National Aeronautics and Space Administration

the earth observer

The Earth Observer. July - August 2018. Volume 30, Issue 4.

Editor's Corner

Steve Platnick
EOS Senior Project Scientist

The year 2018 is shaping up to be another busy one for NASA's Earth Science satellite missions. Already two launches have taken place,[1] and two more are scheduled by the end of the year—see diagram below, which shows the plan for the NASA Earth Science fleet through 2023, and highlights the recent launches.

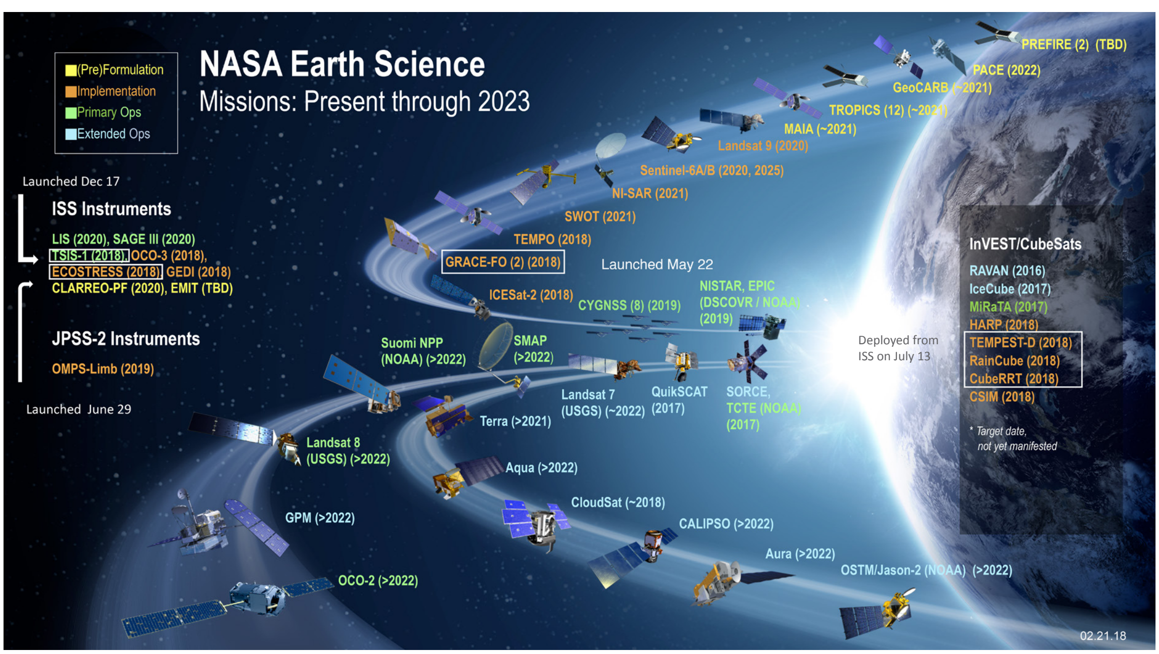
On June 29, 2018, NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument successfully launched aboard the SpaceX commercial resupply mission-15 (CRS-15) from Space Launch Complex 40 at Cape Canaveral Air Force Station in Florida. The Dragon spacecraft was successfully deployed and arrived at the International Space Station (ISS) on July 2. Once there, ECOSTRESS was removed from the Dragon capsule via the station's Canadarm robotic arm and installed on the exterior of the station's Japanese Experiment Module Exposed Facility (JEM-EF) late on July 5. Functional testing of the instrument is now underway with science operations expected to begin in August.

In our last issue we reported on the successful launch of NASA's Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission on May 22, 2018.[2] By mid-June the twin GRACE-FO satellites had been maneuvered into their operational orbit formation approximately 220 km (137 mi) apart. Engineers also

[1] NASA has actually launched three missions since January. The third was GOES-S, which NASA launched for NOAA. To learn more about the GOES-S launch, see the Editorial of the March–April 2018 issue of *The Earth Observer* [**Volume 30**, **Issue 2**, pp. 1-2—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/Mar_Apr_2018_color%20508_0.pdf*].

[2] The GRACE-FO launch was described in the Editorial of the May–June 2018 issue of *The Earth Observer* [**Volume 30**, **Issue 3**, p. 1—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/May-June%202018%20color%20508.pdf*].

continued on page 2



The diagram shows current plans for the NASA Earth Science fleet through 2023, including missions in primary operations, extended operations, implementation, and preformulation phases. It also points out the launches that have taken place since December 2017. **Image credit:** NASA

In This Issue

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

activated both primary instruments: the accelerometers, which measure forces acting on the satellites other than gravity, e.g., atmospheric drag or solar radiation pressure, and the Microwave Ranging Instruments, which precisely measure the distance changes between the two satellites as they orbit Earth.

The "first light" images from both the MWI and the experimental Laser Ranging Instrument (LRI) have been obtained—see "*First Light" from GRACE-FO's Microwave and Laser Ranging Instruments* on page 24. The LRI is being flown as a technology demonstration, and initial comparisons of the data from the two types of instruments show that they agree as expected. In the months ahead, the GRACE-FO team will continue to fine-tune the MWI and LRI instruments, calibrate the satellites, and prepare for science data collection, which is expected to begin toward the end of August.

Looking ahead, the Ice, Cloud and land Elevation Satellite-2 (ICESat-2) is now at Vandenberg Air Force Base in California in advance of the satellite's launch, scheduled for September 12, 2018. ICESat-2 will use a laser altimeter to monitor changes in ice sheets, glaciers, and sea ice. In June, the satellite was trucked from a Northrop Grumman facility in Arizona to Vandenberg. Since then, ICESat-2 has gone through a final series of tests, including the final ground-based test of its lasers. The next milestone toward launch comes in August, when the ICESat-2 team will transport the satellite to Vandenberg's Space Launch Complex 2. At that point, United Launch Alliance personnel will attach ICESat-2 to the Delta II rocket, which they have already begun assembling. ICESat-2 will be the last satellite to launch on a Delta II, which has been a durable "workhorse" for the space industry for the past two decades, and recently included several NASA Earth Science launches: OCO-2 (2014); SMAP (2015); JPSS-1 (2017); and finally, ICESat-2 (planned for 2018).

The final launch planned for 2018 is the Global Ecosystems Dynamics Investigation (GEDI—acronym pronounced "jedi," as in *Star Wars*) mission. We reported in our last issue that GEDI has been placed on an accelerated track toward launch, which is now planned for November 2018, instead of May 2019. As of this writing, the mission remains on track for its scheduled launch from Cape Canaveral Air Force Station in Florida via SpaceX CRS-16.

In addition to the four missions that have been mentioned, NASA continues to experiment with new and innovative technologies launched on InVEST CubeSats.[3] On May 21, 2018, three Earth science experiments were among those launched as part of the Cygnus OA-9 resupply payload onboard an Orbital Antares 230 rocket. Cygnus OA-9 docked with the ISS on May 24. These three 6U CubeSats were deployed from the ISS on July 13, and will be used to perform on-orbit technology validation activities and test new measurement concepts. The Earth Science payloads are as follows:

- **TEMPEST-D** is a risk mitigation mission for a planned constellation of Earth observation CubeSats that will track the steps in the formation of clouds, precipitation, and storms. **Stephen Reising** [Colorado State University] is the Principal Investigator (PI). To learn more, visit *https://www.jpl.nasa.gov/cubesat/missions/tempest-d.php*.

[3] CubeSats are a type of nanosatellite that can be deployed from standardized dispensers. They are built to standard dimensions called *units*. One unit is equal to 10x10x10 cm (~4x4x4 in). A 6U CubeSat can weigh up to 6.3 lbs (14 kg).

- **CubeRRT** will test a new signal processor to mitigate radio interference impacting microwave radiometer measurements of soil moisture, atmospheric water vapor, sea surface temperature, and winds from orbit. **Joel Johnson** [Ohio State University] is the PI. For more information, visit *https://u.osu.edu/cuberrt*.

- **RainCube** will demonstrate the viability and performance of a new expandable K_a-band precipitation radar that can be packaged into a volume to fit in a nanosatellite. **Eva Peral** [JPL] is the PI. For more information, visit *https://www.jpl.nasa.gov/cubesat/missions/raincube.php*.

Congratulations to the PIs and team members on the successful launch of these CubeSats that have the potential to expand measurement options for future Earth Science missions.

Our existing Earth Science missions continue to age gracefully. In June, the joint NASA–French Space Agency [Centre Nationale d'Études Spatiales (CNES)] Ocean Surface Topography Mission on the Jason-2 spacecraft (OSTM/Jason-2) completed its tenth year measuring the surface height of the global ocean. Launched on June 20, 2008, the Jason-2 satellite continued the more than 25-year data record that began with the Topex/Poseidon mission in 1992.

The Jason series continues to revolutionize our understanding of the dynamics of ocean circulation and global climate change. Building on the pioneering work of Topex/Poseidon, data from Jason-1 (in orbit 2001–2013), Jason-2 (launched in 2008), and Jason-3 (launched in 2016) have established an unprecedented long-term record of consistent, continuous global observations of the Earth's ocean. This overlapping time series has allowed scientists to observe and study both short-lived events such as hurricanes and long-term climate phenomena such as El Niño, La Niña, and the Pacific Decadal Oscillation. It also provides the ability to accurately monitor changes in global mean sea level, one of the most important indicators of human-caused climate change.

In 2017, Jason-2 was placed in a slightly lower orbit, allowing it to collect data along very closely spaced ground tracks, in order to provide very accurate and high-resolution observations of the mean sea surface. This new orbit configuration will also allow geodetic scientists to improve maps of the ocean floor, resolving previously unknown details of the location of seamounts and other features of the ocean bottom.

Future missions in this series include the Jason Continuity of Service/Sentinel-6 (Jason-CS/Sentinel-6) mission, in collaboration with NOAA, the European Space Agency, and EUMETSAT; and the Surface Water and Ocean Topography (SWOT) mission in collaboration with CNES, the Canadian Space Agency, and U.K. Space Agency partners.

Finally, more than 100 science Hyperwall presentations that were given at the NASA booth during the Fall Meeting of the American Geophysical Union (AGU) held in December 2017 are now available on *YouTube*. The presentations cover the range of activities that fall under the four divisions of NASA's Science Mission Directorate—including Earth Science. For more information, see the Announcement on page 26 of this issue. ■

Undefined Acronyms Used in Editorial and Table of Content

COSPAR	Committee on Space Research (International Council for Science)
CubeRRT	CubeSat Radiometer Radio Frequency Interference Technology Validation mission
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
InVEST	In-space Validation of Earth Science Technologies
JPL	NASA/Jet Propulsion Laboratory
JPSS-1	Joint Polar-orbiting Satellite System-1
NOAA	National Oceanic and Atmospheric Administration
OCO-2	Orbiting Carbon Observatory-2
RainCube	Radar in a CubeSat
SMAP	Soil Moisture Active/Passive
TEMPEST-D	Temporal Experiment for Storms and Tropical Systems – Demonstration

feature article

NASA's Worldview Places Nearly 20 Years of Daily Global MODIS Imagery at Your Fingertips

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

EDITOR'S NOTE: This article was originally published on the Earthdata website—*https://earthdata.nasa.gov/modis-in-gibs*. It has been modified for publication in *The Earth Observer*.

Argentina's Mar Chiquita lake is one of the largest saline lakes in the world. Along with an unusually high abundance of resident and migratory bird species in the lake's wetlands, another aspect that makes Mar Chiquita unique is that its water level is constantly changing.

Introduction

Argentina's Mar Chiquita lake is one of the largest saline lakes in the world. Along with an unusually high abundance of resident and migratory bird species in the lake's wetlands, another aspect that makes Mar Chiquita unique is that its water level is constantly changing. These extreme water level fluctuations affect not only its salinity, but also the amount of dust blowing off the lake as it periodically dries out—see **Figure 1**. For **Santiago Gassó** [NASA's Goddard Space Flight Center (GSFC)/Morgan State University—*Associate Research Scientist*], the lake is a living laboratory for his studies into dust transport and is best viewed and studied from great height and with years of observations—exactly the types of imagery provided by NASA's fleet of Earth-observing satellites.

"I'm interested in dust coming out of South America," explains Gassó. "For instance, Mar Chiquita shrank significantly in 2008, 2009, and 2010. [Using satellite imagery,] I can go and check more than a decade of images and find what days were active, how much dust [was produced], and compare activity to El Niño and La Niña years."

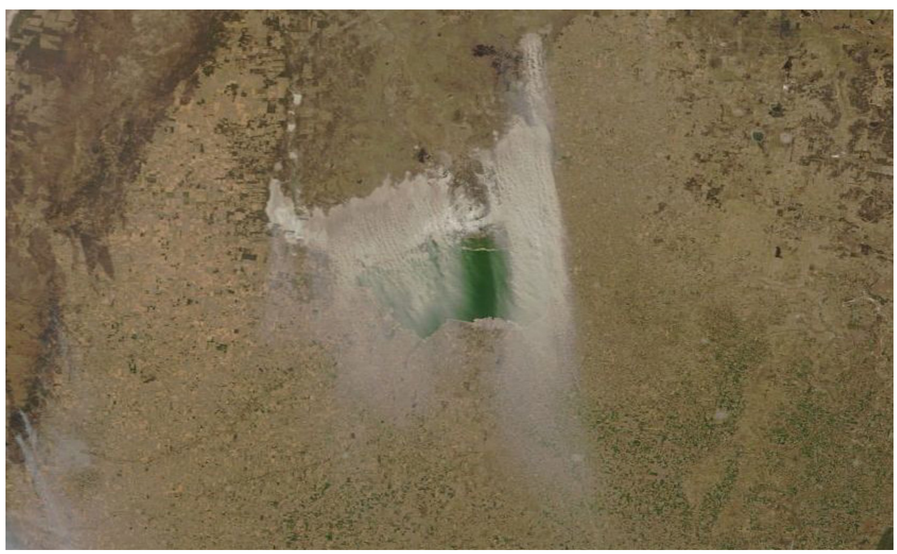


Figure 1. This image shows dust blowing off Mar Chiquita on September 10, 2013, and is created using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. The full-size image is available at *go.nasa.gov/2uGACrz* for interactive viewing using the NASA's Worldview data visualization application. **Image credit:** NASA Worldview

A valuable resource for Gassó's studies of Mar Chiquita is imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua Earth-observing satellites. Terra was launched in late 1999 and was followed by Aqua in 2002. The two satellites have amassed a tremendous archive of imagery and data during their more than 12,000 combined days in orbit—e.g., see Aqua/MODIS images in **Figure 2**.

