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the earth observer

Editor's Corner

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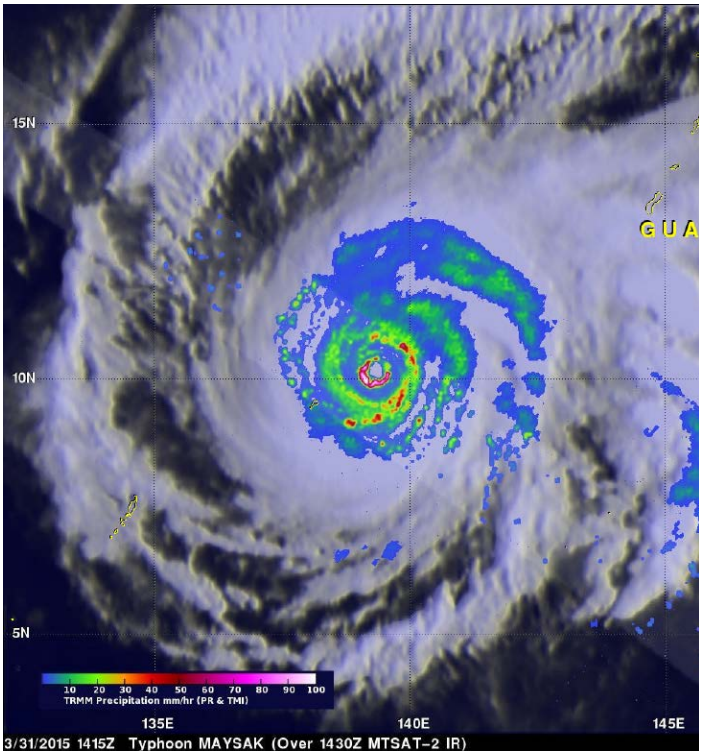
The Tropical Rainfall Measuring Mission (TRMM), a joint mission between NASA and JAXA to study rainfall for weather and climate research, was launched in November 1997, with a design lifetime of three years. TRMM officially came to an end on April 8, 2015 (see *pmm.nasa.gov/trmm/mission-end*); the spacecraft is expected to reenter the Earth's atmosphere in mid-June. TRMM became a fixture over the global tropics, producing over 17 years of valuable scientific data. TRMM carried five instruments: a three-sensor rainfall suite consisting of the Precipitation Radar (PR), TRMM Microwave Imager (TMI), and Visible and Infrared Scanner (VIRS); and two related instruments, the Lightning Imaging Sensor (LIS) and Clouds and Earth's Radiant Energy System (CERES). Its unique 17-year dataset of global tropical rainfall and lightning became the space-based standard for measuring precipitation, and led to research that improved our understanding of tropical cyclone structure and evolution, convective system properties, lightning-storm relationships, climate and weather modeling, and human impacts on rainfall. The data also supported operational applications such as flood and drought monitoring and weather forecasting.

Prior to its being shut down on April 1 for the upcoming end-of-mission processes, TRMM's PR captured an image of Super Typhoon Maysak as it roared through the warm waters of the West Pacific, south of Guam on March 31, 2015 (see below). It shows the rain intensities within the very heart of the typhoon as it undergoes an eye wall replacement cycle, and is emblematic of the nature and quality of data that TRMM has provided for so many years. Congratulations and kudos to the many TRMM teams that made the mission such a success—from initial mission concept through design, implementation, and operations.



Meanwhile, TRMM's successor, the Global Precipitation Measurement (GPM) Core Observatory, is one year into its three-year prime mission (May 2014-May 2017). With a little more than

continued on page 2

As its final image acquisition, the Precipitation Radar on TRMM captured a textbook example of an eye wall replacement cycle in a tropical cyclone in progress on March 31, 2015. The eye of Super Typhoon Maysak, [*center*] is characterized by descending air and calm conditions. Immediately surrounding the eye is the original inner eye wall (reds and purple) where air is rising in convective updrafts and releasing heat through condensation. Continuing further out from the eye, an outer eye wall is forming (green) that will eventually replace the inner eye wall.

Image credit: Image produced by **Hal Pierce** [NASA's Goddard Space Flight Center (GSFC)/Science Systems and Applications, Inc. (SSAI)] and shortened caption by **Stephen Lang** [GSFC/SSAI]. The full caption with descriptive details can be viewed at *pmm.nasa.gov/mission-updates/trmm-news/trmm-satellite-makes-direct-pass-over-super-typhoon-maysak.*

editor's corner

In This Issue

Reminder: To view newsletter images in color, visit *eospso.nasa.gov/earth-observer-archive.*

a year of overlap between TRMM and GPM, there were multiple cyclones, typhoons, and hurricanes, and just about every type of weather event observed (nearly) simultaneously by both missions. This joint dataset has proved valuable in that the GPM team has shown that the GPM Microwave Imager (GMI) is one of the better calibrated precipitation radiometers currently operating in space. All of the GPM products have been released, including the powerful Integrated Multi-satellite Retrievals for GPM (IMERG) dataset at a 30-minute interval and a 0.1 x 0.1° grid. IMERG is produced in near-real-time (4-6 hrs) for applications, and with a 3-month latency for research studies. In September 2015 the revised GPM products will be released with new algorithm versions.

In other mission-related news, although ISS-RapidScat has been deployed on the space station for only seven months (deployed September 23, 2014), forecasters are already finding this new eye-in-the-sky helpful as they keep watch on major storms around the globe. ISS-RapidScat measures Earth's ocean surface wind speed and direction over open waters. The instrument's data on ocean winds provide essential measurements for researchers and scientists to use in weather predictions—including hurricane monitoring. ISS-RapidScat has observed the already active 2015 Southern Hemisphere hurricane season as well as the Northern Hemisphere's winter storm season. Please turn to the news story on page 32 of this issue to see several examples of the data being returned from ISS-RapidScat.

Previously, we reported that the antenna on Soil Moisture Active Passive (SMAP)—launched January 31, 2015—was successfully "spun up" to nearly 14.6 RPM in a two-stage process in late March[1]. With its spin-up activities complete, the observatory's radar and radiometer instruments were powered on from March 31 to April 3 in a test designed to verify the pointing accuracy of the antenna and the overall performance of the radar and radiometer instruments. The radar data acquired from the test have been processed to generate data products with a spatial resolution of about 30 km. The radiometer data from the instrument test have also been processed to map microwave emissions from Earth's surface, expressed as brightness temperatures, at a spatial resolution of about 40 km. These images appear as Figure 1 and 2, respectively, in the news article on page 30 of this issue, where you can learn more about what these images reveal.

Looking toward the future, Jason-3 is currently scheduled for launch on July 22 from Vandenberg Air Force Base in California onboard a SpaceX Falcon 9 launch vehicle. Jason-3 is the latest in a series of U.S.-European satellite missions that have been measuring the height of the ocean surface for 23 years. The mission's predecessors were TOPEX/Poseidon (launched in 1992), Jason-1 (2001), and the Ocean Surface Topography Mision (OSTM)/Jason-2 (2008, *still active*). Sea level height is a critical piece of information about Earth's natural cycles and how humans are affecting our planet. The Jason satellites have provided the most accurate measurements of global sea level rise to date. Knowing sea level height also improves hurricane forecasts, global

[1] See the Editorial of the March–April 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 2**, p. 2].

positioning and navigation, and the efficiency of fisheries, and other offshore industries.

Jason-3 is an international partnership led by NOAA with participation from NASA, CNES, and EUMETSAT. As they did for the previous missions in the series, JPL built Jason-3's radiometer, GPS, and laser reflector, is procuring the launch, and will help oversee the science team that is responsible for ensuring the quality of the data. The primary science instrument in all these satellites is a radar altimeter, which transmits a microwave pulse to the ocean's surface and determines the signal's return time. When combined with information on the precise location of the spacecraft, the returned radar signals give a record of sea-surface height. Having consistently out-performed their required accuracy, the altimeter has not required a major redesign since Jason-1[2].

In addition, NASA and the USGS will continue their long-standing partnership as they work to develop the Landsat 9 mission. The President's fiscal year 2016 budget request calls for initiation of work on a Landsat 9 spacecraft as an upgraded rebuild of Landsat 8. The budget also calls for the exploration of technologies and systems innovations to provide more cost effective and advanced capabilities in future land-imaging missions beyond Landsat 9, e.g., finding ways to miniaturize instruments to be launched on smaller, less-expensive satellites.

"Moving out on Landsat 9 is a high priority for NASA and USGS as part of a sustainable land imaging program that will serve the nation into the future as the current Landsat program has done for decades," said **John Grunsfeld** [NASA Headquarters—*Associate Administrator for Science*]. "Continuing the critical observations made by the Landsat satellites is important now and their value will only grow in the future, given the long term environmental changes we are seeing on planet Earth."

As they have done with all previous Landsat missions, NASA will build, launch, and perform the initial checkout and commissioning of Landsat 9; USGS will operate the satellite, and process, archive, and freely distribute mission data. GSFC will lead development of the Landsat 9 flight segment and build the Thermal Infrared Sensor (TIRS). With launch planned for 2023, Landsat 9 will propel the Landsat program past 50 years of continuous observations of Earth's changing land surface. Please turn to the news story on page 34 of this issue to learn more about the plans for Landsat 9.

Finally, in this issue we report on the Gregory G. Leptoukh Online Giovanni Workshop, which took place on November 10, 12-14, 2014. Named in honor of one of the founders of the Giovanni online visualization and analysis environment (*disc.sci.gsfc.nasa.gov/giovanni*), the workshop took place in the Earth Science Data and Information System (ESDIS) Adobe Connect Webinar environment. This workshop also featured an interactive global poster session, during which the authors of online posters accepted and responded to questions sent by email on the day designated for the session. Please turn to page 14 to learn more about the latest research results obtained using Giovanni.

On a related note, the Goddard Earth Sciences Data and Information Services Center (GES DISC) recently added 49 data variables to Giovanni-4 (the latest version of Giovanni, which is described in the article referenced above) including: AIRS Carbon Dioxide, NASA Ocean Biogeochemical Model (NOBM), SeaWiFS Deep Blue Aerosol Climatology, TOMS Aerosol and Ozone, TRMM *Version 7*, and TRMM Real-Time Daily. ■

Acronyms used in the Editorial and Article Titles

AIRS	Atmospheric Infrared Sounder
CNES	Centre National d'Études Spatiales [French Space Agency]
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
EOSDIS	Earth Observing System Data and Information System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
Giovanni	Geospatial Interactive Online Visualization ANd aNalysis Infrastructure
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GSFC	NASA's Goddard Space Flight Center
ISS-RapidScat	International Space Station Rapid Scatterometer
JAXA	Japan Aerospace Exploration Agency
JPL	NASA/Jet Propulsion Laboratory
NOAA	National Oceanic and Atmospheric Administration
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
RPM	Revolutions Per Minute

continued on page 39

[2] To learn more about Jason-3, please visit *www.nasa.gov/jpl/jason-3-will-add-to-record-of-the-seas-rise-and-fall*.

feature articles

Seeing is Believing: EOSDIS Worldview Helps Lower Barriers for NASA Earth-Observing Data Discovery and Analysis

Josh Blumenfeld, NASA's Goddard Space Flight Center/ADNET Systems, Inc., joshua.c.blumenfeld@nasa.gov

The EOSDIS is responsible for managing, processing, archiving, and distributing NASA's Earth-observing data, and currently manages the more than nine petabytes of data collected by NASA's satellite, airborne, and field missions.

Introduction

When a sensor aboard one of NASA's Earth-observing satellites sends its raw data back to Earth, the data are in the form of numbers—often a lot of numbers. If you have the right background and training (not to mention time), it is possible to sift through the lines of numbers to discern what the data may indicate. On the other hand, an image created from the same data allows you to rapidly and efficiently begin to make inferences about the data's spatial and temporal significance, and discover patterns that later can be studied and verified through analysis of the numbers behind the image.

Developing and providing efficient and innovative ways for scientists, researchers, students, and others to interact with NASA's tremendous amount of Earth Observing System (EOS) data is an important objective of NASA's Earth Observing System Data and Information System (EOSDIS[1]). The EOSDIS is responsible for managing, processing, archiving, and distributing NASA's Earth-observing data, and currently manages the more than nine petabytes (PB) of data collected by NASA's satellite, airborne, and field missions. To put this amount of data into perspective, one PB is roughly equivalent to 20-million four-drawer filing cabinets filled with text.

Providing Rapid Access to Visualizations of NASA's EOS Data

Once EOS data are collected, they are sent to one of the EOSDIS's 12 discipline-specific Distributed Active Archive Centers (DAACs) for processing, archiving, and distribution. Additional data products are produced by several Science Investigator-led Processing Systems (SIPS) and sent to the appropriate DAAC or DAACs for storage and distribution.

The EOSDIS Worldview data-browsing interface[2] allows users around the world to interactively view images created from EOS data. Worldview is enabled by the EOSDIS's Global Imagery Browse Services (GIBS[3]) products—see **Figure 1**. The goal

[1] The evolution of EOSDIS has been detailed previously in "The Earth Observing System Data and Information System: Where We Were and Where We Are, Parts I and II" in the July-August [**Volume 21**, **Issue 4**, pp. 4-11] and September-October 2009 [**Volume 21**, **Issue 5**, pp. 8-14] issues of *The Earth Observer*. For more information, visit *earthdata.nasa.gov*.
[2] Worldview is accessible at *worldview.earthdata.nasa.gov*
[3] GIBS is accessible at *earthdata.nasa.gov/gibs*

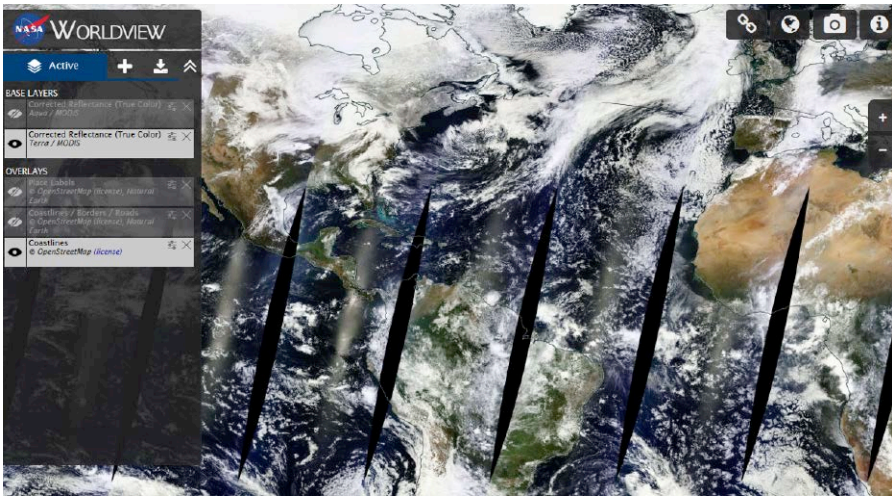


Figure 1: The default base layer on the Worldview home page shows the Earth as it looked within a few hours of a satellite overflight, including clouds, snow cover, storms, and vegetation. The black gaps in this image are areas not covered by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard the Terra satellite overpass on March 25, 2015. GIBS imagery can be selected using the Add Layers button (the "+" symbol under the word "Worldview" in the upper left menu). The Download Data button is under the end "w" in "Worldview." **Image credit:** NASA Worldview

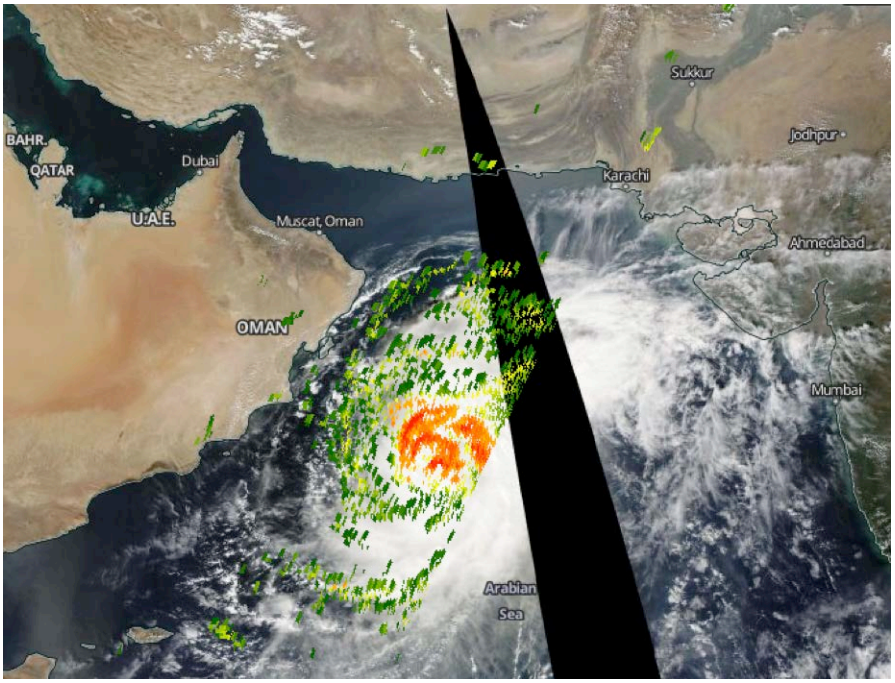


Figure 2: Worldview image of Cyclone Nilofar obtained on October 28, 2014, showing Rain Rate data from the Global Precipitation Measurement (GPM) satellite overlaid on Moderate Resolution Imaging Spectroradiometer (MODIS) Corrected Reflectance data from the Aqua satellite. **Image credit:** NASA Worldview

of the Worldview and GIBS development teams is to transform the way users discover and use EOSDIS data. "I think Worldview and GIBS improve the approachability of the data," says **Ryan Boller** [NASA's Goddard Space Flight Center (GSFC)—*Worldview* and *GIBS Project Manager*]. "For new users, it's an attempt to reduce the barriers to using what we have."

The *standard data products* (that is, data products created using the best available ancillary, calibration, and ephemeris information) that are produced, archived, and distributed by the DAACs are designed for scientific research and other applications that require the most accurate data possible. The trade-off with turning raw data into research-quality data is that those data often are not available until days or even weeks after they are collected.

This time lag, or latency, makes it difficult, if not impossible, to use standard data products to analyze and manage ongoing natural events such as wildland fires or storms. For these applications, data visualizations that are produced as rapidly as possible after a sensor collects the data provide the information necessary to make immediate management decisions. "The applications community, especially the wildland fire community, was really interested in being able to see the imagery rapidly," says Boller. "They didn't need to get to the underlying data; they just needed to determine if there was a fire or not."

*"I think Worldview and GIBS improve the approachability of the data. For new users, it's an attempt to reduce the barriers to using what we have."—**Ryan Boller** [GSFC]*

The EOSDIS solution for enabling rapid access to EOS data is the Land, Atmosphere Near real-time Capability for EOS (LANCE)[4]. LANCE provides more than 100 *near real-time* (NRT) products that are served as imagery through GIBS and can be viewed using Worldview and other client systems, usually within four hours after a sensor collects the data. If desired, users can easily download the data used to create the image—see **Figure 2**.

A Closer Look at Worldview

The EOSDIS development team released Worldview in 2011; it facilitates the interactive browsing of images retrieved from GIBS and enables users to:

- visually analyze data and quickly discern patterns in the data;

[4] LANCE is accessible at *earthdata.nasa.gov/data/near-real-time-data*. It has been discussed in previous articles, the most recent being "NASA FIRMS Helps Fight Wildland Fires in Near Real-Time" in the March–April issue of *The Earth Observer* [**Volume 27**, **Issue 2**, pp. 14-17].

