the next day QuikSCAT revealed that whatever rainwater had accumulated earlier quickly dried up over the whole area. This is indicated by the lighter shades of grey in the image from May 3. (To view these images in color please visit: *photojournal.jpl.nasa.gov/catalog/PIA12006.)*

The rapid dry-up in Santa Barbara together with high winds and unusually high temperatures contributed to the devastating Jesusita fire. QuikSCAT can provide soil moisture information that is critical to enhance the capability for Red Flag Warning and to improve the National Fire Danger Rating System. **Credit:** NASA/JPL/QuikSCAT Science Team.

EOS Data and Information System (EOSDIS): Where We Were and Where We Are, Part I

H. K. Ramapriyan (Rama), NASA Goddard Space Flight Center, Rama.Ramapriyan@nasa.gov

Over 150 million data product files are being sent to hundreds of thousands of users each year and people continue to view EOSDIS favorably.

This article continues our ongoing *Perspectives on EOS* series. To date, the articles in this series have shared perspectives from a number of Earth Observing System (EOS) "pioneers,"—scientists and managers who were personally involved in the early days of the program and actually involved in *making* what we now view as EOS history. Along the way, we've also learned something about the difficult political journey EOS faced as it progressed from inspiring idea to concrete reality.

But there are still more facets of the tale of EOS that need to be told. One of those is the story behind the development of the Earth Observing System Data and Information System (EOSDIS). Our EOS satellites beam back reams of data and information about the condition of Earth every single day, but this information would be all but useless without an effective system to efficiently process it all and make it readily available for use in science research and applications. Today EOSDIS processes over 150 million data products each year, but the journey to making EOSDIS the world-class data and information system it is today has been long and sometimes difficult—and the details of this journey make for a compelling story.

The Earth Observer asked H. K. "Rama" Ramapriyan of Goddard Space Flight Center to share some of the details of this story with us and he graciously agreed. Rama has been involved in the EOSDIS program since its inception and is thus well qualified to reflect on its history. (This article is the first of two planned articles from Rama—the second should appear in our September–October issue.)

Introduction

My involvement with the Earth Observing System Data and Information System (EOSDIS) started in early 1989, almost two years before the U.S. Congress approved the EOS Program as a *New Start*. Having been involved with the program for so long, it is a little difficult to be brief and select a few things to say about the program. However, I will try to put down some of my salient memories of where we were when we got started, where we are now and how we got here. Of course, it goes without saying that any opinions expressed here are my own and not those of NASA or any of the many others who have influenced, managed, used, reviewed or otherwise thought about EOSDIS. In fact, there are differences in points of view about what EOSDIS *is*—so it is important to clarify what I mean when I refer to EOSDIS. For purposes of this discussion, I will define EOSDIS as consisting of all the components being funded by NASA's Earth Science Data System Program through the Earth Science Data and Information System (ESDIS) Project at Goddard[1]. These are: twelve Data

[1] When the EOS Program began, the responsibility for developing and operating the *mission systems*—the systems needed for spacecraft and instrument control, data capture, and initial (Level 0) processing—was with the ESDIS Project as well. After the development was completed and Terra was launched, the responsibility for maintaining and operating the *mission systems* transferred to the newly formed Earth Science Mission Operations (ESMO) Project. So, while I will briefly mention *mission systems* to set the overall context, the focus of this article is on the science systems.

H. K. “Rama” Ramapriyan

Centers[2] [Distributed Active Archive Centers (DAAC)], three of which are using the EOSDIS Core System (ECS) in their operations, nine Science Investigator-led Processing Systems (SIPS), the EOS Clearing House (ECHO), and the networks needed for data flows among these.

Today, EOS standard products are being produced regularly, archived in the data centers, and being ordered or accessed by a broad user community around the world. In fact, over 150 million data product files (see **Figure 1**) are being sent to hundreds of thousands of users each year and people continue to view EOSDIS favorably[3]. Anyone who knows the history of EOSDIS knows there were times when the community had very strong doubts about our ability to achieve this degree of success, so this is a tribute to all of the hard work done to make this system a reality.

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Today, NASA’s Earth Science Data System Program, led by Martha Maiden [NASA HQ], is a mix of *Core* and *Community* capabilities that complement each other to provide balance between stability and innovation. EOSDIS as defined above is a significant part of the *Core* capabilities. All the data system related activities that are selected via peer-reviewed proposals are *Community* capabilities. I have been fortunate

[2] The terms Data Center and DAAC are used somewhat interchangeably. Originally, there were nine DAACs. They were reduced to eight in 1995 after NASA’s *Zero Base Review*. Some of the organizations chose names that were more descriptive of the disciplines assigned to them. In 2004–2008, three organizations that were not in the original list of DAACs were added to the list funded by the EOSDIS budget. These were the Ocean Data Processing System (ODPS) under the Ocean Biology Processing Group, MODIS Adaptive Processing System/Level 1 and Atmosphere Archiving and Distribution System (MODAPS/LAADS), and the Crustal Dynamics Data and Information System (CDDIS). In the light of these changes, we have started to use the more general term EOSDIS Data Centers.

[3] An annual American Consumer Satisfaction Index (ACSI) survey conducted since 2004 by the Claes Fornell International (CFI) Group, an independent entity that surveys various industrial and government organizations, has consistently rated EOSDIS significantly higher than “Overall Federal Government” same as or higher than “Overall (Public and Private Sectors.)”

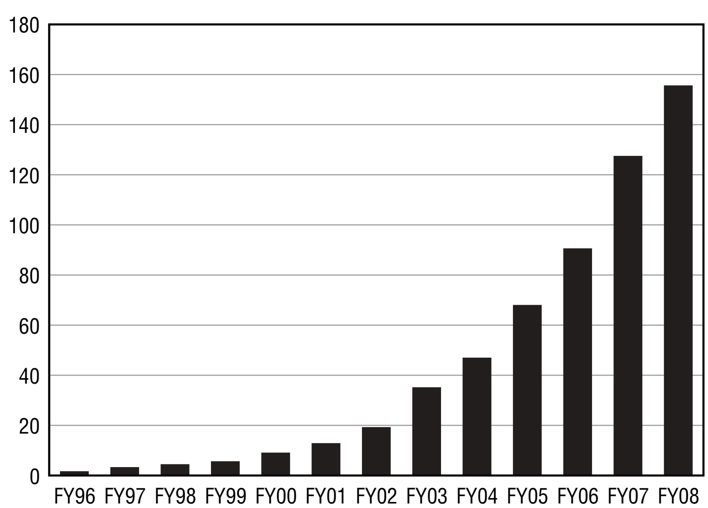


Figure 1. Millions of files distributed from EOSDIS data centers to users.

to be involved in both of these "camps." What follows is a discussion of the *Core* and *Community* capabilities from a historical perspective. The organization of this article is not strictly chronological. However, the first part of this two-part series generally covers the period until the start of the EOSDIS Core System (ECS) contract. The second part will discuss the system's evolution beyond that time to the present and the *Community* capabilities.

Conceiving of an EOSDIS – 1980s

People began thinking about EOSDIS in the mid-1980s—not long after the widespread use of punched cards had become obsolete. At that time the *VT 100* interactive terminal was in vogue as the device with which to submit jobs to run on computers. Very few people had heard of the Internet. The World Wide Web as we know it today was yet to be created. Despite this, a group of forward-looking thinkers (the EOS Data Panel chaired by **Robert Chase**) got together and thought about what the characteristics of a data system to serve Earth science for the next two decades should be. These thoughts were published in a *black cover* report called the *Report of the EOS Data Panel* [*NASA Technical Memorandum 87777*, NASA, 1986]. While some of the specific numbers used in the report are quite trivial today (e.g., 10,000 users; 9,600 bits per second communications links), the design principles and architectural considerations (e.g., modularity, adaptive flexibility, evolvability) are still valuable and worthy of occasional rereading.

When our discussions began in the mid-1980s, the VT 100 interactive terminal was in vogue as the device with which to submit jobs to run on computers. Very few people had heard of the Internet. The World Wide Web as we know it today was yet to be created.

NASA conducted the *Phase A* studies for EOSDIS in the mid-1980s, followed by *Phase B* studies by two major aerospace contractors (Hughes Aircraft and TRW) during 1989 and 1990. **Al Fleig** was the Data System Manager from Goddard's Flight Projects Directorate (Code 400) at the time, and he funded these studies. **Strat Laios** and **Curt Schroeder** of the Mission Operations and Data Systems Directorate (old Code 500) directed them. I was the lead for the Science Data Processing Segment (SDPS) at that time. The studies had to be independent so that one company's conclusions would not be affected by the other. We used to have regular weekly meetings with each company separately. We went to great lengths to ensure independence and fairness. The purpose of the studies was to define what the requirements for EOSDIS should be, to determine how much it should cost, and to help prepare an integrated presentation package for the upcoming Non-Advocacy Review (NAR) of the EOS Program.

While the *Phase B* studies were in progress, an *All-Hands* meeting of the Investigators' Working Group (IWG) took place at Goddard March 20-24, 1989. The IWG consisted of Interdisciplinary Principal Investigators (PIs), Instrument PIs, Team Leaders, and Team Members, all of whom NASA selected through the EOS Announcement of Opportunity. We had to take advantage of the presence of all these people at Goddard to gather their thoughts on requirements—e-mail communication was not nearly as common 20 years ago. We had several interview teams that consisted of representatives from Goddard and Jet Propulsion Laboratory (JPL) staff as well as the two *Phase B* contractors—the interview teams asked IWG participants to fill out a long questionnaire. It was important at that time to figure out "how big" EOSDIS had to be as well as what it had to do (especially for long lead time items such as construction of facilities and contract procurements).

In one of the introductory talks where Al Fleig explained to the IWG the interview process, he mentioned that we needed to know how much computing capacity we needed, whether we needed the equivalent of several *Cray-Y*'s or even "*Cray-Z*'s" of the future! Of course, looking back on this now, it seems laughable that we were worried about the biggest known requirement of those days—1.5 gigaflops for data assimilation. It was during this *All-Hands* meeting that the *Science Advisory Panel for Eos Data and Information*, a.k.a. the EosDIS Advisory Panel or Data Panel of the IWG was formed. It is worth quoting a few sentences to show what the science community and the Data Panel were thinking about EOSDIS at the time. (Note that EOS was still called *Eos* at that time).

"Crucial to the success of the Eos is the EosDIS. The goals of Eos depend not only on its instruments and science investigations, but also on how well EosDIS helps scientists integrate reliable, large-scale datasets of geophysical and biological measurements made from Eos data, and on how successfully Eos scientists interact with other investigations in Earth System Science."

"EosDIS must:

- *adhere to a flexible, distributed, portable, evolutionary design;*
- *distribute data products by appropriate high-bandwidth communication or other media;*
- *operate prototypes in a changing experimental environment."* [4]

During *Phase A* and early in the *Phase B* studies, the concept was to have an analog of the Central Data Handling Facility (CDHF) that was used in the Upper Atmospheric Research Satellite (UARS) Program, except that we were to have two CDHF's—one at Goddard and one at the U.S. Geological Survey's Earth Resources and Observation Science (EROS) Data Center in Sioux Falls. The Data Panel regarded this to be too centralized an approach for *Eos* and pressed on the idea that a much more distributed architecture was required. An important reason for distribution was to take advantage of existing expertise in Earth science disciplines as well as data management at various institutions across the U.S.

In a very real sense, EOSDIS is not a collection of hardware and software, it is a 'place' where scientists communicate with each other and with the data they have collected with the help of their professional colleagues from the engineering and operations disciplines.

In addition to the push for a more decentralized structure, from the very beginning there were differences between the *engineering (designers') view* and the *science (customers') view* of EOSDIS that had to be resolved. The *engineering view* was that EOSDIS was a "thing" to be built with a well-established set of requirements and specifications, involving hardware, software, and operations personnel. Its purpose was to meet the EOS missions' requirements as well as to serve the user community. The view of the *science community* was best expressed by the Data Panel:

"This view that EOSDIS is a 'thing', a piece of hardware, supported by software, seems fundamentally mistaken. In a very real sense, EOSDIS is not a collection of hardware and software, it is a 'place' where scientists communicate with each other and with the data they have collected with the help of their professional colleagues from the engineering and operations disciplines. At about the time of launch, EOSDIS also will have to include a capability to process, store, and make visible large streams of data. It may even be correct to view EOSDIS as the place where the scientists produce information to be used by other scientists. As one of the Panel Members stated, EOSDIS must be run by scientists for scientists." [5]

RAACs – or should they be DAACs?

NASA accepted the recommendation to have a more distributed system. By this time, the Non-Advocacy Review (NAR) of EOS and EOSDIS had been completed and NASA had set up a new organization called the EOS Ground System and Operations Project (Code 423) headed by **Tom Taylor**, formerly the Data System Manager for UARS. Tom hired me as the Deputy Project Manager for the project. Given his experience with the Remote Analysis Centers (RACs) of UARS, we came up with the name Remote Active Archive Center (RAAC) for the distributed components of EO-

[4] Initial Scientific Assessment of the *Eos* Data and Information System, Science Advisory Panel for *Eos* Data and Information, NASA, Eos-89-1, 1989; report written in September 1989, soon after the Preliminary Requirements Review and Preliminary System Design Review by the two Phase B contractors

[5] Panel's Comments on the EOSDIS Final System Design Review (of the two *Phase B* contractors), February 12-16, 1990

SDIS responsible for the processing, archiving and distribution of data. **Dixon Butler**[6], the Program Manager at NASA HQ (and in many ways the "father" of EOSDIS) named the specific RAACs based on specific Earth science discipline expertise and some "political imperatives" for geographic distribution.

I recall a meeting with the Data Panel and the managers of the newly named RAACs where we were discussing the status of EOSDIS. The Data Panel emphasized the fact that we had a considerable amount of Earth science data already, and we should take advantage of this to learn how to design and implement EOSDIS. The data at the RAACs could be made more easily available to the user community. The initial version of EOSDIS that would do this was called *Version 0* EOSDIS or simply *V0*. In the same meeting, **Roger Barry** from the National Snow and Ice Data Center (NSIDC) asked us to change the name RAAC, since the word remote was not appropriate. He said: *"We are not remote to ourselves!"* Hence the name was changed to Distributed Active Archive Center (DAAC).

Given all the infrastructure that had been built, and the data and metadata that had been prepared, it was easy to respond to this concern, and within three months we had a web-based interface for V0 in place.

Version 0

We started out with nine DAACs[7]—they included the Alaska Synthetic Aperture Radar (SAR) Facility (ASF), EROS Data Center (EDC), Goddard Space Flight Center (GSFC), JPL, Langley Research Center (LaRC), Marshall Space Flight Center (MSFC), NSIDC, Oak Ridge National Laboratory (ORNL), and Socio-Economic Data and Applications Center (SEDAC). Our first job was to facilitate establishment of the DAACs as organizations within their host institutions, set goals and success criteria for *V0*, coordinate with the DAACs technically to make sure that their data catalogs were interoperable at an *inventory level*—meaning "one-stop shopping" to find and obtain specific data files (or groups of related files, known as *granules*), and establish implementation plans, budgets, and schedules. **Gail McConaughy**, the Project's System Manager (and Architect), was responsible for the technical aspects of the implementation and I had the responsibility for the managerial aspects. McConaughy coined the phrase *"Working Prototype with Operating Elements"* to describe *V0*. We set a target date of August 31, 1994 as the date for *V0* to go operational. Dixon Butler regarded this as *"a moral equivalent of launch"* as far as strict adherence to schedule was concerned. Also, given the broadening of responsibility from managing the EOS data when they arrived to managing most of NASA's Earth science data, the name of the Project was changed from the EOS Ground System Project to the Earth Science Data and Information System (ESDIS) project**. Even though the system has retained the name EOSDIS (to be in line with the name of the Congressional appropriation language), the Project continues to be called ESDIS to this day.**

Key aspects of *V0* development included: (1) modernizing the data holdings at the DAACs; (2) creating metadata databases at the DAACs; (3) developing an *interoperability layer* (a small amount of software) at each of the DAACs; (4) developing a *V0* Information Management System (*V0* IMS) and a user interface to help users to perform cross-DAAC searches for data. We emphasized involvement of the scientific users by funding individuals to "kick the tires" of the system as it was being developed—these people were called *tire kickers*. They assessed the system and user interfaces as they evolved and made many useful recommendations. The system was ready as planned in August 1994. By this time, the World Wide Web had become available and was growing rapidly. The potential users of *V0*—the scientists, profes-

[6] Butler wrote an earlier article in the *Perspectives* series entitled: "The Early Beginnings of EOS: "System Z" Lays the Groundwork for a Mission to Planet Earth" [**Volume 20, Issue 5**, pp. 4-7.]

[7] During NASA's *Zero-Base Review* in 1995, the DAAC at MSFC was removed from the program. MSFC collaborated with the University of Alabama in Huntsville and other educational institutions to form the Global Hydrology and Climate Center (GHCC). The Global Hydrology Resource Center (GHRC) within GHCC continued to perform some of the functions performed by the DAAC. Other functions were distributed to the other DAACs. In 2009, GHRC was brought back into EOSDIS as a DAAC.

sors at universities and their graduate students—were getting used to the web and expressed disappointment that the *V0* IMS interface was not web-based. Given all the infrastructure that had been built, and the data and metadata that had been prepared, it was easy to respond to this concern, and within three months we had a web-based interface for *V0* in place. The *V0* IMS served a general user community not necessarily aware of where the data of interest were held. However, it was an encumbrance for users who were already familiar with the location of the data, because it provided many options the users had to choose from before finding the data of interest. To accommodate such users, the DAACs developed simpler and more tailored interfaces.

Just as important as the technical aspects of *V0* discussed above were the social and administrative aspects. We developed a general charter for the DAAC User Working Groups (DUWGs) to ensure that each DAAC had a group of representative users to assess its progress and priorities periodically (at least once a year). The charter was then tailored to the individual DUWGs. A User Services Working Group was established to ensure cross-DAAC communication and coordination in user services. Regular communication mechanisms—e.g., weekly telecons and periodic face-to-face meetings of the DAAC Managers and the ESDIS Project—were established. Coordinated outreach processes were set up. All of these are continuing and functioning well to this day.

