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Editor's Corner

Steve Platnick

EOS Senior Project Scientist

In our last issue, we reported that December 18 marked the 10th anniversary of the launch of NASA's Terra mission. To commemorate this milestone in the history of NASA's EOS Program, several *Terra@10* activities took place during the fall meeting of the American Geophysical Union (AGU) in San Francisco, CA. An evening of reminiscences took place on December 14. Speakers included **Marc Imhoff** [Terra Project Scientist]; **Piers Sellers** [NASA astronaut and former Terra Project Scientist]; **Michael King** [Team Leader for the Moderate Resolution Imaging Spectroradiometer (MODIS) and former EOS Senior Project Scientist, 1992–2008]; **Ghassem Asrar** [former Assistant Administrator for Earth Science at NASA Headquarters]; **Angelita Kelly** [representing Earth Science Mission Operations]; and **Anoop Mehta** [representing Science Systems and Applications, Inc. and the Maryland Space Business Roundtable which helped support the event]. Each shared their recollections about the project. Video clips of the speaker's remarks and links to Terra highlights can be found at eosps.gsfc.nasa.gov. Also, on December 16, four AGU sessions were held covering a wide range of Terra science. In addition, the NASA booth in the exhibit hall featured additional presentations on the state of Terra science and the spacecraft (part of a series of informal presentations on NASA Science that took place at the NASA exhibit during the week).

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December 18, 2009 marked the 10th anniversary of the launch of Terra. During the Fall AGU Meeting, a series of events were organized to commemorate *Terra@10*, including a reception the evening of December 14. Four of the speakers at the reception are shown here: **Angelita Kelly** [top photo, third person over]; **Marc Imhoff** and **Piers Sellers** [middle photo]; and **Ghassem Asrar** and **Michael King** [bottom photo].

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The Earth Observer continues our *Perspectives on EOS* series in 2010 with two additional articles that reveal more of the EOS story. In addition to the historical context, we hope these perspectives are helpful to those tasked with planning future Earth observing missions.

The first *Perspectives on EOS* article comes from **Michael King**—see page 4 of this issue. During the *Terra@10* reception at AGU, King shared some of his memories and reflections on Terra, forming the basis for this article. While the remarks were prepared for the specific context of *Terra@10*, they also give unique insight into what it was like to be involved in EOS in the early days as MODIS and Terra were “getting off the ground”—both figuratively and literally. In his article, King says that Ghassem Asrar commented to him on the day Terra

launched, that the future of NASA Earth Science might very well hinge on a successful launch. Looking back from our present-day vantage point, it is indeed hard to imagine NASA Earth Science as we know it today without Terra's and its scientific accomplishments.

Our second *Perspectives on EOS* article comes from **Lisa Shaffer**—see page 7 of this issue—who has been working for more than a quarter-century in various roles at NASA, the National Oceanic and Atmospheric Administration (NOAA), and in the private sector to foster international cooperation in Earth Science observations. During her distinguished career she has gained valuable experience to share on the subject of international cooperation. International partnerships have been crucial to the success of NASA's Earth Observing System from the very beginning and will continue to be important in the development of newer missions. We hope you find Shaffer's perspective on this important issue informative.

The United Nations Framework Convention on Climate Change (UNFCCC) 15th Conference of the Parties (COP15) took place December 7-18 in Copenhagen, Denmark. For the first time, the U.S. Department of State organized a *U.S. Center* at the conference. The exhibit included representations from a number of federal departments and agencies, including NASA. The *U.S. Center* played host to 70 events during the two-week conference, highlighting contributions to advancing scientific understanding of Earth's climate system and the leadership role the U.S. is pursuing internationally to address climate change. The exhibit featured scientific presentations as well as informal talks using the Science On a Sphere (SOS) visualization system provided by NOAA. SOS displayed animated Earth imagery throughout the two-week meeting. **Maurice Henderson** [NASA Goddard] attended the meeting to assist with SOS operations and acted as a docent. Henderson prepared a report of his experience at COP15 that we have adapted for *The Earth Observer*—see the article on page 29 of this issue.

There have been several noteworthy accomplishments for missions in development over the past few months. The Global Precipitation Measurement (GPM) mission recently cleared two major milestones in its development. On December 2, GPM successfully completed its Key Decision Point-C (KDP-C) review with the NASA Agency Program Management Council. The completion of this review resulted in mission confirmation and approval to proceed to *Phase C* of implementation. Also, on December 15, GPM successfully completed its Critical Design Review. The GPM Core Observatory is scheduled for launch in July 2013.

The Landsat Data Continuity Mission (LDCM) also successfully completed its KDP-C review on December 16, and is now cleared to proceed to *Phase C*. Launch of LDCM is tentatively planned for December 2012.

Finally, the Ice, Clouds, and Land Elevation Satellite (ICESat-II) mission successfully completed its KDP-A review on December 11, and is now clear to proceed to *Phase A* of its formulation. ICESat-II is the second of the Earth Science Decadal Survey missions to successfully complete KDP-A (the Soil Moisture Active-Passive mission (SMAP) mission passed KDP-A in September 2008). Launch of ICESat-II is tentatively planned for February 2016. Congratulations to everyone involved in making these mission milestones possible.

As we look forward to new missions, we recognize that many of the current NASA Earth Science missions are well past their prime mission lifetime. On November 23, 2009, the rotating antenna on NASA's Quick Scatterometer (QuickSCAT) stopped spinning, eliminating wide swath (1800 km) observations of ocean surface vector winds used for operational weather forecasting. This event followed a pattern of increasing friction in the bearings that allow the antenna to spin. The scatterometer instrument itself remains in good health allowing for observations over specific regions. Launched in 1999 with a design life of 2 years, QuickSCAT has far exceeded its science objectives.

The last working laser of ICESat's Geoscience Laser Altimeter System (GLAS) stopped emitting light pulses on October 11, 2009. No science data have been collected since that time. The GLAS Anomaly Review Board assessed the situation and initiated a series of attempts to restart the lasers. If none of the lasers can be restarted, NASA will begin end-of-life engineering experiments to improve future missions and then initiate ICESat decommissioning procedures to minimize orbital debris.

I'd like to acknowledge two recent retirements. Landsat 7 Project Scientist **Darrel Williams** retired from NASA on January 29, 2010. Throughout his long and distinguished career, Williams has been involved in the development of enhanced remote sensing techniques for assessing forest ecosystems. Early in his career, Williams worked extensively on the Landsat program, supporting **Vince Salomonson** as Assistant Project Scientist for Landsat 4 and 5 during the late 1970s and into the early 1980s, until the Landsat program was turned over to NOAA for commercialization. He then worked with **Jerry Soffen** as EOS Deputy Project Scientist from 1989-1990. As Project Scientist during the Landsat 7 era, Williams worked with **Piers Sellers** (who was then Project Scientist for AM-1, which became Terra) to obtain same day coverage by Landsat 7 and Terra, and to develop and implement a Long Term Data Acquisition Plan (LTAP) to ensure the acquisition of a robust global, seasonal archive. They also worked on the image assessment system (IAS) to conduct routine calibration/validation checks to ensure image quality. In 1997, Williams received the prestigious NASA Medal for Outstanding Leadership. On the occasion of his retirement, I thank Williams for his many contributions to NASA and the land remote sensing community.

In addition, **Franco Einaudi** retired from NASA on January 29, 2010. Einaudi has been the Director of the Earth Sciences Directorate (and then Division) at the Goddard Space Flight Center since 2001. In this role, Einaudi was a long-time supporter of the Earth Observing System and the EOS Project Science Office. Best wishes to both Williams and Einaudi in their future endeavors. ■



On Tuesday, December 15, a ribbon-cutting ceremony took place to officially open the NASA Exhibit at the Fall AGU Meeting. Participating in the ceremony [left to right] were **Franco Einaudi** [Goddard Space Flight Center (GSFC)—Director of Earth Sciences Division], **Laurie Leshin** [NASA Headquarters (HQ)—Deputy Associate Administrator for NASA's Exploration Systems Mission Directorate], **Michael Freilich** [HQ—Director of Earth Sciences Division], **Timothy Grove** [AGU President], and **Richard "Dick" Fisher** [HQ—Director of Heliophysics Division].

Highlights and Memories from Terra

Michael D. King, Former EOS Senior Project Scientist, michael.king@lasp.colorado.edu

The early years of work and interaction with scientists on MODIS was educational and broadening, due largely to the wide range of expertise and experience among the team members that was reflected in discussions of band locations, signal to noise, physical capability to retrieve geophysical parameters, and the like.

Terra recently celebrated the tenth anniversary of its launch and the Maryland Space Business Roundtable organized a special event called *Terra@10* that took place during the American Geophysical Union's Fall Meeting in San Francisco, CA to honor this important milestone. Given his extensive involvement with the Moderate Resolution Imaging Spectroradiometer (MODIS) and his broader experience heading up the Earth Observing System (EOS) Program for 16 years, **Michael King** was a natural choice to be one of the invited speakers for a reception that took place the evening of December 14. King shared some of his memories and reflections of being involved in EOS as MODIS and Terra were "getting off the ground"—both figuratively and literally. (King also spoke at one of the science sessions that took place December 16.) *The Earth Observer* obtained King's permission to reprint his remarks (with some slight modifications for context) and use them as a contribution to our *Perspectives on EOS* series.

King is currently a Senior Research Associate in the Laboratory for Atmospheric and Space Physics, University of Colorado, but prior to that, he worked at NASA Goddard for 30 years, having served as Senior Project Scientist of NASA's Earth Observing System (EOS) from 1992–2008. Prior to that, King also served as Project Scientist of the Earth Radiation Budget Experiment (ERBE) from 1983–1992. He has also been actively involved in the development of MODIS, which now flies on Terra and Aqua. King served as Principal Investigator (PI) for the MODIS Airborne Simulator (that flies on the NASA ER-2 aircraft) and has aided immeasurably in the development of atmospheric and land remote sensing algorithms for MODIS. More recently, King became Team Leader of the MODIS Science Team on Terra and Aqua. As a team member, King has been responsible for the five science algorithms being run routinely to process MODIS data.

The grand vision for the Earth Observing System was initiated in the late 1980s by 'friends of **Dixon Butler**,¹ with NASA issuing an Announcement of Opportunity (AO) in January 1988. This AO solicited proposals for scientific investigations involving the provision of data from Earth observing instruments and use of data from instruments to be flown in polar orbit on one of the EOS platforms. I wrote one such proposal for developing the Moderate Resolution Imaging Spectroradiometer (MODIS) cloud optical properties using MODIS-N², and was a co-investigator on the Clouds and the Earth's Radiant Energy System (CERES) PI proposal as well as the CERES Interdisciplinary Science (IDS) proposal. Later, MODIS-T was eliminated and the MODIS acronym was redefined to be a 'spectroradiometer' and not a 'spectrometer,' and was eventually placed on two spacecraft (Terra and Aqua). The timing of this AO was ideal for me because I had just completed work on developing an algorithm for deriving cloud optical thickness and effective radius using visible and near-infrared bands on an airborne instrument, and these papers, written with my senior research associate **Teruyuki Nakajima**, had not yet been published. The algorithm (now widely used) was positively reviewed and had no competition in the category. At the time of the AO, the only guidelines for proposing to a facility instrument team were to be a PI with no co-Is, and to have a unique algorithm.

Until the selection was announced in early 1989, I had no idea that my close colleague and friend, **Yoram Kaufman**, whose office was only two doors from mine,

¹ Dixon Butler discusses the original concept for EOS in his article in the *Perspectives on EOS* 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.]

² MODIS was originally conceived as having two separate instruments.



Michael D. King

had also proposed and had likewise been selected as a MODIS team member to develop aerosol algorithms.

EOS Project Scientist **Jerry Soffen** convened the very first Investigators Working Group (IWG) meeting, consisting of all selected Team Leaders of facility instrument teams, PIs of instrument teams, and PIs of IDS investigations, at Goddard Space Flight Center in March 1989. As part of that meeting, there were pre-meetings of the newly formed science teams, where I met many MODIS science team members for the first time, especially those in oceanography and terrestrial ecology, whom I had never met nor interacted with previously. I was not yet 40 years old, and there were many other young turks like me (e.g., **Steve Running, Chris Justice**).

It was at that meeting that **Vince Salomonson**, the newly selected MODIS Science Team leader, who to me was much older and very senior (then 51), asked if I would be the head of the MODIS Atmosphere Discipline Group. He was thinking about structuring the team into Land, Atmosphere, and Ocean Discipline Groups to focus attention on these three disciplinary areas of capability of MODIS. Over the subsequent years, this team developed very close bonds and collaborations across these disciplines, and I have now published work in Land, Ocean, Atmosphere, and Cryosphere areas, where previously I had worked primarily in radiative transfer and remote sensing of aerosol and cloud optical properties.

The early years of work and interaction with scientists on MODIS were educational and broadening, due largely to the wide range of expertise and experience among the team members that was reflected in discussions of band locations, signal to noise, physical capability to retrieve geophysical parameters, and the like. This interdisciplinary education is not often afforded one in his scientific career. I especially valued discussions with Steve Running, Yoram Kaufman, Chris Justice, **Paul Menzel, Wayne Esaias, Mark Abbott**³, and **Alan Strahler**.

When I was appointed EOS Senior Project Scientist in Summer 1992, I assumed an even larger role in promoting science algorithm development, inter-instrument and interdisciplinary interaction, and was instrumental in establishing the EOS Calibration and Validation Program that did not exist, and had no funding, prior to my appointment. My very first move was to arm twist **Piers Sellers**⁴ into becoming EOS AM Project Scientist (later renamed Terra after an international renaming contest). This was when he was still well-grounded in Earth observations and especially biogeochemistry modeling—i.e., before his career as a satellite! I also appointed **Claire Parkinson** to the role of EOS PM (later renamed Aqua) Project Scientist.

The 1990s were a very turbulent time leading up to the launch and implementation of EOS, with repeated reshaping, rescoping, and rebaselining the EOS program, all various names that all meant a decline in available budget. Though difficult, we managed to gain the cooperation of the Payload Panel and its highly capable chair, **Berrien Moore**, where we collegially discussed various trades in orbits, instrument configura-

³ Mark Abbott shares his memories in his article in the *Perspectives on EOS* series entitled: "A Shift in Direction: EOS in the Mid-1990s". [Volume 21, Issue 5, pp.4-7.]

⁴ Piers Sellers tells his story in his article in the *Perspectives on EOS* series entitled: "Reflections of the Early Days of EOS: A Biased and Unexpurgated History". [Volume 21, Issue 1, pp. 4-8.]

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Ghassem Asrar's comment to me as we both crossed our fingers was that the future of NASA Earth science hinged on the successful launch of this billion-dollar mission. As we all know today, Terra's launch was successful and its instruments operated flawlessly.

tions, and international partnerships. In many of these activities, I chaired a 'Science Team' to look at cost and science trade-offs for various configurations, consisting largely of many EOS Project Scientists and the EOS Program Scientist (**Ghassem Asrar**). This was one of many groups looking at options, with another group looking at instruments and spacecraft configurations, often chaired by **Chris Scolese**, who later became Terra Project Manager, EOS Program Manager, and now serves as the agency's Associate Administrator, the top ranking career civil servant in NASA.

Also in the 1990s, I created a much loved or maligned system of algorithm documentation for EOS, known as the Algorithm Theoretical Basis Documents (ATBD). I required every algorithm developer to document their algorithm early in the development cycle, prior to coding, and that each algorithm be reviewed externally by both written reviewers and a visiting committee. In each case, I invited panelists from abroad, including Japan, New Zealand, and various countries in Europe. This helped to gather strengths and weaknesses of the algorithms, and has remained a resource for teaching at many universities today. One of the responsibilities of creating this process, which worked very well, is that I had to write an ATBD myself (for my MODIS algorithms) and subject it to review. To maintain the value of this process, I even sent mine to my competitor and often critic, **Bill Rossow**, for review. This valuable process helped all algorithm developers as well as the community get a better understanding of what went into the data to be processed and distributed by EOS.

The launch of the Terra spacecraft was complicated by many factors, including the development of the ground system, which Scolese rightly perceived to be behind schedule and incapable of operating the Terra spacecraft. This spacecraft also included solid-state memory, rather than tape recorders, which was a new capability for satellites (also implemented in Landsat 7, as I recall), and used the Tracking and Data Relay Satellite System (TDRSS) to relay data and commands from Terra to the ground. No subsequent EOS spacecraft used TDRSS, largely because of the potential conflicts with the International Space Station and shuttle missions, but it has worked flawlessly for Terra. Finally, six months before launch, the *Centaur* upper stage of a military spacecraft failed during launch, and so an investigation into this failure resulted in launch delays for Terra, which also used the *Centaur* upper stage in its *Atlas IIAS* launch vehicle. This added a marching army cost of \$4 million per month to an already expensive and much delayed mission.

At launch, which I attended in mid-December 1999, I was standing next to Ghassem Asrar as the countdown proceeded. He was then the Associate Administrator for Earth Science at NASA Headquarters. His comment to me as we both crossed our fingers was that the future of NASA Earth science hinged on the successful launch of this billion-dollar mission. As we all know today, Terra's launch was successful and its instruments operated flawlessly. It would be hard to imagine Earth observations today without Terra and the many missions that followed in its footsteps. What some may not recall is that this launch was only weeks before the dreaded Y2K, and much concern over computer clocks turning over to 2000. With this concern, activation and orbit raising of Terra was stretched out much longer than normal, so Terra opened its doors to Earth observation around February 24, 2000, over 2 months after launch.