GIBS and Worldview Provide Easy Access to Daily MODIS Global Imagery

MODIS is an extremely versatile instrument that has sometimes been called the "workhorse" of NASA's Earth Observing System. Its imagery is used to create a variety of data products covering atmosphere, land, cryosphere, and ocean[1] that are used for a wide range of applications—see *More About MODIS* on page 6.

According to Gassó, "MODIS is the right balance of coverage, both spatially and in time. It's also the right combination of spectral bands. With the two sensors deployed—one on

[1] See *https://modis.gsfc.nasa.gov/data/dataprod/index.php* for a complete list.

Figure 2. These images, created using Aqua/MODIS data, show fluctuations in Mar Chiquita's water level in 2003, 2010, 2012, and 2018, and demonstrate how MODIS global imagery enables long-term studies of natural events or specific locations. **Image credit:** NASA Worldview

Aqua and the other on Terra—the whole planet is observed [almost daily] which is a great benefit. The spatial resolution [generally 1 km (~3281 ft) but as high as 250 m (~820 ft) for Bands 1 and 2][2] is about right for detecting general features. If you see a dust plume or a smoke plume [in a MODIS image], you can then see about getting a higher resolution image from, say, Landsat to take a closer look.[3] Worldview [described below] makes this easy since you can overlay the Landsat orbital tracks on the MODIS images."

As of June 2018, all daily global MODIS imagery dating back to the operational start of MODIS data collection in 2000 is available through NASA's Global Imagery Browse Services (GIBS—*https://earthdata.nasa.gov/about/science-system-description/eosdis-components/global-imagery-browse-services-gibs*). GIBS was established by NASA's Earth Observing System Data and Information System (EOSDIS) in 2011 and provides quick access to over 700 satellite imagery products covering every part of the world. The nearly 20 years of MODIS imagery is the longest continuous daily global satellite observation record of Earth ever compiled.

The nearly 20 years of MODIS imagery is the longest continuous daily global satellite observation record of Earth ever compiled.

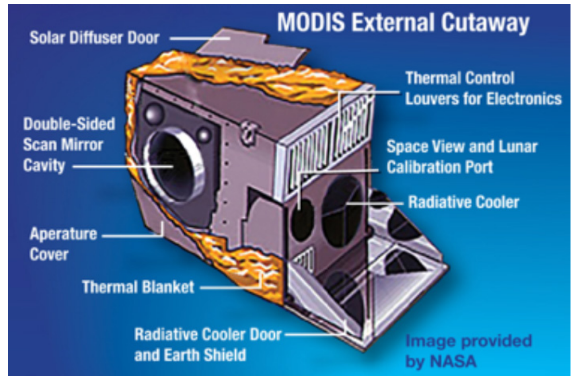
MODIS imagery can be viewed rapidly and interactively using EOSDIS's Worldview visualization application (*https://worldview.earthdata.nasa.gov*). Worldview, which was released in December 2011, pulls imagery from GIBS and allows users to overlay Earth-observing data products on top of a MODIS global base map from Terra or

[2] For some historical perspective on how this 250-m resolution that has proven so useful came to be, refer to "How FIFE Changed MODIS" in the January–February 2017 issue of *The Earth Observer* [**Volume 29**, **Issue 1**, p. 19—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/Jan-Feb%202017%20color%20508.pdf#page=19*].

[3] Landsat images have 30-m (~98-ft) spatial resolution for most bands compared to the up to 250-m (~820-ft) spatial resolution of MODIS.

More About MODIS

Description: Medium-resolution, multispectral, cross-track scanning radiometer
Spectral Bands: 36
Size: 1.0 x 1.2 x 1.6 m (~3.3 x 3.9 x 5.2 ft)
Mass: 229 kg (~505 lb)
Orbit: Sun-synchronous, near-polar
Orbital Height: 705 km (~438 mi)
Resolution: 1 km (~3821 ft) for most bands; as high as 250 (~820 ft) for Bands 1 and 2.
Swath Width: 2330 x 10 km (~1448 x 6.2 mi)
Global Coverage: Every 1 to 2 days



Aqua and easily create data animations. A daily global base map from data collected by the Visible Infrared Imaging Radiometer Suite [VIIRS] aboard the Suomi National Polar-orbiting Partnership [Suomi-NPP] satellite also is available dating back to November 24, 2015).[4]

The availability of all global MODIS imagery in GIBS is the result of more than a half-decade of work involving several NASA teams. "This is the culmination of the work of hundreds of scientists and support staff keeping the satellites healthy to enable us to get these data from MODIS and create these images," says **Ryan Boller** [GSFC—*Worldview Project Manager*]. "Having all the MODIS imagery available [in GIBS] has been a long-term goal of ours."

"This is the culmination of the work of hundreds of scientists and support staff keeping the satellites healthy to enable us to get these data from MODIS and create these images. Having all the MODIS imagery available [in GIBS] has been a long-term goal of ours."
*—**Ryan Boller** [GSFC—Worldview Project Manager]*

Near-real-time data and imagery from the Terra MODIS instrument have been available since 2001 through the EOSDIS Rapid Response system.[5] The static Rapid Response imagery originally was developed to meet the needs of the U.S. Forest Service, the National Interagency Fire Center, and other federal and state users. By 2007 the Rapid Response system had incorporated data and imagery from the Aqua/MODIS instrument. As Boller notes, the advent of global mapping services like Google Maps created a desire for interactive imagery for any point on Earth. As a result, an effort to create daily global MODIS imagery was initiated in 2011 along with the development of an application to allow users to easily interact with this imagery. "We transitioned from the static imagery of Rapid Response to interactive imagery provided through GIBS for viewing in Worldview," he says.

The first daily global MODIS imagery base maps were available in GIBS for interactive viewing in Worldview in 2012, and daily MODIS base maps have been produced ever since. This effort is a collaboration between the GIBS and Worldview teams and NASA's MODIS Adaptive Processing System (MODAPS)—an operations group that was established prior to the launch of Terra for processing MODIS data. These processed data are sent for archiving and distribution to the EOSDIS Land Processes Distributed Active Archive Center (LP DAAC), National Snow and Ice Data Center DAAC (NSIDC DAAC), Ocean Biology DAAC (OB.DAAC), and Level 1 and Atmosphere Archive and Distribution System DAAC (LAADS DAAC).[6]

---

[4] To learn more about GIBS and Worldview, read "Seeing is Believing: EOSDIS Worldview Helps Lower Barriers for NASA Earth-Observing Data Discovery and Analysis" in the May-June 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 3**, pp. 4-8—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/May_Jun_2015_color_508.pdf#page=4*]. The two tools are also discussed in the broader context of EOSDIS in "Earth Science Data Operations: Acquiring, Distributing, and Delivering NASA Data for the Benefit of Society" in the March–April 2017 issue of *The Earth Observer* [**Volume 29**, **Issue 2**, pp. 4-18—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/March%20April%202017%20color%20508.pdf#page=4*].
[5] Rapid Response is the precursor to Worldview. MODIS Subsets and Near Real-Time (Orbit Swath) Images are still available for long-term users and those with relatively slow internet access. However, Rapid Response will be replaced in the fall of 2018.
[6] These DAACS are discussed in more detail in "Earth Science Data Operations: Acquiring, Distributing, and Delivering NASA Data for the Benefit of Society," referenced in Footnote #4.

While continuous MODIS global imagery has been available in GIBS from 2012 to the present, until recently there was a gap in this imagery between the start of the MODIS data record in 2000 and the start of the daily global MODIS base maps in 2012. "Users said to us, 'We know you have the source data available, and we'd like to see it as imagery in Worldview,'" says Boller. The responsibility for processing the missing MODIS imagery for GIBS fell to MODAPS.

MODAPS Fills in the MODIS Imagery Gap

For the MODAPS team, filling in the MODIS imagery archive gap was a challenge, especially given the volume of data involved and the processing resources available. According to **Kurt Hoffman** [GSFC—*MODAPS Lead Operations Analyst*], the volume of MODIS data from Terra and Aqua required to produce GIBS imagery for land alone was more than 3,850 terabytes (TB). (The data volume required for processing MODIS atmosphere imagery was much smaller: about 424 TB.) After processing, MODAPS sent more than 565 TB of land imagery and about 14.41 TB of atmosphere imagery to GIBS—see *From Terra to Terabytes* on page 8.

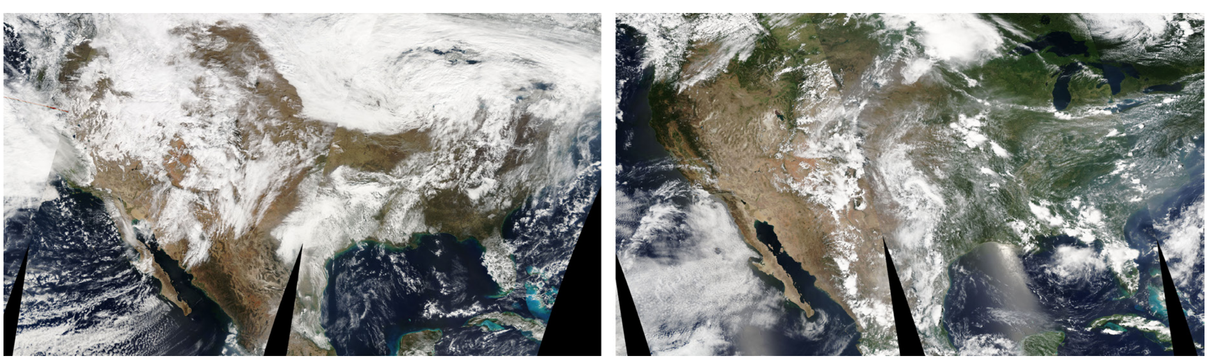
"At first, we thought it would be about spring 2018 when we would get caught up in processing all the MODIS imagery," Hoffman says. "We got lucky during this processing when an extra machine was freed up. We were able to use this extra machine and double down on the processing. In fact, we were able to squeeze in a third machine in the last month. Using these three machines enabled us to [process more data and] meet the pie-in-the-sky goal of finishing this processing in early December [2017]."

Even after MODAPS finished processing the imagery, the data still had to be added to the GIBS collection. "Just ingesting the MODIS data took [the GIBS team] an extra month, and then they had to do an analysis and assessment of the data," says Hoffman. "There are still a few small imagery gaps that we're working on, but it's just one image here, one image there."

As Gassó notes, the ability to have an easily accessible historical perspective dating back almost two decades—e.g., see **Figure 3**—greatly facilitates research. "[Back] in the '80s and '90s, if you wanted to look at, say, clouds off the coast of California, you would have to figure out the time of year when it was best to look at these clouds, then place a data request for a specific window of days when you thought the satellite overflew the area," he says. "You would get a physical tape with these images and have to put this into the processing system. Only then would you know if the image was usable. This process used to take from days to weeks. Now, you can look at images for days, weeks, and even years in a matter of minutes in Worldview, immediately find the images you need, and download them for use. It's fantastic!"

"[Back] in the '80s and '90s, if you wanted to look at, say, clouds off the coast of California, you would have to figure out the time of year when it was best to look at these clouds, then place a data request for a specific window of days when you thought the satellite overflew the area. You would get a physical tape with these images and have to put this into the processing system. Only then would you know if the image was usable. This process used to take from days to weeks. Now, you can look at images for days, weeks, and even years in a matter of minutes in Worldview, immediately find the images you need, and download them for use. It's fantastic!"

*—**Santiago Gassó** [GSFC/Morgan State University—Associate Research Scientist]*



Terra/MODIS, February 24, 2000—*https://go.nasa.gov/2uKVIoM* **Aqua/MODIS, July 4, 2002—***https://go.nasa.gov/2GNZuTg*

Figure 3. Shown here are the first images of the continental U.S. obtained by Terra/MODIS on February 24, 2000 [*left*] and by Aqua/MODIS on July 4, 2002 [*right*]. **Image credit:** NASA Worldview

From Terra to Terabytes

A *byte* is the amount of storage space required for a single character of type. Moving upward in size is the kilobyte (KB), megabyte (MB), gigabyte (GB), and terabyte (TB). According to the My NASA Data website (*https://mynasadata.larc.nasa.gov/science-practices/data-volume-and-units*) 1 TB is equivalent to about 1000 digital copies of Beethoven's Fifth Symphony or all the x-rays in a large hospital. NASA's Hubble Space Telescope generates about 10 TB of new data per year, and the total Hubble archive is currently over 150 TB in size.*

* Hubble statisitcs cited in this sentence come from NASA's *About the Hubble Space Telescope* page at *https://www.nasa.gov/mission_pages/hubble/story/index.html*.

Summary

For the MODAPS, GIBS, and Worldview teams, the completion of this effort gives MODIS users access to a tremendous resource that enables studies into our changing planet reaching back almost 20 years, including the effects of urbanization, historic storms and natural events, and, of course, ongoing changes to Mar Chiquita—see **Figure 4**. "This is really an impressive chunk of data considering the wide range of research scientists can use these data for," says Hoffman.