- manage ongoing, time-critical natural events such as wildland fires, dust storms, and floods through the use of NRT data; and
- acquire the data underlying the imagery, which can be retrieved using the Download Data button on the Worldview menu.

The default Worldview base layer is a true-color image of Earth from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Terra and Aqua Earth-observing satellites that shows the Earth as it looked within the past few hours. Overlays, including national borders, coastlines, and place names, can be added to the base map with a single click. Users have the option of several additional base layers, including Corrected Reflectance in several MODIS bands, NASA's *Blue Marble*[5] image of Earth, and *Earth at Night*—last two base layers are shown in **Figure 3**.

Figure 3: Worldview features more than a dozen static and dynamic base layer options. Shown here are the *Blue Marble* (August 2004, shaded relief and bathymetry), from MODIS [*left*], and *Earth at Night* 2012, from Suomi National Polar-orbiting Partnership (NPP)/Visible Infrared Imager Radiometer Suite (VIIRS) [*right*]. Both images are available via NASA's Earth Observatory website (*earthobservatory.nasa.gov*). **Image credit:** NASA Worldview

Once a base layer is selected, users can overlay more than 120 data visualizations by simply selecting a check box. These visualizations include data from instruments on the Terra, Aqua, Aura, and Global Precipitation Measurement (GPM) missions, as well as socioeconomic data products from NASA's Socioeconomic Data and Applications Center (SEDAC). Over the next year, data from the Advanced Microwave Scanning Radiometer 2 (AMSR2) on the Global Change Observation Mission-Water 1 (GCOM-W1), Sea Ice Concentration data from the Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7[6], and data from the Soil Moisture Active Passive (SMAP) mission will be added. Users have great flexibility to add multiple layers to analyze a wide range of environmental criteria to create the visualization needed—see **Figure 4**.

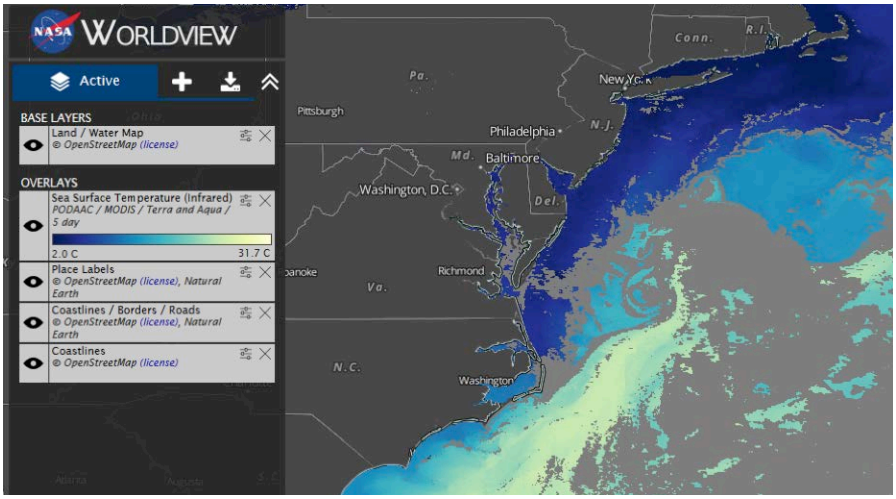


Figure 4: Worldview image from April 1, 2015, using the Land/Water Map base layer with an overlay of sea surface temperature (infrared). The "Blue 9" color palette is selected for the key. **Image credit:** NASA Worldview

[5] The Blue Marble: Next Generation is a series of color images of Earth for each month of 2004 with a resolution of 500 m (1640 ft) per pixel at a global scale. To learn more please visit *earthobservatory.nasa.gov/Features/BlueMarble*.

[6] To learn more about history of, accomplishments of, and measurements from the Nimbus series of satellites, see "Nimbus Celebrates Fifty Years" in the March–April 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 2**, pp. 18-31].

Current data products can be compared with data from earlier days, months, and years by using the slider along the bottom of the Worldview home page. Data dating back to May 2012 currently are available, although data dating back to the start of the Terra and Aqua missions will be available in several stages throughout 2015 and 2016 (see *Future Plans,* below).

A Closer Look at GIBS

GIBS, which also was released in 2011, is a set of Web services that provide access to NASA's Earth-observing imagery and serve visualized data products to Internet-enabled clients, such as Worldview. It is important to note that Worldview is not part of GIBS, rather Worldview displays GIBS data. This allows anyone to use the GIBS open services to build their own client or to retrieve imagery available through GIBS for use in other venues, such as educational websites—see *Worldview is One of Many GIBS Clients* below.

GIBS servers ingest imagery created by EOSDIS DAACs, SIPS, LANCE, and other data providers and save these images as full-resolution, mosaicked layers. These layers are then divided into preconfigured tiles that are stored at predefined zoom levels and can be delivered rapidly to client systems like Worldview. "Once the imagery is in GIBS, loading it into Worldview [or other GIBS clients] is very fast since everything is defined at this point," says Boller.

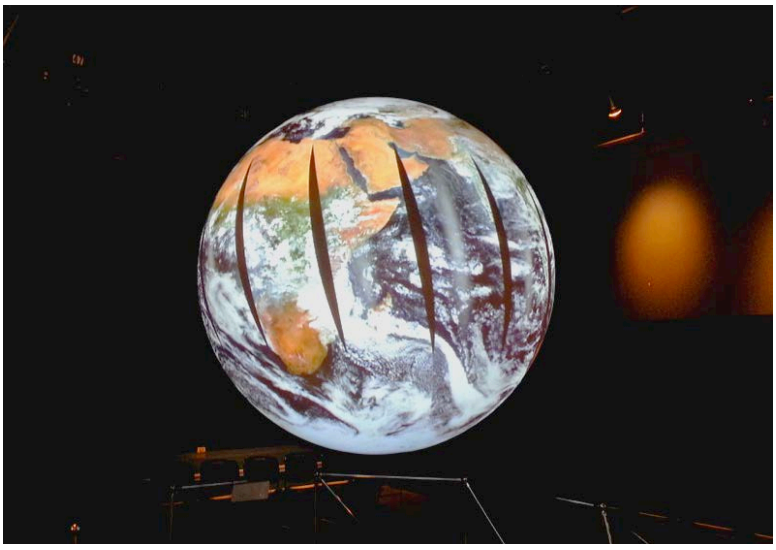
Future Plans

The Worldview and GIBS development teams are working on several enhancements that will further improve the usefulness of these systems for users of NASA Earth-observing data.

One of the most eagerly anticipated developments is the addition of the entire MODIS data record into GIBS. While MODIS data date back to 1999 (the launch of NASA's EOS Terra satellite) and 2002 (the launch of the EOS Aqua satellite), MODIS data in GIBS go back only to 2012. "Right now, we have imagery starting in May of 2012 and it runs through a few hours ago," Boller says. "Having the entire MODIS archive within GIBS is a major goal of ours."

Worldview is One of Many GIBS Clients

Along with *Worldview*, other GIBS clients include the Public Broadcasting Service, which uses GIBS imagery on its *Cloud Lab* website (*www.pbs.org/wgbh/nova/labs/lab/cloud*), and the National Oceanic and Atmospheric Administration's *Science on a Sphere*® presentations. The National Weather Service uses images provided by GIBS to help pinpoint ice accumulations for shipping, and the Environmental Protection Agency combines data from ground stations measuring air quality with satellite imagery from GIBS to provide better context for air-quality data. The Hayden Planetarium at the Rose Center for Earth and Space at the American Museum of Natural History in New York City even uses GIBS imagery in some of its planetarium shows.



Science on a Sphere® uses computers and video projectors to display GIBS data on a 1.8-m (6-ft)-diameter sphere at GSFC's Visitor Center. **Image credit:** Ryan Boller

The open services that GIBS provides can be found at *wiki.earthdata.nasa.gov/display/GIBS*, and sample Web clients can be found at *github.com/nasa-gibs/gibs-web-examples*. This access allows users to build their own clients to access and use GIBS products. "We want to separate GIBS and Worldview because we want people to use GIBS if they want to build their own clients," Boller says. "If you don't have your own client, then you can still look at the imagery and download the data using Worldview."

Since its introduction in 2011, Worldview has become an integral component in initial analysis and discovery of NASA's Earth science data. In addition, its ability to provide access to visualizations of data within four hours of when the data were collected makes Worldview an invaluable tool for land managers, forecasters, or anyone needing NRT data to manage ongoing natural events.

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In Worldview, a new Events Feed will enable users to select specific events, such as a hurricane or a dust storm, and immediately jump to visualizations of these events. This feature may help Worldview users discover other datasets that can assist in their research—not just to show that an event is happening, but that there are many datasets available that may be useful for gaining a deeper understanding of that event.

Of course, as Earth-observing missions are developed and launched, new data will be added to the DAACs and subsequently find their way to GIBS as new image products. For example, the launch of the SMAP mission this past January will lead to a host of new products relating to global soil moisture, crop health, and drought.

Finally, EOSDIS development teams are making improvements to GIBS that will enable it to handle thousands of data products and serve client systems more rapidly. As a result, Worldview users and other GIBS clients should expect a dramatic increase in the number of GIBS products over the next year or two.

Summary

Since its introduction in 2011, Worldview has become an integral component in initial analysis and discovery of NASA's Earth science data. In addition, its ability to provide access to visualizations of data within four hours of when the data were collected makes Worldview an invaluable tool for land managers, forecasters, or anyone needing NRT data to manage ongoing natural events.

While Boller is the first to admit that Worldview is still a system under development, he also is clear that it is achieving its intended purpose.

"Worldview and GIBS help to lower the barriers involved with using [NASA's] data," he says. "I think they enable not just easier use, but also new discoveries to be made and new applications to be developed." ■

kudos

Kudos

Claire Parkinson [NASA's Goddard Space Flight Center (GSFC)—*Climate Change Senior Scientist and Project Scientist for Aqua*] has been named this year's recipient of the William Nordberg Memorial Award for Earth Science. This high-achievement award recognizes a GSFC scientist who exhibits qualities of broad scientific perspective, enthusiastic programmatic and technical leadership on the national and international levels, wide recognition by peers, and substantial research accomplishments in understanding Earth system processes.

Parkinson has been awarded this prestigious honor for her work enabling a deeper understanding of the role of sea ice in the climate system, for outstanding leadership of Earth Observing System (EOS)/Aqua science, and for impressive educational outreach accomplishments.

Parkinson has been a climatologist at GSFC since July 1978 and a Senior Fellow at GSFC since 2005. Her research emphasis has been on polar sea ice and its connections to the rest of the climate system and to climate change, with a particular emphasis on satellite remote sensing. Since May 1993, Claire has additionally been the Project Scientist for the Aqua satellite mission, which launched in May 2002 and is transmitting data on many atmospheric, ocean, land, and ice variables. She has also written several books and is now Chair of the GSFC Senior Fellows.

Please join us in congratulating Parkinson on this award.

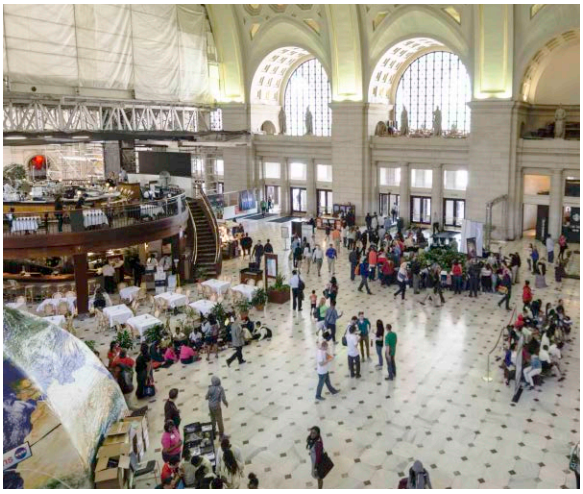
NASA Celebrates 45th Earth Day in the Nation's Capital

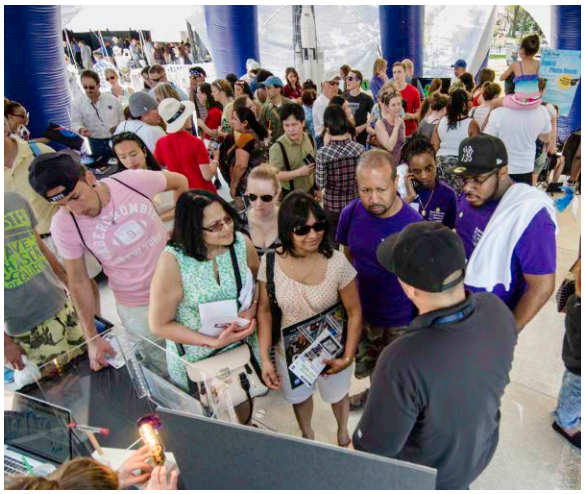
Alan Ward, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., alan.b.ward@nasa.gov
Heather Hanson, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., heather.h.hanson@nasa.gov

In commemoration of the forty-fifth Earth Day, NASA teamed with the Earth Day Network to share stories with the public about how the agency uses the vantage point of space to achieve a deep scientific understanding in several areas including our home planet, the sun and its effects on the solar system, other planets and solar system bodies, the interplanetary environment, and the universe beyond. This year, NASA had activities at two different venues in Washington, DC as part of *Global Citizen 2015 Earth Day* on April 17-18 at the Washington Monument Grounds on the National Mall, and to kick off the official Earth Day celebration at Union Station on April 21-22. NASA's Science Gallery exhibit and a variety of hands-on demonstrations and activities were offered at both locations—see **Table 1** on page 12.

Coming on the heels of such an exciting year for NASA Earth Science (with five launches since February 2014[1]), this was a great opportunity to showcase NASA's wide range of activities to the public. On April 18 alone, it is estimated that over a million people visited the

[1] In the sequence launched, these include GPM, OCO-2, RapidScat, CATS, and SMAP. To learn more about these missions, refer to Editorials in recent issues of *The Earth Observer* as well as to feature articles on: GPM—November–December 2013 [**Volume 25**, **Issue 6**, pp. 4-11]; OCO-2—July–August 2014 [**Volume 26**, **Issue 4**, pp.4-11]; RapidScat—September–October 2014 [**Volume 26**, **Issue 5**, pp. 4-9]; and SMAP—January–February 2015 [**Volume 27**, **Issue 1**, pp. 14-19].





NASA celebrated the 45th anniversary of Earth Day at two venues in Washington DC: On April 17-18 at the Washington Monument Grounds on the National Mall and at Union Station on April 21-22. Large crowds visited both locations: On April 18 alone, it is estimated that more than 10,000 people visited the NASA exhibit on the National Mall. **Image credit:** NASA/Ishon Prescott

National Mall to participate in the Global Citizen 2015 Earth Day activities, which included a concert by several well-known pop singers. Of that number, perhaps as many as 10,000 visited the NASA exhibit, with at least 1000 completing five or more of our hands-on activities.

Former NASA Astronaut **Piers Sellers** signed autographs on April 18 at the National Mall. **Image credit:** NASA/Ishon Prescott

Former NASA Astronaut **John Grunsfeld** signed autographs on April 22 at Union Station. **Image credit:** NASA/Ishon Prescott

NASA's Hyperwall was exhibited at Union Station, displaying NASA Science imagery and visualizations throughout the two days. In this photo from April 22, **Michael Freilich** took a turn providing opening remarks. **Image credit:** NASA/Aubrey Gemignani

NASA Administrator **Charles Bolden**, [*left*] is seen on stage with **will.i.am** [*right*] during the Global Citizen 2015 Earth Day event on April 18 at the Washington Monument Grounds. Both of them highlighted how the agency is using space-based sensing to better understand how our planet works, how we affect it, and how it might change in the future. **Image credit:** NASA/Joel Kowsky

NASA Administrator **Charles Bolden** [NASA Headquarters (HQ)] got a few moments on the main stage on Saturday afternoon alongside pop star **will.i.am**. Bolden used the time to emphasize the importance of studying our home planet from space. Also on April 18 and 22, former NASA Astronauts **Piers Sellers** [NASA's Goddard Space Flight Center (GSFC)] and **John Grunsfeld** [NASA HQ] were on hand to sign autographs and answer questions about what it was like to view Earth from space.

NASA's Earth Day activities also offered opportunities for formal learning. Groups of students—many scheduled but some impromptu—visited the National Mall throughout the day on April 17 and Union Station on April 21 and 22. When their group completed at least five activities, each student received a NASA bag containing recent printed materials relevant to NASA Earth Science. Altogether, around 1000 students participated.

The NASA Hyperwall was demonstrated at Union Station. On April 21 **Steve Graham** [NASA's Goddard Space Flight Center (GSFC)—*Science Program Support Office*], **Tom Wagner** [NASA HQ—*Program Scientist for Cryospheric Sciences*], and **Joel Green** [Space Telescope Science Institute—*Project Scientist for Office of Public Outreach*] gave informal presentations throughout the day to groups of students. On April 22—Earth Day—there were a series of formal presentations on the Hyperwall stage. To kick things off, **Johanna Bozuwa** [Earth Day Network—*Director of Education*], **Ellen Stofan** [NASA HQ—*NASA Chief Scientist*], **John Grunsfeld** [NASA HQ—*Associate Administrator of the Science Mission Directorate*], **Michael Freilich** [NASA HQ—*Director of the Earth Science Division*], **Arthur Lehe** [Federal Emergency Management Agency—*Individual and Community*

Preparedness Division, National Preparedness Directorate], **Anne Hall** [U.S Department of State—*Acting Principal Deputy Assistant Secretary*], as well as a representative from Union Station, Washington Gas, and Amtrak all took turns providing opening remarks and welcoming attendees to the celebration. A range of speakers on several topics followed throughout the day—see **Table 2** on page 13. Students, teachers, and the general public were impressed by the Hyperwall presentations.

Students at Union Station experience the wonder of the *Dynamic Planet* exhibit, which can show a variety of NASA science datasets on a spherical display. The students are standing in front of a touchscreen that controls the spherical display and gives a description of what is being shown on the display. **Image credit:** NASA/Ishon Prescott

NASA's *Science Gallery* was on display at the National Mall (shown here) and at Union Station. The "gallery" is an assortment of NASA images displayed on fabric, particularly useful in venues where electricity is not readily available, such as the Mall. Here, **Steve Graham** talks to a group about the images on display. Other NASA and support representatives served as docents for the gallery images throughout the four days. **Image credit**: NASA/Ishon Prescott

Students at both the National Mall (shown here) and Union Station could become *Super Sleuths* as they took an *Earth Imagery Challenge*. **Jennifer Brennan** and **Minnie Wong** [both from GSFC—*Earth Observing System Data and Information System*] helped them follow "clues" to solve an imagery mystery and learned how NASA satellites are taking measurements of planet Earth from space. **Image credit**: NASA/Ishon Prescott

On April 18 the Department of State had its *Rainwater Exhibit* on display at the National Mall. This was a live demonstration of a rainwater collection and filtration system, including plants, rocks, and a working "rain" system. **Image credit:** NASA/Ishon Prescott

Students enjoyed learning about clouds from the GLOBE program both at the National Mall and at Union Station (shown here). The *Cloud in a Bottle* activity was a big hit with all ages. Here, **Peter Falcon** [NASA/Jet Propulsion Laboratory] and **Winnie Humberson** [GSFC] lead the students through the activity. The delighted and intense expressions on the student's faces speak volumes. **Image credit:** NASA/Ishon Prescott

Table 1. List of demonstrations and hands-on activities that took place on the National Mall (April 17-18) and inside Union Station's Main Hall (April 21-22).