Finally, the launch of the *Earth Observatory* (earthobservatory.nasa.gov), envisioned by **David Herring** and then Terra Project Scientist Yoram Kaufman, has enabled the general public, schools, media, and the like to have ready access to global Earth observations. Images from the *Earth Observatory*, which are far more extensive than just Terra, now appear regularly in the news media, especially during severe storms and natural hazards. Fires in the western U.S., floods in the Mississippi Valley and elsewhere, snow storms, smoke, dust, and haze, droughts, volcanoes and earthquakes, tsunamis, and just plain beautiful imagery are all found on the Earth Observatory. This has partly

An International Perspective on EOS

Lisa Shaffer, Sustainability Solutions Institute, University of California, San Diego, Lshaffer@ucsd.edu

International partnerships have been crucial to the success of NASA's Earth Observing System. These partnerships have been an important part of the story of EOS from the very beginning and will continue to be important as newer missions (e.g., those proposed by the Decadal Survey) are developed and implemented. As with other aspects we have discussed in this series to date, it is important we learn lessons from our past experience as we plan for our future. **Lisa Shaffer** has been working in various roles at NASA, NOAA, and in the private sector to foster international cooperation in Earth Science observations over more than a quarter-century. During her distinguished career, she has gained valuable wisdom to share on the subject of international cooperation. *The Earth Observer* asked Shaffer if she would share her perspective on this important topic with our readers, and she graciously agreed.

Shaffer spent the first 25 years of her career in Washington, DC, where she held a variety of positions in NASA, the National Oceanic and Atmospheric Administration (NOAA), and the private sector. Her focus was on fostering international cooperation in studying the Earth from space. In 1998, Shaffer joined Scripps Institution of Oceanography, where she was responsible for international relations and program development for nine years. In September 2007, she moved from Scripps to the University of California San Diego (UCSD) Office of Research Affairs to devote her time to building a sustainability program across the UCSD campus, and to pursue an executive Masters in Business Administration (MBA) degree at UCSD's Rady School of Management. She completed her MBA in August 2009. Shaffer's Bachelor of Arts (BA) degree in Political Science and International Relations is from the University of Michigan, and her Doctor of Philosophy (PhD) degree in Public Policy is from the George Washington University.

When I started in 1976, I had no idea that I would devote 17 years of my life to NASA and the National Oceanic and Atmospheric Administration (NOAA), and in my own way make a small contribution to saving the planet!

My international experience at NASA began in 1976 when I joined the International Affairs office, responsible for what was then called *Applications*. I had a Bachelor of Arts in International Relations, two years of work experience, and no particular interest in outer space. To me, NASA was where we spent a lot of money on rockets and satellites, and in

return got asbestos fire-fighting suits and *Teflon* frying pans. I had no idea how important NASA was and would be to the future of this planet. And I had no idea that I would devote 17 years of my life to NASA and the National Oceanic and Atmospheric Administration (NOAA), and in my own way make a small contribu-



Lisa Shaffer

tion to saving the planet! I left NASA several times, first for a five-year stint in an aerospace company, then five years at NOAA/National Environmental Satellite, Data and Information Service (NESDIS) in charge of international and interagency affairs. I always came back though, because I believed that through NASA, I was really

There was not much discussion about international cooperation when I first started working for NASA. At that point, the U.S. was pretty much the only game in town. However, that began to change as NOAA's "open" data policy and NASA's international investigator programs (part of EOS) provided many opportunities for researchers around the world to advance knowledge of their regions and to contribute to research in global processes.

helping meet global needs for observations and analysis of our changing planet. I ultimately left for good in 1998 to follow **Charlie Kennel**, who, a few years after he left NASA, had become Director of Scripps Institution of Oceanography, in San Diego where I now happily reside.

When I joined NASA, *Applications* pretty much meant weather satellites, telecommunications satellites, and the Earth Resources Technology Satellite (ERTS), which later became known as Landsat. I worked with foreign principal investigators (PIs) in the Landsat program, to help them get access to limited tape recorder time to acquire data over their test sites. In addition, I reviewed their progress reports to see what they were learning as they gained access to their first glimpses of their countries from space. I also worked with **Morris Tepper** [NASA Headquarters (HQ)—*Former Director of Meteorological Systems*] and **Jim Dodge** [NASA HQ—*Former Program Manager in the Applications Division*] on a coordinated sounding rocket program through Latin America called the Experimental Inter-American Meteorological Rocket (EXAMETNET). We mounted the Agency for International Development Satellite (AIDSAT) program to use the Applications Technology Satellite 6 (ATS-6) in developing countries. I also worked with **Dick Barnes** [NASA HQ—*Former Division Director in International Relations and then European Representative*] on the Satellite Instructional Television Experiment (SITE) program to bring satellite-based education to rural villages in India.

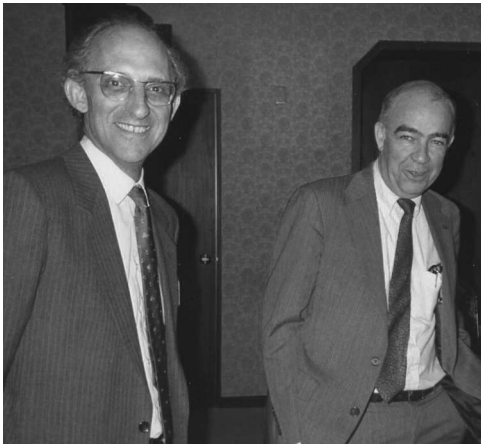
There was not much discussion about international cooperation when I first started working for NASA. At that point, the U.S. was pretty much the only game in town. However, that began to change as NOAA's "open" data policy and NASA's international investigator programs (part of EOS) provided many opportunities for researchers around the world to advance knowledge of their regions and to contribute to research in global processes. During my time in Washington, I was involved in Landsat commercialization (and its subsequent semi-un-commercialization). This represented the first major area of unhappiness in our international relations as NASA first imposed fees on station operators, then changed the rules altogether in the aftermath of the Earth Observation Satellite Company (EOSAT) debacle. Indirectly, I think the U.S. commercialization policy also encouraged France to try commercialization of its *Système Pour l'Observation de la Terre* (SPOT) satellite data, also to the detriment of the scientific community.

On the positive side, I had the opportunity to work on developing the *Bromley Principles*¹ on open data exchange, as well as on the creation of the International

¹ As EOS began to take shape in the early 1990s, there was a review of U.S. data policy and management, and one outcome was that the Committee on Earth and Environmental Sciences (CEES) elaborated a set of Global Change Research Data Principles. The policy was first made public by D. Allan Bromley, the Director of the Office of Science Technology Policy (OSTP) at the time, and thus became known as the *Bromley Principles*.



In November 1987, a combined meeting of the EO-ICWG, International Forum On Earth Observations Using Space Station Elements (IFEOS), and IPOMS, was held in Tokyo, Japan. [Left photo] Bizzarro Bizzarri [Italian Space Agency] and Bob Pfeiffer [European Space Agency Earth Observations (ESA EO)]. [Right photo] Chris Readings [ESA EO], Lisa Shaffer, and Guy Duchossois [ESA EO].



The November meeting also included other scientists. [Left photo] Chris Readings (ESA EO) and Shelby Tilford. [Right photo, starting third from the left] Shelby Tilford, Dixon Butler, Brent Smith, and Jim Graf.

Polar-Orbiting Meteorological Satellite Group (IPOMS), the Earth Observations International Coordination Working Group (EO-ICWG), and the Committee on Earth Observations Satellites (CEOS). I also worked on the 10-year negotiation that led to a collaborative relationship between NOAA and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). In addition, I was involved in the development of the Earth Observing System, which was originally conceived as an international space station polar platform and later evolved into its present configuration. I was also around for the start of the international Group on Earth Observations (GEO).

International cooperation in the EOS era has some very important success stories that should be applauded; the international scientific and policy community is enormously enriched by the ability of the U.S. and its international partners to work together. NASA has collaborated with France on the Ocean Topography Experiment (TOPEX)/Poseidon mission and its heirs, Jason-1 and the Ocean Surface Topography Mission (OSTM). More recently, we have worked with France on the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO). NASA partnered with Japan to place the NASA Scatterometer (N-SCAT) on the short-lived Advanced Earth Observing Satellite (ADEOS), as well as to develop and launch the Tropical Rainfall Measuring Mission (TRMM) and AMSR-E on Aqua.

We've partnered with Canada on Radarsat, the Measurement of Pollution in the Troposphere (MOPITT) instrument, and CloudSat. We've also worked with Germany on the Shuttle Radar Topography Mission (SRTM), the Gravity Recovery and Climate Experiment (GRACE), and are working with Argentina on the upcoming Aquarius/Satélite de Aplicaciones Científicas-D (SAC-D) mission. There have been international instruments on all three of the major EOS missions—i.e., Terra, Aqua, and Aura. We've also established data exchanges with the European Space Agency's (ESA) Earth Remote Sensing Satellites (ERS-1 & 2), Envisat, and various geostationary meteorological satellites. This is by no means a complete list, but it does give a sense of the many international partnerships in which NASA participates. The realization that CEOS is alive and well 25 years after we convened the first meeting at the old NOAA offices in Georgetown, Washington, DC in 1984, is amazing and is a testament to its continued relevance. If it were not making a useful contribution, it surely would not continue to attract the time and investment reflected in its work.

Of course, we must also acknowledge that there were plans and aspirations that were not realized, compromises made, and opportunities missed along the way. I recall the early expectation that ESA or EUMETSAT would provide a Microwave Humidity Sounder (MHS) for Aqua that never happened. But often a failure creates an opportunity; in this case, the Brazilians developed the Humidity Sounder for Brazil (HSB)

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EO-ICWG provided an opportunity for a very deep interaction than would otherwise have been possible and enabled representatives to understand each other's perspectives, constraints, and ambitions.

and got a chance to become part of the EOS family that might otherwise not have happened. Likewise, a Japanese instrument planned for Aura didn't materialize, leaving room for the Dutch to contribute the Ozone Monitoring Instrument (OMI). There was a lot of frustration from the original Space Station partners at the ever-changing configuration, timelines, and constraints as the International Polar Orbiting Platform evolved into EOS and eventually morphed into its present form. And, almost from the beginning, there were dreams of a much more elaborate integrated international system, a dream that still has not been fully realized at the dawn of the second decade of the 21st century.

While CEOS was evolving as the overarching international collaboration group, a very intensive process was taking place in the EO-ICWG. NASA, NOAA, and the ESA (i.e., the original Space Station partners) originally formed the EO-ICWG in 1986 to coordinate polar platform programs and payload planning, but both its role and its participation soon expanded. The U.S. contingency to EO-ICWG included representatives from NASA (**Shelby Tilford, Dixon Butler**², and myself) and NOAA (**Stan Schneider** and **Brent Smith**). Besides the U.S. representatives, participants included the ESA (**Bob Pfeiffer, Guy Duchossois, Chris Readings**) and the EUMETSAT (**John Morgan**) for Europe; the Japan Science and Technology Agency (JSTA), the Ministry of International Trade and Industry (MITI), the Japanese Environment Agency (JEA), the Japanese Meteorological Agency (JMA), and the National Space Development Agency (NASDA) for Japan (**Tasuku Tanaka, Chu Ishida, Yukio Haruyama, Tad Inada**); and the Canadian Space Agency (CSA) for Canada (**Ed Langham, Lynn McNutt**).

NASA's objectives for the EO-ICWG were to:

- promote the International Earth Observing System (IEOS) to advance understanding of the Earth system;
- promote effective use of Earth observation spacecraft (e.g., by coordinating payload planning); and
- promote continuity of operational services provided currently by NOAA's polar-orbiting satellites and development of future operational services.

At the time, our vision for the IEOS was to serve as the coordinated aggregate of the participating agencies' end-to-end Earth observing systems. Through EO-ICWG, we attempted to coordinate EOS, ADEOS, TRMM, and the Polar Orbiting Earth-observation Mission (POEM)³. (For various reasons, ERS and Radarsat were kept out of the formal discussions.) In retrospect, it is clear just from the list of agencies, that there was a wide range of objectives and perspectives on an international observing system. We had operational and research organizations, and some agencies responsible for an entire mission and others who were just instrument providers and data users. I don't think the NASA vision was truly shared by the other partners. There was too much uncertainty and lack of institutional trust for independent agencies to embrace that much interdependence.

EO-ICWG's main success was a set of data exchange principles that committed the members to share more than would likely have happened otherwise. EO-ICWG also provided an opportunity for a very deep interaction that enabled representatives to understand each other's perspectives, constraints, and ambitions. In the end, we (NASA) abandoned the idea that this group could create a truly integrated global system in the way envisioned at the time, and merged EO-ICWG into CEOS. I believe

² Dixon Butler discusses the original concept for EOS in his article in the *Perspectives on EOS* 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.]

³ This was the name of the original large polar orbiting platform that the European Space Agency was going to construct, that later morphed into the Envisat and Metop missions.

much of the learning and the personal relationships that developed as a result of EO-ICWG were instrumental in future developments within EOS and eventually led to the development of GEO. However, I must admit that the vision of EO-ICWG has not yet been achieved.

As a political scientist, I am amazed and impressed by our achievements in international cooperation, despite the forces working against us. Starting with program and agency structures, missions, decision-making, and budgeting processes, there are fundamental differences. For example, U.S. tax dollars go to support the activities of NASA and NOAA. Taxpayers do not have an opportunity to choose which sensor or which mission they want to participate in. As a result, data are openly available to the public and in the U.S. NASA cannot exclude users, say, in Ohio, or charge them more because their state decided it had other priorities than EOS. In ESA, by contrast, Earth observation programs were part of the “optional” budget, and since not all ESA member states chose to fund ERS or Envisat, ESA’s data policy and industrial policy had to reflect the different roles of its members. They couldn’t give the same benefits (data, industrial contracts) to participating and non-participating states. This made it challenging to work out arrangements that felt fair and viable on both sides. Similarly, the backdrop of space commercialization in the U.S. and the drama of Landsat, plus the need for annual budget appropriations and changing configurations of NASA’s programs, created insecurities in our partners who were in organizations that could make multi-year program and budget commitments not subject to Congressional oversight.

In Earth observations, international cooperation is further complicated by the overlap between military and civilian applications of the same technologies. This brings questions about industrial policy and the balance within each of the participating countries and regional organizations as to the extent of interdependence acceptable. While a rational global perspective might suggest that one organization could take responsibility for developing and operating observing systems for ocean altimetry, another for high resolution optical imaging, and yet another for interferometric Synthetic Aperture Radar (SAR), with all the data shared through a cooperative framework, the realities are that nations have industrial and national security objectives that influence their investment in space-based systems and sensor technology development. These objectives were not always explicitly discussed in developing civilian space collaborations, but clearly influenced some of the programmatic decisions of the U.S. and its partners. The international scientific community is important and beloved, but sometimes does not have the same political influence as major industrial aerospace and defense contractors. National policies on launch vehicles are also driven by many considerations that may impose constraints on optimal (as seen by the civilian program managers) arrangements for particular Earth-observing satellite missions.

As I look back on my years of service at NASA, I think I have learned that successful international collaboration involves four key elements:

1. a deep understanding of each side’s interests, which need to be overlapping, but are not likely to be identical;
2. personal relationships built on communication and trust;
3. institutional commitment at the highest level; and
4. “adaptive management” to enable flexibility as external and internal conditions change.

At the time I left NASA in 1998, international relationships represented over \$4 billion in direct foreign contributions to NASA’s Earth science program and \$4 billion more in complementary activities. Much has happened since then, and I remain hopeful that through GEO, CEOS, and other current structures, continued and deepened collaboration will take place. ■

As a political scientist, I am amazed and impressed by our achievements in international cooperation, despite the forces working against us.

EOS Terra Celebrates 10 Years

Karen Yuan, NASA Goddard Space Flight Center, karen.yuan@nasa.gov

On December 18, 1999, at 10:57:39 AM Pacific Standard Time (PST), Terra successfully launched on an Atlas IIAS from Vandenberg Air Force Base in California into clear blue skies. After orbiting the Earth 994 times, Terra officially opened for business when it transmitted its “first light” images on February 24, 2000. They included the pristine snow-covered landscape of the James Bay in Ontario, Canada and the vibrant shades of blue and green between the two distinct bodies of water around the Mississippi Delta.

For the past 10 years, Terra has collected an unprecedented decade of data on Earth’s atmosphere, lands, oceans, and solar energy balance. The research community, government resource management agencies, and policymakers have benefited from Terra’s data.

Since its launch, Terra has downlinked 724 terabytes of data and produced 72 data products. According to **Marc Imhoff**, Terra Project Scientist, “The first step in eliminating uncertainty and improving our understanding of Earth’s systems is to accumulate a large base of observations of sufficient quality to allow for inter-comparison. Terra has done exactly that. Ten years of calibrated and validated measurements of the planet’s land surface, atmosphere, and oceans are enabling quantum leaps forward for Earth System Science.” As of Spring 2009, over 3,200 peer-reviewed papers using Terra data have been published.

In the late 1980s, NASA’s Mission to Planet Earth initiative, which eventually evolved to the Earth Observing System (EOS), established a mandate to study Earth as an integrated system. Much larger than the Terra spacecraft, the original concept for the EOS platform carried more than 16 instruments. Later, to allow for better managing of the payload and ground systems, EOS broke into several platforms, the flagships Terra, Aqua, and Aura.