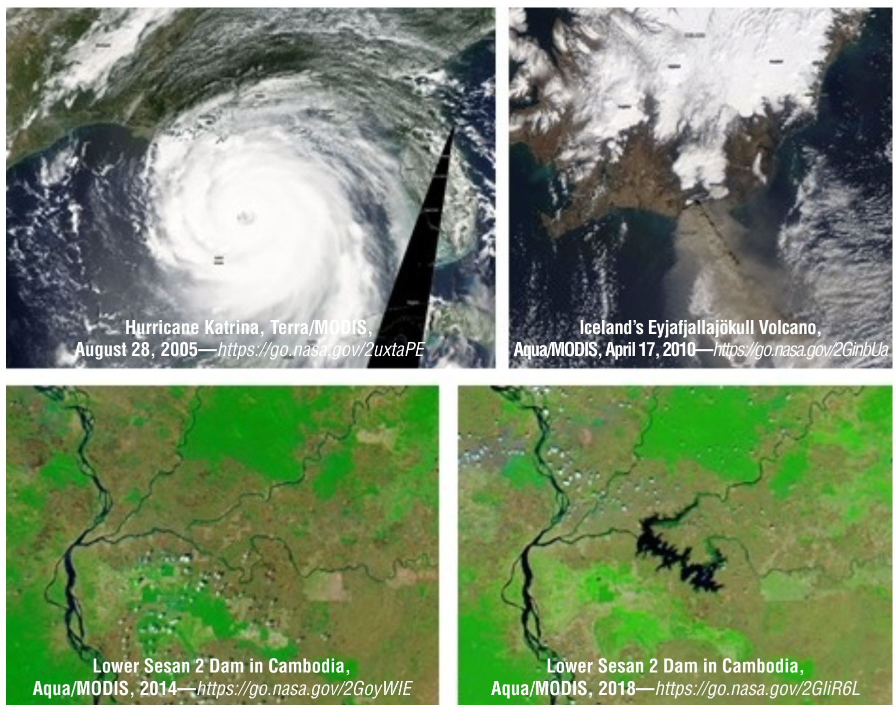


Figure 4. Now that all the archived MODIS global imagery from Terra and Aqua are available in GIBS, users can use Worldview to explore historical events like Hurricane Katrina [*upper left*], the eruption of Iceland's Eyjafjallajökull Volcano [*upper right*], and study the effects of human-caused change, such as the impact of the Lower Sesan 2 Dam in Cambodia [*lower image pair*]. **Image credit:** NASA Worldview

Boller agrees and acknowledges that finally having all daily global MODIS imagery in GIBS is the fulfillment of a long-standing desire—the MODIS past finally reaching the present. "It has been rewarding to see how excited our users are when we release new imagery or extend the imagery timeline back another few years," he says. "Now, to be able to go from the very start, the very first image, to the present and move forward provides a sense of completeness and the potential for new discoveries."

See for yourself and use Worldview to interactively explore almost 20 years of change as observed by MODIS. ■

CERES Science Team Meeting Summary

Walter Miller, NASA's Langley Research Center/Science Systems and Applications, Inc., walter.f.miller@nasa.gov

Overview

The twenty-ninth Clouds and the Earth's Radiant Energy System (CERES) Science Team Meeting was held May 15-17, 2018, at NASA's Langley Research Center (LaRC) in Hampton, VA. **Norman Loeb** [LaRC—*CERES Principal Investigator*] hosted and conducted the meeting. The major objectives of the meeting were to:

- review the performance of CERES instruments;[1]
- discuss data product validation;
- discuss the imminent reprocessing from March 2016 with Collection 6.1 data from the Moderate Resolution Imaging Spectroradiometer (MODIS);[2] and
- discuss the path forward for the next edition of CERES products.

All the presentations from the meeting are available online at *https://ceres.larc.nasa.gov/science-team-meetings2.php?date=2018-05*. Selected highlights from the presentations given at the meeting are summarized in this article.

Programmatic and Technical Presentations

On the first day of the meeting, Working Group Chairs gave a series of programmatic and technical presentations.

Norman Loeb presented the *State of CERES*, in which he reported that the first Joint Polar Satellite System (JPSS-1) Satellite[3] launched on November 18, 2017, carrying CERES Flight Model 6 (FM-6) into orbit. He also reported that the CERES Ocean Validation Experiment (COVE—*https://cove.larc.nasa.gov*) instruments will be placed on Granite Island, MI (located in Lake Superior), in June 2018. These instruments will be collocated with eddy covariance measurements of the Great Lakes Evaporation Network (GLEN). Loeb also included some CERES observations that show the impact of the most recent El Niño on the zonal radiation budget; he showed how the measurements from 2014 through 2017 compare to those obtained between 2000 and 2014. The shortwave (SW) flux is lower due to fewer clouds in the tropical Pacific; the longwave (LW) flux is higher due to increased sea surface temperature (SST) and fewer clouds; and the net flux is also higher—see **Figure 1**.

David Considine [NASA Headquarters (HQ)] spoke about Earth Venture-Continuity (EV-C) missions, a new mission category identified in the 2017 Earth Science Decadal Survey.[4] The idea is to use these EV-C concepts to continue building upon the *Program of Record*, which refers to the Earth science missions already in orbit or in development—but to do it more efficiently.

[1] There are currently six CERES instruments active on four satellites: two on Terra [FM-1 and -2]; two on Aqua [FM-3 and -4]; one on the Suomi National Polar-orbiting Partnership (NPP) [FM-5]; and one on NOAA-20 [FM-6].
[2] MODIS flies on NASA's Terra and Aqua platforms.

[3] The Joint Polar Satellite System (JPSS) is our nation's next-generation polar-orbiting operational environmental satellite system. JPSS is a collaborative program between the National Oceanic and Atmospheric Administration (NOAA) and NASA. JPSS-1 has been renamed NOAA-20.
[4] In recognition of the fact that Earth science observation in space involves a constant tension between exploring new scientific terrain and continuing existing observations—which sometimes need to last for decades to provide useful information about climate change—the 2017 Earth Science Decadal Survey identified a category called *Earth Venture Continuity*, that would allow scientists to propose ways of continuing existing observations (Program of Record) at lower cost. The full 2017 Earth Science Decadal Survey report can be downloaded from *http://sites.nationalacademies.org/DEPS/esas2017/index.htm*.

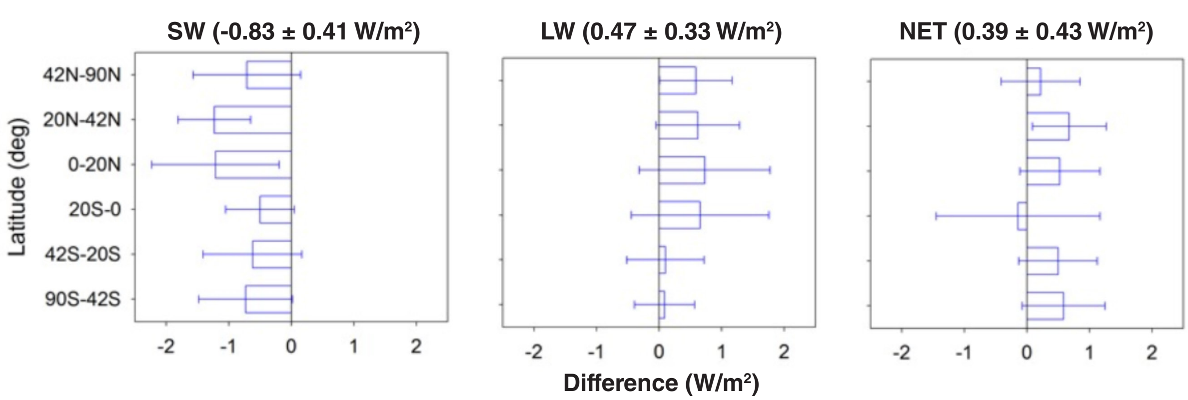


Figure 1. The zonal mean differences between the mean top of atmosphere (TOA) fluxes from July 2014 through June 2017 (i.e., the time period of the most recent El Niño) and the earlier period of July 2000 through June 2014 from Energy Balanced and Filled (EBAF) TOA Edition 4.0 product. The outgoing reflected shortwave (SW) flux difference [*left*] is negative due to fewer clouds in the tropical Pacific, the outgoing emitted longwave (LW) flux difference [*center*] is positive due to increased sea surface temperature (SST) and fewer clouds, and the net incoming flux difference [*right*] is also positive. NET = S – (SW + LW), where S represents the incoming solar radiation. **Image credit**: Norman Loeb

NASA's Earth Science Division has chosen radiation budget measurements for the first EV-C to demonstrate a technique or approach for making long term broadband measurements with the appropriate characteristics, e.g., wavelength covered, stability, accuracy, and calibration requirements.

Susan Thomas [LaRC/Science Systems and Applications, Inc. (SSAI)] reported steady calibration trends for FM-1 through FM-5—based on on-orbit calibration targets. The CERES FM-5 Start of Mission Spectral Response Function (SRF) is being reevaluated to address the difference between clear ocean and all-sky scenes observed in intercomparison studies between the CERES instruments on the Suomi National Polar-orbiting Partnership (NPP) and Aqua satellites. The updated SRF and radiometric scale difference will be included in Suomi NPP Edition 2 processing.

Kory Priestley [LaRC] announced that the FM-6 commissioning activities have successfully been completed. FM-6 differed from previous CERES instruments by having a LW channel instead of a window channel. Radiance measurements from the "new" LW channel tracks favorably with the "classic" LW measurement, which is obtained by subtracting the shortwave (SW) channel from the total channel. They are within 2% without any calibration adjustments applied yet.

William Smith, Jr. [LaRC] showed that results from an updated cloud mask and retrieval algorithms applied to the Geostationary Operational Environmental Satellite (GOES)-16 Advanced Baseline Imager (ABI) data produced results closer to the MODIS results than the previous GOES satellites. (In January 2018, GOES-16 became GOES East, replacing GOES-13 that had been serving in that capacity.) GOES-16 cloud information will now be included in the CERES Synoptic One-degree and Cloud Type Histogram products. Smith summarized the impact of including data from the Crosstrack Infrared Sounder (CrIS) on Suomi NPP in the Suomi NPP cloud mask. The CrIS data provide radiances at 6.7 and 13 µm—two channels that VIIRS does not have, but MODIS does. These channels impact cloud fraction calculations mostly over snow and ice surfaces in the polar night. However, including the data from CrIS only showed very modest improvement at polar night where skill is relatively poor. Therefore, the Science Team decided not to include CrIS data in Suomi NPP cloud processing and to work on other methods to improve the polar cloud fraction.

Wenying Su [LaRC] investigated Angular Distribution Models (ADMs) for several stratifications of mixed-phase clouds over the ocean. The largest improvement came when the mixed phase is further divided into two groups. Su's study applied the CERES Edition 2 ADM using the clouds produced from Edition 4 to determine the uncertainty attributed to the ADMs. Global monthly mean SW flux bias was between -0.8 and 0.2 W/m^2 and LW flux bias was -0.5 W/m^2.

David Kratz [LaRC] reported on impacts to the parameterized surface fluxes with the change from MODIS Collection 5 to Collection 6. The polar night surface LW fluxes showed the largest change. Use of MODIS Collection 6.1 is expected to reduce the change due to corrections to the water vapor channel.

Dave Doelling [LaRC] briefed the team on his group's approach to converting geostationary narrowband imager radiances into broadband fluxes. He showed the results from intercalibrating MODIS radiances with several of the new Geostationary satellite images: Himawari-9, Meteosat-11,[5] and GOES-16. He introduced the MODIS and Geostationary Instantaneous Cloud Comparison Tool that allows matching and visualizing gridded MODIS and geostationary clouds information for times when they are both available. This has reduced the time necessary to validate geostationary imager cloud algorithms.

Dave Rutan [LaRC/SSAI] presented an analysis of changes between versions of MODIS aerosol data and how the results obtained using the Model of Atmospheric Transport and Chemistry (MATCH) change with the different inputs. Collections 6 and 6.1 have improved coverage over Collection 5, but reduced global aerosol optical depth.

Paul Stackhouse [LaRC] reported on using the ArcGIS architecture to geospatially enable the entire Prediction of Worldwide Energy Resource (POWER) data archive (*https://power.larc.nasa.gov*) for access to growing applied science users. A user clicks on the map interface to obtain point or region data for single or multiple variables. The product resolution has improved to 0.5° x 0.5° latitude and longitude for fluxes and meteorological parameters.

Kathleen Moore [LaRC] announced that all CERES production has migrated into CERES AuTomAted job Loading sYSTem (CATALYST), allowing automated submission of jobs.

Jeff Walter [LaRC] gave an overview of the Atmospheric Science Data Center's (ASDC) cloud computing vision and strategy. The ASDC will be providing a highly configurable, on-premise, private cloud environment. The use of Platform as a Service (PaaS)[6] for website hosting has already been made available.

[5] Himawari is the Japanese Meteorological Agency's and Meteosat is the European Organization of Meteorological Satellite's (EUMETSAT) line of geostationary satellites.
[6] Platform as a Service (PaaS) refers to a category of cloud computing services that provides a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure typically associated with developing and launching an app.

Brant Dodson [LaRC/SSAI] provided insight into scientific investigations that the Global Learning and Observations to Benefit the Environment (GLOBE) clouds and CERES dataset has supported. He noted that 87% of the time-matched observations agreed on the presence of clouds. Dodson also showed that cirrus clouds are the most prevalent cloud type seen by observers. This makes these ground-based observations most helpful because it is cirrus clouds that CERES observations most frequently miss. The information will support work on improving algorithms.

