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Editor's Corner

Steve Platnick
EOS Senior Project Scientist

We are delighted to announce that this issue of *The Earth Observer* marks our 25th anniversary. In honor of this milestone, a special printed version of this anniversary issue is presented in full-color. (Note that all electronic issues have been available in color since 2011, see *eospso.nasa.gov/earth-observer-archive*.)

Our first issue came out in March 1989—the same month and year that a distributed information system, which came to be called the World Wide Web, was proposed at CERN. At that time, something unique was being proposed for Earth science at NASA. Disciplines that traditionally had functioned separately were brought together to collaborate on satellite missions to study our home planet on an unprecedented scale. In an era before the existence of the World Wide Web, *The Earth Observer* was created as a means to get the word out about this new interdisciplinary science endeavor and keep hundreds of scientists and engineers, scattered literally around the globe, informed about the latest news on the evolving Earth Observing System (EOS).

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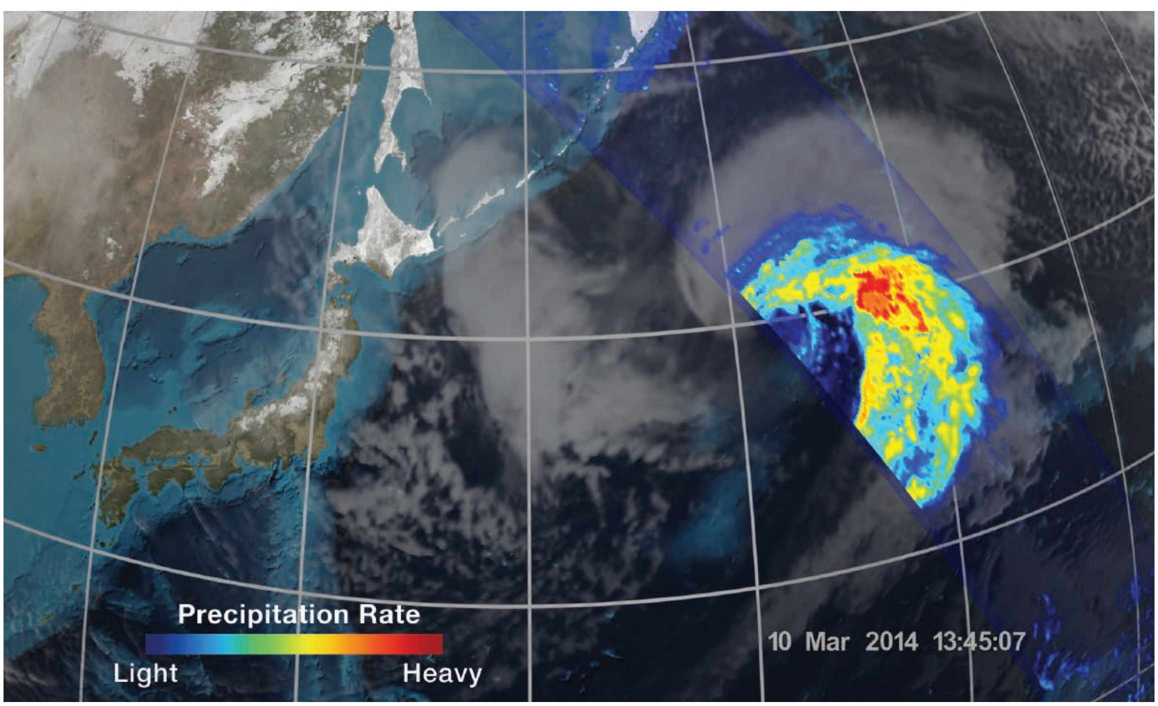

Launched on February 27, 2014, the Japan Aerospace Exploration Agency (JAXA) and NASA have released the first images from the Global Precipitation Measurement (GPM) Core Observatory. The image above comes from the GPM Microwave Imager (GMI) and shows precipitation associated with an extratropical cyclone in the northwest Pacific Ocean on March 10, 2014. Captured ~1700 kilometers (1055 miles) east of Japan, the colors depict the rain rate; red areas indicate heavy rainfall, while yellow and blue indicate less intense rainfall. The blue areas in the upper left indicate falling snow. **Credit:** NASA's Earth Observatory

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In This Issue

The Earth science of today—and the future—builds upon that foundation, and for the past 25 years, *The Earth Observer* has been documenting the progress of EOS and its descendants, and reporting to the Earth-science community. This issue includes an article that reflects on those 25 years, including memories and reflections of some key events in EOS history from those who participated in its development—the retrospective journey begins on page 4.

Scattered throughout this issue are quotes from some of our readers reflecting on the value of the publication to them. The quotes came from a variety of sources, but the prevailing sentiment among them is that *The Earth Observer* still remains a valuable resource for the latest in NASA-related Earth-science news. In this issue, specifically, we have reports from five recent science team meetings (GRACE, SORCE, Landsat, Land-Cover Land-Use Change, and Ocean Surface Topography) and from the ESIP Federation.

In keeping with the retrospective focus of this issue, *The Earth Observer* ran a series of 12 "Perspectives on EOS" articles, the first of which appeared in our March–April 2008 issue with the subsequent 11 articles being published periodically until May–June 2011. (A number of the anecdotes used in our 25th anniversary article mentioned above originally appeared in these articles.) I am happy to report that we have now compiled these articles into a single volume, which can be found at *eospso.nasa.gov/earthobserver/new-perspectives-eos*.

The Earth Observer published these perspective articles in hopes that the stories told and lessons-learned would be helpful to those tasked with planning future Earth observing missions. Feedback we have received (including some of the quotes included in this issue) indicates that these articles, as well as other content in the newsletter, has achieved that objective. In addition, they have proven to be an excellent collection of recollections and memories from key members of the EOS program. As such, these articles are a valuable historical resource.

Even as we reflect on our past, we celebrate our present and forge ahead toward the future. As we reported in our last issue, 2014 is an ambitious year for spaceborne Earth science at NASA. The year began with a bang on February 27, 2014 at 1:37 PM Eastern Standard Time (February 28 at 3:37 AM Japan Standard Time), when the joint NASA–Japan Aerospace Exploration Agency (JAXA) Global Precipitation Measurement (GPM) Core Observatory was launched aboard a Japanese H-IIA rocket from Japan's Tanegashima Space Center on Tanegashima Island in southern Japan.

I am pleased to report that the launch of the GPM Core was a complete success. The spacecraft separated from the rocket 16 minutes after launch, at an altitude of 247 mi (398 km). The solar arrays deployed 10 minutes later, powering the spacecraft, and enabling it to begin to transmit telemetry. Things have continued to go well for GPM. On March 12 the spacecraft fired its thrusters for a 30-second checkout of their performance.

The burn, called a *delta-v*, changes the velocity of the spacecraft to adjust the altitude of its orbit. This short maneuver did not greatly alter the satellite's orbit but was used instead for further calibration of the thrusters. Additional burns have since been completed. Functional checkout activities and internal calibration of the Dual-frequency Precipitation Radar (DPR) continues. Both the DPR and the GPM Microwave Imager (GMI) have begun collecting data on rain and snow, and the science team at the Precipitation Processing System at NASA's Goddard Space Flight Center has begun the process of verifying data accuracy. "First light" images from DPR and GMI were released on March 25—see image on front cover.

The GPM mission is a major step in improving upon the capabilities of the Tropical Rainfall Measurement Mission (TRMM), a joint NASA-JAXA mission launched in 1997 and still in operation. While TRMM measured precipitation in the tropics, the GPM Core Observatory expands the coverage area from the Arctic Circle to the Antarctic Circle. GPM will also be able to detect light rain and snowfall, a major source of available fresh water in some regions. The research and applications communities eagerly anticipate the release of the first precipitation data from GPM, which is expected no later than six months post-launch. To learn more about GPM's launch please read the news story on page 46 of this issue.

Still to come in 2014 are launches of the second Orbiting Carbon Observatory (OCO-2) and Soil Moisture Active–Passive (SMAP) missions, as well as the deployment of the Cloud–Aerosol Transport System (CATS) and Rapid Scatterometer (RapidScat) instruments to the International Space Station.

The way forward to the future is never without obstacles. Like any business, NASA must work with the administration and Congress on a budget. This year's President's proposed budget was made public on March 11 and there are a few items of note regarding NASA Earth science missions. These include:

- Review of schedule and budget for the second Ice, Clouds, and land Elevation Satellite (ICESat-2) due to inadequate progress with the Advanced Topographic Laser Altimeter System (ATLAS);
- halt in development of the third Orbiting Carbon Observatory (OCO-3), which was scheduled to launch to the International Space Station; and
- delay in delivery of the third Stratospheric Aerosol and Gas Experiment to the International Space Station (SAGE III on ISS) to address delays in the delivery of its pointing system.

The overall news from the President's FY15 budget request is quite good for the future of NASA Earth science. The year ahead promises to be an exciting one (see *eospso.nasa.gov/files/mission_profile.pdf*) with missions on the horizon that will help us continue to assess the state of our home planet and improve our understanding of its changing climate. Here's to the next 25 years! ■

*I look to **Editor's Corner** for a concise, up to date overview of what is happening in Earth Science. It makes keeping up with the broad spectrum of missions and activities a little easier.*

*—**Bruce Wielicki** [NASA's Langley Research Center—Senior Earth Scientist in the Science Directorate, Former CERES Principal Investigator]*

Acronyms Not Defined in Editorial and Article Titles (in order of occurrence)

Editorial

CERN	Conseil Européen pour la Recherche Nucléaire [European Organization for Particle Physics]
GRACE	Gravity Recovery and Climate Experiment
SORCE	Solar Radiation and Climate Experiment
ESIP	Earth Science Information Partners

Article Titles

LCLUC	Land-Cover Land-Use Change
JAXA	Japan Aerospace Exploration Agency

The Earth Observer: Twenty-Five Years Telling NASA's Earth Science Story

Alan B. Ward, NASA's Goddard Space Flight Center/Global Science and Technology Inc., alan.b.ward@nasa.gov

This issue marks the twenty-fifth anniversary of *The Earth Observer* newsletter. The story of our newsletter is inexorably linked to the overarching story of NASA's Earth Observing System (EOS). Since **Alan Ward**, the current Executive Editor of *The Earth Observer*, has been a part of the editorial team for over half of its history and is well versed in the story of EOS itself, he is a fitting choice to provide some perspective on this occasion.

The newsletter began as a means of telling the larger EOS story, and to get the word out about the development of an entirely new way of studying the Earth. As of this writing in 2014, NASA's Earth-science activities have amply shown their worth, based to a large extent on the tremendous successes of EOS. In 1989, however, EOS was just a concept—one that the fledgling interdisciplinary community needed to learn about, as there were strong indications that their research activities would be affected by this new approach. The result was that the scientists and engineers involved in EOS in the 1980s and 1990s literally built pieces of EOS from the ground up. The Earth sciences of today—and the future—build upon that foundation, and for 25 years *The Earth Observer* has been documenting the progress of EOS and its descendants, and reporting to the Earth-science community.

The Earth Observer's twenty-fifth anniversary is a fitting occasion to reflect upon those origins, which are best understood in the larger context of the genesis accounts of EOS. By way of the memories and reflections of some of those who were there, Ward takes us back to a time "before the beginning"…*

—**Heather Hanson**, Assistant Editor, *The Earth Observer*

*The original source of several of the anecdotes shared in this article was the "Perspectives on EOS" series that ran in periodic installments in *The Earth Observer* between 2008 and 2011. While references here are to individual articles in the series, a compilation containing all these articles in a single volume can be downloaded from *eospso.gsfc.nasa.gov/earthobserver/new-perspectives-eos*.

Seeing Earth as a System of Systems

The year is 1983. The Reagan administration has a philosophy of "the sky's the limit" when it comes to space exploration. Earth science languished during the late 1970s, but in the early 1980s, seeds of hope begin to sprout. A NASA Advisory Panel convenes to consider the possibility of conducting Earth observations from large platforms in polar orbit. They didn't know it at the time, but this group is one of the pioneers in *Earth system science*—looking at the Earth as a system of interrelated systems requiring interdisciplinary cooperation to form as complete a picture of things as practicable. (The term would gain widespread use after publication of the Bretherton Report in 1986[1].)

Earth science languished during the late 1970s, but in the early 1980s, seeds of hope begin to sprout.

Acting at the direction of **Burt Edelson**, Associate Administrator for Space Science and Applications at NASA Headquarters (HQ), **Pitt Thome**, former Director of the Earth Observations Division at HQ, assembles a group of ten individuals from what had traditionally been disparate science disciplines to meet and share their observational requirements and to look for overlaps that might allow them to work together on a single mission.

Who was in the room? As **Dixon Butler**, who later became Program Scientist for EOS, recalls it[2]: "There are ten people there, every one of whom is either a program manager at Headquarters or a manager at a field center…" He acknowledges that—with time—he doesn't remember the names of all the participants, but he is clear that in addition to himself and Pitt Thome, **David Atlas**, who was the Laboratory for Atmospheres Chief at NASA's Goddard Space Flight Center (GSFC) at the time, and

[1] *Earth System Science: Overview* (1986) and *A Closer View* (1988), Earth System Sciences Committee of the NASA Advisory Council (NAC), NASA. The report is named after the NAC Committee's chair, **Francis Bretherton** [University of Wisconsin, Madison].

[2] *Earth System Science at 20 Oral History Project (www.jsc.nasa.gov/history/oral_histories/NASA_HQ/ESS/ButlerDM/ButlerDM_6-25-09.htm),* Edited transcript of Butler's interview with Rebecca Wright of NASA's Johnson Space Center.

Anne Kahle from NASA/Jet Propulsion Laboratory (JPL) were present. There was also a representative from what would later become known as NASA's Stennis Space Flight Center who was leader of the Earth observations group at Bay St. Louis, MS, as well as someone from the Engineering Directorate at GSFC. Other program managers from HQ and JPL rounded out the group of ten.

Butler recalls an open exchange where everyone brought his or her point of view to the table but, after two meetings, the second of which took place at JPL, progress was slow. As he put it: "So we all talk about our stuff, and there's geology and geophysics talked about, and land resources and ecosystems and everything. It's not clear how we are ever going to get a mission out of this. I mean, it's really not clear."

A Late Night Epiphany

And that's when, as Butler said it, "the magic happened." At his hotel after that long day of meetings, Butler remembers pondering the day's discussion. As executive secretary for the NASA Advisory Panel, Butler reviewed his notes and organized them to prepare for the next day's deliberations. That's when he finally had his epiphany, wondering why they/he hadn't seen it before? The connection was as clear as the liquid that was so prevalent on our world and so fundamental to life as we know it: *Water* was what all these disciplines had in common!

Left to Right: **Shelby Tilford**, **Dixon Butler**, and **Stan Wilson** in March 1990 at an EOS Investigators Working Group meeting. (This photo originally appeared in the March 31, 1990 issue of *The Earth Observer*—**Volume 2**, **Number 3**.)

"I'm sort of thinking about, 'Well, what connects these people?' Stretching it a little bit, I say, 'Look, it's water. This is the water planet. The fact that we've got water in all these phases, whether it's the Arctic or [whether it's] rainfall, the heat transport happens heavily through the condensation/evaporation of water. We've got the [oceans…and] even volcanoes are heavily influenced by water—and water shapes the geology you can see. It's a water-dominated planet. So water hangs us together.'"

From there, Butler worked late into the night, sketching his vision of a payload of six observing instruments, to include a weather radar, a large passive microwave sensor, visible and infrared imagers of high and moderate resolutions, and a temperature and moisture sounder. (He didn't recall the other.) The next morning he shared his idea with the group and was somewhat surprised at how well his concept was received.

Following this favorable response from his colleagues, Butler laid out payloads for two more large platforms that would be launched from the Space Shuttle's cargo bay, and could be serviced by astronauts in a manner similar to that used to service the Hubble Space Telescope. [This is the pre-*Challenger* era at NASA—a time when various plans for using the Space Shuttle and the planned Space Station *Freedom* for Earth observations were being considered[3].]

NASA Administrator **James Beggs** soon endorsed the "in house" *System Z* concept, but Butler realized he would need to garner wider support (i.e., beyond NASA) for his concept. He essentially "started from scratch," assembling a working group composed of 20 individuals, most of whom were from outside NASA, that met several times. The outcome of those meetings was a similar—but improved—concept known as the *Earth Observing System (EOS)* that became the center piece of NASA's Mission to Planet Earth. The rest, as they say, is EOS history.

From the Prairies to the Heavens

Piers Sellers, now Deputy Director of the Sciences and Exploration Directorate at GSFC, recalls the first time he learned about the EOS concept[4]. At the time, he was a young, up-and-coming scientist in the Biospheric Sciences Branch at GSFC. In 1987

[3] Learn more about *The Earth Observing Legacy of the Space Shuttle* in September–October 2011 issue [**Volume 23, Issue 5,** pp. 4-18].
[4] **Piers Sellers** shared his memories of the early days of EOS in his *Perspective* [**Volume 21, Issue 1,** pp. 4-8].

The intrepid crew *[left to right]*, **Piers Sellers**, **Forrest Hall**, and **Andy Black** prepare to board a small *Cessna* at the Prince Albert airport during the Boreal Ecosystem–Atmosphere Study (BOREAS) in Canada during the mid 1990s. Piers would pilot the plane while Forrest and Andy mapped potential tower sites. **Image credit**: **Forrest Hall**.

he and his colleagues had been busying themselves with a series of large-scale field experiments on the vast prairies of Kansas to observe and model land-surface/atmosphere interactions, and to measure the important parameters from space. He recalls hearing about something called EOS for the first time "while fighting off the chiggers, heat rash, and curious cows." (The photo on this page was taken during the Boreal Ecosystem–Atmosphere Study (BOREAS) campaign, another remote field campaign in which Sellers and other EOS investigators participated during the mid-1990s.)

In 1988, during a break between the Kansas field campaigns, Sellers attended a briefing that Butler gave on EOS. He remembers Butler being "armed with a stack of mind-blowing viewgraphs," and giving a detailed review of his concept of a large spacecraft, bristling with 17 instruments—a manifest designed to reflect the interdisciplinary nature of the proposal. (This platform, the first of two being proposed, was known as *EOS-A*; the other was called *EOS-B.)* "Egad!," thought Sellers, "This thing will blot out the sun whenever it comes over." It is from these school-bus-sized origins that the first EOS designs became known as "Galactica." Later, during Dan Goldin's tenure as NASA Administrator, this term became a derogatory reference for the large-platform concept. Sellers recalls going away from that 1988 briefing wondering what would become of this inspiring idea.

I've been reading The Earth Observer from the get-go. It's a great way to keep up to speed with the science coming out of EOS and other places, and a great way to find out what all my friends in science are up to.
Here's to 25 more years!
*—**Piers Sellers** [NASA's Goddard Space Flight Center—Deputy Director of Science and Exploration Directorate]*

It wasn't long before Sellers found out. In 1988 NASA released an Announcement of Opportunity (AO) for EOS, and in 1989 teams were selected. Sellers recalls Butler and friends "touring the country like a small rock group trying to drum up support from a flagging Earth-science community that had long been used to hearing of grandiose NASA projects that never came to fruition." As a consequence, many of the older scientists Butler talked to were quite skeptical of his plan and reluctant to submit proposals. Many of those who ultimately did so were young investigators—people like Sellers himself, as part of a team of scientists that submitted a "freelance" proposal in response to the AO. This team subsequently received several million dollars of funding over the next decade. In addition to Sellers, that interdisciplinary team included several other young scientists who today are well known in the Earth science community: **Compton "Jim" Tucker**, **Inez Fung**, **Dave Randall**, **Eric Barron**, and **Chris Justice**. Clearly, early EOS funding was contributory to long and successful careers for many Earth-science investigators!

How Do We Actually Make It Happen?

It wasn't long before Sellers and many of his peers (29 in all) who had been selected for *EOS interdisciplinary investigations*—i.e., the theory, modeling, and integrative data analysis work—began to ask: *Okay, now what?* They knew that they had been chosen to be part of EOS, but what exactly were they supposed to do? Dixon Butler, who wrote the EOS AO, convened a meeting at GSFC's Building 8 in March 1989 to begin to wrestle with that question. The 29 interdisciplinary investigators sat around a U-shaped table with the instrument investigators around the outside; they began a discussion. Prior to EOS, the interdisciplinary collaboration that is commonplace today in Earth science investigations was all but nonexistent: Many at that table had never met before this meeting, and although some may have had prior relationships, there had certainly never been collaboration on the grand scale being envisioned under the EOS rubric.

When **Michael King**, who later became the EOS Senior Project Scientist, recalls this meeting he said that, "This was the first time I met **Steve Running**, **Chris Justice**, **Otis Brown**, **Mark Abbott** and many of the land and ocean scientists who, with me, had been accepted to develop algorithms for the proposed Moderate Resolution Imaging Spectroradiometer (MODIS). I had worked mostly in atmospheric science (both clouds and aerosols) up until that point in time, primarily from aircraft and the ground—never [from] space before. It opened my eyes to the vast interdisciplinary uses of such an exciting instrument as MODIS—proposed as having both a nadir-viewing and tilt instrument at the time."

I have been fortunate to have "grown up" with The Earth Observer. It was one of the publications passed around the research group that I joined in 1991 fresh from my PhD program. I read it to find out who was who and what they were doing with that "alphabet soup" of acronyms that was EOS. The fact that it has presented the human side of the science has made it enjoyable to read—though writing inputs to it was never as enjoyable as reading it.
*—**Kurt Thome** [GSFC—Terra Project Scientist]*

As noted earlier, the EOS plan called for the establishment of 29 interdisciplinary science (IDS) teams. There would be active involvement of a large number of universities, national and international laboratories, and other research organizations. The idea seemed straightforward enough: These IDS teams would forge new alliances by bringing together representatives from a wide range of disciplines, organizations, and scientific experts across the globe. It all sounds good in theory, but the devil is in the details. As noted earlier, many an inspiring vision has died on the long road to becoming reality. Could EOS avoid that fate?

The meeting at GSFC was the first of a series of what became known as Investigator Working Group (IWG) meetings that would take place at locations around the country from March 1989 until November 2002. It was during the early meetings that the details of how EOS would actually work in practice were ironed out. Later meetings were also an opportunity to share early results from EOS missions. Eventually the widespread use of the Internet and online communications tools brought an end to the need for these large gatherings. There was also a series of Payload Panel meetings held over the years, where detailed designs of the instruments proposed to fly on each spacecraft were carefully decided upon. These were followed by instrument- and discipline-specific Science Team meetings to review the progress of each of the planned instruments and prepare for the development of data analysis algorithms.

Where Do We Store All These Data?