Terra was the first of the large EOS satellites to launch. Originally named EOS AM-1, it orbits Earth 16 times a day from an altitude of 705 km and crosses the equa-

tor at 10:30 AM. It carries five sensors: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Clouds and the Earth’s Radiant Energy System (CERES), Multi-angle Imaging Spectroradiometer (MISR), Moderate-resolution Imaging Spectroradiometer (MODIS), and Measurements of Pollution In The Troposphere (MOPITT). These sensors collect primary data and their ground-processing teams run data analysis algorithms and perform calibration and validation to generate data products on a daily basis. Terra’s success

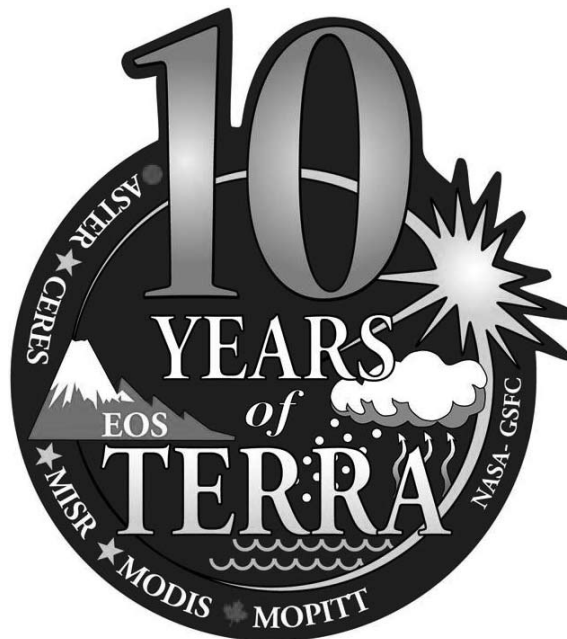
in engineering and science collection is a blueprint for subsequent remote-sensing satellites to emulate.

The mission is an international collaboration between the United States, Canada, and Japan. NASA contributed the spacecraft, launch vehicle, and the CERES, MISR, and MODIS instruments while the Canadian Space Agency and Japanese Ministry of Economy, Trade and Industry provided MOPITT and ASTER, respectively. According to **Yasushi Yamaguchi**, ASTER Science Team member, “The partnership is one of the most successful between the U.S. and

Japan’s science collaborations.”

Terra’s decade in orbit is truly an important milestone in understanding how natural phenomenon and anthropogenic activity affect the Earth system. **Bruce Wielicki**, CERES Co-Principle Investigator, states, “We need to remember that climate data records only start reaching above the noise of natural variability in 10 to 15 years. Terra is just approaching this milestone.”

To commemorate Terra’s decade of accomplishments, the Terra Project Science Office hosted a 10th Anniversary discussion session in San Francisco in December, followed by a reception sponsored by the Maryland Space Business Roundtable and a day of special science sessions at the 2009 Fall American Geophysical Union Meeting. Plans are also underway to celebrate Terra’s “first light” at the Goddard Space Flight Center. ■



GLOBE's Worldwide Student Climate Research Campaign, 2011–2013

Donna Charlevoix, GLOBE Program, Climate Research Campaign Coordinator, charlevo@globe.gov

The Global Learning and Observations to Benefit the Environment (GLOBE) Program promotes the teaching and learning of science, enhances environmental literacy and stewardship, and promotes scientific discovery in schools around the world. Since its launch in 1995, GLOBE's focus has expanded from local classroom investigations centered on following data collection protocols to global student research campaigns emphasizing research investigations using student-collected data.

GLOBE will launch the Student Climate Research Campaign in September 2011. The goal of the campaign is to *engage* students and teachers in scientific climate research. The Campaign will *enhance* climate literacy by *empowering* students and citizens to *investigate* and *take action* on climate issues of local importance. The Campaign will engage the entire GLOBE community of 112 countries and link students with scientists, other students, and organizations exploring climate issues in their local communities. Students will present their climate research results at an international event in 2013.

The Campaign will focus on four areas critical to understanding climate change: ecosystems and biodiversity, energy and carbon footprints, local and extreme weather, and air pollution and human health. Teachers will be trained in a fundamental understanding of climate and the climate system and then coached on how to guide students through the scientific research process in the classroom. Students will develop their



GLOBE students determine biomass in a forest in Scandinavia.

own climate research questions, focusing on a problem or issue of local relevance, and will investigate their questions through hands-on, inquiry-based methods. The Campaign will provide students and teachers the opportunity to be actively involved in the study of one of society's most challenging issues.

The GLOBE program is funded by NASA and the National Science Foundation (NSF), and housed in the University Corporation for Atmospheric Research (UCAR) in Boulder, CO. Since 1995, the GLOBE Program has trained over 50,000 teachers to collect scientifically valid data and guide students through the scientific research process. These teachers represent over 20,000 schools, and more than 20 million student measurements have been reported to the GLOBE database.

GLOBE is interested in furthering partnerships and connecting students and teachers with climate experts. Scientists, teachers, and students interested in participating in the Campaign or contributing ideas or learning activities can contact ClimateCampaign@globe.gov.



GLOBE students and teacher estimate biomass during the GLOBE Learning Expedition 2008 in South Africa.

Joint NASA LCLUC Science Team Meeting and GOFC–GOLD/NERIN, NEESPI, MAIRS Workshop “Monitoring Land Cover, Land Use and Fire in Agricultural and Semi-arid Regions of Northern Eurasia”

Tatiana Loboda, University of Maryland, College Park (UMCP), tloboda@hermes.geog.umd.edu

Chris Justice, UMCP, justice@hermes.geog.umd.edu

Garik Gutman, NASA Headquarters, garik.gutman@nasa.gov

Lev Spivak, National Center of Space Research and Technologies (Kazakhstan), levspivak@hotmail.com

Olga Krankina, Oregon State University, olga.krunkina@oregonstate.edu

Nadiya Muratova, National Center for Space Research and Technology, nmuratova@mail.ru

The Joint NASA Land Cover Land Use Change (LCLUC) Science Team Meeting and Global Observations of Forest Cover – Global Observations of Land Dynamics (GOFC–GOLD)/Northern Eurasia Regional Information Network (NERIN), Northern Eurasia Earth Science Partnership Initiative (NEESPI), and Monsoon Asia Integrated Research Study (MAIRS) Workshop was held in Almaty, Kazakhstan September 15-19, 2009. The workshop provided a forum for international scientific exchange on critical land use issues in Central Asia, facilitated coordination of satellite-based research and applications within the region, and strengthened research undertaken within the NASA LCLUC program. The workshop provided a follow-up on the discussions and research collaboration initiated in the 2007 Fall NEESPI/LCLUC meeting in Urumqi, China.

The National Center for Space Research and Technology (NCSRT) of Kazakhstan’s National Space Agency (KNSA) hosted the meeting. The NCSRT is the leading national institution in Kazakhstan and one of the leading institutions in Central Asia focusing on development and operational implementation of land monitor-

ing methodologies based on various remotely-sensed data sources. Equipped with its own ground-receiving station, the NSRTC processes and archives data from the U.S. Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS), Indian IRS-1C/1D and IRS P6, and Canadian RADARSAT-1 instruments. This capability enables NSRTC to support the operational needs of land management agencies as well as develop scientific data products.

A total of 184 scientists and land managers from 16 countries (representing Belgium, China, Germany, Iran, Italy, Japan, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Russia, Tajikistan, Turkmenistan, Ukraine, United States, and Uzbekistan) attended the workshop. One of the goals of the workshop was to initiate the development of a regional Central Asian information network, which would sustain the regional exchange of information and satellite monitoring. The full agenda as well as presentations from the meeting are available at the LCLUC web site: lcluc.umd.edu.



Meeting participants gather on the first day of the workshop.

Workshop Framework

The workshop opened with the address from the head of the KNSA, Kazakh cosmonaut **Talgat Musabayev**. In his remarks, Musabayev emphasized the commitment of KNSA to support the needs of operational and scientific observations of land from space by preparing the launch of two high resolution satellites collecting data at 1-m and 7–20-m resolutions, respectively. He also noted that the role of KNSA in the global space program is expected to increase significantly in the near future once the Baikonur space launch pad becomes a major venue for human space-flight missions after the cancellation of NASA's shuttle program. Zhumabek Zhantayev, a member of the National Academy of Sciences of Kazakhstan and the president of NSRTC followed Musabayev and echoed his acknowledgement of the importance of the work undertaken by the participants of the workshop.

Brief presentations followed the opening remarks and described the existing international programs involved in monitoring and assessment of environmental change in Central Asia. They also outlined opportunities for regional and international collaborations within the framework of these programs.

Garik Gutman [NASA HQ—*LCLUC Program Manager*] summarized the LCLUC program and current areas of emphasis for NASA's Earth observation program. In his presentation, Gutman pointed out that synergistic use of NASA and commercial U.S. assets in optical remote sensing allows evaluation of various processes across different spatial (from 1 km to 1 m) and temporal (yearly to twice daily observations) scales. He noted that during its 50-year record, NASA launched a suite of systematic and exploratory missions collecting LCLUC-relevant information, with the Landsat program of particular importance with its unprecedented length of data record and resolution of imagery.

Environmental processes occurring within Central Asia fall within the area of interest of two large regional science programs. The MAIRS program, introduced by **Jianguo Qi** [NASA-MAIRS—*Program Scientist*] placed a strong emphasis on advancing the understanding of the interactions between human and natural compo-

nents of ecosystem functioning in the monsoon Asian region. These interactions are in support of sustainable development. **Multu Ozgodan** [University of Wisconsin] described the NEESPI program and mentioned that Central Asia is of particular interest because it covers many transitional zones (including forest-steppe, steppe-desert, and mountain systems), which frequently are vulnerable to internal and external change.

The collaboration of scientists within Northern Eurasia is supported through an established GOFCC–GOLD regional network (NERIN), designed to provide the interface between producers of satellite data products and national level data users. **Olga Krankina** [GOFCC–GOLD/NERIN—*Coordinator*] invited the regional workshop participants to join the newest data dissemination initiative in Asia in April–May 2010.

Science Issues

Concern about the environmental impact of global climate change on the Central Asian region was at the forefront of the meeting agenda.

The workshop focused on relating the observations of environmental and land-use processes directly to human well-being, thus linking the scientific research to operational land monitoring and decision-making support. The increasing demand for agricultural production and concerns about food security; natural disasters such as fire, drought, and flooding; degradation of land resources through soil erosion; and dramatic reductions in fresh water availability are the immediate concerns in dry lands of Central Asia. Remotely sensed observations and analysis play an important role in quantifying changes in these phenomena and informing land management decisions. The workshop covered the four major themes of land cover, land use/agriculture, water resources, and fire with the goal of reviewing the existing regional approaches to monitoring these processes and the availability of satellite data sources, products, and monitoring capabilities.

Zairulla Dyusenbekov [Kazakhstan] delivered a plenary overview of the historic perspective and present state of the land resources of Kazakhstan. He noted that currently only 52% of land resources in Kazakhstan are actively developed with 48% of the territory found in the "reserve" category. Agricultural land use (85% pasture



Meeting participants examine agricultural practices in Kazakhstan during a field visit.

and 10% croplands) comprises nearly two-thirds of the developed lands and exceeds by far other land-use types in the Republic of Kazakhstan. Dyusenbekov named desertification as the greatest threat to land resources of Kazakhstan. Many presenters echoed this statement.

Rashid Kulmatov [Uzbekistan] stated that land degradation due to overgrazing, overcultivation, poor irrigation and salinization of soil, and deforestation are primary threats to land resources of the Aral Sea Basin as well. Inefficient agricultural practices and poor condition of the irrigation network lead to widespread water-driven erosion of irrigated lands and waste of water resources.

Water quality and quantity are of high importance in this region of moisture-limited ecosystems. **Natalya Agaltseva** [Uzbekistan] and **Jiquan Chen** [U.S.] presented observations and modeling of Central Asian river discharge and surface water balance. These findings show an overall decrease of water discharge driven by a direct increase in water consumption and modification of land cover through reduction of woody vegetation and subsequent increase in grasslands and deserts. The presenters also expressed a rising concern about water availability in connection with observed and predicted changes in mountain glaciers. **Zamir Ahmed Soomro** [Pakistan] presented a national approach for capturing and storing rainwater within natural depressions in the landscape to increase water storage capacity and minimize water loss. Transboundary water issues are likely to become prominent and contentious within the immediate future and **Alexander Nikolaenko** [Kazakhstan] raised the importance of international cooperation in solving them.

Monitoring land and water resources is directly connected with the vital issue of short- and long-term food security and agricultural production. **Nadiya Muratova** [Kazakhstan], **Olivier Leo** [Italy], **Igor Savin** [Russia], and **Andrey Chernov** [Russia] introduced regional and national systems of satellite-based monitoring of crop production and forecasting of crop yields. All presenters emphasized the need to supplement the available moderate resolution observations with high and very high resolution imagery to improve the accuracy of agricultural monitoring.

Chris Justice [GOF-C-GOLD Fire, Group on Earth Observations (GEO) Ag—U.S.] invited regional scientists to participate in a Global Earth Observing System of Systems (GEOSS) Agricultural Experiment aimed at evaluating the applicability of a suite of Earth Observing (EO) data sources including very high and moderate resolution optical data and microwave observations.

The role of satellite observations in disaster monitoring is also well established in the region. **Oleg Arkhipkin**

[Kazakhstan] and **Magsar Erdenetuya** [Mongolia] presented regional and national systems of fire monitoring. Operational goals of fire monitoring dictate the need for near-real time data availability and thus they are more developed within countries with data receiving capabilities, such as Mongolia and Kazakhstan. However, globally available datasets described by **Tatiana Loboda** [U.S.] present a viable alternative for countries that currently do not possess a national fire monitoring capacity.

The workshop presentations and discussions stressed the importance of developing adaptation strategies to climate-induced changes in ecosystem functioning. **Lubov Lebed** [Kazakhstan] presented long-term meteorological trends indicating a consistent increase in temperature and decrease in precipitation between 1850 and 2000 and the potential changes in pasture biomass productivity under the projected scenarios of climate change. **Irina Vitkovskaya** [Kazakhstan] noted that under the observed climate change the transitional “steppe-desert” areas appear to have been shifting towards desert conditions between 2000 and 2008. Changes in economic situation further amplify climate-induced changes as **Dennis Ojima** [U.S.] and **Chuluun Togtohyn** [Mongolia] demonstrated. They showed that vulnerability of rangelands to climate and land-water use changes in Mongolia increased since the transition to a market economy in 1992.

The workshop provided a fruitful environment for the regional and international participants to exchange knowledge about environmental concerns in Central Asia and share methodological advances in monitoring various land-use and ecological processes using satellite data. The participants identified five research areas of greatest concern: 1) the quality and quantity of fresh water resources as the strongest case for a regional network activity; 2) crop yield estimation, crop monitoring, and agricultural use of fire in the context of ensuring regional food security; 3) land and soil degradation leading to reduction in land productivity over time and increasing vulnerability of the natural and agricultural systems; 4) climate change and variability in the context of concerns for adaptation of human systems’ different conditions, understanding processes, and informing policy makers; and 5) augmenting fire monitoring capabilities with regional fire ecology research in support of long-term fire management strategies.

At the end of the workshop, the participants voiced a unanimous consensus for better regional cooperation in addressing the issue of land monitoring in support of scientific research and decision making for resource management. The similarities in historical development of the region are now expressed in the similarity of the environmental issues across the region and potentially lead to trans-boundary tensions over resource availability. These tensions are particularly expressed in disputes

over fresh water quality and quantity between the countries sharing common watersheds. The shared challenges within the region and the diversity in economic and technological development have led to recognition that greater regional cooperation, both in terms of science and resource management, would be beneficial. Participants welcomed a decision to create the Central Asia Regional Information Network (CARIN) in the framework of GOFC–GOLD. CARIN will facilitate the continued flow and exchange of data and methodologies as well as scientific findings throughout the region. Representatives from all participating countries in Central Asia, including Kazakhstan, Uzbekistan, Tajiki-

stan, Kyrgyzstan, Turkmenistan, Mongolia, China, and Russia, welcomed and supported the network. A planning meeting for the network will be held in the spring of next year in Almaty, followed by a GOFC–GOLD Regional Network Workshop tentatively planned for 2011 to be hosted in Uzbekistan.

A two-day training session followed the workshop, with 63 meeting participants attending. The session aimed at informing the regional experts and decision makers about publicly available satellite-based datasets and introducing data processing methodologies necessary to ensure high quality of output. ■

ESIP Federation Elects 5 New Partners

On November 16, 2009, the Federation of Earth Science Information Partners (“ESIP Federation”) elected five new partners for full membership. Representing each type of ESIP Federation Partner, this new class of applicants demonstrates the continued interest in the ESIP Federation from the broad continuum of Earth science data and technology interests. The new partners include:

- *Chapman University, Schmid College of Science (Type II)*, **Menas Kafatos**, Orange, California;
- *Earth System Grid Center for Enabling Technologies (Type I)*, **Dean N. Williams**, Lawrence Livermore National Laboratory, Livermore, California;
- *ISciences (Type III)*, **Lisa Emmer**, Ann Arbor, Michigan;
- *NASA Planetary Data System (Type I)*, **Steve Hughes**, Jet Propulsion Laboratory, Pasadena, California;
- *Satellite Educators Association (Type III)*, **Paula Arvedson**, Pasadena, California.