There was anxiety, concern, anger, and misconception about the formatting issue that was akin to what one of my colleagues called "religious wars."

Data Format Wars

Also during the years of *V0* development, in collaboration with the DAACs, we conducted a study of formats commonly used in Earth science with the intention of establishing a standard format to be used for representing EOS data. These were not just formats in the sense of rules for arranging bits, but formatting systems with support tools. The idea was that using one format (formatting system) would make it economical to provide an extensive set of tools and services for using and manipulating data. No format available at the time met all the requirements we had listed, but the Hierarchical Data Format (HDF) from the National Center for Supercomputing Applications (NCSA) at the University of Illinois came quite close. So we selected HDF as the distribution format for *V0* data to get some experience with HDF, while recognizing that the data that were previously in various other formats that would need to be supported in their native formats. There was anxiety, concern, anger, and misconception about the formatting issue that was akin to what one of my colleagues called *"religious wars."* Some people thought we would actually convert all of the old Earth science data into HDF. The HDF and a more particularized version of it called HDF EOS have been used for producing and storing most of the EOS data products. In addition, today translations into many other commonly used formats are being supported. I still occasionally hear complaints from some users about HDF, but for the most part users seem quite satisfied with the format and the tools that go with it.[8]

The Big Contracts

In parallel with the *V0* development, the ESDIS Project was designing two major subsystems to satisfy the requirements for "big" data flows from the EOS missions. The EOS Data and Operations System (EDOS) would be developed for data capture and initial (Level 0) processing of the satellite telemetry through a contract awarded to TRW in 1994. Meanwhile, in 1993 Hughes (which later became Raytheon) received a contract to develop the ECS. ECS would satisfy the remaining requirements: the Flight Operations Segment (FOS) would handle spacecraft and instrument operations while the Science Data Processing Segment (SDPS) would handle processing, archiving, and distribution of the data from the EOS instruments. There was an extended *blackout* period from 1991–1993 for the procurement of the contract

[8] Of the 2763 users who responded to the ACSI survey in 2008 referred to previously [see Footnote 3], 41% indicated that HDF/HDF EOS was their preferred format, with the next highest preferences being for GeoTIFF (20%), NetCDF (8%), ASCII (8%) …

for ECS. During that time, with the exception of a few civil servant scientists, the scientific user community had to be kept in the dark about the procurement (i.e., requirements, evaluation criteria, status, etc.) in order to comply with regulations.

The first exposure the community had to ECS after the procurement *blackout* and contract award came during the System Requirements Review in August 1993. The review took place in Goddard's Building 8 auditorium to accommodate all interested individuals, and it was a full house. (The Data Panel was present, chaired by **Jeff Dozier** who had previously served as EOS Senior Project Scientist.) Some key events at that meeting highlighted the mood of that meeting and underscored the differences in thinking between the contractor, as well as NASA's engineering managers, and the science community. Almost immediately after the welcoming logistics announcements, came a presentation by **Marsh Caplan**, the Hughes Program Manager. Before Caplan got through his first few slides, Dozier asked him a question about the evolutionary requirements. While the Hughes presenters were detailing requirements for the system with an *assumed architecture*, the questions from the Panel were directed towards how changes would be accommodated. One of the presenters said he came from a military software development background where if a question about a requirement came up he would go to a colonel for clarification and he would get an answer. Clearly, NASA did not have a *requirements colonel* but rather wanted to have the science community provide input on requirements.

*Clearly, NASA did not have a **requirements colonel** but rather wanted to have the science community provide input on requirements.*

As the *assumed architecture* was discussed, the Panel asked how NASA and Hughes would ensure that the system was distributed. While we argued the system was indeed distributed (given the nine DAACs we had at that time), the Panel objected to its being merely geographically dispersed rather than logically distributed (i.e., they objected to the development's leading to a single system that would be replicated at each DAAC.) Also, given the size of the contract, some members of the Panel were expecting the contractor to have been ready with a system *"that would knock our socks off"* at the beginning of the contract, even though as a cost plus awards fee contract, the work on the contract would not begin until the contract was in place.

When the ECS contract began, the intention of the ESDIS Project was to place a version of ECS at each of the DAACs and migrate all of the data managed by *V0* to the ECS. However, soon after the start of the contract, it became clear that this was neither necessary nor desirable to do. The four DAACs (ASF, JPL PO.DAAC, ORNL DAAC and SEDAC) that did not have major data flows from EOS instruments were removed from the ECS requirements, and would develop and maintain their own *V0*-based systems to archive and distribute data within their responsibility. The remaining four DAACs (GSFC, LaRC, LP DAAC at EDC, and NSIDC) were to have hardware and software developed and installed by the ECS contractor.

Concluding Remarks (Part 1)

In this part of the two-part series, we have seen how the concept of EOSDIS originated over 20 years ago, some of the concerns that the science community had, how the name DAAC came into being, the development of *Version 0* EOSDIS, and the beginning of the ECS contract. In the next part we will cover the numerous reviews of EOSDIS, some of the hurdles encountered and the remedies that led to a successful deployment of EOSDIS, the evolution of *Community* capabilities, and the most recent evolution of the *Core* capabilities. ■

NASA Honor Awards Recipients—Langley Research Center

The Earth Observer would like to congratulate the 2009 Langley Research Center (LaRC) Science Directorate recipients of the NASA Honor Awards. The recipients listed are involved in LaRC Earth Science activities.

NASA's most prestigious honor awards are approved by the Administrator and presented to a number of carefully selected individuals and groups of individuals, both Government and non-Government, who have distinguished themselves by making outstanding contributions to the Agency's mission. For a complete description of each award, please visit: *nasapeople.nasa.gov/awards/nasamedals.htm.*

Distinguished Public Service Medal
Thomas A. Evert [Northrop Grumman Space Technology— *Clouds and the Earth's Radiant Energy System* (*CERES) instrument development*]

Distinguished Service Medal
Bruce A. Wielicki [Climate Science Branch]

Exceptional Achievement Medal
Xu Liu [Chemistry & Dynamics Branch]
Pamela L. Rinsland [Atmospheric Science Data Center]

Exceptional Public Service Medal
William H. Hunt [Science Systems and Applications, Inc.— *Cloud-Aerosol Lidar and Infrared Pathfinder Satellite* (*CALIPSO) Lidar*]

Exceptional Scientific Achievement Medal
Kuan-Man Xu [Climate Science Branch]

Exceptional Service Medal
Lin H. Chambers [Climate Science Branch]
Richard S. Eckman [Chemistry & Dynamics Branch]
James K. Geiger [Chemistry & Dynamics Branch]
Syed Ismail [Chemistry & Dynamics Branch]
Martin G. Mlynczak [Climate Science Branch]

Outstanding Leadership Medal
James H. Crawford [Chemistry & Dynamics Branch]
Gary G. Gibson [Climate Science Branch]
Lelia B. Vann [Science Directorate]

Group Achievement Award
LaRC NPOESS Atmospheric Sounder Testbed-Interferometer (NAST-I) Team—EAQUATE
NASA Langley Optical Active-passive Remote Sensing Instrument Suite (OASIS) Team—San Joaquin Valley AMI Field Mission
Surface Ozone Protocol for Global Learning and Observations to Benefit the Environment (GLOBE) Team—Creation of environmental learning tool

Operation Ice Bridge: A Journal of My Expedition to Greenland

Chris Chrissotimos, NASA Goddard Space Flight Center, cchrissotimos@sesda2.com

*Hi, my name is **Chris Chrissotimos**. I work for the Earth Observing System Project Science Office (EOSPSO). I am working on a project to create a video for NASA's Airborne Science Program that features an overview of the program and highlights some of the program's recent efforts and upcoming science campaigns. This past April I had the opportunity to travel to Greenland to observe an aircraft field experiment called Operation Ice Bridge (OIB) and gather some footage for the video. The purpose of the OIB campaign is to "bridge" the potential data gaps between the end of the Ice, Clouds, and land Elevation Satellite (ICESat) I mission and the launch of the ICESat II satellite mission currently planned for 2015. The campaign took place March 30–May 10, 2009 and was based out of Thule, Greenland. NASA was actively involved in this campaign with participants from Wallops Flight Facility (Wallops), Dryden Flight Research Center, Ames Research Center [Earth Science Project Office (ESPO)], and Goddard Space Flight Center. The National Oceanic and Atmospheric Administration (NOAA), the University of Kansas, and the University of Alaska also participated.*

During the campaign a series of science flights over Greenland, Alaska, and the Arctic Ocean took place. The aircraft were equipped with airborne lidar and radar sensors to measure sea ice thickness and glacial ice thickness, and sub-glacial lakes—information which can be used to verify similar measurements that ICESat makes. Another campaign will also be flown this fall focusing on science flights over the Antarctic Ocean and Antarctica.

*What follows is a journal of my experiences on the campaign from April 15–24. To find out more about Operation Ice Bridge please visit the NASA news article at **www.nasa.gov/topics/earth/features/greenland_flights.html**, and at the Ames ESPO homepage at **www.espo.nasa.gov/oib/**.*

April 15, 2009

Hurry up and wait!

Today was a runaround! Between packing for the trip and grabbing video equipment the day flew by in what seemed like a few seconds…and before I knew it, it was time to leave for the airport. I arrived at Baltimore/Washington International Thurgood Marshall Airport (BWI) for my flight as per instructions at 9:30 PM—even though the flight was not supposed to leave until 2:00 AM the following morning. Time had been racing by all day, but once I checked in, it seemed to come to a standstill. I've been on many flights in my life, and I've certainly been subjected to much longer layovers than the one I had today. It's just that I was really anxious to get started on my expedition to Greenland, and so it seemed like the wait was forever. I made good use of the time however, and called some friends that I had not spoken to in a while, which helped to ease my anticipation—at least a little.

April 16, 2009

What day is it?

Finally its 12:45 AM Thursday; we are putting our carry-on items through security and will be boarding shortly. I met up with **Seelye Martin** from the University of Washington School of Oceanography who is Principal Investigator (PI) for OIB. I also met **Rich Rogers**, a pilot from Wallops, as well as **Larry O'Connor** and **Sinead Farrel** from NOAA's Laboratory for Satellite Altimetry, who are both Sea Ice Co-PIs. After introductions and short discussions we boarded the plane. I was designated one of the 30 seats aboard the Air Force's DC-8. (NASA also has a couple of DC-8s minus the seating and instead has a science laboratory where scientists can accompany their instruments.) In preparation for takeoff the engines started, and we appeared to be on our way…or so I thought. The engine stopped and the pilot quickly informed us that one of the gyros on the DC-8 was faulty and was in need of repair. The good news was that it would only delay our departure for an hour. After another short delay, we embarked on our 6.5-hour journey to Thule Air Base.

Luckily, I was able to get some sleep on the plane (I usually have a hard time sleeping on a plane; I must have been tired from all the preparation and anticipation.) I woke up about an hour before landing, ate breakfast, and then we landed, and proceeded to spend the next hour *clearing orders*. After we finished, I met **Cate Fairchild,** the P-3 aircraft Mission Director for OIB from Wallops, who gave the new arrivals a short tour of the base. Cate also introduced us to the crew that was not flying on the current day's mission. We set up our meal cards and ate lunch at the mess hall. Then we travelled to the *BX*, the equivalent to an extremely small *Wal-Mart* that has a little bit of everything from food to clothes to flat panel TVs.

Group photo of the OIB team in front of NASA's P-3 airborne space laboratory. **Credit:** Chris Chrissotimos.

After dropping off the packages in my room, it was off to the hangar for the Operation Ice Bridge group photo, and a chance to meet the remainder of the team. They gave me a warm welcome in the hangar and then we quickly went outside again. Cate asked me to take a photo of the team lined up in front of the NASA's P-3 airborne space laboratory, so I began to set up my camera, Everyone seemed a bit anxious to get the photo done probably because it was around 0°F outside and once I realized this, I quickly finished setting up and snapped off a couple of shots to ensure that all of us didn't freeze to death. Then it was time for dinner, followed by the OIB mission briefing given by **Bill Krabill**, Principal Investigator for Arctic Ice out of Wallops. Finally, after a long day, it was off to bed for the early start tomorrow.

April 17, 2009

First flight

Well, I woke up this morning at 5:00 AM and figured I'd get a jumpstart on things. As I was heading down to the hall to brush my teeth, Cate greeted me and told me that they had received word that a National Science Foundation (NSF) staff member had gotten lost at the *Summit* camp[1] during whiteout storm conditions and that the P-3 and crew would join the search and rescue effort. I quickly prepared myself, ate at the mess hall, and made my way to the P-3 hangar.

After we boarded the plane, **Rich Rogers** gave the new staff (Seelye, Sinead, Larry, and myself) a safety tutorial. Shortly after the briefing it was decided that there were enough planes involved in the *Summit* camp search, so we proceeded with our scheduled science mission.

Once we were on our way, I was completely awestruck with what I observed on my first flight. We were flying at an altitude of roughly 1500 ft over northwest Greenland's glaciers, ice sheets, and sea ice on a flight that traversed between Thule and Upernavik. This low vantage point allowed you to see vast features, most of which I had never seen before. It was truly amazing and words don't really do it justice.

[1] *The Earth Observer* recently chronicled Lora Koenig's recent experience at *Summit* camp in a two-part article that ran in our March–April and May–June issues [**Volume 20**, **Issue 2**, pp. 13-17 & **Issue 3**, pp. 4-10.]

I was also taught a hard lesson pretty quickly on my first flight in Greenland. Though I had never suffered airsickness before in the many flights I have been on throughout my life, I had a "near miss" this time. Flying at such a low altitude produces a tremendous amount of turbulence as you fly down from the ice sheet and through the mouth of the glacier, and finally over the sea ice. Anyone who plans on shooting while in flight should heed this advice—if you are shooting through a viewfinder you should scrap the effort under heavy turbulence. You can't control it, so don't try. Luckily, I fought off the air sickness with a *Coke* though unfortunately some of my colleagues did not fare as well.

Video still from the cockpit of the P-3 flying at low altitude over a glacier in northwest Greenland. **Credit:** Chris Chrissotimos.

Pilot's view of the P-3's onboard navigation systems—which the pilots refer to as the "PacMan" system. **Credit:** Chris Chrissotimos.

One of the most interesting aspects of the equipment featured on the P-3 is the aircraft's navigation equipment. Pilots on the plane have nicknamed it the *Pac Man* system. It provides the aircrew the ability to view the scheduled flight path on a liquid crystal diode (LCD) monitor located next to the flight's primary pilot. The scheduled flight path is displayed as a series of light blue overlapping circles. On top of that set of circles is the actual progression of the aircraft displayed as another set of green overlapping circles led by an airplane shaped icon. The pilot also has the ability to zoom in or out of the flight path to view the path as closely as he likes. When the flight path is viewed close up, the pilot can make minute steering adjustments (down to 1-m-accuracy.) In a sense, it allows the pilot to adjust the current plane path to line up exactly with the planned science flight—just like how *Pac Man* makes turns in his maze to gobble up power pellets. This feature is extremely useful to precisely trace flight plan turns as it enables pilots and scientists to fly and accurately make measurements over the same flight path made in previous years. This translates into highly accurate and concise tracking of ice measurements over time.

April 18–19, 2009

Does the sun ever set in Greenland?

Thule Air Base shuts down normal airstrip operations for the weekend. This means that it is a necessary down day for the aircrew, and our team took advantage of the time. I got to catch up on some much needed sleep. I also had the opportunity to share a couple of meals with the crew and science team on Saturday, and meals are always a great opportunity to get to know people. They were such a great group, each with fascinating stories.

Mount Dundas framed by Thule Air Base's piping system. **Credit:** Chris Chrissotimos.

After lunch, I decided to take a stroll around the base and observed the piping system, which interestingly enough is above ground. The pipes are contained within heated tubes to ensure that the water lines do not freeze. The bases' buildings vary in size, but are primarily made up of doublewide trailers and seem to resemble a large recreational vehicle (RV) park. On my tour, I made my way down toward the sea ice and got a great panoramic view of Mount Dundas, which juts out into the bay. It is a magnificent relic of volcanic activity and an ancient sea.

An arctic fox on Thule Air Base. **Credit:** Chris Chrissotimos.

Since I was a glutton for taking pictures and exposing the camera to sub-freezing temperatures for more than a few minutes, I had to constantly battle with my camera batteries. I did my best to ration the batteries for the majority of the hike and managed to get a picture of an arctic fox running between two doublewides. After dinner I enjoyed TV in the lounge, talked to my wife, and wrote some e-mails. Later that night around 11:30 PM, I noticed that the sun was just starting to set (what a weird experience!) At this time of year in the Arctic, the sun doesn't really truly set; it goes close to the horizon and slowly begins to rise about an hour or two later. Despite how movies illustrate the problems with falling asleep under these conditions, room darkening shades and curtains do the job easily!

Sunday was very similar to Saturday with more rest and relaxation and a little exploration. I also helped out with the design of the OIB mission souvenir mug. After dinner, the whole team got together for a mission planning meeting for Monday. We decided that I should be in the cockpit of the P-3 for takeoff and landing for filming purposes. I was definitely excited. Cate also shared some good news with us—the search and rescue effort for the lost NSF staff member was successful. He was found shortly after his snowmobile was located and is now being sent to receive urgent medical attention in Nuuk, Greenland.

April 20, 2009

P-3 Pull back and Lasers

I got an early start today! After a quick breakfast at 6:00 AM, I hustled over to the hangar (about a quarter of a mile away from my quarters) with tripod and cameras. By 6:30 AM, I quickly set up the tripod to film the "pull back" of the NASA P-3 out of the hangar. It was a pretty photographic site observing what seemed to be a dimly lit hangar with giant doors that roll open to expose the Arctic landscape behind the runway. I thought it was cold inside the hangar but when the doors opened I realized just how drastic the temperature difference between the inside and the outside was. The change in temperature created mirage-like effects around the P-3 as it was hauled from the hangar onto the tarmac. I then boarded the plane and got setup in the cockpit for takeoff. It was a first for me, certainly an experience that I will never forget. It's now easy to understand why pilots do what they do; what a rush of excitement!