Demonstrations and Hands-On Activities		
Dates	**Activity**	**Description**
April 17-18	AERONET	Participants learned about tiny atmospheric particles that are invisible to our eyes, but which play an important role in regulating Earth's climate, as they experienced the Aerosol Robotic Network (AERONET) in action.
April 17-18 April 21-22	Are You a Super Sleuth? Take the Earth Imagery Challenge †	Participants followed "clues" to solve an imagery mystery and learned how NASA satellites are taking measurements of Earth from space.
April 17-18 April 21-22	Aviation and the Environment	Earth's atmosphere protects life in many different ways. But, what would happen if our atmosphere suddenly disappeared? Participants learned how pilots and astronauts protect themselves as they travel to the very edge of Earth's atmosphere.
April 17-18 April 21-22	Digital Photo Booth	This was a chance to get your face in space. Participants walked away with a real keepsake.
April 21-22	Dynamic Planet †	This touchscreen interface allowed participants to control a spherical display to show a variety of remote sensing satellite datasets.
April 17-18 April 21-22	Eyes on the Earth 3D: Come Fly With NASA.	Participants virtually flew along with NASA's fleet of Earth science missions and observed climate data from a global perspective in an immersive, real-time, three-dimensional (3D) visualization experience.
April 17-18 April 21-22	GLOBE@20: Cloud in a Bottle †	Participants created a cloud in a bottle and learned about the important role clouds play in our atmosphere.
April 17-18 April 21-22	Icy Worlds, Big Discoveries	Participants learned about NASA's upcoming flyby of the icy world Pluto, along with *Plutopalooza* events that they could participate in, activities to download, and resources to share.
April 22	Know Your Earth	How well do you know your Earth? Participants took quizzes and earned a prize if they correctly answered each question.
April 17-18 April 21-22	Measuring Precipitation: On the Ground and From Space	Participants learned how rain gauges work, made their own gauge using a reused plastic water bottle, and tested and calibrated it to compare it to an official scientific gauge.
April 17-18 April 21-22	Puzzling Changes in the Land	To learn about how satellites study change over time, participants arranged a time series of Landsat images or pieced together a Landsat scene to reveal Earth's changing landscape.
April 18	Rainwater Exhibit: A Green Embassy †	This was a live demonstration of a rainwater collection and filtration system that included plants, rocks, and a working rain system.
April 17-18 April 21-22	Searching for Life Beyond Earth	Participants learned how what we discover about Earth is applied to the search for life in the universe.
April 17-18 April 21-22	The Balloon Program	Up, up, and away! Participants learned how NASA balloons are used to understand our dynamic Earth.
April 17-18 April 21-22	Ultraviolet Beads	Participants became "UV detectors" as they made their very own bracelet composed of beads that change color in the presence of UV light.

† Pictured in this article.

Table 2. List of Hyperwall presentations that took place on Tuesday, April 22, 2014 inside Union Station's Main Hall.

Hyperwall Science Stories	
Presentation Title	**Presenter****
Observing Our Changing Planet from Space	**Ellen Stofan**
NASA's Earth Observation Capabilities: Meeting the Challenges of Climate and Environmental Change	**Michael Freilich**
Space Station to Ground—What's Up?	**Tara Ruttley** [NASA's Johnson Space Flight Center—*Associate Program Scientist for the International Space Station*]
America's PrepareAthon	**Arthur Lehe**
Measuring Rain and Snow for Science and Society	**Dalia Kirschbaum** [GSFC—*Applications Scientist for GPM*]
Watching the Blue Planet from Space	**Eric Lindstrom** [NASA HQ—*Program Manager for Physical Oceanography*]
Tracking Down Extreme Climate Change on Mars	**Michelle Thaller** [GSFC—*Assistant Director for Science Communications and Higher Education*]
Global Climate Observations from Earth Viewing Satellites	**Jack Kaye** [NASA HQ—*Associate Director for Research of the Earth Science Division*]
Observing Earth's Poles*	**Thomas Wagner**
Eyes on the Earth 3D: Come Fly with NASA	**Kevin Hussey** [NASA/Jet Propulsion Laboratory—*Manager of Visualization Technology Applications and Development*]
Search for Life Beyond Earth*	**Joel Green** [Space Telescope Science Institute]
Why A-Train?	**Steve Platnick** [GSFC—*Earth Observing System Senior Project Scientist*]
GLOBE Hydrology on Four Pole Creek	**Representatives from Huntington High School**, Huntington, WV
Earth Rise	**Ernie Wright** [GSFC—*Producer, Goddard Scientific Visualization Studio (SVS)*]
Breathe Easier—NASA Observations Highlight Improving Air Quality	**Bryan Duncan** [GSFC—*Deputy Project Scientist for Aura*]
Visualizing NASA Data	**Horace Mitchell** [GSFC—*Director, SVS*]
World of Change—Landsat	**Michael Taylor** [GSFC—*Communication and Public Engagement Specialist for Landsat*]
Earth at Night from Space*	**Steve Graham**
Eyes on the Earth 3D: Come Fly with NASA	**Kevin Hussey**
Autoloop of NASA Science Stories	**Docents**

* These presentations were also given on April 21.

** Affiliations and positions not listed here appear in the text.

By all accounts, NASA's contributions to Earth Day activities were a resounding success. Of course, an event of such magnitude didn't just happen by chance; it required a solid team effort from start to finish. Before all was said and done, literally hundreds of people from several NASA Centers were involved with Earth Day in some capacity, across a range of activities. Among so many, these included participating in planning telecons, designing promotional materials, setting up tents and tables at the two venues, manning one of the hands-on activities, networking with the public, giving a Hyperwall presentation, stuffing NASA bags for students, assembling ultraviolet bracelets, taking photographs, stacking boxes behind the scenes, or even a combination of any or all of these and more. Without them, NASA's activities would not have been so popular or successful.

NASA looks forward to celebrating Earth Day again in Washington, DC, in 2016. Details of this forthcoming event will be provided in a later issue of *The Earth Observer*. ■

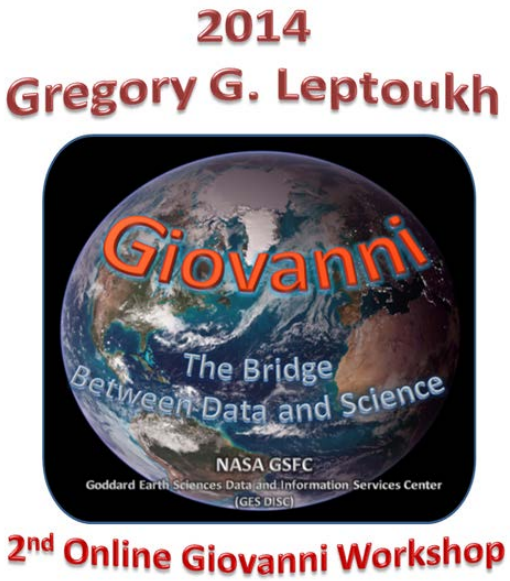
meeting summaries

The Second Gregory G. Leptoukh Online Giovanni Workshop

James G. Acker, NASA's Goddard Earth Sciences Data and Information Services Center/Adnet Inc., james.g.acker@nasa.gov

Introduction

The second Gregory G. Leptoukh Online Giovanni Workshop took place on November 10, 12-14, 2014. It featured the work of authors who had used the Goddard Earth Sciences Data and Information Services Center (GES DISC) Interactive Online Visualization ANd aNalysis Infrastructure ("Giovanni")[1] (as described below) in their research and publications released from 2012 to 2014. The workshop took place in the Earth Science Data and Information System (ESDIS) Adobe Connect Webinar environment, allowing oral presentations to be given both live and with an audio feed accompanying the slide presentation. This workshop also featured an interactive global poster session, during which the authors of online posters (either single-frame or as PDF slides) accepted and responded to questions sent by email on the day designated for the poster session. To provide context, prior to summarizing the workshop and accompanying poster session, this article will present a brief history of Giovanni. The first online workshop was described in a previous article in *The Earth Observer*[2].



History of Giovanni

During 2002 **Yoram Kaufman** [NASA's Goddard Space Flight Center (GSFC)—*Atmospheric Scientist*] and **Gregory Leptoukh** [GES DISC—*Data Manager*] began collaborating on a new way to visualize and analyze Earth science data. They wanted to create a system that would exploit the capabilities of data browsers and the World Wide Web, both of which were rapidly expanding in the early 2000s. Kaufman apparently said at one time that he was not a computer programmer, and wanted a way to use his computer to visualize the data himself, i.e., without otherwise "expert" help.

The result of Kaufman and Leptoukh's collaboration was the first version of Giovanni, which was released in 2002. This version provided several different basic analysis options, such as data mapping, regional subsetting, time-series generation, data averaging over specified time periods, x-y scatter plots, Hovmöller plots[3], and animations of consecutive time periods. It also provided visualization options, including different color palettes and user-specified color palette ranges. Giovanni was originally used with atmospheric data from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra and Aqua missions, Tropical Rainfall Measuring Mission (TRMM) data, and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) ocean-color data products. To make the analyses run quickly and to simplify the data analysis software undergirding the system, Giovanni operated on Level 3 global gridded data products almost exclusively.

Since the original version, Giovanni has been built with specific data portals dedicated to data from different missions and projects; as the number of missions and projects increased, the number of portals has increased. Data portals were constructed for the Atmospheric Infrared Sounder (AIRS) onboard Aqua, Ozone Measuring Instrument (OMI) onboard Aura, for the Global and North American Land Data Assimilation Systems (GLDAS and NLDAS respectively), and the Modern-era Retrospective Analysis for Research and Applications (MERRA). Existing data portals were augmented with additional data from other instruments, such as MODIS-Aqua ocean color data standard and research products. Some data portals were built to combine data from various sensors for a specific project, as was the case for the Northern Eurasia Earth Science Partnership Initiative (NEESPI), or for comparative analyses of similar data types, notably, atmospheric aerosol data—one of Kaufman and Leptoukh's major research interests.

The newest version of Giovanni, Giovanni-4, is currently in a period of rapid development, during which new capabilities and data products are being added. Two major advances are planned for the new version: Gionvanni-4 will eliminate the independent data

[1] The "G" in Giovanni was later changed to "Geospatial."
[2] See "2012 Gregory G. Leptoukh Online Giovanni Workshop" in the March–April 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 2**, pp. 39-40].
[3] A *Hovmöller plot* is a commonly used way of plotting meteorological data to highlight the role of waves. Hovmöller diagrams are also used to plot the time evolution of vertical profiles of scalar quantities such as temperature, density, or concentrations of constituents in the atmosphere or ocean.

portals used by its predecessor versions, and will also add the capability to search for a product over the entire suite of available data products. The new version will also be capable of serving data remotely from other data archives, utilizing OPeNDAP[4] and other Web data access protocols. (To learn more about the new version, please see *Giovanni-4* on page 17.)

Despite being conceived primarily as a "data exploration" tool, with the "hard science" being performed on higher spatial and temporal resolution data, the ease of use Giovanni offers has led to its increasing popularity as a tool for research. In 2004 three research publications appeared that used Giovanni, and every year since has seen a substantial increase in the number of journal publications acknowledging the use of the system—which, as a happy result, puts more impetus on the Giovanni development team to create a faster, more flexible, and even more accurate system. In both 2013 and 2014 more than 200 journal papers cited the use of Giovanni.

Unfortunately, Kaufman's tragic passing in 2006 and Leptoukh's untimely death early in 2012 mean that neither of Giovanni's founders are alive to witness the current expanding global usage of the system they conceived and created. However, the legacy of the founders lives on. One of Leptoukh's ideas was to promote the use of Giovanni by having a meeting that showcased the various ways in which the system was being used for research. Given that Giovanni is an online data analysis infrastructure, it seemed only fitting that these workshops take place "virtually." In 2012 the first such workshop was organized and conducted—and dedicated to Leptoukh. It took place "silently" (i.e., by using the *WebEx* text chat capability to accompany slide presentations), as researchers from around the world presented the results of recently published research that had used Giovanni. The first meeting was successful, and in 2014 a second workshop was scheduled. While there was no workshop in 2013, an initial class of 12 images was inducted into the *Giovanni Image Hall of Fame*[5].

[4] OPeNDAP stands for Open-source Project for a Network Data Access Protocol; it is both the name of a commonly used data access protocol and of the organization that developed it.

Summary of the Second Workshop

The first day of the workshop opened with workshop convenor, **James Acker** [GES DISC] offering words of greeting and acknowledging those who helped make this meeting possible. He particularly thanked **Jennifer Brennan** [ESDIS] for hosting the meeting. Acker followed his introduction with a presentation on the current state of Giovanni's data products and visualization capabilities. This presentation emphasized new datasets and data portals that had been added to the Giovanni-3 data system.

Christopher Lynnes [GES DISC—*Leader of Giovanni-4 Development Project*] provided a comprehensive overview of the status of Giovanni-4, highlighting several of the system's newest visualization capabilities (see **Figure 1** and the sidebar on *Giovanni 4*). The morning finished with a short discussion of recent research and Giovanni's social media connections: Giovanni has a *Twitter* account (*@nasa_giovanni*), and several demonstration videos are available on the NASAGESDISC *YouTube* account. New videos will soon be available, demonstrating how to perform basic visualization and analysis procedures in Giovanni-4.

[5] View the "hall of fame" images at *disc.sci.gsfc.nasa.gov/giovanni/additional/newsletters/giovanni-news-newsletters/giovanni_news_jan_2014_hof_issue.pdf.*

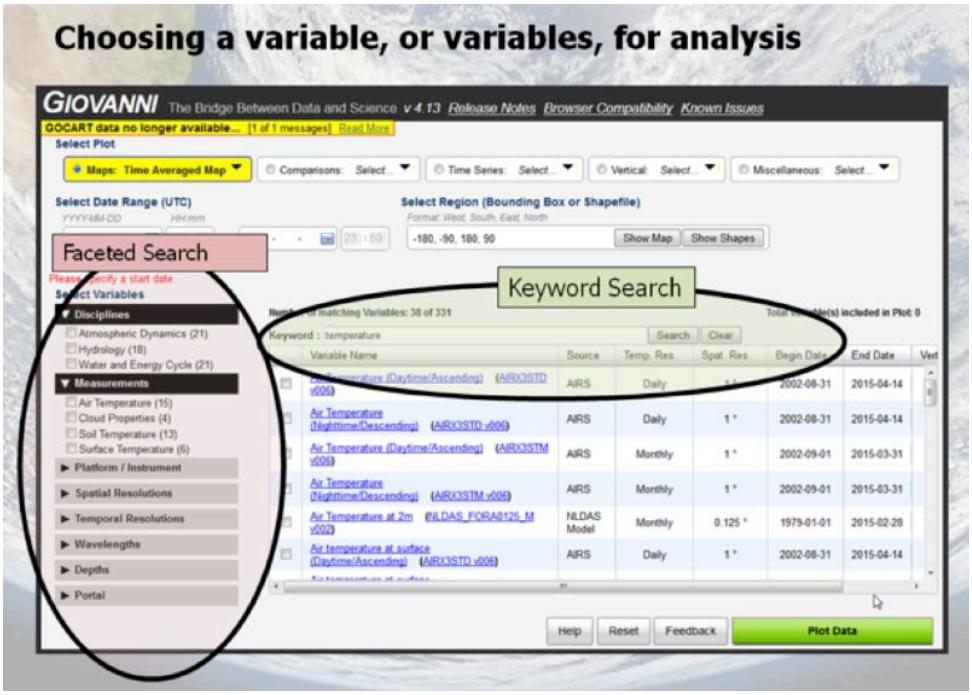


Figure 1. Christopher Lynnes described the status and development of Giovanni-4. One of the elements of the new user interface is different search options, including Faceted Search and Keyword Search. **Image credit**: James Acker

In the afternoon of the first day, **Cecile Rousseaux** [GSFC] described advances in the NASA Ocean Biogeochemical Model (NOBM) analysis, which now incorporates MODIS-Aqua data. This ongoing effort, led by Watson Gregg [GSFC] has not yet identified significant trends in global ocean chlorophyll over the 15 years covered by the data. NOBM chlorophyll data are noteworthy because data assimilation provides "cloud-free" daily data global maps. In the next presentation, **Gregory Jenkins** [Howard University] discussed the impact of Saharan dust in West Africa, including the impact of West African dust on regional public health concerns, e.g., meningitis and asthma. The first day of the workshop concluded with **Ramesh Singh** [Chapman University] giving a presentation on natural hazards and remote sensing. He showed several remarkable remotely sensed precursors to significant earthquakes.

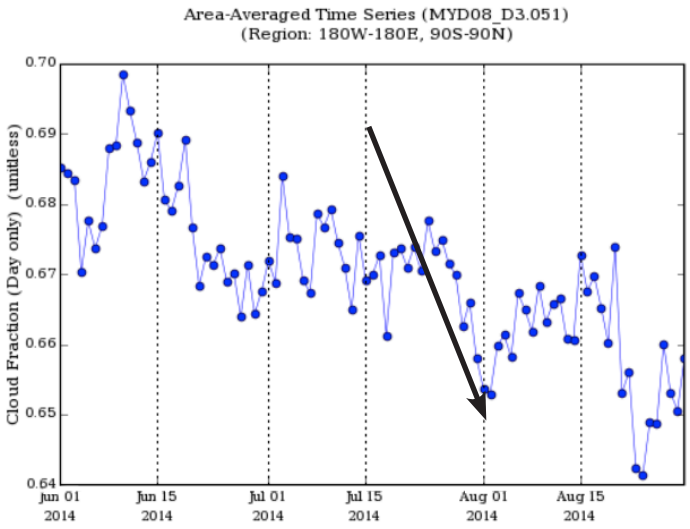


Figure 2. James Acker examined the heavy cyanobacteria bloom in Lake Erie that threatened the water supply of Toledo, OH in August 2014. The data shown here, obtained from MODIS-Aqua, indicate a decrease in cloud fraction in the days just prior to the crisis (shown by the black arrow). MODIS-Aqua has a daytime afternoon observational overpass, so these observations suggest that sunny summer afternoons contributed to the explosive growth of the toxic phytoplankton. Increased solar radiation and increased water temperature are both factors favorable to the growth of *Microcystis*. **Image credit**: Image by James Acker; data from the MODIS Adaptive Processing System (MODAPS) in Giovanni

Pavel Kishcha [Tel Aviv University, Israel] led off the second day with a presentation on the hemispheric asymmetry of aerosols and clouds over the tropical Atlantic. The observed asymmetry was seasonal and most pronounced from March through July—due to dust from the Sahara Desert. **Adnan Al-Azri** [Sultan Qaboos University, Oman] discussed the changing phytoplankton species spectrum in the Arabian Sea, particularly observations of large *Cochlodinium polykrikoides* blooms in 2008 and 2009. Regional oceanographic conditions, which included enhanced upwelling on the Iranian and northern Omani coasts, warm coastal waters, and higher nutrient concentrations, enabled the unusual bloom to persist for ten months. **John Lehrter** [Environmental Protection Agency] demonstrated how multiple remotely sensed data products contribute to models, thus allowing examination of the development and persistence of *coastal hypoxia* on the Louisiana continental shelf in the Gulf of Mexico. Coastal hypoxia, also known as "dead zones," is due to the respiration of organic matter primarily from surface phytoplankton growth, and causes dramatic reduction of oxygen concentrations in bottom waters. **Bumjun Kil** [University of Southern Mississippi] described the cause of an optically detectable "tail" observed in the Gulf of Mexico after the passage of Hurricane Isaac. This unique event occurred when rainfall from the hurricane exported some of the Gulf's shallow coastal waters offshore, which contained elevated concentrations of organic matter. The tail resulted when this organically enriched water flowed into an unusual configuration of the Gulf of Mexico's circulation regime. **Yoana G. Voynova-Buckley** [University of Delaware] concluded the day with a discussion about the subject of upwelling and the Delaware Bay, a process which delivers nutrients to the lower bay and coastal ocean. She noted that any phytoplankton benefiting from these available nutrients are immediately consumed by hungry zooplankton.