Invited Science Presentations

During the morning on the second day, two invited presenters provided insight that helps explain the smaller equilibrium climate sensitivity (ECS)[7] seen in observations than those in long-duration (100-year) climate model runs.

Mark Zelinka [Lawrence Livermore National Laboratory (LLNL)] investigated time dependence of cloud feedback on ECS using the linear-forcing feedback framework. The ECS estimates obtained from observations are consistently smaller than those of climate models. He showed that this discrepancy can be explained by accounting for variation in the pattern of warming and cloud feedback. When the warming is concentrated in tropical ascending regions it strengthens low-level stability, leading to increases in low cloud cover across the tropics. The effect is more localized when the warming is in a tropical descent region. When heating is localized to the ascent region, the cloud feedback is more negative than in response to uniform warming. The most recent 30 years has shown more localized warming than the spatially-uniform greenhouse warming in models, leading to the underestimation of ECS.

[7] The ECS refers to the equilibrium change in global mean near-surface air temperature that would result from a sustained doubling of the atmospheric (equivalent) carbon dioxide concentration.

Kyle Armour [University of Washington] used the same linear-forcing feedback framework that Zelinka discussed to look at the challenges in trying to infer radiative feedback from observations. There are a variety of distinct radiative feedbacks governing the radiative response to warming that proves problematic when using observations to determine ECS. For example, sea surface temperature (SST) increases in the Western Pacific have more global impact than a similar increase in the Eastern Pacific—see **Figure 2**. The term, *inferred climate sensitivity* (ICS), is used to cover transient feedback. ICS can be measured from prescribed SST climate model runs. It is generally smaller than ECS when evaluated in climate models and matches the value obtained from observations.

Contributed Science Presentations

A variety of topics were covered during the many contributed science presentations, which took place on the second and third days of the meeting. These included:

- methods to estimate climate sensitivity;
- approaches to understanding cloud radiative feedback;
- determination of heating rates;
- validation efforts—where CERES cloud properties are compared with surface and cloud observations or other satellite products;
- improvements to existing Earth Radiation Budget (ERB) products; and
- efforts to improve algorithms for future CERES products.

For a summary of presentations, see the **Table** on pages 12-13.

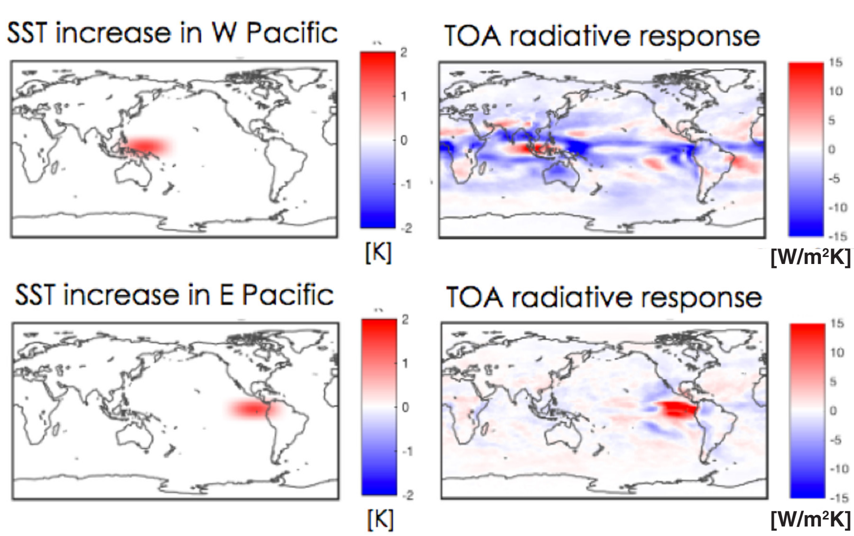


Figure 2. The radiative response to localized patches of warming using the National Center for Atmospheric Research (NCAR) Community Atmosphere Model (CAM4) model. A forced increase in SST in the Western Pacific [*upper left*], a tropical ascending region, leads to strong TOA radiative response across the tropics [*upper right*]. While a similar SST increase in the Eastern Pacific [*lower left*] has only a localized TOA radiative response [*lower right*]. **Image credit:** Kyle Armour

Table. List of Contributed Science Presentations at the Twenty-ninth CERES Science Team Meeting.

Speaker [Affiliation]	**Summary**
Andrew Dessler [Texas A&M University (TAMU)]	Continued the discussion of ECS (that began in the *Invited Science Presentations*) by looking at changes in the 500-mb temperature over climate model runs to determine ECS. This approach reduces the interdecadal variability and magnitude of the ECS compared to the approach using surface temperature.
Xianglei Huang [University of Michigan]	Showed that two different methods of looking at cloud forcing produce the same broadband result but show significantly different contributions from various parts of the spectrum.
Tyler Thorsen [NASA's Langley Research Center (LaRC)/University of Washington]	Matched the monthly zonal CERES observed flux anomalies by using water vapor and cloud anomalies.
Hailan Wang [LaRC/Science Systems and Applications, Inc. (SSAI)]	Described a diagnostic tool used to determine surface and atmospheric contributions to SW Top of Atmosphere (TOA) flux. CERES observations and reanalysis broadly agree that variability in the atmosphere dominates in non-polar regions and variability at the surface dominates in polar regions.
Hai-Tien Lee [University of Maryland]	Compared the representation of TOA all-sky and clear-sky fluxes by three different reanalyses to Edition 4 CERES data.
Kuan-Man Xu [LaRC]	Investigated the use of three indices to determine the amount of convective aggregation in cloud objects from CERES observations. Consistency is better when the area of the cloud cluster is accounted for in the index instead of just separation distance.
Sergio Sejas [LaRC]	Used data from CERES and from the Atmospheric Infrared Sounder (AIRS) on Aqua to estimate the greenhouse effect—the difference between the LW surface flux and the outgoing LW radiance.
Mike Bosilovich [NASA's Goddard Space Flight Center]	Provided an update on the Global Modeling and Assimilation Office's (GMAO) efforts to develop an integrated Earth system analysis that will have coupled atmosphere, ocean, land, and cryosphere where changes in one are used in the other models. His focus was on aerosol and ocean improvements.
Seung-Hee Ham [LaRC/SSAI]	Identified a potential bias in SW albedo due to partially cloud-filled imager pixels.
Laura Hinkelman [University of Washington]	Compared heating rates between observations obtained by the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite and CERES, which operate on different spatial scales. The heating rate has a large peak area that leads to a high likelihood of sampling the heating rate close to median, regardless of scale.
Erica Dolinar [University of North Dakota]	Presented results on radiative heating rate in single-layer ice clouds based on a dataset she developed, the CloudSat 2B-FLXHR-LIDAR, and CERES–CALIPSO–CloudSat–MODIS [CCCM] dataset.
Dong Wu [GSFC]	Identified what might be coherent interannual oscillations in summertime Arctic and subarctic TOA fluxes. The equatorward progression has been intensifying since 2009.
Patrick Taylor [LaRC]	Discussed the Barents–Kara Sea region as being the significant location of Arctic warming amplification. Clouds do matter to Arctic amplification, but their indirect impact of modulating the circulation response may be more important than the direct effect on the albedo.
Brad Hegyi [LaRC]	Analyzed the slow 2016-17 Arctic sea ice growth season and its connection to higher moisture intrusions. The increase in moisture led to increased downwelling of LW flux and higher surface temperature, reducing sea ice growth.

Table. (cont.) List of Contributed Science Presentations at the Twenty-ninth CERES Science Team Meeting.

Speaker [Affiliation]	**Summary**
Ping Yang [TAMU]	Introduced a two-layer snow albedo model to improve radiative transfer model results. The model uses a snow water equivalent (SWE) for the first layer, the effective radius that differs between the two layers, and the black carbon internal mixing, which is the same for both layers.
Tom Akkermans [Royal Meteorological Institute of Belgium]	Described an Advanced Very High Resolution Radiometer (AVHRR) based Climate Data Record (CDR) of SW TOA radiative fluxes being developed by the Satellite Application Facility on Climate Monitoring (CMSAF) Project. The Earth Radiation Budget Experiment (ERBE) algorithm to convert the imager narrowband-to-broadband and then ADMs are applied. They are working on a 42-year record.
Miklos Zagoni [representing himself]	Described research studying the equilibrium dynamic in net radiation at the surface and transfer of energy to the atmosphere through sensible and latent heat flux.
Bijoy Thampi [LaRC/SSAI]	Evaluated fluxes using machine learning methods on CERES radiances. The Artificial Neural Net produced fluxes had lower bias than those using the ERBE algorithm when compared to the Single Scanner Footprint products.
Baike Xi [University of Arizona]	Showed that CERES–MODIS Edition 4 clouds compare favorably with Atmosphere Radiation Measurement (ARM) North Slope of Alaska ground observations. Cloud fractions are within 5% whether compared by time of day or cloud phase (i.e., liquid or ice).
Fu–Lung Chang [LaRC/SSAI]	Described a new approach using the five MODIS carbon dioxide channels for detecting multilayer clouds. CALIPSO and Cloudsat data are used in the multilayer algorithm validation.
Chris Yost [LaRC/SSAI]	Presented results of comparisons between CERES–MODIS and CALIPSO clouds. The CERES–MODIS cloud retrieval does not detect too many low-level water clouds, but it overestimates the cloud fraction when clouds are less than the 1-km (~0.6-mi) imager pixel resolution.

Conclusion

By all accounts, the twenty-ninth CERES Science Team Meeting was very productive. Topics covered in presentations included ECS, cloud feedback, the Arctic, new radiation budget products, and improvements to algorithms. The next CERES Science Team Meeting will be held in conjunction with the Earth Radiation Budget Workshop, September 10-13, 2018, at National Center for Atmospheric Research (NCAR) in Boulder, CO. Representatives from the Geostationary Earth Radiation Budget (GERB) and Scanner for Radiation Budget (ScaRab) instrument teams will be participating. ■

Summary of the Spring 2018 NASA Land-Cover and Land-Use Change Science Team Meeting

Kristofer Lasko, University of Maryland, College Park, klasko@terpmail.umd.edu
Catherine Nakalembe, University of Maryland, College Park, cnakalem@umd.edu
Krishna Vadrevu, NASA's Marshall Space Flight Center, krishna.p.vadrevu@nasa.gov
Christopher Justice, University of Maryland, College Park, cjustice@umd.edu
Garik Gutman, NASA Headquarters, ggutman@nasa.gov

The 2018 NASA Land Cover and Land Use Change (LCLUC) program's Science Team Meeting was held April 3-5, 2018, at the Marriott Washingtonian Center, located in Gaithersburg, MD. The meeting featured invited presentations, reports from the LCLUC Science Team members funded as a part of South and Southeast Asia Research Initiative (SARI), as well as Synthesis Projects from Research Opportunities in Space and Earth Sciences (ROSES) 2015 selections. Poster presentations with lightning talks highlighted recent results from ongoing LCLUC-related research, including the Interdisciplinary Research in Earth Science (IDS) Program and the New Investigator Program (NIP), as well as introductions of the most recently selected LCLUC-funded projects. The last day of the meeting focused on the final results from the first round (2014) LCLUC Multi-Source Land Imaging (MuSLI) projects (which are listed at *http://lcluc.umd.edu/content/multi-source-land-imaging-musli*), the status of the Harmonized Landsat–Copernicus Sentinel-2[1] (HLS) data initiative (*https://hls.gsfc.nasa.gov*), and future interactions with the Landsat Science Team.[2]

[1] The European Space Agency's Sentinel missions were developed specifically to meet the operational needs of the Copernicus comprehensive Earth-observing program. Each Sentinel mission is based on a constellation of two satellites to fulfill revisit and coverage requirements, providing robust datasets for Copernicus services. The two mentioned in this article are Sentinel-1, a synthetic aperture radar mission, and Sentinel-2, a land-imaging mission with resolution comparable to that of Landsat. To learn more about the Sentinel missions, visit *https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Overview4*.

[2] To read a summary of the 2017 Summer Landsat Science Team Meeting, see the January–February issue of *The Earth Observer* [**Volume 30**, **Issue 1**, pp. 21-25—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/Jan_Feb_2018_color508_0.pdf#page=21*].

This year's meeting was highly successful, with about 120 participants from across the country including LCLUC principal investigators (PIs), research collaborators, post-docs, LCLUC-funded graduate students, researchers from the U.S. Geological Survey (USGS), NASA, and even a high school student conducting LCLUC-related research at NASA's Goddard Space Flight Center (GSFC).

Day One

Garik Gutman [NASA Headquarters (HQ)—*LCLUC Program Manager;* see photo below] kicked off the meeting by stating that since the program's inception over 300 projects have been funded, and socioeconomic components to land use research is one of the program's priorities. He showcased the success of the program's regional initiatives including SARI, Northern Eurasia's Future Initiative (NEFI), and the Monsoon Asia Integrated Research for Sustainability (MAIRS) under

LCLUC program manager, **Garik Gutman**, sets the science trajectory for the meeting, associated discussion sections, and lightning talks. **Photo credit:** Catherine Nakalembe

A group picture showing the meeting participants on the first day of the meeting, including scientists, graduate students, program managers, collaborators, principal investigators, and other LCLUC community members. **Photo credit:** Kristofer Lasko

Future Earth's Asia Initiative.[3] Gutman emphasized the importance of the LCLUC program's capacity building activities such as training, often included before or after LCLUC regional meetings coordinated through strong partnerships with SERVIR[4] and SilvaCarbon,[5] space agencies such as the Geo-Informatics and Space Technology Development Agency (GISTDA, Thai space agency), and nongovernmental organizations such as the SysTem for Analysis, Research and Training (START) program. **Chris Justice** [University of Maryland, College Park (UMD)—*LCLUC Program Scientist*] spoke after Gutman's overview, and reviewed the goals and objectives of the meeting.