NASA's P-3 on the tarmac. **Credit:** Chris Chrissotimos.

Bill Krabill and flight crew in the P-3 cockpit. **Credit:** Chris Chrissotimos.

Today's flight is over the northeast corner of Greenland, and included a pass down the near center of the Greenland ice sheet. During the flight, I got the opportunity to learn more about the instruments that are onboard the P-3 for this mission. **Jim Yungel**, **Rob Russell**, and **Matt Linkswiler** are the onboard operators for the two Airborne Topographic Mapper (ATM) featured on the aircraft. They explained that the ATM is a scanning lidar that observes the Earth's topography. It also has been used since 1993 to measure the Greenland ice sheet and track the changing arctic and antarctic icecaps and glacier elevations; the ATM is also used to measure sea-ice thickness.

I can't say it enough—**everything** I saw was breathtaking. Both being a passenger and shooting in the cockpit for landing was another testament to pilots' skill set. All I have to say is that Rich Rogers' landing was one of the smoothest that I have ever had. Over the duration of the flight, I shot so much footage that I need to do a transfer tonight to ensure that I have space to shoot more tomorrow. At the evening meeting there was a discussion about which flight would be on tomorrow's agenda. Would it be a flight focusing on flying over sea ice in the Arctic Ocean or another glacier run? The call will depend on the weather report in the morning.

April 21, 2009 **Down Day**

After an early breakfast, it was a quick discussion about which flight would be optimal for the day. Based on the weather report, the proposed glacier flight would not be the best choice because of fogged out conditions that would make for a dangerous and difficult flight through the glacial mountain passes. Instead the sea ice flight would be taken. Bill suggested that it would be an ideal day for me to video the P-3's takeoff and landing from the ground and visit **Earl Frederick** in the Global Positioning System (GPS) shack.

The P-3 landing in Thule. **Credit:** Chris Chrissotimos.

Since the sea ice flight required a later takeoff than normal, it provided a little down time prior to the flight. This gave some of the crew the opportunity to look at some of the video "dailies" that I had already shot. The team seemed pleased with what I had captured, and Bill requested that I send some clips to **Andrew Roberts** at NASA Headquarters. Andrew is the Airborne Science Program Director, and wanted to use some of my clips in one of his upcoming presentations. Bill and Seelye helped me select some highlights and I quickly edited a short sequence, and left it to render while I went to film the takeoff of the P-3. The Thule Air Base staff was kind enough to allow me to film the takeoff from the top deck of the Air Traffic Control tower (another first for me!) It provided me with a near "eagle's eye" view of the entire runway allowing me to capture the P-3 ascending for today's mission.

After I got back I checked my video and sent it off to Andrew. I then met up with **Jeff Sigrist**, who had a mandatory down day as part of the P-3 flight crew, to head down to see Earl at the GPS shack. Once at *the shack* (so-named because it literally is an 8' x 8' building full of GPS equipment) down near Thule Pier, Earl gave me a tour of the equipment. He explained that the GPS radar setup outside the shack communicates with onboard P-3 navigation equipment operated and monitored throughout the flight by **John Sontag**. It ensures accuracy of the flight paths as the sensors are gathering science measurements during flight. Earl's job is to calibrate the GPS radar everyday and troubleshoot any issues on the fly in order to aid in the navigation of the P-3.

Earl Frederick calibrating the Operation Ice Bridge ground GPS antenna. **Credit:** Jim Yungel.

Sea ice in the Thule harbour. **Credit:** Chris Chrissotimos.

An arctic hare.
Credit: Jim Yungel.

This is vitally important since the data gathered will be incorporated with the GPS data to correct for the plane's movement and orientation to ensure accurate measurements. Upon return of the daily P-3 flights, the plane will do a calibration pass over *the shack* and airstrip before landing on the runway as a security measure.

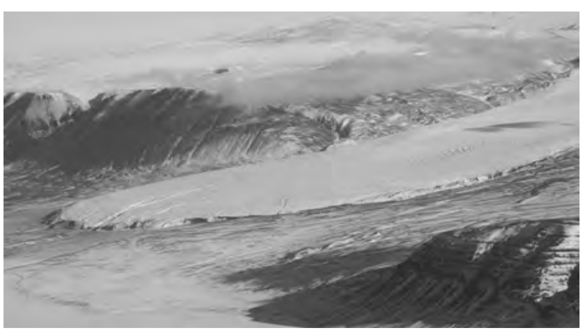
Outside *the shack,* Earl guided me through his daily routine of calibrating the antenna. Our tutorial was briefly interrupted when an Arctic hare passed by. Arctic hares are interesting animals that are quite big and have large hind legs to bound over deep snow. But back to the GPS antenna…During a lunch break, Earl escorted Jeff and me onto the nearby sea ice. It was another memorable experience. Of course most people have walked or skated on frozen ponds and lakes before, but this was actually the frozen ocean that I was walking on. I never thought I'd ever do that in my life. In the distance, I could see the nearby islands, and several icebergs still frozen in the sea ice from last year's winter freeze. (On a side note, Earl mentioned that only a few days earlier the annual local dog race competition and the base's "broom hockey" competition had taken place.) There was also some rifting ice nearby that had dragged some of the beach sand up with it which gave the mostly blue and white ice a brownish tinge. Another bonus of being on the sea ice was that it afforded another spectacular view of Mount Dundas.

Once we were back at *the shack* Jeff and I called for a base cab and rushed back to the airstrip to film the P-3's landing. Once at mission operations Mitch, the airstrip manager, personally drove me onto the airstrip (at a safe distance from the runway of course) to film the descent and arrival of the P-3; wow…that's another first to add to the list…what a day.

April 22, 2009

PARIS and Peterman

The next day the weather had cleared and we got the "green light" to fly over what Bill feels is *"some of the most spectacular scenery that you will see in your life."* After seeing it, I'd have to agree…



A glacier in northwestern Greenland can be seen far off in the distance in this photo. **Credit:** Chris Chrissotimos.

View of the PARIS Radar screen as the P-3 makes cross-sectional passes of Peterman Glacier. **Credit:** Chris Chrissotimos.

Today's takeoff from the cockpit was another unforgettable visual. From the ground, the sky was completely cloud covered as **Matt Elder**, today's P-3 pilot, ascended into it. In a split second, the clouds completely consumed the cockpit's windshields, obscuring the view lasting for 4–5 seconds, then magically opening up to a pristine blue sky.

Once we made it to one of our primary locations, I completely understood exactly what Bill had mentioned and was once again awestruck by the Humboldt, Peterman, Steensby, and Ryder glaciers and sea ice that I was witnessing in northwestern Greenland.

Back to the science…Several of today's flight paths were various cross section passes of the Peterman glacier. The Pathfinder Advanced Radar Ice Sounder (PARIS) radar, operated by **Marshall Jose**, is one of the featured payloads on the P-3 for this mission.

It greatly improves the visibility of internal layering and bottom topography of continental ice sheets and glaciers. PARIS' observations give us precise measurements of the depth of the slowly moving glacier. It was quite interesting to observe the variance of the ice sheet as it was digitally drawn on Marshall's monitor.

Directly across from Marshall sat **Ben Panzer** operating the University of Kansas' snow radar, an ultra-wideband radar system capable of direct measurement of snow thickness. It also gathered good data measurements of the ice sheet and sea ice.

During the u-turns necessary to make the glacial cross-sections we had the opportunity to get a glimpse of a grounded U.S. Army Air Force B-29 airplane that was stranded and abandoned in the glacial lakebed in 1947. We enjoyed more spectacular views of the glaciers as our flight continued, and returned to Thule Air Base in time for dinner.

April 23, 2009

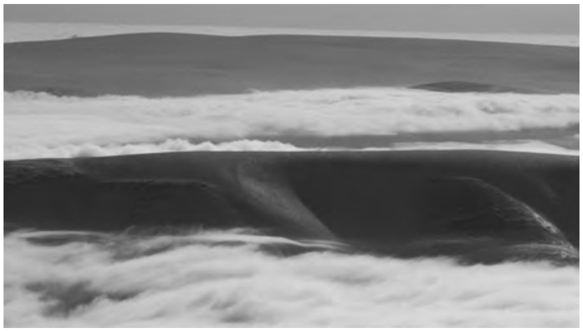
What to do on my last day in Thule?

I had a little bit of a debate this morning…I had the option to stay on the ground and record another set of ground-based takeoffs and landings or I could go back up for another science flight with the team. Even though I had recorded a fair amount of aerial footage, Bill easily persuaded me by informing me that we would be flying over some new glaciers that the team had not measured before. (Trust me, if you were in my position you would become addicted to flying through and over glaciers and probably have made the same decision.) On the way to the Dauguard–Jensen Glacier across central Greenland, we flew over the NSF's Greenland Ice sheet *Summit* camp—the same camp where the rescued NSF staff member was trying to get back to when he got caught in whiteout conditions a few days ago.

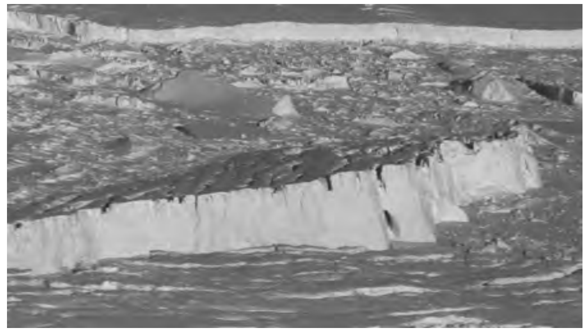
Panoramic view from P-3 cockpit. **Credit:** Chris Chrissotimos.

Once we were in east-central Greenland we surveyed the Dauguard–Jensen Glacier whose slowly travelling ice off the main ice sheet resembles an enormous cascading waterfall with steep increments. Despite the amount of video I took, and the sites I had already seen during my flight days, at one point I had to just stop recording. I was dumbfounded by what I was seeing. No video or pictures could do any justice to the 180° panorama that the cockpit offered another gem for my memories. As the day continued, we flew over and through the newly observed glacial canyons that Bill had mentioned. These teardrop-shaped glacier canyons were quite narrow and featured huge crevasses that seemed to loop around as we reached the end of each canyon.

The relatively quiet return flight from the east coast gave me enough time to gather more onboard operation shots and talk at length with the science team and flight crew. As we landed, it was comforting to know that a nice dinner was waiting for us. **Bill McGregory** of the flight crew had worked very hard on his mandatory down day to prepare a scrumptious spaghetti feast for everyone on the team. After dinner, we all took turns sharing pictures that we had taken. Within the next couple of days the



Layered clouds over Greenland's mountains and ice sheet. **Credit:** Chris Chrissotimos.



Calving front of a glacier. **Credit:** Chris Chrissotimos.

team will be moving operations and be based out of Sonde, Greenland for a set of science flights observing southern Greenland. Earl was doing an excellent job of making me feel guilty for leaving tomorrow. He was trying to convince me to stay for another week. I easily would have been up for it, if I didn't need to get the footage from this trip edited and ready for presentation at an upcoming conference only a week away. We all turned in for the night and I packed in preparation for my journey home.

April 24, 2009

Flight home

Glacial crevaces with the mountain ridge and icesheet in the background. **Credit:** Chris Chrissotimos.

Up like clock work at 5:00 AM, I quickly got ready for my return home. I checked and then double-checked that everything was packed. I made my way over to Mission Operations for check in at 5:30 AM for the weekly rotator flight back to the U.S. a few hours later. I figured that I would be one of the first there, but found out that I was at least 12th in line. Luckily enough both Bills, Rich, Larry, and Seelye where there waiting to get on the flight as well, so we had a good chat to pass the time. Once checked in we all made our way to the mess hall for our final breakfast in Thule, and said our goodbyes to the rest of the team, who will stay and finish the rest of the science missions. The homebound crew boarded the DC-8, and we were soon in the air. I sat next to Rich Rogers and, amazingly, we had six uninterrupted hours of conversation which ranged from photo techniques to old Navy and family stories. As the flight progressed the landscape beneath us gradually transformed from white ice and snow, to browns, and then to green as we made our way down the coast of North America. The colors looked so lush and saturated in comparison to the shades of blues, grays, and whites that I had experienced over the past week. I was a little sad when I realized all the scenery that I had left…but then I realized that I would spend the following week editing the footage and get to relive my experiences of my magnificent trip, and that's not so bad. Bill and Rich gave me a ride home and we discussed possibly doing this again sometime, and made plans for a visit to Wallops in the near future to keep gathering content for my DVD project. ■

P-3 Pilot Rich Rogers, self portrait. **Credit:** Rich Rogers.

HITRAN: A History

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In the 1960s, **Laurence Rothman** joined the Air Force Cambridge Research Laboratories near Bedford, Massachusetts. The lab had a project with the goal to detect and identify jet aircraft at a distance. However, the terrestrial atmosphere posed a problem to the interpretation of the signals—the usual infrared signature of jets would be distorted by the molecular absorptions of gases throughout the atmosphere.

The concept of the project was in many ways typical of leaps in scientific progress: the confluence of several new technologies at the same time. These new technologies included the maturation of computers capable of reading databases, high-resolution spectroscopic techniques in the laboratory (such as *Fourier transform* spectrometers), new theoretical techniques for dealing with molecular absorption properties and transmission, and new infrared detectors that could be used for acquiring target signatures.

In essence, this database is like a fingerprint for the molecular absorption in the atmosphere, and the archive can be likened to the genome project in biology.

At the initial stages of the development of the spectroscopic database, a group of experts on the principal absorbers in the terrestrial atmosphere was formed, under the direction of **John Garing** and **Bob McClatchey**. It was code-named *GOATS*, standing for Group On Atmospheric Transmission Studies. The group recognized that a database of the major absorbers would provide a map of the atmosphere, and coupled with transmission calculations, would provide the location and abundance of gases like water vapor, carbon dioxide, and methane. With this initiative, the HIgh-resolution TRANsmission molecular absorption database, or HITRAN, was conceived. In essence, this database is like a *fingerprint* for the molecular absorption in the atmosphere, and the archive can be likened to the genome project in biology.

The first edition of HITRAN came out in 1973 on magnetic tape. It contained the spectral lines of seven major absorbers in the infrared—water vapor, carbon dioxide, ozone, nitrous oxide, carbon monoxide, methane, and oxygen. Rothman assumed direction of the project in 1975, and soon the database expanded to include more gases and spectral coverage from the microwave to visible regions of the electromagnetic spectrum. Part of this expansion was enabled by funding from the Department of Transportation (DOT), which at the time, was concerned about the effects of the proposed supersonic transport (SST) on the upper atmosphere.

The HITRAN Advisory Committee (including NASA observers)

Then, in the 1980s, NASA became interested in using HITRAN in its remote sensing studies. Thanks to NASA support, the database has been extended considerably. The parameter set has expanded from the original four—*wavenumber of transition*, *line intensity, collision-broadened width*, and *lower state energy*—and the accuracy of parameters in the database has continually increased. Cross-section data are available for numerous heavier molecules such as anthropogenic trace gases with the potential for global warming and ozone depletion. High-resolution line-by-line codes and moderate spectral resolution band-model codes employ HITRAN as input in order to perform remote-sensing calculations. They have taken advantage of the new properties in HITRAN to increase their effectiveness.

HITRAN has supported measurements from Earth Observing System (EOS) instruments like the Atmospheric Infrared Sounder (AIRS), the High-Resolution Dynamics Limb Sounder (HIRDLS), Measurements of Pollution in the Troposphere (MOPITT), and the Tropospheric Emission Spectrometer (TES). The database is important to studies investigating the abundance and distribution (geographic, altitudinal, and temporal) of man-made chemicals in the atmosphere.

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Today, the 2008 version of HITRAN contains several million line transitions for 42 different molecules. There are additional molecules represented by infrared cross-sections, and similar sets of both line parameters and cross-sections in the ultraviolet region. An analog database, called HITEMP, contains high-temperature spectroscopic absorption parameters.

Rothman directs the HITRAN and HITEMP projects from the Atomic and Molecular Physics Division at the Harvard-Smithsonian Center for Astrophysics in Cambridge, MA. However, the effort is truly international. There is an international HITRAN advisory committee composed of about 12 members who are not only the major contributors of data (both experimental and theoretical), but who also perform validation tests. These tests are most frequently applied to NASA, the European Space Agency (ESA), Canadian, and Japanese satellite remote-sensing retrievals.

To obtain instructions to access the compilation, submit a *Request Form* at: *www.cfa.harvard.edu/HITRAN*. The site also includes facts and frequently asked questions about the database. The details of the current HITRAN edition can be found in the article **L.S. Rothman, et al.**, "The HITRAN 2008 molecular spectroscopic database," *Journal of Quantitative Spectroscopy & Radiative Transfer*, vol. 110**,** 533-572 (2009).

Note that ongoing improvements to many molecular bands are still being made. Updates, improvements, and corrections to the edition are posted in the "HITRAN UPDATES" sub-page of the HITRAN website (*www.cfa.harvard.edu/HITRAN/*). Please email any problems encountered, as well as successes or suggestions, to **Laurence Rothman** at: *lrothman@cfa.harvard.edu*. ■

featured articles

NASA "Treks" to Iowa for Problem-Solving Competition

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Students from around the world gathered to participate in the 30th Odyssey of the Mind (OM) World Finals, a creative problem-solving competition held at Iowa State University, in Ames, IA, May 27-30. These students had advanced from competitions held earlier in the year at local, regional, state, or country levels and were in Iowa to compete for the title of World Champion.

The 2009 World Finals marked the ninth year NASA's Earth Observing System Project Science Office (EOSPSO) sponsored a long-term problem.