The final day of live presentations began with the subject of neural networks. **Michael Taylor** [National University of Athens, Greece] succeeded in deftly describing how neural networks were used with several NASA data sources to characterize aerosol size distributions, globally. **Shovonlal Roy** [University of Reading, U.K.] revealed how time-series data acquired from Giovanni can be used to analyze phytoplankton biodynamics, including their growth rate and size spectra. His research provides insight into the global distribution and population change of oceanic phytoplankton. **YangYang Xu** [National Center for Atmospheric Research] showed an analysis that distinguished several different aerosol types over California. These results could be used to derive the contribution of each aerosol type to radiative forcing and atmospheric heating. Xu's results indicated that the sun may be perceived as shining brighter over "sunny California" during the past two decades, mainly due to reduction of the elemental carbon aerosol. The day finished with **James Acker** describing how he used two datasets in Giovanni to examine possible precursors to a toxic algae bloom in Lake Erie. This bloom endangered the water supply of Toledo, OH, in the summer of 2014. Acker's analysis indicated that a few days of very warm and very clear sunny summer afternoons likely initiated an explosive growth of the toxic phytoplankton species *Microcystis* in the shallow western end of the lake, where the water intake for the city is located (see **Figure 2**).

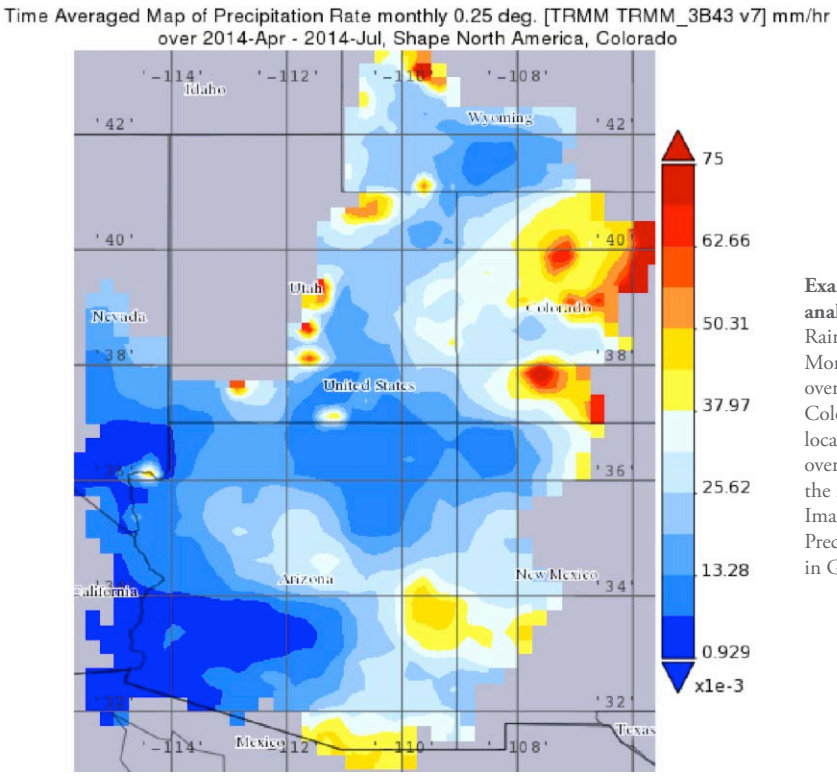
Giovanni-4

Giovanni-4 is the newest version of Giovanni. It is being developed with agile programming, so new releases of the system are anticipated to be frequent as new capabilities and new data products are added. The primary difference between Giovanni-4 and its predecessors is that it uses a *faceted data search* selection system that allows selection of any data products that are currently available in the system. Faceted search is distinctly different from the previous data portal system—discussed in the main article text. Giovanni-4 is also being developed with processing speed as a paramount consideration, and the system generally demonstrates processing speed increases by a factor of five to six, compared to its predecessor. The system speed is being challenged by high-spatial- and -temporal-resolution datasets. As an example, the Integrated Multi-SatellitE Retrievals for the Global Precipitation Mission (IMERG) dataset from the Global Precipitation Measurement (GPM) mission includes data with half-hourly temporal resolution.

The system is also being developed with open architecture and off-the-shelf software, which will allow other data archives to set up their own Giovanni systems. This aspect of the system is part of the Federated Giovanni project, in which data from several archives—the Land Processes Distributed Active Archive Center (LPDAAC), the Physical Oceanography DAAC (PODAAC), the Ocean Biology Processing Group (OBPG), and the MODIS Adaptive Processing System (MODAPS)—will be made accessible through Giovanni. Some DAACs may choose to set up their own Giovanni in a virtual machine environment or as a full, stand-alone system. Other archives will allow their data to be served remotely through the GES DISC Giovanni system using OPeNDAP.

Giovanni-4 has already added several analytical capabilities that were not previously available to users. One example of these capabilities is the interactive x-y scatter plot, which shows a changing scatter plot display as the boundaries of the region of interest are modified. Another example is shapefile analysis (shown below), which allows data to be averaged within the boundaries of states or major watersheds, rather than simply a rectangular area. In addition, the time-series analysis capabilities have been enhanced with a long-sought capability to create time-series for seasons or months in consecutive years: The previous time-series analysis operated on data that were available only in successive time steps, such as days or months.

Giovanni-4 can be accessed at *giovanni.gsfc.nasa.gov/giovanni.*



Example of Giovanni-4 *shapefile* analysis. The map shows Tropical Rainfall Measuring Mission (TRMM) Monthly Precipitation Rate averaged over the period April-July 2014 for the Colorado River watershed. Note the localized area of precipitation directly over Lake Mead (lower left—just to the right of the '36'). **Image credit**: Image by James Acker; data from the Precipitation Processing System (PPS) in Giovanni

meeting summaries

Summary of the Global Poster Session

The workshop also featured a Global Poster Session, which was an international event featuring contributions from Ecuador, Russia, India, Nigeria, and the U.K., as well as several from institutions in the U.S. **Sheila Serrano** [National Polytechnic School, Ecuador] and colleagues examined the self-organized criticality of rainfall events in their country. They found a power-law behavior in the relationship of the number of rainfall events to the amount of rainfall (in mm) for 10-minute-resolution precipitation data. **Prashant Kumar** [Atmospheric and Oceanic Sciences Group (EPSA) Space Applications Centre, Indian Space Research Organization] described how assimilation of satellite rainfall data improved weather models for India. Using a variety of satellite datasets, **Anubha Agrawal** [Energy and Resources Institute University, India]. quantified several different influences on the Himalayan mountain environment. He confirmed that air pollution is a clear contributor to regional changes, including the loss of glaciated area.

Potentially related to Agrawal's research was the work described by **B. Abish** [Cochin University, India] who showed evidence of a long-term "memory" (i.e., time dependence) of atmospheric aerosols in the region of India. On a similar regional and topical theme, **Dimitris Kaskaoutis** [Shiv Nadar University, India] classified weather conditions that contributed to aerosol events over the Indo-Gangetic Plains. Kaskaoutis contrasted the difference between post-monsoon and winter conditions, for which the aerosols are primarily anthropogenic, and the premonsoon and monsoon conditions, which include a natural dust component. The monsoon also was a major player in research by **Karl Szekielda** [Hunter College of the City University of New York], who observed monthly changes in chlorophyll concentrations on the west coast of Luzon, Philippines. One reason for the enhanced chlorophyll concentration was the flow of advected water out of Manila Bay.

Maria Tzortziou [GSFC and Earth System Science Interdisciplinary Center (ESSIC), University of Maryland] leads a team that has been studying ozone and nitrogen dioxide concentrations for the Chesapeake Bay urban watershed. She reported on the team's work using Pandora spectrometers and data collected from aerial campaigns, and compared these data to satellite data from OMI and with air-quality models. Ozone exhibited a distinct weekly cycle in this region. **Radina Soebiyanto** [Goddard Earth Sciences Technology and Research] looked at the connection between seasonal influenza (a.k.a., the "flu") and specific humidity in three Central American countries. **Katrin Schmidt** [British Antarctic Survey, U.K.] used Giovanni and other datasets to look at factors that control phytoplankton productivity around South Georgia Island in the Southern Ocean. One of the key factors was iron contained in the krill fecal pellets, which can be released by microbial digestion, and subsequently serve to fertilize phytoplankton growth "downstream" in the currents around the island. **Julius Akinyoola** [Rufus Giwa Polytechnic University, Nigeria] used Giovanni to characterize aerosol concentrations over Nigeria. He found the highest concentrations occurred in the industrialized coastal region of southern Nigeria, where petroleum production is an important activity.

Sergei Sitnov [A.M. Obukhov Institute of Atmospheric Physics, Russia] is a frequent Giovanni user who used the system to research the effects of the blocking anticyclone that occurred over Eastern Russia in the summer of 2010. An intense heat wave, dry soils, and huge wildfires occurred during this event, which caused very high concentrations of aerosols and carbon monoxide in the atmosphere. The abnormal weather also caused a "mini-hole" of ozone depletion on the stratosphere over Russia. **Margaret Wonsick** and **Rachel Pinker** [both at University of Maryland] described the characteristics of aerosols over the Indo-Gangetic Basin from 2000-2012. They compared MODIS and Multi-angle Imaging Spectroradiometer (MISR) data to model output, and determined the potential impact of aerosols on solar dimming, atmospheric heating, and cloud dissipation, from March through May—which is the build-up to the monsoon season.

Conclusion

The Second Gregory G. Leptoukh Online Giovanni Workshop successfully demonstrated the expanding range of Earth science research topics that can be addressed with Giovanni. Giovanni-4 will enhance the ability of researchers to use the data in a multidisciplinary fashion, as it allows simultaneous analyses of every data variable in the system. The addition of new variables from data archive partners will continue Giovanni's record of success in facilitating more widespread use of NASA Earth science data.

Acknowledgment: This is an expanded version of a summary of the Second Gregory G. Leptoukh Online Giovanni Workshop that appeared in the October-November 2014 issue of *The Giovanni News* newsletter, which is available at *disc.sci.gsfc.nasa.gov/giovanni/additional/newsletters/giovanni-news-newsletters/giovanni_news_oct_nov_2014*. Readers interested in subscribing to *The Giovanni News* should contact the author for instructions. ■

Landsat Science Team Meeting: Winter 2015

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Introduction

The U.S. Geological Survey (USGS)-NASA Landsat Science Team (LST) met at NASA's Goddard Space Flight Center (GSFC) from February 3-5, 2015. LST co-chairs **Tom Loveland** [USGS Earth Resources Observation and Science (EROS) Center—*Senior Scientist*] and **Jim Irons** [GSFC—*Landsat 8 Project Scientist*], opened the three-day meeting with a review of meeting objectives. Primary meeting topics included agency plans for a sustainable land imaging program; Landsat 7 and 8 operations, with special attention paid to the Landsat 8 Thermal Infrared Sensor (TIRS); and concepts and plans for making the Landsat archive and Landsat products more science-relevant. The presentations from the meeting presentations are available at *landsat.usgs.gov/science_LST_feb2015.php*.

Sustainable Land Imaging Status

Brad Doorn [NASA Headquarters—*Water Resources Program Manager of the Applied Science Program*] and **Sarah Ryker** [USGS—*Deputy Associate Director of the Climate and Land Use Mission Area*] presented the proposal for the formation of a Sustainable Land Imaging (SLI) Program, which is part of the President's proposed fiscal year 2016 budget. The program goal is to provide investments in technology innovations and observational capabilities that ensure continuation of land imaging for the next 20 years. The major components of the plan include:

- A Class-D Thermal Infrared Free Flyer (estimated 2019 launch) to fly in constellation with a reflective band imager (e.g., Landsat 8 or Sentinel-2[1]) and provide low-cost mitigation against an early loss of the Class-C TIRS instrument on Landsat 8, while demonstrating the feasibility of constellation flying.
- Landsat 9, referred to as the "Landsat 8 repeat build," which is a full-Class-B system (including thermal imager), with a 2023 launch target. This is viewed as a low-programmatic-risk implementation of a proven system.
- Investments in sustained technology and systems innovation, which are to include several hardware, operations and data-management; and data-processing investigations that will be conducted to identify appropriate technologies for next-generation missions.
- Landsat 10 Class-B, full-spectrum mission, with a tentative 2030 launch. The mission definition will be shaped by the technology investments conducted between 2015 and 2018.

Doorn and Ryker stressed that the plans are subject to congressional approval and that the specific configuration could be modified based on budget realities and scientific and technical investigations.

The LST members had a lively discussion about the SLI proposal, and in particular, the projected 2023 Landsat 9 launch date. With Landsat 7's end-of-mission date currently estimated to be early 2018, there could be at least a three-year period with only one Landsat acquiring imagery. Since there have been two functioning Landsats providing 8-day global coverage for the majority of Landsat's nearly 43 years, the loss of 8-day coverage would have significant impacts on Landsat data users. For example, there would be a reduction of cloud-free observations needed for all land applications. This would have a major impact on the many applications that need cloud-free observations at specific periods (e.g., growth, senescence, harvest periods), and studies in regions with persistent seasonal cloud cover, short growing seasons, and rapid phenology. In addition, there are a growing number of operational applications requiring more-frequent observations, including agricultural assessments, snow mapping, water resources investigations, and wildfire and other emergency response applications. The LST acknowledged that Sentinel-2 could provide important data-gap mitigation, but there are unresolved technical and programmatic issues that add risks.

The LST members concluded that the SLI program is a needed step towards securing Landsat operational status, and that after nearly 43 years of continuous imaging, Landsat may finally achieve the funding commitment needed to ensure definitive measurements of the condition of Earth for future generations. They suggested that the next phase of the approval and definition process pay close attention to ensuring Landsat continuity, including the longstanding *ad hoc* requirement of eight-day repeat coverage needed for time sensitive applications and for mitigation of frequent cloud cover. In order to avoid a data gap, creative strategies that reduce the time until Landsat 9 launch deserve attention.

[1] Sentinel-2 will be a land-monitoring constellation that will consist of two satellites: Sentinel-2A is scheduled to launch June 11 from the European Space Agency's spaceport near Kourou, French Guiana; Sentinel-2B is scheduled to launch in mid-2016 from Plesetsk Cosmodrome in Russia. These missions were described in "An Overview of Europe's Expanding Earth-Observation Capabilities," which appeared in the July–August 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 4**, pp. 4-15].

Attendees at the Winter 2015 Landsat Science Team meeting at GSFC

The LST committed to writing a white paper expressing support for moving towards establishing a long-term plan for SLI.

Phil Dabney [GSFC—*Landsat Data Continuity Mission (LDCM) Instrument Scientist*] and **Jeff Masek** [GSFC—*Landsat Project Scientist*] wrapped up with a discussion of new imaging technologies that may play a role in future land-imaging missions. They reviewed a range of technical capabilities including smaller, lower-cost satellite technologies and a number of instrument design considerations (e.g., imaging spectroscopy, wider imaging swath); they also discussed notions of multi-satellite constellations. Their broad conclusions were that primary drivers are to reduce Landsat instrument size while maintaining image quality. While new technologies will help, there are fundamental restrictions on how far size reductions can go without compromising shortwave infrared (SWIR) and thermal infrared measurements. It was also suggested that new imaging technologies may be able to maintain current capabilities while also offering broader spectral coverage with finer resolution, with spectroscopy offering new and unique opportunities to the science community.

Landsat Archive Status

Gene Fosnight [USGS—*Landsat Data Acquisition Manager*] summarized changes in the Long Term Acquisition Plan (LTAP) that governs Landsat 7 and 8. Landsat 7 data acquisitions are focused on continental landmasses in order to increase imaging rates and reduce instrument wear. Over 500 Landsat 7 images per day are currently being acquired and Landsat 8 acquisitions have been increased to 725 images per day.

Brian Sauer [USGS EROS—*Landsat Sustaining Engineering Project Manager*] reported that the Landsat archive continues to expand rapidly due to both the increased daily acquisitions from Landsats 7 and 8, and because of the repatriation of historical scenes from international ground stations. The Landsat archive now contains more than 5.5-million scenes. Since the repatriation activity started, 3-million new images have been added to the USGS EROS archive. The largest outstanding source of historical coverage is held by the European Space Agency (ESA), and the transfer of their holdings is underway. India and Thailand recently announced plans to transfer data from their archives. An estimated 3-million images will be transferred from these stations.

Sauer also reported that downloads continue to rise significantly. Nearly 6.8-million scenes were downloaded by users in Fiscal Year 2014. That was an increase of nearly 2.5-million downloads from the previous fiscal year.

Landsat 7 and 8 Status

Guy Thayer [The Aerospace Corporation/USGS—*Flight Systems Manager*] gave a brief summary of the status of Landsat 7 and 8. Landsat 7 has been on orbit for 15 years—well past its 5-year design life. A number of spacecraft components are being monitored (e.g., attitude control system, remote telemetry command box, power control unit) but overall, Landsat 7 is acquiring more imagery than at any point in its history.

There was considerable discussion on the end-of-mission for Landsat 7. Fuel depletion is expected by late 2018, but the imaging life can be extended with reduced orbit maintenance. Preliminary analysis shows that if Landsat 7 is authorized to continue imaging outside of its nominal 10:00 AM equator crossing time window, the mission could be extended until early 2020. At that point, however, the local solar time would be 9:15 AM. The LST encouraged continued imaging until 2020. As Landsat 5 orbit decayed to an approximate 9:15 AM orbit in the late-1990s, there is precedent for imaging outside the nominal crossing time.

Thayer reported that, except for Landsat 8 TIRS issues, all other systems are functioning normally. The acquisition rate has been raised from the design requirement of 400 images per day to 725. Operational Land Imager (OLI) performance is stable and radiometric and geometric performance continue to exceed requirements.

As indicated earlier, the Landsat 8 TIRS has two issues. The first is a stray-light anomaly that creates nonuniform radiometric response across the focal plane. The effect is most acute in band 11, varies within and between scenes, and is most noticeable in homogeneous areas that should have a uniform

instrument response. **Dennis Reuter** [GSFC—*TIRS Instrument Scientist*] explained that stray light was adding a spatially varying signal (ghosting) to the focal plane. Analysis indicates that the stray-light artifacts are related to out-of-field light reflecting from a lens mounting ring in the TIRS telescope.

Ron Morfitt [USGS EROS—*Calibration/Validation Manager*] summarized NASA, USGS, and Rochester Institute of Technology (RIT) efforts to define potential correction strategies for the issues named in the previous paragraph. One approach uses external coincident thermal sensor data from NOAA's Geostationary Operational Environmental Satellites (GOES) or the European Organisation for the Exploitation of Meteorological Satellite's (EUMETSAT's) Meteosat series. This approach provides the most accurate compensation, but cannot be used in areas where GOES or Meteosat data are unavailable. There would also be extended latency in product generation. A second approach, using in-scene data, would not have latency issues, but the correction is not as robust. The group concluded that because neither approach is mature enough for implementation, potential solutions will be revisited at the next LST meeting. Meanwhile, use of band 11 is not recommended.

The second TIRS issue is a problem with the side-A scene-select mirror (SSM) encoder electronics, a component that controls the alignment of the TIRS scene-select mirror, which moves the TIRS field-of-view from Earth-facing to an internal blackbody and to deep space for calibration. In October 2014 a steady unexpected increase in the mechanism control electronics (MCE) current magnitude was observed and by mid-December, the threshold current limits were exceeded and imaging was suspended. Imaging was resumed with the SSM in mode-0 and thermal collections continued while an anomaly resolution board (ARB) investigated the root cause of the SSM problem and assessed the hazards to the TIRS instrument. In mode-0, radiometry is only minimally affected (~0.2 K, worst case), but geometry is degraded. The Landsat product generation system is not currently capable of processing mode-0 products, so the collected data have been archived, but not processed for distribution.