Darrel Williams attended that first IWG meeting. (See *Getting the Word Out About EOS...* on page 9 to learn more about Williams' role as the first Executive Editor of *The Earth Observer*). He recalls one of the more contentious talks given by **Milt Halem**, who was Chief of the Space Data and Computing Division and later became Assistant Director for Information Sciences and Chief Information Officer at GSFC. Halem made a presentation about projected data storage needs for the complex architecture that became known as the EOS Data and Information System (EOSDIS). His suggestion that a whole new building would be required just to warehouse all of the tapes of data being sent back from the many EOS satellites was not popular. (Remember, this was nearly 30 years ago, and communications and data storage technologies were nowhere near as robust as they are now.) This was just the first of many hurdles that would need to be cleared in order to build and implement a data system that could store and process all the data (nearly a petabyte was anticipated) that would pour down from orbit each year.

Owing to advances in information technology and other factors, in the early 1990s, the original concept of having one or two large, centralized data centers morphed into what we today know as *Distributed Active Archive Centers (DAACs)*—where data archiving, product generation, and information services are structured across a network of smaller centers. The evolution of EOSDIS has been described elsewhere[5] and will not be repeated here, except to say that *The Earth Observer* played an important role in telling that story. From early on, this publication has included periodic articles informing the community about significant achievements in the development of EOSDIS.

The Earth Observer provides a unique venue for communication of science highlights, team meetings, major events, and project and program updates to the entire EOS family. Without it, one could not keep up with a large number of important events in a rapidly evolving program.

—***Ghassem Asrar*** *[Joint Global Change Research Institute—Director, Former EOS Program Manager/Associate Administrator for Earth Science]*

H. K. "Rama" Ramapriyan, Assistant Project Manager of the Earth System Data and Information Systems organization that is responsible for overseeing the data acquisition and distribution component of EOSDIS, acknowledges the importance of *The Earth Observer* in this context: "For the last 25 years, *The Earth Observer* has been a good source of information to a broad community of readers interested in Earth observations. I have found the articles interesting, informative, and easy-to-read. Occasionally, I go back to older issues to refresh my memory on key events in the history of EOS. Given the broad readership, I have encouraged my data systems colleagues to write articles when key developments of general interest have occurred."

[5] **Rama Ramapriyan** described the evolution of the EOSDIS in his two-part *Perspective* [**Volume 21**, **Issue 4 & 5**, pp. 4-10 & pp. 8-14].

Shown here are a few snapshots of past IWG meetings, gleaned from *The Earth Observer* archives.

[*Left to right*] **Darrel Williams**, **Bruce Barkstrom**, and **Alexander Goetz** at the November 1990 IWG.

[*Left to right*] **Bruce Guenther**, **Bill Barnes**, **Les Thompson**, and **Dot Zukor** at the November 1990 EOS IWG.

Ghassem Asrar [*left*] and **Michael King** [*right*] at the March 1993 EOS IWG.

[*Left to right*] **Peter Brewer**, **Jeff Dozier**, **Bruce Barkstrom**, **Mark Abbott**, and **Dave Glover** [*seated*] at the 1994 IWG.

Getting the Word Out About EOS: *The Earth Observer* is Born

As activity for the Earth Observing System (EOS) began to "ramp up" in the late 1980s, it soon became apparent that there needed to be some means developed to keep hundreds of scientists and engineers, scattered literally all around the world, informed about the latest developments in EOS. To meet this need, *The Earth Observer* newsletter was initiated—with the first issue published in March 1989. In an era prior to the World Wide Web and before e-mail was commonplace and reliable*, the bimonthly newsletter quickly became a vital communications link for the fledgling EOS community.

In 1989 **Gerald "Jerry" Soffen,** Project Scientist for the *Viking* Mars mission in the 1970s, was chosen, as the first EOS Senior Project Scientist. He was the one, as Piers Sellers once described it, tasked with "putting socks on the octopus" that was EOS. A biologist by training, Soffen had mounted a prescient photograph on his office wall, showing him wrestling with an anaconda. Soffen chose Sellers to be his deputy, but Sellers did not remain in this position for very long. He would continue to be actively involved in EOS however, and became Project Scientist for the AM-1 mission in 1992, before departing GSFC to enter astronaut training in 1996. (Sellers would go on to be a "human satellite," as a NASA astronaut from 1996–2011. Before coming "back to Earth" at GSFC, he flew on three Shuttle missions and logged nearly 41 hours on spacewalks.)

When Sellers stepped down as Soffen's deputy, **Vince Salomonson,** the GSFC Earth Sciences Director and former Landsat Project Scientist, turned to **Darrel Williams,** his former Assistant Project Scientist, and asked him to take the job. Williams later went on to succeed Salomonson as Landsat Project Scientist and subsequently become Associate Chief of the Hydrospheric and Biospheric Sciences Laboratory at GSFC. It was in his role as Deputy EOS Project Scientist under Soffen that Williams became the first executive editor of *The Earth Observer*—along with **JoBea Cimino** (later **Way**) at NASA/Jet Propulsion Laboratory, which had proposed a separate platform.

Williams had just completed his doctoral studies at the University of Maryland, and he recalls the early days working with Soffen on EOS as being tumultuous, as the two of them wrestled with how to implement this huge project that involved scientists scattered about the world. He remembers tense conversations among himself, Soffen, **Renny Greenstone** (who subsequently became a longtime technical editor for the newsletter and other EOS Project Science Office projects), and **Kristine Wheeler** (who worked for Soffen at the time) about how best to share useful information about EOS.

Soffen knew someone working on the first floor of his building who might be able to help them in this effort. **Charlotte Griner** at the time worked for **Jim Green**, head of the National Space Science Data Center (NSSDC), doing outreach tasks. (Griner remembers assembling publications using a primitive version of *PageMaker* on an ancient and temperature-sensitive Macintosh computer, dubbed the "Fat Mac.") Soffen asked Griner if she was ready for a new challenge. Apparently she was: Griner accepted Soffen's offer to come work for him in November 1989 and helped him organize what became known as the EOS Project Science Office. She replaced Williams and Cimino as executive editor for *The Earth Observer* around January 1990, and continued to serve in that capacity through 2004.

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* NASA experimented with the *ARPANet* system for e-mail in the mid-to-late 1980s, but sometimes messages would get lost in a "black hole" and never reach intended recipients. Needless to say, this did not bode well for the breadth and depth of communications needed to bring EOS to an operational state.

Evolution in Action: Restructure, Rescope, Rebaseline, and Reshape

In 1990, **Jeff Dozier** came from the University of California at Santa Barbara (UCSB) to become the second EOS Senior Project Scientist, replacing **Jerry Soffen** (see **page 9**), and serving until 1992, when he returned to UCSB. Though his tenure was brief, Dozier presided over an important period of EOS history. EOS received a *New Start* from Congress in 1990 (FY91) but then was subjected to constant political and economic pressures over the next several years. In response to all these pressures to move forward within a more constrained budget, the EOS mission architecture literally changed overnight. During a meeting convened to examine everyone's ideas for different ways to implement EOS, **Chris Scolese**, EOS System Engineer, and **Marty Donohoe**, EOS Instrument Manager, with science guidance from Dozier and Dixon Butler, redesigned the EOS space segment, changing it from a large polar platform to a set of three medium-sized spacecraft. The payload was apportioned among these *flagship missions,* all of which had sun-synchronous orbits but with different equator-crossing times. This would allow both morning (10:30 AM) and afternoon observations (1:30 PM), as well as a third observing time chosen to be optimal for atmospheric chemistry observations (1:45 PM). These were originally called AM-1, PM-1, and CHEM-1 (at that time envisioned as the first in a series of three identical spacecraft launched every five years), and were later renamed Terra, Aqua, and Aura, respectively. Beyond these three satellites, EOS was to fly instruments on various other spacecraft, including a series of scatterometers, the altimeters that flew as Jason-1 and -2, Landsat-7, and solar sensors.

The Earth Observer benefits the Aura team and the broader community by fostering communication across disciplines. Articles contain unique overviews of science and team meetings that keep the Aura team in-the-know about Aqua, Terra, and other NASA Earth-Observing missions, and keep our colleagues in different disciplines up-to-date on new results from atmospheric chemistry.

*—**Anne Douglass** [GSFC—Aura Project Scientist]*

During the early-to-mid-1990s, NASA Administrator **Dan Goldin** put EOS under continuing review and budget pressure[6]. The severe rescoping of the first decade of EOS implementation cut the total budget (i.e., FY91 - FY00) from $17 billion at the time of the FY91 new start to about $7.25 billion by FY94. While understandably frustrated by setbacks and delays, the community worked tirelessly to restructure, rescope, rebaseline, and reshape EOS during this period[7]. Some of the planned instruments had to be sacrificed, but new technologies were incorporated into the survivors, and many of the desired capabilities were preserved in the satellites we have in orbit today.

Many editorials and articles in *The Earth Observer* from this period describe decisions made and meetings held in response to all the revisions to the EOS Program that Congressional budget cuts mandated. The scientist who guided EOS through most of that period was Michael King, who replaced Dozier in summer 1992. Darrel Williams recalls the day he first met King, at an IWG meeting in Keystone, CO in July 1992. He and Vince Salomonson caught a ride to lunch with a friend of Salomonson's whom Williams didn't know. Williams asked Salomonson if he had made any progress on choosing Dozier's replacement. There was an awkward pause, after which, Salomonson responded: "As a matter of fact I have. Meet Michael King"—who was driving the car. Such meetings and connections were commonplace as EOS activities ramped up.

During his tenure as EOS Senior Project Scientist, King played a prominent role in promoting and documenting science algorithm development by requiring Algorithm Theoretical Basis Documents for each instrument, thereby fostering interinstrument and interdisciplinary interaction. He was also instrumental in establishing the EOS Calibration and Validation Program, which previously had no funds allocated to it. King reorganized the office so that key Earth system scientists would serve as project

[6] **Mark Abbott** describes the shifts in direction in EOS during the mid-1990s in his *Perspective* [**Volume 21**, **Issue 5**, pp. 4-7].

[7] **Greg Williams** chronicled the series of revisions to EOS in his *Perspective* [**Volume 21**, **Issue 2**, pp. 4-12].

scientists for each individual mission (a structure that exists to this day), and initiated regular meetings with these project scientists to keep everyone abreast of important issues impacting each mission. It was King who convinced Piers Sellers to serve as EOS AM-1 (later *Terra*) Project Scientist. Around the same time, King chose project scientists for other EOS missions, including **Claire Parkinson** for EOS PM-1 (later *Aqua*)—a role that she still holds—and **Mark Schoeberl** for EOS CHEM-1 (later *Aura*)—a position he filled from 1993 to 1994, and again from 1999 to 2009.

King describes *The Earth Observer* as a major source of information during the developmental years of EOS, for the interested scientific community and for Congressional staffers, members of Congress, and the "budget masters." The editorials became a widely read portion of each issue, and there was much pressure to inform the readership of developments in the program, including key personnel changes, reviews, program developments, and appropriated budgets. King recalls having to carefully consider the content for the editorial in each issue. Such careful research and wording needed to develop suitable content for the editorials continue to be important parts of our process today. Even in an era of nearly ubiquitous and instantaneous information via e-mail, Internet, and social media, many readers still depend on the editorials and other newsletter content to keep them informed on the latest news about NASA Earth Science activities.

King retired from NASA in 2008 and moved to the University of Colorado, but he still actively reads *The Earth Observer* to learn of key program changes, selections of Venture Class missions, launch developments, field campaigns, and key scientific findings.

The Earth Observer has provided a wonderful reference over the years of the activities going on in NASA's Earth-observing missions. This includes considerable valuable information that is generally not included in scientific journal articles, such as the minutes of Science Team meetings, insiders' stories of the trials and excitement of field campaigns, and information about satellite launches (both pre- and post-launch) and relevant Congressional deliberations. As the individual newsletter issues come out, they keep the readers up-to-date on many NASA Earth-observing activities, but of equal importance is the archive of the issues, providing a long-term record of the Earth-observing program.

*—**Claire Parkinson** [GSFC—Aqua Project Scientist]*

A View from the Masthead

In late 2004, Charlotte Griner stepped down as Executive Editor, and Steve Graham took the position for about nine months. I (**Alan Ward**) replaced Graham in the summer of 2005, toward the end of King's tenure at NASA. This was about a year after Aura was launched—completing what was originally envisioned as the "EOS First Series." **Steve Platnick** replaced King as EOS Senior Project Scientist in 2008, at first on an acting basis, and then permanently. Prior to this, Platnick served as Deputy Project Scientist for Aqua, and has provided leadership to the program, working with colleagues to guide NASA Earth science into a new reality under the pressures of constricting budgets and changes in administration at NASA and other cognizant organizations. He also provides guidance for editorial content for *The Earth Observer*, continuing the historical insistence on high-quality, timely, and interesting articles and news items.

In the years I have been executive editor, the newsletter has moved in new directions. The content of each issue has evolved to parallel the changes in NASA's Earth science program in the "post-EOS" era. We have shifted our primary focus from presenting detailed summaries of Science Team meetings (most of which are now readily available online at team- and mission-specific sites) to feature articles that convey the compelling and exciting stories of Earth science research and ways in which Earth science data are used to address issues of societal importance. While we still report on Science Team meetings, we encourage authors to provide focused reports that summarize the content and to highlight key decisions—as opposed to printing detailed and often very technical meeting minutes, which was the norm in older issues.

The look of *The Earth Observer* has evolved over the years. This graphic shows the different front-page layouts that have been used. Note how our logo evolved and eventually disappeared. After 2004, new NASA communications guidelines required the NASA logo to be shown on the front instead of the individual program logo. Since 2011, online issues of *The Earth Observer* have been available in color.

We also continue to report on the progress of EOS missions. In the last two years, we have highlighted the tenth anniversaries of the launches of several EOS-related missions—the Gravity Recovery and Climate Experiment (GRACE), Aqua, and Solar Radiation and Climate Experiment (SORCE) missions—and plan a similar article for Aura later this year. We have followed the progress of new (i.e., post-EOS) missions on their journey toward launch and beyond. We also highlight relevant blogs via our *Blog Log* and include several news stories from *nasa.gov* in each issue that feature Earth science, as well as education and public outreach activities.

Although *The Earth Observer* has long been a gray-scale publication, since 2011 an online version of each issue has been available in color. We currently have ~6000 subscribers, including a substantial number of international readers. In another effort to be sensitive to economic and environmental realities, we offer the option to "Go Green" and receive the full-color PDF exclusively via e-mail[8]. A small but not insubstantial number have chosen this option to date and we encourage more to consider this option. Future plans call for the development of an *e-book* version of the newsletter that would allow it to be read easily on various mobile devices.

[8] Instructions on how to "Go Green" can be found on the back cover of this issue.

The Earth Observer: A True Team Effort

From the very beginning, production of *The Earth Observer* has required the contributions of a team of people. Many hours of work go into the production of every issue. Most of this work takes place behind the scenes and is transparent to our readers, but it is critical to the publication you hold in your hand today. While it is not practical to publish a "complete" list of names, we wish to take this opportunity to thank all past and present contributors to the newsletter, and specifically recognize our current staff. The editorial team (**Alan Ward**, **Heather Hanson**, **Mitch Hobish**, and **Ernest Hilsenrath**) meticulously reviews every item that is published. (There is also a group of senior managers and scientists at GSFC and NASA HQ that review the layout of each issue prior to publication.) Each issue is beautifully laid out and illustrated by, **Debbi McLean**, our top-notch graphic designer. **Ryan Barker** does a thankless but necessary task for each issue, labeling and packaging all of the issues we ship to international readers, and **Cindy Trapp** maintains the database of our subscribers. I also wish to recognize the previous contributions of **Winnie Humberson**, who was a former graphic designer for the newsletter, as well as **Steve Graham**, who served a brief stint as Executive Editor. As the current Executive Editor, I am proud to be part of this team and want to thank them for all the hard work they do to maintain the level of quality that our readers have come to expect.

Our Best Metric of Success

Perhaps the best testament to the "success" of *The Earth Observer* comes via feedback received from our readers. We frequently receive emails thanking us for an article or suggesting an improvement, and we do our best to listen and respond. To reflect this kind of input and commentary, we solicited input from a selected list of subscribers—mostly within NASA[9]. I was humbled by the response; it seemed to be an outpouring of affirmation for value *The Earth Observer* has provided and continues to provide to our readers. **The quotes in this article (in light blue)—and scattered throughout the entire issue—show that there is something for everyone in *The Earth Observer*.**

Among those we asked to contribute a quote was **Jim Irons**, who is a longtime veteran of EOS, having been Darrel Williams' Deputy for many years, and currently serving as Project Scientist for the Landsat 8 mission. His reply (see quote, right) seems like a fitting way to end this essay, as it effectively summarizes what *The Earth Observer* has endeavored to provide these past 25 years.

EOS initiated a golden era of Earth monitoring from space and The Earth Observer has been there the whole time to document the triumphs, trials, and tribulations of the endeavor. As a Project Scientist for Landsat 8, The Earth Observer has been my window into the larger program. I have relied on the bi-monthly publication to keep me current with progress of the other flight projects as well as the scientific advancements and greater public awareness engendered by the EOS. It has also served as a way to stay in touch with the many friends and colleagues working throughout the community of Earth scientists engaged in observations from space. I have often compared and contrasted the roles, responsibilities, and styles of fellow project scientists, as reflected in The Earth Observer's reports, with my own efforts. Someday someone will write the definitive history of the EOS and The Earth Observer will serve as primary source material. It provides an indelible record of the EOS era.

*— **Jim Irons** [GSFC—Landsat 8 Project Scientist]*

On to the Next Twenty-Five Years…

We've come a long way since *The Earth Observer's* first issue was published in March 1989. Twenty-five years of NASA Earth science history have unfolded and our publication has been there to "observe" it and chronicle the history of our program. Even with seemingly endless information available from many sources, *The Earth Observer* is still a valuable resource for the latest in NASA-related Earth-science news. Through all the changes, our staff—see *The Earth Observer: A True Team Effort*, above—remains committed to the vision identified in the very first issue of reporting on timely news and events relevant to Earth science at NASA. ■

[9] *The Earth Observer* certainly recognizes and appreciates that our readership extends well beyond NASA, but for purposes of this exercise, we limited our solicitation to a selected list of readers, most of whom were affiliated with Earth science at NASA.

NASA LCLUC Science Team Meeting on Land Use and Water Resources in Central Asia

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Rationale for the Meeting

Two key challenges facing Central Asian countries include land degradation and water resource management. Land-cover change, unsustainable land use, and poor management of river waters in the region have created disputes. As the countries of Central Asia are heavily dependent on use of fragile dry lands and limited arable land, land-use change and water management are central issues in the region. A number of regional and international efforts have been made to understand the causes, extent, rate, and societal implications of land-use changes in the region, but these efforts have not been synthesized or framed effectively to address emerging issues.

To help fill this gap, NASA's Land Cover/Land Use Change (LCLUC) program organized a Science Team Meeting focusing on land use and water resources in Central Asia in Bukhara, Uzbekistan, November 7-15, 2013. The Tashkent Institute of Irrigation and Melioration (TIIM) hosted the meeting, which was co-organized by the Monsoon Asia Integrated Regional Study (MAIRS) Program, Global Observations of Forest and Land Cover Dynamics (GOFC-GOLD) Central Asia Regional Information Network (CARIN), and the Northern Eurasian Earth Science Partnership Initiative (NEESPI), with the support from SysTem for Analysis, Research and Training (START). Nearly one hundred scientists attended the meeting, with forty international participants from eleven different countries.

In addition to the science team meeting, there were two other related activities: a LCLUC Leadership Summit (November 7-9) with the TIIM, Bukhara campus (TIIMB) and Samarkand Agricultural Institute (SAI) serving as hosts—see *Leadership Summit* on page 18; and a two-day training session (November 14-15) for students and early-career scientists—see *Training Workshop* on page 19.

The objectives of the science team meeting were to:

- Present the latest research findings that address regional climate, land-use, and water resource issues in Central Asia;
- exchange data, information, and knowledge across the region and with international communities

Group photo of LCLUC Science Team Meeting attendees.

that promote strategies to mitigate food and water sustainability challenges in the region; and

- understand the role, availability, and accessibility of Earth observations for addressing the related science and applications questions, and to strengthen the CARIN.

Opening Presentations

Mukhamadkhan Khamidov [TIIMB—*Rector*], **George Krol** [U.S. Department of State, U.S.—*Ambassador to Uzbekistan*], **Shavkat Khamraev** [Government of Uzbekistan—*Deputy Minister of Agriculture and Water Resources*], and **Saidkul Arabov** [State Committee of Land, Geodesy and Cadaster, Uzbekistan—*Chair*] each gave opening addresses.

Following these remarks came a series of presentations that gave an overview of the LCLUC projects in Central Asia and provided a scientific assessment of land use and water resources in the region.

Chris Justice [University of Maryland, College Park, U.S.] highlighted important land-use and water resource issues in Central Asia. He stated that the institutional and legal frameworks for water-resource management established in the early 1990s in Central Asian countries are not well suited for current national needs, and stressed that subregional cooperation will be essential in resolving transboundary water issues.

Garik Gutman [NASA Headquarters, U.S.] provided an overview of NASA's LCLUC program. Over the fifteen years since it was organized, the LCLUC program has supported approximately 200 research projects that address many regions of the world, including Central Asia. Gutman showcased several of the current NASA LCLUC research projects in Central Asia that examined regional hydrology and glacier dynamics, the role of LCLUC in water budgets and use, land-atmosphere dust interactions, and assessing the vulnerability of the *grain belt* in the semi-arid region. He stressed the need for synergistic use of the data from multiple satellites for LCLUC research, such as those from Landsat, Terra and Aqua [specifically the Moderate Resolution Imaging Spectroradiometer (MODIS)], Suomi National Polar-orbiting Partnership (NPP), and the European Space Agency's Sentinels, scheduled for launch in 2014 and 2015.

Jigauo Qi [Michigan State University, U.S.] presented an overview of the MAIRS program. Stating that Central Asian countries are highly vulnerable to climate change, he stressed the need for interdisciplinary approaches to tackle coupled climate-human-environmental system problems. He highlighted MAIRS initiatives in Central Asia for *Future Earth*, a global platform for international research collaboration on global environmental change and sustainable development. He stated that a dry land working group has been formed and a science plan has been drafted for the *Future Earth in Asia* component of the program.

The Earth Observer is not only the go-to source for detailed updates on important [Science Team] meetings by a wide array of Earth science disciplines incorporating satellite data, but also serves as a vital "corporate memory" for the NASA Earth Science program. I have learned much from the retrospectives of various NASA endeavors (EOS, Landsat, etc.) written for The Earth Observer by Earth science veterans. They have provided rich context for much of what happens in Earth Science Division these days.

*—**Woody Turner** [NASA HQ—Program Scientist for Ecological Diversity and Ecological Forecasting]*

Pasha Groisman [National Oceanic and Atmospheric Administration (NOAA), U.S.] described NEESPI projects in Central Asia, which address land-use and cryosphere changes, hydrological studies integrating LCLUC and climate, and LCLUC studies on drought mapping and monitoring. NEESPI is currently focused on integrated assessments and climate change projections over Central Asia.