The 2009 World Finals marked the ninth year NASA's Earth Observing System Project Science Office (EOSPSO) sponsored a long-term problem. This year's problem, *Earth Trek*, focused on generating awareness of environmental changes and their impacts. Each team designed and built a small vehicle capable of visiting four locations. Teams determined the environments to be visited—e.g., rain forests, beaches, and mountain ranges. As a vehicle left one location and traveled in a group of vehicles to another place, its appearance changed. Team performance was rated on visits to locations, environments chosen, and changes in vehicle appearance.

Other NASA-featured activities at World Finals included the Earth Science *E-Theatre*, a dynamic theater-style presentation that showcases Earth observations and visualizations in high-definition format. The *E-Theatre* features satellite launch animations, as well as visualizations made from NASA Earth science satellite data.

Over the past year, NASA supported OM's preliminary competitions by posting Earth science information on a special web site hosted on NASA's Earth Observatory—*earthobservatory.nasa.gov. The Earth Observatory* serves as a host to many teacher and student learning modules. Web links were provided to assist students in developing solutions to problems facing Earth.

Steve Graham welcomes the OM participants on behalf of NASA. **Credit:** Chris Chrissotimos.

Out of the 148 teams participating in *Earth Trek* at World Finals, the following won top honors in their division:

Division I

1st Place: West Vincent Elementary School—Chester Springs, PA
2nd Place: Shanghai Foreign Language Primary School—Shanghai, China
3rd Place: Afton Elementary School—Morrisville, PA
4th Place: Greenlawn Elementary School—Bainbridge, NY
5th Place: Horizon Elementary School—Johnston, IA
6th Place: J.Y. Joyner Elementary School—Raleigh, NC
6th Place: Sanfordville Elementary School—Warwick, NY

Division II

1st Place: Pennridge South Middle School—Perkasie, PA
2nd Place: Magnolia Intermediate School—Grass Valley, CA
3rd Place: Corunna Middle School—Corunna, MI
4th Place: Ho Fung College—Hong Kong, Hong Kong
4th Place: Formus—Monterrey, Mexico
5th Place: Abington Heights Middle School—Clarks Summit, PA
6th Place: Georgia Military College Prep School—Milledgeville, GA

Opening Ceremonies of the 2009 Odyssey of the Mind World Finals, held at the Hilton Coliseum on the campus of Iowa State University. **Credit:** Chris Chrissotimos.

6th Place: Halstead Middle School—Halstead, KS
6th Place: Northern Lakes Community Church—Traverse City, MI

Division III
1st Place: Hayes Foundation—Castleton, VT
2nd Place: St. John Neumann High School—Williamsport, PA
3rd Place: Corunna High School—Corunna, MI
4th Place: Abington Heights High School—Clarks Summit, PA
5th Place: Tempe Preparatory Academy—Tempe, AZ
5th Place: Irondequoit High School—Rochester, NY
6th Place: Bear River High School—Grass Valley, CA

Division IV
1st Place: Davenport University-Lettinga—Grand Rapids, MI
2nd Place: University of Georgia—Athens, GA
3rd Place: Penn State University—State College, PA

The Corunna Middle School (Corunna, MI) and Formus (Monterrey, Mexico) teams also received the prestigious Ranatra Fusca Award—an award given to OM teams who exhibit exceptional creativity, risk-taking, and out-of-the box thinking.

NASA reaches over two million students, teachers, parents, and coaches around the world through its sponsorship of an OM problem, stimulating interest in learning about Earth system science among all ages. The OM program, founded in 1978, is an international educational program promoting team effort and creative problem solving for students from kindergarten through college. Over 850 teams from the U.S. and other countries, including China, Poland, Canada, South Korea, Mexico, and Germany, participated in World Finals this year.

NASA reaches over two million students, teachers, parents, and coaches around the world through its sponsorship of an OM problem, stimulating interest in learning about Earth system science among all ages.

NASA's Earth Science Division conducts and sponsors research, collects new observations from space, develops technologies, and extends science and technology education to learners of all ages. Through a better understanding of our home planet, NASA hopes to improve prediction of climate, weather, and natural hazards using the unique vantage point of space.

For the 2010 OM Competition, NASA's EOSPSO will sponsor **Problem 1**: *Nature Trail'R*. To access the OM official web site, visit: *www.odysseyofthemind.com.*

meeting/workshop summaries

NASA's contribution to the Group on Earth Observations (GEO) Global Agricultural Monitoring System of Systems

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NASA and the U.S. Department of Agriculture (USDA) have a long history of working together to monitor global agriculture from space that dates back to the 1970s. One of the most recent initiatives the two agencies have participated in is the Global Agricultural Monitoring (GLAM) Project. GLAM is a joint research initiative between USDA Foreign Agricultural Service (FAS), NASA Goddard Space Flight Center (GSFC), the University of Maryland, College Park (UMCP) and South Dakota State University. ***Chris Justice*** *[UMCP] and* ***Jim Tucker*** *[GSFC] serve as Co-PIs of the GLAM Project. As part of the GLAM project Justice receives support from NASA to lead the Agricultural Monitoring Task of the Group on Earth Observations (GEO) [****Task Ag-07-03****]. The aim of this task is to bring together the international agricultural monitoring community to form a Community of Practice (CoP) that will develop and implement an integrated global agricultural monitoring* ***system of systems*** *building on existing systems and international Earth Observing assets. The GEO Agricultural Monitoring CoP has convened a series of workshops to bring together the agricultural monitoring community to develop an implementation plan for this task. The most recent workshop on building a Global Agricultural Monitoring System of Systems (GLAMSS) was convened February 11-13, 2009 in Beijing, China, and hosted by the Institute of Remote Sensing Applications (IRSA) at the Chinese Academy of Sciences (CAS). The meeting was attended by close to 100 participants representing 51 national and international agencies and organizations concerned with agricultural monitoring.*

Introduction

Global agricultural production faces increasing pressure from more frequent and extreme weather events such as floods and droughts, increasing economic pressures, rising energy costs, civil conflicts, rapid population growth, changing diets, and land degradation. All these pressures combine to place increasing *strain* on society's ability to provide an adequate and safe supply of food for an ever-increasing global population. Simply put, there is a limit on the planet's capacity that we may be rapidly approaching, and we must find ways to increase our world's agricultural productivity to meet the growing demands of society.

In response to the growing *stress* on our world's food supply, the past few years have seen a dramatic increase in the demand for timely, comprehensive global agricultural "intelligence." Global agriculture monitoring systems are critical to providing this kind of "intelligence." Being able to see the "big picture" can lead

Attendees at the GEO Agricultural Monitoring Workshop Beijing, February 2009.

to the development of fair and efficient global market trading (e.g., carbon and agriculture commodities), as well as effective policies on critical issues of today—e.g., climate change, biofuels, and economic growth. Effective global agriculture monitoring can provide essential economic and environmental indicators through timely, comprehensive, reliable, and objective information on global croplands distribution and on crop development and condition as the growing season progresses.

For this reason, the GEO has targeted *Agriculture* as one of the applications where enhanced international cooperation has the potential to provide a major benefit to society (*www.earthobservations.org/*) and NASA has chosen Agriculture as one of its seven Applied Science Program themes.

There are already a number of established national and international agricultural monitoring systems, that play a fundamental role in the decision-making processes that govern food aid and agricultural products in the global market. Some of these systems use a combination of ground-based and satellite-derived observations. But up until now, there has been little communication between these systems and GEO (and NASA) hope that enhanced observations and better coordination will help meet the increasing demand for reliable information.

The goal of the GEO, as an intergovernmental framework, is to enhance the availability and use of Earth observations through international coordination, exploiting the growing potential of Earth observations to support decision making in an increasingly complex and environmentally stressed world. As of March 2009, GEO's members included 77 governments, the European Commission, and 56 intergovernmental, international, and regional organizations.

NASA's Involvement in Agriculture Monitoring

NASA has a long history of directly supporting agriculture monitoring. NASA and USDA worked together to develop the first large-scale effort to monitor agriculture from space in the 1970s—the Large Area Crop Inventory Experiment (LACIE) Program. They followed up this effort with the Agriculture and Resources Inventory Surveys Through Aerospace (AgRISTARS) program initiated in 1980. Building on this experience NASA is enhancing the agricultural monitoring and the crop-production estimation capabilities of the USDA Foreign Agricultural Service (FAS) using the new generation of NASA satellite observations. The GLAM project is building one of the leading, most comprehensive global agriculture monitoring systems that serves as an integral component to the USDA's FAS Decision Support System (DSS) for agriculture. Presently, the FAS is the only operational provider of timely, regular, global crop production estimates.

The GLAM Project

The GLAM Project is building a new near-real time global agricultural monitoring system based on NASA science data. The system will be a comprehensive data management system for remote-sensing based global agriculture monitoring; located at GSFC, the system will be owned and operated by the FAS. The system currently includes a customized web-based information-analysis and data-delivery system developed combining the capabilities of the Global Inventory Mapping and Monitoring System (GIMMS) Advanced Very High Resolution Radiometer (AVHRR) system, the Moderate Resolution Imaging Spectroradiometer (MODIS) Advanced Processing System [MODAPS], and the MODIS Rapid Response System. The system enables the FAS analysts to monitor crop growing conditions and to locate and track the factors impairing agricultural productivity. This system currently provides FAS crop analysts with time series AVHRR Global Area Coverage (GAC) data (1981–present) and MODIS vegetation indices (2000–present) and MODIS Rapid Response (250-m imagery within 2–4 hours of overpass).

GLAM is also working on new products custom designed to meet FAS needs, including a dynamic, interactive global croplands likelihood map at 250-m resolution. The GLAM system, through its web-based technology, analysis tools, and NASA datasets, has improved the USDA's FAS operational capabilities to monitor global crop production and has become the primary tool that FAS analysts turn to for monitoring crops and for forecasting yield and production of the major crops grown worldwide. The extensive web-accessible Database Management System (DBMS) provides a substantial opportunity for a range of applications requiring frequent, timely, global moderate resolution data. Future plans include expanding the capability to fuse coarse and moderate resolution satellite data and preparing the system for data from instruments planned for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible Infrared Imager Radiometer Suite (VIIRS) and the Landsat Data Continuity Mission (LDCM). NASA and USDA are making contributions from the GLAM Project to the larger GEO GLAMSS effort.

GEO Agriculture Monitoring Workshops

Current agricultural monitoring systems operate at a variety of scales with two primary foci: (1) food security and famine early warning; and (2) production monitoring for ensuring stable global and national markets of agricultural crops.

While some of these systems are quite effective, there are large disparities in the monitoring capabilities of developed and developing nations. The agricultural statistics generated by the various systems vary in terms of levels of accuracy, availability, transparency, and timeliness. There is currently little coordination between these systems, despite the fact that they share common data needs and provide similar agricultural information to decision makers. In addition to these systems that identify anomalies and estimate agricultural production, there is a growing interest in establishing new systems to monitor changes in agricultural land use.

Recognizing the importance of improving the ability to monitor agricultural systems and the limited extent of international cooperation, members of the GLAM team, with NASA support, helped to organize a set of well-attended, international GEO agriculture monitoring workshops. The first two workshops were joint Integrated Global Observations for Land (IGOL) – GEO workshops that the Food and Agriculture Organization (FAO) hosted in Rome, Italy in 2006 and 2007. Representatives of major agricultural monitoring groups from around the world, the agriculture research community, and the major space agencies attended these first two meetings. At these workshops an initial strategy for the *GEO AG-07-03* task was outlined and the GEO Agricultural Monitoring Community of Practice (CoP) was formed in order to design and implement a Global Agricultural Monitoring System of Systems (GAMSS). At the workshop, the participants agreed that three types of agricultural monitoring activities should be the primary focus for the task: (1) monitoring of agricultural production; (2) monitoring for famine early warning; and (3) monitoring of agricultural land use change. The participants also developed an implementation plan and a set of requirements for Earth observation for agriculture.

The 2009 GEO Beijing Workshop on Developing an Agricultural Monitoring System of Systems

In February 2009, another major planning workshop took place that focused on developing an agricultural monitoring system of systems. This event was held jointly with the partner GEO Tasks on Agricultural Risk Management (*AG 07-03b*) and Agricultural Capacity Building (*AG-07-03c*). Over 100 attendees representing more than 50 national and international organizations concerned with agricultural monitoring and global food security participated in the workshop. The goals of the workshop were to:

- refine the requirements, the system components, and the data policies and practices needed for an effective agricultural monitoring system;
- outline a best practices document on agricultural monitoring and risk management;
- update and refine the agriculture monitoring task work plan and the 2015 task targets; and
- increase the visibility and participation of Chinese agricultural monitoring efforts.

Workshop Summary

The workshop opened with an introductory session that included talks by the Deputy Director of the Bureau of International Cooperation of CAS and by the Deputy Administrator of USDA/FAS on projections and economics of global food supply and demands.

Chris Justice from the GLAM team and lead of the *GEO AG-0703* task provided a vision for the GEO GLAMSS. A series of overview presentations followed that reviewed the state of the science, and each focused on one of the four main functions of an agricultural monitoring system which include: (1) agricultural production monitoring; (2) famine early warning; (3) monitoring of agricultural land-cover change; and (4) seasonal to annual agricultural forecasting and risk reduction.

John Townshend [UMCP—Integrated Global Observations of the Land (IGOL)] presented a strong case for establishing a free and open data policy in order to allow for effective implementation of a monitoring system of systems. Representatives from the Committee on Earth Observing Satellites (CEOS), IRSA and the World Meteorological Organization (WMO) also gave overview presentations on current and future systems and data initiatives for agricultural monitoring. A session on the vision and goals for a GLAMSS focused on the near-term priorities, challenges, opportunities, and future directions for agricultural monitoring.

A special session highlighted Chinese efforts in agricultural monitoring and included presentations on the three operational Chinese agricultural monitoring systems operated by CAS: *CropWatch*, the Chinese Ministry of Agriculture, and the China Meteorological Administration. The last day of the workshop included a special summary session for Chinese policy makers and included presentations from the former Minister of the Environment, the Vice-President of CAS, a Chinese Meteorological Administration administrator, a member of the Congress of the Ministry of Agriculture, and a deputy director from the National Bureau of Statistics. The participants of this session were enthusiastic about the progress of GEO agricultural monitoring, promised strong Chinese support and cooperation, and proposed hosting a dedicated GEO Agricultural Monitoring Center.

Through a series of breakout sessions and discussions the workshop participants:

- discussed the adequacy of the current observation systems for agricultural monitoring;
- developed an outline for a best practices report for agricultural monitoring;

- identified the priority observation enhancements for *in-situ* and satellite components of the monitoring system; and
- developed a near-term implementation plan for the GEO agricultural monitoring task and the 2015 task targets.

GEO Task 0703 Near-Term Implementation Plan

Through the discussions and breakout sessions the CoP proposed a series of activities that were grouped into four near-term initiatives:

A Production, Acreage, Yield (PAY) multi-source online database initiative

At present four different groups generate agricultural statistics on a regular basis for multiple countries: the USDA's FAS, Joint Research Center (JRC), the Italian Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) Joint Research Center's (JRC) Monitoring Agricultural ResourceS (MARS) Unit, the Chinese Institute of Remote Sensing Applications' (IRSA) *CropWatch*, and the United Nations Food and Agricultural Organization (FAO) Global Information and Early Warning System (GIEWS). The crop statistics from these programs are a critical factor in determining global commodity prices and identifying countries in need of food aid. To allow for comparisons between crop statistics generated by these agencies, the participants decided to develop a common centralized online database of Production, Area, and Yield (PAY). This PAY database will enable identification of agreements and disagreements in national level crop statistics, providing a convergence of evidence for similar statistics and helping identify areas that should be looked at more carefully where statistics differ significantly. Initially the database will be populated with national level estimates from the four programs identified above and will later be expanded to include statistics from individual countries.

The Joint Experiments on Crop Assessment and Monitoring Initiative (JECAM)

The goal of the JECAM experiments is to facilitate the intercomparison of monitoring and modeling methods, product accuracy assessments, data fusion, and product integration for agricultural monitoring. The plan to accomplish this is to set up a number of regional experiments in cropland pilot sites around the world that are representative of a range of agricultural systems. The idea is to collect time-series datasets from a variety of Earth observing satellites and *in-situ* data sources at each site. To this end the Committee on Earth Observing Satellites (CEOS,) which is the space arm of GEO, and other data providers are supporting this activity with the acquisition and timely provision of data for the experiments.

The objectives of JECAM are to compare data from disparate sources, methods, and results over a variety of cropping systems; to reach a convergence of the approaches; and to develop monitoring and reporting protocols and best practices for different agricultural systems. It is hoped that these comparative experiments will enable international standards to be developed for data products and reporting. JECAM–China was proposed at the workshop and datasets for this site are currently being assembled and will be openly distributed to the CoP. Several other regional experiments have been proposed and are currently in the design phase. These include JECAM–Canada, JECAM–Argentina, JECAM–Brazil, and JECAM–Ethiopia.

The minimum requirements for JECAM participation include:

- leadership by a Space Agency and a half-time scientist for the overall experiment coordination;
- a pilot site manager for each site;
- a full-time data analyst to help with data intercomparisons;
- five JECAM workshops to be held over the next three years; and
- a commitment from data providers to supply satellite data for the test sites.

It was recommended that the following categories of Earth observing datasets be provided by the GEO-partner space agencies:

- *Very high resolution imagery* for area estimate production and crop mapping validation. It is desirable to have three acquisitions over samples distributed in the site [e.g., from the Advanced Land Observation Satellite (ALOS) 2.5-m sensor and Resourcesat Very High Resolution (VHR) sensor.]
- *Wide swath instrument* for crop mapping and crop monitoring: all possible acquisition [e.g., from the Advanced Wide Field Sensor (AWifs) and HuanJin-1.]
- *Coarse resolution data* for crop condition monitoring on a daily basis [e.g., from MODIS and Envisat Medium Resolution Imaging Spectrometer Instrument (MERIS).
- *S data* for crop area indication in cloudy regions: all possible acquisitions [e.g., from Envisat Advanced Synthetic Aperture Radar (ASAR) and ALOS Phased Array type L-band Synthetic Aperture Radar (PALSAR).