The ARB investigation concluded that the likely cause of the current rise is restricted to side-A electronics, so plans were made to switch to the redundant side-B electronics. This change was made on March 6, 2015. Following a brief period for instrument calibration, TIRS acquisitions, processing, and distribution resumed. For the mode-0 imagery collected between late-December and early-March, ground system processing modifications will be in place by mid-May and all mode-0 TIRS imagery will be processed and released for public distribution. For a full summary of the schedule for TIRS reprocessing, see *landsat.usgs.gov/mission_headlines2015.php*.

Landsat Product Improvements

Brian Sauer reviewed USGS plans for Landsat product enhancements and took input from the LST on technical issues or user impacts that require further consideration. Sauer explained that a specific goal is to have consistent products across the full Landsat record.

In the area of *Quality Band Cloud Assessments*, Sauer described plans to convert to the *Fmask* algorithm for the cloud and shadow mask elements of Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), and OLI scenes. For Multispectral Scanner System (MSS) data, a simple decision tree algorithm is planned. In addition, a land-based cloud-cover-score attribute would be added to the quality band that provides cloud percentages just for the land area within scenes. The LST supported the changes, but emphasized the need to conduct comparisons between alternative methods and to provide provisional products prior to the implementation so that operational users can adjust their processing flows to the new quality-band data. They also suggested adding confidence ratings that would provide additional information on the quality of the cloud and shadow attributes.

Several topics related to *Auto-reprocessing and Other Improvements* dealt with improvements in scene geometry and radiometry, including reprocessing when definitive ephemeris become available, *bumper-mode calibration*[2], and Level-1 systematic processing with terrain correction. The LST supported the improvements. However, there was considerable discussion of near-real-time product *versus* more "controlled," higher-quality products. The LST members expressed concern about the current lack of sufficient information to enable users to know which version is being accessed. Policies for flushing the Landsat on-demand Level-1 product cache and clearer version information for filenames and metadata are urgently needed. Until version information becomes available, any significant changes to Level-1 processing parameters should result in clearing out the cache.

In reference to the *Top-of-Atmosphere* (TOA) *Reflectance Metadata and Coefficients File*, improvements in metadata add coefficients that enable scaling to TOA reflectance and the generating solar illumination and viewing angles for use in per-pixel TOA reflectance and downstream surface reflectance processing. The additions are

[2] The scan mirrors on the Landsat 5 and 7 satellites switched from their primary operating mode to a backup mode in early 2002 and 2007 respectively in order to overcome internal synchronization problems arising from long-term wear of the scan mirror mechanism. When the instruments operate in this so-called *bumper mode*, scan start and stop angles are impacted and scan timing telemetry, used to correct the image geometry, is eliminated. A mathematical model of the scan mirror's behavior must be applied that includes parameters that characterize the time-varying behavior of the scan mirror bumpers.

only to the content of metadata and ancillary files; the per-pixel corrections will initially have to be applied by the users. Once implemented in Level-1 processing by the ground system, this will make TM and ETM+ data consistent with OLI. The LST generally supported the improvements, but recommended releasing provisional products for community review.

An evaluation of *Level-1 Data Format* is underway to assess alternatives to GeoTIFF file formats that permit use of data delivery services such as Open-source Project for a Network Data Access Protocol (OPeNDAP) and Open Geospatial Consortium (OGC) Web Coverage Service (WCS). Evaluation of several data format alternatives to GeoTIFF, such as HDF5 and JPEG2000, concluded that JPEG2000 provides the highest lossless compression rates and small additional computation times; it is also the format planned for Sentinel-2. This change, if implemented, will not take place until 2016. The LST supported the format change but suggested that sample data be provided as early as possible so that users can test the format in current and planned applications.

Jim Storey [USGS/Stinger Ghaffarian Technologies Inc.—*Landsat 8 Geospatial Imaging Scientist*] presented plans to improve geolocation accuracy results by *Ground Control Point (GCP) Library Updates*. The improved Landsat 8 geolocation accuracy has led to identification of areas where the current GCP library is deficient. Regions with poor accuracy are being retriangulated, using Landsat 8 data for control while holding the surrounding area fixed, to ensure scene-to-scene consistency. This is being implemented in three phases, with first phase corrections addressing those regions with the most significant geolocation errors. Once the inaccurate GCPs are corrected, additional Landsat 8 GCPs will be added to the global library. Since the current GCPs are from the 2000 timeframe, the additional control should improve corrections in dynamic areas. The GCP update effort will be completed by late-2015.

John Dwyer [USGS EROS—*Landsat Project Scientist*] gave an update on progress in *Level-2 Products,* to provide surface reflectance and temperature products. Surface reflectance for all Landsat TM and ETM+ scenes are routinely available and provisional Landsat 8 OLI products were recently released. Artifacts in the OLI provisional products (e.g., "blockiness" near coastlines, inland water bodies, forested regions, and in areas of significant terrain change) are being investigated. Once these issues are resolved, the provisional label will be removed. Regarding surface-temperature products for TM, ETM+, and TIRS, the USGS, NASA/Jet Propulsion Laboratory, and RIT developers are continuing to work toward releasing surface temperature products. No release date has been set.

Dennis Helder [South Dakota State University—*Landsat Science Team*], **Brian Markham** [GSFC—*Landsat 8 Calibration Scientist*], **Joel McCorkel** [GSFC—*Landsat Science Team*] and **Jim Storey** provided a comprehensive Landsat calibration update on behalf of the Landsat calibration/validation team. Helder presented an analysis of Landsat 8 OLI radiometric performance since launch, and concluded that striping due to relative gain differences is largely not noticeable, but are most apparent in blue and SWIR bands. Vicarious methods of relative gain estimation perform similarly to onboard methods. Finally, the relative gains are changing slightly, but can be tracked using both diffuser and vicarious methods, and are being updated quarterly to minimize user impacts.

Markham showed radiometric stability statistics, and concluded that OLI is very stable, with the least stability in the coastal aerosol band (1% degradation over two years). Independent analysis shows that reflectance uncertainties are lower than those for radiance (~2% *versus* ~3%, respectively). The Landsat calibration/validation team recommends using OLI reflectance calibration, and advises propagating this calibration back to earlier Landsat sensors.

McCorkel summarized Climate Absolute Radiance and Refractivity Observatory (CLARREO)-sponsored design objectives for cross-calibration activities at the Aglodones Dunes test site in southern California using ground, airborne [Goddard's LiDAR, Hyperspectral & Thermal Imager(G-LiHT)], and satellite (Landsats 7 and 8) measurements. The data collected during 2015 will be used to improve satellite sensor inter-calibration.

Finally, **Storey** reviewed Landsat 8 geometric performance, and concluded that Landsat 8 meets or exceeds all requirements. Of note is that geolocation accuracy is measured at 18.1 m (~59 ft) circular error versus 29.2 m (~96 ft) circular error for the Landsat global land survey data.

One of the LST's priorities is improving the Landsat MSS record so that the full 43-year Landsat history can be used for land-change investigations. **Warren Cohen** [U.S. Forest Service—*Landsat Science Team*] and **Justin Braaten** [Oregon State University—*Graduate Research Assistant*] presented their perspectives on priorities for improving the MSS record. The radiometric relationship between MSS and other Landsat instrument measurements has been established due to the cross-calibrated work completed by **Dennis Helder** and colleagues. However, improving image geometry, cloud- and shadow-mask algorithms, developing surface reflectance algorithms, and defining standard cross-sensor spectral indices are needed. The LST concluded that more attention needs to be placed on improving the MSS record, and accepted Cohen and Braaten's recommendations for

priorities. The USGS was encouraged to assess the complexity of the improvements that are needed to increase the science value of the MSS record.

Sentinel-2 Investigations

Brian Markham and **John Dwyer** provided an update on NASA and USGS plans to establish synergy between Landsat and Sentinel-2. Markham summarized an ongoing technical exchange between the Landsat calibration/validation team and ESA's Sentinel-2 counterparts, addressing radiometric characteristics and performance between the Landsat 8 OLI and the Sentinel-2 Multispectral Instrument (MSI). Their objective is to support the synergistic use of Landsat and Sentinel-2 data and to facilitate calibration compatibility between the OLI and the MSI. Markham summarized relative spectral response and illustrated the similarities in SWIR bands and differences in the visible and near-infrared bands and discussed signal-to-noise ratio statistics between MSI and OLI. The group is currently trying to identify near-simultaneous orbital paths with similar view angles that can be used for cross-calibration.

Dwyer described the steps that USGS is taking to implement an initial capability for archiving and distributing all Sentinel-2 Level-1C format data (orthorectified TOA reflectance) from the USGS EROS long-term archive. Currently, planned capabilities will allow for an online disk cache of 360 days of Sentinel-2 imagery. Analysis is ongoing for providing reformatting that will make the Sentinel-2 imagery more consistent with Landsat Level-1T data.

Other Topics

Kass Green [Kass Green and Associates] summarized the activities of the Landsat Advisory Group (LAG). The LAG is part of the National Geospatial Advisory Committee and advises the federal government on the requirements, objectives, and actions of the Landsat Program as they apply to ongoing delivery of societal benefits for the U.S. and the Earth observation community, globally. The LAG recently updated their analysis of the value of Landsat and concluded that *"$350 million to over $436 million economic value of just one year of Landsat data far exceeds the multi-year total cost of building, launching, and managing Landsat satellites and sensors. It can be expected that these savings, and others not addressed here, will continue to accelerate."* Additional details are found at *www.fgdc.gov/ngac/meetings/december-2014/ngac-landsat-economic-value-paper-2014-update.pdf.*

Garik Gutman [NASA—*Land Cover Land Use Change (LCLUC) Program Manager*] summarized two LCLUC solicitations. Awards will be made this spring for Multi-Source Land Imaging research that address instrument characterization and cross-calibration, harmonization of data formats, standardization of the preprocessing algorithms, surface reflectance and derived products, and development of basic algorithms. He also identified some of the research already underway that contributes specifically to the synergistic use of Landsat and Sentinel-2 data. Finally, Gutman mentioned plans for a late-2015 solicitation addressing land-use and land-cover change research focused on South Asian topics.

Jeff Masek reviewed the effort of the Terrestrial Ecosystems Carbon Cycle Land Use/LandCoverChange and Biodiversity (TECLUB) study group. NASA established TECLUB to provide science input to the upcoming National Research Council Decadal Survey. The agency convened a group of experts and tasked them with identifying priority measurements needed to meet current and emerging science needs. A draft report is available at *cce.nasa.gov/cgi-bin/cce/teclub_comments.pl.*

Jim Nelson [USGS EROS—*Engineering and Development Manager*] introduced the EROS Architecture Study Team (EAST), which is tasked with providing a high-level concept for the systems architecture, infrastructure, and processes required to meet EROS Center strategic objectives. By summer 2015 EAST must define high-level concepts, considerations, assumptions, risks and benefits, and alternatives for the future EROS architecture and infrastructure that meets the needs of key EROS stakeholders and user communities. This requires consideration of new, cost-efficient technology, as well as potential interagency, international, and private-sector partnerships. NASA and NOAA representatives are contributing to EAST.

Tom Loveland gave a status report on the development of a special issue of *Remote Sensing of Environment* addressing Landsat 8 Science Results. Slated for publication in January 2016, the issue will contain 25 articles that address Landsat 8 performance, science, and applications advances, and the extension of the Landsat time series.

The next Landsat Science Team meeting will be held at the USGS EROS Center near Sioux Falls, SD, July 7-9, 2015. ■

meeting summaries

2014 GRACE Science Team Meeting

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The Gravity Recovery and Climate Experiment (GRACE) mission entered its thirteenth year on March 18, 2014. A joint endeavor between NASA and the Deutsches Zentrum für Luft-und-Raumfahrt (DLR) [German Aerospace Center], the twin GRACE satellites continue to improve our understanding of Earth's dynamic nature, making precise measurements of changes in gravity signals associated with exchange of mass between several Earth-system components. The 2014 GRACE Science Team Meeting (GSTM) took place September 29 – October 1, 2014, at the GeoForschungsZentrum (GFZ), Potsdam, Germany. More than 100 scientists and engineers attended the meeting, which provided 65 oral presentations and 13 posters in moderated discussions across 7 scientific sessions, addressing:

- GRACE Mission and Science Data System Status;
- Geodesy and Analytical Techniques and Intercomparison of GRACE Products;
- Multidisciplinary Applications;
- GRACE Follow-On, Gap Filling, and Future Gravity Missions;
- Cryosphere;
- Oceanography; and
- Hydrology.

Opening Remarks and Programmatic Updates

After a welcome by host **Frank Flechtner** [GFZ—*GRACE Co-Principal Investigator*], the meeting began with a presentation by **Byron Tapley** [University of Texas at Austin (UT), Center for Space Research (CSR)—*GRACE Principal Investigator*] on the status of and prospects for the GRACE mission. The mission has produced 137 (out of a maximum possible 150[1]) *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 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 Explorer (GOCE). He also stated that GRACE is advancing our understanding of global sea level change and contributions to that change from ice sheets.

Several programmatic presentations came next.

Mona Witkowski [NASA/Jet Propulsion Laboratory (JPL)] reviewed GRACE flight operations and satellite health. In particular, spacecraft battery operations require regular monitoring and management, to maximize satellite lifetime.

[1] To save energy the instruments onboard the GRACE satellites are turned off in a regular cycle. This leads to data gaps, and hence there are only usable data for 137 out of the 150 possible months that GRACE has been in orbit. The improvements are a natural evolution of satellite data releases and mainly due to improvements in the background models.

Group photo of 2014 GRACE Science Team Meeting attendees.

Gerhard Kruizinga [NASA/JPL] reviewed the status of JPL GRACE Level-1 processing.

Srinivas Bettadpur [UT/CSR]**, Michael Watkins** [NASA/JPL—*GRACE Project Scientist*[2]**],** and **Christoph Dahle** [GFZ] reviewed the status of the latest Level-2 products produced by the three centers.

Sean Bruinsma [Centre National d'Études Spatiales (CNES)—French Space Agency] presented information about the GOCE mission that came from ESA's *Living Planet Symposium*, held in Edinburgh, Scotland, in September 2013.

Science Sessions

The remainder of the meeting comprised seven 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.gfz-potsdam.de/en/section/globalgeomonitoringandgravityfield/topics/development-operation-and-analysis-of-gravity-field-satellite-missions/grace/gstm/gstm-2014/proceedings*.

GRACE Analysis Techniques and Intercomparisons of GRACE Products

Several presentations in this session introduced additional GRACE Level-2 solutions processed by groups at the Technical University (TU) of Bern and TU Graz in Germany, and at CNES. There was an update on a gridded product using physical constraints to solve for monthly GRACE gravity fields. Another group evaluated GRACE Level-2 products generated at different research centers against common metrics (e.g., Greenland's mass loss), and different ways to derive improved low-degree coefficients using new datasets and models were presented. Of key importance to the accuracy of GRACE data, data from the *star camera*—which is necessary for processing ranging and accelerometer data—were examined for errors, which led to parameterization of those errors to explore their effects on the resulting gravity fields. A third group examined the anomalies and analysis changes in the Atmosphere-Ocean De-aliasing product (AOD), coefficients which describe six-hourly, short-term atmospheric, oceanic, and atmosphere/ocean combined mass variations, important for generating the Level-1B orbit and gravity products.

The remaining presentations addressed GRACE data analysis methods and algorithms that focus on the problem of reducing noise in gravity estimates. With new 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.

GRACE Follow-On, Gap Filling, and Future Gravity Missions

This session included a summary of the GRACE Follow-On (GRACE-FO) flight system, payload, and ground-system status, all of which are progressing well toward a planned 2017 launch. Subsequent presentations provided additional detail about the laser interferometer and accelerometer status and expected performance. These GRACE-FO talks were augmented with a series of presentations on the use of nondedicated satellite laser ranging (SLR) and Global Positioning System (GPS)-tracked satellites for potential gap filling (if needed) between GRACE and GRACE-FO, and possible mission architectures that could succeed GRACE-FO farther into the future.

Multidisciplinary Applications

The multidisciplinary session opened with a discussion of accelerations in surface mass transport over the GRACE period. While both Greenland and Antarctica showed significant accelerations in mass loss, Alaska's glaciers showed a mass loss deceleration. Most other accelerations were not statistically significant, due to the limited record length and interannual variations. Contributions from *low-degree gravity coefficients* (e.g., geocenter and Earth oblateness) can be sizable and need further assessment. The second presentation described a new Antarctic regional glacial isostatic adjustment (GIA) estimate, derived from a combination of improved trends from GRACE; ESA's Environmental Satellite (Envisat); NASA's Ice, Cloud, and land Elevation Satellite (ICESat); and GPS data, which is part of the ESA-Support to Science Element (STSE)'s project known as Regional Glacial Isostatic Adjustment and CryoSat Elevation Rate Corrections in Antarctica (REGINA) (*www.regina-science.eu*). This approach used the distinctive signatures of elastic and viscoelastic processes from GRACE and GPS to identify elastic components in the GIA estimate and distinguish those from present-day mass loss.

Additional presentations continued the discussion of recent and historic GIA rates in Antarctica (specifically, Graham Land and the greater Antarctic Peninsula), and the implications on current mass balances. The new model for mass loss in this region suggests changes that started at least in the 1980s and are linked to substantial viscoelastic flow in Earth's mantle.

[2] Beginning July 1, 2015, **Michael Watkins** will become Director of the University of Texas, Center for Space Research, replacing **Byron Tapley** in that role. Tapley will remain affiliated with UT/CSR and remain GRACE PI. **Carmen Boening** [JPL] will become the new Project Scientist for GRACE as of July 1, but Watkins will remain actively involved in the GRACE mission.

meeting summaries

The final presentation in this session compared polar motion excitation functions computed from different sets of gravimetric coefficients. While there is good agreement between gravimetric-hydrological excitation functions and geodetic residuals for a statistical (χ^2) component of gravimetric excitation functions, differences between the processing centers still exist for the other components. Finally, a poster showcased successful strategies to enhance science and practical applications of the proposed GRACE-FO mission based on findings supported by NASA's Applied Science Program. Recent applications from both academic and operational users were presented, to identify projects where GRACE data may improve decision-making.

Cryosphere

The cryophere session included presentations addressing improvements in techniques for deriving ice mass change rates (and accelerations) and their error estimates. Leakage from ocean signals could contribute a bias in Antarctic mass loss of up to 20 Gt/yr and errors associated with stripes are insignificant at time scales of 10 years and longer. A significant correlated error reduction in the standard GRACE product may be needed to separate contributions from surface mass balance and ice discharge in Greenland. Research using new Release-02 GSFC mascon solutions found a continuous increase in mass loss in Alaska, Greenland, and Antarctica, and a gain in mass in East Antarctica. Data from SLR and the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) sensor showed that a reconstruction of mass loss captures major loss features of the ice sheets and has potential for bridging the data gap between GRACE and GRACE-FO. Other work showed that the acceleration in mass loss is widespread in Greenland and localized in a few regions in Antarctica, with a large increase in the Canadian ice caps. An analysis of JPL GRACE mascon solutions in terms of local-to-regional variability in Antarctic ice mass change since 2003 revealed that a significant percentage of the interannual signal in various locations is dominated by surface mass balance.

Oceanography

The oceanography session brought forth major advances due to improvements in data quality enabled by Release-05 gravity field solutions. Locations discussed ranged from the Bay of Bengal to the global oceans, from the Arctic Ocean to the Antarctic Bellingshausen Basin. The topics included both barotropic and baroclinic ocean motions, tides and currents, as well as contributions of ocean circulation to polar motion, and ranged in frequency from semidiurnal (tides), to 30-to-60-day oscillations, to decadal time scales.

