Over Thirty Years Reporting on NASA's Earth Science Program

The Earth Observer

National Aeronautics and Space Administration

September – October 2021. Volume 33, Issue 5

The Editor's Corner

Steve Platnick
EOS Senior Project Scientist

On September 27, 2021, at 11:12 AM Pacific Daylight Time, a United Earth Alliance Atlas V 401 rocket slipped through the thin marine layer of clouds hanging over Vandenberg Space Force Base in California, carrying the Landsat 9 satellite (as well as four CubeSats[1]) into orbit. About 80 minutes later, the ground station in Svalbard, Norway, acquired a signal from Landsat 9, much to the delight of the launch team. The mission is now conducting checkouts of its two instruments—the Operational Land Imager–2 (OLI-2) and Thermal Infrared Sensor–2 (TIRS-2)—before beginning to acquire data.

OLI-2 and TIRS-2 will measure a combined total of 11 wavelengths of visible, near-infrared, shortwave-infrared, and thermal-infrared light. On each orbit, the instruments will capture scenes in a swath that is 185 km wide. Each pixel in a Landsat scene represents an area of about 30 m across—roughly the size of a baseball infield.

Landsat 9 will continue an unprecedented nearly-half-century-long record of high-resolution land imagery. It joins Landsat 8 in orbit and essentially replaces Landsat 7, which is running out of fuel and will soon exit the 705-km Morning Constellation.[2] To date, seven previous Landsat satellites have collected more than 9 million scenes.[3] Once operational, Landsat 9 will add more than 700 scenes of Earth to that number each day. The data are processed and stored at the U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD, where nearly five decades' worth of data from all the Landsat satellites are stored and made available—for free—to the public.[4]

My congratulations on a successful launch and best wishes for a successful mission to **Jeff Masek** [GSFC—*Landsat 9 Project Scientist*], **Del Jenstrom** [GSFC—*Landsat Project Manager*], and the entire USGS and NASA Landsat team.

continued on page 2

[1] These are not Earth Science missions. Learn more at *go.nasa.gov/2WUYIOq*.
[2] The other current member of the Morning Constellation is Terra. Previous members were SAC-C and EO-1.
[3] Although there have been eight previous Landsat launches, only seven contributed to the data record. Landsat 6 launched in 1993 but failed to reach orbit.
[4] To learn more about Landsat 9, which is very similar to its predecessor, Landsat 8, see the July–August 2021 issue of *The Earth Observer* [**Volume 33**, **Issue 4**, pp. 4–12—*go.nasa.gov/3ln3mhE*].

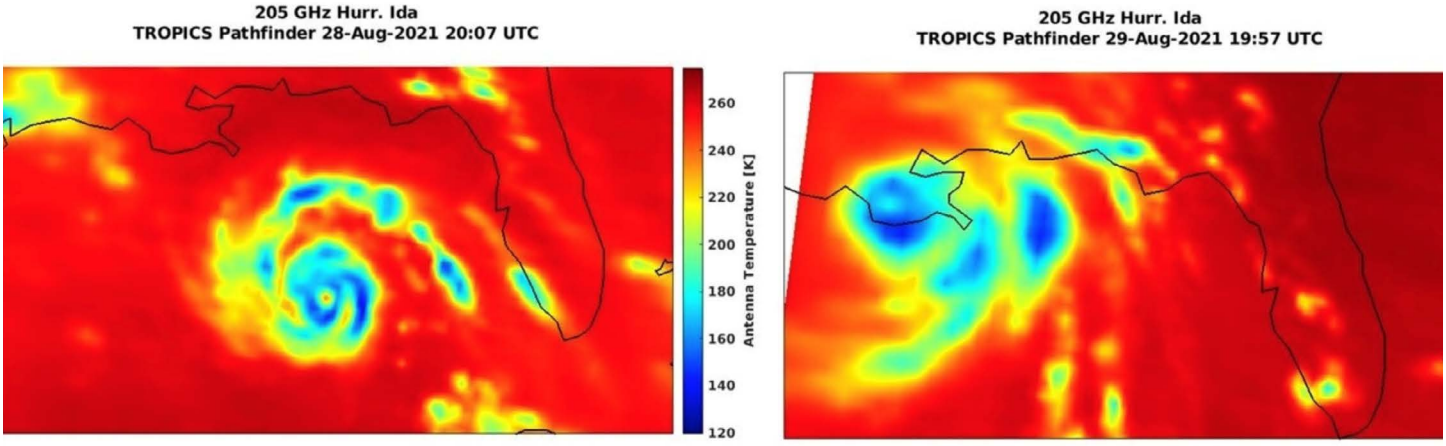


Figure. Shown above are two images of Hurricane Ida observed at 205 GHz by the TROPICS Pathfinder satellite on August 28 and 29, 2021—just before [*left*] and after [*right*] landfall. Detailed storm structure is evident in the August 28 image, with a well-defined eyewall and inner rainband as well as a prominent outer rainband. In the August 29 image there are two convective rainbands to the east of the inner core region. Such outer bands are often associated with tornadoes at landfall and are thus important to observe accurately. **Image credit:** NASA TROPICS, *terra.nasa.gov/about/terra-instruments/misr*

editor's corner

In This Issue

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

In our last issue we reported on the successful launch of the Pathfinder satellite for the Time Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission on June 30, 2021.[5] This Pathfinder satellite is intended to test the technology, communication systems, and data processing before the six satellites comprising the TROPICS constellation launch in 2022.

On August 8, 2021, the satellite captured global first light images from the onboard microwave cross-track sounder at three different frequencies: 91 GHz, which is sensitive to water vapor; 115 GHz, which provides measurements of temperature at Earth's surface and in the lower atmosphere; and 205 GHz, which yields measurements of the precipitation-sized ice particles contained within clouds.

A couple of weeks later, on August 28 and 29, TROPICS Pathfinder obtained observations of Hurricane Ida before and after the storm made landfall in Louisiana—see **Figure**. The bright bands to the north and east of the center on the August 28 image [*left*] is a *squall line*—an intense line of thunderstorms.

The full TROPICS constellation will orbit Earth in three planes, collecting temperature, water vapor, precipitation, and cloud ice measurements on a frequent, near-global scale to study storms and other meteorological events. This will allow for more frequent measurements around the globe, allowing scientists to study storms as they develop and then use the newly-acquired knowledge to improve forecasting capabilities.

To view the first light images and learn more about TROPICS Pathfinder, see *go.nasa.gov/3iEvlr2*.

In addition to working on these two new missions, NASA scientists and engineers are working to maintain our existing fleet. On September 22, 2021, the Terra Flight Operations Team executed a successful reboot of Terra's solid-state recorder (SSR), which has allowed for full science data acquisitions to continue for all five of its instruments: ASTER, CERES, MISR, MODIS, and MOPITT. The reboot was necessitated after 16 of the 58 printed wire assemblies (PWAs) had gone offline one-by-one over the course of Terra's lifetime. The most recent two PWAs that went offline in June 2021 led to further reduced data capacity storage for MISR and MODIS data. This is the second time since launch that Terra has had a SSR reboot. The first was back in 2001, after the first PWA went offline.

The SSR reboot took twelve hours to complete and resulted in all 16 of the offline printed wire assemblies being restored to operational status. Terra's data storage capacity is now restored to what it was at launch—an impressive achievement for a mission that will celebrate 22 years in orbit this December!

While Terra is now fully collecting science data, the spacecraft is beginning to reach the end of its fuel supply. In February 2020 Terra stopped doing platform maneuvers that control its equator crossing time to conserve fuel for possible collision avoidance maneuvers. Terra will also continue collecting data after an orbit lowering maneuver planned for fall 2022.

[5] To learn more about the TROPICS Pathfinder launch, see the "Editor's Corner" in the July–August 2021 issue of *The Earth Observer* [**Volume 33**, **Issue 4**, pp. 1–2].

With all PWAs completely restored, Terra will be able to collect full data acquisitions from all five instruments throughout the lowering process. The lowering maneuver upholds agreements to ensure Terra is a safe distance from the other missions in the Morning Constellation when fuel to maintain Terra's orbit has been depleted. To learn more about Terra's SSR reboot, see *go.nasa.gov/3uQVOqe*.

ICESat-2 celebrated the third anniversary of its launch on September 15, 2018. Since launch, ICESat-2 has fired nearly 1 trillion laser shots collecting extraordinarily accurate height measurements across the globe. The instrument and spacecraft remain healthy. ICESat-2 data have yielded major results detailing changes in the thickness of the ice sheets of Greenland and Antarctica, the year-round cycle of sea ice freeboard and thickness, changes in major water reservoir storage, global vegetation canopy height measurements, new bathymetry profiles of shallow waters, and much more. Ongoing work includes progress towards approximately three-day latency *QuickLook* products with the support of the interagency Satellite Needs Working Group and preparation for end of prime mission and mission extension.