Olga Krankina [Oregon State University, U.S.] provided an overview of the GOFC–GOLD program and networks, their structure, organization, and function, including Northern Eurasia Regional Information Network and CARIN activities. She stressed the need for regional cooperation and commitment from individuals and institutions to successfully implement regional network activities.

Alim Pulatov [TIIMT—Uzbekistan, *Meeting Host*] showcased some of the ongoing LCLUC activities at TIIM, with particular emphasis on the Eco-GIS Center, which is involved in geospatial LCLUC studies including water-resource research. He welcomed international collaborations with TIIM on LCLUC research.

Panel Discussions

The week-long meeting featured five different panels with overview presentations, followed by short presentations and extended group discussions. This format facilitated greater interaction among scientists. After these discussions there was a final plenary discussion that focused on data and knowledge gaps, which also identified research priorities for the region. Themes for the panels were:

- Aral Sea basin issues;
- agricultural land use and water resources;
- CARIN priorities for LCLUC research;

- monitoring land use, water resources, fires, and impacts; and
- high-elevation and water-resource research.

Some of the important points captured during the panel discussions and presentations are summarized below.

Aral Sea Basin

The Central Asian Republics depend on the rivers of the Aral Sea Basin for drinking water, irrigation, and hydroelectric power. The river waters in the upstream countries of the Basin (Kyrgyzstan and Tajikistan) are used for hydroelectric power, especially during the winter months, whereas in the downstream countries (Turkmenistan, Kazakhstan, and Uzbekistan), the Basin waters are used for agricultural purposes in summertime. In all countries, the traditional *flood irrigation* method is used, where water is pumped or brought to the fields and allowed to flow along the ground among the crops. Although this method is simple and cheap, more than half of the water is not used by the crops, and is wasted because of losses from evaporation and filtration. These losses, estimated to be about 40%, come from poor development of the irrigation networks and ineffective water management. The regional scientists at the meeting indicated that cotton monoculture is a major factor for water depletion and ecological problems in the region. Multiple crop rotations with legumes should be encouraged, and *drip irrigation* should be used for agro-ecosystem sustainability. They also agreed that replenishing the shrinking Aral Sea to its original state seems almost impossible; however, mitigation measures (e.g., building reservoirs and restoring wetlands) can be undertaken to reduce further degradation. All participants agreed that following the existing international laws on transboundary water issues through regional cooperation is the only way to "solve" the water resource issues in the region. With respect to the geospatial data on the Aral Basin and surroundings, the GIS Center at the Institute of Geography, Karakalpak State University (Uzbekistan), has been involved in creating digital databases on geobotanical aspects, landscape classification maps, protected areas, geomorphology, and other related issues useful for water/natural resource management.

Agricultural Land Use and Water Resources

In Central Asia, more than 60% of the population live in rural areas and work in the agriculture sector. Land suitable for crop production is 20% of the total agricultural land (and as low as 4% in Turkmenistan) and livestock production is important in the region. Cotton and wheat are the dominant crops in Central Asia and these crops rely heavily on irrigation. In Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, 80% of cropland is irrigated, while, in sharp contrast, the percentage in Kazakhstan is only 7%. Most of the agricultural areas in all these countries have been degraded by excessive cotton monocropping. However, the trend is changing, as cotton is being replaced by wheat. The region also produces a wide variety of crops in smaller amounts, including barley, corn, flax, grapes, beets, apples, apricots, and nuts; such diversification is good for the economy. Nonetheless, as a result of years of poor irrigation practices, there are large areas of salinization in the region, and this problem needs immediate attention. Further, diversion of water for irrigation has resulted in severe environmental problems in the downstream areas of the Syr Darya and Amu Darya Basins near the Aral Sea. Efficient water resource management is therefore a priority for the region.

Specific to Uzbekistan, land reform processes after 1991 led to smaller farm sizes, creation of protected areas, fewer pastures, and other changes in the distribution of land use. There is an urgent need to develop comprehensive management plans for ecologically sensitive lands. From the perspective of the international development community, ongoing LCLUC phenomena can be captured using remote sensing data and the patterns can be linked with underlying processes for effective planning and management in Central Asian countries.

With respect to climate change scenarios for the region, the Intergovernmental Panel for Climate Change Fifth Assessment Report shows no improvement in precipitation prediction, and there is a high uncertainty about changes in future precipitation, information that will be critical for agriculture and land-use planning.

CARIN Priorities for LCLUC Research

Scientists from Central Asian countries—including Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, and the invited representatives from Caucasus (Armenia, Azerbaijan, and Georgia—participated in the panel, identifying priority LCLUC research areas for their respective regions. These included: water, snow and glacier monitoring (quantity and changes); agricultural research for improved crop production, irrigation and water management, and cotton residue treatments; vegetation mapping and monitoring; pests and crop disease monitoring; addressing land-degradation issues; reclamation of saline soils; and monitoring and conservation of critical ecosystems such as lakes and high-elevation forests. To strengthen science and education in Central Asia, the panelists suggested organizing joint international projects as teams, thereby addressing pressing regional LCLUC issues; strengthening collaborative efforts on water resources and management; organizing capacity building and training activities in remote sensing and geospatial technologies; and forming a regional agricultural network in Central Asia, perhaps either by expanding CARIN to include the Caucasus region or developing a separate GOFC-GOLD network for the Caucasus countries (Georgia, Armenia, and Azerbaijan).

Monitoring Land Use, Water Resources, Fires, and Their Impacts

Participants felt that remote sensing and geospatial technologies are underexploited for LCLUC research in the region, and for operational management of water resources, fires, and environmental management. For example, since Kazakhstan gained independence from the former Soviet Union in 1991, there has been a significant reduction in pasture resources due to increases in livestock-based agricultural practices. Since around 2000, records indicate significant reductions in vegetation cover in pasturelands have resulted in a loss of productivity. Thus, use of remote sensing imagery to map pastureland productivity for decision support can provide useful information. Some international collaborations have resulted in generation of applicable products for the region. **Martin Kappas** [University of Gottingen, Germany] showed regionally calibrated *leaf area index* (LAI) time-series products from NOAA's Advanced Very High Resolution Radiometer (AVHRR) data for Kazakhstan from 1982 to 2010. **Abror Gafurov** [GeoForschungsZentrum (GFZ), the German Research Center for Geosciences] showed advanced snow-cover mapping products using MODIS data useful for hydrological studies.

Fire mapping from MODIS data suggests that Central Asia accounts for only 2% of total global fires. Agricultural residue burning in some northern provinces of Uzbekistan is common and practiced for disposing of wheat residues; however, it is illegal in most cases. MODIS active fire data are used by the Jeyran Eco-Center to monitor local fires in dry land vegetation and to detect illegal agricultural burning. There is an opportunity to develop regional fire products through calibration and validation of global data in dry land areas. Additionally, local participants emphasized the need for capacity building, education, and training in water-resource research and modeling.

High-elevation and Water-resource Research

Over the globe, between 70% and 80% of glaciers are located in high mountain areas, of which 35% are concentrated in Central Asia. More than 60% of the water supply for Central Asia comes from snow-water melt, 20% from glacier melt, 18% from rain, and 1% from other sources. The Central Asian Institute of Applied Geosciences (CAIAG) in Kyrgyzstan is involved in generating regional geospatial datasets useful for water resource research, which includes soil, land use, climate, agro-ecological potential, and water management maps.

The Earth Observer is a great service and resource for the [Earth science] community. It does a great job covering key events and has helpful graphics. The balance of topics and well-written, accessible articles make [the newsletter] a welcomed arrival in my inbox. It's a great way to inform the NASA community about efforts to apply Earth observations as well as to highlight the missions, data, and research that enable applications in the first place.

*—**Lawrence Friedl** [NASA Headquarters—Director of Earth Science Division's Applied Sciences Program]*

CAIAG is also involved in glacier research, conducting meteorological, seismic, and global positioning systems (GPS) measurements in high-altitude glacial regions in Kyrgyzstan. Their research suggests an increase in regional glacier retreat rates from 1970 to the 1990s. For example, in the mountain regions of Akshiyrak, Kyrgyzstan, a relative loss in the area of 13% was observed; similarly, in it was 34% in Djetim, 19% in Borkoldoi, 10% in Nijniy Naryn, and 15% in At-Bashi. The glacier retreat is mostly observed in small glaciers. Integrated meteorological, remote sensing, and instrumentation data suggests that over Central Asia over the last thirty years, snow-covered-areas shrank by 15% and glacier-covered-areas by 10%. Absolute values of precipitation over the whole Central Asia were negative for the last 30 years with the most significant deficit in the alpine regions and Kazakhstan steppes during summer. For the same region, an increase in annual air temperature of 0.68 °C was observed over the last thirty years, and for all of Central Asia, total river runoff has decreased by 4%.

Earth Observations and Remote Sensing for LCLUC Studies

This session took place on the third day of the meeting, and included presentations on potential synergistic use of Landsat and Sentinel data, and potentially merging these data to obtain three-to-five-day coverage, useful for agriculture monitoring. Examples were also provided of remote sensing projects conducted at the University of Würzburg (Germany).

Invited Presentations

In addition to the above panel discussions, the meeting included two invited talks. **Rik Leemans** [Waginingen University, Netherlands] discussed *Integrated Modeling of LCLUC and Interactions*, in which he stressed the need for clear conceptualization, quantification, and validation of all important relationships between LCLUC-vegetation-climate for holistic understanding of societal/policy problems through continuous dialogue with users.

Leadership Summit

As part of the Leadership Summit, the international participants visited different research and educational institutes in the region, with the goal of building collaborations with LCLUC scientists and projects. The scientists from Tashkent Institute of Irrigation and Melioration's Bhakura campus (TIIMB) and Samarkand Agricultural Institute (SAI) organized field trips for the team to familiarize them with the local environment, particularly the dry lands, agriculture, and water resources in the region.

TIIMB has faculty expertise in land management and cadastral studies, geodesy, hydraulic engineering, water management, and hydromelioration. Remote sensing expertise for LCLUC studies is still being developed, and local scientists expressed strong interest in collaboration with scientists, internationally.

SAI, which offers masters' and doctoral programs, was established in 1929 and is one of the oldest and currently the leading educational establishment in agricultural land-use research in Central Asia. The institute has existing collaborations with the U.S. Department of Agriculture (USDA) and Wageningen University (Netherlands). The institute eagerly looks forward to building collaborative research in remote sensing and geospatial technologies linked to agricultural land-use research.

Participants visited the Jeyran Ecocenter, one of the prominent protected natural areas in Bukhara Province in Uzbekistan, and en route had a chance to see local agriculture (dominated by cotton and wheat crops), desert landscapes, and salt-affected dry land areas—as shown in the photos. The field visit included a stop in the Zarafshan River Basin, which was formerly a sub-basin of the Amu Darya Basin, but which connection was lost as increased amounts of water from the river and its tributaries were diverted for irrigation. Local engineers explained that the Zarafshan Reservoir is currently serving nine million people, and showcased how water-use plans are helping basin-wide management of water in the region, including the benefits of recently introduced and expanding drip irrigation.

Xerophyllous vegetation dominated by scrublands and Salsola at the Jeyran Ecocenter in Bukhara, Uzbekistan. **Image credit:** Krishna Vadrevu

Vast areas of salt deposits on the land surface along a road in Samarkand, Uzbekistan. **Image credit:** Krishna Vadrevu

Shahid Habib [NASA's Goddard Space Flight Center] spoke on *Utilizing NASA's Earth Observations for Societal Applications*, which showcased the potential of NASA's remote sensing observations and models for quantifying water balance parameters and hydrological modeling studies.

Conclusion

Common themes that surfaced during the discussions were the need to strengthen regional cooperation to solve transboundary water-use issues in the region, and improve decision-making in the region informed through consensus scientific assessment. Participants identified the need to develop regionally consistent land-use and land-cover datasets. Participants realized that in most Central Asian countries, use of geospatial technologies is limited and that the remote sensing research community is small and mostly engaged in local projects. Thus, pathways from research to operational use and sharing of new techniques and methods should be explored. Some geospatial training capabilities already exist at various research institutes and universities, but they need strengthening. Participants also agreed to work on maintenance, ownership, and governance issues for long-term sustainability of CARIN and its activities. There is a considerable interest from international donors such as the World Bank and USAID, to fund projects over Central Asia on water resources, agriculture, and energy, and in this context, regional scientists could explore such opportunities to address regional-scale questions relevant to all countries in the region. Overall, the meeting was highly successful in addressing LCLUC and water resource issues in Central Asia. Additional information on this and other LCLUC meetings may be found at *lcluc.umd.edu/meetings.php?mid=48*. ■

Training Workshop: Geospatial technologies and models for land and water resources in Central Asia

The TIIM Eco-GIS center organized a two-day training event for students and young investigators. It featured eight international experts from several countries, who served as trainers for the 45 participants. The topics addressed included:

- Introduction to remote sensing data and products;
- hydrological cycle changes over the extratropical land areas;
- the contemporary hydrophysical state of the Aral Sea and its impact on the coastal zones of Kazakhstan and Uzbekistan;
- geospatial analytical methods and critical data/methodological issues specific to Central Asia;
- geoinformatic applications in Central Asia; and
- remote sensing techniques for monitoring land-use and land-cover change, including irrigation and salinity issues in Uzbekistan.

The Earth Observer newsletter provides information about current and recent activities and accomplishments involving the satellites that we operate in the Earth Science Mission Operations Project at NASA's Goddard Space Flight Center (GSFC). This information is appreciated by the operations and ground system teams that work 24 hours a day, seven days a week, to keep the missions safe and providing data to meet science requirements. The newsletter articles and images on the latest accomplishments using data from the Earth-observing missions have inspired the teams and given them a sense that what they are doing is very important and contributes to the success of the missions.

—***Angie Kelly*** *[GSFC—Earth Science Mission Operations]*

Ocean Surface Topography Science Team Meeting

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The 2013 Ocean Surface Topography Science Team (OSTST) Meeting was held in Boulder, CO, October 8-11. The meeting was held in parallel with the seventh Coastal Altimetry Workshop (CAW), and expanded to four days to accommodate a joint session between OSTST and CAW that was held on October 8, specifically to focus on results from the new high-resolution, along-track altimeter: using Synthetic Aperture Radar Mode (SARM) data from the European Space Agency's (ESA) CryoSat-2 mission. These high-resolution data will eventually become commonplace on future altimetry missions. This year's meeting was complicated by the 2013 shutdown of the U.S. Federal Government, which prevented several key participants from attending the meeting, including program managers from both NASA and the National Oceanic and Atmospheric Administration (NOAA).

The primary objectives of the OSTST Meeting were to:

- Provide updates on the status of Jason-1 and Ocean Surface Topography Mission (OSTM)/Jason-2 (hereinafter, Jason-2);
- conduct splinter meetings to address the various geophysical corrections made to improve the accuracy of altimeter data and altimetry data products; and
- discuss the science requirements for future altimetry missions.

This report, along with all of the presentations from the plenary, splinter, and poster sessions are available on the AVISO website: *www.aviso.oceanobs.com/en/courses/sci-teams/ostst-2013.html.*

Update on Ocean Surface Topography Missions

The Jason-1 mission ended in 2013 due to a failure of its last remaining transmitter, after having completed 11.5 years of service and one complete 406-day geodetic (or marine-gravity-field related) orbit. After the transmitter failure, Jason-1 was successfully decommissioned in this orbit at an altitude of 1324 km (~823 mi), where it poses no collision risk to the Ocean Topography Experiment (TOPEX/Poseidon), Jason-2, or any future Jason missions that would be in the same orbit. During the Wednesday morning plenary session, **Rosemary Morrow** [Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS)] gave a presentation on the many scientific accomplishments of Jason-1; details may be found at *www.aviso.oceanobs.com/fileadmin/documents/OSTST/2013/oral/Morrow_v2.pdf.*

Jason-2 launched in June 2008 on the former ground track of Jason-1 and TOPEX/Poseidon. All systems continue in good condition and the satellite is operating nominally. Jason-2 experienced three *safe hold modes* (SHMs) in 2013—where the satellite moved to a sun-pointing orientation in response to an error or upset during otherwise routine operations. These were the first such events of the mission, and in each incident recovery to nominal operation was successful; the causes for these SHMs remain under investigation. Jason-2 continues to collect high-quality science data and—apart from the short periods where science data were not collected—continues to meet all mission and Level 1 science requirements.

With regard to future OST missions, Jason-3 development is nominal, with satellite, instruments, and ground system activities all making good progress. Complete integration of the satellite is expected during 2014, and as of the meeting being described here, the planned launch date remained set for March 2015. However, Congress reduced NOAA's FY14 budget for Jason-3 by approximately $18 million, cutting the budget in half for this FY. NOAA management and NASA, as NOAA's acquisition agent for the U.S. instruments and launch services, are working together to determine the impact and develop options to maintain the current March 2015 launch date.

The Jason Continuity of Service (Jason-CS) mission will continue the Jason series of research and operational oceanography missions and its payload will include a K_u/C-band radar altimeter, a K/K_a-band passive microwave radiometer, and Global Navigation Satellite System (GNSS) equipment, including the time-tested Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) system. Progress on planning and development of Jason-CS is ongoing. As recommended by the OSTST in previous meetings, an interleaved

The Earth Observer is a scientific and educational gem. Constantly improving for 25 years, it has kept its finger on the pulse of the home planet. Its style is no rant and no slant, images displayed elegantly and facts explained clearly.

*—**Bill Patzert** [NASA/Jet Propulsion Laboratory—Oceanographer/Climatologist]*

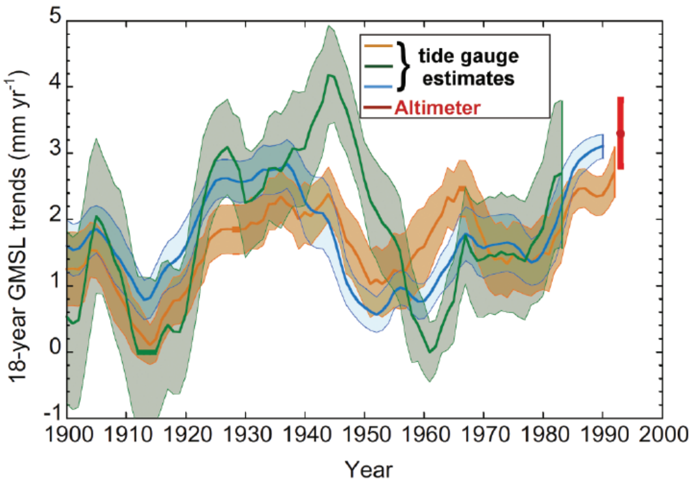

Figure 1. Longterm time series of climate variables are crucial for understanding climate change. This graph shows the rate of global sea level rise as it changes over time from 1900 to 2000. Although most of the historical observations are based on tide gauge data, the presentations stressed that satellite altimeter data (the red bar at the end) has been an important tool in the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5). **Image credit**: from IPCC AR5, Chapter 3.

altimeter mode is now the baseline for the mission, which will simultaneously provide both *low-resolution mode* (LRM) and *high-resolution synthetic aperture radar mode* (SARM) data. In addition, implementation of a radiometer with long-term stability (likely to be maintained through the use of an onboard calibrator) is now also included in the baseline mission, as recommended by the OSTST. The team expressed its appreciation for the responsiveness of the Jason-CS project in all of these instances. Securing funding for Jason-CS remains a significant hurdle and is now driving the schedule, with launch unlikely before 2020.

NOAA has announced that it does not expect approval of its FY15 budget request for a *New Start* for Jason-CS, and that it is now working on a FY16 request. This automatically introduces a one-year delay into the start of development for the JPL-developed payload instruments. With these new factors, the readiness for launch has now been moved from the fourth quarter of 2019 to the second half of 2020. This reinforces a recommendation adopted earlier by the OSTST team to strive for an earlier launch date for Jason-CS and to maintain the current launch date of Jason-3 to ensure that there is overlap with the expected five-year lifetime of Jason-3.

Keynote Presentations

Six keynote presentations took place during the meeting's plenary sessions. Probably the most significant report came from **Don Chambers** [University of South Florida] and **Steve Nerem** [University of Colorado's Cooperative Institute for Environmental Sciences (CIRES)], who discussed recent results from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), which noted that satellite altimeter data provide important measures of global climate change by monitoring global sea level rise—see **Figure 1**. The keynote presentations are summarized in the **Table** below, and the presentations themselves can be viewed at *www.aviso.altimetry.fr/en/user-corner/science-teams/sci-teams/ostst-2013/ostst-2013-presentations.html*.

Table. Keynote presentations from the 2013 OSTST meeting.

Speaker	Institution	Topic
Don Chambers	University of South Florida	Ocean observations of climate change: Overview of the IPCC's fifth assessment rReport
Steve Nerem	University of Colorado's CIRES	Understanding and projecting sea level change: Overview of the IPPC's fifth assessment report
Rosemary Morrow	Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS)	Jason-1: 11.5 years of accomplishments
Jacques Verron	Le Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE)	Satellite with ARgos and ALitka (SARAL/Altika)
Lee-Lueng Fu	NASA/Jet Propulsion Laboratory	Surface water and ocean topography mission design for advancing mesoscale oceanography
Patrice Klein	Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)	Meso/submesoscale dynamics and their impact on sea level
Kevin Trenberth	National Center for Atmospheric Research (NCAR)	Earth's energy imbalance and implications for ocean heat content

Splinter Sessions

Outside of the plenary sessions, focused splinter sessions were held on the following topics:

- Precision orbit determination;
- regional and global calibration and validation;
- instrument processing;
- near-real-time products and multimission applications;
- outreach, education, and altimetric data services;
- the geoid, mean sea surfaces, and mean dynamic topography;
- quantifying errors and uncertainties in altimetry data; and
- science results from satellite altimetry.

Several of the splinter sessions, including a joint session with the CAW, focused on use of new high-resolution altimetry data from along-track SAR processing of altimetry data. SAR data from CryoSat-2 show that at wavelengths shorter than 100 km (~62 mi), LRM data have higher variance.

During the discussion of quantifying errors, **Pierre Thibaut** [Collecte Localisation Satellites (CLS)] suggested that the *spectral bump* in Jason-2 data was due to *waveform contamination* and depends on the along-track footprint of the altimeter—see **Figure 2**.

Satellite altimeter data continue to be refined as tools for measuring ocean currents. When combined with satellite gravity observations from ESA's Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) mission—launched in 2009, and ended in 2013—and other tools used to estimate the time-averaged, dynamic ocean topography, multimission satellite altimetry can now provide a much higher-resolution look at ocean surface currents—see example in **Figure 3**.