Jack Kaye [NASA HQ—*Associate Director of Research for NASA's Earth Science Division*] gave an invited presentation. He recognized the good work being undertaken by the program, provided a summary of current and upcoming NASA missions, and announced that the LCLUC program will continue to receive funding to continue its interdisciplinary research. Kaye answered questions from the audience and noted that NASA is supportive of including data from international satellite assets and commercial data providers to address Earth system science. He also pointed out the improved capabilities of geostationary satellites for high-temporal-resolution monitoring of the land surface, e.g., for land cover change relating to wildland fires, and monitoring of urban areas with frequent observations of night lights and their changes.

Ariane de Bremond [Global Land Programme (GLP)—*Executive Officer*] reviewed the GLP science themes, which focus on linking sustainable land systems using modeling, monitoring, and case study syntheses of specific topics, e.g., land-use conflict, land governance, land-management systems, urban-rural interaction, and global sustainable development. LCLUC research is a major focus for GLP; it continues to nurture a network of internationally renowned scientists, nodal offices, and working groups, and pursues partnerships with many programs including Future Earth and the United Nations International Land Coalition. During the discussion that followed, a clear connection between GLP and the NASA LCLUC program surfaced. The GLP has strong linkages with societal applications and benefits resulting from LCLUC research, making a partnership with the NASA program very useful.

One major part of the meeting included a series of presentations within the SARI component of the LCLUC program. **Krishna Vadrevu** [NASA's Marshall Space Flight Center (MSFC)] began with a discussion about the origin of the SARI program. He explained that the concept arose from discussions following a field trip during a regional meeting in Kerala, India in 2013. Shortly after that, Vadrevu—along with other LCLUC researchers, **Ruth DeFries** [Columbia University], **Rama Nemani** [NASA's Ames Research Center], **Karen Seto** [Yale University], and **Dan Brown** [University of Washington]—consulted with Garik Gutman and Chris Justice to further develop the idea. With a common goal, SARI leverages the research being undertaken at NASA and regional institutes and universities with science capacity-building activities being undertaken by a large network of nonprofit organizations, universities, and programs such as NASA SERVIR.

Following Vadrevu's opening remarks on SARI, representatives of 13 LCLUC–SARI funded projects gave presentations. All of the talks focused on activities in South Asia. Specific presentation topics in this session included: forest change monitoring, agriculture land use and food security, disease transmission, LCLUC and armed conflict, urban growth challenges, sustainable livelihoods in rural communities, drivers of forest plantation establishment, forest change and degradation monitoring, consequences of changes in mangrove forests attributed to land use change such as shrimp farming expansion as well as natural processes of erosion—all with implications on carbon storage, biodiversity, and the economy; demographic change and related LCLUC, coastal zone impacts of LCLUC, and progress in cropland monitoring with remote sensing.

Krishna Vadrevu highlighted that the SARI program has been productive in recent years, citing as examples publication of a book on land–atmosphere interactions and several compilations of special issues of peer-reviewed journals such as *Environmental Research Letters*, *Environmental Pollution*, *International Journal of Remote Sensing*, *Journal of Environmental Management*, and *International Journal of Digital Earth*. Following the presentations, Vadrevu led a discussion session, during which he noted that the current round of SARI projects has focused on specific case studies in countries such as Nepal, India, and Myanmar. However, broader LCLUC issues applicable to large spatial scales will be needed as a focus for future projects. In addition, participants agreed on the need for regional

[3] Future Earth is a ten-year international research program launched in June 2012 at the United Nations Conference on Sustainable Development (Rio+20) that is intended to provide critical knowledge required to face the challenges posed by global environmental change and to identify opportunities for a transition

[4] SERVIR, a joint venture between NASA and the U.S. Agency for International Development provides state-of-the-art, satellite-based Earth monitoring, imaging and mapping data, geospatial information, predictive models and science applications to help improve environmental decision making among developing nations in eastern and southern Africa, the Hindu-Kush region of the Himalayas, and the lower Mekong River Basin in Southeast Asia. SERVIR is not an acronym; it is derived from a Spanish word meaning "to serve."

[5] SilvaCarbon is an interagency technical cooperation program of the U.S. government organized to enhance the capacity of selected tropical countries to measure, monitor, and report on carbon in their forests and other land-surface types.

LCLUC and water resources management projects, as this is an area of international concern. **Jiaguo Qi** [Michigan State University] is leading one such project studying the impact of the Mekong River (Vietnam) dam, which is part of Future Asia/MAIRS and NASA Interdisciplinary Sciences.

The participants also reiterated the need for an effort to bring together disparate funding sources to strengthen science capacity in the region to make better use of Earth observations data by leveraging partnerships, funding, and yielding larger educational payoffs. In the discussion that ensued, the participants recognized the benefit of a stronger connection with the GLP to increase the policy impact of LCLUC science. This strengthened partnership would be especially timely, as several SARI projects are reaching maturity. **Dan Brown**, **Jeff Fox** [both from East-West Center[6]], and other SARI members highlighted that local-scale SARI research results and processes should soon be applied to broader regional-scale themes, thereby increasing the impact of those research efforts. In addition, there will be future SARI projects that synthesize the local and national-level research to provide a broader regional perspective and inform the relevant science applications. Also, in the coming years, impactful SARI-wide review articles are anticipated that will make a contribution to broader LCLUC science. **Chris Justice** stressed the need for LCLUC PIs to leverage regional science meetings in SARI countries, as an opportunity to develop grants with local country scientists for co-funded research [e.g., with United States Agency for International Development (USAID) or regional development banks] to address the current gap in science findings and to aid in decision making. Various other issues were raised during the discussion section, including how to better communicate science findings that have policy implications, beyond using peer-reviewed research publications.

Day Two

The second day of the meeting focused on international linkages and capacity building in the South/Southeast Asia region. **Krishna Vadrevu** presented on how SARI connects with the NASA SERVIR program to facilitate improved international training for young scientists in South/Southeast Asia. He also shared recent SERVIR program highlights on behalf of **Nancy Searby** [NASA HQ]. Specific to the Southeast Asia region, the SERVIR program has a SERVIR-Himalaya hub in Kathmandu, Nepal, and also a hub in the Lower Mekong Delta.

SERVIR-Himalaya has conducted recent projects assisting with agricultural drought warning and geovisualization systems for water monitoring. The Lower Mekong Delta hub has developed partnerships with international research institutions and has provided useful tools and training driven by application needs across its four thematic areas of agriculture and food security, water resources, land cover and ecosystems, and weather and climate. Some example projects of note include a regional land-cover-monitoring system as well as web-based tools for flood-damage assessment. These and other applications are driven by user demand and are implemented through partnerships with Global Forest Watch[7], University of Maryland, SilvaCarbon, and many other regional partners.

Jiaguo Qi gave a presentation about the MAIRS and Future Earth's Asia Initiative, which provided a clear opportunity for collaboration between the MAIRS and SARI.There are already plans underway to conduct a science meeting to be held jointly with associated capacity-building activities in the Southeast Asia region.

The LCLUC program has traditionally funded synthesis projects, which pull together project findings to further develop a broader regional understanding and strengthen the theoretical underpinning to regional LCLUC science. Included among the presentations and posters were several that focused on current LCLUC synthesis projects including: **Steve Walsh** [University of North Carolina] who reported on LCLUC island processes; **Ariane de Bremond,** who discussed socio-environmental synthesis of the global land rush; and **Randolph Wynne** and **Valerie Thomas** [both from Virginia Tech], who presented information on region-specific LCLUC drivers of transition and future scenarios for the Southeast U.S. In coming years synthesis projects derived from SARI countries will be solicited.

A poster presentation closed out the second day of the meeting. It featured 30 posters with a wide range of topics. A list of all presentations can be downloaded from the LCLUC website at *http://lcluc.umd.edu/sites/default/files/lcluc_documents/LCLUC_2018_posterPresentations.pdf*.

Day Three

The third day of the meeting was dedicated to the MuSLI section of the LCLUC program. **Jeff Masek** [GSFC—*MuSLI Project Scientist*] led this portion of the meeting. The MuSLI team consists of full-scale continental/global scale products (called *Type I* projects) and

[6] The East–West Center was established by the U.S. Congress in 1960 to promote better relations and understanding among the people and nations of the United States, Asia, and the Pacific through cooperative study, research, and dialogue. Learn more at *https://www.eastwestcenter.org/about-ewc/mission-and-organization*.

[7] Global Forest Watch (GFW) is an online platform that provides data and tools for monitoring forests. By harnessing cutting-edge technology, GFW allows anyone to access near-real-time information about where and how forests are changing around the world. Learn more at *https://www.globalforestwatch.org*.

regional prototype products (called *Type II* projects).[8] Both types are focused on developing innovative approaches and datasets using multiple sensor data (i.e., Sentinel-1, Sentinel-2, Landsat 8). The HLS Surface Reflectance Product is a core product for MuSLI, representing the most widely accessible multispectral, medium-to-high spatial resolution satellite data. The synergistic use of the Sentinel-1, Sentinel-2, and Landsat 8 sources provides unprecedented opportunities for timely and accurate observation of land surface dynamics at improved temporal frequencies—previously unachievable at this spatial resolution. Activities to harmonize data products have been funded by the LCLUC program since 2014, including a new round of funded projects in 2018. Sample data are now accessible at *https://hls.gsfc.nasa.gov*.

David Roy [South Dakota State University] showcased a combined Landsat 8–Sentinel-2 burned-area product that offers potential for improved small-fire burn detection; the output of the first stage of production is to be released for Africa. He also presented improved coregistration software for combined Landsat 8–Sentinel-2 (*https://openprairie.sdstate.edu/landsat_sentinel_registration/2*).

This session focused on the results from the first round of MuSLI-funded projects. It included wrap-up presentations from several MuSLI investigators. **William Salas** and **Nathan Torbick** [both affiliated with Applied GeoSolutions] described their effort to develop near-real-time and operational rice mapping products including drought assessment and impacts on rice production. **Joseph Sexton** [UMD] reported on global tree- and water-cover mapping. **Chris Small** [Columbia University] summarized his research on urban growth and infrastructure through development of a physically based, satellite-derived index to map human settlement patterns, changes, and quantifying co-evolution of settlement networks across the landscape through time.

There were also presentations from **Matthew Hansen** [UMD] on multisource methods for improving crop type mapping, area estimation, and sampling methods in the U.S., as well as **Mark Friedl** [Boston University] on seasonal dynamics of land surface phenology integrating multiple satellite observations—see **Figure 1**, and **Chengquan Huang** [UMD] on near-daily inundated area mapping with SAR and optical datasets over North America.

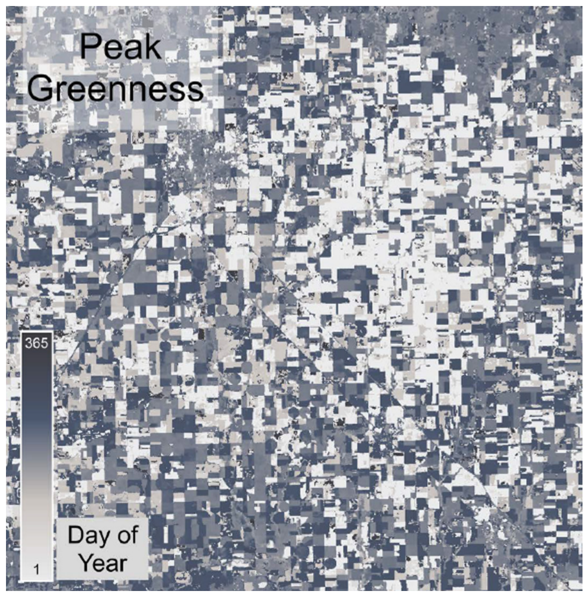


Figure 1. An example of a MuSLI project result from using combined Landsat 8 and Sentinel-2 satellite data product to map the day of peak vegetation greenness over a cropland area of Kansas. **Image credit**: Mark Friedl

[8] MuSLI Type I projects integrate previously demonstrated algorithms and dataset validation, but applied to multiple satellite dataset integration and with data processing costs supported by NASA. In contrast, MuSLI Type II projects focus on developing algorithms and products at a regional scale, especially in order to demonstrate feasibility of a global scale product.

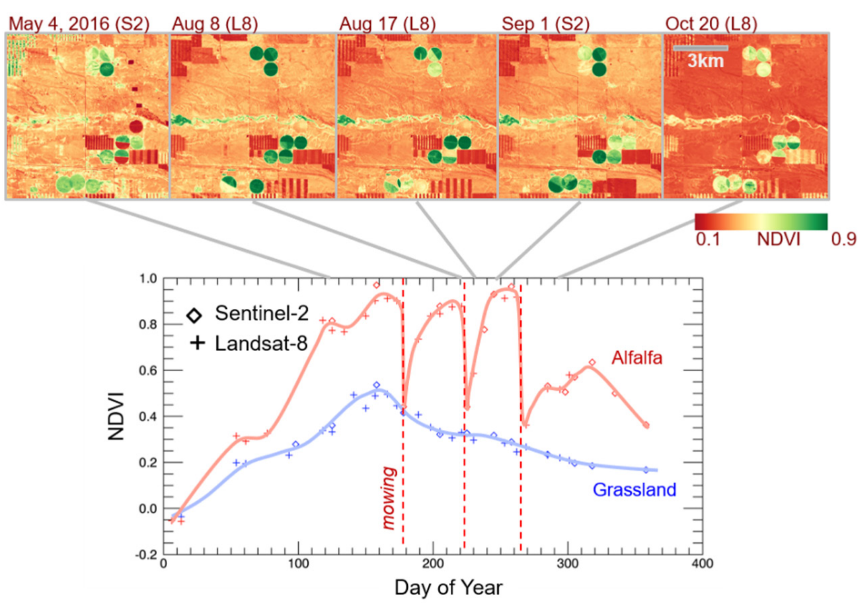


Figure 2. HLS product example shown with Sentinel-2 (S2) and Landsat 8 (L8) integrated together showing seasonal phenology (greening) for natural grassland and irrigated alfalfa fields near Cheyenne, WY, between May and October 2016, observed from Harmonized Landsat 8/Sentinel-2 data products. The high temporal density of observations allows individual mowing events to be detected within alfalfa fields. **Image credit**: From Jeff Masek's presentation

A new feature of this meeting as compared to previous years was the addition of *lightning talks* from the eight most recently funded MuSLI projects (2018-2020), with topics including: land-surface phenology, various agricultural applications (i.e., agricultural abandonment, crop yield mapping), and land-surface temperature. One novel project (led by Petya Campbell) is mapping vegetation function and chlorophyll content. The lightning talk approach helped the broader LCLUC community to become familiar with scientists newly working in these areas and to get an idea of the trajectory for the latest in cutting-edge research topics.