NASA's satellites have been observing several natural disasters that have unfolded in recent months. For example, the ECOSTRESS mission observed two of the fires that have ravaged the Western U.S. this summer: the Bootleg Fire in southern Oregon and the Dixie Fire in northern California. The Rapid Analytics for Disaster Response (RADR)-Fire team at Pacific Northwest National Laboratory have been experimenting with incorporating ECOSTRESS data into a new tool now being implemented for first responders like the U.S. Forest Service. To learn more, see the News story on page 12 of this issue.

Another recent example was Hurricane Ida, which made landfall as a Category 4 storm near Port Fourchon, LA, on August 29, 2021—16 years to the day after Hurricane Katrina made landfall and devastated New Orleans. In addition to the images obtained by the TROPICS Pathfinder mission shown on page 1, NASA satellites obtained many more images of that storm as it made landfall and then tracked up the Tennessee and Ohio Valleys, to the mid-Atlantic and New England, dumping heavy rain along its track. The figure on page 17 of this issue shows an image pair that combines nighttime light data from the VIIRS day/night band on Suomi NPP and base map information obtained from Landsat 8's Operational Land Imager to track the power outages in New Orleans. Other examples of data that NASA collected on the storm can be found at *go.nasa.gov/3lkxoSS*.

An important role that NASA undertakes is to provide data to foster scientific research. For NASA's Science Mission Directorate (SMD) and Earth Science Data Systems (ESDS) Program, this means anywhere in the world is allowed access to more than 57 petabytes (PB) of NASA Earth observing data—along with all documentation, code, algorithm theoretical basis documents (ATBDs), and other ancillary materials. The feature article in this issue describes an evolving NASA paradigm called *open-source science*, which is taking previous open science efforts to the next level and making research conducted using NASA data—and scientific research in general—more inclusive, collaborative, diverse, and equitable. Turn to page 5 of this issue to learn more about what this means for NASA Earth science data users.

This editorial ends on a somber note, as we must report the sudden passing of **Gail Skofronick–Jackson** on September 7, 2021. Gail was deployed with the joint NASA–European Space Agency Convective Processes Experiment–Aerosols & Wind (CPEX-AW) airborne campaign team to St. Croix in the U.S. Virgin Islands. The team had a couple of down days, so Gail and a small group went for a hike. She passed away in an accident while on that hike. (The NASA part of CPEX-AW has subsequently been cancelled.) Gail had been with NASA since 1997, working first at GSFC and then at NASA Headquarters. More details are available in the *In Memoriam* on page 4 of this issue.

I extend my deepest condolences to Gail's family during this time of loss. She was a beloved colleague and friend to many in the NASA Earth Science community. While her legacy will live on at NASA, her dynamic presence will surely be missed. ■

List of Undefined Acronyms Used in Editorial and/or Table of Contents

AGU	American Geophysical Union
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CERES	Clouds and the Earth's Radiant Energy System
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
EO-1	Earth Observing–1
EOS	Earth Observing System
GLOBE	Global Learning and Observation to Benefit the Environment
GPM	Global Precipitation Measurement
GSFC	NASA's Goddard Space Flight Center

continued on page 13

in memoriam

In Memoriam
Gail Skofronick–Jackson

The Earth Observer is deeply saddened to announce the sudden passing on September 7, 2021, of a beloved member of the NASA Earth Science community. **Dr. Gail Skofronick–Jackson** was deployed with the joint NASA–European Space Agency Convective Processes Experiment–Aerosols & Wind (CPEX-AW) airborne campaign team to St. Croix in the U.S. Virgin Islands. The team had a couple of down days while the aircraft was undergoing maintenance, so Gail and a small group went for a hike. She passed away in a tragic accident while on that hike.

Gail was a brilliant scientist—and a deeply passionate and principled person—who carried her enthusiasm for life over into her career at NASA. She was a dedicated researcher whose interests included passive remote sensing, radiative transfer theory, and detection and estimation of falling snow using active and passive spaceborne sensors.

At the time of her death, Gail was serving as a program manager in the Science Mission Directorate at NASA Headquarters (HQ), where she provided scientific expertise and management support for the Weather Focus Area in the Research and Analysis Program of NASA's Earth Science Division. She also provided leadership for numerous NASA satellite missions and field and aircraft campaigns.

Prior to her appointment at NASA HQ, Gail worked in various capacities at NASA's Goddard Space Flight Center beginning in 1997, including as a postdoctoral research associate, the chief of the Mesoscale Atmospheric Processes Laboratory, and the project scientist for NASA's Global Precipitation Measurement (GPM) mission.

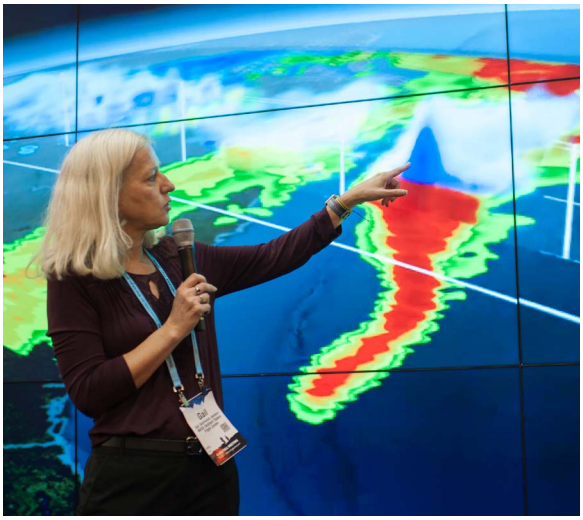
She received her B.S. degree in electrical engineering (EE) from Florida State University and her M.S. and Ph.D. degrees in EE from Georgia Institute of Technology. She was a member of the American Geophysical Union (AGU) and American Meteorological Society (AMS).

Gail not only knew the science but was also a dynamic communicator and storyteller. She often volunteered to give presentations at conferences using NASA's Hyperwall and sat for many interviews. For example, in December 2018, she was interviewed as part of AGU's Narratives Project being conducted via StoryCorps.[1] The podcast can be accessed at *archive.storycorps.org/interviews/as-soon-as-it-snow-lands-it-starts-to-metamorphosize-an-interview-with-gail-skofronick-jackson*.

"Gail has been a friend and trusted colleague since we both did our graduate work in passive remote sensing almost 30 years ago. She was one of our very best—brilliant, thoughtful, and deeply committed to the science we do and the integrity with which we do it. And she died being exactly who she was—an avid outdoors person, an athlete, and an admirer of our Earth."

— **Karen St. Germain** [NASA Headquarters, Director of the Earth Science Division]

Gail is survived by her husband, Dr. David Jackson, and other family members to whom we extend our deepest condolences during this time of loss. She was a beloved colleague and friend to many within NASA. She will be sincerely and deeply missed. ■



Gail in front of the NASA Hyperwall at the 2017 AGU Fall Meeting. **Photo credit:** NASA

[1] To learn more, see *archive.storycorps.org/user/agu-narratives*.

Open-Source Science: The NASA Earth Science Perspective

Kevin Murphy, NASA Headquarters, kevin.j.murphy@nasa.gov

Since its establishment, NASA has acquired and provided data about space and Earth's atmosphere to foster scientific research. These data are integral components of research into Earth's interconnected systems, and NASA Earth science data have been openly available to all users since the Earth Observing System Data and Information System (EOSDIS) became operational in 1994 as a key component of NASA's Earth Observing System (EOS).[1] Further, since 2015 data systems software developed through NASA research and technology grants and awards has been made available as *open-source software*,[2] which means that the source code for these tools is freely available for inspection, modification, and enhancement.[3] These policies and practices enable anyone anywhere in the world to access more than 57 petabytes (PB) of NASA Earth science data—one of the largest repositories of Earth science data on the planet—fully, openly, and without restriction.[4]

The development of open-source software fundamentally changed how software was shared, and enabled software and code to be available more broadly and shared collaboratively with diverse groups to accelerate software development. These features of the open-source software movement are key attributes of what is known as *open science*, which is defined as "a collaborative culture enabled by technology that empowers the open sharing of data, information, and knowledge within the scientific community and the wider public to accelerate scientific research and understanding."[5]

A system based on open science aims to make the scientific process as transparent (or *open*) as possible by making all elements of a claimed discovery readily accessible, which enables results to be repeated and validated. Out of this open science concept, an evolving scientific paradigm called *open-source science* is emerging.

Open-source science builds on concepts from the open-source software revolution that expanded participation in code development and applies these concepts to the scientific process to accelerate discovery by conducting science openly from project initiation through implementation. The result is the inclusion of a wider, more diverse community in the scientific process as close to the start of research activities as possible. This increased level of commitment to conducting the full research process openly and without restriction enhances transparency and reproducibility, which engenders trust in the scientific process. It also represents a cultural shift that encourages collaboration and participation among practitioners of diverse backgrounds, including scientific discipline, gender, ethnicity, and expertise. Open-source science is more equitable science.

A system based on open science aims to make the scientific process as transparent (or open*) as possible by making all elements of a claimed discovery readily accessible, which enables results to be repeated and validated.*

[1] The story of the evolution of EOSDIS (up to 2009) was told in a two-part article, "EOS Data and Information System, Where We Were and Where We Are," that appeared in the July–August 2009 and September–October 2009 issues of *The Earth Observer* [**Volume 21, Issue 4**, pp. 4–10 and **Volume 21**, **Issue 5**, pp. 8–15—*go.nasa.gov/3uzO6AL*].