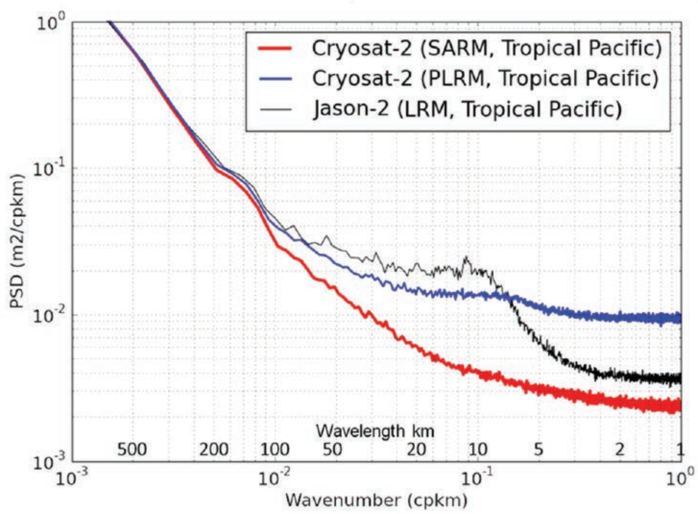

Figure 2. This graph shows the wavenumber spectrum from along track altimeter data for both high resolution (SARM) [*red curve*] and low resolution (PLRM) [*blue curve*] modes of CryoSat, as well as for Jason-2 [*black curve*], over the Tropical Pacific. Note that Jason-2 delivers only Low Resolution Mode data. The respective curves show the amount of energy at different spatial scales in the data. The "bump" in the Jason-2 curve between 20 km (~12.4 mi) and 5 km (~3.1 mi) has long been attributed to instrument noise, but recent work suggests that it may be due to *waveform contamination*. **Image credit**: Pierrre Thibaut [CLS]

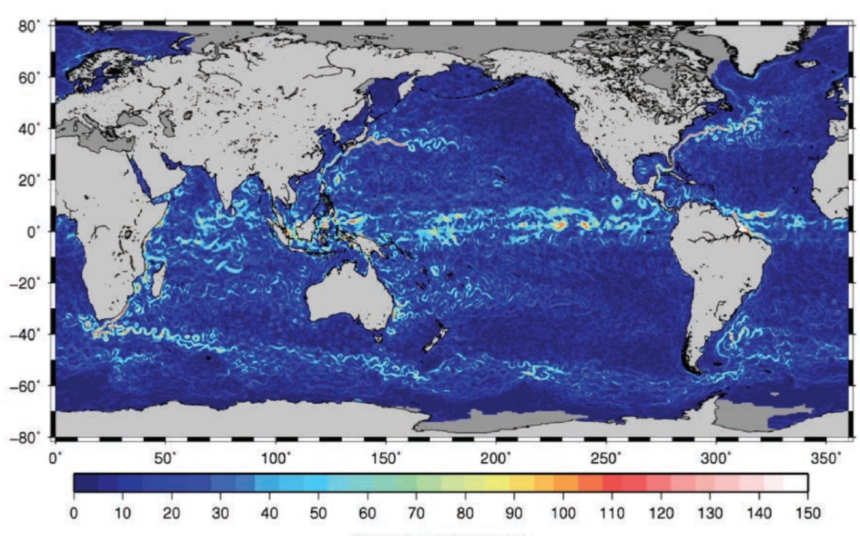

Figure 3. Satellite altimetry data can be combined with an estimate of the time-averaged mean dynamic topography from CLS to measure the "tilt" of the sea surface, and produce maps of the *absolute speed* of the ocean surface. Shown here is a single seven-day snapshot from late 1992. **Image credit**: Sandrine Mulet [CLS]

Acknowledgments

The OSTST expresses its appreciation to responsible space agencies and project teams for the following accomplishments:

- Acceptance of interleaved mode as the baseline for Jason-CS;
- acceptance of a climate-quality, three-frequency radiometer as baseline for Jason-CS;
- investigation of an additional high-frequency radiometer for Jason-CS;
- acceptance of all-ocean and land coverage in SAR mode as baseline for Sentinel-3;
- release and processing of over-ocean CryoSat-2 data;
- completion of the extremely successful 11.5-year Jason-1 mission;
- approval of extended funding for Jason-2;
- successful launch and commissioning of SARAL/Altika and fast delivery of high-quality data products to the community; and
- recognition from agencies funding OST missions of the ongoing need to continue processing of Jason-1 data.

Closing Plenary

The closing plenary session focused on reprocessing data from the joint U.S./French TOPEX/Poseidon mission, launched in 1992. After 14 years in orbit (far exceeding its planned mission life), the mission ended in 2006 owing to a malfunction. Concern over the changing point-target response of the TOPEX altimeter has prevented reprocessing to date. Recent work to analyze data over lakes has been used to help understand the point-target response in the face of leakage. The current plan is to make a new retracked *geophysical data record* (GDR), consistent with GDR-C processing, which should become available in early 2015. While TOPEX reprocessing remains a top priority, plans to reprocess Jason-1 and Jason-2 data to a new GDR-E standard are underway, and Jason-1 data should be completely reprocessed by the end of 2014. OSTST members are encouraged to download, analyze, and provide feedback on reprocessed data from CNES.

The next OSTST meeting will be held at Lake Constance, Germany, October 28-31, 2014. The theme will be "New Frontiers of Altimetry." There will be also a SARAL/Altika workshop on October 27 and an International Doris Service (IDS) workshop October 27-28. For additional details, visit: *www.ostst-altimetry-2014.com*. ■

The Earth Observer has been a beneficial publication venue for our participants to communicate their projects and the application of NASA Earth observations to the Earth science community. It also has served as a great learning ground for our [DEVELOP National Program] participants to experience the process of writing and editing scientific articles describing their research.

*—**Lauren Childs-Gleason** [LaRC—DEVELOP Program's National Science Lead]*

Landsat Science Team Meeting: First Landsat 8 Evaluations

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Introduction

The U.S. Geological Survey (USGS)-NASA Landsat Science Team (LST) met at the USGS' Earth Resources Observation and Science (EROS) Center near Sioux Falls, SD, from October 29-31, 2013. All meeting presentations can be downloaded from *landsat.usgs.gov/science_LST_October_29_31_2013.php*.

The meeting opened with a telephoned welcome from **Anne Castle** [Department of the Interior—*Associate Secretary for Water and Science*]. Castle thanked the LST members for their service to the Landsat missions and emphasized how important the team's efforts are to the success of the Landsat program. She summarized the discussions underway between NASA, USGS, and the White House Office of Management and Budget to transform Landsat into a sustained land-imaging program, with a series of continuous satellite deployments. —see discussion throughout, and especially the section on **Sustained Land Imaging Planning** on page 27.

Elizabeth Thrond [Augustana College], representing the Midwest Archive Conference (MAC), then presented the MAC President's Award to the 2006-2011 LST. The LST members were selected because of the team's significant efforts to expand the global Landsat archive, and for their advocacy for the Landsat free and open data policy. The impacts of such expansion and free access are manifold.

Tom Loveland [EROS—*Senior Scientist*] and **Jim Irons** [NASA's Goddard Space Flight Center (GSFC)—*Landsat 8 Project Scientist*], co-chairs of the LST, set the stage for the three-day meeting and discussed the primary meeting goals, which were to:

- Review the status of LST Landsat 8 investigations;
- discuss the status and requirements for Landsat 9 and beyond; and
- establish plans for improving Landsat science products.

Loveland and Irons stressed the importance of understanding the value of Landsat 8's new capabilities and whether they should be required for future Landsat missions. They also stressed the responsibility of the science team to contribute to the scientific and technical aspects of a sustainable land-imaging program by clearly representing the breadth of Landsat user requirements. Finally, they suggested that this is the most important LST meeting since 2006 and likely the most important

Group photo of Landsat Science Team Meeting attendees. **Image credit:** David Hair, USGS of this current science team, owing to the combined NASA and USGS efforts to define sustained land imaging concepts by August 2014.

Landsat 8 Operations Status

Brian Markham [GSFC—*Landsat 8 Calibration Scientist*] initiated the technical meeting by providing a report on the radiometric performance of both the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). He said that OLI has been performing well since launch. The measured signal-to-noise ratio (SNR) characteristics exceed design requirements, and OLI outperforms the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) by factors of between 6 and 12. Measurement stability also exceeds requirements, and there is no evidence of significant contamination or degradation of the instrument or onboard calibration devices. Uniformity has been improving—with striping reduced by half—but there are still some discontinuities at focal plane module boundaries. Based on vicarious measurements, the absolute radiance and reflectance calibration generally agree within ±2%.

Regarding TIRS, Markham reported that the instrument is performing well in terms of SNR performance and radiometric stability, but radiometric accuracy of the thermal Band 11 (11.50–12.50 µm) has led to the advisory that at this time Band 11 should not be used for split-window calculations. Banding and streaking issues are a concern with TIRS; the instrument meets banding/streaking uniformity metrics for certain Earth scenes, but fails for others.

Based on the performance analysis, OLI and TIRS data recalibration is needed to increase the precision of OLI radiance-to-reflectance conversion coefficients and to adjust edge detector relative gains in overlap areas between sensor chip assemblies, and to improve the absolute calibration of thermal band 10.[1]

Jim Storey [USGS/Stinger Ghaffarian Technologies Inc.—*Landsat 8 Geospatial Imaging Scientist*] reviewed OLI and TIRS geometric performance, and reported that all geometry requirements are being met or exceeded. Band-to-band, worst-case registration is in the 3.28–4.07-m (~10–13-ft) range for OLI, and 8.7–10.5-m (~28–34-ft) range for TIRS. OLI-to-TIRS band registration is 18.8–20.8 m (~61–68 ft) [worst case], which is well below the 30-m (~98-ft) specification. Geodetic absolute accuracy was 37.0 m (~121 ft) circular error, well under the 65.0-m (~213-ft)specification. The geometric accuracy of the orthorectified Level-1T (L1T) datasets is 11.4 m (~37 ft) circular error, under the 12.0-m (~39 ft) specifications; no evidence of image jitter has been found. Landsat 8 geodetic accuracy in some areas is better than the current ground control observations used to orthorectify all Landsat images. As a result, Landsat 8 data may be used to improve the existing ground control data.

Storey also reported on an effort to develop an approach and tools for generating Landsat 8 scene pixel-level viewing angle and sun angle measurements. The approach is to provide enhanced metadata with each L1T product and a tool for users that would allow computation of scene viewing angles. The LST agreed to test the prototype angle-generation tool and to provide feedback to Storey on its viability as a permanent capability.

Gene Fosnight [USGS EROS—*Landsat Data Acquisition Manager*] summarized efforts to define a multimission acquisition strategy. With both Landsat 7 and 8 collecting data, mission operations staff are working on a new scheduling approach that maximizes the percentage of sunlit Earth imaged each day. Depending on the extent of the landmass associated with each day's orbits, Landsat 7 currently images between 350 and 450 of the 540–630 daily sunlit opportunities. By using Landsat 7 mainly for continental areas, the daily acquisition rate would be fixed at 470 images. Landsat 8 is acquiring approximately 550 images per day and covers almost all land masses, including continents, coastlines, islands, and special-interest areas, such as Antarctica. This approach results in a significant increase in daily science data while reducing instrument wear.

Jim Lacasse [USGS EROS—*Landsat Operations Team Leader*] closed the Landsat status session with a report on Landsat operations and the Landsat data archive. Landsat 8 operations are nominal for all systems, and the satellite has acquired as many as 732 images in a 24-hour period. While the latency design requirement is to be able to process 95% of the daily acquisitions to an L1T product within 24 hours, the system is currently generating nearly 100% of the L1Ts within 5 hours of the data being received at the EROS Center.

Landsat 7 has been operating for more than 14 years. While it has had scan-line corrector, gyro, and fuel-line thermostat problems, it continues to acquire more than 350 global images each day. At this point, it has sufficient fuel to continue operations through 2017. Lacasse mentioned that 1256 coincident Landsat 7 and 8 images were collected in late-March 2013 during the Landsat Data Continuity Mission (LDCM) commissioning phase. The images are available to anyone interested in addressing the differences and synergies between data from the two missions. They can be viewed using standard USGS query tools such as *Earth Explorer* (*earthexplorer.usgs.gov*) and *Glovis* (*glovis.usgs.gov*).

[1] **UPDATE**: A reprocessing took place in February 2014.

The Landsat archive now includes more than five million images:

Landsat 8 OLI-TIRS: 149,273 scenes
Landsat 7 ETM+: 1,685,804 scenes
Landsat 4-5 Thematic Mapper (TM): 1,904,473 scenes
Landsat 1-5 Multispectral Scanner: 1,299,399 scenes

Archive statistics can be found at *landsat.usgs.gov/Landsat_Project_Statistics.php*.

There has been a substantial increase in archive holdings due to the success of the Landsat Global Archive Consolidation (LGAC) initiative conceived by the 2006–2011 LST. LGAC was established to repatriate international Landsat holdings not found in the USGS EROS Landsat archive. As of October 2013 2.55 million LGAC scenes have been added. The largest international collection, held by the European Space Agency, is now being delivered to the USGS. Lacasse concluded by mentioning that in Fiscal Year 2013, 4.36 million Landsat images were downloaded from EROS, substantially higher than the 2.73 million images downloaded the previous year.

Landsat 8 Science and Applications

Each of the LST members reported on their Landsat research, and where possible, their evaluation of Landsat 8 data. Collectively, the 20 research presentations showcased the:

- Excellent radiometric and geometric performance of the Landsat 8 instruments;
- opportunities resulting from the improved daily acquisition capacity;
- data quality improvements associated with the cirrus band;
- seamless integration of Landsat 8 data into many operational applications and scientific investigations; and
- potential new applications resulting from the additional spectral measurements.

The presenters, topics, and key findings from each presentation follow.

Kurt Thome [GSFC—*Terra Project Scientist*], with **Joel McCorkel** [GSFC] discussed *Absolute Radiometric and Climate Variable Intercalibration of Earth Observing Sensors*. Simultaneously acquired Landsat 7 and 8 data, when compared with other airborne and field measurements, show calibration results within ~4% absolute uncertainty, suggesting that Landsat provides a critical sampling resolution bridge between current and upcoming satellite, airborne, and ground-based observatories.

Eric Vermote [GSFC] discussed the *Development of Landsat Surface Reflectance Climate Data Records*. A preliminary Landsat 8 surface-reflectance product has been developed and is being validated; the addition of the Band 9 (the Landsat 8 cirrus band) should improve atmospheric corrections.

David Roy [South Dakota State University] described *Continuity of the Web Enabled Landsat Data (WELD) Product Record in the LDCM Era,* discussing the lack of Landsat 8 saturation over bright targets (as compared to Landsat 7) and how improved geolocation improves the quality of large-area products.

Yongwei Sheng's [University of California, Los Angeles] discussed *Developing Decadal High Resolution Global Lake Products from LDCM and Landsat*, describing how early results show that Landsat 8 radiometry is superior to that from Landsat 7 and will result in improved delineation of water bodies.

Crystal Schaaf [University of Massachusetts, Boston] presented *North American Land Surface Albedo and Nearshore Shallow Bottom Properties from Landsat and MODIS/VIIRS* [2], and said that a preliminary Landsat 8 albedo product has been generated and is being evaluated.

John Schott [Rochester Institute of Technology] discussed *The Use of LDCM for the Monitoring of Fresh and Coastal Water*, stating that Landsat 8 radiometric performance should increase the ability to characterize chlorophyll, suspended materials, and colored dissolved organic matter.

Ted Scambos [University of Colorado] discussed *Cryospheric Applications of the Landsat Data Continuity Mission (or Landsat 8),* describing how Landsat 8's improved acquisition capabilities offer significant opportunities for polar-region imaging campaigns. He stated that the improved geometry will lead to greater use in quantifying ice flows.

Ayse Kilic [University of Nebraska-Lincoln] and **Richard Allen** [University of Idaho] presented *Developing and Enhancing Landsat-Derived Evapotranspiration and Surface Energy Balance Product*, wherein they reported excellent correspondence in the comparison of surface albedo and evapotranspiration during the Landsat 8 underflight of Landsat 7, and that the addition of the cirrus band helps explain unexpected cool temperatures.

Feng Gao [U.S. Department of Agriculture, Agricultural Research Service] discussed *Mapping Vegetation Phenology, Water Use, and Drought at High Spatiotemporal Resolution Fusing Multiband and Multiplatform Satellite Imagery*, stating that Landsat 8's 30-m (~98.4-ft) thermal sharpening results are comparable

[2] MODIS is the Moderate Resolution Imaging Spectroradiometer; VIIRS is the Visible Infrared Imaging Radiometer Suite.

to those from Landsat 7; additional testing will require Landsat 8 surface temperature processing.

Jim Vogelmann [USGS] described *Ecological Disturbance Monitoring using Landsat Time Series Data,* and showed that there is a substantial improvement in the clarity of surface features in Landsat 8 imagery (over Landsat 7) due to the increased dynamic range and overall improved radiometry.

Alan Belward [European Commission Joint Research Centre] presented *Understanding the Global Land-Use Marketplace*, describing how Landsat continues to be the "gold standard" for global land-cover monitoring. The robust data acquisition strategy and distribution policy increases Landsat's importance for monitoring global land change.

Leo Lymburner [Geoscience Australia] described *Multitemporal Analysis of Biophysical Parameters Derived from the Landsat Series of Satellites*, stating that preliminary Landsat 8 results show the potential for retrieving shallow water bathymetry, improving vegetation characterization, and increasing the potential of nighttime imaging.

*Perhaps the best summary statement was **Alan Belward's** observation that while there are literally hundreds of Earth observation missions, Landsat stands out as the "gold standard" due to the systematic acquisition of global imagery, the consistent high data quality, and the accessibility of these data to anyone in the world.*

Patrick Griffith on behalf of **Patrick Hostert** [Humboldt University of Berlin—Germany] presented *Synergies Between Future Landsat and European Satellite Missions for Better Understanding Coupled Human-Environment Systems*. He stated that there is need for a Landsat 8 surface reflectance product, and recommended that efforts be undertaken to identify synergy between Landsat 8 and the European Space Agency's (ESA) Sentinel-2 platforms, the first of which is currently scheduled for launch in 2014.

Mike Wulder [Canadian Forest Service] focused on *Integrating the Past, Present, and Future of Landsat*, and discussed the integrity of the full Landsat production chain. He said that the confidence users have in Landsat data continues to enable operational applications and implementation of composited products.

Robert Kennedy [Boston University] discussed *Using Time-Series Approaches to Improve Landsat's Characterization of Land Surface Dynamics*. He described how Landsat 8 surface reflectance products are needed for long-term monitoring, and pointed out that a quick analysis of basic data products such as the normalized burn ratio shows consistency between Landsat 8 and previous missions.

Randolph Wynne [Virginia Tech] discussed *Integrating the Past, Present, and Future of Landsat*, explaining that preliminary results show slight improvements in Landsat 8 *versus* Landsat 7 correlations between leaf area index and the normalized difference wetness index.

Curtis Woodcock [Boston University] focused on *Better Use of the Landsat Temporal Domain: Monitoring Land Cover Type, Condition, and Change*. He explained that the Landsat 8 cirrus band significantly improves detection of clouds and cloud shadows. He also stated that image classification accuracies are improved using Landsat 8 *versus* 7 data, due to improved radiometric resolution, and that *variograms* show reduced noise and increased variance in Landsat 8 data.

Warren Cohen [USDA's Forest Service] presented *Ecological Applications of Landsat Data in the Context of U.S. Forest Service Science and Operational Needs*, showing that Landsat 8 potentially extends the Landsat record to 50 years, and offers the continuity of observation needed to understand changes in natural resources.

Jim Hipple [USDA's Risk Management Agency] discussed *Integrating Field-Level Biophysical Metrics Derived from Landsat Science Products into a National Agricultural Data Warehouse*, and described how growing condition variables derived from Landsat will be used to assess field-level conditions that relate to crop insurance issues.

David Johnson [USDA's National Agricultural Statistical Service] described *Operational Monitoring of U.S. Croplands with Landsat 8*, explaining that the USDA's annual crop type mapping used nearly 1000 Landsat 8 scenes in this year's cropland data layer generation

Sustained Land Imaging Planning

The Executive Branch of the U.S. government has initiated planning for a sustainable land imaging program. **Matt Larsen** [USGS—*Associate Director for Climate and Land Use Change*] gave an overview of the planning process that is to produce a solution for the next Landsat mission—and missions for the next 25 years. With Landsat 7's fuel-based end-of-life in 2017 and Landsat 8's five-year design life coming in 2018, there is considerable urgency to initiate development of the next Landsat. NASA is leading the planning process, with the USGS as a partner. **Brad Doorn** [NASA Headquarters—*Applied Sciences Program, Water Resources Program Manager*] emphasized that NASA's goal is to define a sustained, space-based, global land imaging capacity for the nation, that is driven by meeting user requirements. A Request for Information (RFI) was issued in September 2013 to identify concepts for future missions. NASA is required to provide an architecture plan to the White House by August 15, 2014.

Tim Newman [USGS's Land Remote Sensing Program—*Acting Program Coordinator*] provided additional details regarding the activities underway to define future Landsat capabilities. While the shape of the future land imaging program is still being determined, it is certain that the strong cooperation between NASA and the USGS, established during Landsat, will continue, with NASA leading the architecture investigations and USGS working toward documenting user requirements. The USGS's National Land Imaging Requirements study has gone through a pilot phase in which requirements from federal users of moderate resolution imagery were collected. The NASA-led Architecture Study Team (AST) will use the results in their consideration of future mission concepts.

Newman also briefly summarized the recent National Research Council's (NRC) report, *Landsat and Beyond: Sustaining and Enhancing the Nation's Land Imaging Program* (*www.nap.edu/catalog.php?record_id=18420*). The report concludes that the U.S. Government should establish a "sustained and enhanced land imaging program" with sufficient funding to meet current and future needs. The NRC's report calls for the development of a plan for a program that capitalizes on NASA's and USGS's strengths; maintains current capabilities; enhances imaging capabilities and data products via emerging technologies; and establishes a research and development component for improved data products, new measurement methods, and approaches for meeting evolving requirements.

Del Jenstrom [GSFC—*AST Manager*] described the formation of a NASA–USGS AST, as mentioned earlier, that will assess architecture options for a long-term sustainable land-imaging program. The AST will analyze and prioritize user requirements, evaluate instrument and observatory designs, consider architecture technical concepts and business models, and conduct cost assessments. Recommended architectures must be delivered to NASA's Earth Science Division in May 2014.

Curtis Woodcock and **David Roy** [LST co-leaders] led a discussion of several scientific and technical issues associated with future Landsat plans. These included:

- Identifying critical characteristics and specifications (e.g., data consistency and accessibility, geographic coverage, temporal frequency, latency, spectral bands, spatial resolution, accuracy) for future missions, and their traceability to specific science and applications;
- defining data continuity approaches that ensure that long-term science investigations and operational program investments are preserved;
- determining the relative compatibility that ESA's Sentinel-2 mission offers the Landsat community in terms of science applications; and
- assessing required radiometric accuracy and stability needed for applications, and the science impact of temporal variability in radiometry.