The Coordinated Data Initiatives for Global Agricultural Monitoring (CDIGAM) Initiative

A priority for building a global monitoring system is accessibility to timely and frequent satellite data during the growing season, and ensuring the continuity of these observing systems. To that end, several data initiatives have been identified under CDIGAM. At present, NASA's MODIS data are one of the primary data sources that the main agricultural monitoring systems rely on, and thus both the timely delivery of these data and the continuity of this data class are fundamental for the success of a global agricultural monitoring sytsem. A partnership with the GEO Task *DA 0903,* led by **Tom Loveland** [USGS] and **Jeff Masek** [NASA], has been fostered to develop a global moderate resolution, ortho-rectified dataset (60–30 m) from multiple international data sources for 2010. This will build on the previous NASA/USGS Global Land Surveys for 1990, 2000, and 2005, and will provide data needed for monitoring agricultural land-use change. Under CDIGAM the FAO GIEWS program is leading an effort to compile the best available information on global agricultural areas, crop calendars, and cropping systems. The USAID Famine Early Warning System (FEWS) and the World Meteorological Organization (WMO) are leading an effort to identify critical gaps in the current *in-situ* meteorological observations for Africa and to explore the means that can be used to fill these gaps. Other data initiatives that have been proposed include the development of a global field-size database using multi-resolution data and the formulation of a coordinated global satellite data acquisition strategy for agricultural areas.

A free and open data policy remains a high priority for the Global Agricultural Monitoring community and will to a large degree determine the success of the Task and ultimately GEOSS as a whole. The GLAMSS CoP is committed to promoting an equitable data policy, allowing sharing of data amongst the community. Recent developments such as the free and open access to Landsat data and the entire Landsat archive by the USGS, the continued free and open availability of MODIS data by NASA, and recent data commitments by China and Brazil provide some positive steps by data providers in the right direction.

The Global Agricultural Monitoring System of Systems (GLAMSS) Thematic Workshop Series [GTWS] Initiative

Additional community workshops are needed to discuss a number of thematic and methodological topics to improve communication amongst the CoP, to develop *best practices* and standards, and to encourage cooperation and coordination. A number of thematic workshops have already been held by the CoP. NASA, through the GLAM project, has been instrumental in organizing and supporting these workshops. In 2008 the ISPRA Joint Research Centre (JRC) hosted a workshop on crop area estimation. A *best practices* document developed at this workshop can be found at: *mars.jrc.ec.europa.eu/mars/Bulletins-Publications/Best-practices-for-crop-area-estimation-with-Remote-Sensing*. The JRC also hosted a workshop on satellite rainfall estimation in 2008 and a follow-up workshop will be held later this year. Canada is hosting a thematic workshop on the use of synthetic aperture radar/optical agricultural monitoring, to be held in Banff, Canada, in October 2009 (*www.cgeo.gc.ca/announce/sar-ros-eng.pdf*). India is hosting a joint workshop of the ISPRS WGVIII/6 and the GEO Task *Ag 0703* on climate change and agriculture to be held at the ISRO Satellite Applications Center (SAC) in Ahmedabad, in December 2009 (*www.commission8.isprs.org/wg6*).

Selected Workshop Recommendations

The workshop recommendations fall into three primary categories: (1) recommendations to the GEO Secretariat and working groups; (2) recommendations to the GEO partners including CEOS as the satellite arm of GEO and WMO as the primary international *in-situ* observation coordination body; and (3) recommendations to the GEO agriculture monitoring CoP. The primary recommendations are specified below:

- The GEO Secretariat should establish a GEO Data Policy that allows for free, open, and timely access to satellite data and products for global agriculture monitoring in order to enable the implementation of the GEO *Ag 0703* task.
- CEOS should help to ensure the continuity of Earth observations which are a requirement for operational agricultural monitoring.
- Operational agricultural monitoring necessitates the timely availability and access to satellite data that depends on using multiple sources of satellite data with different temporal and spatial resolutions, so CEOS and WMO should work to improve data accessibility and interoperability.
- To achieve the desired enhancements to global agricultural monitoring the Agricultural Monitoring Community of Practice should:
    - Develop standards to be used for agriculture monitoring including a set of standards for both *in-situ* and Earth observing satellite (EO) data products, collection procedures, metadata, and product accuracy.
    - Assist the integration of satellite data into operational monitoring systems in developing countries.
    - Enhance integration of EO derived biophysical and physical measures into crop yield models.
    - Enhance timeliness of EO and *in-situ* data delivery.
    - Compile a *best practices* sourcebook for agricultural monitoring to address issues of crop production estimation, agricultural land-cover change, famine early warning, and seasonal to annual forecasting and risk reduction.

- Increase multi-agency national crop assessment missions.

- To achieve sustainable capacity building in support of global agricultural monitoring, the Agricultural Monitoring Community of Practice should focus on the following general areas:
  - Developing and supporting data sharing (exchange) protocols in countries with less developed information systems;
  - Ensuring optimal utilization of available observations (*in-situ* and satellite data) in support of agricultural monitoring through pragmatic training programs based on "best-practice" by CoP; and
  - Focusing on sustainable capacity building strategies that leverage existing resources with the support of satellite operators.

2015 Task Target

As part of the GEO Secretariat coordination, a set of 2015 Targets have been developed for each GEO Task. During the workshop the targets for the GLAMSS were updated as follows:

- Develop a coordinated global agricultural monitoring system of systems, combining information from multiple observing and reporting systems, providing timely, objective, reliable, and transparent information to support global food security.
- Enhance monitoring and modeling systems to utilize Earth observing capabilities to provide timely, objective, reliable, and transparent agricultural statistics and information at the national level.
- Establish a global coordinated early warning system of systems to anticipate shortfalls or anomalies in agricultural production to facilitate timely intervention and the provision of advice on appropriate actions.

Conclusion

The workshop was successful and constructive and concluded that through commitment from the space agencies, the international community, and national governments, the realization of an effective Global Agricultural Monitoring System of Systems is attainable in the near future. The essential components for such a monitoring system have been largely demonstrated, whether it be in the research domain, in operational prototypes, or in operational systems. What is needed now is support from the international GEO partners in terms of providing open data policies and timely data delivery, ensuring continuity of Earth observing missions, enhancing *in-situ* networks, making a commitment to capacity building, and to the active participation of the community of practice in carrying out the specified task. Achieving this kind of support will lead directly to significant societal benefits including increased global food security and improved agricultural management. Given NASA's open data policy, its long-term partnership with the USDA to improve agricultural monitoring from space and enhance our national agricultural monitoring capability, and its current leadership role in GEO, it is in a strong position to contribute to the emerging Global Agricultural Monitoring System of Systems and the associated societal benefits. ■

EOS Science Outreach Team Wins NASA Honor Award

Our EOS Project Science Office (EOSPSO) education and outreach group (**Winnie Humberson**, Task Lead) received the **2009 NASA Public Service Group Achievement Award**. This team award is given to a group of non-government personnel for outstanding accomplishments while participating in a significant program or project that has contributed substantially to the NASA mission. **Robert Strain**, Goddard's Center Director, presented the award to Humberson (who received on behalf of the entire team) at the 2009 Honor Awards Ceremony held on June 3. The Science Mission Directorate (SMD)/EOS team was cited for its "*outstanding contributions to outreach, promoting NASA's science and technical accomplishments, and its positive impact on society.*"

NASA LCLUC Spring Science Team Meeting Summary

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Land-cover/land-use change (LCLUC) remains the most visible manifestation of global change around the world. It is the subject of an integrated research program using NASA's assets to address the intersection between the physical and human dimensions of global change. The LCLUC Spring Science Team Meeting was held at the Bethesda, MD Marriott from March 31-April 2, 2009, with 89 participants, 27 presentations, and 27 posters. The purpose of this meeting was to hear results from funded research projects on the various impacts of land-use change and to update the community on related program developments. In addition, a special session was held to discuss the future directions for the human dimension of the program. A full day session was given for presentations and discussion of observations and data for LCLUC research.

LCLUC Spring Science Team Meeting Participants

Opening Session

The opening session included a program update from **Garik Gutman** [NASA Headquarters (HQ)—*LCLUC Program Manager*] who described recent proposal selections and a new Principal Investigator (PI) database to help with program reporting. This was followed by a presentation from **Mike Freilich** [NASA HQ—*Earth Science Division Director*] on how land-cover/land-use change science plays in to NASA's Earth Science Program. Freilich mentioned the FY09 budget and the stimulus augmentation; the need to complete the five Earth science missions now under development, including NPOESS Preparatory Project (NPP) and Landsat Data Continuity mission (LDCM); and the sequence of the Decadal Survey Missions. T**he take-home message from the latter presentation focused on outreach, namely that the science community needs to communicate what we are doing and why it's important, achieve technical and substantive success in our activities, and articulate what we have discovered or demonstrated and its implications.** The recent LCLUC brochure (*lcluc.umd.edu/Program_Information/brochure.asp*) is a step in this direction.

Science Presentations

The science presentations at the meeting took the form of a review, each with contributions from several program PIs, in the context of the broader research sub-discipline in question. These review presentations can be downloaded from: *ftp://ftp.iluci.org/LCLUC_APR2009/*. A sample of the reviews is provided below.

In a review of LCLUC impacts on regional hydrology in Central Asia, **Geoff Henebry** [South Dakota State University (SDSU)] pointed to three significant aspects of land change within this region, namely the continued land and water degradation resulting from irrigated cultivation in the Aral Sea Basin, the deintensification of agriculture in the semi-arid zone of northern Kazakhstan, and the collapse of livestock production within the region. These land-use changes have been driven by policies and institutions. Agricultural land-use practices have had a big impact on regional hydrology during the past two decades, modulating the magnitude, timing, and location of fluxes and stocks. He noted that regional climate models are being used effectively to study LCLUC impacts but that the *in-situ* hydrological monitoring networks needed to parameterize and validate the models have deteriorated since the 1990s. Recent research shows that observed trends in streamflow in the region appear to represent a climate signal and that precipitation trends may be a result of land-use and climate change.

Lahouari Bounoua [NASA Goddard Space Flight Center (GSFC)] presented a review of research on the biophysics, hydrology, and large scale urbanization in semi-arid regions. Bounoua showed that urbanization is increasing in semi-arid regions often at the expense of fertile agricultural land and that the resulting surface energy budgets are modulated mainly by albedo and transpiration. The urban heat island effect is not as marked as in temperate climates and the hydrological cycle is characterized by increased runoff during precipitation events. An inverse modeling technique was presented for assessing the minimum water requirements for irrigation systems in semi-arid environments. Water requirements for drip irrigation were shown to be about 43% of that needed for spray irrigation.

Chris Small [Columbia University] presented a review addressing the hydrological impacts of LCLUC on urban environments. Small reported on a number of modeling studies within the program, showing that although urban areas cover a small percentage (~3%) of land area globally, they have a disproportionate impact on the environment. Unprecedented urban growth has characterized the last decades of the twentieth century particularly in the developing world. Population density is a primary driver for nitrogen, phosphorus, and total suspended solid fluxes into our estuaries. Regional scale studies are showing the impact of urbanization on climatology and freshwater species richness. Modeling the impacts of future projections of urban land-use change reveals significant impacts on reduced base flow, and increased runoff and convective precipitation.

Volker Radeloff [University of Wisconsin] gave a review of LCLUC in Eastern Europe, which provides a "natural experiment" to address how broad-scale drivers and disturbance influence land use and study the impacts of diverged nations, socioeconomic upheaval, and land abandonment. Studies have quantified post-Soviet land abandonment, forest loss, and illegal logging. For example, using satellite data to locate and quantify afforestation and deforestation, carbon stocks are being tracked, showing that Georgia and Romania will remain carbon sinks for the foreseeable future. Satellite data are also being used to study the *rewilding* of lands. Radeloff showed some examples of the resulting negative and positive impacts on saiga and bear populations, respectively. Different policies provide stark differences in land use and land cover and resulting environmental and social issues for the nations of Eastern Europe.

The LCLUC program has supported a number of studies in the Amazon Basin, as part of the NASA Large-scale Biosphere Atmosphere (LBA) Experiment. **Eric Davidson** [Woods Hole Research Center—*LBA-ECO Project Scientist*] gave an overview of the LCLUC research in the LBA. Results using microwave data to map wetlands provided input for a basin-wide (i.e., below 500 m) estimate of methane emissions of 22 Tg C/yr. A combination of ground plots and microwave data were used to estimate total forest biomass for the basin (86 Pg C +/- 20%). The Amazon has experienced extensive land-use change over the last few decades. The rate of deforestation, the interannual variability, and the fate of deforested land have been successfully quantified using Landsat data. From 2001–2004, 20% of the deforestation was due to direct conversion to cropland. The Brazilian Space Agency estimated 12,000 km^2 of deforestation and 15,000 km^2 of forest degradation had occurred in 2007. During the 1998 El Niño event, the area burned was thirteen times more than the area burned in a normal year and was twice the area of deforestation. In the Araguaia Basin, river discharge has increased by 25% since the 1970s with two-thirds of that increase attributed to land-cover change.

Bob Walker [Michigan State University] summarized seven land-use modeling studies including simulation, econometric, agent-based, and behavior models. Models of deforestation have been generated at multiple scales with process-based projection capability, either projecting deforestation patterns associated with a given road network or generating road networks and providing scenarios of deforestation and forest fragmentation. Walker discussed a number of challenges to the modeling community including the goodness of fit, the treatment of model uncertainty, and capturing forest dynamics with different transitions.

Billie Lee Turner II [Arizona State University] gave a presentation on strengthening the human dimension of LCLUC. Areas for continued or future emphasis within the program include inferring and scaling human behavior; examining the tradeoff between land systems; inclusion of dynamic land-use change in integrated models as well as topical research areas of land-use and climate change, urbanization, the role of institutions in land-use decisions and the impacts of the changing global economy (macro structure); and role of international conventions on land-use change. There was considerable discussion following the presentation on the possible reasons for a recent decline in the social science component of the program and ways in which this component could be reinvigorated, including suggestions concerning future calls for proposals and the peer review process.

Observations and Data Session

The LCLUC observations and data session started with a sequence of presentations on the international observation programs in which the program is an active player. **John Townshend** [University of Maryland—*Chairman of the Integrated Global Observations of Land (IGOL) Theme*] presented an overview of the land Essential Climate Variables (ECVs.) The ECVs were developed by the Global Climate Observing System (GCOS) to meet the needs of the Framework Convention on Climate Change (UNFCCC) and include Land

Cover, Albedo, Fire Disturbance, Biomass, and Leaf-Area Index. Townshend summarized the ECV standards status document, presented to the Subsidiary Body for Scientific and Technical Advice (SBSTA) in 2007 and the Guidelines for Satellite Datasets and Products document developed by GCOS in 2009. He recommended the setting up of an interagency mechanism(s) to ensure that high quality ECVs are generated and that agency roles and responsibilities are clearly identified.

Jim Tucker [GSFC—*Co-chair U.S. Global Change Research Program (GCRP)/Climate Change Science Program (CCSP) Observations Working Group*] gave the U.S. GCRP/CCSP perspective on land observations, emphasizing the need for the continued combination of Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat sensors for the study of climate change and the carbon cycle. New capabilities of these sensors are needed for the study of vegetation height/structure and atmospheric carbon dioxide.

Tony Janetos [Pacific Northwest National Laboratory—*Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) Chairman*] gave an overview of the activities of the GOFC-GOLD Program, which is a major international program on land satellite observations. He emphasized the on-going Reducing Emissions from Deforestation and Degradation (REDD) Sourcebook initiative, a new implementation team being formed on biomass monitoring and change, and a new initiative on land use being undertaken jointly with the Group on Earth Observations (GEO) focusing on global agricultural monitoring.

Joanne Nightingale [GSFC] presented on recent developments of the Committee on Earth Observation Satellites (CEOS) Land Product Validation (LPV) Working Group and the teams and validation protocols and reporting standards being developed for land-cover change, fire, biophysical characteristics, surface energy, land-surface temperature and soil moisture.

Martha Maiden [NASA HQ—*Chair CEOS Working Group on Information Systems and Service (WGISS)*] gave an overview of WGISS activities and their relationship to the Group on Earth Observations (GEO), with emphasis on the Land Surface Imaging Constellation, the Data Democracy initiative, and the Disaster Societal Benefit Area (SBA). She also discussed cooperation with the CEOS Working Group on Calibration and Validation (WGCV) on global datasets and quality.

The second session on observations focused on Landsat. **Jeff Masek** [GSFC] presented the status of the Global Land Survey (GLS)—a joint NASA/U.S. Geological Survey (USGS) project—to provide global ortho-rectified datasets for 2005 and 2010. The sets contribute to the GEO Task on Global Land Cover (DA 0903a). GLS 2005 is now complete and letters have been sent to solicit international participation in GLS 2010.

Jim Irons [GSFC] presented the status of LDCM. This mission has been nine years in formulation. The Critical Design Review for the Operational Land Imager (OLI, a.k.a., Landsat 8) was completed in October 2008. The retargeted launch date is December 2012. USGS will be responsible for the mission ground system, comprised of flight operations, data processing, and archive. A Thermal Infrared Sensor (TIRS) with two bands with 120-m spatial resolution is being considered for launch on the same platform.

Curtis Woodcock [Boston University—*Landsat Science Team Co-Chair*] presented the priorities for the Landsat Science Team. He noted that since the Landsat archive was opened for free download that the number of scenes delivered by the USGS has increased fifty-fold. The team has organized around a number of priority issues, including the impending *data gap* prior to the launch of OLI, future Landsat class missions beyond LDCM, and the Global Consolidated Landsat Archive. Technical working groups have formed to address cloud masking, surface reflectance, and temperature as standard OLI products and carbon mapping and monitoring. Future issues include operational land-cover change monitoring, cloud screening of the Landsat archive data, and definition of long-term sensing scenarios beyond "Landsat 9."