“The ESIP Federation continues to attract Earth science data and information experts to its membership. Our diversity and ability to work across disciplines, sectors and federal agencies has enabled this community to advance in ways greater than the sum of its parts.” says **James Frew**, ESIP Federation President. “The ESIP Federation’s reputation is growing as the place for community-driven collaboration in the Earth sciences.”

Now in its second decade, the ESIP Federation has **115 partners** representing a wide range of Earth science data interests. ESIP Federation partners include Earth science data centers, environmental research groups, practitioners in the application of environmental data, educators, and technologists. Across these diverse interests, public, private, and non-profit organizations are represented.

The ESIP Federation is a consortium of Earth science data and technology professionals spanning government [NASA, National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), U.S. Geological Survey (USGS)], academia, and the private sectors (both commercial and nonprofit). The organization is dedicated to transforming research data and information into useful and usable data and information products for decision makers, policymakers, and the public. Initiated by NASA in 1997, the ESIP Federation provides data, products, and services to decision makers and researchers in public and private settings. The Foundation for Earth Science provides administrative and staff support to the ESIP Federation.

Ocean Surface Topography Science Team Meeting

Joshua K. Willis, Jason-1 Deputy Project Scientist, NASA Jet Propulsion Laboratory, joshua.k.willis@jpl.nasa.gov

Executive Summary

The 2009 Ocean Surface Topography Science Team (OSTST) Meeting was held in Seattle, Washington June 22-24, 2009. The primary objectives of the meeting were to:

1. provide updates on the status of Jason-1 and Ocean Surface Topography Mission (OSTM)/ Jason-2—hereafter referred to as Jason-2;
2. review the progress of science research;
3. approve the release of the Jason-2 geophysical data record (GDR); and
4. conduct splinter meetings on various topics—significantly, the error budget of altimetry data products.

This report, along with all the presentations from the plenary, splinter, and poster sessions, are available online at: sealevel.jpl.nasa.gov/OSTST2009/index.html.

The Jason-1 spacecraft is healthy except for the two Turbo Rogue space receivers (TRSR)—a.k.a., Global Positioning System (GPS) Receivers—that have failed. However, Jason-1 precision orbit determination (POD) measurements continue to meet the mission requirements based on data from the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) and Laser Retroreflector Array (LRA) instruments.

Jason-2 was launched in June 2008. After a six-month calibration/validation period, Jason-1 and Jason-2 are now flying in a *tandem mission* formation. This provides scientists with double the amount of science data and a more detailed look at smaller-scale ocean phenomena, such as eddies and tides in the coastal areas and shallow seas, than is possible with just one satellite. Jason-2 now occupies the former ground track of Jason-1 and the Ocean Topography Experiment (TOPEX)/Poseidon. All systems are in good condition and the satellite is operating nominally.

Lee-Lueng Fu [NASA/Jet Propulsion Laboratory (JPL)—*NASA Project Scientist for the Jason Mission*] began the meeting with some opening remarks, during which he charged the Science Team with evaluating the Jason-2 GDR and coming to a decision on its public release. Fu introduced **Rosemary Morrow** [Laboratoire d'Etudes en Géophysique et Océanographie Spatiale (LEGOS)—France], **Juliette Lambin** [Centre National d'Etudes Spatiales (CNES)—French Space Agency] and **Josh Willis** [JPL] as new Project Scientists.

The meeting featured six keynote talks including an update on science results of the tandem missions, status

and prospects of other satellite altimeters, planned sea surface salinity and gravity missions, and the challenges of understanding and observing global sea level change. The Jason-1–TOPEX and Jason-2–Jason-1 tandem missions, in addition to providing critical periods of cross-satellite calibration, have provided improved sampling and resulted in numerous breakthroughs in understanding mesoscale variability in the ocean and its interaction with the large-scale circulation, improvements of shallow water tides, and increased operational use of altimeter wind/wave observations. Given the scientific and operational needs for better coverage and reduced errors, there will be an ongoing need for a constellation of altimeter satellites as well as a concerted effort to quantify errors across the numerous existing and upcoming missions.

NASA's Aquarius Mission, planned for launch in 2010, and the European Space Agency's Soil Moisture and Ocean Salinity Mission (SMOS), launched in November 2009, will provide observations of surface salinity. Combined with altimeter observations and estimates of ocean circulation, these new observations will provide important insight into the marine freshwater budget. Launched in March 2009, the European Space Agency's (ESA) Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) satellite is operating well and will soon provide estimates of the *geoid* that will be used to estimate the time-mean ocean dynamic topography with centimeter accuracy at 100-km scales. Knowledge of the *geoid* with sufficient accuracy could eventually pave the way for non-repeat altimeter missions.

Two of the keynote talks addressed observations of global mean sea level rise and served to open a plenary session on understanding errors related to global sea level rise. The rate of sea level rise during the altimeter era is significantly larger than the historical rate estimated for most of the 20th century. Evidence suggests that the rate of mass loss in the cryosphere has accelerated since the early 1990s.

These altimeter sea level rise observations have the potential to be extremely valuable to society, but to fulfill their full potential the measurements must be shown to be accurate. Therefore, it is important to carefully account for, and attempt to reduce, the uncertainties in the numerous and complex measurement systems involved in the altimeter observations.

The plenary session on the sea level error budget contained several presentations highlighting the need for a more comprehensive understanding of both systematic and random errors in the altimeter datasets. Numerous

sources of error exist, but of particular concern were the need to understand and reduce errors caused by inaccuracies in the reference frame as well as errors resulting from drifts and jumps in the radiometers onboard all of the satellite altimeters. After a discussion of the need for improvement of the radiometer data, the OSTST adopted the following recommendation:

Given the societal relevance and scientific importance of global sea level rise, and given the climate focus and operational nature of the Jason-3 mission, the Science Team recommends that the Project take steps to improve the accuracy of the global mean sea level measurement. This will ensure that global signals such as the ongoing rise of 3 mm/year and the 4–5 mm interannual fluctuations associated with El Niño/Southern Oscillation (ENSO) will continue to be observed with sufficient accuracy and that data be released in a timely manner to facilitate monitoring of these signals. Although a Level 1 science requirement for global mean sea level accuracy was placed on Jason-2, only the radiometer design was updated from Jason-1 to achieve this capability. As a result, exhaustive scientific calibration activities have been required to ensure sufficient accuracy of the global sea level record. Furthermore, the Jason-2 radiometer is presently calibrated using natural Earth targets. This risks contamination by other climate signals and reduces the independence of the mean sea level measurement.

Therefore, the science team recommends that a study be initiated immediately to identify all components of the measurement system whose drift could affect the globally-averaged sea level estimate. The study should indicate those components under Project control, and determine the cost and feasibility of complying with the Level 1 science requirement that existed for Jason-2: to, “maintain the stability of the global mean sea level measurement with a drift less than 1 mm/year over the life of the mission.” The project should coordinate with the science team during and after the study, so that instrument stability requirements can be set before mission development begins and to ensure that Jason-3 meets this Level 1 science requirement.

The quality of the Jason-1 GDR-C and Jason-2 GDR-T¹ were evaluated by several groups. The analysis of the formation flight phase between Jason-1 and Jason-2 show very good agreement between the measurement systems of the two satellites. The origin of the relative range bias between Jason-1 and Jason-2 (~70 mm) has been discovered recently. This needs further investigation

¹ GDR-C is the latest round of reprocessed Jason-1 data. GDR-T is a pre-release of the Jason-2 GDRs—i.e., there are still some updates planned.

(notably on the C-band) but, if the bias is confirmed, then both satellites are measuring sea surface consistently, but too high by about 20 cm. Investigations are in progress to explain the difference between Jason-1 and 2 and TOPEX.

After reviewing the status and accuracy of the Jason-2 GDR, the OSTST also made the recommendation to release the data to the general public.

A splinter session was devoted to analysis and discussion of altimeter data from inland and coastal regions. Several large efforts to improve altimeter data quality in these regions are underway. Results suggest that these data can be highly valuable and there is considerable interest in continuing to improve and exploit altimeter data in these regions.

Finally, **Doug Alsdorf** [Ohio State University] presented a summary of the status of development of the Surface Water Ocean Topography (SWOT) mission. After discussion, the OSTST adopted the following recommendation regarding SWOT:

There is an urgency to make new observations for fundamental understanding of:

1. the vertical transfer of heat and nutrients in the ocean for improving ocean climate prediction models;
2. the storage and discharge of land water for improving the prediction of the shifting freshwater supplies in a changing climate;
3. the interaction between ocean currents, sea ice, ice shelf, and ice sheets for improving the prediction of polar ice melting.

The Ocean Surface Topography Science Team recommends that NASA and CNES allocate the necessary resources for a speedy development of the SWOT mission, including prelaunch campaigns for collecting field data supporting the validation of the measurement approach.

Program and Mission Status

Key project personnel from the four partner organizations provided updates on mission and science status. Program leads at NASA and CNES began the session with status updates of the altimetry and oceanography programs at their respective organizations.

Eric Lindstrom [NASA Headquarters—*Ocean Program Scientist*] noted that 26 U.S. principal investigators (PIs) had been selected for the new OST Science Team for the next four years. The next solicitation will likely appear in NASA's 2011 Research Opportunities in Space and Earth Sciences (ROSES) solicitation with proposals due in March 2012. He also noted that a four-party memo-

random of understanding (MOU) has been drafted between NASA, NOAA, CNES, and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) for the upcoming Jason-3 mission.

Eric Thouvenot [CNES—*Ocean Program Manager*] reported on the CNES altimetry program with a focus on Jason-1, Jason-2, and the Indian Satellite with ARgos and ALtiKa (SARAL) mission that will carry the AltiKa altimeter². CNES also committed to the contribution of a *Proteus* spacecraft and project team support to Jason-3, which is being planned as a joint mission involving CNES, EUMETSAT, and NOAA—tentative launch date is 2013. CNES is also planning for participation in wide-swath altimetry (e.g., SWOT).

François Parisot [EUMETSAT—*Jason-2 Project Manager*] discussed EUMETSAT's involvement in altimetry programs with a focus on Jason-3 and its potential follow-on—currently dubbed Jason-CS (CS meaning “continuity of service”). EUMETSAT is seeking to contribute 60 M Euros to Jason-3; by the end of 2009 the funding should be approved, leading to a mid-2013 launch of Jason-3. A four-party MOU between NASA, CNES, NOAA and EUMETSAT is under development with the program being led by NOAA and EUMETSAT. Preliminary discussions have begun for planning Jason-CS. EUMETSAT will also be involved in the operation of the ESA's Sentinel-3 mission, and will also support SARAL.

John Lillibridge and **Laury Miller** [both from NOAA] discussed NOAA's roles in the Jason-2 and Jason-3 missions. For Jason-2, NOAA is providing satellite command and control and is producing and distributing the Operational Geophysical Data Record (OGDR). Data recovery is good (~99.9%) and NOAA is meeting distribution requirements. NOAA has proposed a \$210M budget for Jason-3, to pay for launch, radiometer, GPS, satellite command and control, telemetry, near real-time data processing, data archiving, and distribution. Although the budget is not final, Congress has proposed \$20M for an FY2010 start for Jason-3. NOAA has also identified sea level rise as a major theme of any new U.S. Climate Service. Finally, NOAA is developing a radiometer calibration project to ensure smooth transition of Jason-3 from research to operations.

Jérôme Benveniste [ESA—*Program Manager*] gave a presentation on the status of ESA missions. GOCE was successfully launched in March 2009, and is working well. The first science assessment will occur at the end of June, and a workshop will be planned for the beginning of 2010. Cryosat will launch in February 2010

² AltiKa is a Ka-band altimeter that operates at 35 GHz. SARAL/AltiKa is a joint mission between CNES and the Indian Space Research Office; it is tentatively scheduled for launch in late 2010.

and provide classical altimetry data over land. SMOS launched in November 2009. ENVISAT, now 7-years old, will enter a new orbit in October 2010. Sentinel-3 is under development. Finally, ESA has initiated the “Global Monitoring of Essential Climate Variables” program element. This will include reprocessing of ERS-1&2 and ENVISAT data to improve quality.

Jason-1 and 2 Project and Program Status

Gerard Zaouche [CNES] provided an overview of Jason-2 status. The satellite is operating well and all instruments are fully operational after one year of the mission. OGDR and Interim Geophysical Data Record (IGDR) datasets are being delivered. GDRs have been made available to PIs. The Poseidon-3 altimeter has had 100% data availability since the last OSTST; the only losses have been due to software updates. The DORIS system is working well. Most of the 8.3 cm absolute altimeter bias between Jason-1 and Jason-2 in the *Ku-band* has been related to differences in the characterization parameters set during ground measurements. The remaining difference between Jason-1 and Jason-2 is about 1 cm, but investigations are still in progress to explain the difference between Jason-1&2 and TOPEX.

Glenn Shirliffe [JPL—*Jason-1 Project Manager*] provided an overview of Jason-1 status. Jason-1 was maneuvered into a new orbit that is interleaved and has a 5-day lag relative to the Jason-2 orbit. Jason-1 continues to meet and exceed all Level 1 science requirements and has a 67% probability to maintain operation to April 2011, and sufficient fuel to go back to its original orbit if needed. In September 2009, the NASA Senior Review Panel recommended that funding for Jason-1 be extended to 2013, with another review scheduled for 2011. Despite loss of both TRSR 1 and 2, Jason-1 is still meeting Level 1 POD requirements with 1.5 cm root mean square (RMS) precision.

Keynote Presentations

A series of keynote presentations took place during the meeting that gave an overview of tandem mission results, and reported on the status of other missions—including altimeters, ocean salinity missions, and gravity missions. In addition, two of the keynote speakers addressed issues regarding the observation of global sea level rise from space. These two talks preceded a plenary session on error budgets for altimeter observations.

Links to the keynote talks, listed below, are available on the meeting website: sealevel.jpl.nasa.gov/OSTST2009/index.html.

- *Jason-1 Tandem Mission: Early results* – **Josh Willis**
- *Status of other altimetry missions: AltiKa, Cryosat,*

Sentinel-3, Jason-3, Chinese programs, etc. – **Juliette Lambin** [CNES]

- *Linking ocean circulation, the water cycle and climate: New science opportunities with salinity satellite missions* – **Gary Lagerloef** [Earth and Space Research—PI for NASA's Aquarius mission]
- *Absolute ocean circulation from altimetry: Current status and prospects for the upcoming GOCE era* – **Marie-Hélène Rio** [Collecte de Localisation Satellite (CLS)]
- *Sea Level Change: Past, Present, and Future* – **Steve Nerem** [University of Colorado]
- *Sampling and systematic errors in the global sea level change problem* – **Carl Wunsch** [Massachusetts Institute of Technology]

Plenary Session on Altimeter Sea Level Error Budgets

Wednesday's plenary session focused on sea level error budgets, emphasizing the current status as well as the need for future improvements. **Rui Ponte** [Atmospheric and Environmental Research, Inc.], **Joel Dorandeu**, [CLS] and **Alix Lombard** [CNES] served as session chairs.

There were eight formal talks and five poster contributions on a wide variety of issues. Full details of the talks and posters can be found on the meeting website.

Ponte and Dorandeu emphasized the need for a vastly expanded treatment of the errors across the range of available altimeter datasets. Details on the systematic and random components of the errors, their spatial and temporal characteristics, correlations structures, and other properties, are needed to allow for best use of the data by the diverse user community and provide insight on how to improve error budgets of future altimeter missions.

Poster Sessions

Two poster viewing sessions took place during the meeting. Links to the posters are available on the meeting website: sealevel.jpl.nasa.gov/OSTST2009/index.html. The posters were grouped into the following categories:

- general ocean surface topography science results (e.g., modeling/data assimilation, mean dynamic topography, tropical ocean, coastal ocean, sea level, ocean circulation/air-sea interaction, ocean eddies, land/ice/hydrology);
- sea level error budgets: current status and future improvements;
- global and *in-situ* calibration and validation;
- precision orbit determination and *geoid*;
- instrument processing;
- near real-time products validation and application;
- coastal and inland altimetry; and
- outreach.

Splinter Sessions

The theme for the splinter sessions—in particular for calibration/validation, POD/*geoid*, tides/high frequency (HF) aliasing, sea-state bias/retracking—was evaluation of the Jason-2 GDR product with a goal of recommending it for public release by the end of the meeting. The splinter sessions were organized as follows:

- local and global calibration and validation;
- instrument processing;
- precision orbit determination and *geoid*;
- near real-time products validation and application;
- outreach/education;
- inland/coastal altimetry; and
- general ocean surface topography science.

Comprehensive summaries of the splinter sessions can be viewed at: sealevel.jpl.nasa.gov/OSTST2009/index.html.

Conclusions

Lee-Lueng Fu and **Josh Willis** chaired the closing session. Before summaries from the splinter session chairs, Fu presented plans for a special issue on Jason-2 Cal/Val results in *Marine Geodesy* that would be dedicated to the late Yves Menard. The accepted papers are due by February 10, 2010 and publication is scheduled for June 2010. The Chief Guest Editor for the issue is George Born. Also a special session on ocean surface topography will be held at the 2010 Ocean Sciences Meeting, February 22-26 in Portland, OR.