Additional issues discussed included spectral precision advances (e.g., hyperspectral imaging), spectral band registration needs, coincident measurement issues (e.g. temporal separation of thermal imaging from the reflected bands), and the impacts of radiometric error. The LST established study teams that will prepare formal statements on each.

Landsat Science Products

The final meeting objective, to develop plans for improving Landsat science products, was discussed in general terms. **John Dwyer** [EROS—*Landsat Ground System Scientist*] led off the discussion with a brief update on USGS' plans to produce higher-level Landsat products. He reported on the availability of Landsat 4-7 TM and ETM+ surface reflectance products, the development status of the surface temperature product, and Essential Climate Variable (ECV) activities.

The LST then broadly discussed how the 2008 Landsat free-data policy changed data analysis approaches. Increasingly, users require access to data spanning longer periods and larger geographic areas. This suggests that, in the future, the on-demand model for L1T product downloads will become obsolete. Another important priority is generation of Landsat science datasets meeting international Climate Data Record and ECV standards. **David Roy** presented a philosophy for establishing a science information product program. The team agreed to prepare a *white paper* outlining a possible direction, given the uncertainties and constraints associated with the Landsat program.

Other Business

Darrel Williams [Global Science and Technology, Inc.—*Chief Scientist*] briefly reported on activities at the National Geospatial Advisory Committee's Landsat Advisory Group (LAG). The LAG is developing responses to several study questions related to Landsat. The questions address product opportunities, emerging computing and data management approaches, and an assessment of the NRC *Landsat and Beyond* report. The reports should be available by the end of 2014.

Conclusion

The meeting provided the first complete review of Landsat 8 experiences and capabilities. While the investigations into data quality, compatibility, and science and applications opportunities are still at an early stage, the initial results indicate that Landsat 8 is exceeding expectations. The team's findings are especially important as discussions on the strategies and characteristics of the next generation of land imaging satellites unfold. The next meeting will be scheduled during the summer, 2014. The specific dates and location are to be determined. ■

2013 GRACE Science Team Meeting

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The Gravity Recovery and Climate Experiment (GRACE) mission entered its twelfth year on March 18, 2013. A joint endeavor of NASA and the Deutscheszentrum für Luft-und-Raumfahrt (DLR) [German Aerospace Center], the twin GRACE satellites continue to improve our understanding of the Earth's dynamical nature, making precise measurements of changes in the gravity signals associated with exchange of mass between several Earth system components. The 2013 GRACE Science Team Meeting (STM) took place October 23-25, 2013, at the University of Texas Center for Space Research (UT/CSR) in Austin, TX. More than 100 scientists and engineers attended the meeting, which consisted of 61 oral presentations and 10 posters in moderated discussions in 10 scientific sessions, addressing:

- GRACE mission and science data system status;
- geodesy and analytical techniques;
- intercomparison of GRACE products;
- mean gravity field;
- multidisciplinary applications;
- GRACE Follow-On mission;
- solid Earth;
- cryosphere;
- oceanography; and
- hydrology.

Opening Remarks and Programmatic Updates

The meeting began with a presentation by host **Byron Tapley** [UT/CSR—*GRACE Principal Investigator*] on the status of and prospects for the GRACE mission. The mission has produced 125 (out of a maximum possible 133) *Release-05* monthly measurements of Earth's gravity field that are improved by approximately a factor of two over the previous *Release-04* product. Tapley showed some preliminary results from a gravity model that incorporated data from both GRACE and the European Space Agency's (ESA) Gravity-field and steady-state Ocean Circulation Explorer (GOCE). He also stated that GRACE is advancing the understanding of global and regional terrestrial water budget components and described a specific example, involving surface water reservoir storage in Texas, which was shown to be closely correlated with the GRACE data.

Several programmatic presentations came next.

John LaBrecque [NASA Headquarters—*GRACE Program Manager*] noted the creation of the NASA/ESA Interagency Gravity Satellite Working Group.

Mona Witkowski [NASA/Jet Propulsion Laboratory (JPL)] reviewed GRACE flight operations and satellite health. In particular, spacecraft battery operations require regular monitoring and management, where the focus is on maximizing the satellite lifetime.

Gerhard Kruizinga and **David Wiese** [both from JPL] reviewed the status of JPL GRACE Level-1 processing and JPL Release-05 mascon solutions, respectively.

Group photo of 2013 GRACE STM attendees.

Frank Flechtner [GeoForschungsZentrum (GFZ) German Research Center for Geosciences—*GRACE Co-Principal Investigator*] reviewed the updated *Release-05a* product, which was modified to resolve trend differences seen with respect to the other analysis centers and replaces the earlier Release-05 (previously released).

Sean Bruinsma [Centre National d'Études Spatiales (CNES), French Space Agency] presented a selection of slides about the GOCE mission from the ESA Living Planet Symposium, held in September.

Science Sessions

The remainder of the meeting comprised nine science sessions**,** each with a series of invited and contributed presentations, and a closing period for questions and answers. In addition, posters relevant to each topic were displayed for discussion throughout the meeting. The GRACE STM program and abstracts, along with the presentations and a few of the posters are available at *www.csr.utexas.edu/grace/GSTM/past.html*.

GRACE Analysis Techniques

Three of the presentations in the GRACE Analysis Techniques session focused on error characteristics of the inputs to GRACE data processing. One group addressed the physical processes that might explain some of the artifacts in GRACE accelerometer data, known as *twangs*. A second group examined star camera errors and developed a parameterization of those errors to see the effects on the resulting gravity fields. A third group examined the anomalies and analysis changes in the Atmosphere-Ocean De-aliasing (AOD) product.

The remaining presentations addressed GRACE data analysis methods and algorithms that address the problem of reducing the noise in the gravity estimates. With different filtering strategies being made available, the uncertainties in the monthly estimates can be better quantified. An additional presentation demonstrated an ocean calibration approach to correct for spurious accelerations that are typically absorbed by the various empirical parameters.

The Earth Observer provides a great vehicle for documenting and archiving summaries of our Science Team meetings. The electronic archives make it easy to re-visit how a mission developed and matured over its lifetime.
*—**Norman Loeb** [LaRC—CERES Principal Investigator]*

Presenters in this session included: **Nadje Peterseim** [Technical University (TU) Munich]; **Pedro Inácio** [TU Delft]; **Peter Bender** [Joint Institute of Laboratory Astrophysics (JILA)/University of Colorado (UC)]; **Elisa Fagiolini** [GFZ]; **Sean Bruinsma** [CNES]; **Scott Luthcke** [NASA's Goddard Space Flight Center (GSFC)]; **Lei Wang** [Columbia University], **Bryant Loomis** [Stinger Ghaffarian Technologies Inc.]; and **Yunzhong Shen** [Tongji University, China]; **Katherine Quinn** [Atmospheric and Environmental Research (AER)] and **Bryan Killet** [JPL] presented posters related to this session.

Intercomparisons

Adrian Jäggi [University of Bern] presented an investigation into combining products from the different analysis centers with the goal of producing a regularly updated *combination product*. **Carly Sakumura** [UT/CSR] presented the results of a similar investigation into the creation of an *ensemble product*, concluding that the combination outperformed individual solutions.

GRACE Follow-On

The GRACE Follow-On (GRACE-FO) session focused on the mission, scheduled for launch in August 2017. Its architecture and operations concept are very similar to that of GRACE; *Phase C/D* started in March 2014. This session reviewed the programmatic and mission status and the status of two key technology mission elements: its laser interferometer and accelerometer. There was also conversation during this session about methods of filling the probable *data gap* that will result if the GRACE mission ends before GRACE-FO launches.

Presenters in this session included: **Mike Watkins** [JPL]; **Bernard Foulon** [TU Delft]; **Christoph Dahle** [GFZ]; and **Matthieu Talpe** [UC].

Mean Gravity Field Models

The presentations in this session addressed methods of combining GRACE data with those from GOCE [and laser ranging from the Laser Geodynamics Satellites (LAGEOS) in two cases] to determine the mean gravity field. The GRACE satellite-to-satellite tracking data provides a strong constraint on the lower degree gravity harmonics but it is limited to approximately degree and order 180. GOCE, in contrast, uses measurements of the gravity gradients with a single satellite at a lower altitude, and is thus capable of extending the satellite-only gravity models up to degree/order 240 to 260. Beyond that, terrestrial gravity information is required. The latest GFZ/Groupe de Recherches en Géodésie Spatiale (GRGS) gravity model, *EIGEN6C3*, combined satellite data with terrestrial gravity data to determine the mean field to degree/order 1949.

Presenters in this session included: **Sean Bruinsma** [CNES]; **Bo Zhong** [Wuhan University of Technology, China]; and **Christoph Förste** [GFZ].

Multidisciplinary

The multidisciplinary session opened with the discussion and determination of the annual *geocenter motion*. GRACE cannot measure the motion of the Earth's mass center (equivalent to the degree-one gravity harmonics) but such information is essential for a complete picture of total mass-change estimates. After this, came a discussion of the effect of land water mass contributions to the sea-level "fingerprint," noting that the typical scaling applied to smoothed gravity estimates may need to be different for different time scales. The next presentation addressed the mass budget for global mean sea level rise, where data from GRACE help address the challenge of separating steric and mass contributions. The following presentation addressed how the manner in which water is stored over Australia may have contributed to the sea level discrepancy of 2009-2012. The session closed with a discussion of the NASA Energy and Water Cycle Study (NEWS), which will establish the current state of the global energy cycle to serve as a benchmark for climate change studies. GRACE-based terrestrial water storage data have been used in the *Bulletin of the American Meteorological Society*'s annual "State of the Climate" issue since 2010.

Presenters in this session included: **Xiaopang Wu** [JPL]; **Chia-Wei Hsu** [University of California, Irvine (UCI)]; **Jianli Chen** [UT/CSR]; **Carmen Boening** [JPL]; and **Matt Rodell** [GSFC].

Solid Earth

The solid Earth presentations focused on using time-variable gravity data and other datasets (such as GPS-determined bedrock uplift rates) to study *glacial isostatic adjustment* (GIA). The GIA signal is of concern because its value is not well determined from independent data, and that uncertainty makes it difficult to determine how much of the observed Antarctic and Greenland mass change can be attributed to GIA. Three of the presentations discussed methods to refine the *rheological parameters*, since Antarctica-wide models were shown to be insufficient unless the lateral variability in mantle viscosity and lithospheric thickness are taken into consideration. One of the concerns is the impact of deglaciation since the "Little Ice Age," but it was shown that the effect on the GRACE estimates is probably small.

The other area of ongoing interest is the co- and postseismic processes associated with large earthquakes. The signal from at least five significant earthquakes is visible in the GRACE time series (see **Figure 1**) indicating that the intersatellite ranging data effectively provide a new class of earthquake observations. Postseismic activity is evident in the GRACE data even ten years after the 2004 Sumatra-Andaman earthquake. However, there can

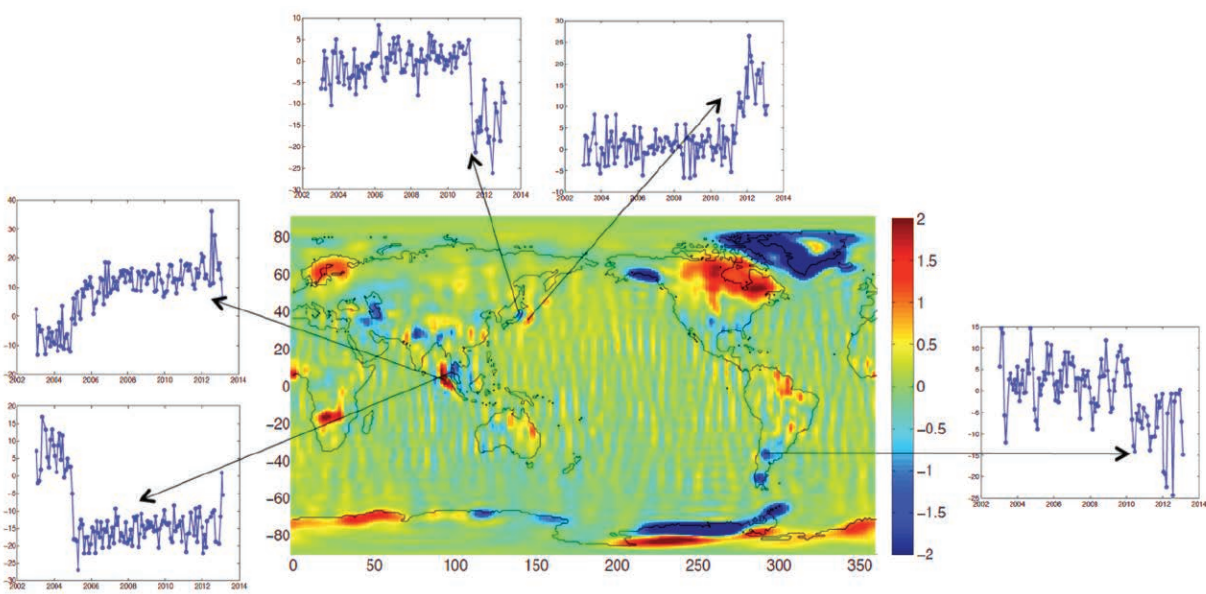

Figure 1. GRACE can detect the impact of earthquakes—even years after they occur. The map in the middle depicts *coseismic* (i.e., during) and *postseismic* (i.e., after) gravity changes associated with recent earthquakes from the GRACE gravity field observations. Red indicates a positive gravity change on one side of the fault slip and blue indicates a negative change on the other side. The two time series on the left show the gravity changes associated with the two sides of the 2004 Sumatra-Andaman earthquake. The two time series on top show the two sides of the 2011 Japan earthquake, and the time series on the right indicates the negative gravity change associated with the 2010 earthquake in Chile. **Image credit:** Modified from *S.C. Han et al.*, Journal of Geophysical Research-Solid Earth, 2008.

The Earth Observer newsletter delivers pictures and stories that are both intriguing and informative. I have used the images and articles for my own education and even for supplementing disaster summaries for interagency response. The recap of the Science Team meetings provides a great vehicle for keeping abreast of the broad expanse of activities across our many Earth science disciplines. The Earth Observer is one publication I look forward to receiving in my mailbox.
*—**Michael Goodman** [NASA HQ—Interim Program Executive for Earth Science Data Systems]*

be large discrepancies between the GRACE observations and model predictions, due to the topographic effects associated with a significant horizontal displacement.

Presenters in this session included: **A Geruo** [UC]; **Tyler Sutterly** [UCI]; **Erik Ivins** [JPL]; **Jin Li** [Shanghai Astronomical Observatory, China]; and **Shin-Chan Han** [GSFC].

Cryosphere

The cryophere session included presentations addressing improvements in techniques for deriving mass rates (and accelerations) and their error estimates; and studies of cryospheric processes at smaller spatial scales, such as are found with high mountain glaciers. Improved *mascon* solutions are providing regional detail in the ice mass losses, with statistically significant areas of acceleration such as are found with the Antarctic Pine Island Glacier and in Queen Maud Land, and in Northwest and Southwest Greenland. The question of whether the cause of the acceleration in Greenland is a change in the *snow mass balance* (SMB) or glacier discharge was examined; the conclusion was that SMB can explain most of the acceleration—possibly due to a shift in the North Atlantic Oscillation about the time of the start of the GRACE record. Besides GRACE, the long-term (~36-year) laser ranging observations to geodetic satellites also provide insight into the nature of the global mass redistribution at the largest spatial scales. The last presentation showed a successful simulation using GRACE and the Ice, Clouds, and Land Elevation Satellite (ICESat) data in a global kinematic inversion to separate present day mass trends from GIA: However, care is required because of the different spatial scales of GRACE and ICESat.

Presenters in this session included: **Isabella Velicogna** [UCI]; **Ki-Weon Seo** [Seoul National University, Korea]; **Jianbin Duan** [Ohio State University]; **Andreas Güntner** [GFZ]; **Scott Luthcke** [GSFC]; **Minkang Cheng** [UT/CSR]; and **Yan Jiang** [JPL]. **Ole Anderson** [TU Delft] and **Pangaluru Kishore** [UCI] presented posters related to this session.

Oceanography

The oceanography session demonstrated that GRACE provides unique and valuable observations over the ocean, with implications for measuring heat content and understanding regional sea-level variations. The opening presentation examined ocean variability at subannual to interannual periods using the improved Release-05 products. Contrary to the general rule that interannual sea level is mostly steric, this work showed that sea level corresponded with ocean bottom pressure over deep extratropical regions and shallow or semi-enclosed areas. Based on simulated data assimilation experiments, GRACE mascon solutions demonstrate the potential to help separate steric from nonsteric contributions to sea surface height. Examining data over the northwestern tropical Pacific, long baroclinic *Rossby waves* have for the first time been detected with satellite gravity data. On the western Pacific Sahul Shelf, half of the observed sea level rise over the last decade (which appeared to be relatively large compared to previous decades) can be attributed to steric change and the other half to a mass increase—possibly because of an intensification of the equatorial Pacific easterlies. Examining the oceanic contribution to polar motion, there is a significant interannual exchange of mass between the Pacific and Indo-Atlantic oceans, which is observed by ocean models and by GRACE.

GRACE data are helping to improve our understanding of the ocean, particularly in polar regions where data coverage from satellite missions and *in situ* data are sparse. Examining GRACE data over the Arctic Ocean, the primary mode of monthly ocean bottom pressure variation was shown to be a basin-wide variation driven by southerly winds in the Fram Strait. In other work, GRACE data could recover the Antarctic Circumpolar Current transport variability with reasonable accuracy. The preliminary result from an ocean tide model comparison test with GRACE data was presented: All the models performed well in nonpolar deep oceans, but all had large errors around Antarctica, indicating the need for the assimilation of GRACE data into tide models.

Presenters in this session included: **Katherine Quinn** [AER]; **Carmen Boening** [JPL]; **Jamie Morison** [University of Washington]; **Christopher Piecuch** [AER]; **Jessica Makowski** [University of South Florida]; **John Wahr** [University of Colorado]; **Sarah Kwon** [University of South Florida]; and **Richard Ray** [GSFC]. **Ole Anderson** [TU Delft], **Yvonne Firing** [JPL], **Per Knudsen** [TU Delft], and **Denis Volkov** [University of Miami] presented posters related to this session.

Hydrology

The hydrology session opened with a presentation of preliminary results from assimilating GRACE and Moderate Resolution Imaging Spectroradiometer (MODIS) data into estimating snow mass as part of the total water storage. The remaining presentations addressed water availability changes observed by GRACE in the Mississippi River basin, severe drought in Texas (see **Figure 2**), water variations in 15 Russian river basins, north China water depletion, and depletion of fossil aquifers in the Saharan and Arabian regions, the Congo River basin, and the Yangtze River basin.

Presenters in this session included: **Yongfei Zhang** [UT/Jackson School of Geosciences]; **Zong-Liang Yang** [UT/Department of Geological Sciences]; **Di Long** [UT/Bureau of Economic Geology]; **Leonid Zotov** [Sternberg Astronomical Institute/Moscow University, Russia]; **Wei Feng** [Chinese Academy of Sciences (CAS)]; **Mohammed Sultan** [Western Michigan University]; **Hyongki Lee** [University of Houston]; and **Zizhan Zhang** [CAS]. **Joseph Awange** [Curtin University, Australia] and **Jianliang Huang** [Natural Resources Canada] presented posters related to this session.

Conclusion

Even though GRACE has long since exceeded its design lifetime, the mission continues to deliver extended data records of global mass redistribution for continued use in all Earth science disciplines. The multinational mission operations team at German Space Operations Centre (GSOC), GFZ, JPL, and UT/CSR, together with industry support, continues to work towards minimizing the data gap, before GRACE-FO continues these measurements into the next decade.

The next GRACE STM will be held in Potsdam, Germany, September 29 – October 2, 2014.

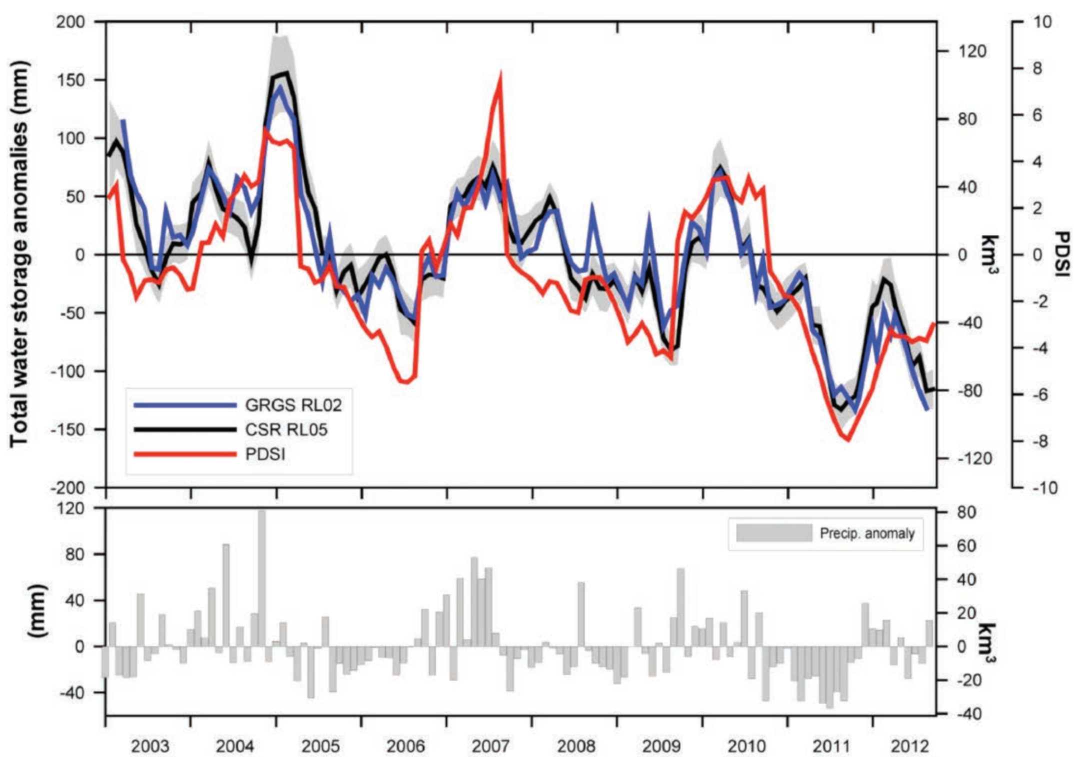

Figure 2. GRACE is providing a means to study drought from space. In 2011 the state of Texas experienced a severe drought, which shows up clearly in the water storage data above. The time series [*top*] shows a comparison of two GRACE-derived *total water storage anomalies* (TWSA) [blue and black curves] with the well-known Palmer Drought Severity Index (PDSI) for Texas [red curve]. The bar graph [*bottom*] shows the corresponding precipitation anomalies. GRACE shows a water storage depletion of approximately 62 km^3 (~15 mi^3) during the 2011 drought. **Image credit**: Modified from *Di Long et al.*, Geophysical Research Letters, 2013. doi: 10.1002/grl.50655

ESIP Federation's 2014 Winter Meeting: Celebrating 15 Years of Activity

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*As of April 1, 2014, **Carol Meyer** is no longer with the ESIP Foundation. Any future inquiries should be directed to the new interim Executive Director, **Chuck Hutchinson**, University of Arizona—*Professor Emeritus*, *chuck@earthsciencefoundation.org*.