The session ended with **Bryant Cramer** [USGS] who presented different aspects of USGS involvement with Landsat. Current efforts include developing a multi-source data acquisition plan to mitigate a potential Landsat *data gap* and augmenting the single data stream from Landsat 8. In the latter context, USGS is working with the European Space Agency (ESA) on possible joint operations of Landsat 8 and Sentinel 2. He noted that additional funding is needed for USGS LDCM operations and any *data buys* associated with filling the potential Landsat *data gap*; he also stated that the funding pathway for an operational Landsat program is not evident. Following his talk, there was an animated discussion from the community on the need to build two OLI instruments, while a plan for the future of U.S. land imaging is being formulated; the need for NASA to stay actively engaged in the future of the Landsat program; the requirement for higher temporal frequency from Landsat class observations; and the comparatively rapid deployment of Landsat class systems by other nations.

The afternoon session included a summary of LCLUC-related research findings from the Earth Observing-1 (EO-1) system. **Betsy Middleton** [GSFC—*EO-1 Project Scientist*], and **Robert Wolfe** [GSFC—*Terra Deputy Project Scientist for Data*] presented on the state of MODIS instruments and land products.

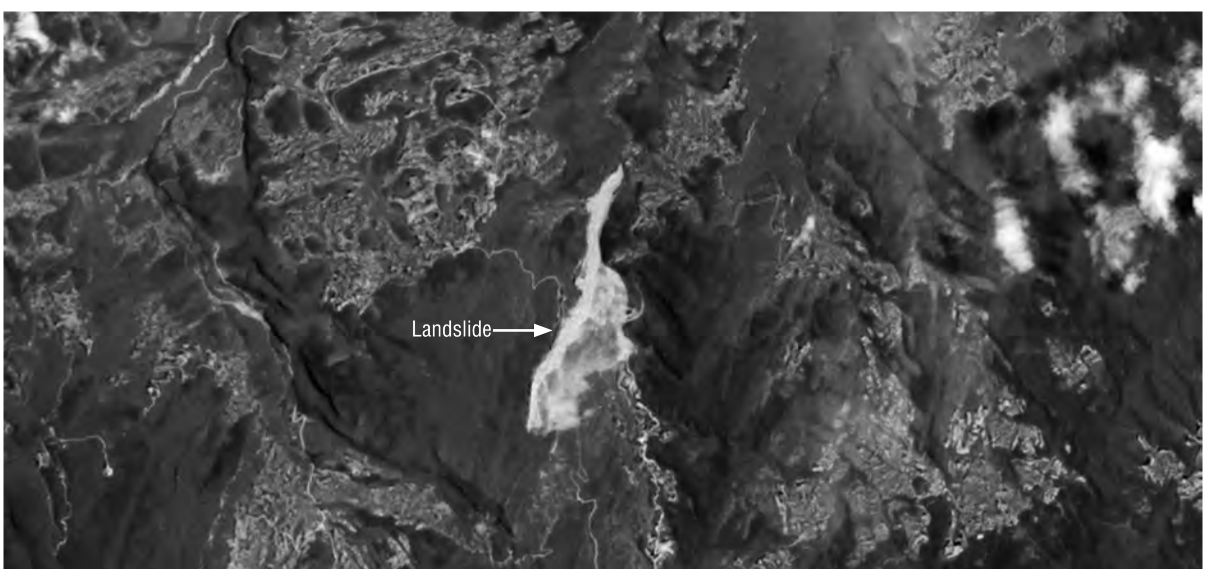
Diane Wickland [NASA HQ] presented on the Decadal Survey land science rationale, plans, and mission phasing. Of particular note for the LCLUC community are the near-term *Tier 1* missions—Soil Moisture Active and Passive (SMAP) and Deformation, Ecosystem and Dynamics of Ice (DESDynI)—and their respective capabilities for soil moisture and vegetation structure mapping. In the mid-term, the *Tier 2* Hyperspectral Infrared Imager (HyspIRI) mission will have capabilities for moderate resolution (60 m) thermal and hyperspectral remote sensing. The community was encouraged to participate in science definition and development of requirements through workshops planned over the next 18 months. Concerns from the community about the need for balance between these new experimental missions and systematic observations were noted.

Future Directions Session

Chris Justice [University of Maryland College Park—*LCLUC Project Scientist*] and **Garik Gutman** led the final session of the workshop, which focused on future directions for LCLUC. The program has demonstrated, through the use of NASA satellite data, that over the past few decades rapid changes in land use and land cover have occurred at local to regional scales with significant impacts on the environment and social systems. These data have been used in part to initialize projections of future land-use change. **However, the impact of LCLUC on social systems has received relatively little attention to date. How the research community should address social vulnerability or resilience needs further consideration.** Climate change with an emphasis on mitigation through land-use practices and land-use adaptation is becoming a major program focus. Program management recognizes the need for the human dimensions aspect of proposed LCLUC research to be integral to the research question, rather than an appendage. There is a growing body of research within the program on the role of institutions and policy impacts on LCLUC, which warrants synthesis. As a result of recent selections, urban growth is receiving more attention from the program. Regional focus for the program is currently on South Asia but is turning to South America, beyond the Amazon.

With respect to observations, the community is encouraged to take advantage of the newly opened Landsat archive and the 2005 GLS datasets. Increased international cooperation on Landsat class data exchange needs to be developed prior to the launch of the LDCM, and the continuation of the Landsat program will be critical to the LCLUC research program. The program also will need to consider a future fine-resolution *data buy* in support of LCLUC process studies.

The next LCLUC Team Meeting will be convened jointly with the International Monsoon Asia Integrated Regional Study Program, the Northern Eurasia Earth Science Partnership Initiative, and the GEO Agricultural Monitoring Task. The meeting will focus on land-use change in dryland systems and will be held in Almaty, Kazakhstan, September 15-20, 2009.



On June 5, 2009, a mountainside collapsed in the Chongqing region of southern China. The landslide dropped some 420 million ft^3 (12 million m^3) onto several homes and an iron ore mine, trapping dozens of people. According to a June 18 report from Xinhua News Agency, 64 people remained missing. This photo-like image was captured by the Advanced Land Imager (ALI) onboard NASA's Earth Observing-1 (EO-1) on June 17, 2009, revealing a giant scar of bare land that fans out toward the south on an otherwise vegetated landscape. To view this image in color please visit: *earthobservatory.nasa.gov/IOTD/view.php?id=38978*. **Credit:** NASA's Earth Observatory.

CERES Science Team Meeting Summary

Jim Closs, NASA Langley Research Center, Science Systems and Applications, Inc., james.w.closs@nasa.gov

The Spring 2009 meeting of the Clouds and the Earth's Radiant Energy System (CERES) Science Team was held April 28-30, 2009, at the City Center at Oyster Point Marriott Hotel in Newport News, VA. **Norman Loeb** [NASA Langley Research Center (LaRC)—*CERES Principal Investigator*] hosted the meeting. A more detailed summary and full presentations are available on the CERES web site at: *science.larc.nasa.gov/ceres.*

Major objectives of the meeting included review and status of CERES instruments and data products including:

- A series of updates on the status of CERES, NASA, the Earth Observing System, and the upcoming 2009 Earth Science Senior Reviews;
- A report on plans for putting CERES on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and its precursor, the NPOESS Preparatory Project (NPP);
- A report on the status of Terra and Aqua shortwave (SW)/longwave (LW)/total channel calibration for *Edition 3* of the CERES data;
- An update on the status of CERES Flight Model-5 (FM5) and FM6;
- An update on *Edition 3* cloud algorithm development and validation, as well as Clouds and Radiative Swath (CRS) *Edition 2* Validation;
- A report on the status of the Synoptic (SYN), Monthly Regional (AVG), and Monthly Zonal and Global (ZAVG) Radiative Fluxes and Clouds data products—the *Level 3* Gridded Version of Computed Top Of Atmosphere (TOA), Atmosphere (ATM), and Surface (SFC) fluxes;
- An update on efforts to extend Surface Averages (SRBAVG), International Satellite Cloud Climatology Project (ISCCP)-like-Geostationary-enhanced (GEO), and SYN/AVG/ZAVG data products to August 2007, including overcoming (Multi-functional Transport Satellite (MTSAT) calibration challenges;
- An update on ISCCP-like Moderate Resolution Imaging Spectroradiometer (MODIS) and GEO data products;
- A report from the CERES Data Management Team including a discussion of the instruments on Terra, Aqua, and the one planned for NPP;
- An update from Atmospheric Sciences Data Center (ASDC);
- An overview of the NPP Science Data Segment;
- An update on the Student's Cloud Observations Online (S'COOL) and S'COOL Rover observations; and
- A status report on the Goddard Earth Observing System—Model 5 (GEOS-5).

In addition, the team heard a number of specific CERES Co-Investigator reports, and there was a poster session focusing on the NPP Science Data Segment and the NPP Instrument Calibration Support Element (NICSE).

Norman Loeb [LaRC] presented an overview and status of CERES, NASA, EOS, Senior Reviews, NPP and NPOESS, and the Decadal Survey missions. He gave an overview of the CERES project structure, data processing flow and data products, and CERES on NPP and NPOESS.

CERES on Aqua successfully completed an End-of-Prime Mission Review in December 2008, and a Terra/Aqua Senior Review proposal was submitted in March 2009. The Senior Review panel meets in May, and publication of the panel's report is due in June. New budget guidelines and instructions to projects follows in July, and based on those instructions the projects will revise their implementation plans to the Earth Science Directorate in August.

CERES FM5 completed integration and testing on the NPP spacecraft in November 2008, and the contractor with Northrop Grumman, has started to build FM6 from spare parts. The CERES team received a LaRC center award for completing FM5 integration on cost and on schedule. FM6 instrument delivery is scheduled for August 2012, with NPOESS-C1 launch scheduled for 2014.

Congratulations to CERES Clouds team lead Pat Minnis on being named a fellow by the American Geophysical Union, and to Tom Evert (Northrop Grumman Corp.) for receiving the NASA Distinguished Service Award for his role in the design and development of the CERES FM1–FM6.

Kory Priestley [LaRC] gave an overview and update of the CERES Instrument Working Group, CERES flight schedules, and *Edition 3* data product study results. Radiometric performance requirements for CERES are more stringent than for the Earth Radiation Budget Experiment (ERBE) by a factor of two, and requirements per *Ohring et. al.*[1] are more stringent than CERES by a factor of 3–5—emphasizing the importance of instrument calibration. The CERES calibration/validation approach involves a rigorous pre-launch ground calibration program, independent studies to characterize on-orbit performance, and a well understood approach

[1] Report of Achieving Satellite Instrument Calibration for Climate Change (ASIC) Third Workshop, May 16-18, 2006, National Conference Center, Lansdowne, VA.

to data release. In the future CERES will fly in a single orbit with one instrument per spacecraft, eliminating key direct comparison validation capabilities. This increases the influence of radiometric performance in cost/schedule trades, and establishes collaborations with the National Institutes of Standards and Technology (NIST) and other international agencies.

The CERES team has started assembling the FM6 instrument, which will have enhanced on-board calibration equipment. A proposed Shortwave Spectral Internal Module (SSWIM) will include a legacy evacuated tungsten lamp with a supplemental 'blue' light emitting diode (LED), and new photodiode monitor(s) for independent monitoring of source outputs. A Mirror Attenuator Mosaic (MAM) solar diffuser attenuates direct solar views, and provides a relative calibration of the shortwave channel and the SW portion of the total channel.

Edition 3 data product studies involve incorporating all known physically based changes in gain and other calibration coefficients for each instrument, and implementing a method of placing all CERES instruments on the same radiometric scale at mission start. Results of these studies show that residual calibration errors in the *Omega-1* studies are dominated by spectral degradation of sensor optics in the reflected solar bands. This results in an artificial decreasing trend in the reflected solar measurements, and divergence between daytime and nighttime Outgoing Longwave Radiation (OLR) records with time.

The next series of presentations provided updates on various CERES subsystem activities.

- **Patrick Minnis** [LaRC] reported on *Edition 3* cloud algorithm activities.
- **Dave Kratz** and **Shashi Gupta** [Both at LaRC] reported on Surface-Only Flux Algorithm (SOFA) development.
- **Thomas Charlock** [LaRC] shared recent developments in Surface and Atmosphere Radiation Budget (SARB) products.
- **David Doelling** [LaRC] reported on Time Interpolation and Spatial Averaging (TISA) activities.
- **Erika Geier** [LaRC] reported on the activities of the CERES Data Management Team.
- **John Kusterer** and **Mike Little** [Both at LaRC] gave an update on the Atmospheric Science Data Center (ASDC).
- **Robert Wolfe** [NASA Goddard Space Flight Center] provided an update on the NPP Science Data Segment (SDS).
- **Lin Chambers** [LaRC] provided an update on Student's Cloud Observations On-Line (S'COOL).

Day two began with break out working group sessions, including the Angular Modeling Working Group led by **Norman Loeb**, the SARB/SOFA Working Group led by **Thomas Charlock**, and the Cloud Working Group led by **Patrick Minnis**.

A pair of **invited presentations** highlighting exciting new science followed…

Roy Spencer [University of Alabama/Huntsville] presented a talk on *Separating Forcing from Feedback with Phase Space Analysis, or Do Cloud Changes Cause Temperature Changes…or the Other Way Around?* His goal is to diagnose climate sensitivity (feedback) from satellite data to determine whether manmade global warming will be a catastrophe or is barely measurable.

Spencer's previous work showed that climate sensitivity is probably being overestimated because natural cloud variations causing temperature variations "looks like" positive feedback. He explained that feedback cannot be estimated when it is in response to time-varying radiative forcing of temperature (i.e., radiative forcing obscures feedback) unless forcing is known and removed. He speculates that climate models are too sensitive because they have been built and validated assuming that the observed co-variations between radiative fluxes and temperature have been due to feedback alone. This will lead to an overestimate of climate sensitivity, because clouds causing temperature change will always look like positive feedback. In other words, fewer clouds causing warming 'looks like' positive feedback if you assume causation in the wrong direction.

Joel Norris [Scripps Institute of Oceanography] spoke on *Clouds in the Climate System: Why is This Such a Difficult Problem, and Where do We go from Here?* His topic reinforced the 4th Intergovernmental Panel on Climate Change (IPCC) report on key uncertainties in climate change, namely that cloud feedbacks (particularly from low clouds) remain the largest source of uncertainty [to climate sensitivity]. This is because no stable system to monitor global cloudiness and radiation on multidecadal time scales exists, and also because cloud and radiation measurements are insufficiently integrated with associated meteorological processes.

Norris contends that *meteorological memory* can mix cloud radiative impact on temperature with cloud response to temperature, and because of this it is essential to consider joint meteorological forcing of cloud and temperature. Similar mechanisms are at work with aerosols, but in this case, since clouds have a non-instantaneous response time, it is essential to consider *meteorological history*. He also explained that previous work has likely overestimated the impact of *"thermodynamics"* (temperature and lapse rate change), and that atmospheric circulation change associated with global warming may instead play a leading role. To reduce these uncertainties, he recommends correcting (to the extent possible) the historical cloud and radiation record, integrating meteorological conditions with cloud and radiation measurements, and assimilating cloud and radiation measurements into global models.

Following the two invited presentations, there were a series of **Co-Investigator reports** with updates on new data products and science results. The topics discussed are summarized in the table below. Please refer to the URL listed above for more details on each presentation.

Norman Loeb led a final wrap-up and discussion of action items from the meeting. He reiterated the importance of delivering *Edition 2* gains and spectral response functions through the end of December 2008, and finalizing gains for *Edition 3* instrument improvements. The Clouds team is expected to deliver *Edition 3*-Beta-2 in August 2009 and *Edition 3* in March 2010. SOFA is expected to submit remaining validation papers, as is SARB with CRS methodology/validation papers.

The Fall 2009 CERES meeting will be held November 3-5, 2009 at the Marriott in Fort Collins, CO.

Topic	Speaker	Institution
MODIS Aerosol Assimilation for SARB	David Fillmore	Tech-X Corporation
The GEOS-5 System and Future Plans	Michelle Rienecker	Goddard Space Flight Center
Dynamically and Thermal-Dynamically Stratified Aerosol and Cloud Interaction	Wenying Su	Langley Research Center/Science Systems and Applications Inc. (SSAI)
TOA Global Component Aerosol Direct Radiative Effect	Xuepeng Zhao	NOAA/National Environmental Satellite, Data, and Info Service/ National Climactic Data Center
Variations in Terra Cloud Properties with SST Anomaly	Zachary Eitzen	Langley Research Center/SSAI
Working with CERES data to test parameterizations in CAM	Jerry Potter	University of California, Davis
Satellite observations of global and regional energy budgets	Bing Lin	Langley Research Center
Global warming due to increasing absorbed solar radiation	John Fasullo	National Center for Atmospheric Research (NCAR)
NOAA 9 Radiation Budget Data Upgrade	Lou Smith	Langley Research Center/National Institute of Aerospace (NIA)
Overview of CALIPSO–CloudSat–CERES–MODIS merged product	Seiji Kato	Langley Research Center
Radiative Flux Anomalies from 2000 to 2008 based on Combined CERES and FLASHFLUX Data	Takmeng Wong	Langley Research Center
An Estimate of Infrared Radiation Forcing by Sub-Visual Ice Clouds	Wenbo Sun	Langley Research Center/SSAI
Cloud Forcing of Surface Radiation	Pam Mlynczak	Langley Research Center/SSAI
Cloud Properties from MODIS & CERES-MODIS Observations and CAM3 Simulations	Yue Li	Texas A&M University
Arctic Clouds and Their Impact on Surface and TOA Radiation Budget	Xao Dong	University of North Dakota
The *Ed3-Beta2* Modified Algorithms for Multilayer Cloud Property Retrievals	Foulung Chang	Langley Research Center/NIA
Effect of the Inhomogeneity of Ice Crystals on Retrieving Ice Cloud Optical Thickness and Effective Particle Size	Yu Xie	Texas A&M University
Identifying Opaque and Non-Opaque Tropical Upper-Tropospheric Ice Clouds from Measurements of MODIS 8.5, 11, and 12 μm Bands	Gang Hong	Texas A&M University

ASDC at NASA Langley Releases New CERES Products

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center (LaRC) in collaboration with the Clouds and the Earth's Radiant Energy System (CERES) announces the release of the following datasets:

CER_SSF_Aqua-FM3-MODIS_Ed2C-MOD-C4-Land-IGBP
CER_SSF_Aqua-FM4-MODIS_Ed2C-MOD-C4-Land-IGBP

Two years of Aqua data (January 1, 2004–December 31, 2005) are available for the specialized *SSF Ed2C-MOD-C4-Land-IGBP* dataset.