From a global perspective, the important topic of Earth's surface temperature "hiatus" was discussed, showing that surface temperatures over land and ocean have, on average, not increased over the past decade, while energy input to the Earth and greenhouse gases have not changed significantly—a discrepancy of 0.64 W/m^2 in the energy balance calculation. Various explanations have been offered for this puzzling observation, most notably that the deep ocean has absorbed this excess heat. This work—using GRACE, altimetry, and Argo float data—demonstrated that within the uncertainties, the upper 2000 m (6600 ft) of the ocean has absorbed this "missing" heat (see **Figure 1**).

The global ocean distribution of barotropic and baroclinic contributions to ocean bottom pressure in GRACE data, and a version of the Estimating the

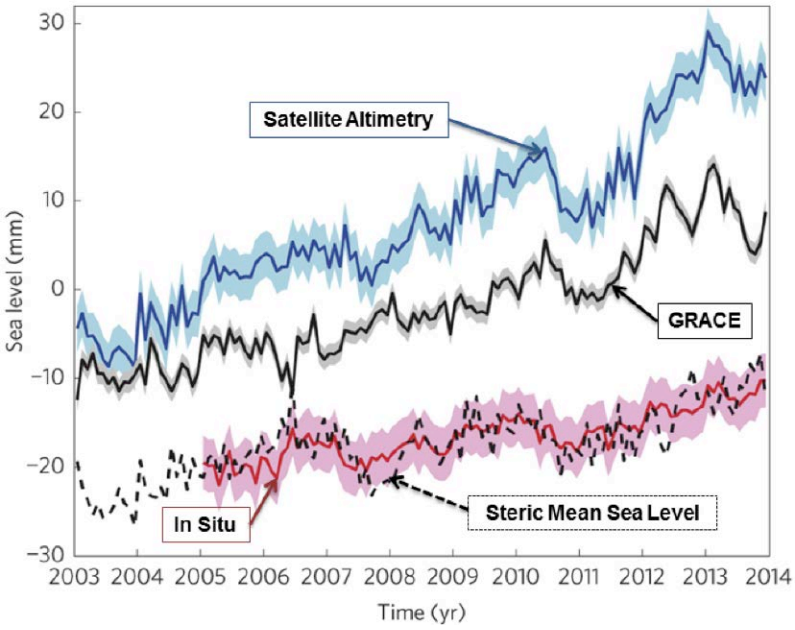

Figure 1. GRACE, in combination with sea surface height estimates from altimetry and ocean heat content from Argo buoys, helps to quantify potential contributions from deep ocean variability to global sea level change. The estimates are observed variations by satellite altimetry, ocean mass contributions based on GRACE data, and steric sea level based on *in situ* observations. The dashed black curve shows the indirect steric mean sea-level estimate inferred by removing ocean mass contributions from the observed sea-level time series. Seasonal signals have been removed from all curves, and the curves are offset for clarity. Shaded blue, gray, and pink, where shown, denotes one standard deviation of uncertainty in the respective estimates. The agreement between the red (*in situ*) line and the dashed black (steric mean sea level) curve indicates that the heat absorbed by the ocean is stored in the upper 2000 m (6600 ft) of the ocean. **Image credit**: William Llovel [JPL] *et al.*

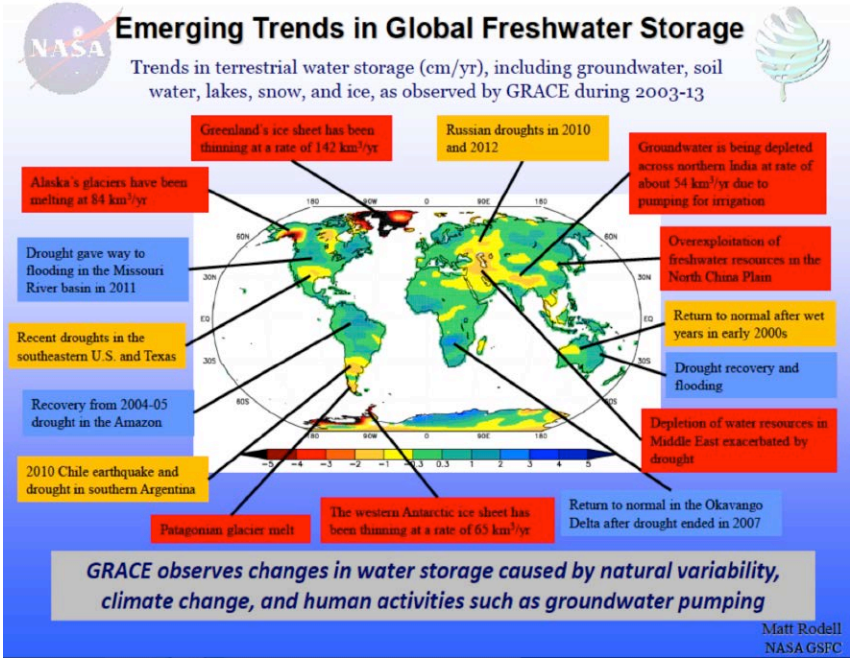

Figure 2. GRACE can detect long-term changes in freshwater storage, including extensive droughts, depletion due to groundwater pumping, and melt from the major ice sheets and mountain glaciers. **Image credit:** Matt Rodell [NASA's Goddard Space Flight Center] *et al.*

Circulation & Climate of the Ocean (ECCO[3]) ocean state estimate were presented. In the barotropic mode, sea level and ocean bottom pressure (OBP) are strongly correlated, while baroclinic motions act differently in sea level and OBP. This work thus showed regions where baroclinic Rossby waves, flow-topography interactions, and vertically-trapped signals are evidenced.

A number of the presentations reported on research in polar regions. One focused on the Arctic ocean and showed that a combination of GRACE OBP with data from a bottom pressure recorder (BPR) are well correlated with the Arctic Oscillation Index, and that a modal decomposition of GRACE data with the BPR could help bridge a data gap between GRACE and GRACE-FO. GRACE data and the "model adjoint" tool—central to an ECCO state estimate—were used to find the mechanism behind a coherent, near-uniform fluctuation in OBP and sea level across the Arctic Ocean and Nordic Seas and winds along the continental slope of the Arctic. Another presentation focused on the Antarctic Circumpolar Current transport and its relation to wind forcing.

Other presentations focused on smaller scale processes. For example, there was a discussion of a high-frequency (30-60 day) oscillation in the Argentine basin region of the South Atlantic, which showed that two numerical models failed to properly represent a signal present in GRACE and radar altimetry of anticyclonic propagation trapped in that basin. There was also discussion of a study focusing on the Bay of Bengal region using GRACE, altimetry, and *in situ* data in a joint inversion and concluding that sea level rise in the Bay of Bengal is currently dominated by steric effects, which include thermal expansion and well as the impact of salinity. In this case, thermal expansion is dominant.

[3] ECCO is a consortium that was established in 1998 as part of the World Ocean Circulation Experiment (WOCE) with the goal of combining a general circulation model (GCM) with diverse observations in order to produce a quantitative depiction of the time-evolving global ocean state.

Hydrology

The hydrology session focused on advances in hydrology applications of GRACE data products, including signal interpretation, model assimilation, hydrological trends, long-term freshwater storage variations, and terrestrial hydrology. The session opened with a presentation on hydrologic extremes detected by GRACE (see **Figure 2**). Other talks addressed GRACE climate applications and addressed models and observations of drought, groundwater depletion, validation of global hydrologic cycle models, terrestrial water storage variations, atmospheric model synergies with GRACE, and assimilation of GRACE with other observations to determine variations in Siberian permafrost.

Conclusion

While 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 missions operations team [which is comprised of representatives from the German Space Operations Centre (GSOC), GFZ, JPL, and UT/CSR] is working, with industry support, to minimize the data gap between the GRACE measurements and the GRACE-FO measurements and ensure continuity of this important measurement into the next decade.

The next GRACE STM will be held in Austin, Texas, September 21–23, 2015. ■

meeting summaries

ECOSTRESS Science Team Meeting

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Introduction

The first ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) Science Team meeting took place on December 14, 2014, at the SF Green Space[1] in San Francisco, CA. Attendees included **Simon Hook** [NASA/Jet Propulsion Laboratory (JPL)—*Principal Investigator (PI)*], **Joshua Fisher** [JPL—*Science Lead*], **Glynn Hulley** [JPL], **Martha Anderson** [U.S. Department of Agriculture (USDA)], **Andrew French** [USDA], **Rick Allen** [University of Idaho], **Eric Wood** [Princeton University], and **Christopher Hain** [University of Maryland].

ECOSTRESS is one of two instruments chosen from the second Earth Venture Instrument (EVI-2) Pathfinder Program Announcement of Opportunity (AO)[2]. The ECOSTRESS radiometer is currently planned for delivery to NASA's Johnson Space Center in 2017, with launch to the International Space Station (ISS) scheduled for shortly thereafter from Kennedy Space Center with Space X. The mission will provide a high-resolution spatial and temporal view into vegetation-water dynamics and how ecosystems respond to changes in climate. It will be the first mission that will be able to observe diurnal changes in global vegetation.

Meeting Highlights

The purpose of the meeting was for the science team to review mission science specifications, milestones, and schedules, and to further detail the roles and responsibilities of each science team member.

Simon Hook kicked off the meeting with an overview of the ECOSTRESS mission. As PI, Hook is responsible for the complete science investigation and for ECOSTRESS instrument development and activities necessary to deliver the science results, as agreed to in the Program Level Requirements Appendix (PLRA) of the AO. The mission leverages the successful design, construction, and testing of the Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR), which was initially developed to support testing and assessment for the Hyperspectral Infrared Imager (HyspIRI[3]) under the auspices of the Earth Science Technology Office (ESTO). ECOSTRESS consists of a cross-track, push-whisk-broom, scanning, multiband filter radiometer with five spectral bands between 8 and 12.5 µm, and a high spatial resolution of 38 m (125 ft, in-track) by 69 m (226 ft, cross-track), and will be deployed on the Japanese Experiment Module – External Facility on the ISS—see **Figure**. Because of the precessing orbit of the ISS, the ECOSTRESS will enable vegetation water stress assessments on a diurnal scale[4].

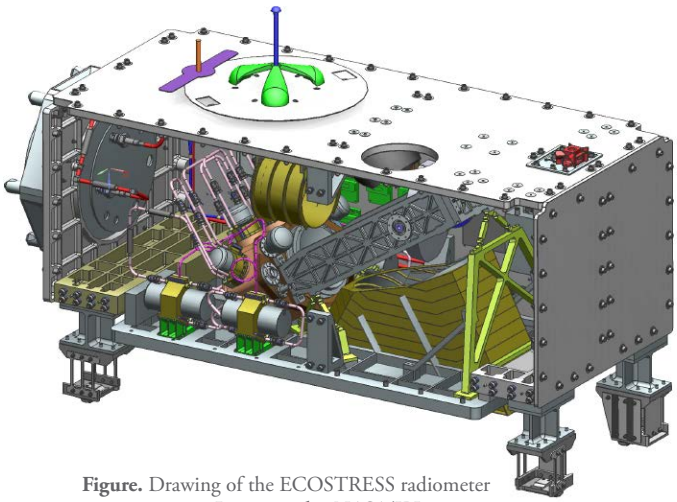

Figure. Drawing of the ECOSTRESS radiometer in its container. **Image credit**: NASA/JPL

Joshua Fisher then presented the science questions that ECOSTRESS will address, which include:

- How does the terrestrial biosphere respond to changes in water availability?
- How do changes in diurnal vegetation water-stress impact the global carbon cycle?

[1] For more information, visit *www.sfgreenspace.com/greenspace/the-space*

[2] The Science Mission Directorate (SMD) at NASA Headquarters selected two proposals from among those submitted in response to the Second Stand Alone Mission of Opportunity Notice (SALMON-2), Program Element Appendix (PEA) M: Earth Venture Instrument-2, *NNH12ZDA0060-EVI2.* The other instrument chosen was the Global Ecosystem Dynamics Investigation (GEDI).

[3] The 2007 National Research Council's (NRC) 2007 Decadal Survey report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, identified HyspIRI as a *Tier-2* priority. The most recent update on the progress of HyspIRI appears in the March–April 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 2**, pp. 32-33].

[4] The sidebar, *Changes Throughout the Day*, in the article "ISS RapidScat: Measuring Ocean Winds from the International Space Station" in the September–October 2014 issue of *The Earth Observer* [**Volume 26**, **Issue 4**, p. 8] explains how the unique orbit of ISS allows for full sampling of diurnal and semidiurnal wind cycles. Similar sampling will be used to study diurnal water stress changes in vegetation. ECOSTRESS will be able to capture a diurnal cycle within a short period of time.

- Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improving drought estimation?

As Science Lead, Fisher will help ensure that each of the science objectives are met and captured within the mission's measurements and algorithms.

Glynn Hulley covered the planned ECOSTRESS data products—see **Table**. Specifically, he discussed how ECOSTRESS data will be processed to Level-2 [surface temperature and emissivity], which will allow for the development of Level-3 [Evapotranspiration (ET)] and Level-4 [Water Use Efficiency (WUE), Evaporative Stress Index (ESI)] products. **Martha Anderson** then presented details about how she will use the ALEXI[5] model to develop ET products and work with JPL to produce Level-4 ESI measurements. These products can be used to study vegetation water stress or develop applications such as early warnings to farmers and water resource managers of impending drought. Typical users may include water resources agencies in the Western U.S. and farmers, who can use this information to help in their response to drought conditions, water availability, and agricultural water requirements. Other users may be the U.S. Department of Agriculture and the U.S. Agency for International Development. Examples of how this kind of information has been used in the past include planning food aid interventions, improving irrigation water use efficiency practices, and estimating historical water use for negotiating water rights transfer.

Table. Planned ECOSTRESS data products

Data Product	Description
Level-0	Raw collected telemetry
Level-1	Calibrated geolocated radiances
Level-2	Surface temperature and emissivity
Level-3	Evapotranspiration (ET)
Level-4	Water Use Efficiency (WUE); Evaporative Stress Index (ESI)

Expected Contributions of ECOSTRESS

In addition to introducing the new mission, many of the discussions highlighted the contributions expected from ECOSTRESS data. The mission will significantly contribute to our ability to monitor water stress in vegetation on a field-to-continental scale with considerable implications for understanding Earth's water and energy cycles, as well as applications in global water and food security issues. ECOSTRESS will have a revisit frequency of four days for most of the continental U.S. and will also sample other key regions throughout the world with various sampling times each day; this sampling pattern will thus allow for evaluations of vegetation water stress on a diurnal scale, which no other mission has done at a global scale with such resolution and accuracy. Some of the specific contributions include:

- detecting differences in plant water use among highly heterogeneous landscapes, both natural and human-dominated;
- detecting where and when plants shut down[6] during the day due to water stress;
- detecting which plants are more water-use efficient than others, with implications to mortality susceptibility under increasing droughts;
- helping inform agricultural management decisions;
- helping account for longwave contributions to energy balance/net radiation calculations;
- investigating ET response to global drought events, to allow downscaling of regional evaporative stress indices, yielding impacts on phenology due to such stress.

Conclusion

The first ECOSTRESS science team meeting provided an opportunity to discuss the ECOSTRESS science goals and objectives and refine the plans and schedules for delivering ECOSTRESS data and science results. Going forward, the ECOSTRESS team anticipates holding annual open meetings before the Fall American Geophysical Union Meetings, and contributing to ongoing HyspIRI meetings.

Additional information about ECOSTRESS is available online at *ecostress.jpl.nasa.gov*. ■

[5] ALEXI stands for Atmosphere-Land-Exchange Inverse, which is used to model evapotranspiration.

[6] Morphological, biochemical, physiological, and molecular processes can stop functioning properly when plants are under stress. If the stress is long term, this can lead to fallowed areas or death of these plants. More specifically, plants close their leaf pores (*stomata*) when water-stressed. This cuts off their ability to take up carbon dioxide and conduct photosynthesis; thus, the carbon-uptake and water-release process is "shut down" when stomata are closed.

in the news

NASA Soil Moisture Mission Produces First Global Maps

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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.

With its antenna now spinning at full speed, NASA's new Soil Moisture Active Passive (SMAP) observatory has successfully retested its science instruments and generated its first global maps, a key step to beginning routine science operations next month.

SMAP launched January 31, 2015, on a minimum three-year mission to map global soil moisture and detect whether soils are frozen or thawed. The mission will help scientists understand the links among Earth's water, energy, and carbon cycles; help reduce uncertainties in predicting weather and climate; and enhance our ability to monitor and predict natural hazards such as floods and droughts.

In late March, mission controllers at NASA's Jet Propulsion Laboratory successfully spun SMAP's 20-ft-wide (6-m) antenna up to its full speed of 14.6 revolutions per minute in a two-step process. SMAP's spinning antenna makes cone-shaped scans across Earth's surface, measuring a 620-mi-wide (1000-km) swath of the ground as it flies above Earth from pole to pole at an altitude of 426 mi (685 km). The wide swath width and polar orbit allow SMAP to map the entire globe with high-resolution radar data every two to three days.

With its spin-up activities complete, the observatory's radar and radiometer instruments were powered on from March 31 to April 3 in a test designed to verify the pointing accuracy of the antenna and the overall performance of the radar and radiometer instruments. The radar data acquired from the test have been processed to generate data products with a spatial resolution of about 19 mi (30 km).

SMAP's radar, operating at 1.2 GHz, works by transmitting microwave pulses to the ground and receiving and measuring the strength of the signals that bounce back from Earth, called *backscatter*. Water—including water in soil—responds differently than dry soil does to microwaves. Water changes the strength of backscatter and microwaves' *polarization* (the orientation of the electrical field of the microwaves). Therefore, backscatter from soil containing more moisture is stronger and is polarized differently than backscatter from drier soil.

The extent of this difference allows scientists to distinguish the amount of moisture present in the soil. SMAP's radar emits pulses with two different polarizations, horizontal and vertical, to make a more complete measurement of this effect.

Like the radar, SMAP's radiometer detects differences in microwaves caused by water in soil; but it measures Earth's natural microwave emissions at the frequency of 1.4 GHz. Around the globe, the most striking difference in these natural emissions is between water and land surfaces. A desert emits microwaves at about three times the rate a lake does. Because the difference is so large, even a small amount of moisture in soil causes a change that a radiometer can measure accurately.

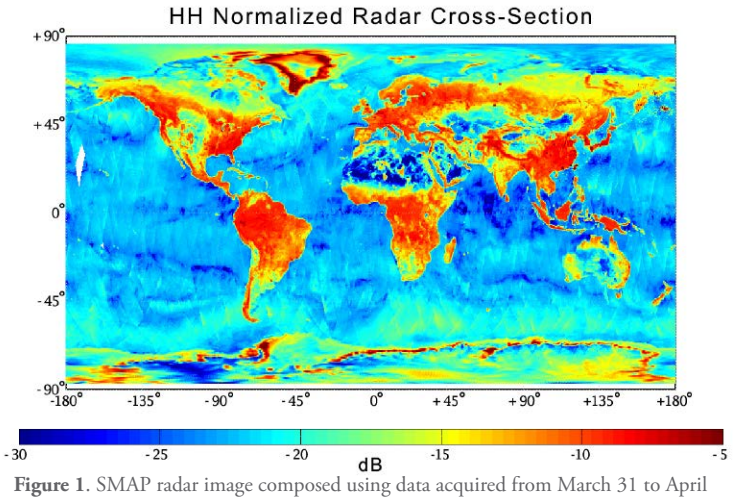

Figure 1. SMAP radar image composed using data acquired from March 31 to April 3, 2015. Weaker radar signals (blue) reflect low soil moisture or lack of vegetation, such as in deserts. Strong radar signals (red) are seen in forests. SMAP's radar also takes data over the ocean and sea ice. See text for more description. **Image credit**: NASA/JPL, GSFC

In the composite radar image (shown in **Figure 1**) global land, ocean, and ice conditions are readily apparent. The weaker radar signals measured over the Sahara and Gobi Deserts, depicted in blue shades, reflect their very low soil moisture content and lack of vegetation cover. In contrast, the densely vegetated Amazon and Congo rain forests have very strong radar signals, depicted in reds. In North America, the boreal forests and tree canopies in the Rockies, Sierra Nevada, and Cascade mountain ranges, and areas east of the Mississippi River, also have strong radar echoes. Grasslands and prairies in the U.S. Great Plains, a great expanse of flat land, exhibit relatively lower-strength radar echoes.