Doug Alsdorf [Ohio State University] gave a final plenary presentation on the status of the SWOT mission. Alsdorf emphasized the importance of SWOT to both the oceanographic and hydrological communities. The primary oceanographic objectives of the SWOT mission are to characterize the ocean mesoscale and sub-mesoscale circulation at spatial resolutions of 10 km and larger. The hydrologic science objectives of the SWOT mission are to measure the storage change in lakes, reservoirs, and wetlands larger than 250 m x 250 m and to estimate discharge in rivers wider than 100 m (with a goal of 50 m) at sub-monthly, seasonal, and annual time scales. The instrument will be a *Ka-band* Synthetic Aperture Radar (SAR) interferometric system with 2 swaths, 60 km each. Onboard data compression will provide 1-km resolution over the ocean. No onboard data compression will occur over land allowing for 50-m resolution. The orbit inclination will be 78° with a 22-day repeat yielding global coverage with 2 samples each repeat period. The Mission Science Requirements Document is available on the web; swot.jpl.nasa.gov/news/index.cfm?FuseAction=ShowNews&NewsID=21.

Evaluation of the Jason-2 GDR

The quality of the Jason-2 GDR-T was discussed at length. **Nicolas Picot** [CNES] stated that although the current GDR meets all requirements, improvements are available for Jason-2 GDR analysis. It is important to provide a consistent and seamless data product across all altimeter records. After reviewing the status and accuracy of the Jason-2 GDR, the OSTST made the following recommendation regarding its public release:

The Ocean Surface Topography Science Team recommends that the Jason-2 Geophysical Data Records, version T, be released to the general public. This recommendation is based on evidence presented at the OSTST meeting in Seattle that demonstrates the data on this product meets all mission requirements and has accuracy as good as, or better than, data from the Jason-1 Geophysical Data Records.

Future Missions

The importance of maintaining the accuracy and continuity of the precision altimeter record was emphasized several times during the meeting. With transition of responsibility for the altimeter missions to the operational agencies and the development of Jason-3 drawing near, considerable discussion was given to the need for a more comprehensive understanding of both systematic and random errors in the altimeter data sets. A lengthy discussion led to the adoption of the recommendations by the OSTST stated in the **Executive Summary** of this article.

After the closing plenary talk given (from **Doug Alsdorf**), the OSTST discussed the importance of the SWOT mission and adopted the recommendation, also stated in the Executive Summary, regarding SWOT.

Future Meetings

The next meeting will be held October 18-20, 2010, in Lisbon, Portugal. The meeting will be held in conjunction with the annual International Doris Service (IDS) meeting as well as a workshop for the upcoming SWOT mission. As a theme, the meeting will focus on high resolution remote sensing of ocean dynamics and hydrology. ■

Highlights and Memories from Terra

continued from page 6

been possible because of the rapid development of computing capability and the Internet. I recall getting a presentation in my office at Goddard on *Mosaic* for Unix workstations back in 1992 or 1993 before Web browsers were available for normal personal computers and the World Wide Web was in its infancy. The evolution of EOS satellite observations coincided with a dramatic increase in computer capability for processing, archiving, displaying, and disseminating these observations. Without any of these, the data archive today would be full of infrequently accessed Earth observations.

Congratulations to Terra for its many and continued contributions. May it live on for another 10 years! ■



Terra transmitted its *first light* images on February 24, 2000. This image—a subset from the Moderate Resolution Imaging Spectroradiometer (MODIS) flying aboard the Terra satellite—shows James Bay, a saltwater body that occupies an area of 32,000 km². Fast ice (smooth-looking ice grounded to the shore) is visible around the edge of the bay and Akimiski Island. Ice flows are seen in the interior of the bay, as well as snow cover in the forests surrounding the bay. **Credit:** MODIS Atmosphere Science Team

CERES Science Team Meeting

Jim Closs, LaRC/Science Systems and Applications, Inc., james.w.closs@nasa.gov

The Fall 2009 Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held November 3-5 at the Marriott Hotel in Fort Collins, CO. Norman Loeb [Langley Research Center (LaRC)—*CERES Principal Investigator*] convened the meeting. David Randall and Graeme Stevens [both from Colorado State University], and Jeff Kiehl [National Center for Atmospheric Research (NCAR)] gave invited presentations. David Randall also hosted the CERES Team dinner at his home the evening of November 3.

Full meeting presentations are available on the CERES web site at: science.larc.nasa.gov/ceres/STM/2009-11/index.html.

The major objectives of the meeting included review and status of CERES Instruments and Data Products including:

- status reports on the CERES instruments currently in orbit and on the CERES instruments planned for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) as well as its precursor, the NPOESS Preparatory Project (NPP);
- status reports on the NASA Earth Observing System (EOS) and on the recent Earth Science Senior Review;
- updates on Terra and Aqua shortwave (SW), longwave (LW), and TOTAL channel calibration for *Edition 3*;
- update on the status of CERES Flight Models 5 & 6 (FM5 & FM6)—i.e., the instruments planned for NPP and NPOESS respectively;
- updates on *Edition 3* cloud algorithm development and validation;
- updates on plans for Clouds and Radiative Swath (CRS) Validation for *Editions 2 & 3*;
- discussion about extending several CERES data products to December 2007 including Monthly Top of Atmosphere and Surface Radiation Budget Averages (SRBAVG), the International Satellite Cloud Climatology Project (ISCCP)-like-GEO product, and the Synoptic and Monthly Mean Radiative Fluxes and Clouds (SYN/AVG/ZAVG) products;
- discussion of overcoming calibration challenges with the Japanese Meteorological Satellite (MTSAT);
- discussion of ISCCP-like Moderate Resolution Imaging Spectroradiometer (MODIS) and Global Earth Observations (GEO) Data Products;
- discussion of making CERES Level-3 *Edition 3* Data Products more user friendly and working towards early release of *Edition 3* quality Level-3

Top of Atmosphere (TOA) Fluxes through the end of 2008;

- updates from the Data Management Team covering the Terra, Aqua, and NPP missions, as well as plans to optimize CERES Processing;
- an update on the Goddard Earth Observing System model—*Version 5* (GEOS-5);
- an update from the LaRC Atmospheric Sciences Data Center (ASDC); and
- an update on the Students' Cloud Observations On Line (S'COOL) and the S'COOL Rover.

Norman Loeb [LaRC] presented an overview and status of CERES, NASA, EOS, Senior Reviews, NPP/NPOESS, and the National Research Council's Decadal Survey missions. The CERES instruments on Terra and Aqua continue nominal operations, and integration of CERES FM-5 was completed on NPP in November 2008. CERES FM-6 is currently being assembled from spare parts for integration on NPOESS Charlie-1 (C1), currently scheduled to launch in 2014. The CERES team identified calibration improvements that should be made on FM-6. As of now, there are no plans to implement the most important of these recommendations; however, the discussions with NOAA and NASA HQ are ongoing.

The CERES team is working toward an early release (early 2010) of the *Edition 3* data product, which is a hybrid of *Edition 2* and *Edition 3* products. It will use best-quality *Edition 3* instrument radiances and *Edition 2* cloud properties to generate Level-3 TOA fluxes as quickly as possible through the end of 2008. It will also consist of a small subset of SRBAVG cloud and TOA radiation parameters.

The Terra and Aqua Senior Review proposals for CERES resulted in an optimal budget awarded for the next two years. Additional funding will be used to improve CERES data ordering tools at the LaRC Atmospheric Science Data Center, and optimizing processing procedures to increase data products throughput.

NASA is still committed to implementing Decadal Survey *Tier 1* missions, which include the Climate Absolute Radiance and Refractivity Observatory (CLARREO); Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI); Soil Moisture Active-Passive (SMAP); and the Ice, Cloud and Land Elevation Satellite (ICESat-II). LaRC will manage the CLARREO mission, which will focus on high accuracy long-term climate change trends and serve as an in-orbit calibration standard for CERES and other instruments.

Lastly, congratulations to CERES Clouds Subgroup lead Patrick Minnis for being named both an American Geophysical Union (AGU) and American Meteorological Society (AMS) fellow!

Kory Priestley [LaRC] gave an overview and update of the CERES Instrument Working Group, flight hardware performance and status, and *Edition 3* data product release details. CERES has accumulated over 35 years of instrument data from the Tropical Rainfall Measuring Mission (TRMM), Terra, and Aqua. FM 5 & 6 on NPP and NPOESS, respectively, will extend this data record significantly. The fabrication, integration, and test program for CERES FM-5 is complete on NPP, with a projected launch date in mid to late 2011. The ground calibration program for FM-5 was the most extensive to date, with 33 days under continuous vacuum, and six supplemental tests beyond the legacy procedures.

The NOAA-directed CERES FM-6 project for NPOESS completed an enhanced study phase to review legacy processes and procedures, interface control document (ICD) generation, and an enhanced calibration design study. Contract negotiations with Northrop Grumman were completed in April 2009, a Systems Readiness Review was held in September, and *delta* Preliminary Design Review is scheduled for January 2010. The CERES project is pursuing an enhanced on-board shortwave in-flight calibration source (SWICS) to provide on-orbit traceability of the SW channel radiometric performance, and an improved Mirror Attenuator Mosaic (MAM) with a reference detector to attenuate solar irradiance. These improvements are not yet approved per NOAA direction; however, discussions are ongoing.

Incorporating *Edition 3* data helps to improve residual calibration errors that are present in CERES *Edition 2* data products due to spectral degradation of sensor optics. *Edition 3* data will incorporate all known changes in instrument gain and other calibration coefficients, and implement a method of placing all CERES instruments on the same radiometric scale at mission start. This will significantly improve the artificial decreasing trend in reflected solar measurements and the divergence between daytime and nighttime outgoing longwave radiation (OLR) records with time.

The group also heard updates on several CERES Sub-system activities:

- **Susan Thomas** [LaRC/Science Systems and Applications Incorporated (SSAI)] presented an update on FM1–FM4 *Edition 3* Radiometric Calibration;
- **Nitchie Manalo-Smith** [LaRC/SSAI] presented an update on FM1 and FM2 *Edition 3* Spectral Darkening;
- **Patrick Minnis** [LaRC] gave an update on the CERES *Edition 3* Cloud Algorithm;

- **Dave Kratz** [LaRC] and **Shashi Gupta** [LaRC/SSAI] gave an update on the status of CERES–Surface Only Flux Algorithms (SOFA) Algorithms for *Edition 3*;
- **Tom Charlock** [LaRC] and **Dave Rutan** [LaRC/SSAI] discussed recent developments in the Surface–Atmosphere Radiation Budget (SARB) and Clouds and Radiative Swath (CRS) algorithms, as well as checks with independent data;
- **Dave Doelling** [LaRC] gave an update on time-space averaging;
- **Jonathan Gleason** [LaRC] gave an update on behalf of the CERES Data Management Team; and
- **Sue Sorlie** [LaRC/SSAI] presented an update on behalf of the Atmospheric Science Data Center Update.

Break out Working Group sessions took place the morning of November 4, and included the Angular Modeling Working Group—chaired by **Norman Loeb**, the SARB/SOFA Working Group—chaired by **Tom Charlock**, and the Clouds Working Group—chaired by **Patrick Minnis**.

A series of invited presentations followed the Working Group sessions:

David Randall [Colorado State University] presented a talk on *The Ongoing Revolution in Global Modeling*. **Randall** traced the history of global modeling from the 1960s to today, and emphasized the impact of computing power in modern modeling. He pointed out that today's very-high resolution models are conceptually simpler than those of a decade ago, but they are vastly more numerically complicated. Statistical theories, or *parameterizations*, increase conceptual complexity, and the need to predict statistics over large finite volumes is a major source of this complexity.

Randall presented the keys to building a better global cloud-resolving model (GCRM), and pointed out two new models with unique designs but similar results. The next challenge is to unify the parameterizations between conventional models and the global cloud-resolving models. He concluded by stating that computers and models co-evolve, and that current technology trends are pushing models towards higher resolution. Explicit representation of deep convection over the entire globe is now possible with GCRMs, and will revolutionize the field.

Graeme Stephens [Colorado State University—*Principal Investigator for NASA's CloudSat mission*] spoke on *The Controlling Influence of the Radiation Budget on Precipitation*. Stevens discussed energy balance and the effect of water vapor feedback on downward longwave radiation and radiative cooling. He also discussed cloud effects on the radiation budget, the radiative controls

of global precipitation, and the character of precipitation—as learned from Earth observations such as those from CloudSat. He pointed out that water vapor is the greatest thermal absorbent in the atmosphere, but is dependent on temperature for its amount. Stevens contends that the observed increase in downward longwave radiation is approximately equally split into temperature and water vapor contributions, and is a controlling influence on atmospheric net radiative heating/cooling.

On the effect of clouds on the Earth's energy balance, the introduction of clouds doesn't change significantly the column solar absorption but they do significantly redistribute the absorbed energy in the column. He pointed out the differences between observed precipitation and models, emphasizing that models produce rain two to four times too frequently and two to three times too light regardless of resolution.

Stephens summarized by stating that with global warming we expect an increase in atmospheric water vapor ~7% per degree Kelvin, and that this drives a water vapor feedback involving important increases in Downward Longwave Radiation (DLR) which is amplified/suppressed by moisture feedbacks. This lower level

vapor change drives changes in radiative cooling that in turn control the rate of increases of global precipitation but at a rate significantly less than water vapor.

The **table** below summarizes a series of science reports given during the meeting that included updates on new data products and science results.

Norman Loeb led a final wrap-up and discussion of action items from the meeting. He reiterated the importance of delivering *Edition 3* instrument, clouds, and SOFA improvements, with staggered deliveries in early- to mid- 2010. Three *Institute of Electrical and Electronic Engineers (IEEE)* papers are being planned on CERES cloud property retrievals and validation, as well as validation papers for SOFA and SARB. A new data ordering tool will be delivered in May 2010, and the data management team is preparing for a large number of processing code deliveries to the ASDC.

The Spring 2010 CERES meeting will be held April 27-29, 2010, at the Marriott Hotel at City Center at Oyster Point in Newport News, VA. ■

Summary of Science Reports given during the CERES Science Team Meeting

Topic	Speaker	Institution
Comparisons of CERES TOA Fluxes with GEOS-5 Reanalysis Fluxes	Andrew Dessler	Texas A&M University
Seasonal Contributions to Climate Feedbacks in the NCAR CCSM3.0	Patrick Taylor	NASA Langley Research Center
Low Cloud Feedback Diagnosed from LES Modeling and CERES Observations	Kuan-Man Xu	NASA Langley Research Center
Cloud Radiation Convective Feedbacks Inferred from the A-Train Observations	Matt Lebsock	Colorado State University
A Reexamination of "On the Determination of Climate Feedbacks from ERBE Data"	Takmeng Wong	NASA Langley Research Center
Implied Ocean Heat Transports in the Standard and Super-Parameterized Community Atmospheric Model	Charlotte DeMott	Colorado State University
The Climatology and Interannual Variation of Band-By-Band Longwave Cloud Radiative Forcing: Model vs. Observations	Xianglei Huang	University of Michigan
Effects of Clouds on the Radiation Balance as Derived from the New CloudSat Fluxes Product	David Henderson	Colorado State University
CALIPSO, CloudSat, CERES, and MODIS Merged Data Product (CCCM): Improvements of Satellite-Derived Cloud, Aerosol, and Radiative Flux Profiles	Seiji Kato	NASA Langley Research Center

Summary of Science Reports given during the CERES Science Team Meeting (continued)

Topic	Speaker	Institution
Overview and Status of the ScaRaB Megha-Tropiques Mission	Remy Roca	French MT Science Team
Interannual Variations of Surface Radiation	Lou Smith	Langley Research Center/ National Institute for Aerospace
Effect of Invisible Clouds on Radiation Energy Budget	Wenbo Sun	Langley Research Center/SSAI
A Global Perspective on the Plane-Parallel Nature of Oceanic Water Clouds Using Data Synergy from MISR and MODIS	Lusheng Liang	Langley Research Center/SSAI
Estimation of Outgoing Longwave Radiation from AIRS Radiance Measurements	Fengying Sun	NOAA/NESDIS
Comparison of Anomalies and Trends of OLR as Observed by CERES and Computed from Geophysical Parameters Derived from Analysis of AIRS/AMSU Data	Joel Susskind	NASA Goddard Space Flight Center
A Comparison of Multilayer Clouds Inferred Between Passive and Active Satellites	Fu-lung Chang	Langley Research Center/NIA
Principal Component Radiative Transfer Model Spectral Longwave Simulations Using 5 Years of SSF/MOA Compared with CERES Observed Broadband Nadir Radiances	Fred Rose	Langley Research Center/SSAI
Land Surface Latent Heat Estimations Using Surface Radiation Data: Preliminary	Bing Lin	NASA Langley Research Center
Observations for Evaluating CMIP5 Simulations	Jerry Potter	University of California, Davis
Estimation of Atmospheric Column SW Absorption Under Clear Sky and Optically Thick Clouds Using Both Satellite-Surface Observations and GCM	Xiquan Dong	University of North Dakota
Student' Cloud Observations On-line (S'COOL) Update	Lin Chambers	NASA Langley Research Center

HDF/HDF-EOS Workshop Summary

Daniel Marinelli, NASA Goddard Space Flight Center, daniel.j.marinelli@nasa.gov

The 13th Hierarchical Data Format (HDF) and HDF for the Earth Observing System (HDF-EOS) Workshop took place November 3-5, 2009, at the Raytheon Riverdale development facility in Riverdale, MD. Eighty-seven people attended with varied interests ranging from their perspectives as users, tool developers, and data producers. This year's theme was, *Closing the Gap: Harnessing the Power of HDF Through Established Technologies*.

The agenda with presentations and posters for all three days can be found at:
hdfeos.org/workshops/ws13/workshop_thirteen.php.