For this processing, the input scene ID map used is based on the *MOD12C1* product, which is the Moderate Resolution Imaging Spectroradiometer (MODIS) derived scene ID map based on MODIS *Collection 4* yearly (2004) Level 3 global data. The only difference between the *SSF Ed2C-MOD-C4-Land-IGBP* and SSF *Edition2C* datasets is that SSF *Edition2C* used the 1990s-based International Geosphere Biosphere Programme (IGBP) map supplied by the U.S. Geological Survey (USGS), while *SSF Ed2C-MOD-C4-Land-IGBP* used the more recent *MOD12C1* land cover map described above. The IGBP map has some influence on the selection of the Angular Distribution Model for inverting radiances measured by the CERES instrument to irradiances (radiative fluxes).

Both Flight Model 3 (FM3) and FM4 data were processed for January 2004–June 2004. After that, only data from the instrument predominantly in cross track for the data month are processed.

The Single Scanner Footprint Top-of-Atmosphere (TOA)/Surface Fluxes and Clouds (SSF) data product contains instantaneous footprint data that are unique for studying the role of clouds, aerosols, and radiation in climate.

On March 30, 2005, at approximately 18:42 Universal Time (UTC), the Aqua FM4 shortwave (SW) channel stopped functioning. Therefore, only the Aqua FM3 data were processed after this time.

Information about the CERES products, including products available, documentation, relevant links, sample software, tools for working with the data, etc. can be found at the CERES data table: *eosweb.larc.nasa.gov/PRODOCS/ceres/table_ceres.html.*

For information regarding our data holdings or for assistance in placing an order, please contact:

Atmospheric Science Data Center
NASA Langley Research Center
User and Data Services
Mail Stop 157D, 2 S. Wright Street
Hampton, VA 23681-2199
Phone: 757-864-8656
E-mail: *larc@eos.nasa.gov*
URL: *eosweb.larc.nasa.gov*

First Take: Data Users Line Up to Give On-Camera Earth Observation Testimonials

Kathryn Hansen, NASA Earth Science News Team, khansen@sesda2.com

Set lights glaring and camera rolling, Guo Huadong explained that immediately after the Sichuan earthquake, his center collected high-resolution synthetic-aperature radar (SAR) and optical airborne remote sensing data—as well as different satellite data—to take a high-tech look at the affected areas.

On May 12, 2008, a deadly earthquake paralyzed China's Sichuan province and killed tens of thousands. For the survivors, the ordeal did not end there. Aftershocks continued to rattle the region for months, heightening the risk from newly posed natural hazards. To identify areas of risk, **Guo Huadong** of the Center for Earth Observation and Digital Earth at the Chinese Academy of Sciences in Beijing, turned to Earth observation data.

Huadong's experience was just one of 17 stories recorded at the 33rd International Symposium on Remote Sensing of Environment (ISRSE) conference in Stresa, Italy. Earth science data users from business, government, and academia in 35 countries converged at the Stresa Congress Center May 4-8, attending talks, plenary sessions and workshops.

Tapping into the diverse group, producers of the Earth Observations Story Project—spearheaded by **Lawrence Friedl** of NASA Headquarters—collected "video testimonials" as part of an outreach effort to describe, explain, and celebrate the variety of ways people use Earth observations to benefit society.

If you had five minutes in front of the camera, what story would you tell?

Set lights glaring and camera rolling, Huadong explained that immediately after the Sichuan earthquake, his center collected high-resolution synthetic-aperature radar (SAR) and optical airborne remote sensing data—as well as different satellite data—to take a high-tech look at the affected areas. "At that time there was no communication and no transportation," he said, "so Earth observation becomes a very important tool."

Just two hours after the quake, the group was able to compare satellite observations from before and after the event. They analyzed the number and location of threats such as landslides and unstable *barrier lakes*—rivers that have been dammed up by landslides.

"With satellite data we can monitor the situation and make an analysis, create a map that classifies hazardous regions, and then create a report for decision makers in local and central government," Huadong said. Those reports aided rescue efforts and decision-making about the safest locations to rebuild.

The 33rd International Symposium on Remote Sensing of Environment (ISRSE) conference was held in Stresa, Italy.

Robert Brakenridge shared a story about a different kind of natural hazard: floods. As director of the Dartmouth Flood Observatory in Hanover, N.H., Brakenridge uses satellite data to map past and present floods. The lengthy record is now illustrating which occurrences of flooding are anomalous, and the emerging picture could help relief groups decide where to direct limited flood aid resources.

Others told stories about using Earth observations to protect Russia's boreal forests by influencing where timber is collected, or to advance fledgling environmental monitoring projects in Madagascar. A common theme throughout the interviews was the importance of extending the data record into the future.

"We have plans to collect data again," Huadong said about the Sichuan earthquake. "How has the environment changed in a year?" The new data will have implications for future building, which comes at a time when some of the 1 million affected in the province are waiting for a permanent, safe place to live.

Look for more information about these and other Earth Observations Story Project interviews coming soon online.

Ekaterina Tsybikova of Transparent World, a non-profit and non-governmental partnership, speaks with Kathryn Hansen of the NASA Earth Science News Team (back to camera) about how her organization uses images of Earth from space to monitor, map, and help preserve Russian boreal forests and protected areas. Tsybikova was one of 17 users of Earth observation data who faced the camera to record their story at the May 2009 International Symposium on Remote Sensing of Environment in Stresa, Italy. **Credit:** Mark Malanoski.

South Carolina Wildfire Offers Langley Researchers Close-up Look at Smoke

Patrick Lynch, NASA Langley Research Center, patrick.lynch@nasa.gov

When a pile of burning debris got out of control and sparked a wildfire north of Myrtle Beach, SC, in late April, a team of researchers from NASA Langley's Science Directorate jumped into action.

The group, including scientists from NASA and the U.S. Environmental Protection Agency (EPA), had been watching for an opportunity to collect real-world data on wildfires with a High Spectral Resolution Lidar (HSRL) on-board a *King Air B200*. This specially instrumented aircraft takes vertical measurements of aerosols—in the case of fires, smoke—that helps researchers understand how much smoke is produced by fires and how high smoke plumes rise and move through the atmosphere. Researchers need data on smoke plumes and wildfire emissions to better understand their impact on regional air quality and the climate system.

The morning of Friday, April 24, two days after the fire began to spread, pilot **Les Kagey**, operations engineer **Mike Wusk**, and lidar researcher **Ray Rogers** lifted off from Hampton, VA, for a day of criss-crossing smoke plumes from the Highway 31 fire. The research derived from this study, which is funded by the EPA, will be used to improve air pollution models that the agency uses for policy and regulatory decisions, said **Jim Szykman**, an EPA scientist from the National Exposure Research Laboratory in the Office of Research and Development, who is stationed at Langley.

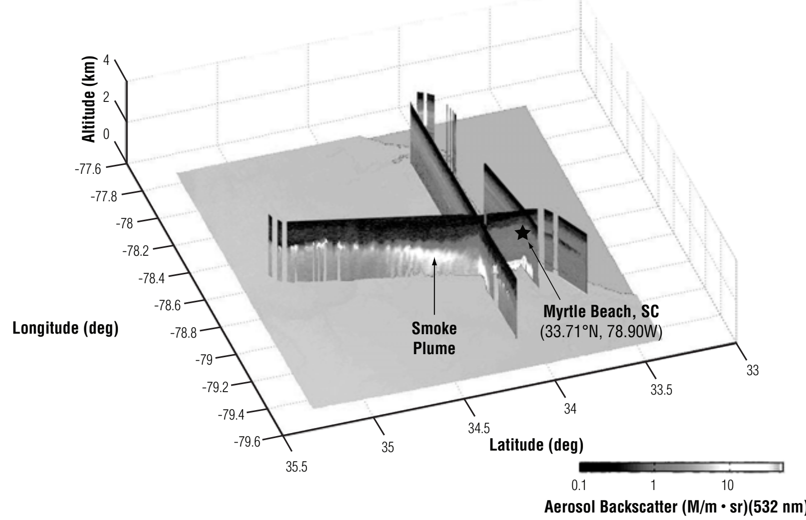
"We've been talking about how we'd respond to an opportunity like this for some time—a quick deployment of the HSRL," Szykman said. "You never know when a fire is going to start and we wanted to test our readiness. Though unfortunately this was our opportunity."

The HSRL team had recently finished flights used to validate the measurements made by the Langley-managed Cloud–Aerosol Lidar and Pathfinder Satellite Observation (CALIPSO) satellite, and was able to react quickly when the South Carolina fire broke out, Szykman said. The lidar was also used last year in the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) campaign to observe aerosols and smoke in the Arctic and, in collaboration with the EPA, to sample pollution in California's San Joaquin Valley in 2007.

The Highway 31 fire ultimately burned about 19,600 acres, forced the evacuation of about 4,000 people, and destroyed about 70 homes while damaging even more. The fire burned on private and state-owned lands made up of pine forest with peaty soils that can smolder long after the fire is largely contained—a common ecosystem in the Southeast U.S. The fire burned more intensely on Thursday, prior to the lidar overflight, but Friday's flight still captured intense flare-ups and smoldering fuels, which are crucial to piecing together a complete picture of fire emissions.

An afternoon of flying over the fire's smoke plume produced data on the plume's height, the amount of aerosols—smoke, soot and haze—generated by the fire, and how the aerosols eventually dispersed in the atmosphere. The data from the research flight will be useful,

Myrtle Beach, South Carolina "Highway 31 Fire" – April 24, 2009



These vertical profile images, taken the afternoon of Friday, April 24 using the Langley Science Directorate's High Spectral Resolution Lidar, show how the plumes of smoke from the Myrtle Beach wildfire moved up and away from the source. The data will be used to improve EPA models of fire emissions. To view image in color please visit: *www.nasa.gov/topics/earth/features/myrtlebeachfires.html*. **Credit:** NASA HSRL Team.

Langley researchers Mike Wusk, Ray Rogers, and pilot Les Kagey flew a *King Air B200* equipped with a High Spectral Resolution Lidar over the wildfires in South Carolina to measure the behavior of the smoke plume produced by a blaze that ultimately burned 19,600 acres of land. To view photo in color please visit: *www.nasa.gov/topics/earth/features/myrtlebeachfires.html.* **Credit:** Mike Wusk/NASA HSRL Team.

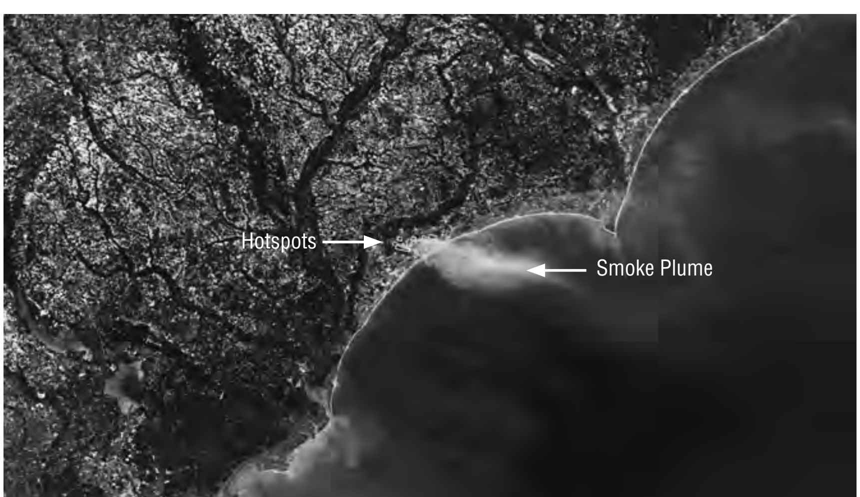
and are a precursor of research the EPA and Langley's Science Directorate, including researcher Amber Soja, have in store for the 2009 fire season, Szykman said. The data will also be combined with other observations and measurements—including fire temperature and land-use practices to learn more about how fires burn in various ecosystems.

The EPA develops annual fire emission estimates in conjunction with state and local agencies and other federal agencies including the U.S. Forest Service (USFS). Fires are one of many important emission sources that are inputs to EPA's regional chemical transport model known as the Community Multiscale Air Quality (CMAQ) model. The model is used by the EPA for environmental management and policy activities including setting regulations and regional strategy development for attainment of National Ambient Air Quality Standards.

These data and future CALIPSO and HSRL data will be used as part of a larger collaboration between NASA, EPA, Michigan Tech Research Institute, University of Louisville, and the USFS to enhance the inclusion of fire emissions in the National Emissions Inventory and the height of smoke plumes in the CMAQ. Current climate change scenarios predict fire severity will increase, making it increasingly important to understand the impact of smoke and aerosols on air quality, human health, and the climate.

"We continually try to improve how our models perform," Szykman said. The data from the South Carolina flight "will give us a better understanding of how well the modeled data predicts the real data we gathered from actual fires."

A camera mounted underneath the *King Air B200* snatched this aerial image of the fires. To view photo in color please visit: *www.nasa.gov/topics/earth/features/myrtlebeachfires.html.* **Credit:** NASA HSRL Team.



Wildfires burned along the South Carolina coastline on April 22–23, 2009, leaping over a highway and heading for a heavily populated area in North Myrtle Beach. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this image at 12:17 local time (16:17 UTC) on April 23, 2009. The white outlines in this image mark hotspots where MODIS detected unusually warm surface temperatures associated with the fires. The plume of pale gray smoke blows east-southeastward over the ocean. To view this image in color please visit: *earthobservatory.nasa.gov/IOTD/view.php?id=38303.* **Credit:** NASA/GSFC MODIS Rapid Response Team.

NASA, Japan Release Most Complete Topographic Map of Earth

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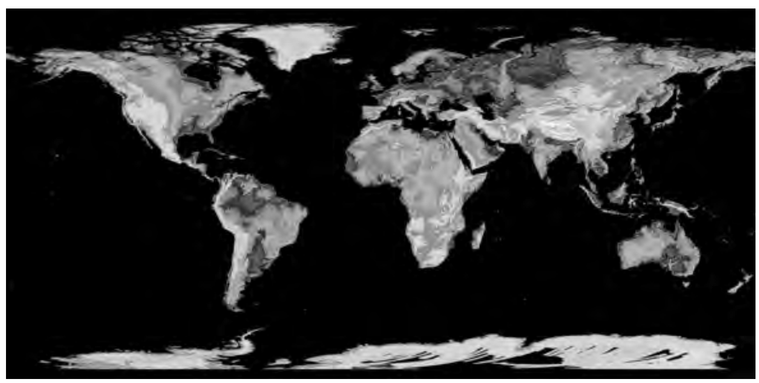
On June 29, 2009, NASA and Japan released a new digital topographic map of Earth that covers more of our planet than ever before. The map was produced with detailed measurements from NASA's Terra spacecraft.

The new global digital elevation model of Earth was created from nearly 1.3 million individual stereo-pair images collected by the Japanese Advanced Spaceborne Thermal Emission and Reflection Radiometer, or (ASTER), instrument aboard Terra. NASA and Japan's Ministry of Economy, Trade and Industry (METI) developed the dataset. It is available online to users everywhere at no cost.



This image was created by processing and stereo-correlating the 1.3 million-scene ASTER archive of optical images.

"This is the most complete, consistent global digital elevation data yet made available to the world," said **Woody Turner**, ASTER Program Scientist at NASA Headquarters in Washington. "This unique global set of data will serve users and researchers from a wide array of disciplines that need elevation and terrain information."

According to **Mike Abrams**, ASTER Science Team Leader at NASA's Jet Propulsion Laboratory, the new topographic information will be of value throughout the Earth sciences and has many practical applications. "ASTER's accurate topographic data will be used for engineering, energy exploration, conserving natural resources, environmental management, public works design, firefighting, recreation, geology, and city planning, to name just a few areas," Abrams said.

Previously, the most complete topographic set of data publicly available was from NASA's Shuttle Radar Topography Mission. That mission mapped 80% of Earth's landmass, between 60° N–57° S. The new ASTER data expand coverage to 99%, from 83° N– 83° S. Each elevation measurement point in the new data is 30 ft (98 m) apart.

"The ASTER data fill in many of the voids in the shuttle mission's data, such as in very steep terrains and in some deserts," said **Michael Kobrick**, Shuttle Radar Topography Mission project scientist at JPL. "NASA is working to combine the ASTER data with that of the Shuttle Radar Topography Mission and other sources to produce an even better global topographic map."

NASA and METI are jointly contributing the ASTER topographic data to the Group on Earth Observations, an international partnership headquartered at the World Meteorological Organization in Geneva, Switzerland, for use in its Global Earth Observation System of Systems. This *system of systems* is a collaborative, international effort to share and integrate Earth observation data from many different instruments and systems to help monitor and forecast global environmental changes.

NASA, METI, and the U.S. Geological Survey validated the data, with support from the U.S. National Geospatial-Intelligence Agency and other collaborators. The data will be distributed by NASA's Land Processes Distributed Active Archive Center at the U.S. Geological Survey's Earth Resources Observation and Science Data Center in Sioux Falls, S.D., and by METI's Earth Remote Sensing Data Analysis Center in Tokyo.

ASTER is one of five Earth-observing instruments launched on Terra in December 1999. ASTER acquires images from the visible to the thermal infrared wavelength region, with spatial resolutions ranging from about 50–300 ft (15–90 m). A joint science team from the U.S. and Japan validates and calibrates the instrument and data products. The U.S. science team is located at JPL.