[2] For a detailed description of NASA's Earth Science Data Systems (ESDS) Program open-source software policy, see *go.nasa.gov/2WkvlEW*.

[3] For a broad discussion of NASA Earth science data operations, including the EOSDIS Distributed Active Archive Centers (DAACs), see "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—*go.nasa.gov/3kKFOTy*]. For an overview of the DAACs and a review of their milestones, see *go.nasa.gov/3uhu5yN*.

[4] At the end of August 2021, the total EOSDIS archive volume was 57.2 PB. To learn more, visit *go.nasa.gov/3ueDGGL*.

[5] This definition and more information on other topics discussed in this article can be found in a 2021 article by Rahul Ramachandran, Kaylin Bugbee, and Kevin Murphy: "From Open Data to Open Science," *Earth and Space Science* [**Volume 8**, **Issue 5**—*doi:10.1029/2020EA001562*].

The SMD and ESDS vision is to use open-source science principles to expand participation in the scientific process, improve reproducibility, and accelerate scientific discovery.

Open-Source Science in NASA's Science Mission Directorate

Open-source science is a foundational objective of NASA's Science Mission Directorate (SMD) and SMD's Earth Science Data Systems (ESDS) Program.[6] Along with the wide dissemination and use of openly available Earth-observing data, the SMD promotes and facilitates the full and open sharing of all *metadata* (information that describes data), documentation, models, images, and research results achieved using these data and makes available the source code used to generate, manipulate, and analyze the data.[7] The SMD and ESDS vision is to use open-source science principles (described below) to expand participation in the scientific process, improve reproducibility, and accelerate scientific discovery.

Three primary elements work together to fulfill open-source science objectives:

- Open access to data, software, and any information coming out of research, such as journal articles, blog posts, and similar products as early in the scientific process as possible;
- open access to the scientific process with transparency and active inclusion of different communities; and
- a collaborative and inclusive process that is welcoming and open to everyone.

The definition of open-source science and its foundational elements imply four distinct meanings to *open*. Open means *transparent*, in that scientific results and processes should be visible, accessible, and reproducible to a wide audience. Open also means *inclusive* and welcoming to participation by and collaboration with a diverse range of people and organizations. Further, open implies *accessible* to all users with *reproducible* processes and results.

Open-Source Science as an Evolving Paradigm

The development of open-source science has been aided by the growth of *big data* collections,[8] cloud-based computing systems, and open-source web applications and environments; increases in personal-computer processing power; and the ability to work close to cloud-based data collections with little more than a reliable internet connection.[9]

As noted earlier, the shift to open-source science is a change from more traditional science systems that have barriers to participation in the scientific process—see **Figure 1** on next page.

These barriers include:

- Restrictions on algorithm or code sharing;
- requirements for expensive processing equipment or systems;

[6] For more detail, please see "SMD's Strategy for Data Management and Computing for Groundbreaking Science: 2019 to 2024," which can be downloaded from *go.nasa.gov/3APYuGX*.

[7] To learn more, see "SMD Policy Document (SPD)-41: Scientific Information Policy for the Science Mission Directorate," which can be downloaded from *go.nasa.gov/2ZCCBgE*

[8] *Big data* refer not only to large-volume data collections, but also to methods developed to extract information from datasets that are too large to be processed using traditional data-processing software.

[9] The ability to work "close" to or "next" to big data collections in a cloud-based data system enables anyone with an internet connection to conduct their analyses and work directly with data in the cloud without having to download or store data. After working with the cloud-based data collection, a researcher needs only to download the results of their analysis—a significant savings in time, cost, and computing power. Having data collections in the cloud also facilitates collaborative work on the same data collection simultaneously by multiple research teams in different locations.

- retention of data for exclusive use by science teams, or delays in sharing research-quality data;
- restrictive journal publishing and research dissemination processes; and
- policies and employment, communication, and collaboration strategies that favor particular groups through stated or unstated preferences for educational level, gender, professional affiliation, geographic location, and other personal attributes.

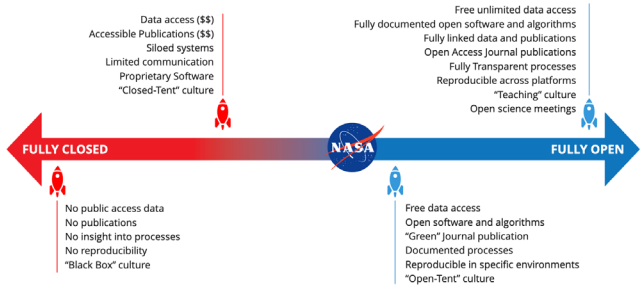


Figure 1. NASA's provision of all mission data, code, algorithm theoretical basis documents (ATBDs), and analysis software places the agency (indicated by the NASA logo) closer to the *Fully Open* side of the continuum of closed [*left*] vs. open [*right*] science systems. Continued enhancements to data systems and architecture—along with greater acceptance of open-source science principles—will help the agency move closer to the Fully Open ideal. **Image credit:** NASA ESDS

NASA SMD and ESDS data policies and practices require that all NASA-funded researchers use open-source software for any code developed as part of the research process. To make this as easy as possible for science teams, the agency provides guidance for the appropriate licensing that needs to be applied to code to ensure it is fully open. In addition, ESDS requires that all developed code be delivered to a publicly accessible repository service that is widely recognized by a large, active, open-source software community and used by developers of Earth science data and tools. ESDS encourages NASA-funded researchers to deliver code and supporting algorithms to the NASA GitHub Repository at *github.com/nasa*.

ESDS also provides resources for standardizing mission code and software. An example of one effort to accomplish this is the development of the Algorithm Publication Tool (APT) for algorithm theoretical basis documents (ATBDs).[10] Created by NASA's Interagency Implementation and Advanced Concepts Team (IMPACT), a prototype of the APT was developed in 2019; the system is now in its second phase of development.[11] When fully operational, the APT will be an important step toward enabling open, reproducible science by helping scientists write standardized, high-quality algorithm documentation collaboratively and provide functionality to make ATBDs open-access literature. A primary goal of the APT is to provide a free and open portal to ensure that all ATBDs are discoverable and accessible to users. High-quality supporting metadata, populated during the ATBD publication phase, will allow users to easily search for documents and the content within so that the most relevant information is readily discoverable.

As noted in NASA's Data and Information Policy, the agency is committed to the full and open sharing of Earth science data obtained from NASA's Earth-observing satellites, suborbital platforms, and field campaigns with all users as soon as these data become available.

Open-Source Science in Practice

An integral element of open-source science is the public provision of data and code as early in the scientific or mission development process as possible. As noted in NASA's Data and Information Policy, the agency is committed to the full and open sharing of Earth science data obtained from NASA's Earth-observing satellites, suborbital platforms, and field campaigns with all users as soon as these data become available. In addition, there is no period of exclusive access to NASA Earth science data. Following a postlaunch checkout period, all data are made available to public user communities.[12]

[10] ATBDs exist for each data product and describe the procedures used to create them. Examples can be found at *go.nasa.gov/3m6utMK*.
[11] More information about the APT, including background papers and the current state of the system's development, is available through the IMPACT website at *go.nasa.gov/2Y4C5Yb*.
[12] To learn more see, the NASA SMD Scientific Information Policy (SPD-41), which is referenced in footnote 7.

Open-source science provides numerous benefits to scientists and those involved in the scientific process. By removing barriers to participation, the diversity of those engaged in the process will increase.

Finally, the publication of results acquired from the use of these data is accomplished using open-access *preprint servers*—online repositories established specifically to disseminate scientific research results or data associated with scholarly papers that are not yet peer reviewed or accepted by traditional academic journals. Preprint servers enable researchers to share initial scientific results with colleagues and receive feedback while a full article is undergoing prepublication peer review. An extensive list of preprint servers organized by discipline, external content indexing, permanence and preservation of content, and other criteria is available through the nonprofit Accelerating Science and Publication in biology (ASAPbio) at *asapbio.org/preprint-servers*.

Benefits of Open-Source Science

Through the implementation of the features previously noted, open-source science provides numerous benefits to scientists and those involved in the scientific process. By removing barriers to participation, the diversity of those engaged in the process will increase. Further, making all data, code, algorithms, and supporting documentation openly available in a variety of locations (through, for example, NASA Earthdata Search,[13] EOSDIS Distributed Active Archive Centers (DAACs), NASA Open Innovation Sites,[14] and the NASA Technical Reports Server[15]) makes the scientific process more transparent and scientific results more reproducible. This, in turn, lends further legitimacy to the scientific process. In addition, the use of standardized mission code and software makes it easier for new users to learn to interact with the data and helps foster greater participation in the scientific process. Finally, broadening the base of those able to work with, analyze, and use Earth science data enables research results to be applied more quickly and broadly for societal benefit.