The first day of the meeting was dedicated to tutorials sessions. The HDF Group (THG), **Elena Pourmal**, **Barbara Jones**, **Peter Cao**, **Joe Lee**, and **Kent Yang** provided in-depth information on all aspects of *version 5* of HDF (HDF5). THG representatives gave tutorials in HDF5 data and programming models, advanced HDF5 features, HDF5 tools, and using visualization tools to access HDF data with Open-source Project for a Network Data Access Protocol (OPeNDAP).

Online help for HDF5 tools can be found at: hdfgroup.org/hdf5tools.html.

Abe Taaheri [Raytheon/Landover] gave an overview and demonstration of the HDF-EOS to GeoTIFF (HEG) conversion tool and the HDF-EOS plug-in library extension to *HDFView*. The HEG tool converts, subsets, resamples, and performs mosaicing on HDF-EOS data as it is converted to GeoTIFF. The HDF-EOS plug-in is a library that extends *HDFView*, a visual tool for browsing and editing HDF *version 4* (HDF4) and HDF5 files, for EOS applications. Information on the plug-in can be found at:

newsroom.gsfc.nasa.gov/sdptoolkit/HDFView/HDFView_hdfeos_plugin.html,

and information on the HEG tool can be found at:

newsroom.gsfc.nasa.gov/sdptoolkit/HEG/HEGHome.html.

John Evans [The MathWorks] gave a tutorial/demonstration of access to HDF5 data via the MATLAB software.

Daniel Kahn [Science Systems Applications, Inc. (SSAI)] then presented the HDF5-Python (h5Py) interface, highlighting the unique and useful similarities between Python data structures and HDF5.

Joe Lee and **Kent Yang** gave an overview of the newly designed HDF-EOS Tools and Information Center website and re-introduced the HDF-EOS user forum. The new website replaced the old website with the same address, hdfeos.org, as of November 2009. The software library and tools information were scrubbed for completeness and accuracy, and the HDF-EOS user forum became operational as well.

Robert Wolfe [NASA GSFC Terrestrial Information Systems Branch] was the keynote speaker and presented, *MODIS (and VIIRS Land) Current and Future use of HDF*. He communicated lessons learned as well as his opinions from Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible/Infrared Imager Radiometer Suite (VIIRS) land applications experience. He stated that the MODIS team is likely to begin providing access to some of their products in the HDF5 format as soon as 2011.

The remainder of the morning's talks contained status updates for HDF and HDF-EOS development and the results of NASA's Earth Observing System Data and Information System (EOSDIS) User Survey for 2009. In the afternoon, **Wei Huang** [University Corporation for Atmospheric Research (UCAR)] provided a description of UCAR's implementation of HDF5 and HDF-EOS5 data access through its National Center for Atmospheric Research (NCAR) Command Library (NCL). NCL provides scientific data analysis and data visualization services. More information for the tool can be found at: www.ncl.ucar.edu.

Ruth Duerr [National Snow and Ice Data Center (NSIDC)] provided an overview and description of what an archive information package would need to contain to effectively ensure long-term usage of the HDF-EOS data.

In the afternoon, Duerr, **Mike Folk** [THG], and **Chris Lynnes** [GSFC] presented the status of their work in ensuring long-term access to remotely sensed HDF4 data. *Phase 1* of the project proved feasibility of the concept and a prototype mapping tool. *Phase 2* of the project is beginning. The goal is to productize the HDF4 mapping schema and provide tools for deployment. The team encourages all interested parties to review the website (www.hdfgroup.org/projects/hdf4mapping/) and consider what it might take to implement this for their archive.

The end of the day was dedicated to the poster session.

Mike Folk led off the next day's talks with a description of THG's support for the National Polar-orbiting Operational Environmental Satellite System (NPOESS), and its precursor, the NPOESS Preparatory Project (NPP). This support includes development and maintenance of software capabilities of the HDF5 libraries and tools that will assist NPP/NPOESS data producers and users. Attendees were encouraged to submit ideas and opinions for areas of emphasis so that resources can be applied most effectively in support of NPP/NPOESS in the coming years.

Joe Lee then presented an update and demonstration of the HDF OPeNDAP Project. The HDF5 OPeNDAP handler was formally released in October 2009 and supports HDF-EOS5 access. Work on the HDF4 OPeNDAP handler is the focus of this year's effort as many more HDF-EOS2 formatted products will be supported through the handler once this work is completed.

Chris Lynnes presented, *Practical Methods for Making HDF Data Usable by NetCDF-based Tools*, giving an overview of GSFC's work in making data available to its community of users as effectively as possible. He showed an array of tools with their associated idiosyncrasies described, and a description of the pros and cons of various approaches that will be examined in the future.

Cheryl Craig [UCAR] presented the status of submitting the Climate and Forecast (CF) Conventions for standardization to the NASA Earth Science Data

Standards Process Group. The CF Conventions are format independent and, while originally developed to describe data stored in netCDF, can be used for HDF5 data as well.

Bill Okubo [ITT Visual Information Solutions] wrapped up the day's presentations with the status of ENVI/IDL support for HDF and other scientific data formats.

The location of next year's workshop was not decided at this time, but the Program Committee will make an announcement sometime in April 2010. We encourage interested parties to serve on the Program Committee by contacting any of the members below:

Program Committee

- **Dan Marinelli**, NASA Goddard Space Flight Center, daniel.j.marinelli@nasa.gov
- **Carol Boquist**, NASA Goddard Space Flight Center, Carol.L.Boquist@nasa.gov
- **Michael Folk**, The HDF Group, mfolk@bdfgroup.org
- **Elena Pourmal**, The HDF Group, epourmal@ncsa.uiuc.edu
- **Kent Yang**, The HDF Group, ymuqun@ncsa.uiuc.edu
- **Ebrahim Taaheri**, Raytheon, Abe_Taaheri@raytheon.com
- **Daniel Kahn**, SSAI, Daniel.A.Kahn@nasa.gov
- **Dawn Siemonsma**, ADNET Systems, dsiemonsma@usgs.com ■



On December 26, 2009, following a Christmas snowstorm, the Advanced Land Imager (ALI) on NASA's Earth Observing-1 (EO-1) satellite captured this image of Snyder, TX and the surrounding area. This picture shows an apparent gradient of snow thickness. Snow cover appears most opaque in the upper right corner of the image, and gradually thins toward the south and west. A combination of snow, bare ground, and the sun's low angle accentuates differences in land use. Grids of major roadways and side streets indicate Snyder's city limits. Immediately southeast of town, a cluster of circles and semicircles suggests center-pivot irrigation systems. Surrounding the town, rectangular and circular shapes indicate cropland. East of town, a highway runs northwest-southeast through the area. **Credit:** NASA's Earth Observatory

COP15 UNFCCC United Nation Framework Convention on Climate Change

Maurice Henderson, NASA Goddard Space Flight Center, maurice.a.henderson@nasa.gov



From December 7–18, 2009, **Maurice Henderson** [NASA Goddard Space Center/Science Systems and Applications, Inc.] attended the United Nations Framework Convention on Climate Change's (UNFCCC) 15th Conference of the Parties (COP15) in Copenhagen, Denmark. Henderson partnered with the National Oceanic and Atmospheric Administration (NOAA) and supported the Science on a Sphere (SOS) global display system in the U.S. Center¹ there. During the conference, he: 1) supported NASA funded scientists scheduled to present with the development and display of an SOS presentation; 2) rendered timely SOS content to match the various themes in the U.S. Center; and 3) served as a docent each day to explain the contribution of NASA and NOAA to the attendees and guests using datasets from NASA missions. Below, in photo journal format, is a chronological review of conference highlights that took place in the U.S. Center. No policy report is offered here; to read about the decisions adopted by COP15, please visit: unfccc.int/meetings/cop_15/items/5257.php.

Sandy MacDonald [NOAA—Director, Earth System Research Laboratory], inventor of Science on a Sphere, opened the *living room* with a short presentation on SOS. A round of informal presentations followed, as the



formal talks were being conducted in the auditorium.

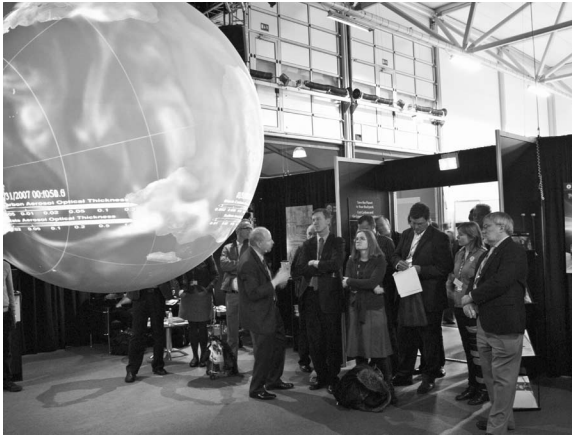
Waleed Abdalati [University of Colorado—Director,

¹ The name for the U.S. exhibit during COP15. For more on the U.S. Center please visit: cop15.state.gov/uscenter/.

Earth Science and Observation Center] was the first of the NASA sponsored scientists to present on SOS. He used a range of the SOS datasets including data from the Gravity Recovery and Climate Experiment (GRACE). He closed with the impact of sea level rise, and typical airline traffic.



Donna Charlevoix [GLOBE Program—Climate Research Campaign Coordinator] introduced the GLOBE program (discussed in the article on page 13 of this issue) in the living room. When we learned that her program would highlight the NASA Earth Observations (NEO) dataset, we prepared a set of SOS clips using the same NEO series. Immediately following her original presentation, she turned to SOS, walked the audience through the NEO data series, and conducted a Q&A.



During each day, the U.S. Center team used the living room to meet the needs of the ever-changing program. Sandy MacDonald filled in on several occasions drawing huge crowds.



The airline traffic animation had them on their knees—literally.



On Tuesday, December 8, Sandy MacDonald hosted a *SphereCast* to the SOS sites around the world providing an update from COP15.

Jeff Masek [NASA—Deputy LDCM Project Scientist] opened on Wednesday, December 9, with an SOS discussion on land cover change. He used several global land cover views and a new SOS clip prepared to show Landsat views from 1972–2009 for selected locations around the world. This clip proved to be quite popular throughout the conference.



NASA invited **James Balog** [Extreme Ice Survey—Director] to bring the Extreme Ice Survey story to COP15. He presented his stunning photo-journalism on the changing cryosphere in the auditorium. Balog's images were repackaged for presentation on the SOS.



Balog incorporated several NASA datasets into his presentation showing the global data, and then presenting still and time-lapsed photos of the changes on the ground. He presented his story five times during the conference, and each presentation drew a large audience.

On Thursday, December 10 and 11, **Jack Kaye** [NASA—Earth Science Division Associate Director] “froze” the audiences with SOS presentations that explored why and how NASA set out to answer questions that have advanced our understanding of Earth System Science.



Kaye’s audiences seemed to hang on every word as he explained some of the challenges NASA encountered in various missions. Here he looks at the Aura nitrogen dioxide (NO_2) data set.



During the first week, the NASA scientists conducted outstanding and engaging SOS presentations and made themselves available for extensive Q&A sessions afterward.

During the conference, the various presentations showcased NASA missions and their observations.

The audiences showed a great deal of interest in the CloudSat dissection of Typhoon Choi Wan, and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) record synced with the Keeling carbon dioxide (CO_2) curve.



The auditorium and the living room held standing room only crowds each day after lunch as the U.S. Center played host to a U.S. Secretary or agency head.



Jane Lubchenco [NOAA—Administrator] was available early in the second week to address the conference, and support her team.



In our planning for the conference, we launched a last minute effort to add an SOS greeting clip to our library. It was a push to get it completed before the opening. We almost made it.

The presentation of the welcome was warmly received.



The second week saw a significant change in the atmosphere. Security got stiffer, and the non-governmental organization (NGO) population was greatly restricted. We hosted four or five presentations each day for significant audiences, but everything was building toward the Heads-of-State visit at the end of the week.

The U.S. Center provided a friendly oasis for many of the conference attendees, and most of the press and camera crews paid us a visit, but their scope did not hit you until you visited the media center.



Speaker of the House **Nancy Pelosi**, and her delegation arrived early Friday morning and introduced astronaut **Mark Kelly**. Rep. **Steny Hoyer** was proud that Goddard was making a contribution to the conference team.

Speaker Pelosi's delegation was a very attentive audience.



Beth Russell [NOAA Earth System Research Laboratory] and **Maurice Henderson** [NASA] presented SOS clips on hurricanes, ocean currents, sea level rise, GRACE, carbon tracker, ocean acidification, sea ice extent, the Intergovernmental Panel on Climate Change (IPCC) temperature models, and the airline traffic animation.



The delegation settled in to watch the addresses by the Heads of State. This gave us a chance to talk to Mark Kelly and his wife Rep. **Gabrielle Gifford**. She asked for U.S. carbon footprint statistics.



We provided per capita CO₂ emissions for the USA and China along with additional statistics from **John Holdren's** presentation earlier in the week. This information was immediately shared with her *Twitter* followers just in time for us to watch the President's address.



NASA and NOAA can take great pride in the contribution that we made to the U.S. presence in Copenhagen. The U.S. Center was at the top of the "must visit" destinations at the Belle Center. By all accounts, the State Department was very pleased with our contribution. ■

NASA Looks for Safer Icing Forecast For Pilots

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

Rory Collins, NASA Langley Research Center, rory.e.collins@nasa.gov

Of the many dangers that plague commercial airplanes, icing stands out as one of the most treacherous. The threat of ice build-up on aircraft surfaces has been known and studied for decades, but now NASA is putting new effort into understanding a different kind of ice danger.

A well-known icing problem involves ice forming on wings and other surfaces that can cause drag and power loss on an aircraft. A different threat emerges when airplanes fly into clouds with high ice content found near thunderstorms in very high altitudes. Ice particles, once thought benign because they would simply bounce off airplane surfaces, can accrete deep inside jet engines and shut down the power. This is called *ice particle icing*, to distinguish it from icing caused by super-cooled liquid droplets, which typically occurs at lower altitudes.

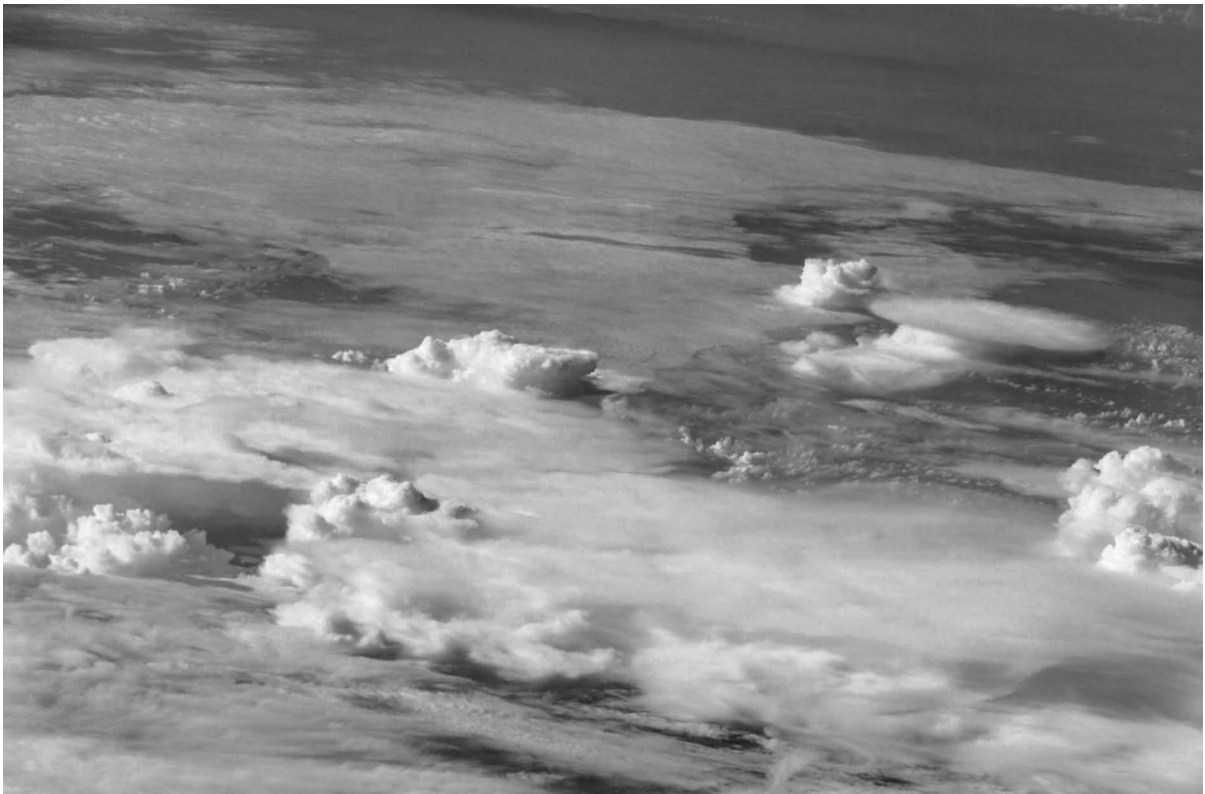
There have been more than 240 icing-related incidents in commercial aviation since the 1990s, of which 62 resulted in power-loss likely due to ice particle icing, according to a study authored by **Jeanne G. Mason**,

J. Walter Strapp, and **Phillip Chow**. This condition is difficult for pilots to identify because in many cases the ice is forming only inside the engine, without any visible icing on the wings.