Jeff Masek and **Chris Crawford** [USGS—*Landsat Science Team*] were pleased to share that progress has been made in combined multisensor products, e.g., surface reflectance using Sentinel-2 and Landsat 8—e.g., see **Figure 2** on page 17. Moreover, there has been progress in integrating the Sentinel-1 Synthetic Aperture Radar data with optical observations. MuSLI scientists discussed challenges with geolocation errors, lack of reprocessing with Sentinel-2, which makes it difficult to implement changes to previously collected or already-processed datasets; cloud masking with Sentinel-2, due to lack of thermal band; and the Sentinel-2 tiling system, which has overlap issues. Efforts are underway to address these problems and to forward any new instrument and data issues to ESA. The participants agreed that a stronger linkage should be made between the NASA MuSLI "Science Team"[9] and the newly selected Landsat Science Team with the possibility of joint meetings, as there is considerable overlap of team members.

Concluding Remarks

Garik Gutman adjourned the meeting. In his concluding remarks he emphasized three key points about the NASA LCLUC program:

1. It is a global program, supported through regional partnerships to enhance regional scientists' access to NASA's remote sensing assets and, conversely, NASA's scientists' access to international data (i.e., data from various governments currently limited in data sharing activities), and field data collection.

2. It acts as a catalyst to further regional science initiatives through networks, by leveraging national, regional, and local knowledge and resources to strengthen NASA's research projects, with regular regional workshops on land-use science and societal priorities.

3. It is a promoter of science capacity building through international data sharing and training on the use of NASA science data.

Gutman indicated that in the coming years, LCLUC will continue regional science funding such as for SARI and NEFI, while also better balancing geographic and thematic research foci, including a renewed focus on Latin America and other regions of the world, while also continuing projects in North America. The continued funding of social science research is critical for LCLUC science as investigators seek to understand the underlying processing driving land cover changes. There is also a need to analyze and synthesize the results from the first and second rounds of SARI and MuSLI projects, and to continue to build upon the success of such international efforts by better integrating networks with other space agencies such as ESA and programs such as the GLP, European Association of Remote Sensing Laboratories (EarSEL), and others.

Overall, the LCLUC Science Team Meeting succeeded in its objective of bringing together LCLUC researchers from across the country to further develop project partnerships and collaborations, address and improve upon ongoing issues relating to multi-source data integration, and collect community feedback regarding LCLUC science and continuing to keep the LCLUC program focus in line with community needs. Looking forward, the next LCLUC-related meeting is the LCLUC/SARI regional science team meeting, to take place in August 2018 in Southeast Asia (location to be determined; visit *http://sari.umd.edu* for updates). Meanwhile, the next LCLUC Science Team Meeting will take place during April 2019 with final details forthcoming (check *http://lcluc.umd.edu* for updates in late autumn or early winter). Members of the NASA LCLUC community are strongly encouraged to register early and attend. ■

[9] Officially, NASA does not consider MuSLI Team a science team; however, within the context of the LCLUC Program they function as a science team, with a "project scientist" assigned by the LCLUC program manager.

3D View of Amazon Forest Captures Effects of El Niño Drought

Ellen Gray, NASA's Goddard Space Flight Center, ellen.t.gray@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While our intent is to reprint it with its original form largely intact, in this case, we did update the last paragraph to contain up-to-date information.

Three-dimensional (3D) measurements of the central Brazilian Amazon rainforest have given NASA researchers a detailed window into the high number of branch falls and tree mortality that occur in response to drought conditions. They found that 65% more trees and large branches died due to an El Niño-driven drought in 2015-2016 than compared to an average year. Understanding the effects of prolonged drought gives scientists a better sense of what may happen to carbon stored in tropical forests if these events become more common in the future.

"Climate projections for the Amazon basin suggest warmer and drier conditions in coming decades," said **Doug Morton** [NASA's Goddard Space Flight Center (GSFC)—*Earth System Scientist*], a co-author on the research recently published in *New Phytologist*.[1] "Drought events give us a preview of how tropical forests may react to a warmer world."

When it doesn't rain in the rainforest, trees are more at risk of dying because they can't get enough water from the soil to their canopies—which can reach 15 to 20 stories high. In a rainforest as vast as the Amazon, estimating the number of dying or damaged trees, where only branches may fall, is extremely difficult and has been a long-standing challenge.

Traditionally, researchers hike in and survey a few acres of trees to measure living trees and dead debris on the ground. Morton and his colleagues took the bird's eye perspective using light detection and ranging (lidar) technology mounted onto an airplane to create a 3D reconstruction of the same forest canopy over three separate flights in 2013, 2014, and 2016. With 300,000 laser pulses a second, the lidar data provide an incredibly detailed depiction of the forest over a much greater area than they could cover on foot.

In Brazil, the researchers flew two 30-mi (50-km) swaths near the city of Santarém in the state of Pará: one over the Tapajós National Forest, and the other over privately owned forests that have been fragmented by a range of land uses. This region of the Amazon typically has a three-month dry season from October through December, the same period when Pacific Ocean sea surface temperatures peak during an El Niño event. El Niño conditions are associated with a delayed start of the rainy season in the central Amazon, leading to an extended dry season that stresses the trees.

Analyzing the three surveys, the team used the lidar data to detect new gaps in the canopy where a tree or branch had fallen in the months between observations. During the non-El Niño period from 2013 to 2014, the branch and tree fall events altered 1.8% of the forest canopy in the study area, a small number on the surface but scaled up to the size of the entire Amazon, it's the equivalent of losing canopy trees or branches over 38,000 mi^2 (~98,420 km^2), or the area of the U.S. state of Kentucky. Tree and branch mortality was 65% higher during the El Niño drought period from 2014 to 2016, or 65,000 mi^2 (168,349 km^2), or the size the U.S. state of Wisconsin. Small changes in the Amazon add up.

"Because it's a big forest, even a subtle shift in an El Niño year has a big impact on the total carbon budget of the forest," said Morton, referring to the balance between how much carbon dioxide trees remove from the atmosphere to build their trunk, branches, and leaves as they grow versus the amount that returns to the atmosphere when trees die and decompose.

Surprisingly, the scientists found that deaths for all tree sizes, as well as the number of smaller branch falls, increased at about the same rate. This means that the drought didn't selectively kill a greater proportion of tall trees than smaller trees, as was previously thought from experiments that simulated drought conditions in small plots.

That's good news for the carbon budget, said Morton, "Large trees hold most of the carbon in any forest. If droughts were to preferentially kill large trees, it would boost the total amount of carbon that's lost from drought as opposed to other disturbance types," he said.

Even so, large trees still made up 80% of the carbon losses. And not just from the trees themselves dying. When a giant tree with a canopy that can be 82 ft (25 m) across falls in the forest it can take out smaller trees in the understory.

[1] For access to the paper, visit *https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.15110*.

continued on page 21

Ramp-Up in Antarctic Ice Loss Speeds Sea Level Rise

Steve Cole, NASA Headquarters, stephen.e.cole@nasa.gov
Alan Buis, NASA/Jet Propulsion Laboratory, alan.buis@jpl.nasa.gov

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.

Ice losses from Antarctica have tripled since 2012, increasing global sea levels by 0.12 in (3 mm) in that timeframe alone, according to a major new international climate assessment funded by NASA and the European Space Agency (ESA).

According to the study, ice losses from Antarctica are causing sea levels to rise faster today than at any time in the past 25 years. Results of the Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE, *http://imbie.org*) were published in the journal *Nature*.

"This is the most robust study of the ice mass balance of Antarctica to date," said assessment team co-lead **Erik Ivins** [NASA/Jet Propulsion Laboratory (JPL)]. "It covers a longer period than our 2012 IMBIE study, has a larger pool of participants, and incorporates refinements in our observing capability and an improved ability to assess uncertainties."

This latest IMBIE is the most complete assessment of Antarctic ice mass changes to date, combining 24 satellite surveys of Antarctica and involving 80 scientists from 42 international organizations.

The team looked at the mass balance of the Antarctic ice sheet from 1992 to 2017 and found ice losses from Antarctica raised global sea levels by 0.3 in (7.6 mm), with a sharp uptick in ice loss in recent years—see **Figure**. They attribute the threefold increase in ice loss from the continent since 2012 to a combination of increased rates of ice melt in West Antarctica and the Antarctic Peninsula, and reduced growth of the East Antarctic ice sheet.

Prior to 2012, ice was lost at a steady rate of about 83.8 billion tons (76 billion metric tons) per year, contributing about 0.008 in (0.2 mm) a year to sea level rise. Since 2012 the amount of ice loss per year has tripled to 241.4 billion tons (219 billion metric tons)—equivalent to about 0.02 in per year (0.6 mm) of sea level rise.

West Antarctica experienced the greatest recent change, with ice loss rising from 58.4 billion tons (53 billion metric tons) per year in the 1990s, to 175.3 billion tons (159 billion metric tons) a year since 2012. Most of this loss came from the huge Pine Island and Thwaites Glaciers, which are retreating rapidly due to ocean-induced melting.

At the northern tip of the continent, ice-shelf collapse at the Antarctic Peninsula has driven an increase of 27.6 billion tons (25 billion metric tons) in ice loss per year since the early 2000s. Meanwhile, the team found the

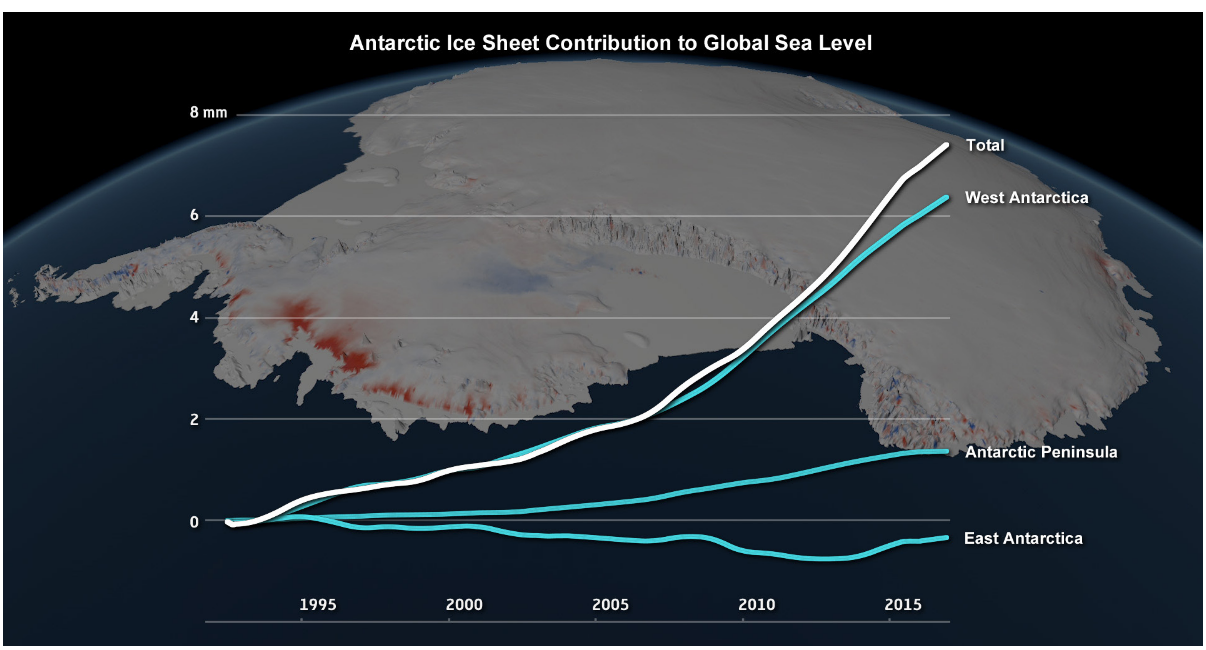


Figure. Changes in the Antarctic ice sheet's contribution to global sea level, 1992 to 2017. **Credit:** IMBIE/Planetary Visions

East Antarctic ice sheet has remained relatively balanced during the past 25 years, gaining an average of 5.5 billion tons (5 billion metric tons) of ice per year.

Antarctica's potential contribution to global sea level rise from its land-held ice is almost 7.5 times greater than all other sources of land-held ice in the world combined. The continent stores enough frozen water to raise global sea levels by 190 ft (58 m) if it were to melt entirely. Knowing how much ice it's losing is key to understanding the impacts of climate change now and its pace in the future.

"The datasets from IMBIE are extremely valuable for the ice sheet modeling community," said study co-author **Sophie Nowicki** [NASA's Goddard Space Flight Center (GSFC)—*Research Scientist and Deputy Chief for the Cryospheric Sciences Laboratory*]. "They allow us to test whether our models can reproduce present-day change and give us more confidence in our projections of future ice loss."