SMAP's radar also takes data over Earth's ocean and sea ice. Variations in radar data over the open ocean reflect variations in surface wind conditions, with relatively low winds in the tropics and high winds at high latitudes. Arctic sea ice, which contains air bubbles and pockets of brine, produces radar echo strengths similar to those seen over grassland or tundra.

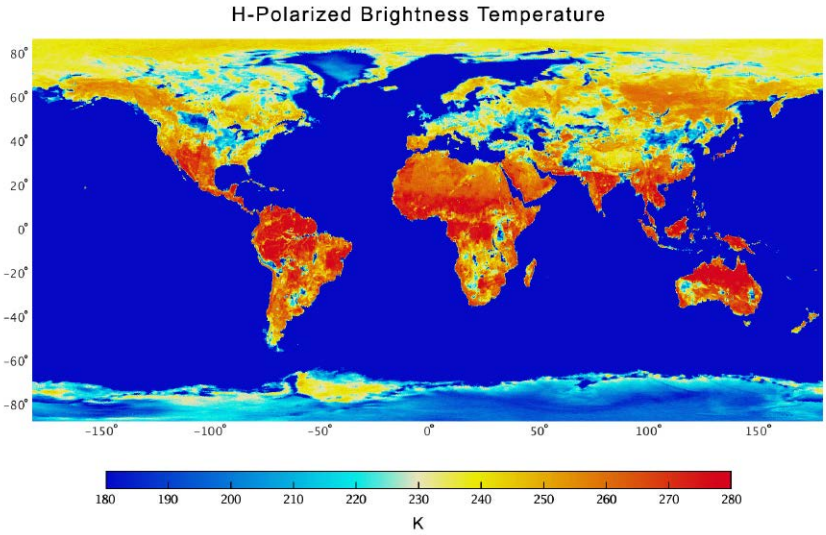

Figure 2. SMAP radiometer image composed of data obtained from March 31 through April 3, 2015 shows surface microwave emissions as brightness temperatures in Kelvin, with strong emissions in red and weaker emissions in blue. Vegetated rainforests and dry deserts show strong emissions; Greenland and Antarctica have weak emissions. **Image credit**: NASA/JPL-Caltech, GSFC

The radiometer data from the instrument test (shown in **Figure 2**) have also been processed to map microwave emissions from Earth's surface, expressed as *brightness temperatures* (a measurement of how much microwave radiant energy is traveling up from Earth's surface to the satellite) in Kelvin (K) and at a horizontal spatial resolution of about 25 mi (40 km). The Amazon and Congo rainforests produced strong emissions, depicted in red shades, due to their large volumes of biomass. Brightness temperatures in the Sahara Desert reach about 80 °F (~ 300 K) due to its low moisture content. The impact of soil moisture is evident over a large region south of the Great Lakes, where an increase in soil moisture due to precipitation in March resulted in relatively cool brightness temperatures of about -100 °F (~200 K). Similar impacts of rain on soil moistures and brightness temperatures are seen in Namibia and Botswana, Africa, where there was significant rainfall in late March.

The radiometer brightness temperatures of Earth's ocean are mostly below -172 °F (160 K), reflected by the ocean's blue color. However, with the application of a different color scale to highlight the subtle variations over the ocean, the effects of winds on the ocean are also apparent. The brightness temperatures of Greenland and Antarctica are low [approximately 100 °F (200 K)] due to their low physical temperatures and the high emissivity of ice and snow (the efficiency of these polar regions at emitting thermal energy). The brightness temperatures of sea ice fall in the middle range because its salt content is less than the salty water in the ocean, but high enough to distinguish it from land surfaces.

The SMAP mission is required to produce high-resolution maps of global soil moisture and detect whether soils are frozen or thawed. SMAP's radar has two data acquisition functions: one for synthetic aperture radar (SAR) processing to produce radar measurements at a spatial resolutions between 0.6 and 1.9 mi (1 and 3 km, respectively), and another for low-resolution processing to produce radar measurements at a spatial resolution of 19 mi (30 km). The SAR function will be used over land surfaces and coastal oceans during routine science operations, while low-resolution processing will be exercised over land as well as over global ocean areas. Since the SAR function was only turned on for limited durations during the test from March 31 to April 3, mission scientists did not obtain enough SAR data to produce global high-resolution maps. SMAP has now begun conducting regular SAR observations that will enable high-resolution global mapping of land surfaces about every two-to- three days.

Scientists will combine measurements from SMAP's radar and radiometer sensors to capitalize on the strengths of each and work around their weaknesses. The radar alone can produce a soil moisture measurement with a spatial resolution of about 1.9 mi (3 km), but the measurement itself is less accurate than the one made by the radiometer. The radiometer alone achieves a highly accurate observation of soil moisture but with a much poorer spatial resolution of about 25 mi (40 km). By combining these separate measurements through advanced data processing, SMAP will provide the user community with a combined soil moisture measurement that has high accuracy and a resolution of 5.6 mi (9 km). The advanced processing required to combine these active and passive measurements is now being functionally checked out, and is the last step in SMAP's post-launch checkout process. SMAP will offer the individual radar and radiometer data, among other data products.

For more information on SMAP, visit *www.nasa.gov/smap*. ■

in the news

NASA's ISS-RapidScat Wind Data Proving Valuable for Tropical Cyclones

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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 International Space Station Rapid Scatterometer (ISS-RapidScat) has been in orbit seven months, and forecasters are already finding this new eye-in-the-sky helpful as they keep watch on major storms around the globe. ISS-RapidScat measures Earth's ocean surface wind speed and direction over open waters. The instrument's data on ocean winds provide essential measurements for researchers and scientists to use in weather predictions—including hurricane monitoring. The NASA instrument arrived at the ISS on September 23, 2014, thereby providing a new resource for tracking and studying storms ranging from tropical cyclones to nor'easters. ISS-RapidScat has been observing the already active 2015 Southern Hemisphere hurricane season as well as the Northern Hemisphere's winter storm season.

According to **Bryan Stiles** [NASA/Jet Propulsion Laboratory—*Lead for RapidScat Data Processing*], "RapidScat data are now used by meteorological agencies around the world, including the U.S. Navy, the National Oceanographic and Atmospheric Administration (NOAA), and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), among others. Wind data obtained by RapidScat have been used by NOAA to detect gale force and storm force conditions and issue warnings to shipping. The wind data are available to both forecasters and scientists. ISS-RapidScat data are used to support real-time weather prediction and to improve the models scientists use to predict both short-term weather and long-term climate trends."

From the station, this orbiting scatterometer instrument uses radar pulses reflected from the ocean's surface from different angles to measure ocean surface roughness, which is then used to determine surface wind speed and direction. This unique vantage point, combined with the fact that the space station orbits Earth every 90 minutes, also allows RapidScat to provide observations on how ocean winds vary over the course of the day.

"Most Earth-observing satellites are in polar, sun-synchronous orbits, meaning they observe the same locations at the same two local times of day with a regular repeating pattern," said **Doug Tyler** [JPL—*RapidScat Team Member*]. "Because of the unique orbit of the space station, RapidScat observations occur at varying times of day with an irregular repeat period. RapidScat sometimes see things several times in a row. For example, the ISS orbit provided three overpasses of [Tropical Storm] Nathan in 23 hours, allowing RapidScat to capture changes in wind speed and direction as the storm developed."

The Joint Typhoon Warning Center (JTWC) forecasts tropical cyclones in several oceans and is also using ISS-RapidScat data. On March 15 at 0428 UTC, JTWC noted, "RapidScat showed that [Tropical Cyclone] Nathan's strongest winds (still assessed at 40 knots) remained in the northern periphery of the system, with significantly weaker winds in the southern portion"—see **Figure 1**. It's helpful to know where the strongest

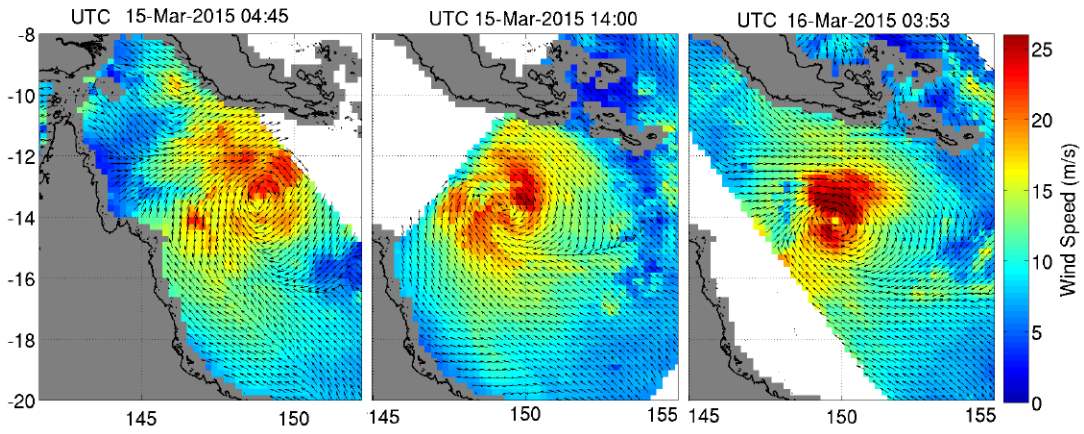

Figure 1. ISS-RapidScat data showed that on March 15, 2015, Tropical Cyclone Nathan's strongest winds were up to 56 mph (90 kph) as indicated by the red shades. Throughout March 15 and 16, the area of strongest winds shifted from north, to east, to northeast. Having such specific knowledge of where the strongest winds are located in the storm is helpful to forecasters when issuing warnings. **Image credit**: JPL/Doug Tyler

winds are in the system to enhance warnings, especially if they are affecting land or in a shipping channel.

The same week, ISS-RapidScat provided surface wind data on the most powerful tropical cyclone to affect the Southern Pacific island nation of Vanuatu—Tropical Storm Pam. After Pam became an extra-tropical cyclone and moved near New Zealand, ISS-RapidScat continued to provide the location and speed of the strongest surface winds, which assisted with warnings (see **Figure 2**).

Earlier this year, ISS-RapidScat also provided wind data on a Nor'easter that affected New England and triggered blizzard warnings on January 27–28, 2015. The wind data captured on the intense system showed the strongest winds on the first day near 78 mph (126 kph) as it moved along the coast, stretching from eastern Long Island, NY, to southern Nova Scotia, Canada. **Figure 3** shows an observation from January 28.

From these examples, it is evident that ISS-RapidScat data are providing valuable information to meteorologists in tracking storm development, from an intense winter nor'easter along the east coast of the U.S. to powerful tropical cyclones in the Southern Pacific Ocean. Thanks to the space station's unique orbit, the data are also helping scientists discover how ocean winds vary on shorter timescales, which will help improve models used to predict both short-term weather and long-term climate trends. ■

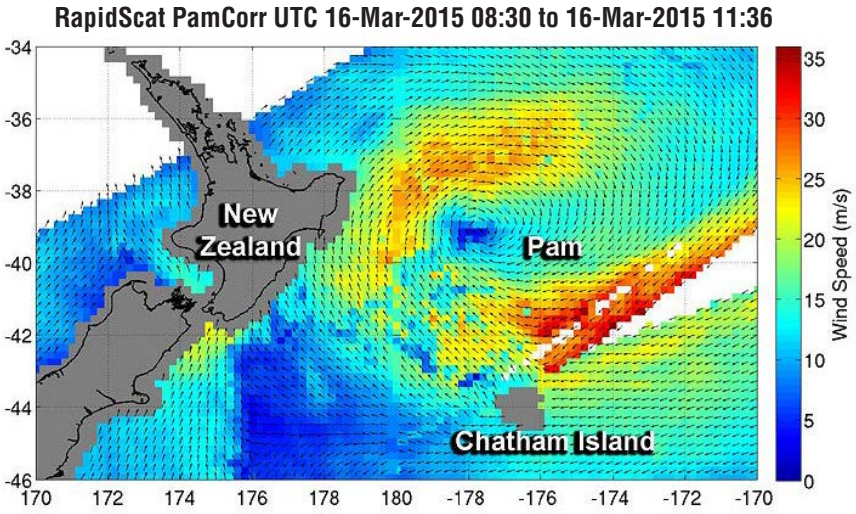

Figure 2. ISS-RapidScat observed Tropical Cyclone Pam on March 16, 2015. At that time, the storm had sustained winds over 67 mph (108 kph), indicated by the red shades located southeast of its center, and was transitioning to an extra-tropical cyclone as it moved near New Zealand. **Image credit**: JPL/Doug Tyler

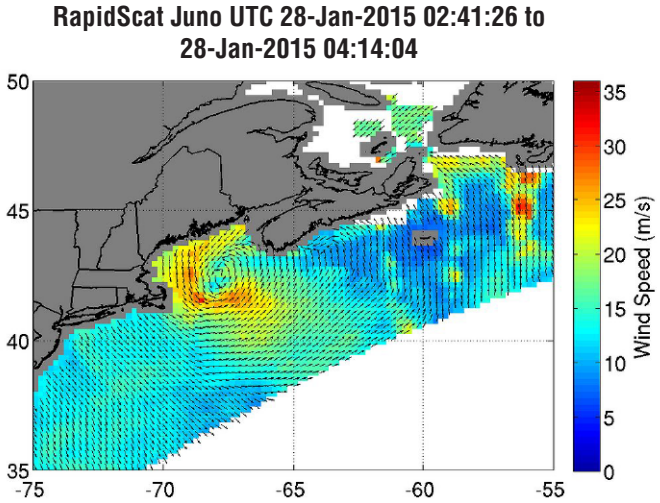

Figure 3. On January 28, 2015, ISS-RapidScat observed a strong Nor'easter that was impacting New England, with some areas near the coast experiencing blizzard conditions. Scatterometer observations obtained from 2:41 to 4:14 UTC, indicate that the storm's strongest winds were located just off-shore from eastern Cape Cod, where sustained winds (red shades) were between 56 and 67 mph (90 to 108 kph). **Image credit**: JPL/Doug Tyler

in the news

NASA, USGS Begin Work on Landsat 9 to Continue Land Imaging Legacy

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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.

NASA and the U.S. Geological Survey (USGS) have started work on Landsat 9— planned for launch in 2023—which will extend the Nation's Earth-observing program's record of land images to half a century.

The Landsat program has provided accurate measurements of Earth's land cover since 1972. With data from Landsat satellites, ecologists have tracked deforestation in South America, water managers have monitored irrigation of farmland in the American West, and researchers have watched the growth of cities worldwide. Further, with the help of the program's open archive, firefighters have assessed the severity of wildfires and scientists have mapped the retreat of mountain glaciers.

The President's fiscal year 2016 budget calls for initiation of work on a Landsat 9 spacecraft as an upgraded rebuild of Landsat 8, as well as development of a low-cost thermal infrared (TIR)-measuring free-flying satellite—scheduled for launch in 2019 to reduce the risk of a data gap in this important measurement. The TIR "free flyer" will ensure data continuity by flying in formation with Landsat 8. The budget also calls for the exploration of technology and systems innovations to provide more cost effective and advanced capabilities in future land-imaging missions beyond Landsat 9, e.g., finding ways to miniaturize instruments to be launched on smaller, less-expensive satellites.

"Moving out on Landsat 9 is a high priority for NASA and USGS as part of a sustainable land imaging program that will serve the nation into the future as the current Landsat program has done for decades," said **John Grunsfeld** [NASA Hedquarters—*Associate Administrator for Science*]. "Continuing the critical observations made by the Landsat satellites is important now and their value will only grow in the future, given the long term environmental changes we are seeing on planet Earth."

Because an important part of the land-imaging program is to provide consistent long-term observations, this mission will largely replicate its predecessor, Landsat 8. Like its predecessor, Landsat 9 will have two instruments onboard, one that captures views of the planet in visible, near-infrared, and shortwave-infrared light, and another that measures the thermal infrared radiation, or heat, of Earth's surfaces. These instruments have sensors with moderate resolution and the ability to detect more variation in intensity than the first seven satellites in the Landsat program.

The Landsat 9 mission is a partnership between NASA and the USGS. NASA will build, launch, and perform the initial check-out and commissioning of the satellite; USGS will operate Landsat 9 and process, archive, and freely distribute the mission's data.

"Landsat is a remarkably successful partnership," said **Sarah Ryker** [USGS—*Deputy Associate Director for Climate and Land Use Change*]. "Last year the White House found that GPS, weather satellites, and Landsat are the three most critical types of Earth-orbiting assets for civil applications, because they're used by many economic sectors and fields of research. Having Landsat 9 in progress, and a long-term commitment to sustainable land imaging, is great for natural resource science and for data-driven industries such as precision agriculture and insurance."

NASA's Goddard Space Flight Center (GSFC) will lead development of the Landsat 9 flight segment. GSFC will also build the Thermal Infrared Sensor (TIRS), which will be similar to the TIRS that the center built for Landsat 8. The new improved TIRS will have a five-year design lifetime, compared to the three-year design lifetime of the sensor on Landsat 8.

"This is good news for Goddard, and it's great news for the Landsat community to get the next mission going," said **Del Jenstrom** [GSFC—*Landsat 9 Project Manager*]. "[Landsat 9] will provide data consistent with, or better than, Landsat 8."

With decades of observations, scientists can tease out subtle changes in ecosystems, the effects of climate change on permafrost, changes in farming technologies, and many other activities that alter the landscape.