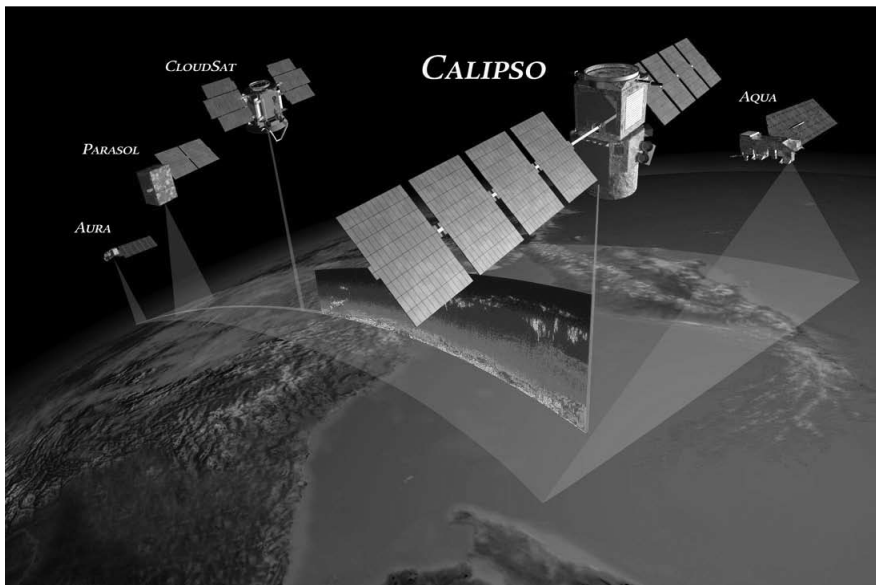
Researchers at NASA Langley Research Center are taking a closer look at the phenomenon, which is considered a significant threat to commercial airlines. NASA scientists are developing ways to identify the conditions that cause ice particle icing to better warn pilots about where this might occur.

“It’s something that hasn’t been explored much,” said **Chris Yost**, a NASA contractor and research scientist with Science Systems and Applications, Inc. in Hampton, VA. Yost said his research is at a preliminary stage now, focused on pinpointing the types of clouds connected with ice particle icing.

“These are deep convection, thunderstorm-like clouds,” Yost said. “Thin, wispy cirrus stuff is not so much a problem.”



Deep convective clouds such as these create conditions that can lead to a dangerous icing threat for commercial flights—one that can cause engine power loss. Researchers at NASA’s Langley Research Center are trying to improve forecasts for this specific threat. These storm clouds were captured from the International Space Station over the East Coast of the United States in September, 2003. **Image courtesy of:** NASA’s Johnson Space Center



NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) is part of a constellation of satellites known as the A-Train. CloudSat and CALIPSO fly in tight formation and provide a unique vertical profile of cloud height and ice-water content. These satellites' data products are helping scientists try to improve forecasts of dangerous icing conditions for commercial aircraft. **Image credit:** NASA

NASA research is aiming to improve weather forecasts that could steer pilots away from trouble. Building on tools developed to detect surface icing conditions, NASA scientists are using cloud observations from two satellites, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite (CALIPSO) and CloudSat. (These two satellites are part of NASA's Afternoon or "A-Train" constellation.)

CALIPSO and CloudSat fly only seconds apart on the same orbit. Together they provide never-before-seen three-dimensional perspectives of how clouds and aerosols form, evolve, and affect weather and climate. In preliminary research, CloudSat and CALIPSO have been used to build on previous methods of identifying the type of moisture particles that lead to ice particle icing problems. CALIPSO's lidar is used to create a vertical profile of clouds to accurately measure cloud height while CloudSat provides the estimates of ice concentration in those clouds. Together the two instruments provide very detailed information about the vertical structure of clouds, and the ice particles within them.

Yost and other SSAI researchers have been working with **Patrick Minnis**, at NASA Langley Research Center, on incorporating CALIPSO and CloudSat data into forecast models with the goal of identifying potential ice particle icing conditions.

NASA's research on ice particle icing began in 2005 with the integration of cloud data from NOAA Geostationary Operational Environmental Satellites (GOES). This was followed on by a field experiment on NASA's

DC-8 in 2007 to compare ice particle measurements from GOES with actual aircraft measurements. While this data significantly increased researchers understanding of the icing process, the integration of CALIPSO and CloudSat data has vastly enhanced the ability to see what is within the clouds.

Yost is currently comparing satellite records of weather conditions with the coordinates and time and date of specific airplane power-loss incidents in recent years. The research could illuminate more specifically what type of weather leads to ice particle icing and whether ice particle icing was a factor in these accidents. Future plans include flights with NASA's DC-8 to take on-board measurements as a comparison point for CALIPSO and CloudSat observations.

Minnis described the group's ongoing work as a first cut, but envisions it leading to better forecasting of potential ice particle icing conditions in the future.

"The ultimate goal of the project is to be integrated into existing forecast models and eventually into the Next Generation Air Transportation System (NextGen) cockpit system," Minnis said.

Aviation safety organizations around the world are presently working with the ultimate goal of being able to accurately forecast inflight icing conditions in real-time for pilots. The integration of NASA satellite data into forecasting models is bringing them closer to that goal, step by step. ■

Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect

Mike Carlowicz, NASA's Earth Science News Team, michael.j.carlowicz@nasa.gov

NASA researchers studying urban landscapes have found that the intensity of the *heat island* created by a city depends on the ecosystem it replaced and on the regional climate. Urban areas developed in arid and semi-arid regions show far less heating compared with the surrounding countryside than cities built amid forested and temperate climates.

“The placement and structure of cities—and what was there before—really does matter,” said **Marc Imhoff**, a biologist and remote sensing specialist at NASA's Goddard Space Flight Center. “The amount of the heat differential between the city and the surrounding environment depends on how much of the ground is covered by trees and vegetation. Understanding urban heating will be important for building new cities and retrofitting existing ones.”

Goddard researchers including **Imhoff**, **Lahouari Bounoua**, **Ping Zhang**, and **Robert Wolfe** presented their findings at the Fall Meeting of the American Geophysical Union in San Francisco, CA on December 16.

Scientists first discovered the heat island effect in the 1800s when they observed cities growing warmer than surrounding rural areas, particularly in summer. Urban surfaces of asphalt, concrete, and other materials—also referred to as *impervious surfaces*—absorb more solar radiation by day. At night, much of that heat is given up to the urban air, creating a warm bubble over a city that can be as much as 2–5°F (1–3°C) higher than temperatures in surrounding rural areas.

The impervious surfaces of cities also lead to faster runoff from land, reducing the natural cooling effects of water on the landscape. More importantly, the lack of trees and other vegetation means less evapotranspiration—the

process by which trees “exhale” water. Trees also provide shade, a secondary cooling effect in urban landscapes.

Using instruments from NASA's Terra and Aqua satellites, as well as the joint U.S. Geological Survey–NASA satellite Landsat, researchers created land-use maps distinguishing urban surfaces from vegetation. The team then used computer models to assess the impact of urbanized land on energy, water, and carbon balances at Earth's surface.

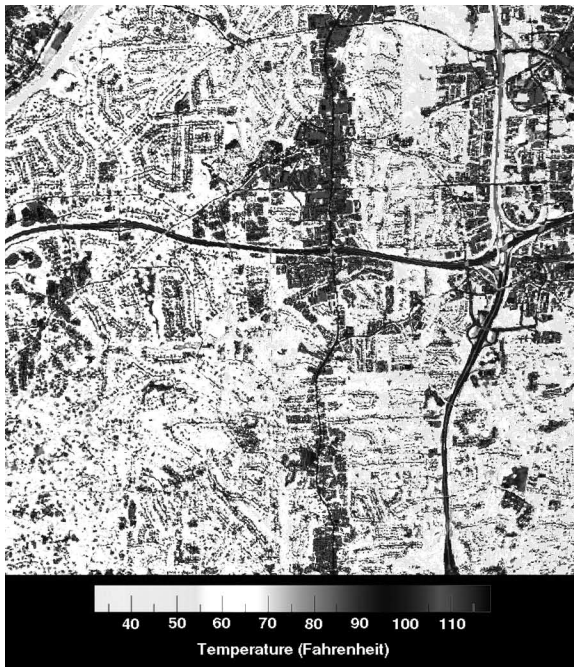
When examining cities in arid and semi-arid regions—such as North Africa and the American Southwest—scientists found that they are only slightly warmer than surrounding areas in summer and sometimes cooler than surrounding areas in winter. In the U.S., the summertime urban heat island (UHI) for desert cities like Las Vegas was 0.83°F (0.46°C) lower than surrounding areas, compared to 18°F (10°C) higher for cities like Baltimore. Globally, the differences were not as large, with a summertime UHI of -0.38°F (-0.21°C) for desert cities compared to +6.8°F (+3.8°C) for cities in forested regions.

In a quirk of surface heating, the suburban areas around desert cities are actually cooler than both the city center and the outer rural areas because the irrigation of lawns and small farms leads to more moisture in the air from plants that would not naturally grow in the region.

“If you build a city in an area that is naturally forested—such as Atlanta or Baltimore—you are making a much deeper alteration of the ecosystem,” said Imhoff. “In semi-arid areas with less vegetation—like Las Vegas or Phoenix—you are making less of a change in the energy balance of the landscape.”



The urban heat island effect can raise temperatures within cities as much as 9°F (5°C) higher than the surrounding countryside. New data suggests that the effect is more or less pronounced depending on the type of landscape—i.e., forest or desert—the city replaced. **Credit:** NASA



LandSat-5 satellite imagery of suburban [left] and urban Atlanta [right] shows the differences in daytime heating, as caused by the urban heat island effect. To view these images in color, please visit: www.nasa.gov/mission_pages/terra/news/heat-islands.html. **Credit:** NASA Goddard's Scientific Visualization Studio

“The open question is: do changes in land cover and urbanization affect global temperatures and climate?” Imhoff added. “Urbanization is perceived as a relatively small effect, and most climate models focus on how the

oceans and atmosphere store and balance heat. Urban heat islands are a lot of small, local changes, but do they add up? Studies of the land input are still in early stages.”

Release of AIRS Level 2 and Level 3 Troposphere CO₂ Data Products

The Atmospheric Infrared Sounder (AIRS) Project is pleased to announce the release of its *Level 2* and *Level 3* free troposphere CO₂ data products. The data cover the globe from 60°S–90°N, beginning in September 2002 to present. The products will be extended as time progresses and the data are processed.

All products are freely distributed through the Goddard Earth Sciences Data and Information Services Center (GES DISC). All new products can be searched through and downloaded from the Mirador engine at the GES DISC:

mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=co2+and+AIRS.

The CO₂ products are also available via the AIRS portal at GES DISC at:

disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/data_products.shtml#CO2.

Data product information on CO₂ and all AIRS data products can be found at:

disc.sci.gsfc.nasa.gov/AIRS/documentation.

Alternatively, users may link to the AIRS Project public web page at the Jet Propulsion Laboratory. The page provides a brief description of the CO₂ data products, including a weighting function figure, a figure comparing the CO₂ trend to the CONTRAIL *in situ* measurements, significant findings to date, and references to journal papers:

airs.jpl.nasa.gov/AIRS_CO2_Data/About_AIRS_CO2_Data/.

NASA Outlines Recent Breakthroughs in Greenhouse Gas Research

Alan Buis, NASA Jet Propulsion Laboratory, alan.buis@jpl.nasa.gov

Sharon Ray, NASA Jet Propulsion Laboratory, sharon.ray@jpl.nasa.gov

Researchers studying carbon dioxide (CO₂), a leading greenhouse gas and a key driver of global climate change, now have a new tool at their disposal: daily global measurements of CO₂ in a key part of our atmosphere. The data are courtesy of the Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua spacecraft.

Moustafa Chahine, the instrument's science team leader at NASA's Jet Propulsion Laboratory, unveiled the new product at a briefing on recent breakthroughs in greenhouse gas, weather, and climate research from AIRS at the December 2009 American Geophysical Union meeting in San Francisco, CA. The new data, which span the seven-plus years of the AIRS mission, measure the concentration and distribution of CO₂ in the mid-troposphere—the region of Earth's atmosphere that is located between 3–7 mi (5–12 km) above Earth's surface. They also track its global transport. The product represents the first release of mid-tropospheric global carbon dioxide data that are based solely on observations. The data have been extensively validated against both aircraft and ground-based observations.

"AIRS provides the highest accuracy and yield of any global carbon dioxide data set available to the research community today," said Chahine. "It will help researchers understand how this elusive, long-lived greenhouse gas is distributed and transported, and can be used to develop better models to identify *sinks*—regions of the Earth system that store CO₂. It's important to study CO₂ in all levels of the troposphere."

Chahine said previous AIRS research data have led to some key findings about mid-tropospheric CO₂. For example, the data have shown that, contrary to prior assumptions, CO₂ is not well mixed in the troposphere, but is rather "lumpy". Until now, models of CO₂ transport have assumed its distribution was uniform.

CO₂ is transported in the mid-troposphere from its sources to its eventual sinks. More CO₂ is emitted in the heavily populated northern hemisphere than in its less

populated southern counterpart. As a result, the southern hemisphere is a net recipient, or sink, for CO₂ from the north. AIRS data have previously shown the complexity of the southern hemisphere's CO₂ cycle, revealing a never-before-seen belt of CO₂ that circles the globe and is not reflected in transport models.

In another major finding, scientists using AIRS data have removed most of the uncertainty about the role of water vapor in atmospheric models. The data are the strongest observational evidence to date for how water vapor responds to a warming climate.

"AIRS temperature and water vapor observations have corroborated climate model predictions that the

warming of our climate produced as CO₂ levels rise will be greatly exacerbated—in fact, more than doubled—by water vapor," said **Andrew Dessler**, a climate scientist at Texas A&M University.

Dessler explained that most of the warming caused by CO₂ does not come directly from CO₂, but from effects known as feedbacks. Water vapor is a particularly important feedback.

As the climate warms, the atmosphere becomes more humid. Since water is a

greenhouse gas, it serves as a powerful positive feedback to the climate system, amplifying the initial warming. AIRS measurements of water vapor reveal that water greatly amplifies warming caused by increased levels of CO₂. Comparisons of AIRS data with models and re-analyses are in excellent agreement.

"The implication of these studies is that, should greenhouse gas emissions continue on their current course of increase, we are virtually certain to see Earth's climate warm by several degrees Celsius in the next century, unless some strong negative feedback mechanism emerges elsewhere in Earth's climate system," Dessler said.

Originally designed to observe atmospheric temperature and water vapor, AIRS data are already responsible for the greatest improvement to five to six-day weather forecasts than any other single instrument in the past



AGU Press conference participants. [Left to right] Thomas Pagano [JPL—AIRS Project Manager], Moustafa Chahine [JPL—AIRS Science Team Leader], Andrew Dessler [Texas A&M—Climate Scientist], and Eric Fetzer [JPL—AIRS Deputy Project Scientist].

decade, said Chahine. JPL scientists have shown a major consequence of global warming will be an increase in the frequency and strength of severe storms. Earlier this year, a team of NASA researchers showed how AIRS can significantly improve tropical cyclone forecasting. The researchers studied deadly Typhoon Nargis in Burma (Myanmar) in May 2008. They found the uncertainty in the cyclone's landfall position could have been reduced by a factor of six had more sophisticated AIRS temperature data been used in the forecasts.

AIRS observes and records the global daily distribution of temperature, water vapor, clouds, and several atmospheric gases including ozone, methane, and carbon monoxide. With the addition of the mid-tropospheric CO₂ data set this week, a seven-year digital record is now complete for use by the scientific community and the public.

For more on AIRS, see airs.jpl.nasa.gov/.

Get the AIRS Carbon Dioxide Data Set

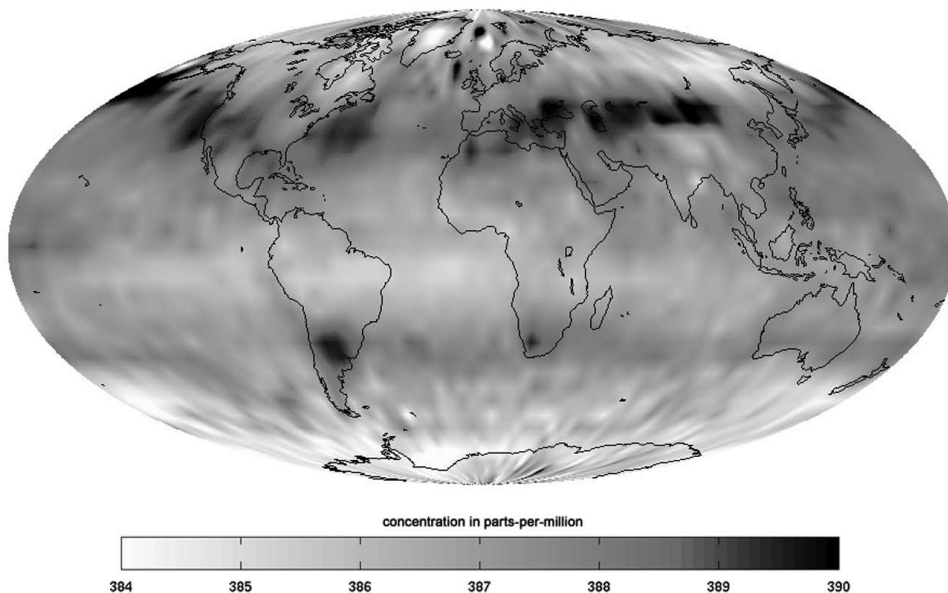
The AIRS carbon dioxide product files may be freely downloaded from the Goddard Earth Sciences Data and Information Services Center. The web page may be used to search for and subset all AIRS data products by type, geospatial location, and time. Data products may be downloaded by ftp or directly via links on web pages:

disc.sci.gsfc.nasa.gov/AIRS/data-holdings

For more information and imagery of the AIRS carbon dioxide data set, please visit the AIRS and CO₂ web page at:

airs.jpl.nasa.gov/AIRS_CO2_Data/AIRS_and_CO2/.