The satellite missions providing data for this study are NASA's Ice, Cloud and land Elevation Satellite (ICESat); the joint NASA/German Aerospace Center Gravity Recovery and Climate Experiment (GRACE); ESA's first and second European Remote Sensing (ERS-1 and -2) satellites, Envisat, and CryoSat-2; the European Union's Copernicus Sentinel-1 and Sentinel-2 missions; the Japan Aerospace Exploration Agency's Advanced Land Observatory System (ALOS); the Canadian Space Agency's RADARSAT-1 and RADARSAT-2 satellites; the Italian Space Agency's COSMO-SkyMed satellites; and the German Aerospace Center's TerraSAR-X satellite.

Tom Wagner [NASA Headquarters—*Cryosphere Program Manager*] hopes to welcome a new era of Antarctic science with data from the recently launched Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) mission and the upcoming launch of NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2).

"Data from these missions will help scientists connect the environmental drivers of change with the mechanisms of ice loss to improve our projections of sea level rise in the coming decades," Wagner said. ■

3D View of Amazon Forest Captures Effects of El Niño Drought

continued from page 19

To understand the relationship between the gaps seen by the airborne lidar system from above and the multiple layers of canopy and understory below, Morton's colleague **Veronika Leitold** [GSFC—*Visiting Scientist from the University of Maryland College Park*] and a team of collaborating scientists at the Brazilian Agricultural Research Corporation and the Federal University of Western Pará conducted field measurements underneath observed gaps in the canopy to measure the woody material that had fallen to the ground. This painstaking effort to measure downed branches and trees was essential to estimate the total amount of carbon lost when trees or branches fall in a tall, multilayered Amazon rainforest.

"[This] is one of the first studies to use repeated lidar during the drought and have people go into the field and conduct all the measurements," said **Paulo Brando** [Woods Hole Research Center—*Ecologist*], who was not involved in the study. "This combination is extremely powerful to understand not only what is happening, but why it is happening, and why it's changing during the drought." He added that two of the big questions in the field of tropical rainforest ecology are how much drought is too much for the forest to withstand and how does it recover? The answers have large implications for the removal of carbon dioxide from the atmosphere.

"Droughts are important components of the global carbon cycle by changing the ability of trees to survive," Brando said. If the number of trees present declines on a large scale, that adds up to a lot of carbon dioxide left in the atmosphere to contribute to greenhouse warming, which can feed the cycle of the Amazon seeing more droughts in the future.

Funding for this research was provided by NASA and the Brazilian National Council for Scientific and Technological Development (CNPq). Lidar data were acquired with support from USAID, U.S. Department of State, the Brazilian Agricultural Research Corporation (Embrapa), and the USDA Forest Service. All data are freely available through the Sustainable Landscapes Brazil Project, online at *https://www.paisagenslidar.cnptia.embrapa.br/webgis*.

To watch a visualization of the aircraft mapping forest canopies, visit *http://svs.gsfc.nasa.gov/12982*. ■

NASA Soil Moisture Data Advances Global Crop Forecast

Kate Ramsayer, NASA's Goddard Space Flight Center, kate.d.ramsayer@nasa.gov

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.

Data from the first NASA satellite mission dedicated to measuring the water content of soils are now being used operationally by the U.S. Department of Agriculture (USDA) to monitor global croplands and make commodity forecasts.

The Soil Moisture Active Passive (SMAP) mission launched in 2015 and has helped map the amount of water in soils worldwide—see **Figures 1** and **2**. Now, using tools developed by a team at NASA's Goddard Space Flight Center (GSFC), SMAP soil moisture data are being incorporated into the Crop Explorer website of the USDA's Foreign Agricultural Service,[1] which reports on regional droughts, floods, and crop forecasts.

[1] The USDA's Crop Explorer tool is at *https://ipad.fas.usda.gov/cropexplorer*.

Crop Explorer is a clearinghouse for global agricultural growing conditions, such as soil moisture, temperature, precipitation, vegetation health, and more.

"There's a lot of need for understanding, monitoring, and forecasting crops globally," said **John Bolten** [GSFC—*Research Scientist*]. "SMAP is NASA's first satellite mission devoted to soil moisture, and this is a very straightforward approach to applying [those] data."

Variations in global agricultural productivity have tremendous economic, social, and humanitarian consequences. Among the users of these new SMAP data are USDA regional crop analysts who need accurate soil moisture information to better monitor and predict these variations.

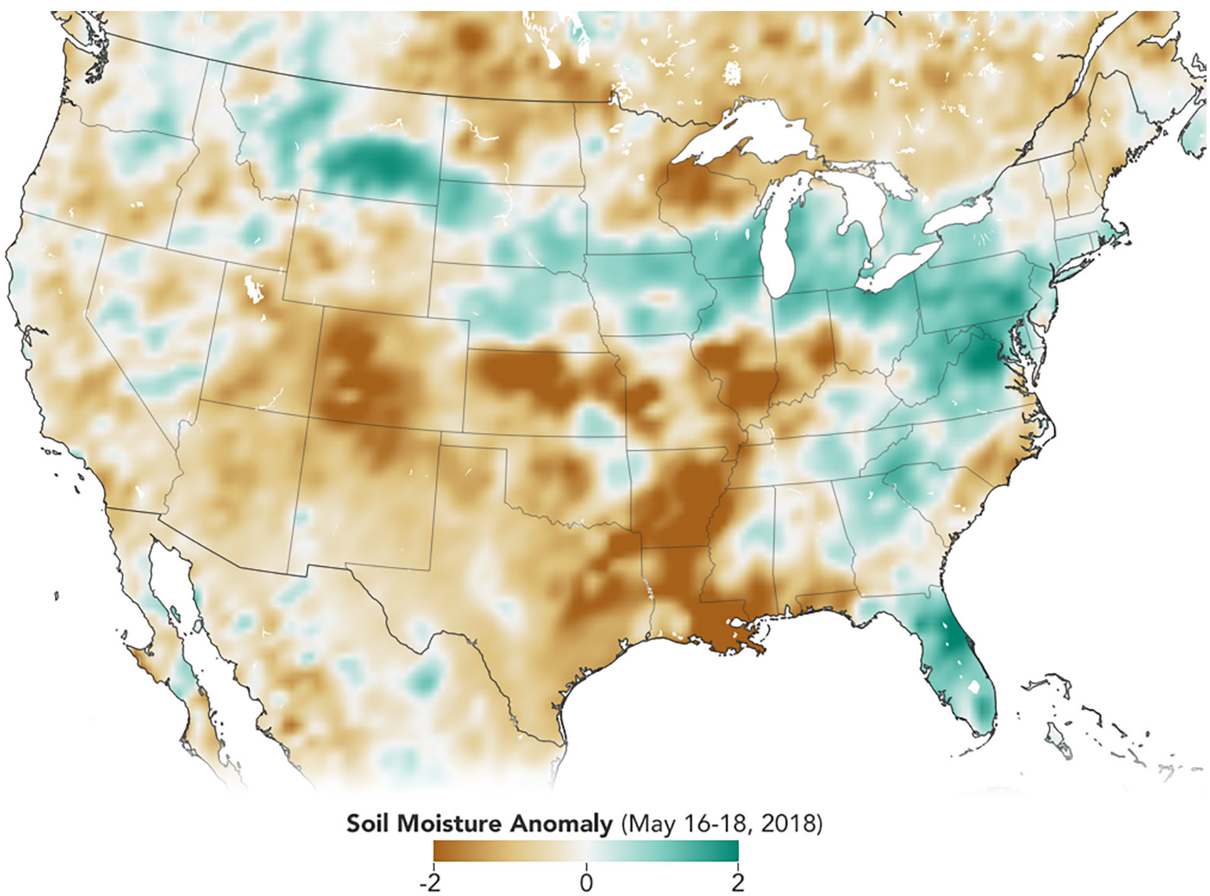


Figure 1. With data from NASA's Soil Moisture Active Passive (SMAP) satellite, researchers can monitor the amount of water in the soils to identify areas prone to droughts or floods. In this map created with SMAP data from May 16-18, 2018, soils that are wetter than normal are seen as light gray shades, while those that are drier than normal are seen as dark gray shades. **Credit: Joshua Stevens** [GSFC]/NASA's Earth Observatory

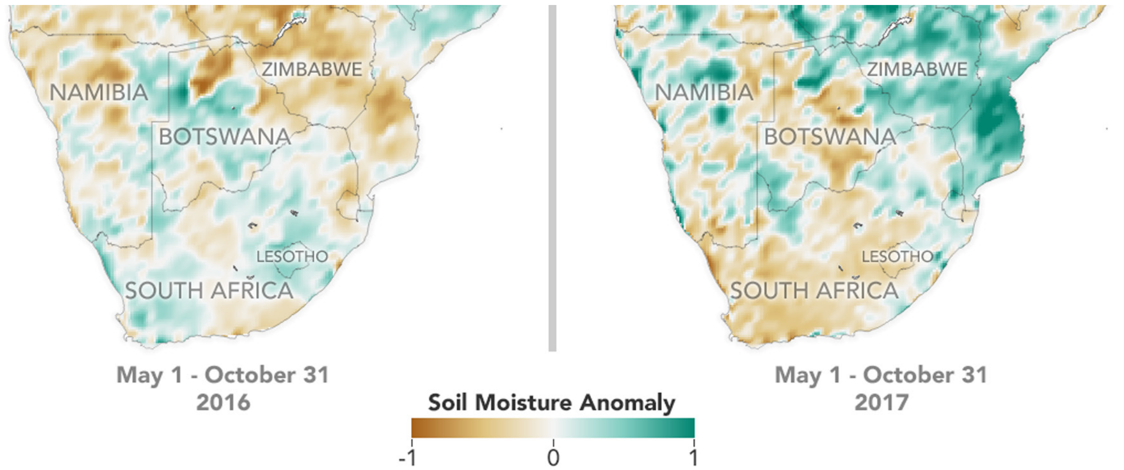


Figure 2. The maps above, based on SMAP data, show *soil moisture anomalies*—how much the moisture content was above or below the norm—and how they've changed in Southern Africa from 2016 to 2017. NASA's SMAP satellite takes global measurements, allowing researchers and resource managers to identify and compare regions that are drier and wetter than normal, even if they are far from weather radar or water gauges. **Credit: Joshua Stevens** [GSFC]/NASA's Earth Observatory

"The USDA does crop forecasting activities from a global scale, and one of the main pieces of information for them is the amount of water in the soil," said **Iliana Mladenova** [GSFC—*Research Scientist*].

In the past, the USDA has used computer models that incorporate precipitation and temperature observations to indirectly calculate soil moisture. This approach, however, is prone to error in areas lacking high-quality, ground-based instrumentation. Now, Mladenova said, the agency is incorporating direct SMAP measurements of soil moisture into Crop Explorer. This allows the agriculture analysts to better predict where there could be too little, or too much, water in the soil to support crops.

These soil moisture conditions, along with tools to analyze the data, are also available on Google Earth Engine.[2] There, researchers, nonprofits, resource managers, and others can access the latest data as well as archived information.

"If you have better soil moisture data and information on anomalies, you'll be able to predict, for example, the occurrence and development of drought," Mladenova said.

[2] For information about SMAP data products in Google Earth Engine, visit *https://explorer.earthengine.google.com/#detail/NASA_USDA%2FHSL%2FSMAP_soil_moisture*.

The timing of the information matters as well, she added—if there's a short dry period early in the season, it might not have an impact on the total crop yield, but if there's a prolonged dry spell when the grain should be forming, the crop is less likely to recover.

With global coverage every three days, SMAP can provide the Crop Explorer tool with timely updates of the soil moisture conditions that are essential for assessments and forecasts of global crop productivity.