Introduction

The Earth Science Information Partners (ESIP) Federation held its semi-annual meeting at the Renaissance Dupont Circle hotel in Washington, DC, January 8-10, 2014,[1] to celebrate the work of its data-practitioner community. The meeting highlighted ESIP's activities over the past 15 years, with specific focus on the organization's future and the convergence of data preservation[2] and related software topics.

Plenary Activities

The meeting featured two keynote addresses and a panel discussion.

In the first keynote address, **Aron Ahmadia** [Software Carpentry and U.S. Army Corps of Engineers], described the state of science software development, noting that, "If you cannot trust the code, you cannot trust the science."

Kevin Ashley [Digital Curation Centre (U.K.)—*Director*] gave the second keynote, offering his perspective on the state of data management and the rate of return on investment on data preservation. Although not a financial return, Ashley stated that, "The return on investment was high." He also emphasized the continuing challenge confronting data managers.

A panel discussion followed, titled, *Visioning for the Science Data Enterprise*, which included **Jeff de La Beaujardière** [National Oceanic and Atmospheric Administration (NOAA)]; **Sky Bristol** [U.S. Geological Survey (USGS)]; **Jeff Walter** [NASA's Goddard Space Flight Center (GSFC)]; and **Mark Luker** [Networking and Information Technology Research and Development (NITRD)]. The panel offered perspectives on the trends, challenges, and solutions faced by the federal science data enterprise. "Users want answers, not data," stated de La Beaujardière, and Bristol pointed to the revolution across the world in how data are being used. Walter discussed *knowledge extraction*, the services NASA should provide, and how it should present and organize data to serve many different consumers. Luker pointed to the need for responsibilities to be distributed across organizations, including the need for many eyes on the problem. The panel was one of many recent ESIP Federation activities that is advocating for a future National Research Council study of the U.S. science data enterprise.

Sky Bristol organized and moderated *A Conversation on the Open Data Initiatives* that featured **Jeff de La Beaujardière**, **Stephen Berrick** [GSFC], **Kevin Gallagher** [USGS], and **Lee Allison** [Arizona Geological Survey]. Each participant provided a different perspective on the implementation of new policies put forward by President Obama's Administration.

Breakout Sessions

Probably the most important work accomplished during ESIP Federation meetings takes place during breakout sessions. This is where the participants "roll up their sleeves" and engage in more focused discussions and other hands-on activities related to a broad range of topics of interest. This year, a full range of technical, educational, and training activities were offered. The list of breakout sessions can be found at *bit.ly/1aK3wY4*.

ESIP Federation Elects Leadership

The ESIP Federation's Constitution and Bylaws specifies a number of positions that must be filled, including term limits. Each year, prior to or during the winter meeting, elections are held. The results of the 2014 election were announced at the winter meeting.[3]

ESIP President:
Peter Fox [Tetherless World Constellation—*Chair*; Rensselaer Polytechnic Institute—*Professor of Earth and Environmental Science and Computer Science*]

ESIP Vice President:
Emily Law [NASA/Jet Propulsion Laboratory (JPL)—*Science Data Systems Manager*]

Chair of the Constitution and Bylaws Committee:
Bruce Caron [New Media Studio]

Chair of the Finance and Appropriations Committee:
Charles Hutchinson [University of Arizona]

Chair of the Partnership Committee:
Tyler Stevens [NASA's Global Change Master Directory]

[1] To read about ESIP's previous semi-annual meeting and to learn more about the Federation, please see *ESIP Federation Meeting Highlights Data Practices* in the September-October 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 5**, pp. 21-23].

[2] To learn more about the topic of data preservation in the context of a GES DISC effort to archive and maintain data from the HIRDLS instrument on Aura, please see our January–February 2014 issue [**Volume 26**, **Issue 1**, pp. 19-21].

[3] The distinctions between the Types of ESIPs have been discussed in previous meeting summaries—e.g., **Volume 25**, **Issue 2**, Sidebar on p. 37.

Chair of the Education Committee:
Roberta Johnson [University at Albany/National Earth Science Teachers Association (NESTA)]

Chair of the Information Technology and Interoperability Committee:
Matt Austin [NOAA/NESDIS]

Chair of the Data Stewardship Committee:
Ruth Duerr [National Snow and Ice Data Center]

Type I (data center) Representative:
Sara Graves [University of Alabama-Huntsville]

Type II (research) Representative:
Ken Keiser [University of Alabama-Huntsville]

Type III (applications) Representative:
Margaret Mooney [University of Wisconsin-Madison]

ESIP Federation Recognizes Community Leaders

During the annual awards ceremony, **Zhenlong Li** [George Mason University], received the inaugural *Robert G. Raskin Scholarship*. Li, who is completing a doctoral degree in geographic and geoinformation science, will deliver a keynote address at the next ESIP Federation meeting, to be held July 8-11, 2014 in Frisco, CO.

Anne Wilson [Laboratory for Atmospheric and Space Physics, University of Colorado] received the *President's Award* for her work in creating the Boulder Earth and Space Science Informatics Group in Colorado and for initiating a conversation within ESIP about a National Research Council study on the science data enterprise.

Charles Hutchinson received the *Martha Maiden Lifetime Achievement Award for Service to the Earth Science Information Community*. The award, named for Martha E. Maiden, NASA's Program Executive for Earth Data Systems, honors individuals who have demonstrated leadership, dedication, and a collaborative spirit in advancing the field of Earth science information. Hutchinson has worked across geographic scales and communities, focusing his efforts locally, regionally, and internationally, to address key human and environmental impacts of desertification.

ESIP Federation Continues to Grow

During the meeting, three new member organizations were elected:

- Microsoft Research (Type III)
- National Academy of Sciences (Type II)
- Science Exchange (Type III)

ESIP Federation membership is strictly voluntary and its continued growth reflects the recognition that the ESIP Federation is a dynamic and collaborative forum where data providers (Type I), researchers (Type II), and application developers (Type III) gather to exchange valuable information.

Additional information about the ESIP Federation's new partners can be found at *wiki.esipfed.org/index.php/Partnership_Applications*.

Conclusion

The ESIP Federation has evolved and grown throughout its 15-year history. The meeting summarized here provided a snapshot of the convergence of activities from across the field of Earth science data and technology to advance the community's collective interest in providing discoverable, accessible, and usable Earth science information to as wide a community as can make use of that information.

According to **Peter Fox**, who is serving his first term as president, "The ESIP Federation's evolution during the past 15 years has allowed it to emerge as an important innovation hub for technological, data, and expertise exchange. The ESIP Federation has attracted new leadership who represent the growing diversity of the ESIP Federation itself. From its inception to address key NASA data system requirements, the ESIP Federation now regularly works across agencies, disciplines, and sectors to advance Earth science informatics and data systems." ■

ESIP Federation's Ignite Event at AGU 2013

At *Ignite* events, presenters share their personal and professional passions, using 20 slides that auto-advance every 15 seconds for a total of just five minutes. The Ignite motto is: "Enlighten us, but make it quick."

A month before the meeting being reported in this article, the ESIP Federation hosted its third annual Ignite event during the American Geophysical Union (AGU) Fall meeting, held in San Francisco, CA. Sponsored by NASA's Applied Sciences Program and held in partnership with AGU's Earth and Space Science Informatics Section, the annual event has attracted more than 150 attendees to hear fast-moving, upbeat, and creative presentations on a range of topics that are outside the norm at a traditional science conference. Emceed by NASA's Applied Sciences Director, **Lawrence Friedl**, the third year of this event was again a forum for quick, entertaining talks—with topics this year ranging from *nudibranchs* (a group of soft-bodied gastropod mollusks) to 500-mile treks in Spain to coastal applications, ontologies, and even project budgeting. In reflecting on the event, Friedl offered, "It's really impressive how people captured a topic in such a short time and such humorous ways. Balanced with traditional AGU talks, the Ignite events highlight a range of Earth science applications in one place, and the speakers really get to the point about where they're directly aiding decisions and actions."

A playlist from this event is available at *bit.ly/1ieWUAw*. The fourth annual Ignite at AGU will be held during the 2014 AGU Fall meeting. Visit *esipfed.org* in summer 2014 for more information, or contact *erinrobinson@esipfed.org* if you would like to participate.

SORCE Science Team Meeting

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Introduction

The SOlar Radiation and Climate Experiment (SORCE) Science Team Meeting was held in Cocoa Beach, FL, January 28-31, 2014. These roughly annual meetings bring together interested members of the broad solar and climate communities to discuss the current understanding of solar variability and the sun's influence on climate and global change. This year's meeting took place just after the eleventh anniversary of SORCE's launch and was an opportunity to celebrate the completion of a solar cycle's worth of SORCE observations. The theme for the meeting was, *Variability in the Sun and Climate Over the SORCE Mission—A Look Back at What We've Learned Over the Last 11 Years.* The motivation for this topic was an in-depth review of the *Top Ten Achievements of the SORCE Mission*[1].

Characterizing the role of the sun in climate variations on time scales of decades is a challenging task, but more than twenty years of high-precision, space-based solar measurements have firmly established that climate forcing is well correlated with variations in the sun's energy output, and particularly for total and ultraviolet (UV) irradiance. SORCE measures these variations of the total solar irradiance (TSI) and solar spectral irradiance (SSI) with unprecedented accuracy, precision, and spectral coverage across UV, visible, and infrared (IR) wavelengths. As an example, when the sun is near the maximum of its activity cycle, it is about 0.1% brighter overall, with much greater changes at UV wavelengths. Such conclusions notwithstanding, many potentially conflicting and interesting perspectives were presented at the meeting. Overall, the meeting provided a valuable forum to address outstanding and important climate issues, and provided inspiration for future studies.

The three-and-a-half-day meeting had six oral sessions, as well as an afternoon poster session that spanned all topics of the meeting. All the presented information was designed to address the following key questions:

- How much have the TSI and SSI varied over the SORCE mission, starting near the maximum for Solar Cycle (SC) 23 and now approaching the near-maximum for the current SC 24?
- What has been learned from connecting the SORCE TSI and SSI measurements to long-term TSI and SSI records?
- What has been learned from comparing TSI and SSI measurements to solar proxies and irradiance model predictions?
- How have Earth's atmosphere and climate changed over the SORCE mission?
- What are the dominant processes and pathways for solar forcing in Earth's environment?
- How have the extended SC minimum in 2007-2009 and lower SC 24 maximum affected climate differently than during the earlier SC 23?
- How can these sun-climate results be effectively applied for reconstructions to the past and for future climate change predictions?
- What are the key science results and lessons learned from the SORCE mission?
- How will the TSI, SSI, and sun-climate records continue in the future?

Session One

The first session addressed the *Role of the Sun in Climate Change During the SORCE Mission*, focusing on the fundamental purpose for SORCE, namely, the role that the sun plays in Earth's climate—particularly as observed in solar cycles 23 and 24. Presentations

[1] These were originally published in the January-February 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 1**, pp. 4-13].

covered a broad range of Earth-atmosphere observations and model studies, and highlighted solar forcing throughout the atmosphere and their impact on climate. They included observations of the upper stratosphere, mesosphere, and thermosphere, highlighting the combined importance of concurrent observations from NASA's SORCE and Thermospheric Ionospheric Mesospheric Energetics and Dynamics (TIMED) missions to identify solar effects on the atmosphere. A number of model studies and statistical methods that employ spectral irradiance were used to explore ozone sensitivity to solar cycle length and related changes in UV radiation. There was also a discussion of solar radiation impacting Arctic sea ice, including evidence that weak solar modulation can be identified in this 36-year long record of TSI measurements.

Robert Cahalan [NASA's Goddard Space Flight Center (GSFC)—*SORCE and TSIS Project Scientist*] summarized many of these aspects of solar influence on climate and the role of SORCE data in determining the nature of the influences. He identified and presented information on nine topics that relate both to the findings from SORCE and technological advances leveraged for the Total Solar Irradiance Sensor (TSIS) mission. These improvements are needed to continue and improve the critical total and spectral irradiance climate record. Cahalan particularly emphasized the importance of TSI observations from the Total Irradiance Monitor (TIM) onboard SORCE in helping scientists define Earth's planetary energy balance—see **Figure 1**. He also discussed the potential impacts of spectral irradiance variability on the temperature structure of the atmosphere. Cahalan concluded with a description of a study (on which he is lead author) that suggests that lunar borehole measurements could help to interpret the sun's variability over the last 400 years[2]. (Cahalan was also honored for his many years serving as SORCE Project Scientist during the meeting—see *SORCE Project Scientist Honored*, next page.)

The Earth Observer is a very valuable publication for scientists and their support personnel. Reading it, one learns what is new in other NASA projects, which colleagues are in the news, and see some details about public outreach projects. Its succinctness is excellent: it makes for a fast read! Congratulations on your twenty-fifth anniversary!

*—**Elena Lobl** [University of Alabama, Huntsville—AMSR-E Science Team Manager]*

[2] Cahalan *et al.*, *Geophysical Research Letters*, **37**, 7705, 2010.

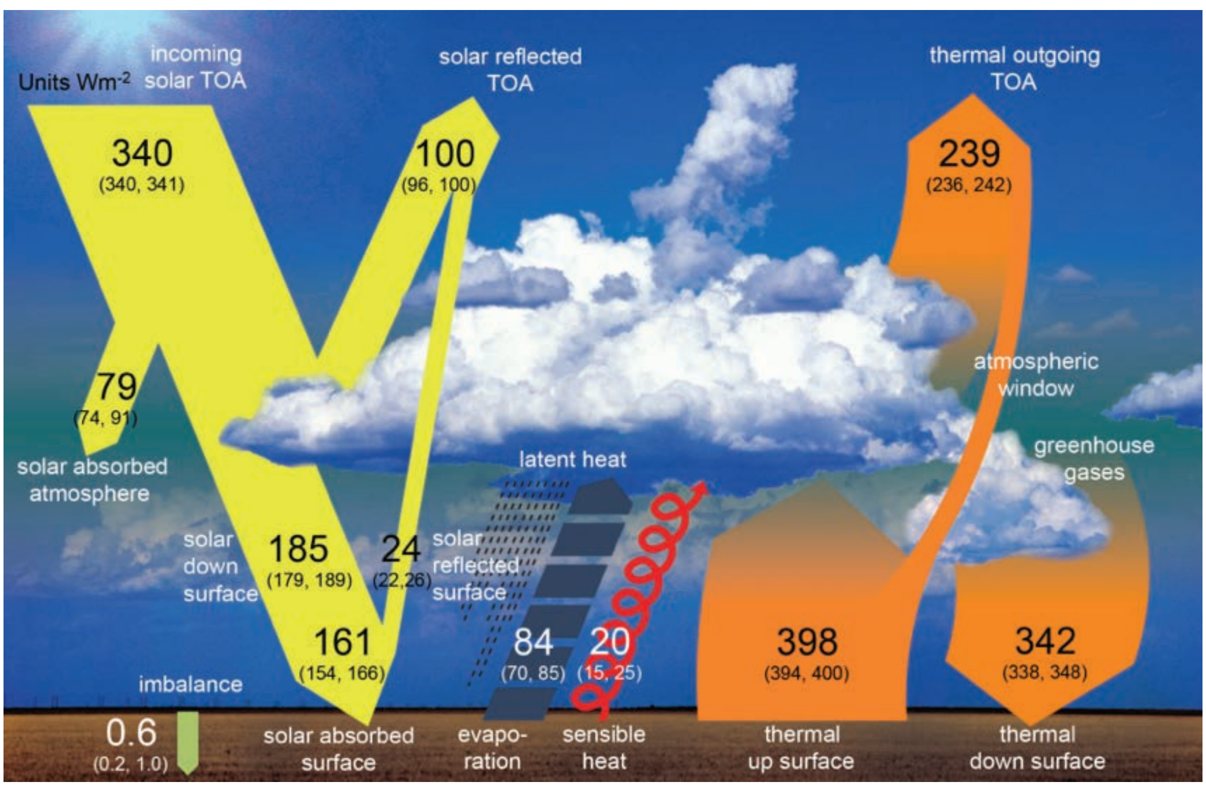

Figure 1. This diagram shows a revised estimate for partitioning of atmospheric processes responsible for maintaining Earth's radiation balance. The numbers in parentheses are the minimum and maximum estimates. The incoming radiation shown in this plot reflects the newly accepted lower value of total solar irradiance (TSI) reported by the SORCE TIM instrument (i.e., the TSI community now agrees that SORCE TSI values are the correct values, lower than previously thought). It is noteworthy that of all the processes shown in this graph, the incoming radiation has the lowest uncertainties. **Image credit:** Wild *et al.*, *Climate Dynamics,* **40**, 11-12, 3107, 2013.

SORCE Project Scientist Honored

During the SORCE Science Dinner, **Robert "Bob" Cahalan** was honored for his many years as the SORCE Project Scientist. He has served in this position from the initial mission concept (1999) to launch (2003), and through a decade of successful measurements. The role of project scientist has been complex, requiring an individual who is both knowledgeable and interested in the science objectives, but also one who effectively advocates for the science and aggressively engages in the political battles to keep the mission on track.

SORCE has been very fortunate to have Bob onboard, advancing our understanding of sun-climate models, global energy balance, and solar radiation. He is recognized for his pioneering theoretical and experimental advances in understanding the role of cloud structure in climate and his leadership in understanding three-dimensional atmospheric radiative transfer. Bob has performed research on global warming and climate change at NASA's Goddard Space Flight Center since 1979. In addition to SORCE Project Scientist, Bob is also the Project Scientist for the joint NASA-National Oceanic and Atmospheric Administration (NOAA) Total and Spectral Solar Irradiance Sensor (TSIS) mission.

SORCE Principal Investigator **Tom Woods** [*right*] thanks **Robert Cahalan** [*left*] for his years of service as SORCE Project Scientist.

A Status Update on TCTE

As part of the TSI Calibration Transfer Experiment (TCTE), a refurbished SORCE-era Total Irradiance Monitor (TIM) was successfully launched from NASA's Wallops Flight Facility on November 19, 2013. The TCTE was designed and built by Laboratory for Atmospheric and Space Physics at the University of Colorado (LASP) in an impressive five-months from contract start to instrument delivery. It is one of six instruments onboard the U.S. Air Force's Space Test Program spacecraft, STPSat-3, based on a Ball Aerospace-built bus. The NASA–NOAA TCTE will study solar energy to help scientists understand the causes of climate change on our planet, as incident sunlight is the primary energy source that drives Earth's climate. TCTE will measure total solar irradiance (TSI) in order to monitor changes in the incident sunlight at the top of Earth's atmosphere.

The TCTE launch continues the TSI climate data record started in 1978 beyond the SORCE/TIM. TCTE is the much-needed "bridge" between SORCE and the planned follow-on TSI mission, TSIS, scheduled to launch in 2017. The continuity provided by TCTE is especially important given the loss of Glory (which had a TIM instrument onboard) in March 2011. Following the completion of TCTE's commissioning activities, SORCE TIM had a very successful seven-day campaign in late December 2013 to allow overlap with TCTE TSI measurements. The SORCE campaign data are available now, and TCTE data products will be available soon. TCTE will continue to monitor the sun's net energy output on at least a weekly basis, and will help scientists better understand the natural causes of climate change on our planet.

The TCTE instrument launched onboard a U.S. Air Force spacecraft [*shown here*], built at Ball Aerospace.
Image credit: Ball Aerospace

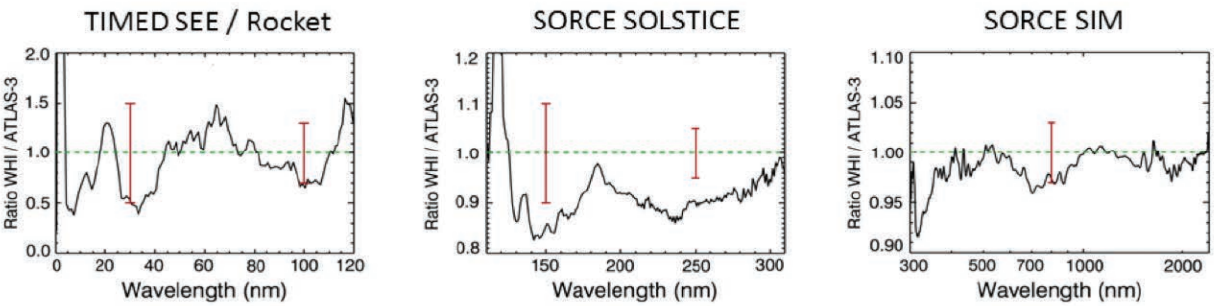

Figure 2. Comparison of irradiance levels from the Whole Heliospheric Interval (WHI) reference spectrum in April 2008 (measured during SC 23 minimum) relative to the ATLAS 3 reference spectrum of November 1994 (measured during SC 22 minimum). These three graphs cover the spectral range from X-rays to near-infrared wavelengths. The ratio of these two spectra—separated by 13 years—suggests lower irradiance values during the SC 23 minimum, but estimated errors of the two spectra make this lower value marginal at the 2σ uncertainty level. Notice the change in scale going from the highly variable extreme ultraviolet part of the spectrum (0-120 nm) to the very quiet visible and infrared spectral regimes (300-2000 nm). **Image credit:** Tom Woods [LASP/CU]

Session Two

The second session was dedicated to understanding the state of SSI measurements. The discussion covered observations across a broad range of wavelengths and diverse observational methods and platforms. The participants considered time series and spectra from several spectrometers used for direct solar measurements, along with findings of Earth-viewing spectrometers and filter radiometers. In summary, when concurrent data are available, the instruments produce excellent agreement for multiple solar rotations over short time intervals, but over longer solar cycle timescales there is still significant disagreement. This remains one of the fundamental challenges for the study of SSI.