NASA Open-Source Science in Practice: MAAP

One example of an ESDS-sponsored open-source science effort is the joint NASA/European Space Agency (ESA) Multi-Mission Algorithm and Analysis Platform (MAAP)—see **Figure 2**. MAAP integrates biomass data from multiple missions operated by different space agencies into a consistent, cloud-based data record that can be openly used by global stakeholders.[16] MAAP code is written in *Jupyter Notebooks* [an

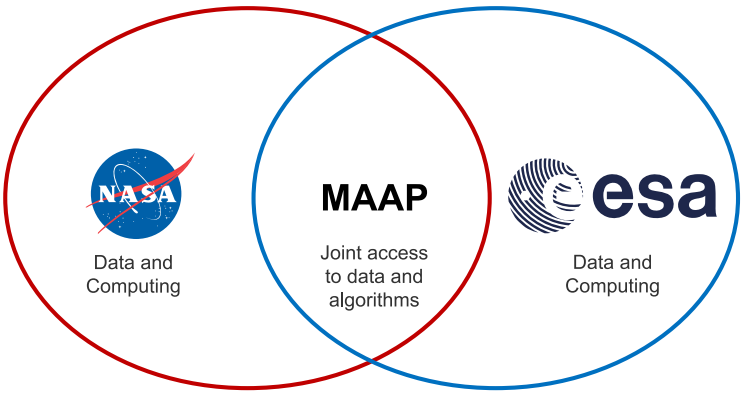


Figure 2. MAAP is a virtual, open, and collaborative environment that leverages cloud technologies to facilitate open data use across aggregated datasets. Using MAAP, NASA and ESA are working together to make terrestrial biomass data and metadata from multiple missions and sources more interoperable across organizations. To learn more, visit *earthdata.nasa.gov/esds/maap*. **Image credit:** NASA MAAP

[13] To learn more, see *go.nasa.gov/3ic97wu*.
[14] NASA has Open Innovation Sites for data (*data.nasa.gov*), code (*code.nasa.gov*), and APIs (*api.nasa.gov*).
[15] The server can be found at *ntrs.nasa.gov*.
[16] Data that will be part of MAAP include the current NASA Global Ecosystem Dynamics Investigation (GEDI) mission and the joint NASA/ESA AfriSAR airborne campaign as well as the upcoming ESA Biomass and joint NASA/Indian Space Research Organisation Synthetic Aperture Radar (NISAR) missions.

open document format based on JavaScript Object Notation (JSON)] that are openly shared between teams using the MAAP platform. Having all MAAP data, code, and infrastructure openly available speeds up the research process and facilitates efficient collaboration. As **Laura Duncanson** [University of Maryland, College Park—*MAAP Project Scientist*] observes, "Now all of us can learn from each other's code. The platform feels like a true paradigm shift; it's the right way forward."

A public announcement of MAAP Version 1 is scheduled for fall 2021, with MAAP Version 2 scheduled for release in spring 2022.

TOPS Steers NASA Toward Open Science

NASA is forming a steering team for an upcoming open-source science initiative: the Transform to Open Science (TOPS). Scheduled to kick off in October 2021, TOPS will coordinate efforts designed to rapidly transform the way NASA researchers—and researchers at other agencies, organizations, and communities—do their work. These efforts will be aligned with SMD's *Strategy for Data Management and Computing for Groundbreaking Science 2019-2024*[17] and further enabled by the National Academies of Sciences, Engineering, and Medicine (NASEM) and United Nations Educational, Scientific and Cultural Organization (UNESCO)[18] recommendations, which are intended to inform NASA's pathway forward to advance open science.

As part of TOPS, 2023 will be designated the Year Of Open Science (YOOS)—a global community initiative to spark change and inspire engagement in open science through events and activities that will help further develop the open-source science paradigm.

As part of TOPS, 2023 will be designated the Year Of Open Science (YOOS)—a global community initiative to spark change and inspire engagement in open science through events and activities that will help further develop the open-source science paradigm.

Open-Source Science in NASA's Earth System Observatory

Open-source science will be a key attribute of NASA's Earth System Observatory (ESO).[19] This array of Earth-observing missions will provide vital information to guide decisions related to climate change, severe weather and other natural hazards, wildfires, and global food production, all in keeping with the recommendations of the 2017 Earth Science Decadal Survey produced by NASEM.[20] NASA missions will be augmented with competitively selected Earth Explorer missions that will bring further innovation and additional key observations to the ESO.

ESO missions will generate greater volumes of data than any previous NASA missions. As stated earlier, the NASA EOSDIS archive volume at the end of August 2021 was more than 57 PB. The first ESO mission alone—the joint NASA/Indian Space Research Organisation Synthetic Aperture Radar (NISAR) mission (scheduled for launch in 2023)—is expected to generate more than 30 PB of data *per year*. NISAR data will help address a variety of complex environmental processes, including ice-sheet collapse and natural hazards such as earthquakes, volcanoes, and landslides.

As part of our commitment to open-source science, NASA will make all ESO mission data, code, and supporting documents available as early in the mission life cycle as feasible. Given the high volume of ESO data, these data will be stored using cloud-based systems and tools will be provided for working with these data directly in the cloud. This strategy will expand the ability of global research teams to collaboratively work with and conduct research using more NASA Earth science data than ever before. The result will be the availability of these data to a broader, more diverse global community of users with the attendant increase in opportunities for scientific discovery.

continued on page 11

[17] A link to this document is available in Footnote 6.
[18] The UNESCO Recommendation on Open Science can be found at *en.unesco.org/science-sustainable-future/open-science/recommendation.*
[19] To learn more about the ESO, see *go.nasa.gov/3wmt4pm*.
[20] For details, see the 2017 document "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space," available for download from *go.nasa.gov/2wXJn2n*.

in the news

NASA at Your Table: The Space Agency's Surprising Role in Agriculture

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

EDITOR'S NOTE: This article is taken from *nasa.gov*. While this material contains essentially the same content as the original release, it has been rearranged and wordsmithed for the context of *The Earth Observer*.

Everybody needs to eat.

Food is a basic necessity and is at the heart of every human culture and our sense of home. It also represents one of our most important connections to Earth. Crops and animal products, whether gathered from the ocean or the land, raised on farms big or small, across vast fields or in our backyards and urban communities, draw on sunlight, water, and soil to grow and thrive.

Producing food has always been challenging, and in the twenty-first century, human-caused climate change is already affecting food security through increasing temperatures, the frequency of extreme events, and changing precipitation patterns. This is increasing the risk of food supply disruptions by shifting growing and pastoral zones, reducing water access and food yield—all of which contribute to the changing landscape of our food and water supply.

In addition, more than 800 million people suffer from chronic hunger worldwide. By 2050, the global population is estimated to grow to 10 billion people. As the population—and the demand for food—continues to expand, we need innovative ways to feed the world.

That's where NASA Earth science data come in.

In the satellite era, Earth-observing data have increasingly become part of the food farming process. With observations from space and aircraft, combined with high-end computer modeling, NASA scientists work with partner agencies, organizations, farmers, ranchers, fishermen, and decision makers to share our understanding of the relationship between the global Earth system and the local environments that provide us food.

Working with local communities and decision makers to determine their needs and how they can best use Earth-observation data, NASA supports those who address issues like water management for irrigation, crop-type identification and land use, coastal and lake water quality monitoring, drought preparedness, and famine early warnings.

See the **Table** for a listing of stories NASA shared of people in the U.S. and abroad on how they use NASA data, such as:

- How they apply NASA science to help plan for and make it through growing seasons in the face of drought and water shortages;
- how Earth science data helps them develop more sustainable farming and aquaculture practices; and
- how partner organizations, such as the U.S. Department of Agriculture, use NASA data to achieve their goals in maintaining and monitoring crops and commodities worldwide.

These stories delve into the science that makes all this possible, showcase current and future satellite missions that collect this essential data, and look forward to the launch of the ninth Landsat mission, a joint mission with the U.S. Geological Survey.[1] The Landsat program has an unparalleled record of nearly 50 years of continuous Earth observations and is one of the essential satellite programs delivering data for agriculture.

[1] **UPDATE:** Landsat 9 successfully launched on September 27, 2021. See the Editorial in this issue for more information.

Table. Links to NASA stories that were released in summer 2021 to demonstrate the many ways NASA science has an impact on the food that reaches your table.