AIRS Carbon Dioxide in the Mid-Troposphere, July 2009



This image was created with data acquired by the Atmospheric Infrared Sounder instrument (AIRS) on NASA's Aqua satellite during July 2009. The image shows large-scale patterns of carbon dioxide concentrations that are transported around Earth by the general circulation of the atmosphere. The lightest areas correspond to a concentration of 382 parts per million and the darkest areas correspond to a concentration of almost 390 parts per million. The northern hemisphere mid-latitude jet stream effectively sets the northern limit of enhanced carbon dioxide. A belt of enhanced carbon dioxide girdles the globe in the southern hemisphere, following the zonal flow of the southern hemisphere mid-latitude jet stream. This belt of carbon dioxide is fed by *biogenesis* activity in South America (where carbon dioxide is released into the atmosphere through the respiration and decomposition of vegetation), forest fires in both South America and Central Africa, clusters of gasification plants in South Africa, and power generation plants in southeastern Australia. To view a color version of this image, please go to the JPL Planetary Photojournal web page at: photojournal.jpl.nasa.gov/catalog/PIA12339. ■



EOS Scientists in the News

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

Where Land Slides, Trying to Learn Why, October 19; *The New York Times*. While there are other relatively small-scale landslide risk analysis and warning programs around the world, researchers including **Robert Adler** (NASA GSFC) are working to provide risk assessment on a much larger scale.

Methane's Role in Global Warming Underestimated, October 30; *USA Today*. A team led by **Drew Shindell** (NASA GISS) finds that chemical interactions between greenhouse gases other than carbon dioxide cause more global warming than previously estimated by the Intergovernmental Panel on Climate Change and other efforts.

NASA Launches Mission to Track Polar Ice by Plane, October 30; *National Public Radio*. This fall, numerous scientists including **Thomas Wagner** (NASA HQ) and **Seelye Martin** (University of Washington) flew on NASA's DC-8 over glaciers in Antarctica as part of the *Operation Ice Bridge* mission, to determine how fast some of the Earth's largest ice sheets are melting, and how much sea level will rise in the coming years.

The Evolution of an Eco-Prophet, October 31; *Newsweek*. Al Gore's views on climate change are advancing as rapidly as the phenomenon itself, and he talked with **Drew Shindell** (NASA GISS) and **Gavin Schmidt** (NASA GISS) and colleagues who run state-of-the-art computer calculations on how much various greenhouse gases contribute to global warming; the relative impact of each, they were finding, was different from what simpler models had suggested.

Unmanned Planes Converted to Climate Scouts, November 5; *Discovery News*. Test flights on a Northrop Grumman Global Hawk aircraft are under way at NASA's Dryden Flight Research Center in California in preparation for a new mission called Global Hawk Pacific (GloPac). **Paul Newman** (NASA GSFC), lead researcher for the mission, explains how the aircraft will make coincident measurements with satellites to collect environmental data.

International Task Force Charged with Improving Air Quality Efforts, November 23, *Space News*. The issue of data rights is one of the key points to be addressed by the air quality community's new task force, according to **Lawrence Friedl** (NASA HQ), and NASA officials are striving to improve communications between scientists working with Earth observations and

end users to ensure that the products the space agency is developing are optimized for public use, according to **Doreen Neil** (NASA LaRC).

Himalayan Glaciers' 'Mixed Picture,' December 1; *BBC News*. There are clear signs of glacial retreat and ice melt from other parts of the world, but few field studies have been carried out in the Himalayas, and **William Lau** (NASA GSFC) explains how NASA products help to provide a broad picture of what is happening regarding the seasonal snow melt, and short term variations.

Healing the Hole in the Ozone Layer Could Heat Antarctica, December 3; *The Sydney Morning Herald*. The hole in the Earth's ozone layer has protected Antarctica from the worst effects of global warming until now, according to a comprehensive review of the state of the Antarctic climate, and the biggest threat to the continent comes from warming seas, said **Robert Bindshadler** (NASA GSFC).

Mandatory Evacuations Issued in Some Canyons with Heavy Rains, December 7; *Los Angeles Times*. Mandatory evacuations were issued for some of California's canyons as officials anticipated heavy rains that could cause mudslides in areas burned during the Station fire; the fire turned what should be a good thing—much needed rains—into something ominous, according to climatologist **Bill Patzert** (NASA JPL).

Wet Winter Foreseen Courtesy of El Niño, December 11; *San Bernardino County Sun*. El Niño, the fickle weather phenomenon that sometimes brings heavy rains to Southern California, has strengthened and is expected to last into spring, and **Bill Patzert** (NASA JPL) notes that only two high rainfall years have been associated with El Niño in recent history: 1997-98 and 1982-83.

Subcontinental Smut: Is Soot the Culprit Behind Melting Himalayan Glaciers? December 15; *Scientific American*. Presenting at a meeting of the American Geophysical Union, **Tepepei Yasunari** (NASA GSFC) reported that he and his colleagues estimated the amount of soot that falls on a typical Himalayan glacier and found that the soot can cause a decrease of between 1.6–4.1% in the glacier's albedo—a measure of its sunlight-reflecting “whiteness”—and that the resulting heating can cause up to a 24% increase in the annual snowmelt; **William Lau** (NASA GSFC) presented the results of a separate study suggesting that soot heating

the atmosphere over India could accelerate the glacier-melting effects of the warm currents that rise up to the Himalayan chain, in a “heat pump” effect.

Weather Device Also Tracks Greenhouse Gas, December 15; *The New York Times*. During a meeting of the American Geophysical Union, instrument project manager **Thomas Pagano** (NASA JPL) explained how the Atmospheric Infrared Sounder (AIRS) aboard NASA’s orbiting Aqua spacecraft measures temperature and cloud cover by recording infrared emissions across the entire globe twice a day, and helps meteorologists predict major storms.

Satellites Weigh California Water, December 15; *BBC News*. Researchers including project scientist **Michael Watkins** (NASA JPL) used data from the GRACE mission, which detects changes in gravity caused by water as it cycles between the sea, to weigh the water lost by California’s heartland since 2003, and found that the San Joaquin River basins that support the highly productive Central Valley, have shed over 30 km³ of water in that time.

With One Space Observatory Down, NASA Uses Another to Map CO₂*, December 17; *Scientific American*. A team of scientists including **Moustafa Chahine** (NASA JPL), **David Crisp** (NASA JPL), and **Joel Susskind** (NASA GSFC) presented new CO₂ data—courtesy of the Atmospheric Infrared Sounder (AIRS), an instrument on board NASA’s Aqua spacecraft—mapping the day-by-day evolution of global CO₂ concentrations in the mid-troposphere.

Vegetation Affects Intensity of Urban Heat Island Effect*, December 17; *The Hindu*. In a study of urban

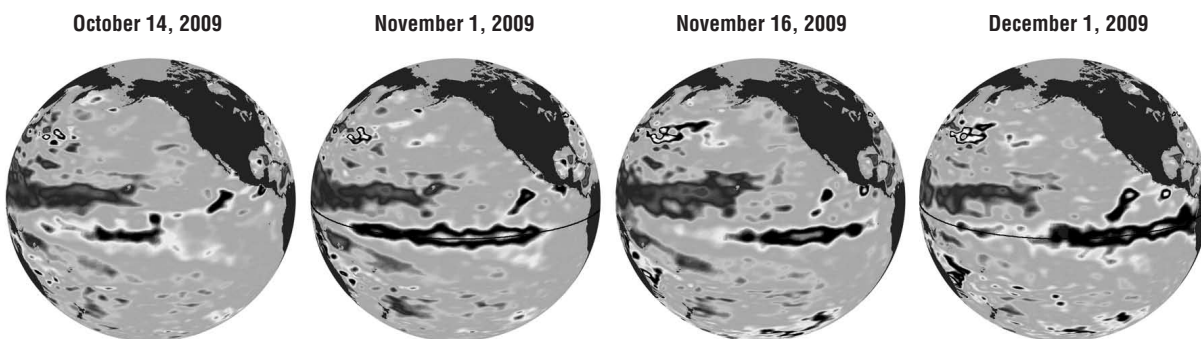
landscapes, researchers including **Marc Imhoff** (NASA GSFC), **Lahouari Bounoua** (NASA GSFC), **Ping Zhang** (NASA GSFC), and **Robert Wolfe** (NASA GSFC) have found that the intensity of the “heat island” created by a city depends on the ecosystem it replaced and on the regional climate.

NASA, Google Offer More Precise Emissions Tracking, December 18; *Associated Press*. NASA and Google are trying to give the world the ability to monitor both the CO₂ pollution and the levels of forest destruction that contribute to global warming. Provided funding, NASA could have a \$330 million “carbon copy,” of the Orbiting Carbon Observatory satellite up flying around Earth in less than three years, according to **Michael Freilich** (NASA HQ).

Earth’s Upper Atmosphere Cooling Dramatically, December 18; *MSNBC/Space.com*. When the Sun is relatively inactive—as it has been in recent years—the outermost layer of Earth’s atmosphere cools dramatically, according to scientists including **Marty Mlynczak** (NASA LaRC), who studied data from NASA’s TIMED mission. The results could help scientists better understand the swelling and shrinking of our planet’s atmosphere.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact Kathryn Hansen on NASA’s Earth Science News Team at khansen@sesda2.com and let her know of your upcoming journal articles, new satellite images, or conference presentations that you think the average person would be interested in learning about.

* For more details on this topic, see News Article in this issue. ■



El Niño Surges; Warm Kelvin Wave Headed for South America. The most recent sea-level height data from the NASA/European Ocean Surface Topography Mission/Jason-2 oceanography satellite show the continued eastward progression of a strong wave of warm water, known as a Kelvin wave, approaching South America. In the eastern equatorial Pacific, this *warm wave* appears as a large area of higher-than-normal sea surface heights (warmer-than-normal sea surface temperatures) between 130°W and the coast of Peru. A series of these types of Kelvin wave events that began in June 2009 initially triggered and has sustained the present El Niño condition.

The above images of sea-level height from October to December 2009 show an area—indicated by the dark band—in the central and eastern equatorial Pacific that is about 4–7 in (10–18 cm) above normal, and sea surface temperatures more than 2–4°F (1–2°C) above normal. For more information and to view these images in color, please visit: photojournal.jpl.nasa.gov/catalog/PIA12404.

Image Credit: NASA/JPL Ocean Surface Topography Team

NASA Science Mission Directorate – Science Education Update

Ming-Ying Wei, mwei@hq.nasa.gov, NASA Headquarters

Liz Burck, Liz.B.Burck@nasa.gov, NASA Headquarters

Theresa Schwerin, theresa_schwerin@strategies.org, Institute of Global Environment and Society (IGES)

2010 NASA Education Resource Showcase Series

NASA's Digital Learning Network presents a series of videoconferences to assist educators in staying current with NASA education resources and related products. During each event, product producers, authors, and experts will demonstrate their materials designed to increase awareness and understanding of NASA science content. Instructional objectives, accessing the materials, and primary contacts for the materials will also be discussed. During the videoconferences, participants will be able to submit questions to the presenter that will be addressed during the presentation.

In the coming months, the following topics will be covered:

- **NASA Fit Explorers:** February 24, 2010, 4-5 p.m. EST;
- **NASA eProfessional Development Network:** Robotics Course: March 31, 2010, 4-5 p.m. EDT;
- **MoonWorld:** April 28, 2010, 4-5 p.m. EDT;
- **On the Moon:** May 26, 2010, 4-5 p.m. EDT.

For more information about these videoconferences and to sign up online, visit dln.nasa.gov/dln/content/webcast/. Questions about these events should be directed to Caryn Long at caryn.long@nasa.gov.

President Obama Launches *Educate to Innovate* Campaign for Excellence in Science, Technology, Engineering, and Math (STEM) Education

The *Educate to Innovate* campaign is a nationwide effort to help reach the administration's goal of moving American students from the middle to the top of the pack in science and math achievement. There will be a series of partnerships involving leading companies, foundations, non-profits, and science and engineering societies dedicated to finding new and creative methods of generating and maintaining student interest and enthusiasm in science and math. Read the full press release at: www.whitehouse.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en.

Earth Observatory Feature: NASA's Newest Map of the World

Due to the increasingly urgent need among Earth and climate scientists for a detailed global image of

the land surface in which the latitude, longitude, and elevation of every pixel have been mapped, NASA and the U.S. Geological Survey collaborated to create the first global portrait of the Earth from NASA's Landsat missions. The new map covers the entire surface of the Earth, and is detailed enough to show features as small as 30 m. View the map at: earthobservatory.nasa.gov/Features/GlobalLandSurvey/?src=ese_ed.

NASA's GOES Project Offers Real-Time Hurricane Alley Movies

Thanks to NASA's Geostationary Operational Environmental Satellite (GOES) Project, individuals can now access real-time data from the Pacific and Atlantic oceans. NASA's GOES Project is offering real-time high definition television (HDTV) movies of the east- and west-coast "hurricane alley" regions. There are two types of movies for both the Eastern Pacific Ocean and the Atlantic Ocean. Two coastal movies (one for each ocean) show four satellite image frames per hour over the previous two days. Two global movies show two frames per hour over the most recent three days. All four movies are automatically updated every hour.

All of the animations can be found at the NASA GOES Project website: goes.gsfc.nasa.gov/. There are four links; each labeled "Hurricane Alley HDTV," next to the GOES-EAST and the GOES-WEST images of the U.S. and the globe. Each link delivers a hurricane alley movie from the area suggested by the image next to the link.

AIRS Produces CO₂ Snapshot

A new image from the Atmospheric Infrared Sounder instrument (AIRS) (grayscale image on page 39 of this issue) shows the transport of carbon dioxide across the globe. Dark blue corresponds to a concentration of 382 parts per million and dark red corresponds to a concentration of almost 390 parts per million. See the image here: www.nasa.gov/images/content/403382main_portalBigPollution.jpg and read more about what it means here: earthobservatory.nasa.gov/Newsroom/view.php?id=41319. ■

EOS Science Calendar | Global Change Calendar

April 20–22, 2010

LCLUC Spring Science Team Meeting, Marriott Bethesda North Hotel & Conference Center, Bethesda, MD. URL: lcluc.umd.edu/

April 27–29, 2010

CERES Science Team Meeting, Marriott Hotel at City Center at Oyster Point, Newport News, VA. URL: science.larc.nasa.gov/ceres/meetings.html

May 19–21, 2010

SORCE Science Team Meeting, Keystone, CO. URL: lasp.colorado.edu/sorce/news/2010ScienceMeeting/index.html

September 27–30, 2010

Aura Science Team Meeting, Boulder, CO

October 27–29, 2010

Landsat “Specialists” Meeting, Boston, MA.

February 22–26, 2010

2010 Ocean Sciences Meeting, Oregon Convention Center, Portland, OR. URL: <http://www.agu.org/meetings/os10/>

March 16–19, 2010

2010 State of the Arctic Conference, Miami, FL. URL: siempre.arcus.org/4DACTION/wi_ai_getArcticInfo/4180

March 21–25, 2010

American Chemical Society Spring 2010 National Meeting and Exposition, San Francisco, CA. URL: portal.acs.org:80/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_MEETINGS&node_id=86&use_sec=false&_uuiid=cd784e2a-1a24-4238-a034-404e45ca97be

June 8–12, 2010

International Polar Year Oslo Science Conference 2010, Oslo, Norway. URL: www.ipy-osc.no/

June 24–27, 2010

American Meteorological Society 38th Conference on Broadcast Meteorology, Miami, FL. URL: www.ametsoc.org/meet/fainst/201038broadcast.html

July 12–16, 2010

ESRI International User Conference, San Diego, CA. URL: www.esri.com/events/user-conference/index.html

July 25–30, 2010

2010 IEEE International Geoscience and Remote Sensing Symposium, Honolulu, HI. URL: www.igarss2010.org/

August 8–13, 2010

AGU Meeting of the Americas, Iguassu Falls, Brazil. URL: www.agu.org/meetings/ja10/

October 2–7, 2010

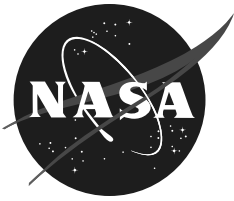
35th Annual Meeting of the National Weather Association, Marriott University Park Hotel, Tucson, AZ. URL: www.nwas.org/events.php

November 16–20, 2010

2010 National Association for Interpretation National Interpreters Workshop, Las Vegas, NV. URL: interpnet.com/workshop/

January 27–28, 2011

International Year of Chemistry (IYC), Opening Ceremony: Chemistry—Our life, Our future, UNESCO HQ, Paris, France. URL: www.chemistry2011.org/



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The Earth Observer Staff

Executive Editor: Alan Ward (alan.b.ward@nasa.gov)

Assistant Editor: Nicole Miklus (nicole.m.miklus@nasa.gov)

Technical Editors: Tim Suttles (tsuttles@bellsouth.net)
Chris Chrissotimos (christopher.g.chrissotimos@nasa.gov)

Design, Production: Deborah McLean (deborah.f.mclean@nasa.gov)



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