As the Session 2 keynote speaker, **Tom Woods** [Laboratory for Atmospheric and Space Physics, University of Colorado (LASP/CU)—*SORCE Principal Investigator*] discussed the Whole Heliospheric Interval (WHI), which is an international effort to observe and model the interconnections between the heliosphere and the solar system in three dimensions. The WHI spectrum was measured during a very quiet solar period near the minimum of SC 23 and combined observations from instruments onboard SORCE, the Solar EUV Experiment (SEE) onboard TIMED, and the calibration rocket developed for the Solar Dynamics Observatory/Extreme Ultraviolet Variability Experiment (SDO/EVE)—see **Figure 2**. This *reference spectrum* compares favorably with the third Space Shuttle-based Atmospheric Laboratory for Applications and Science (ATLAS 3) reference spectrum, a SC 22 analog to the WHI spectrum. WHI indicates slightly lower irradiance values, but at many wavelengths it is not outside the two standard deviation (2σ) error estimates. Woods's presentation also showed results of the observation of flares in TSI—another of the top ten SORCE achievements. The session closed with a discussion of the infrared absolute irradiance measured from the ground.

Panel Discussion and Session Three

Between the first two sessions, there was a panel discussion exploring *Current and Future Plans for Sun-Climate Research*. Panel members included:

- **Madhulika "Lika" Guhathakurta** [NASA Headquarters (HQ)—*STEREO Program Scientist, Lead Scientist for Living With a Star Program*];
- **Cheryl Yuhas** [NASA HQ—*Program Executive*];
- **Tom Sparn** [LASP/CU—*SORCE Program Manager*]; and
- **Werner Schmutz** [Physikalisch-Meteorologisches Observatorium Davos, Switzerland—*Director*].

The discussion focused on the need for continued irradiance missions from the perspective of NASA's Earth Science and Heliophysics Divisions and within the European community. Sparn discussed a potential low-cost means of continuing irradiance missions after the projected launch of TSIS in 2017.

Roger-Maurice Bonnet [International Space Science Institute (ISSI), Switzerland] began the third session, *Decadal and Longer Sun-Climate Variations,* with a keynote presentation that highlighted the many factors that can cause climate change. These variables include natural effects, such as solar and volcanic activity, and anthropogenic effects related to increasing greenhouse gases (GHG) and aerosols. Bonnet also presented a summary of climate change since 1900, with a global average temperature increase of 1 °C and sea level rise of ~15 cm (6 in). The solar influence on these changes is thought to account for about 7% of the total change.

Other speakers went into further detail on the role of the sun in climate change. SORCE SSI measurements imply a larger forcing in the atmosphere than previously expected, but with smaller forcing at the surface. NASA's 35-year Modern Era Reanalysis for Research and Applications (MERRA) atmosphere record shows a strong correlation between solar activity and temperature change. The sun and climate also have a 100-year variation. The 88-year solar *Gleissberg cycle* that reflects changes in the amplitude of the 11-year sunspot cycle appears to be present in deep ocean oscillations, with a 10-to-20 year lag. On even longer timescales, the cosmic-ray produced radionuclide beryllium-10 (^{10}Be) measured in ice cores is used to derive a solar modulation potential that represents solar magnetic activity as far back as 10,000 years.

Jürg Beer [Eigenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (EAWAG)—Swiss Federal Institute of Aquatic Science and Technology] talked about solar activity results from ice core records, and showed that, in addition to the 88-year Gleissberg cycle discussed above, the dominant longer-term solar variations evident in the ice core record have 208-year and 950-year cycles—see **Figure 3**.

Session Four

The fourth session, *Total Solar Irradiance (TSI) Measurements and Composites,* reviewed the 35-year spaceborne data record and summarized the current instrument status and future measurement plans. The 35-year uninterrupted TSI record provides climate researchers the best estimate of the net energy input that powers the Earth's climate system. The presentations indicated that variability in the sun's energy is likely responsible for between 7 and 15% of global warming over the last 150 years. Determining such climate sensitivity relies critically on the stability and continuity of this spacecraft record and how composites are created from the many TSI instruments flown, whereas detecting long-term solar variability relies more on absolute accuracy.

Greg Kopp [LASP/CU] gave the session's keynote presentation, wherein he discussed the requirements of 0.01% for accuracy and 0.001% per year for stability, as both are necessary to discern solar changes on climatic time scales. Kopp showed that these levels have not yet been demonstrably achieved by any flight instrument—but newer instruments are getting close. He showed examples that illustrated how inter-comparisons of data from different instruments help discern artifacts in the data records, thus improving the quality of all the TSI measurements—see **Figure 4**. These intercomparisons have been facilitated by improved national and international collaborations over the last decade. Such collaborations include an SSI team that is formulating an improved TSI composite record for the climate and solar research communities. This new composite will have advantages over existing ones in that it will

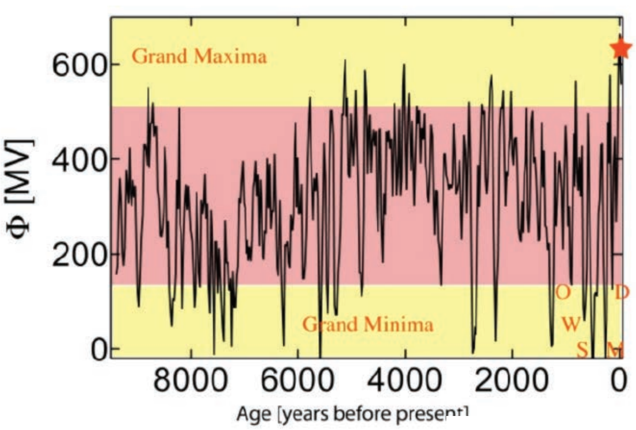

Figure 3. *Solar Modulation Potential from Ice Core Record*. The sun is currently coming out of the Modern Maximum phase (star, top right). Some of the solar activity minima are associated with cold climate and are annotated as: D = Dalton Minimum, which occurred ~ 1800 AD; M = Maunder Minimum, ~1700; S = Spörer Minimum, ~1500; W = Wolf Minimum, ~ 1300; and O = Oort Minimum, ~1000. **Image credit:** Jürg Beer [EAWAG]

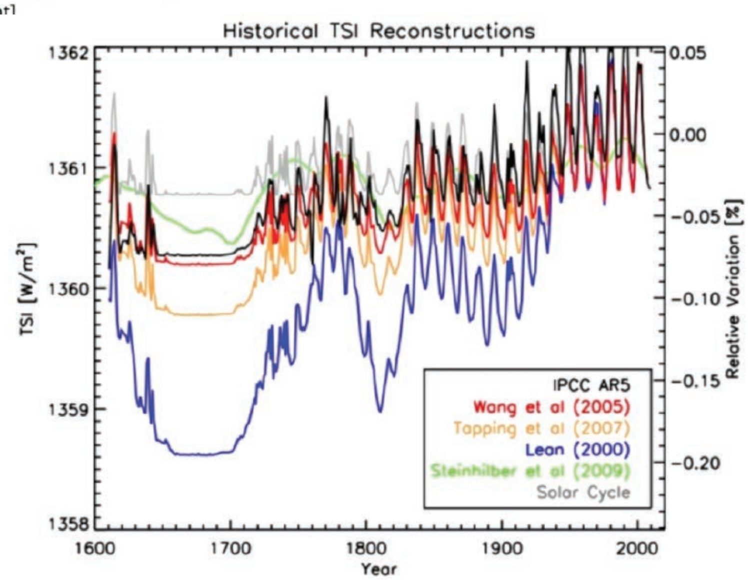

Figure 4. Historical TSI reconstructions indicate the expected range of long-term solar variability driving measurement requirements needed for climate research. **Image credit:** Greg Kopp [LASP/CU]

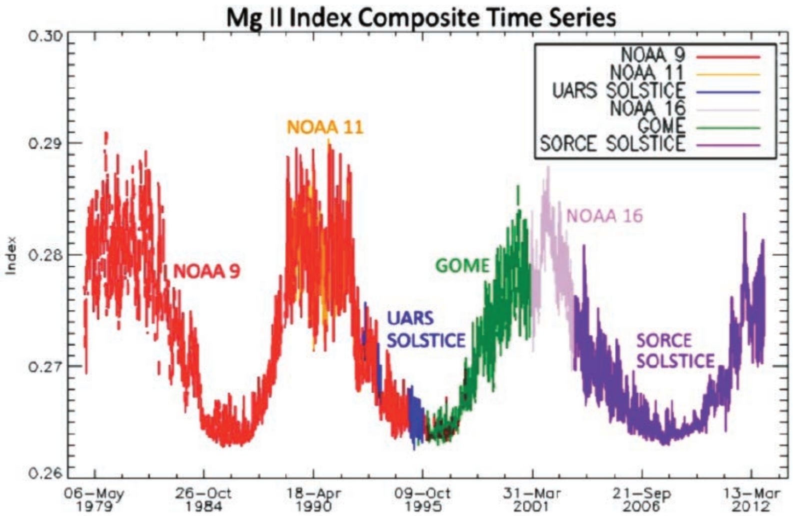

Figure 5. *MgII Core-to-Wing Index Composite Time Series.* This proxy for solar activity has been continuously measured since 1978 by a variety of instruments operated by both NOAA and NASA. SORCE SOLSTICE has been making daily measurements since its launch in 2003. **Acronyms used in figure:** NOAA = *National Oceanic and Atmospheric Administration;* UARS SOLSTICE = Upper Atmosphere Research Satellite / SOLar Stellar Irradiance Comparison Experiment; GOME = *Global Ozone Monitoring Experiment.* **Image credit:** Martin Snow [LASP/CU]

include contributions from all available data using a Bayesian formulation, and have time-dependent uncertainties.

Other presentations in this session addressed the four satellites currently flying TSI instruments, all of which are operating beyond their specified mission lifetimes. For about the past six months, SORCE-TIM has not been taking data. The SORCE team is working on a plan to manage the remaining life of SORCE's batteries and restore limited operations[3]. The Active Cavity Radiometer Irradiance Monitor (ACRIM3) on NASA's Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSAT) (launched in 1999) is currently not acquiring measurements due to spacecraft battery issues. The French PREcision Monitoring Of Solar Variability (PREMOS) experiment on the Picard satellite (launched in 2010) is due to be decommissioned at the end of February 2014. The oldest of these instruments, the Variability of solar IRradiance and Gravity Oscillations (VIRGO) on the SOlar and Heliospheric Observatory (SOHO) spacecraft (launched in 1995), is also still operating. Fortunately, the November 2013 launch of the TSI Continuity Transfer Experiment (TCTE)—see **A Status Update on TCTE** on page 38—will continue this vital climate data record into the future. The U.S. Air Force spacecraft that hosts the instrument is intended only for an 18-month lifetime. The Norwegian Satellite (NORSAT1), scheduled for launch in late 2015 or early 2016, will be carrying a new Compact Lightweight Absolute Radiometer (CLARA) TSI instrument, which will help continue this critical solar climate data record until the launch of the future TSIS.

Session Five

There were three main topics addressed in this session, titled *SSI Composites, Proxies, and Models.* An important new result regarding solar proxies was the discussion of the 30-cm radio emission which comes from the outer layers of the sun. When combined with the widely used 10.7-cm radio flux (F10.7), a greater fraction of solar facular variability is captured. The 30-cm measurements have been recorded on a daily basis since the mid-1950s, and have almost the same duration as F10.7.

Martin Snow [LASP/CU] delivered a keynote presentation, focusing on the magnesium II index (MgII), an important UV proxy. Recent intercomparisons between the SORCE and European MgII measurements have uncovered an artifact in the SORCE data—see **Figure 5**. After correcting for this artifact using the redundant channel (SOLSTICE B)[4], the new SORCE data are in complete agreement with the European measurement.

The second topic covered in this session was the next generation of TSI and SSI models. The current catalog of physics-based models are derived from a set of one-dimensional atmospheres and used to describe the various components of the solar disk. The solar magnetic field's only role in such models is to define the fraction of each type of atmosphere [e.g., quiet sun, active network, bright chromospheric regions (plage)]. The next generation of models may instead use three-dimensional *magnetohydrodynamic* (MHD) calculations to produce radiance and irradiance models of the solar radiative output.

The session concluded with a series of talks about the European effort to create a composite SSI dataset. The SOLar Irradiance Data exploitation (SOLID) is a 10-partner effort involving scientists from seven European countries. Their goal is not only to provide the scientific community with a composite SSI, but also to critically evaluate the uncertainties of all elements that go into creating that composite. Members of the SORCE team are also involved in this effort as both collaborators and data providers.

[3] **UPDATE**: SORCE TIM resumed daily TSI measurements in late February 2014.

[4] There are two SOLSTICE instruments on SORCE. The redundant channel is referred to as SOLSTICE B and the primary is SOLSTICE A.

Session Six

The final session of the meeting focused on the legacy of SORCE and the future directions for solar and climate observations. **Gary Rottman** [LASP/CU—*Former SORCE PI*] provided an excellent overview of the history of the solar irradiance observation programs since the 1970s and the events that eventually defined the SORCE mission[5]. Observations from TSIS will provide the follow-on solar irradiance observations to SORCE. **Graeme Stephens** [NASA/Jet Propulsion Laboratory] discussed National Research Council recommendations[6] to continue the TSI climate record, which emphasize the urgency and need for TSI.

There was much discussion throughout the meeting about the risk of gaps in all areas of the climate records, how international collaboration is as important as ever in addressing these potential gaps, and how smaller and lower-cost satellite missions might be the most viable solution for making future climate observations—see *Workshop on Mitigating Gaps in the SSI Data Record,* below. Some of these potential solutions presented included a radiometric imager concept, Japanese microsatellites, and NORSAT1. This theme of smaller and less-expensive missions for climate measurements was also prominent in posters describing recent TSI and SSI instrument developments.

[5] To read about these events, see *The Sources of SORCE* in January–February 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 1**, pp. 13-14].

[6] To learn more, visit: *www.nap.edu/catalog.php?record_id=18371*.

Conclusion

The eleventh SORCE Science Team Meeting was a great success, where 65 scientists and students from around the world gathered to present their findings on solar irradiance and climate. Most of the 2014 SORCE Meeting presentations are available online at *tinyurl.com/m94dsze*.

The GSFC-LASP Sun Climate Research Center (SCRC) will likely plan the next Sun-Climate meeting for some time in 2015. To stay up to date on the latest news and meeting announcements from SORCE, read the SORCE newsletter at *lasp.colorado.edu/home/sorce/news-events/newsletter*. ■

Workshop on Mitigating Gaps in the SSI Data Record

By Martin Snow, LASP/CU

The SORCE Science Team meeting brought together the world's experts on solar spectral irradiance (SSI), and provided an opportunity to take a "big picture" view of the current state and future of SSI measurements. The overall goal of the workshop was to produce a *white paper* describing the current state of SSI measurements and strategies for mitigating gaps in the observational record.

After a brief introduction, there was a detailed examination of the state of the art in preflight calibration. One of the newest facilities to support these activities is the Spectral Radiometry Facility (SRF) at the Laboratory for Atmospheric and Space Physics (LASP) in Boulder, CO. It uses National Institute of Standards and Technologies (NIST)-developed and -built lasers and a cryogenic radiometer to allow calibration of an SSI instrument to 0.2% (1σ) accuracy. Previous measurements from space have had accuracies of about 2%, so the SRF will provide an order-of-magnitude improvement.

Next to be discussed were future and historical gaps in the SSI data record. The discussion included a review of the SSI measurement catalog, to identify previous gaps. The group assembled a catalog of SSI models that could be used to fill these gaps, acknowledging that different models are better suited to different wavelength domains, and rely upon different proxies for inputs. The workshop ended with a discussion of the LASP *Lyman-alpha composite* as a case study in how to bridge gaps using irradiance models. A subset of the workshop participants will work on writing the white paper over the next several months.

Prior to the SORCE Science Team Meeting, there was a half-day workshop to address current and future spectral solar irradiance (SSI) measurement questions. **Image credit:** NASA

Warm Rivers Play Role in Arctic Sea Ice Melt

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

The heat from warm river waters draining into the Arctic Ocean is contributing to the melting of Arctic sea ice each summer, a new NASA study finds.

A research team led by **Son Nghiem** [NASA/Jet Propulsion Laboratory] used satellite data to measure the surface temperature of the waters discharging from a Canadian river into the icy Beaufort Sea during the summer of 2012. They observed a sudden influx of warm river waters into the sea that rapidly warmed the surface layers of the ocean, enhancing the melting of sea ice. A paper describing the study is now published online in the journal *Geophysical Research Letters.*

This Arctic process contrasts starkly with those that occur in Antarctica, a frozen continent without any large rivers. The sea ice cover in the Southern Ocean surrounding Antarctica has been relatively stable, while Arctic sea ice has been declining rapidly over the past decade.

"River discharge is a key factor contributing to the high sensitivity of Arctic sea ice to climate change," said Nghiem. "We found that rivers are effective conveyers of heat across immense watersheds in the Northern Hemisphere. These watersheds undergo continental warming in summertime, unleashing an enormous amount of energy into the Arctic Ocean, and enhancing sea ice melt. You don't have this in Antarctica."

The team said the impacts of these warm river waters are increasing due to three factors. First, the overall volume of water discharged from rivers into the Arctic Ocean has increased. Second, rivers are getting warmer as their watersheds (drainage basins) heat up. And third, Arctic sea ice cover is becoming thinner and more fragmented, making it more vulnerable to rapid melt. In addition, as river heating contributes to earlier and greater loss of the Arctic's reflective sea ice cover in summer, the amount of solar heat absorbed into the ocean increases, causing even more sea ice to melt.

To demonstrate the extensive intrusion of warm Arctic river waters onto the Arctic sea surface, the team selected the Mackenzie River in western Canada. They chose the summer of 2012 because that year holds the record for the smallest total extent of sea ice measured across the Arctic in the more than 30 years that satellites have been making observations.

The researchers used data from satellite microwave sensors to examine the extent of sea ice in the study area from 1979 to 2012 and compared it to reports of Mackenzie River discharge. "Within this period, we found the record largest extent of open water in the Beaufort Sea occurred in 1998, which corresponds to the year of record high discharge from the river," noted co-author **Ignatius Rigor** [University of Washington, Seattle].

The team analyzed data from the Moderate Resolution Imaging Spectroradiometer (MODIS)

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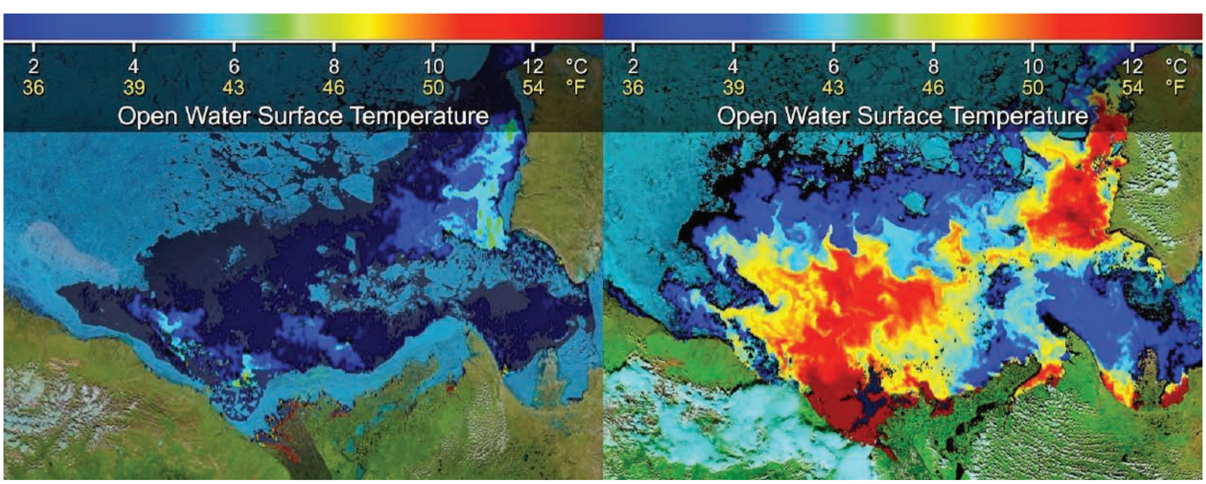

NASA's MODIS instrument measured sea surface temperatures across the Beaufort Sea on June 14, 2012 [*left*] and July 5, 2012 [*right*]. In the later image, warm water from Canada's Mackenzie River has broken through a shoreline sea ice barrier and enhanced sea ice melt.
Image credit: NASA

NASA Radar Demonstrates Ability to Foresee Sinkholes

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

New analyses of NASA airborne radar data collected in 2012 reveal the radar detected indications of a huge sinkhole before it collapsed and forced evacuations near Bayou Corne, LA, that year.

The findings suggest such radar data, if collected routinely from airborne systems or satellites, could at least in some cases foresee sinkholes before they happen, decreasing danger to people and property.

Sinkholes are depressions in the ground formed when Earth surface layers collapse into caverns below. They usually form without warning. The data were collected as part of an ongoing NASA campaign to monitor sinking of the ground along the Louisiana Gulf Coast.

Researchers **Cathleen Jones** and **Ron Blom** [both from NASA/Jet Propulsion Laboratory] analyzed *interferometric synthetic aperture radar* (InSAR) imagery of the area acquired during flights of the agency's Uninhabited Airborne Vehicle Synthetic Aperture Radar (UAVSAR), which uses a C-20A jet, in June 2011 and July 2012. InSAR detects and measures very subtle deformations in Earth's surface.

This is an aerial photo of a 25-acre (10-hectare) sinkhole that formed unexpectedly near Bayou Corne, LA, in August 2012. New analyses of NASA synthetic aperture airborne radar data collected in 2012 reveal the radar detected indications of the sinkhole before it collapsed and forced evacuations. Such data may someday help foresee sinkholes. **Image credit:** *On Wings of Care*, New Orleans, LA

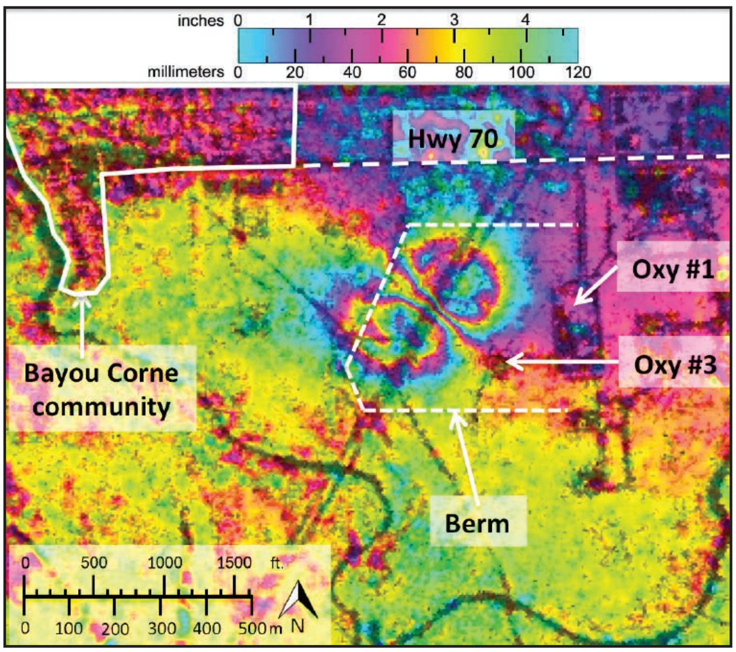
The analyses showed the ground surface layer deformed significantly at least a month before the collapse, moving mostly horizontally up to 10.2 in (260 mm) toward where the sinkhole would later form. These precursory surface movements covered a much larger area—about 1640 x 1640 ft, (500 x 500 m)—than that of the initial sinkhole, which measured about 2 acres (1 hectare). Results of the study are published in the February 2014 issue of the journal *Geology*.