Title	URL
From Seed to Market	*go.nasa.gov/3f3H9Br*
How NASA Brings Food to the Table	*go.nasa.gov/2YVNRo2*
Snacktime with NASA: Chips and Dip (video)	*go.nasa.gov/3hxxILU*
Shoring up the Corn Belt's Soil Health with NASA Data	*go.nasa.gov/3lrNHfs*
Evapotranspiration: Watching Over Water Use	*go.nasa.gov/3lmQSFw*
How Satellite Maps Help Prevent Another 'Great Grain Robbery'	*go.nasa.gov/3CeRF1M*
NASA Watches Water to Help Grow Our Groceries	*go.nasa.gov/3lnayc7*
Snacktime with NASA: Space Salad (video)	*go.nasa.gov/2XgJKm5*
NASA Satellites Help Plan Future for Palau Fish Stocks	*go.nasa.gov/3EjptwQ*
An Upended Ecosystem in the Arabian Sea	*go.nasa.gov/3nvJJoO*
Snacktime with NASA: Ceviche (video)	*go.nasa.gov/3EfgWej*
Feeding the Sea (video)	*go.nasa.gov/3C2XXSi*
Drought Makes its Home on the Range	*go.nasa.gov/3hxfmdZ*
Sizing Up How Agriculture Connects to Deforestation	*go.nasa.gov/3nxXvaO*
Where Food Meets Methane	*go.nasa.gov/3lrq7zt*
Snacktime with NASA: Cheese Board (video)	*go.nasa.gov/3hzAKz8*

Landsat 9, together with other NASA Earth science missions, partner agencies, and the next-generation missions of NASA's Earth System Observatory, will provide a backbone of crucial Earth science information over the next decade. These missions will gather information on Earth's systems from above our heads, to under our feet; the atmosphere, water, land surface, soil moisture, and groundwater beneath Earth's surface. These data and the research that will improve our understanding of how these different parts of the environment interact and work as a system, will help communities and decision makers at all levels strengthen climate resilience and adaptation of the farming systems across all dimensions of food security—availability, access, stability, and utilization. ■

Open-Source Science: The NASA Earth Science Perspective

continued from page 9

Conclusion

Open-source science is the foundation of SMD and ESDS efforts to expand the use of NASA Earth science data to a more diverse, inclusive base of users. This evolving paradigm represents not only a new way of doing science, but a new way of thinking about what science means in terms of who can participate in the scientific process. Providing mission data, code, and supporting documents fully and openly—and as early in the scientific process as possible—broadens potential participation, enables collaborative work with big data collections, and enhances the opportunities for discoveries made using these data. As a result of these new approaches and requirements, open-source science is leading to more equitable science.

Acknowledgements

The author of this article, **Kevin Murphy**, is the Chief Science Data Officer for NASA's Science Mission Directorate (SMD) and the Program Manager for NASA's Earth Science Data Systems (ESDS) Program. Murphy would like to thank **Josh Blumenfeld** [NASA's Goddard Space Flight Center, ESDS Communications Team—*Managing Editor*] and the ESDS Communications Team for their contributions to this article. ■

in the news

ECOSTRESS Data Incorporated into New Wildfire Response Tool

Jane Lee, NASA/Jet Propulsion Laboratory, jane.j.lee@jpl.nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While this material contains essentially the same content as the original release, it has been rearranged and wordsmithed for the context of *The Earth Observer*.

NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) is aiding in the fight against fires in the Western U.S. This instrument on the International Space Station is uniquely positioned to provide wildfire responders with a high-resolution look at fire progression.

As of July 28, 2021, the size of the Bootleg Fire in southern Oregon was more than 410,000 acres (~1660 km^2), making it the largest wildfire currently burning in the U.S. At that time, some 400 buildings and more than 340 vehicles had been destroyed. Wildfire responders had managed to contain about 53% of the fire, and new data from ECOSTRESS helped in that effort. **Figure 1** shows how ECOSTRESS data were used to track the movement of the Bootleg Fire and identify its proximity to critical infrastructure.

ECOSTRESS measures surface temperature from the vantage point of the International Space Station, and its ability to observe fires of the Northwest U.S. often twice per day at a high spatial resolution (~23 ft, or around 70 m) makes it ideal for tracking fires. Researchers on the Rapid Analytics for Disaster Response (RADR)-Fire team at Pacific Northwest National Laboratory have been experimenting with ECOSTRESS data as part of a new tool now being implemented for first responders like the U.S. Forest Service.

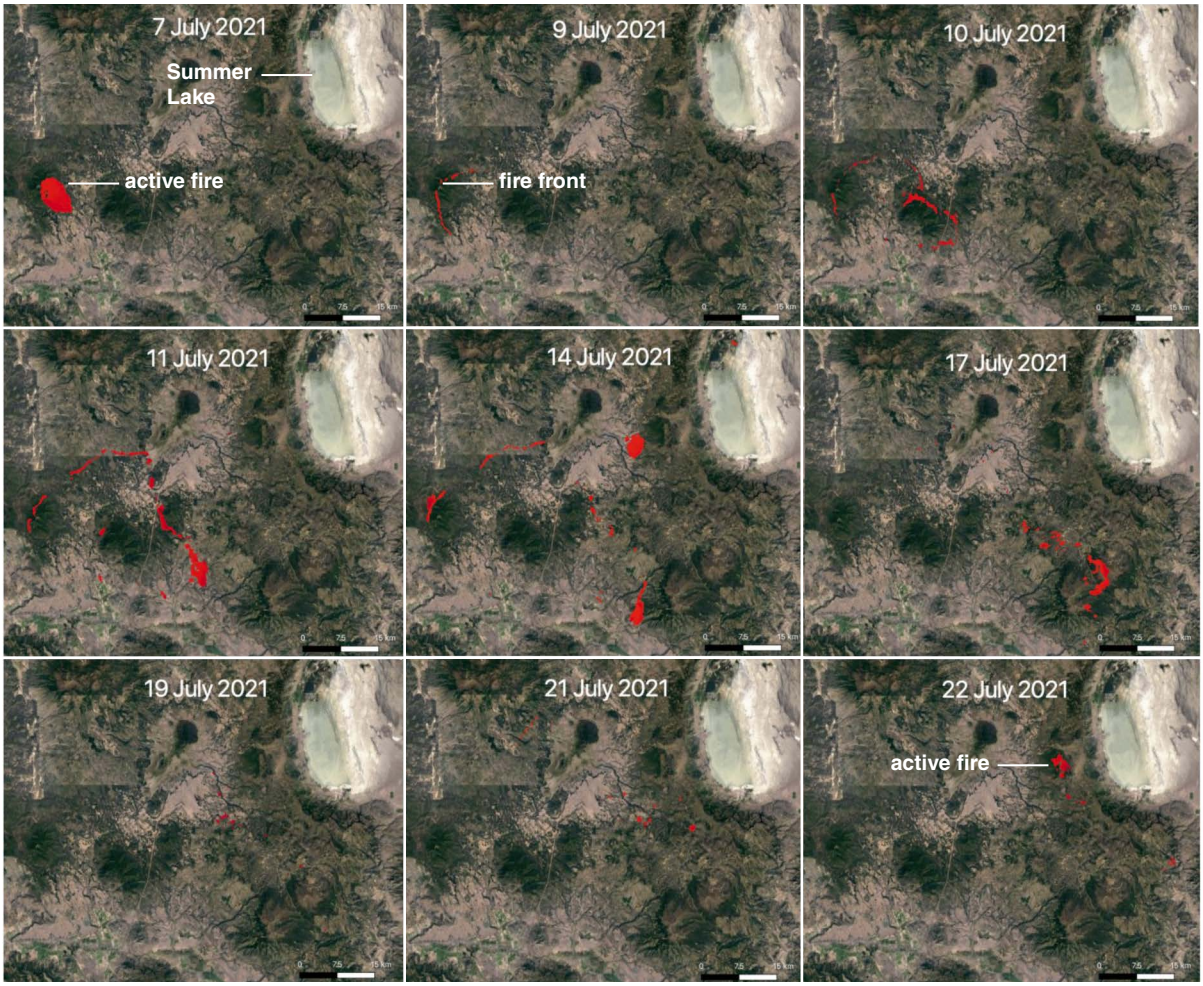


Figure 1. NASA's ECOSTRESS instrument captured ground-surface temperature data over southern Oregon's Bootleg Fire from July 7-22, 2021. Areas in red—the hottest pixels detected—show the fire front, where resources are needed most. **Image credit:** NASA/Jet Propulsion Laboratory (JPL)-Caltech