For visualizations of the new ASTER topographic data, visit: *www.nasa.gov/topics/earth/features/20090629.html*.

Data users can download the ASTER global digital elevation model at: *wist.echo.nasa.gov/~wist/api/imswelcome* and *www.gdem.aster.ersdac.or.jp*.

Satellites Guide Relief to Earthquake Victims

Janet Anderson, NASA Marshall Space Flight Center, Janet.L.Anderson@nasa.gov

On May 28 at 2:24 a.m. local time, a deadly earthquake rocked Honduras, killing seven people and injuring several others, demolishing homes, damaging scores of other buildings, and sending terrified residents running through the streets.

"I woke up immediately, and all I could do was hug my youngest son and pray," says **Dalia Martinez** of San Pedro Sula, Honduras. "After a few minutes, my family and I went outside, where my neighbors were already gathered, likewise terrified about what happened but grateful we were all okay. Since then, we've been sleeping with flashlights and telephones within reach, because the aftershocks have been strong."

Fortunately for Martinez and other shaken residents, disaster officials knew exactly where to send help. A state-of-the-art Earth observation system called SERVIR—which is Spanish for "to serve"—directed them to the hardest hit areas.

SERVIR is a joint effort of NASA, the Center for the Humid Tropics of Latin America & the Caribbean (CATHALAC), the U.S. Agency for International Development, the Regional Center for the Mapping of Resources for Development, and other partners. The system uses satellite imagery to zero in on places where a flood, fire, hurricane, or earthquake has left destruction in its wake. Team members combine satellite data with ground observations, and display (for all to view) a near real-time map of crisis points. At a glance, decision-makers can see the locations of most severe damage so they can send help in a hurry.

"The Honduras earthquake was a perfect example of SERVIR at its best," says **Emil Cherrington**, Senior Scientist at SERVIR's regional operational facility at CATHALAC in Panama. "It was like a chain reaction. People from agencies and organizations in several countries worked together after the earthquake to pinpoint precise locations where support was needed."

Breaking news stories revealed that the worst infrastructural damage was restricted, in general, to Honduras and Belize, so the SERVIR team at CATHALAC began to assemble baseline imagery and data for a bird's eye view of those areas. They contacted **Stuart Frye** of NASA's Goddard Space Flight Center and asked him to arrange satellite imagery.

The next day, Frye notified the team that the Taiwanese would image the hardest hit areas by using their Formosat-2 satellite. In fact, the Taiwanese were already in action.

Cheng-Chien Liu of the National Cheng-Kung University (NCKU) of Taiwan explains: "President Ma Ying-Jeou of Taiwan and his delegation were visiting Belize the night the earthquake struck. As news of the quake spread across the Pacific, all Taiwanese were shocked and very anxious to confirm their safety and that of the people who lived in the countries hit."

"We knew the fastest way to capture images of the disaster area would be to use Formosat-2. So I issued an urgent request for assistance to **Dr. An-Ming Wu**, the Deputy General Director of National Space Organization (NSPO). Even though it was the Dragon Boat holiday and all Taiwanese were enjoying their family reunion, Dr. Wu called the Formosat-2 mission operation team to rush back to the control center. The three critical images were taken in record time!"

Dan Irwin, SERVIR Project Director at NASA's Marshall Space Flight Center, recalls the lightning-fast response: "I was in a bus in Berlin when I received an email from Dr. Liu telling me they had the images ready to send. It was early Saturday morning in Panama, but I called and woke Emil [Cherrington] up anyway to let him know."

"Dr. Liu was the one who lost sleep," says Cherrington. "He stayed up until 2 a.m. Taiwan time sending the images to our servers at CATHALAC. The data volume was huge, so the transfer was slow, but he wouldn't go home until he was sure we received all the images." ■

The earthquake damaged three bridges in Honduras, including the collapse of the central segment of the Democracy Bridge pictured in the before and after images above. **Credit:** Ikonos satellite image [left] courtesy of *GeoEye*. Formosat-2 image [right] provided by Cheng-Chien Liu [NCKU] and An-Ming Wu [NSPO].

EOS Scientists in the News

Kathryn Hansen, NASA Earth Science News Team, khansen@sesda2.com

Dev Niyogi on Urban Sprawl and Storm Intensity, May 21; *Earth & Sky Radio*. In a NASA-funded study, researchers including **Dev Niyogi** (Purdue University) found that intermittent rain in the days before Atlanta's rare urban 2008 tornado, provided temporary drought relief, but also may have moistened some areas enough to create favorable conditions for severe storms to form and intensify.

Satellite Used to Aid in Crop Forecasting, May 27; *United Press International*. NASA is using satellite data to make accurate estimates of soil moisture, thereby improving global crop forecasting; the new modeling product improves the accuracy of soil moisture forecasts by 5% over previous methods, according to **John Bolten** (NASA GSFC).

NASA Research Reveals Soybean Damage Near $2 Billion, May 28; *Web Newswire*. Researchers including **Jack Fishman** (NASA LaRC) and **Jack Creilson** (former NASA LaRC) looked at five years of soybean yields, surface ozone and satellite measurements of troposphere ozone levels in three Midwest states and found that rising surface ozone concentrations are damaging nearly $2 billion in annual U.S. soybean crops.

The Seldom-Seen Devastation of Climate Change, June 1; *Salon*. "Climate Change: Picturing the Science," a new book by climate scientist **Gavin Schmidt** (NASA GISS) and photographer Joshua Wolfe, aims to alter the *out of sight, out of mind* response to climate change by providing a rich photographic record of a warming world.

Ready for Hurricane Season? NASA Is, June 1; *WDBO-AM Orlando*. Kennedy Space Center is ready for hurricane season, and **Allard Beutel** (NASA KSC) says the center plans for just about anything weather related, in case the Space Shuttle needs to be moved off the launch pad.

Predictions for the 2009 Hurricane Season, June 2; *Technology Review (blog)*. Lower-than-normal sea-surface temperatures could "starve" developing hurricanes of their driving force, meaning fewer hurricanes, but peak hurricane season is not until late summer and early fall and **William Patzert** (NASA JPL) says that oceanic and atmospheric conditions can change dramatically.

Conditions Brewing for Possible El Niño, June 6; *Union-Tribune (San Diego)*. An El Niño could bring relief to drought-stricken San Diego County this summer, but **William Patzert** (NASA JPL) does not think this El Niño will likely be a major event.

Scientists Make Breakthrough in Assessing Marine Phytoplankton Health, June 9; *U.S. News & World Report*. Researchers including **Michael Behrenfeld** (Oregon State University) have succeeded for the first time in measuring the physiology of marine phytoplankton through NASA satellite measurements of its fluorescence, which will help scientists to gain a reasonably accurate picture of the ocean's health and productivity about every week, all over the planet.

Global Hawk UAV Adapted for Environmental Research, June 15; *Aero-News.net*. NASA and Northrop Grumman Corporation have unveiled the first Global Hawk unmanned aircraft system to be used for environmental science research, heralding a new application for the world's first fully autonomous high-altitude, long-endurance aircraft; **Kevin Petersen** (NASA DFRC) says the aircraft *represent the first non-military use of this remarkable robotic aircraft system*.

Using Weather Satellites to Predict Epidemics?, June 20; *National Public Radio*. In September 2006, **Assaf Anyamba** (NASA GSFC) and his group predicted heavy rainfall over East Africa and the first human case of Rift Valley Fever followed in mid-December, showing that weather satellites are a powerful tool in curbing the spread of disease.

Report: Warming to Hit State Hard, June 26; *The Press-Enterprise (Southern California)*. The Inland region and other parts of the Southwest are warming faster than most of the nation because of human-induced climate change, and residents there can expect the resulting heat waves, wildfires, and water shortages to worsen, according to a new White House report on global warming, and **William Patzert** (NASA/JPL) called the report frightening—and a conservative estimate of just how bad things will be.

NASA Sends Into Orbit Sophisticated Weather Satellite, Meant to Track Hurricanes and Tornadoes, June 27; *Los Angeles Times*. A new weather satellite—second of the more advanced Geostationary Operational Environmental Satellites (GOES)—rocketed into orbit, giving forecasters another powerful tool for tracking hurricanes and tornadoes; deputy project manager **Andre Dress** (NASA GSFC) called the satellite network … *the most sophisticated weather satellites that we actually have on this planet ... off this planet.*

Wayne Esaias on Honeybee Behavior, June 29; *Earth & Sky Radio*. **Wayne Esaias** (NASA GSFC) has been using satellite data to track plant and pollinator relationships across the United States, an idea he got after discovering that the bees he keeps in Maryland were making honey earlier and earlier in the year.

Radar Lets NASA See Beneath Surface of Faults, June 29; *San Francisco Chronicle*. **Andrea Donnellan** (NASA/JPL) and **Eric Fielding** (NASA/JPL) are using a new airborne radar to see what lies beneath the surface of California's San Andreas and Hayward faults, providing information that researchers hope will lead to improved quake forecasting, updated building codes, and emergency planning to meet seismic hazards.

Drones Seek Storms' Secrets, June 29; *Florida Today*. NASA plans a test flight in September of the Global Hawk predator drone, with hopes of having it ready for next year's hurricane season; program scientist **Ramesh Kakar** (NASA HQ) explains the benefits of a drone compared to manned aircraft and describes the instruments it will carry.

Linking Climate and Habitability, June 29; *Astrobiology Magazine*. In a study led by **Cynthia Rosenzweig** (NASA GISS), published last year in *Nature*, scientists for the first time linked the effects of climate change specifically to human activity.

NASA and USGS Announce Availability of Global Land Survey 2005 Data

NASA and the U.S. Geological Survey (USGS) are pleased to announce that the Global Land Survey (GLS) 2005 dataset is now essentially complete, and is available for download from USGS Earth Resources Observation and Science (EROS). Instructions for download are provided below.

The GLS2005 offers global, orthorectified Landsat coverage centered on 2005, designed to support long-term mapping of land-cover and vegetation trends. The dataset is composed of a single leaf-on, cloud-minimized image for each WRS-2 path/row location. In cases where Landsat-7 imagery have been used, multiple images have been merged and radiometrically adjusted to minimize gaps caused by the failure of the Landsat-7 scan-line corrector. Images were selected to optimize seasonal timing [vegetation greenness derived from the Advanced Very High Resolution Radiometer (AVHRR)] and to minimize cloud cover. These data, together with those from the earlier GLS epochs (1975, 1990, 2000) offer a unique resource for assessing changes in the terrestrial environment during the last 35 years.

Currently about 140 images remain to be added to the GLS2005 dataset, primarily over Indonesia and Brazil. As these images are processed they will be available through the GLOVIS interface (see below). Additional information on the Global Land Survey project may be found at the GLS web site: *gls.umd.edu*.

The GLS2005 dataset may be cited as: "USGS and NASA, 2009, Global Land Survey 2005, Sioux Falls, SD USA: USGS Center for Earth Resources Observation and Science (EROS)." Citations for the generation of the dataset are as follows:

Gutman, G., Byrnes, R., Masek, J., Covington, S., Justice, C., Franks, S., and R. Headley, "Towards monitoring land-cover and land-use changes at a global scale: The Global Land Survey 2005", *Photogrammetric Engineering & Remote Sensing*, 74, 6-10, 2008.

Franks, S., Masek, J.G., Headley, R.M.K., Gasch, J., and Arvidson, T., "Large Area Scene Selection Interface (LASSI). Methodology for selecting Landsat imagery for the Global Land Survey 2005", *Photogrammetric Engineering and Remote Sensing*, in press.

Individual GLS scenes may be downloaded from the USGS Global Visualization Viewer: *glovis.usgs.gov*. At the top under "Select Collection" you can choose "Global Land Survey" and "GLS 2005" from the pull-down menus.

Bulk distribution of the GLS on hard media will be available to order through the University of Maryland Global Land-Cover Facility (GLCF; *www.landcover.org*). An orders page is available so that single epochs or the entire collection can be purchased. USB2 hard drives will be purchased through GLCF as part of the order.

Contact: Dr. Jeffrey Masek, (301) 614-6629, *Jeffrey.G.Masek@nasa.gov*

NASA Science Mission Directorate – Science Education Update

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Astronomy and Earth Science Workshops for K-4 Teachers

Millbrae, CA, September 12–13

A weekend of hands-on workshops and informative science talks will be offered as part of the 120th anniversary meeting of the nonprofit Astronomical Society of the Pacific. These workshops will take place at the Westin Hotel near the San Francisco Airport. The program will include space science and Earth science workshops for K-4 educators, as well as sessions for educators who work in informal settings (such as museums, nature centers, amateur astronomy clubs, and community organizations.)

No background in astronomy will be assumed or required. Experienced educators from the Society's staff, from NASA and National Science Foundation (NSF) sponsored projects, and from educational institutions around the country will be presenting. Only a limited number of spaces will be available, and, thanks to conference supporters, registration for each day of the workshop will be only $39. Thanks to the support of the Spitzer Space Telescope Science Center, a limited number of travel-support scholarships (of up to $300 per person) will be made available for educators.

Sunday afternoon will feature a special non-technical lecture series about the search for life among the stars, with some of the leading scientists from the Search for Extra-Terrestrial Intelligence (SETI) Institute describing the scientific experiments now under way to identify life beyond Earth.

For more information, visit *www.astrosociety.org/events/2009mtg/workshops.html*.

NASA Endeavor Science Teacher Certificate to Begin Accepting Applications for Cohort 2

Applications Accepted July 1–September 30, 2009

The NASA Endeavor Science Teaching Certificate Project awards one-year fellowships each year to over 40 current and prospective teachers. The Project is administered by U.S. Satellite Laboratory, Inc. Funding authorization for the Project is provided through the NASA Endeavor Teacher Fellowship Trust Fund as a tribute to the dedicated crew of the Space Shuttle *Challenger*.

In partnership with state departments of education, Endeavor Fellows take five graduate courses in an innovative, LIVE (online) format from the comfort of their home or school and learn to apply research-based pedagogical strategies and cutting-edge Science, Technology, Engineering and Mathematics (STEM) content to their classroom contexts while becoming a part of a special network of like-minded educators across the Nation.

Endeavor Fellows will be awarded a NASA Endeavor Certificate in STEM Education from Teachers College, Columbia University. In addition, graduate credits are awarded from other regionally-accredited partners in higher education. For more information, visit: *www.us-satellite.net/endeavor/index.cfm*.

Earth Science Week K-9 Student Contests

Entries Due: October 16

American Geological Institute (AGI) is sponsoring three national contests for Earth Science Week 2009. The photography, visual arts, and essay contests allow both students and the general public to participate in the celebration, learn about Earth science, and compete for prizes.

The photography contest, open to all ages, focuses on *How Climate Shapes My World*. The visual arts contest, titled *The Climate Where I Live*, is open to students in grades K-5. Finally, students in grades 6-9 are eligible to enter the essay contest: *Climate Connections*. Essays of up to 300 words should describe how climate interacts with Earth's systems–geosphere, hydrosphere, atmosphere, and biosphere—in your area.

The first-place prize for each contest is $300 and a copy of AGI's *Faces of Earth* 2-DVD package. To learn more about these contests, including how to enter, visit *www.earthsciweek.org/contests*.

NASA Earth Observatory World of Change

Inspired by its 10th anniversary, *The Earth Observatory* has pulled together a special series of NASA satellite images documenting how our world has changed during the previous decade. The latest installment examines the fluctuations in sea ice surrounding Antarctica. View it and others at *earthobservatory.nasa.gov/Features/WorldOfChange/*. ■

EOS Science Calendar

August 11–13
2nd HyspIRI Science Workshop, Pasadena, CA
URL: *hyspiri.jpl.nasa.gov*

September 14–17
Aura Science Team Meeting, Netherlands.
URL: *aura.gsfc.nasa.gov/*

November 5–6
GRACE Science Team Meeting, Austin, TX.
URL: *www.csr.utexas.edu/grace/GSTM/*

September 9–10
SMAP Applications Workshop, Silver Spring, MD.
URL: *smap.jpl.nasa.gov/events/index.cfm?FuseAction=ShowNews&NewsID=12*

September 18
OMI Science Team Meeting, Leiden, the Netherlands.
URL: *www.knmi.nl/omi/research/project/meetings/ostm14/index.php* [Takes place the day after the Aura Science Team Meeting.]

November 3–5
CERES Science Team Meeting, Fort Collins, CO.
URL: *science.larc.nasa.gov/ceres/meetings.html*

November 3–5
HDF-EOS Workshop XIII: Closing the Gap—Harnessing the Power of HDF Through Established Technologies. URL: *hdfeos.net/workshops/ws13/workshop_thirteen.php*

Global Change Calendar

August 16–19, 2009
Wilhelm and Else Heraeus Seminar on Determination of Atmospheric Aerosol Properties Using Satellite Measurements, Bad Honnef, Germany
URL: *http://www.iup.uni-bremen.de/eng/events/*

August 16–20
238 American Chemical Society National Meeting and Exposition: Chemistry and Global Security: Challenges and Opportunities, Washington, DC.
URL: *portal.acs.org/*

August 31–September 4
World Climate Conference-3, Geneva, Switzerland.
URL: *www.wmo.int/wcc3/*

September 15–20
Land Cover Land Use Change Science Team Meeting, Almaty, Kazakhstan. URL: *lcluc.umd.edu/*

October 18–21
Geological Society of America Annual Meeting, Portland, OR. URL: *www.geosociety.org/meetings/2009/*

November 3–5
6th GOES Users' Conference, Monona Terrace Convention Center, Madison, Wisconsin. Contact: *Dick.Reynolds@noaa.gov* or *james.gurka@noaa.gov*
URL: *http://cimss.ssec.wisc.edu/goes_r/meetings/guc2009*

November 13–14
GEOSS Workshop XXXI, Washington, DC.
URL: *www.ieee-earth.org/Conferences/GEOSSWorkshops*

December 14–18
American Geophysical Union Fall Meeting, San Francisco, CA. URL: *www.agu.org/meetings/fm09/*

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