"While horizontal surface deformations had not previously been considered a signature of sinkholes, the new study shows they can precede sinkhole formation well in advance," said Jones. "This kind of movement may be more common than previously thought, particularly in areas with loose soil near the surface."

The Bayou Corne sinkhole formed unexpectedly August 3, 2012, after weeks of minor earthquakes and bubbling natural gas that provoked community concern. It was caused by the collapse of a sidewall of an underground storage cavity connected to a nearby well operated by Texas Brine Company and owned by Occidental Petroleum. On-site investigation revealed the storage cavity, located more than 3000 ft (914 m) underground, had been mined closer to the edge of the subterranean Napoleonville salt dome than thought. The sinkhole, which filled with *slurry*—a fluid mixture of water and pulverized solids—has gradually expanded and now measures about 25 acres (10.1 hectares) and is at least 750 ft (229 m) deep. It is still growing.

"Our work shows radar remote sensing could offer a monitoring technique for identifying at least some sinkholes before their surface collapse, and could be of particular use to the petroleum industry for monitoring operations in *salt domes*," said Blom. "Salt domes are dome-shaped structures in sedimentary rocks that form where large masses of salt are forced upward. By measuring strain on Earth's surface, this capability can reduce risks and provide quantitative information that can be used to predict a sinkhole's size and growth rate."

Typically, sinkholes have no natural external surface drainage, and they form through natural processes and/or human activities. They occur in regions of *karst* terrain where the rock below the surface can be dissolved by groundwater, most commonly in areas with limestone or other carbonate rocks, gypsum, or salt beds. When the rocks dissolve, they form spaces and caverns underground. Sinkholes vary in size from a few feet across to hundreds of acres, and some can be very deep. They are common hazards worldwide and are found in all regions of the U.S., with Florida, Missouri, Texas, Alabama, Kentucky, Tennessee, and Pennsylvania reporting the most sinkhole damage. While sinkhole deaths are rare, in February 2013 a man in Tampa, FL, was killed when his house was swallowed by a sinkhole.



Analyses by NASA's UAVSAR radar performed after the Bayou Corne, LA, sinkhole formed show it was able to detect precursory ground surface movement of up to 10.2 in (260 mm) more than a month before the sinkhole collapsed in August 2012. This interferogram was formed with images acquired on June 23, 2011 and July 2, 2012. Colors represent surface movement, with one full color wrap corresponding to 4.7 in (120 mm) of displacement. **Image credit:** NASA/JPL

The human-produced Bayou Corne sinkhole occurred in an area not prone to sinkholes. The Gulf Coast of Louisiana and eastern Texas sits on an ancient ocean floor with salt layers that form domes as the lower-density salt rises. The Napoleonville salt dome underneath Bayou Corne extends to within 690 ft (210 m) of the surface. Various companies mine caverns in the dome by dissolving the salt to obtain brine and subsequently store fuels and salt water in the caverns.

Jones and Blom say continued UAVSAR monitoring of the area as recently as October 2013 has shown a widening area of deformation, with the potential to affect other nearby storage cavities located near the salt dome's outer wall. Because the Bayou Corne sinkhole is now filled with water, it is harder to measure deformation of the area using InSAR. However, if the deformation extends far past the sinkhole boundaries, InSAR could continue to track surface movement caused by changes below the surface. Continued growth of the sinkhole threatens the community and Highway 70, so there is a pressing need for reliable estimates of how fast it may expand and how big it may eventually get.

"This kind of data could be of great value in determining the direction in which the sinkhole is likely to expand," said Jones. "At Bayou Corne, it appears that material is continuing to flow into the huge cavern that is undergoing collapse."

Blom says there are no immediate plans to fly UAVSAR over sinkhole-prone areas.

"You could spend a lot of time flying and processing data without capturing a sinkhole," he said. "Our discovery at Bayou Corne was really serendipitous. But it does demonstrate one of the expected benefits of an InSAR satellite that would image wide areas frequently."

"Every year, unexpected ground motions from sinkholes, landslides, and levee failures cost millions of dollars and many lives," said Jones. "When there is small movement prior to a catastrophic collapse, such subtle precursory clues can be detected by InSAR." ■

NASA and JAXA Launch New Satellite to Measure Global Rain and Snow

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

The Global Precipitation Measurement (GPM)[1] Core Observatory, a joint Earth-observing mission between NASA and the Japan Aerospace Exploration Agency (JAXA), thundered into space on February 27 at 1:37 PM Eastern Standard Time [February 28 at 3:37 AM Japan Standard Time (JST)] from Japan.

The four-ton spacecraft launched aboard a Japanese H-IIA rocket from Tanegashima Space Center on Tanegashima Island in southern Japan. The GPM spacecraft separated from the rocket 16 minutes after launch, at an altitude of 247 mi (398 km). The solar arrays deployed 10 minutes after spacecraft separation, to power the spacecraft.

"With this launch, we have taken another giant leap in providing the world with an unprecedented picture of our planet's rain and snow," said NASA Administrator **Charles Bolden**. "GPM will help us better understand our ever-changing climate, improve forecasts of extreme weather events like floods, and assist decision makers around the world to better manage water resources."

GPM lifts off to begin its Earth-observing mission. **Image credit**: NASA/Bill Ingalls

The GPM Core Observatory will take a major step in improving upon the capabilities of the Tropical Rainfall Measurement Mission (TRMM), a joint NASA–JAXA mission launched in 1997 and still in operation. While TRMM measured precipitation in the tropics, the GPM Core Observatory expands the coverage area from the Arctic Circle to the Antarctic Circle. GPM will also be able to detect light rain and snowfall, a major source of available fresh water in some regions.

To better understand Earth's weather and climate cycles, the GPM Core Observatory will collect information that unifies and improves data from an international constellation of existing and future satellites by mapping global precipitation every three hours.

"It is incredibly exciting to see this spacecraft launch," said **Art Azarbarzin** [NASA's Goddard Space Flight Center (GSFC)—*GPM Project Manager*]. "This is the moment that the GPM Team has been working toward since 2006. The GPM Core Observatory is the product of a dedicated team at GSFC, JAXA, and others worldwide. Soon, as GPM begins to collect precipitation observations, we'll see these instruments at work providing real-time information for the scientists about the intensification of storms, rainfall in remote areas, and so much more."

The GPM Core Observatory was assembled at GSFC and is the largest spacecraft ever built at the center. It carries two instruments to measure rain and snowfall. The GPM Microwave Imager (GMI), provided by NASA, will estimate precipitation intensities from heavy to light rain, and snowfall: by carefully measuring the minute amounts of energy naturally emitted by precipitation. Developed by JAXA and the Japan's National Institute of Information and Communication Technology, the

[1] To learn more about GPM, please see the feature article *The Earth Observer's* November-December 2013 issue [**Volume 25**, **Issue 6**, pp. 4-11].

Dual-frequency Precipitation Radar (DPR) will use emitted radar pulses to make detailed measurements of three-dimensional rainfall structure and intensity, allowing scientists to improve estimates of how much water the precipitation holds. Mission operations and data processing will be managed from GSFC.

"We still have a lot to learn about how rain and snow systems behave in the bigger Earth system," said **Gail Skofronick-Jackson** [GSFC—*GPM Project Scientist*]. "With the advanced instruments on the GPM Core Observatory, we will have for the first time frequent unified global observations of all types of precipitation, everything from the rain in your backyard to storms forming over the oceans to the falling snow contributing to water resources."

"We have spent more than a decade developing DPR using Japanese technology, the first radar of its kind in space," said **Masahiro Kojima** [JAXA—*GPM/DPR Project Manager*]. "I expect GPM to produce important new results for our society by improving weather forecasts and prediction of extreme events such as typhoons and flooding."

The GPM Core Observatory is the first of NASA's five Earth science missions launching this year. With a fleet of satellites and ambitious airborne and ground-based observation campaigns, NASA monitors Earth's vital signs from land, air, and space. NASA also develops new ways to observe and study Earth's interconnected natural systems with long-term data records and computer analysis tools to better see how our planet is changing. The agency freely shares this unique knowledge with the global community and works with institutions in the U.S. and around the world that contribute to understanding and protecting our home planet. ■

Warm Rivers Play Role in Arctic Sea Ice Melt

continued from page 43

instrument on Terra to examine sea ice patterns and sea surface temperatures in the Beaufort Sea. They observed that on June 14, 2012, a stretch of *landfast sea ice* (sea ice that is stuck to the coastline) formed a barrier that held the river discharge close to its delta. After the river water broke through the ice barrier, sometime between June 14 and July 5, the team saw that the average surface temperature of the area of open water increased by 11.7 °F (6.5 °C)—see image pair on page 43.

"When the Mackenzie River's water is held back behind the sea ice barrier, it accumulates and gets warmer later in the summer," said Nghiem. "So when it breaks through the barrier, it's like a strong surge, unleashing warmer waters into the Arctic Ocean that are very effective at melting sea ice. Without this ice barrier, the warm river waters would trickle out little by little, and there would be more time for the heat to dissipate to the atmosphere and to the cooler, deeper ocean."

"If you have an ice cube and drop a few water droplets on it, you're not going to see rapid melt," said co-author **Dorothy Hall** [NASA's Goddard Space Flight Center]. "But if you pour a pitcher of warm water on the ice cube, it will appear to get smaller before your eyes. When warm river water surges onto sea ice, the ice melts rapidly."

Nghiem's team has linked this sea ice barrier, which forms recurrently and persistently in this area, to the physical characteristics of the shallow ocean continental shelf, and concludes the seafloor plays a role in delaying river discharge by holding the barrier in place along the shore of the Mackenzie delta.

The team estimated the heating power carried by the discharge of the 72 rivers in North America, Europe, and Asia that flow into the Arctic Ocean. Based on published research of their average annual river discharge, and assuming an average summer river water temperature of around 41 °F (5 °C), they calculated that the rivers are carrying as much heat into the Arctic Ocean each year as all of the electric energy used by the state of California in 50 years at today's consumption rate.

While MODIS can accurately measure sea surface temperature where rivers discharge warm waters into the Arctic Ocean, researchers currently lack reliable field measurements of subsurface temperatures across the mouths of river channels. Nghiem said more studies are needed to establish water temperature readings in Arctic-draining rivers to further understand their contribution to sea ice melt. ■

NASA Earth Science in the News

Patrick Lynch, NASA's Earth Science News Team, patrick.lynch@nasa.gov

Mangroves Move Up Florida's Coast, January 3; *Science News.* Florida's mangrove forests are on the move. Satellite images from the past three decades reveal that these diverse coastal ecosystems have crept up the state's Atlantic coast, in response to rising winter temperatures. To chart the expansion of these tidal-zone-loving tropical trees, ecologist **Kyle Cavanaugh** [Smithsonian Environmental Research Center] and colleagues compared images taken by Landsat satellites from 1984 to 2011—see series of images below. During this period, the area occupied by mangrove forests south of about 30° N latitude, where Saint Augustine sits, grew by around 1200 hectares (12 km^2). Most of the increase occurred north of 27.5° N latitude, around the city of Vero Beach. The mangroves' gains come mainly at the expense of salt marshes. The researchers found through a statistical analysis that mangroves did not respond to higher average temperatures, but expanded in places where winter lows once fell below 4 °C (~39 °F) but now rarely do.

NASA Says 2013 Was Seventh-Hottest Year—And it Won't Stop There, January 21; *Los Angeles Times*. Global warming continues unabated—even as large poritons of the U.S. have recently been shivering under the influence of the polar vortex. No matter, NASA says, the average global temperature hasn't ceased its upward creep. On January 21, 2014, the agency announced the results of a study by its Goddard Institute for Space Studies showing 2013 in a tie with 2006 and 2009 as the seventh-warmest years since 1880; the years 2005 and 2010 are the warmest on record. Year over year, temperatures may drop, but more important is the change decade over decade, scientists say. There's been a rise of 1.4 °F (~0.8 ºC) since 1880 as greenhouse gases in the atmosphere have ratcheted up, the research shows.

NASA Putting New Eyes on Earth in 2014, January 23; *CNN.com*. NASA has announced an ambitious slate of launches for 2014, aimed at putting new eyes on the Earth and its atmosphere. A total of five missions—three satellites and two instruments that will be mounted on the International Space Station—are scheduled to go into orbit between February and November. They'll measure carbon dioxide in the air, water in the soil, rainfall, cloud layers, and ocean winds, providing "immediately useful" readings that will help improve both short-term weather forecasts and long-term climate projections, said **Michael Freilich** [NASA Headquarters—*Director of NASA's Earth Science Division*]. "This tremendous suite of five new instruments and missions that will be launching this year will truly reinvigorate our observing system and expand it,"

The joint NASA-Japan Aerospace Exploration Agency (JAXA) Global Precipitation Measurement (GPM) Core Observatory successfully launched aboard a Japanese H-IIA rocket from the Tanegashima Space Center in Tanegashima, Japan on February 27, 2014 at 1:37 PM Eastern Standard Time. **Image credit:** NASA/Bill Ingalls

Freilich said. The launches come two years after the National Academy of Sciences warned that budget pressure, program delays, and launch failures had left scientists facing a "rapid decline" in Earth observations as the U.S. satellite fleet aged.

NASA Satellite Data Raise Hope of Reviving Aral Sea, February 19; *Times of India*. New data say that although the long-term water picture for the Aral Sea watershed—which has lost 90% of its water—is bleak, short-term prospects are better than previously thought. Its watershed encompasses Uzbekistan and parts of Tajikistan, Turkmenistan, Kyrgyzstan, and Kazakhstan. **Kirk Zmijewski** and **Richard Becker** [both from the University of Toledo, Ohio] wanted to find out whether all of the water was gone for good, or whether some of it might have ended up elsewhere in the watershed, behind dams or in aquifers. They also wanted to gauge whether decreasing rainfall had contributed to the catastrophic water loss. The researchers used data from NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites to map monthly changes in mass within the watershed from 2003 to 2012. They mapped the entire Aral Sea watershed and found that each year throughout the decade, the watershed lost an average of 4.6 to 5.4 mi^3 (~22 km^3) of water or the equivalent of one Lake Mead per year—only about half as much as the rate at which the Aral Sea itself is losing water (5.8 mi^3, or 24 km^3).

Arctic Melt Causes More Climate Problems Than Anticipated, February 20; *Australia Broadcasting Corporation*. For 50 years or so, scientists have warned that if Arctic ice melts, the planet will be less able to reflect the sun's energy, which will further fuel global warming. Now, a new study using more than 30 years of satellite measurements has confirmed this hypothesis, warning that melting Arctic ice is having a greater impact on the world's energy balance than previously thought. The study, published in *Proceedings of the National Academy of Sciences*, is thought to be the first to accurately calculate how much extra energy the Earth has absorbed as Arctic ice melts. Since the 1970s, the study says the Arctic has warmed by 2 °C (~3.6 °F)—more than double the global average—while the amount of ice left at the end of the melt season each September has dropped by 40%. **Ian Eisenman** [Scripps Institute of Oceanography—*Assistant Professor*], who carried out the research said, "Our study showed the Arctic has darkened quite a bit during the past 35 years, and hence it is absorbing a lot more solar radiation than it used to." The study used data from NASA's Clouds and the Earth's Radiant Energy System (CERES).

***Successful Launch for Rain-Tracking Satellite,** February 27; *CNN.com*. A Japanese rocket roared into orbit early on February 28, 2014, carrying what NASA calls its most precise instrument yet for measuring rain and snowfall. The four-ton spacecraft is the most sophisticated platform yet for measuring rainfall, capable of recording amounts as small as a hundredth of an inch an hour, said **Gail Skofronick-Jackson** [NASA's Goddard Space Flight Center—*GPM Deputy Project Scientist*]. The $900 million satellite is a joint project with the Japan Aerospace Exploration Agency (JAXA). A little over a half hour after launch, GPM had successfully reached its intended orbit, deployed its solar panels, and began beaming signals back to its controllers. Once fully activated, GPM will use both radar and microwave instruments to directly detect falling snow for the first time. It will also combine data from other satellites with its own readings, beaming back a snapshot of worldwide precipitation every three hours, Jackson said. "We can start using the data for all sorts of applications—for floods, for landslide predictions, for tracking hurricanes so we know what part of the coastline to evacuate." Those data will boost not only immediate storm forecasts, but also aid climate scientists who have been working on long-term climate models to describe a changing world.

*See news story in this issue for more details.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact ***Patrick Lynch*** *on NASA's Earth Science News Team at* ***patrick.lynch@nasa.gov*** *and let him know of upcoming journal articles, new satellite images, or conference presentations that you think would be of interest to the readership of* ***The Earth Observer****.* ■

Earth Science in the News *is my favorite feature. These brief summaries quickly relate lots of exciting happenings in the different disciplines that I find both informative and inspiring.*

*—**David Young** [LaRC—Deputy for Science Directorate, CLARREO Project Scientist]*

NASA Science Mission Directorate – Science Education and Public Outreach Update

Theresa Schwerin, Institute for Global Environmental Strategies, theresa_schwerin@strategies.org
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Earth Day with NASA at Union Station

Date—April 21-22

This year NASA has teamed with Earth Day Network to raise awareness about our planet and to highlight particular themes in Earth science. NASA's Hyperwall and Science Gallery will be on display, and hands-on activities and demonstrations will take place April 21-22, 2014, at Union Station in Washington, DC. The Hyperwall will feature high-definition data visualizations and captivating satellite imagery. On Tuesday, April 22, 2014 (the official Earth Day), nearly 20 scientists will deliver exciting Hyperwall science presentations.

Join NASA at Union Station to celebrate Earth Day!

Powering the Satellite – Grades 5-8

This activity on solar energy invites students in grades five through eight to use computers to perform research on how solar panels convert sunlight into energy. Students will then use math skills to calculate the surface area of solar panels on a satellite, and the total power generated while the panels are in different positions. At the end of the activity, the students will write a report on their findings.

For more information and to view download resources, visit: *www.nasawavelength.org/resource/nw-000-000-003-656*.

NASA Wavelength Special Collection—GPM Resources

In celebration of the launch of the Global Precipitation Measurement (GPM) Core Observatory[1], *NASA Wavelength* is featuring a special collection of resource materials that address precipitation and Earth's water cycle. These materials include lesson plans, videos, activities, and interviews, at levels suitable for a wide range of students.

View the collection at *www.nasawavelength.org/resource-search?missionOrProgram=GPM&n=100*.

What is a Polar Vortex?

There has been a lot of talk about the *polar vortex* lately. People from all over the United States and Canada have blamed recent cold weather on this phenomenon. What is the polar vortex? Where did it come from? How does it cause such cold weather? Learn more, with a new video from *SciJinks*, available at *scijinks.jpl.nasa.gov//polar-vortex*.

Beautiful Earth Event with NASA's Digital Learning Network

Date—April 24

Join fellow students for a special one-hour broadcast from the Digital Learning Network Studio at NASA's Goddard Space Flight Center for a musical and visual tour of Earth as seen from space. There will also be a discussion with Global Precipitation Measurement (GPM) mission scientists! With in-person audiences and interaction via webcast, this event will engage students and teachers across the country.

For more information on participating, please contact *vcasa@umbc.edu* or visit: *beautifulearth.gsfc.nasa.gov*.

OSIRIS-REx *321Science*—New Videos

In recognition of the one-year anniversary of the Chelyabinsk, Russia asteroid impact event, the Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-Rex) mission's *321Science* video team has posted three new videos. These videos address the mission's scientific objective to understand the orbital motions of this asteroid in greater detail, including a look at the *Yarkovsky Effect*—a thermal force that affects rotating bodies in space (like asteroids)—that can change orbital characteristics.

To view these videos, visit: *www.youtube.com/osirisrex*. ■

The first place I turn is the ***Education and Public Outreach Update****. It is a great location to publicize some of our own accomplishments, watch what others are doing, and alert us to new opportunities.*

*—**Lin Chambers** [LaRC—Climate and Radiation Studies Director, Head of CERES S'COOL Program]*

[1] See news story on page 46 of this issue.

EOS Science Calendar

April 22–24, 2014
CERES Science Team Meeting, Hampton, VA.
ceres.larc.nasa.gov/science-team-meetings2.php

April 23–25, 2014
Land-Cover/Land-Use Change Science Team Meeting, Rockville, MD.
lcluc.umd.edu/meetings.php?mid=52

April 29–May 1, 2014
MODIS Science Team Meeting, Columbia, MD.
modis.gsfc.nasa.gov/sci_team/meetings/201404/index.php

July 8–11, 2014
ESIP Federation Summer Meeting, Frisco, CO.
esipfed.org/meetings

July 15, 2014
Aura 10th Anniversary TED-Style Talks, Greenbelt, MD.
aura.gsfc.nasa.gov

August 4–8, 2014
Precipitation Measurement Mission Science Team Meeting, Baltimore, MD.
pmm.nasa.gov/meetings/all/2014-pmm-science-team-meeting

September 15–18, 2014
Aura Science Team Meeting, College Park, MD.
acdb-ext.gsfc.nasa.gov/People/Witte/

September 29–October 2, 2014
GRACE Science Team Meeting, Potsdam, Germany.
www.csr.utexas.edu/grace/GSTM

October 28–31, 2014
Ocean Surface Topography Science Team Meeting, Lake Constance, Germany.
www.ostst-altimetry-2014.com

Global Change Calendar

April 27–May 2, 2014
European Geosciences Union General Assembly 2014, Vienna, Austria.
www.egu2014.eu

April 28–May 2, 2014
Japan Geoscience Union Meeting, Yokohama, Japan.
www.jpgu.org/meeting_e/information.html

May 22–23, 2014
Remote Sensing for Conservation, London, U.K.
remote-sensing-biodiversity.org/zsl-symposium

July 13–18, 2014
IEEE International Geoscience and Remote Sensing Symposium, Québec, Canada.
igarss2014.com

July 28–August 1, 2014
Asia Oceania Geosciences Society, Sapporo, Japan.
www.asiaoceania.org/aogs2014

August 2–10, 2014
40th COSPAR Scientific Assembly, Moscow, Russia.
www.cospar-assembly.org

December 15–19, 2014
American Geophysical Union Fall Meeting, San Francisco, CA.
meetings.agu.org

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Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain dates, meeting name, location, and relevant URL. Newsletter content is due on the weekday closest to the 15th of the month preceding the publication—e.g., December 15 for the January–February issue; February 15 for March–April, and so on.

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