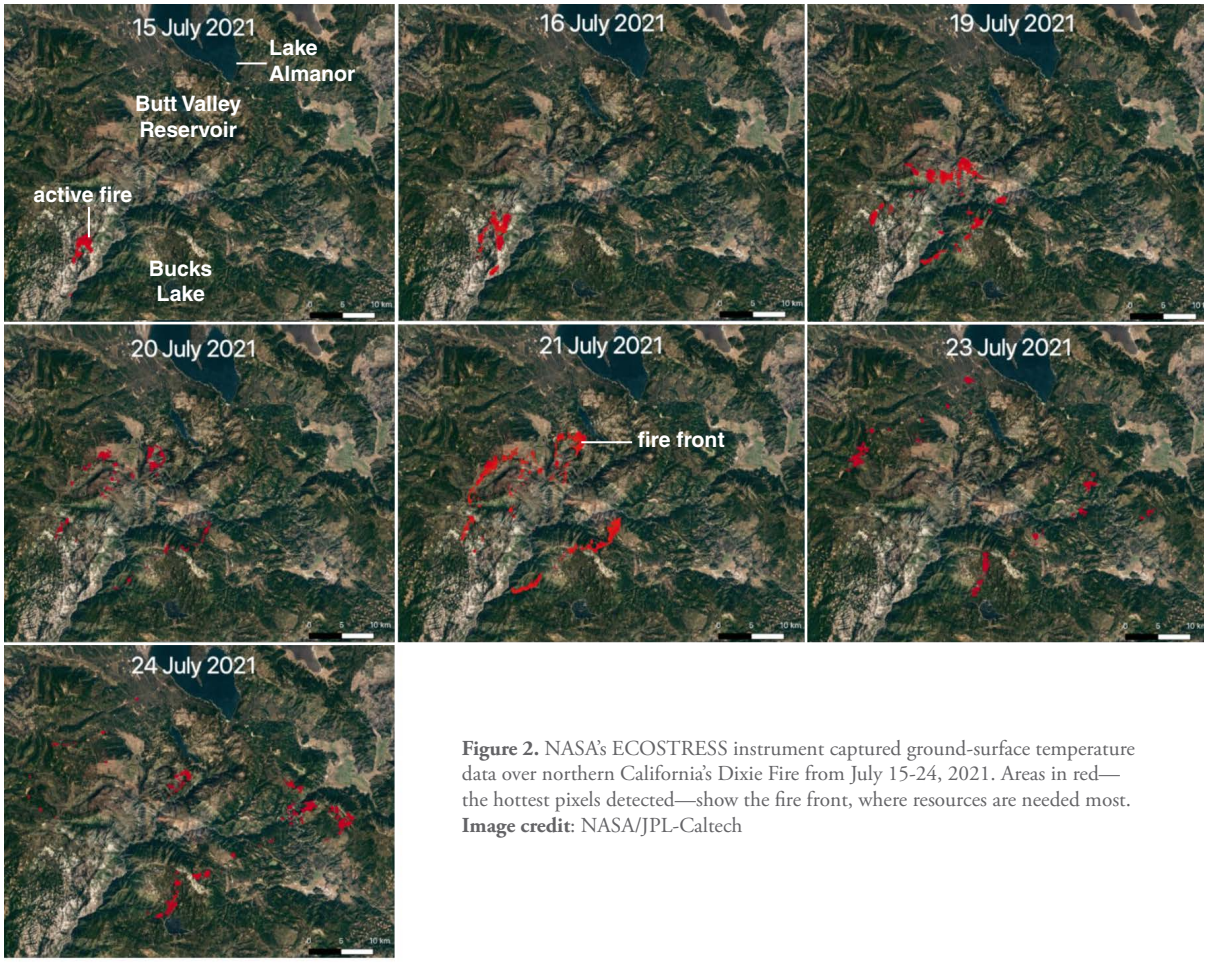


Figure 2. NASA's ECOSTRESS instrument captured ground-surface temperature data over northern California's Dixie Fire from July 15-24, 2021. Areas in red—the hottest pixels detected—show the fire front, where resources are needed most. **Image credit**: NASA/JPL-Caltech

The capabilities of ECOSTRESS are unique. Satellites that acquire data more frequently don't have high-enough resolution to track the fine line of the fire front, and satellites with higher resolution than ECOSTRESS cross over the same area much less frequently (every 5 to 16 days).

ECOSTRESS also captured data over Northern California's Dixie Fire, showing fire movement from July 15-24, 2021—see **Figure 2**. The most heavily affected areas are south of Lake Almanor in Plumas County. As of July 27, the Dixie Fire was 23% contained.

As of this writing, more than 7000 personnel have been involved in the wildfire response to the two fires. Although they have many tools in their arsenal, the use of spaceborne data like those provided by ECOSTRESS is still relatively new—and also serves as a good example of the versatility and real-world impact satellite data can provide. ■

List of Undefined Acronyms Used in Editorial and/or Table of Contents

continued from page 3

ICESat-2	Ice, Clouds, and Land Elevation Satellite–2
MISR	Multi-angle Imaging Spectroradiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITT	Measurements of Pollution in the Troposphere
Suomi NPP	Suomi National Polar-orbiting Partnership
SAC-C	Satélite de Aplicaciones Científicas–C
VIIRS	Visible Infrared Imaging Radiometer Suite

in the news

Trapped Saltwater Caused Mangrove Death After Hurricane Irma, NASA Data Show

Sofie Bates, NASA's Earth Science News Team, sofie.bates@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While this material contains essentially the same content as the original release, it has been rearranged and wordsmithed for the context of *The Earth Observer*.

When Hurricane Irma hit southern Florida in September 2017, the storm buffeted coastal mangrove forests with winds over 116 mph (~187 km/h)—strong enough to rip off leaves, break branches, and snap tree trunks in half. Of the mangrove forest damaged by Hurricane Irma, about 83% recovered after the first year. But the rest didn't, leaving scientists wondering why some trees did not bounce back.

Using NASA data collected before and after Hurricane Irma, researchers found that storm surge and trapped seawater—not wind—ultimately caused the trees to die. According to results published June 28, 2021, in *Nature Communications*,[1] trees survived in places where salty water brought in by the hurricane was able to drain. But in areas where the saltwater was trapped in low-lying areas without enough drainage, the mangroves could not recover. The findings suggest that improving the flow of water near submerged mangroves or flushing them with freshwater could help restore mangroves after a hurricane.

Mangroves have adapted to live along the coast. These forests act as a barrier to protect inland areas and coastal communities during a storm. Some species have a network of above-ground *prop roots* that support the tree, while others have roots that look like long fingers poking out of the ground, providing extra support to stabilize the tree and provide oxygen to the root system. These semisubmerged root networks are also an important nursery habitat for fish and other marine species.

[1] To read the study, visit *www.nature.com/articles/s41467-021-24253-y*.

"Even though mangroves are hardy, sturdy trees, they still need certain conditions to maintain that protective barrier. And if environmental conditions change even a little, it can have a huge effect and lead to complete die off in entire regions, which could leave those coastal regions even more vulnerable to the next storm," said **Lola Fatoyinbo** [NASA's Goddard Space Flight Center].

Snapshots Before and After the Hurricane

In the spring of 2017, the team set out to document how mangrove forests change and grow over time. When Hurricane Irma passed over their study sites several months later, the scientists saw an opportunity to see how the mangrove forests would respond.

They repeated the measurements they had done before the hurricane hit, flying an airplane carrying a high-resolution camera and other scientific instruments over large swaths of the Everglades. The data collected using Goddard Lidar, Hyperspectral and Thermal Imager (G-LiHT), which includes a laser that emits pulses that bounce off the top of the tree canopy, the ground, or anywhere in between before returning to the sensor, provided snapshots of the structure of these mangrove ecosystems before and after Irma. That allowed the scientists to get a three-dimensional view of the tree canopy–and compare how it had changed after the hurricane.

According to the G-LiHT and Landsat satellite data, 62% of mangroves in southwest Florida suffered canopy damage from Hurricane Irma—see **Figure**. The team mapped the dead and damaged areas and compared them to places with high wind speed, high storm surge,

Figure. Aerial photographs of the mangrove forests taken on March 28, 2017, before [*left*] and after [*right*] Hurricane Irma on December 1, 2017, show the extent of the damage to the forest canopy. **Image credit:** NASA/G-LiHT Science Team

taller trees, land elevation, and other factors to see if there was any overlap. NASA's Global Modeling and Assimilation Office provided a model of wind speeds during the hurricane; storm surge data came from Louisiana State University's Coastal Emergency Risks Assessment and the National Oceanic and Atmospheric Administration (NOAA).

Storm Surge: A Salty Assault on Mangroves

The team found that Hurricane Irma killed over 10,000 hectares (>24,710 acres) of mangrove forest in southwestern Florida—about the size of 24,700 football fields. During the storm many areas were under nearly 10 ft (~3 m) of water, however, most of the dead trees were in areas where salty ocean water came in during Irma and never drained away, submerging mangrove forests for months. The trees in these areas—often at low elevation or with bowl-shaped topography—had not recovered three years after Irma.

"The wind is doing damage, but the nail in the coffin is storm surge," said **David Lagomasino** [East Carolina University's Outer Banks Campus—*Coastal Geomorphologist*]. Excess salt and water from trapped storm surge may choke roots, change microbial communities, break down the soil, and kill other vegetation, Lagomasino says, which could lead to tree death.

Storms on the Horizon for Mangrove Forests

The problem will likely worsen as climate change alters the behavior of hurricanes. Storms are becoming larger and intensifying more rapidly. More storms are also moving slowly and stalling over an area, dumping torrential rain and bringing high winds and storm surge.

"What we're seeing is that more and more of the mangroves aren't able to recover, and that's what's scary," said Fatoyinbo. "Even though mangroves are so tolerant of these extreme conditions, they're still really vulnerable." ■

GLOBE Program Receives Prestigious Award from AGU

The Global Learning and Observations to Benefit the Environment (GLOBE) Program has won the American Geophysical Union (AGU)'s 2021 Excellence in Earth and Space Science Education Award! This award is intended to recognize an individual or group/team that has demonstrated a sustained commitment to excellence in geophysical education. GLOBE joins a long list of distinguished recipients, dating back to the first recipient in 1997—Robert Ballard, who discovered the wreckage of *Titanic*.

The award recognizes over a quarter century of hard work and dedication that has resulted in:

- GLOBE growing from an organization with participants located in a small number of countries when it was founded in 1995, to 126 countries represented today;
- an ever-expanding database with over 200 million measurements as of today;
- and an increasing number of student research projects.