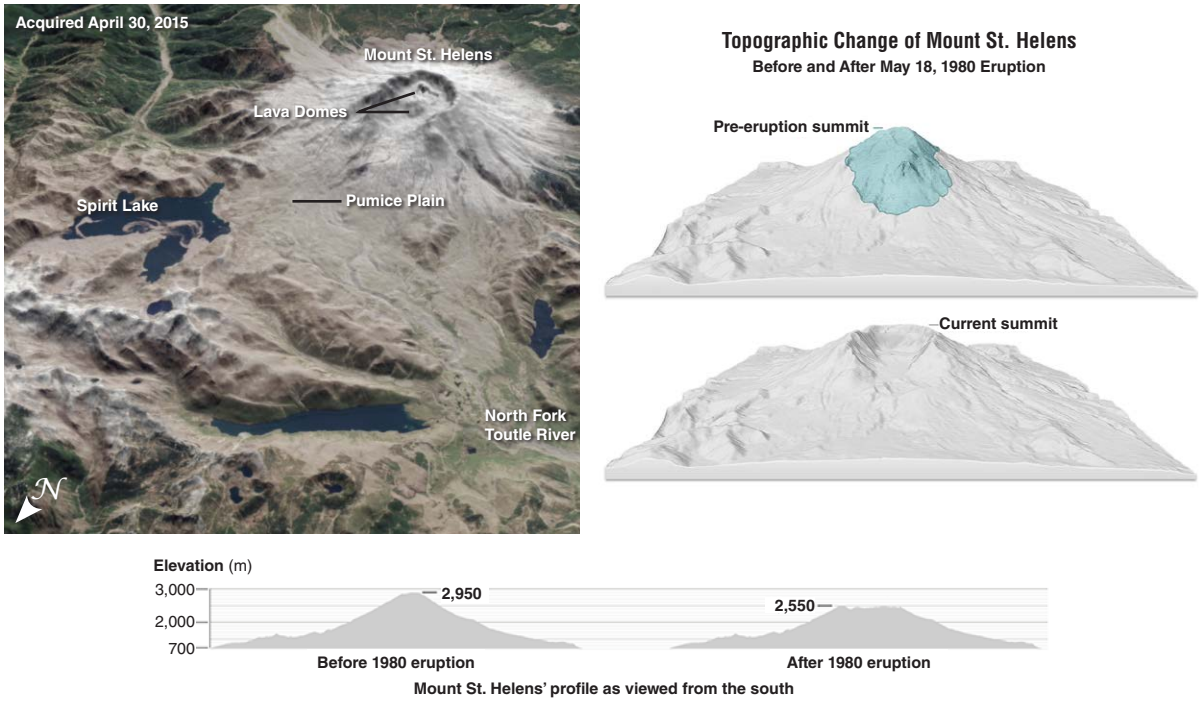
"With a launch in 2023, Landsat 9 would propel the program past 50 years of collecting global land cover data," said **Jeffrey Masek** [GSFC—*Landsat 9 Project Scientist*]. "That's the hallmark of Landsat: the longer the satellites view the Earth, the more phenomena you can observe and understand. We see changing areas of irrigated agriculture worldwide, systemic conversion of forest to pasture—activities where either human pressures or natural environmental pressures are causing the shifts in land use over decades."

"We have recognized for the first time that we're not just going to do one more, then stop, but that Landsat is actually a long-term monitoring activity, like the weather satellites, that should go on in perpetuity," Masek said.

For more information on the Landsat program, visit *landsat.gsfc.nasa.gov* and *landsat.usgs.gov* ■

Mount St. Helens 35 Years After Eruption

Kathryn Hansen, NASA's Goddard Space Flight Center, kathryn.h.hansen@nasa.gov



May 18, 2015, marked the 35th anniversary of the eruption of Mt. St. Helens. The ASTER image [*left*] was acquired on April 30, 2015; it shows the area as it looks today. The image pair [*right*] shows digital elevation model data comparing the topography of the mountain before and after the eruption. See text for further description. **Image credit:** NASA Earth Observatory images by Jesse Allen and Joshua Stevens, using Landsat data from the U.S. Geological Survey and ASTER GDEM2 data from NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.

On May 18, 1980, Mount St. Helens gave way to a cataclysmic flank collapse, avalanche, and explosion that killed 57 people and displaced many others. The event dramatically reshaped the volcano and surrounding land in southwest Washington.

Now, 35 years later, satellites in orbit and scientists on the ground still monitor the mountain and track its recovery. The top left image shows a three-dimensional view of the mountain, looking toward the southeast, as it appeared on April 30, 2015. The image was assembled from data acquired by the Operational Land Imager on Landsat 8 and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on Terra.

The mountain's north flank was the site of the collapse and lateral explosion that devastated 390 km^2 (150 mi^2) of the landscape. The image pair [*top right*], based on digital elevation models from the U.S. Geological Survey, shows the elevation of the volcano's summit before and after the blast.

Deposits from the landslide on the north flank—one of the largest in recorded history—buried the valley of the North Fork Toutle River with debris up to 180 m (600 ft) deep in some places. Rivers have since reworked their way across the landscape, and new vegetation has greened up much of the land. The Pumice Plain still looks barren in the satellite imagery, but ground surveys note that small plants have regrown here too.

Not all of the recovery, however, is natural. According to According to **Steve Malone** [University of Washington—*Professor Emeritus*], much of the blowdown area was replanted and fertilized to get commercial crops (e.g., timber) growing again. "Only within the monument have things been left to recover naturally."

Scientists also keep a vigilant watch on the inside of the crater, where two lava domes have formed. In the top left image, the dome in the crater's foreground grew until 1986, at which time the volcano became quiet again. Renewed activity in 2004—followed by a phase of lava extrusion that lasted until 2008—formed a second lava dome immediately behind the first.

Log rafts are still visible in Spirit Lake [*top left image*]. These drifting rafts are composed of floating trees, thousands of which were uprooted and carried there in 1980. The raft is gradually shrinking in size from year to year as trees sink to the bottom of the lake.

Not visible in this image, however, is the 2600-m-long (8500-ft-long) drainage tunnel constructed in 1985 to carry water from the lake, through a ridge, and into a nearby creek. Eruption debris had blocked the natural outlet into North Fork Toutle River, so the tunnel was built to control the water level and prevent a potentially disastrous flood. News reports say the tunnel is becoming constricted and "needs work." ■

NASA Earth Science in the News

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

Study Raises Concerns Over Big, Rapidly Thinning Antarctic Glacier, March 18; *CNN.* NASA and University of Texas scientists have raised concerns about a large, rapidly thinning glacier in Antarctica—warning it could contribute significantly to rising sea levels. They say they've discovered two openings that could channel warm seawater to the base of the huge Totten Glacier. The glacier is bigger and thinning faster than all the others in East Antarctica. It contains enough ice to raise the global sea level by at least 11 ft (3.4 m) over several centuries, according to the researchers—a group that included **Dustin Schroeder** [NASA/Jet Propulsion Laboratory (JPL)]. Scientists had previously detected warm water on the seaward side of the glacier, but until now, they had found no evidence that it could threaten coastal ice. According to the study's lead author, **Jamin Greenbaum** [University of Texas], "We now know there are avenues for the warmest waters in East Antarctica to access the most sensitive areas of Totten Glacier." The scientists partly based the research on data collected by Operation IceBridge.

Arctic Ice Reaches a Low Winter Maximum, March 24; *The New York Times*. The annual peak of winter ice over the Arctic Ocean this year covered a smaller extent than at the end of any winter since 1978—the year scientists began keeping consistent satellite records. NASA scientists and researchers at the National Snow and Ice Data Center reported that this year's maximum occurred on February 25—about two weeks earlier than the average—see **Figure**. According to **Walt Meier** [NASA's Goddard Space Flight Center (GSFC)], an expert on sea ice, summer minimums in the Arctic's ice cover can have a greater effect on the global climate than winter maximums. During the relatively sunny summers, the dark ocean surface of ice-free parts of the Arctic absorbs much more solar energy than highly reflective sea ice. This can create a warming feedback loop when the ocean absorbs sunlight and heats the air above it. Meier said that during the winter much of the ice near the edges of the ice sheet covering the Arctic is thin and seasonal, whereas some of the older and thicker ice melts during the summer. The differences between these seasonal processes mean winter ice cover does not help predict how much ice there will be by the end of summer. "When you lose summer ice you aren't really just losing it for that year, you're also losing some ice from many years ago," Meier said. "That makes it harder for things to go back towards normal."

Snow Melting 16 Days Earlier in Wyoming Mountains, March 26; *CBSNews.com.* The spring snowmelt now comes more than two weeks earlier than it did in the 1970s in the Wind River Range—a spectacular sweep of glacier-carved granite peaks rising from the plains of north-central Wyoming. The trend is part of a larger snow shortfall across the Western U.S. documented by many researchers. **Dorothy Hall** [GSFC] and her colleagues were interested in seeing how this widespread snowmelt trend plays out in a specific region; they chose to focus on the Wind River Range's Fremont Lake Basin. They directly measured the mountain snow cover with Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) images. Hall's study reported that since the 1970s in the Fremont Lake Basin, the area covered by snow has decreased, and stream flows have decreased and are also peaking earlier. Weather records from the same time period show a warming trend, with rising spring and summer nighttime temperatures. Higher nighttime temperatures can cause more snow to melt the next day, the study researchers said.

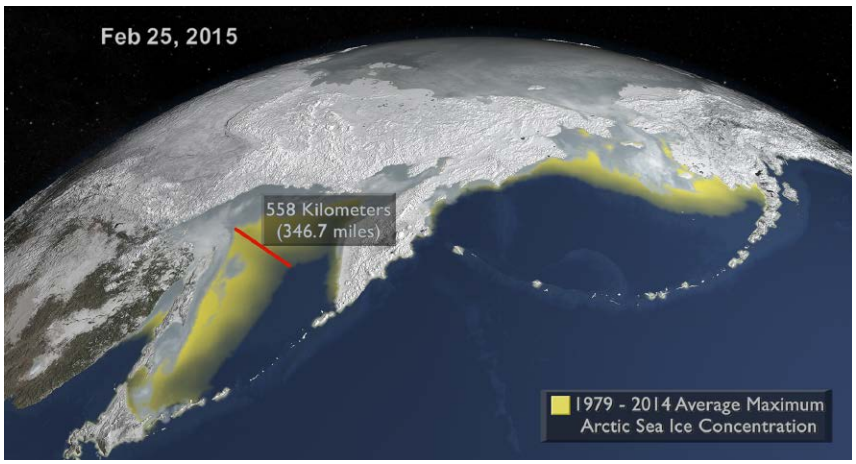


Figure. This map compares the 2015 sea ice maximum (gray) to the 1979–2014 average maximum (gray + yellow). A distance indicator shows the maximum difference between the two in the Sea of Okhotsk north of Japan. **Image credit**: NASA's Goddard Space Flight Center.

"Earlier snowmelt impacts the water resources of most of the state of Wyoming, which has been undergoing a drought since 1999," said Hall.

More Frequent Big Storms Behind Increasing Rain Amounts in Tropics, March 26; *The Washington Post*. As the Earth has warmed, scientists have observed an increase in heavy rainfall in the tropics. Now they know the source, concludes a NASA study: an increase in organized areas of thunderstorms, or what is known as *deep convection*. "What we are seeing is more big and organized storms and fewer small and disorganized rain events," said study author **Jackson Tan** [NASA's Wallops Flight Facility]. This result is surprising; scientists have generally expected that, as Earth warms, increasing water vapor in the atmosphere would lead to increasing rainfall in all types of weather systems. "This work changes our perception of why tropical precipitation is increasing," said study co-author **George Tselioudis** [NASA's Goddard Institute for Space Studies]. "We thought it was because the warmer atmosphere holds more moisture and, therefore, when storms occur they rain more, but that doesn't seem to be the case. Instead, the warmer tropical atmosphere becomes better organized to produce large storms more frequently." The scientists based their work on the rainfall record produced by the Tropical Rainfall Measuring Mission (TRMM) and International Satellite Cloud Climatology Program (ISSCP).

NASA Instruments Scan Forests Ravaged By Wildfire, Help In Planning Recovery Efforts, April 13; *Tech Times*. NASA says maps of two megafires that struck California recently, created in cooperation with the U.S. Forest Service, could help answer questions about the best way to go about forest recovery efforts. New datasets, gathered by the Forest Service and JPL, have been combined to create maps so highly detailed that they even show single trees, the space agency says. The researchers created maps of the Rim fire, which consumed around 250,000 acres (1012 km^2) around and inside Yosemite National Park in 2013, and the King fire close to Lake Tahoe, which burned 97,000 acres (393 km^2) in 2014. Officials say that these maps will aid the Forest Service in its restoration and recovery projects underway in the area. The data were gathered from visible light, infrared, and lidar instruments being developed for NASA's Hyperspectral Infrared Imager (HyspIRI) satellite mission. Although that mission is years away from launch, airborne prototypes of the instruments were taken aloft to gather the data on the wildfires. Officials hope the maps created from those data can answer a number of fundamental questions about forest recovery plans: e.g., where the surviving live trees in a blackened landscape are—to provide seed for regrowing a forest; where the most dangerous dead trees are—which could put crews rebuilding trails and roads at risk; and whether new habitats have been created—which fire-dependent wildlife species could use to their advantage.

Methane and Climate Change: Scientists Struggle to Solve Four Corners Mystery, April 14; *Nature World News*. It's hard to imagine how until recently we could have missed a 2500-mi^2 (6475-km^2) cloud of methane (CH_4) hovering above the Four Corners region of the Southwest U.S.—where Arizona, Utah, Colorado and New Mexico meet. Scientists actually first noticed the data years ago, but the measurements obtained were so extreme that they wanted to wait a few years before investigating the region in detail. Last year, researchers at the University of Michigan and NASA conducted a detailed analysis using images taken between 2003 and 2009 by an instrument on the European Space Agency's Environmental Satellite (ENVISAT). It turns out the data didn't lie. This "methane hot spot" is the nation's biggest concentration of CH_4—more than triple the standard ground-based estimate. To gain better insight into the anomalously high CH_4 concentration, NASA, along with researchers from several other institutions, are conducting a field campaign in the region this spring, using a suite of airborne and ground-based instruments that will yield more detailed data than satellite observations. "With all the ground-based and airborne resources that the different groups are bringing to the region, we have the unique chance to unequivocally solve the Four Corners mystery," said **Christian Frankenberg** [JPL]. The planes are carrying the Hyperspectral Thermal Emission Spectrometer (HyTES) and the Next-Generation Airborne Visible/Infrared Imaging Spectrometer (AVIRISng), which, when combined, can make highly sensitive measurements of CH_4, and show how concentrations vary even every few feet, allowing scientists to identify individual sources.

***New NASA Satellite Gets the Dirt on Soil Moisture,** April 23; *Climate Central*. Tracking soil moisture is a dirty job, but someone has to do it. Soil moisture is a critical indicator of drought. For decades, ground observations have done the heavy lifting but they're few and far between. After months of calibration, the satellite—dubbed the Soil Moisture Active Passive (SMAP) mission—has sent back the first global view of soil moisture. SMAP uses two instruments—a radar and a radiometer—to measure soil moisture at a 5.6-mi (9-km) resolution. The goal is to provide a better view of how water moves across the planet, particularly on land (a helpful piece of knowledge for humans). The map was created using the radar, which sends microwave pulses from the satellite down to the Earth's surface 426 mi (686 km) below, and then measures what is reflected back to the instrument.

*See related news story in this issue.

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****.* ■

NASA Science Mission Directorate – Science Education and Public Outreach Update

Theresa Schwerin, Institute for Global Environmental Strategies, theresa_schwerin@strategies.org
Morgan Woroner, Institute for Global Environmental Strategies, morgan_woroner@strategies.org

Smallsat Technology Partnerships Solicitation

Audience: Higher education educators and students
Proposal Deadline: June 8, 2015

NASA is extending an opportunity to college and university teams to propose small spacecraft technology projects to be conducted in collaboration with NASA researchers. NASA will competitively select about eight projects from those proposed by university teams and fund them for up to two years. Awards for each project will include up to $100,000 to each university team per year. Proposed projects could involve laboratory work to advance a particular spacecraft technology or the development of a new small satellite. For more details please visit *nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId=%7BEE5E8712-1E80-3B5C-23B9-7F80A1F1689A%7D&path=open.*

NASA Community College Aerospace Scholars Program – Fall 2015 Session

Audience: Higher education students
Application Deadline: June 24, 2015

NASA Community College Aerospace Scholars (NCAS) is an interactive online learning experience for community college students interested in pursuing a NASA-related science, technology, engineering, or mathematics career. The program culminates with an onsite experience where selected students interact with NASA scientists and engineers. NCAS is open to community college students who are U.S. citizens. Applicants must have access to the Internet. For more details please visit *ncas.aerospacescholars.org.*

NASA Postdoctoral Fellowships

Audience: Post doctoral students (position attained by the time the program begins.)
Application Deadline: July 1, 2015

The NASA Postdoctoral Program offers scientists and engineers unique opportunities to conduct research in space science, Earth science, aeronautics, exploration systems, lunar science, astrobiology, and astrophysics.

Awards: Annual stipends start at $53,500—with supplements for specific degree fields and high cost-of-living areas. There is an annual travel budget of $8000, a relocation allowance, and financial supplement for health insurance purchased through the program. Approximately 90 fellowships are awarded annually.

Eligibility: An applicant must be a U.S. citizen, lawful permanent resident, or foreign national eligible for J-1 status as a research scholar to apply. Applicants must have completed a Ph.D. or equivalent degree before beginning the fellowship, but may apply while completing the degree requirements. Fellowships are available to recent or senior-level Ph.D. recipients. Fellowship positions are offered at several NASA centers.

To obtain more information and to apply for this exciting opportunity, visit *nasa.orau.org/postdoc*.

SciJinks: What is El Niño?

Audience: Middle and high school students and educators

El Niño is a weather pattern that occurs in the Pacific Ocean, but it is so big that it affects weather all over the world. While this year's El Niño isn't much to write home about, past El Niño years saw widespread and significant global weather effects. Find out more about El Niño and what causes it at *scijinks.gov/el-nino*.

NASA's Climate Kids: OFFSET

Audience: Elementary school students and educators

Check out the latest educational game from NASA's Climate Kids—OFFSET! Take matters into your own hands and help cut back on carbon emissions. Part pong, part resource-management, and 100% retro fun, this game is challenging, exciting, and educational. Play it today! Visit *climatekids.nasa.gov/offset* to learn more.

GLOBE Program Marks 20 Years of Global Earth Science Education

On April 22, 2015—Earth Day—NASA, the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), and the Department of State celebrated 20 years of international cooperation and collaboration to engage students, scientists, and teachers in 114 countries in the scientific exploration of Earth's environments and climate through the Global Learning and Observations to Benefit the Environment (GLOBE) science and education program. Learn more about how the twentieth anniversary was celebrated around the world at *www.nasa.gov/press-release/globe-program-marks-20-years-of-global-earth-science-education*. For more information about GLOBE, visit *www.globe.gov*. ■

EOS Science Calendar

June 23–25, 2015
Earth Science Technology Forum 2015,
Pasadena, CA.
esto.nasa.gov/forum/estf2015/index.html

July 7–9
Landsat Science Team Meeting, USGS EROS Center,
Near Sioux Falls, SD

July 13–17, 2015
Precipitation Measurement Mission Science Team Meeting, Baltimore, MD.
By invitation only (Contact *Lisa.A.Nalborczyk@nasa.gov*)

September 21–23, 2015
GRACE Science Team Meeting, Austin, TX.
www.csr.utexas.edu/grace/GSTM

October 19–23, 2015
Ocean Surface Topography Science Team Meeting,
Washington, DC.

November 10–13, 2015
SORCE Sun-Climate Symposium, Savannah, GA.
go.nasa.gov/1zRx2Hj

Acronyms used in the Editorial and Article Titles
(continued from page 3)

TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time

Global Change Calendar

June 22–July 2, 2015
26th International Union of Geodesy and Geophysics,
Prague, Czech Republic.
www.iugg2015prague.com

July 13–15, 2015
3rd South Central and Eastern European Regional Information Network (SCERIN) Workshop,
Transylvania, Bulgaria.

July 20–24, 2015
19th GLOBE Annual Partner Meeting,
Los Angeles, CA.
www.globe.gov/events/eventsdetail/globe/19th-annual-globe-partner-meeting

July 26–31, 2015
IEEE International Geoscience and Remote Sensing Symposium, Milan, Italy.
www.igarss2015.org

August 2–7, 2015
12th Annual Asia Oceania Geosciences Society Meeting,
Singapore.
www.asiaoceania.org/aogs2015

August 16–20, 2015
250th American Chemical Society National Meeting,
Boston, MA.
www.acs.org/content/acs/en/meetings

November 9–13, 2015
GEO-XII Plenary and Ministerial Summit,
Mexico City, Mexico.
earthobservations.org/index.php

November 30–December 11, 2015
COP-21, Paris, France.
www.cop21paris.org

December 14–18, 2015
American Geophysical Union Fall Meeting,
San Francisco, CA.
fallmeeting.agu.org/2015

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Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. 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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