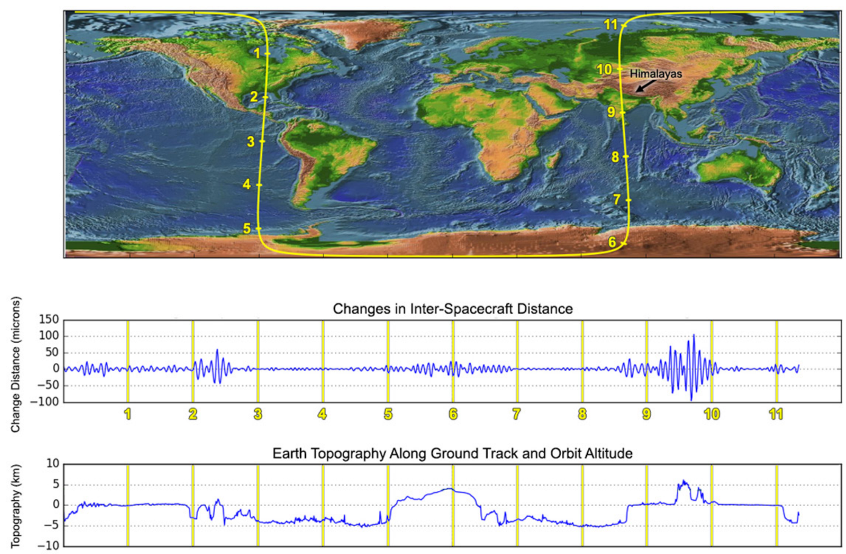
For more than a decade, the USDA Crop Explorer products have incorporated soil moisture data from satellites. It started with the Advanced Microwave Scanning Radiometer-E (AMSR-E) instrument aboard NASA's Aqua satellite, but that instrument stopped gathering data in late 2011. Soil moisture information from the European Space Agency's Soil Moisture and Ocean Salinity (SMOS) mission is also being incorporated into some of the USDA's products. This new, high quality input from SMAP will help fill critical gaps in soil moisture information. ■

"First Light" for GRACE-FO's Microwave and Laser Ranging Instruments

Referenced on page 2 of Editorial

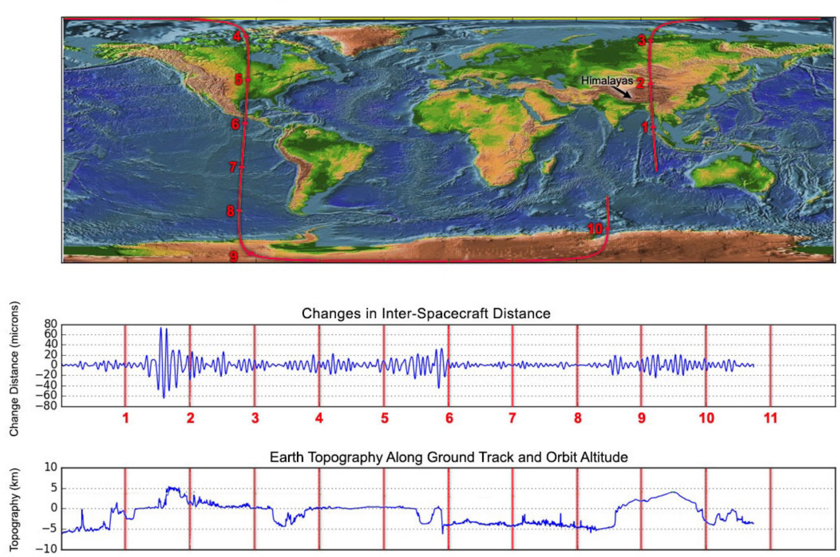
To demonstrate the initial performance of GRACE-FO's microwave ranging system, the GRACE-FO team examined its measurements of changes in the distance between the two satellites as they flew over the Himalayas. The results are shown in the top figure, which members dubbed "The Himalaya Plot"—because that is where the largest gravity variations are evident. Along the satellites' ground track [*traced on map*], the distance between the two spacecraft changes [*top plot*] as the mass distribution underneath varies (e.g., from mountains) [*bottom plot*]. The observed intersatellite distance changes, which can be as large as hundreds of microns, are in good agreement with expectations. These results give the team confidence that the mission's key microwave ranging system is performing well.

GRACE-FO Single-Orbit Ground Track, May 30, 2018



Shown below is the first "Himalaya Plot" obtained using the experimental laser ranging instrument (LRI)—but not at the same time as the one shown above. Along the satellites' ground track [*traced on map*], the distance between the two spacecraft changes [*top plot*] as the mass distribution underneath varies (e.g., from mountains) [*bottom plot*]. The key finding is that the LRI's measurements match well with those obtained by the microwave instrument.[1]

GRACE-FO Single-Orbit Ground Track, June 14, 2018



[1] To learn more about these events please see *https://www.nasa.gov/feature/jpl/grace-fo-turns-on-range-finder-sees-mountain-effects* and *https://www.nasa.gov/feature/jpl/first-laser-light-for-grace-follow-on*.

NASA Earth Science in the News

Samson Reiny, NASA's Goddard Space Flight Center, Earth Science News Team, samson.k.reiny@nasa.gov

EDITOR'S NOTE: This column is intended to provide an overview of NASA Earth Science topics mentioned by online news sources during the past few months. Please note that editorial statements, opinions, or conclusions do not necessarily reflect the positions of NASA. There may be some slight editing in places primarily to match the style used in *The Earth Observer*.

***Antarctica Ice is Melting Faster. Coastal Cities Need to Prepare—Now**, June 22, *washingtonpost.com*. Scientists have given Antarctica a thorough physical exam. A landmark study published in the journal *Nature* combined the work of 80 scientists from 42 institutions, including NASA, and found that, since 1992, Antarctica has lost nearly 3 trillion tons of ice—enough to raise sea levels by a little less than a centimeter.[1] Of that total amount of loss, 40% has occurred in the past five years. The ice-loss rate is now triple what it was a decade ago. One should guard against assuming that trends will continue as they have in the immediate past. But there is more reason to fear that ice loss will worsen rather than abate. East Antarctica, once gaining mass, now appears to be losing it. And scientists warn of instability in major West Antarctic ice formations that could lead to catastrophic ice loss. The paper took data from researchers who estimated Antarctic ice loss in 24 studies using three methods. These three methods resulted in parallel, wholly independent readings that largely matched up.

NASA Discovered Why Greenland's Glaciers Are Melting at Different Speeds, June 23, *inverse.com*. The Tracy and Heilprin glaciers have been observed by scientists since 1892, partially due to their mysterious nature. Even though the adjoining glaciers flow side-by-side and experience the same weather and ocean conditions, Tracy has melted nearly four times faster than its neighbor. NASA's Ocean Melting Greenland (OMG) is a five-year campaign to better understand the extent to which ocean water is melting the ice sheet of the world's largest island. As part of the campaign, the OMG team documented the disparity between Tracy and Heilprin as they flowed in the Inglefield Gulf in northwest Greenland. NASA published the campaign's findings in the journal *Oceanography*, showing that Tracy and Heilprin's initial similarities were just the tip of the iceberg.[2] In the 125 years that the two glaciers have been observed, Heilprin has retreated upstream less than 2.5 mi (~4 km), while Tracy has retreated more than 9.5 mi (~15 km). Past studies from NASA's Operation IceBridge used ice-penetrating radar to discover that Tracy is seated on bedrock at a depth of 2000 ft (~610 m) below the ocean surface, but Heilprin only extends 1100 ft (~335 m). This would contribute somewhat to Tracy's increased melting rates—since it's a deeper glacier that is more exposed to Greenland's warm water layer, which begins about 660 ft (~200 m) below the surface. And yet, most of Tracy's disappearance has taken place at the top of the glacier. "Most of the melting happens as the water rises up Tracy's face," said **Josh Willis** [NASA/Jet Propulsion Laboratory—*OMG Principal Investigator*]. "It eats away at a huge chunk of the glacier." To get to the bottom of this puzzling contradiction, OMG sent a research boat into the Inglefield Gulf and discovered a warm-water plume flowing into Tracy and a cold-water plume passing through Heilprin.

James Hansen Wishes He Wasn't So Right About Global Warming, June 18, *apnews.com*. James Hansen wishes he were wrong. He wasn't. NASA's top climate scientist in 1988, Hansen warned the world on a record hot June day 30 years ago that global warming was here and worsening. In a scientific study that came out a couple of months later, he even forecast how warm it would get, depending on emissions of heat-trapping gases. The hotter world that Hansen envisioned in 1988 has pretty much come true so far, more or less. Three decades later, most climate scientists interviewed rave about the accuracy of Hansen's predictions given the technology of the time. In his 1988 study, Hansen and colleagues used three different scenarios for emissions of heat-trapping gases—high, low, and medium. Hansen and other scientists concentrated on the middle scenario. Hansen projected that by 2017, the globe's five-year average temperature would be about 1.85 °F (1.03 °C) higher than the 1950 to 1980 NASA-calculated average. NASA's five-year average global temperature ending in 2017 was 1.48 °F (0.82 °C) above the 30-year average.

[1] Article can be accessed at *http://www.nature.com/articles/s41586-018-0179-y*.

[2] To read more, visit *https://www.nasa.gov/feature/jpl/omg-the-waters-warm-nasa-study-solves-glacier-puzzle*.

***El Niño Destroyed 65 Percent More Trees in The Amazon Rainforest, An Area the Size Of Wisconsin, Per NASA**, June 18, *inquisitr.com*. The 2015 drought was produced by an El Niño event—the warm phase of the El Niño Southern Oscillation (ENSO). That El Niño caused climate fluctuations as measured by sea surface temperatures that have killed 65% more trees and large branches in the Amazon Rainforest than are typically lost in an average year. The conclusion comes from an in-depth analysis by scientists at NASA's Goddard Space Flight Center and the Brazilian Agricultural Research Corporation (Embrapna),[3] who published their findings in a study featured in the journal *New Phytologist*. According to NASA, the research, based on data gathered during three separate flights (in 2013, 2014, and 2016), was based on an innovative technique of measuring the living trees and dead debris on the ground of the rainforest, which yielded a three-dimensional (3D) model of the Amazon's forests. In the past, such measurements have required scientists trekking to a portion of the rainforest to collect data. This time the team came up with the brilliant idea to attach a light detection and ranging (LiDAR) instrument onto an airplane and survey the forest canopy from above.

****Browse 20 Years of Earth's Weather with NASA's Incredible Worldview Tool**, June 5, *bgr.com*. Whenever NASA shows off a stunning new image of Earth from space it's fun to take a few minutes to soak up all the details. What we sometimes forget is that NASA's high-flying tools don't just capture those amazing moments—they capture everything. For almost two decades NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) has been observing weather patterns here on Earth. And now, thanks to the magic of the internet, you can journey through it all, day by day, right from your browser. NASA updated its Worldview easy-to-use application with the incredible wealth of weather data. In addition to the update, NASA released a brief video[4] showcasing a few of the highlights hidden in the massive amount of data, showing you when and where to zoom in if you want to check it out for yourself.

[3] Embrapna is a shorthand for the Portuguese Empresa Brasileira de Pesquisa Agropecuária.

[4] To view the video on YouTube, visit *https://www.youtube.com/watch?time_continue=3&v=X16cfGPL2wA*.

*See news story in this issue.

**See feature article in this issue.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact ***Samson Reiny*** *on NASA's Earth Science News Team at* ***samson.k.reiny@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****.* ■

Now Available: NASA Science Presentations from the 2017 AGU Fall Meeting

More than 100 science presentations that were given at the NASA booth at the Fall Meeting of the American Geophysical Union (AGU) held in December 2017 are now available on *YouTube*. The presentations, which took place in front of NASA's Hyperwall (*https://eospso.gsfc.nasa.gov/content/about-nasas-hyperwall*), have been divided into four categories: Flash Talks (roughly 7 minutes each), and Earth Talks, Sun Talks, and Planet and Moon Talks (all roughly 15 minutes each). The presentations are found at NASA's Scientific Visualization Studio (SVS) *YouTube* channel at the following links:

Flash Talks
https://www.youtube.com/playlist?list=PL55HrL0eJVEb0PKjIquG9yQFrbNbIAXGl

Earth Talks
https://www.youtube.com/playlist?list=PL55HrL0eJVEYzak_73qMELtNmJRnL7ql0

Sun Talks
https://www.youtube.com/playlist?list=PL55HrL0eJVEafGcJBjPCdsNwp852b31u3

Planet and Moon Talks
https://www.youtube.com/playlist?list=PL55HrL0eJVEb96SgQ3MxK2Bk8ZPqxMsSO

We hope you enjoy them—and learn something!

Earth Science Meeting and Workshop Calendar

NASA Community

September 24–29, 2018
Ocean Surface Topography Science Team Meeting, Ponta Delgada, Azores, Portugal.
https://www.altimetry2018.org/QuickEventWebsitePortal/25-years-of-progress-in-radar-altimetry-symposium/esa

April 1-4, 2019
ABoVE Science Team Meeting, La Jolla, CA.

September 10-13, 2018
CERES Science Team Meeting, Boulder, CO.
[Joint w/GERB and ScaRaB]
https://ceres.larc.nasa.gov/science-team-meetings2.php

September 11-13, 2018
OMI Science Team Meeting, de Bilt, Netherlands.
https://projects.knmi.nl/omi/research/project/meetings/ostm21/details.php

October 1-5, 2018
Sounder Science Team Meeting, Greenbelt, MD.
https://airs.jpl.nasa.gov/events/41

October 8-12, 2018
Precipitation Measurement Mission Science Team Meeting, Phoenix, AZ.
https://pmm.nasa.gov/meetings/all/2018-pmm-science-team-meeting

January 22-24, 2019
Aura Science Team Meeting, Pasadena, CA.

Global Science Community

September 10-13, 2018
Earth Radiation Budget Workshop
[GERB, ScaRaB] Boulder, CO.
[Joint w/CERES STM]

September 24–29, 2018
25 Years of Progress in Radar Altimetry Symposium
Ponta Delgada, Azores, Portugal.
https://www.altimetry2018.org/QuickEventWebsitePortal/25-years-of-progress-in-radar-altimetry-symposium/esa

December 10-14, 2018
Fall Meeting of American Geophysical Union, Washington, DC.
https://fallmeeting.agu.org/2018/welcome/

January 6-10, 2019
American Meteorological Society, Annual Meeting, Phoenix, AZ.
https://annual.ametsoc.org/index.cfm/2019/

Code 610
National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

PRSRT STD
Postage and Fees Paid
National Aeronautics and Space Administration
Permit 396

(affix mailing label here)

eospso.nasa.gov

The Earth Observer

The Earth Observer is published by the Science Communication Support Office, Code 610, NASA's Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5561, FAX (301) 614-6530, and is available in color at *eospso.nasa.gov/earth-observer-archive*.

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 1st of the month preceding the publication—e.g., December 1 for the January–February issue; February 1 for March–April, and so on.

To subscribe to *The Earth Observer*, or to change your mailing address, please call Cindy Trapp at (301) 614-5559, or send a message to *cynthia.trapp-1@nasa.gov*. If you would like to stop receiving a hard copy and be notified via email when future issues of *The Earth Observer* are available for download as a PDF, please send an email with the subject **"Go Green"** to *cynthia.trapp-1@nasa.gov*. Your name and email address will then be added to an electronic distribution list and you will receive a bi-monthly email indicating that the next issue is available for download. If you change your mind, the email notification will provide an option for returning to the printed version.

The Earth Observer Staff

Scan code to access *The Earth Observer* archive online

Printed on Recycled Paper

NP-2018-1-159-GSFC