Along the way, GLOBE has also built a collaborative community of students, teachers, scientists, and others to meaningfully contribute to our understanding of the Earth system. This international community is intended to help inspire the next generation of science, technology, engineering, and math (STEM) professionals.

NASA, the National Science Foundation, the National Oceanic and Atmospheric Administration, and the U.S. Department of State have all provided unwavering support to the GLOBE Program since 1995. The University Corporation for Atmospheric Research has a cooperative agreement with NASA to run the GLOBE Implementation Office.

AGU will formally recognize GLOBE along with all this year's award recipients during the #AGU21 Fall Meeting, to be held December 13–17, 2021, in New Orleans, LA—and online everywhere. This celebration is a chance for AGU's community to recognize the outstanding work of our colleagues and be inspired by their accomplishments and stories.

The Earth Observer staff extends congratulations to the GLOBE Program on this outstanding achievement.

To learn more, see *www.globe.gov/news-events/globe-news/-/newsdetail/10157/the-globe-program-proud-recipient-of-agu-2021-excellence-in-earth-and-space-science-education-award*.

in the news

Passing Clouds Cause Some Marine Animals to Make Mini-Migrations During the Day

Sofie Bates, NASA's Earth Science News Team, sofie.l.bates@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While this material contains essentially the same content as the original release, it has been rearranged and wordsmithed for the context of *The Earth Observer*.

Every evening, small fish and microscopic animals called *zooplankton* journey to the ocean surface, where they feast on microscopic plants under the moonlight before returning to the depths at dawn. With data collected during the EXport Processes in the Ocean from Remote Sensing (EXPORTS) field campaign in 2018 to the Northeastern Pacific Ocean, scientists have now shown that some zooplankton living in the twilight zone of the ocean at depths of greater than 985 ft (300 m) swim up and down also in response to shifts in light due to cloud cover.

The nightly trek from the ocean depths to the surface has been called the largest migration on Earth, because of both the number of animals who make the nightly trek and how far these tiny creatures travel roundtrip. NASA has observed this global migration with a space-based laser on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite.[1] Scientists have also documented these migrations during events such as eclipses, full moons, and storms.

"The amount that they swim is pretty remarkable given their body length," said **Melissa Omand** [University of Rhode Island Graduate School of Oceanography]. "It's like me in Rhode Island going to Boston and back every day," she said—traveling roughly 80 mi (129 km).

Throughout the day, when clouds pass overhead, zooplankton make "minimigrations" of about 50 ft (15 m) on average. These add up to 30% of the average nightly migration distance, the team reported in a study published in the journal *Proceedings of the National Academy of Sciences*.[2] The findings could have implications for scientists' knowledge of the metabolic requirements of zooplankton, which are key players in the marine food web and the transfer of carbon in the ocean.

The discovery comes from data collected during NASA's EXport Processes in the Ocean from Remote Sensing (EXPORTS) mission, which seeks to better understand the export and fate of carbon from the upper ocean to the deep ocean using satellite observations and state of the art ocean technologies. Omand was one of the more than 100 scientists from nearly 30 research institutions that participated in the science campaign. During the expedition, they used an instrument called an acoustic doppler current profiler (ADCP) to measure ocean currents. The instrument sends out pings of sound that bounce off suspended material in the water column, like particles or zooplankton. Some of those pings are reflected to the instrument, while others are scattered.

When Omand went below deck to analyze the ADCP data on her computer, she noticed something intriguing. There were unusual "wiggles" in the data, signifying that something was moving up and down in the water column. Based on the frequency of the sound waves (150 kHz), and the marine animals captured in nets of other concurrent EXPORTS experiments, that something was most likely zooplankton. She also noticed that those wiggles lined up with the changes in sunlight measured by the radiometer—a device that measures the intensity of sunlight—mounted on the ship.

To Omand, this implied that the zooplankton were swimming up and down as the light changed due to clouds passing overhead. She made a simple computer model that confirmed her suspicions: the zooplankton were following *isolumes*, or areas in the ocean with the same amount of light throughout. For example, when cloud cover prevented sunlight from reaching as deep in the ocean, the zooplankton would swim toward the surface to stay in water with their preferred brightness. When the clouds passed, they would swim back down. According to the model, the zooplankton were responding to changes in brightness of only 10% or 20%—an imperceptible difference to Omand and the rest of the crew standing on the ship deck.

"This finding poses some really good questions about whether there's an evolutionary or ecological advantage to this daytime behavior," said Omand. She notes, however, that this is just one series of observations in one spot in the northeastern Pacific Ocean. In addition, the ADCP data cannot pinpoint specific zooplankton species. These new results show that some twilight zone animals are considerably more active than previously thought. More information is needed to fully understand why zooplankton exert energy swimming up and down all day in response to small changes in light, and if this behavior is common among different zooplankton species and throughout oceans worldwide.

"But it's such a cool thing to have a window into the daytime lives of these little animals," Omand said, "and hopefully this sheds light on the cues these animals are using and why they do what they do." ■

[1] For more information, see "NASA, French Space Laser Measures Massive Migration of Ocean Animals" in the January–February 2020 issue of *The Earth Observer* [**Volume 32**, **Issue 1**, p. 39—*go.nasa.gov/396FXdk*].
[2] To read the study, visit *www.pnas.org/content/118/32/e2022977118.short?rss%3D1*.

NASA Earth Science in the News

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

EDITOR'S NOTE: This column is intended to provide a sampling of NASA Earth Science topics reported 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*.

NASA Satellites Map Out New Orleans Power Outage Caused by Hurricane Ida, September 1, *techtimes.com*. Data from NASA satellites have been used to map the power outage in New Orleans, LA, caused by Hurricane Ida. The scientists who worked on the maps are from NASA's Goddard Space Flight Center as well as the Universities Space Research Association (USRA). The satellites used in the mapping include the Suomi National Polar-orbiting Partnership (NPP) and Landsat 8. According to NASA's Earth Observatory, Suomi NPP was able to capture nighttime lights data from New Orleans on August 9 and 31—see **Figure 1**. Landsat 8 provided the data used for the base maps of New Orleans. **Miguel Román** [USRA] said that "the imagery is surprisingly cloud free. It usually would take at least 48 hours for skies to clear up enough after an event like this." Román noted that at this aftermath stage, the imagery captured a lot of diesel-power and backup generation, which utilities do not monitor.

NASA Talks About Why We Have to Protect the Ozone Layer, August 27, *slashgear.com*. According to research from NASA, Lancaster University (U.K.), and other groups, remediating the Earth's ozone layer so far has protected the planet's vegetation and prevented an increase of 0.85 °C (~1.5 °F) warming around the planet.[1] According to the new study, the impact of plants hadn't been accounted for in previous research on climate change. The new study looked at what would have happened to plants in the absence of the ozone layer. Researchers investigated two hypothetical scenarios, including the result of a protected world and the world had chlorofluorocarbons (CFCs) not been banned. The worst-case scenario assumed CFC emissions increased at a rate of 3% every year from the 1970s on. That scenario found significant thinning of the ozone layer across the globe by 2050. By 2100 the ozone holes that formed in the tropics would be more significant than the hole in the ozone layer observed in the Antarctic. The depleted ozone would allow more ultraviolet radiation to hit Earth's surface and prevent plants from storing carbon in their tissue and the soil. In that worst-case scenario, carbon dioxide levels are estimated to be 30% higher than we currently see on Earth, leading to a planet that would be 0.85 °C warmer because of the impact on plants alone.

[1] To read the full study, visit *https://www.nature.com/articles/s41586-021-03737-3*.

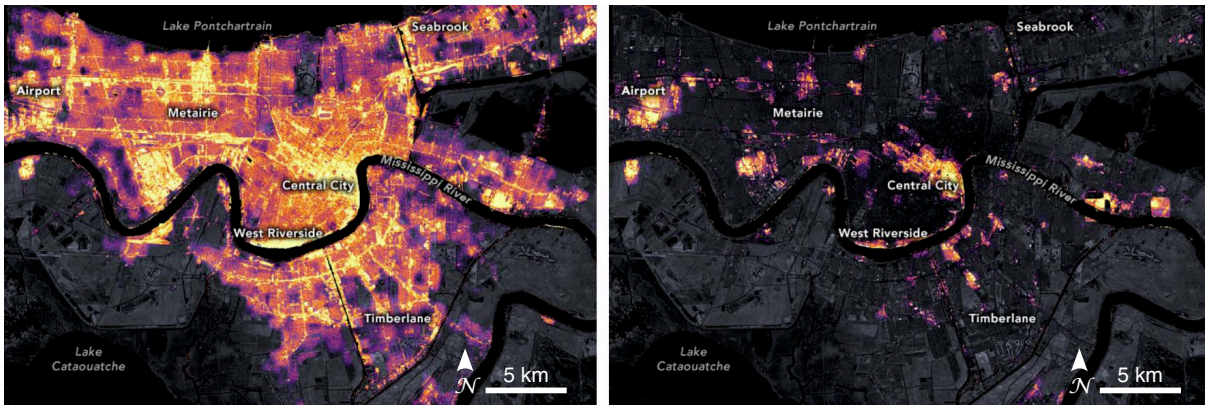


Figure 1. The images above show nighttime lights data acquired by the Suomi NPP satellite before [August 9; *left*] and after [August 31; *right*] Hurricane Ida made landfall on August 29, 2021. The base maps make use of data collected by the Landsat 8 satellite. The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard Suomi NPP has a low-light sensor—the day/night band—that measures light emissions and reflections. This capability has made it possible to distinguish the intensity, types, and sources of lights and to observe how they change. The data are then processed to account for changes in the landscape (such as flooding), the atmosphere, and the Moon phase, and to filter out stray light from sources that are not electric lights. For more information and to download the images, visit *go.nasa.gov/3tWZnL5*. **Credit:** NASA's Earth Observatory

NASA Scientists Spot Troubling, Extreme Melting in Greenland from a Plane, August 26, *mashable.com*. **Josh Willis** [NASA/Jet Propulsion Laboratory] flew over Greenland in August 2021 and gazed at a sprawling polar world of melted ice and dark pools of water. In mid-August, a potent heat wave melted large swaths of the Greenland ice sheet. So far in 2021, the island's melted area is far above the 1981 to 2010 average to date, by some 1 million mi^2 (~2.6 million km^2). "What's important to know is that all the big melt years have happened in the last two decades or so," Willis told Mashable between Greenland flights. "That's because the melt in Greenland is getting more extreme with every decade due to human interference with the climate." Arctic scientists have found that, over the last couple decades, Greenland is melting faster than it has in at least 350 years. The ice sheet is shrinking. As the climate warms, and heat waves become increasingly extreme, major melting events are even happening at the island's typically frigid summit. Willis and his team were not actually flying around to survey the melting on the mainland. As part of NASA's Oceans Melting Greenland mission, they were dropping sensors into the seas around the giant island's coast, to measure how the warming ocean is eating away at some of the largest glaciers on Earth. But while flying over Greenland en route to pick up more equipment, Willis and his team were "stunned" by Greenland's current melt—see **Figure 2**. Their captain, Jim Haffey, said he'd never seen this scale of melting before. "He's been flying over the ice sheet for 25 years and he's seen pretty much everything," said Willis. "As a scientist, I always want to look at the data before taking someone's word on what they've seen. This time, the records told the same story as the pilot."

Figure 2. Photo of sprawling areas of melted ice on Greenland. **Credit:** NASA

Rain Recorded at the Summit of Greenland's Ice Sheet for the First Time Ever, August 19, *gizmodo.com*. In August 2021, the Greenland ice sheet underwent a major melting event. The melting was quickened by a wholly unexpected and unwelcome visitor: rain. Seven billion tons of rain fell on the country, and for the first time in recorded history, it rained at the Greenland Summit Camp, a research station near the normally frigid top of the ice sheet. It was also only the third time this decade that temperatures ever rose above freezing at Greenland's summit, according to the National Snow and Ice Data Center, leading to large-scale melted areas. These large-scale melts can do serious damage to the ice sheet even if they only last a few days. The darker liquid water can absorb the Sun's energy and cause the surrounding ice to melt faster than frozen forms, destabilizing the snow and *firn* (granular snow on the ice surface that has not been compressed) below the surface. The blitz of water can interfere with ice sheet dynamics over the longer term as well. "During melt events, these processes can occur over parts of the ice sheet that do not typically experience melt, making the impact more widespread," **Lauren Andrews** [NASA's Global Modeling and Assimilation Office] said in a statement to NASA's Earth Observatory. "Positive feedbacks like these are starting to take their toll."

***How the Space Station is Helping U.S. Fire Crews Battle Wildfires**, July 31, *digitaltrends.com*. Modern technology is lending a much-needed hand in tracking wildfires. A special piece of equipment onboard the International Space Station orbiting 250 mi (~402 km) above the Earth is one such tool. Data from NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) assisted crews dealing with the enormous wildfire in Bootleg, OR, which started in early July. ECOSTRESS, which arrived at the orbiting outpost in 2018, can measure the surface temperature on Earth. Data from ECOSTRESS is sent to a team at the Rapid Analytics for Disaster Response (RADR) at the Pacific Northwest National Laboratory, which uses it to advise first responders like the U.S. Forest Service.

***Seed to Market: How NASA Helps Bring Food to the Table**, July 27, *wdrb.com*. This spring, NASA, the U.S. Department of Agriculture (USDA), and George Mason University released Crop Condition and Soil Moisture Analytics (Crop-CASMA), a tool that shows 1-km- (0.62-mi)- resolution soil moisture and vegetation conditions for the U.S.[2] With Crop-CASMA, instead of relying on soil moisture reports for large regions, farmers can see differences in moisture between much smaller areas—about the size of a couple of golf courses. The USDA also uses Crop-CASMA to power their monthly Crop Progress Reports, which provides farmers updates on their state's soil moisture, crop health, and growing progress. "What's really cool about what NASA

[2] To read about the tool, visit *go.nasa.gov/3yna7Eu*.

continued on page 19

Earth Science Meeting and Workshop Calendar

NASA Community

October 26–28, 2021
AIRS/Sounder Science Team Meeting, *virtual*
[Rescheduled from September]
https://go.nasa.gov/2Y7KjhY

Global Science Community

December 13-17, 2021
AGU Fall Meeting, New Orleans, LA.
and online everywhere. *www.agu.org/Fall-Meeting*

January 24-27, 2022
AMS Annual Meeting, Houston, TX.
annual.ametsoc.org/index.cfm/2022

NASA Earth Science in the News

continued from page 18

does is that everything is in the public domain," said **John Bolten** [NASA's Goddard Space Flight Center—*Associate Program Manager of Water Resources for the NASA Applied Sciences Program*]. "Our products are free and publicly accessible to everyone around the world." As NASA's Earth-observing satellites collect all these data, NASA's Earth Science Division works with farmers, water resource managers, and others to determine what data they need and how they can best be put to use.

A Study Predicts Record Flooding in the 2030s, and It's Partly Because of the Moon, July 14, *npr.org*. A new study on high-tide flooding predicts that the mid-2030s could be catastrophically wet in U.S. coastal regions—and it could stay that way for an entire decade. Led by members of the NASA Sea Level Change Team from the University of Hawaii, the study says that high-tide flooding could happen more frequently on several U.S. coasts.[3] Flooding at high tide, often called *nuisance flooding*, already occurs with regularity in many coastal communities as water routinely sloshes into streets, yards, and businesses.

Two factors could converge to worsen flooding at high tide, the study says: rising sea levels fueled by climate change, and the Moon's orbit. The Moon's orbit is due for its regular "wobble." That is entirely natural, NASA says, and it has been recorded as far back as 1728. Half of the Moon's 18.6-year cycle creates lower high tides and higher low tides; the other half creates higher high tides and even lower low tides. But NASA says global sea level rise will likely push those high tides higher, and one of the study's co-authors, **Ben Hamlington** [NASA/Jet Propulsion Laboratory—*NASA Sea Level Change Team Leader*], said that because waters will be higher, this lunar cycle could have a much more dramatic effect. "We're getting closer and closer to the flooding thresholds or tipping point in these coastal locations," he said. "The same variability in the past that didn't cause flooding is now going to cause flooding." The study shows that high tides will exceed flooding thresholds more often. Floods, the study predicts, could also start occurring in "clusters" that last a month or longer, depending on how the Sun, Moon, and Earth are positioned, according to NASA. "Low-lying areas near sea level are increasingly at risk and suffering due to the increased flooding, and it will only get worse," **NASA Administrator Sen. Bill Nelson** said. "The combination of the Moon's gravitational pull, rising sea levels, and climate change will continue to exacerbate coastal flooding on our coastlines and across the world."

*See News Story in this issue.

[3] To read the study, visit *https://www.nature.com/articles/s41558-021-01077-8*.

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

Official Business
Penalty for Private Use: $300

eospso.nasa.gov

The Earth Observer

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

Article submissions, contributions to the meeting calendar, and other suggestions for content are welcomed. Contributions to the calendars should contain date, location (if meeting in person), URL, and point of contact if applicable. Newsletter content is due on the weekday closest to the first 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. Finally, note that print copies of *The Earth Observer* are no longer sent to addresses at GSFC; they will be emailed to the addresses we have in our database. If you are located at GSFC and still wish to receive a print copy, you may provide a home (or alternative) address to Cindy Trapp, and we can add it to our database.

The Earth Observer Staff

Executive Editor:	Alan B. Ward (*alan.b.ward@nasa.gov*)
Associate Editor:	Heather H. Hanson (*heather.h.hanson@nasa.gov*)
Assistant/Technical Editor:	Mitchell K. Hobish (*mkh@sciential.com*)
Technical Editor:	Ernest Hilsenrath (*hilsenrath@umbc.edu*)
Assistant Editor:	Douglas Bennett (*douglas.bennett@nasa.gov*)
Design, Production:	Deborah McLean (*deborah.f.mclean@nasa.gov*)

Scan code to access
The Earth Observer
archive online

Printed on Recycled Paper

NP-2021-8-684-GSFC