Over Thirty Years Reporting on NASA's Earth Science Program

The Earth Observer

National Aeronautics and Space Administration

July–August 2023. Volume 35, Issue 4

The Editor's Corner

Steve Platnick
EOS Senior Project Scientist

This summer—just ahead of the peak of the Atlantic Hurricane season—the NASA **Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats** (TROPICS) mission released its "first light" images. TROPICS is a constellation of observing platforms that measures temperature, humidity, and precipitation with spatial resolution comparable to current operational passive microwave sounders—but with unprecedented temporal resolution. TROPICS is comprised of four 3U CubeSats,[1] each hosting a 12-channel passive microwave radiometer. While the primary mission objective of TROPICS is to relate temperature, humidity, and precipitation structure to the evolution of tropical cyclone intensity, a diversity of other applications have also been identified for TROPICS, including data assimilation, rainfall monitoring, and disaster response. There are also plans for synergistic applications with other satellite missions—in particular with NASA's other hurricane-focused CubeSat constellation: the **Cyclone Global Navigation Satelllite System** (CYGNSS). To learn more about these collaborations, see the **2023 Joint Applications Workshop on NASA's TROPICS and CYGNSS Satellite Missions**. Links to many of the presentations are included on the agenda.

The TROPICS qualification unit was launched as a Pathfinder on June 30, 2021, aboard a SpaceX Falcon 9 rideshare into a Sun-synchronous orbit. The constellation of four additional satellites was successfully deployed on two separate Rocket Lab Electron rocket launches on May 8 and May 26, 2023.[2] Testing during the Pathfinder phase enabled accelerated spacecraft commissioning, calibration, and validation for the constellation, with first light images—see **Figure**, *below*—released on July 19, 2023. For more information on NASA's

[1] CubeSats are typically manufactured in standard 10x10x10 cm (~4 in^3) Units (U) that weigh up to 2 kg (4.4 lbs). To learn more see **CubeSats and Their Roles in Earth Science Investigations** in the November–December 2020 issue of *The Earth Observer* [**Volume 32**, **Issue 6**, pp. 5–17].

[2] TROPICS was originally planned as a six-satellite constellation, however the Astra 3.3 rocket carrying the first two cubsesats failed to reach orbit in June 2022, prompting a review and sudsequent switch in launch contractor and vehicle.

continued on page 2

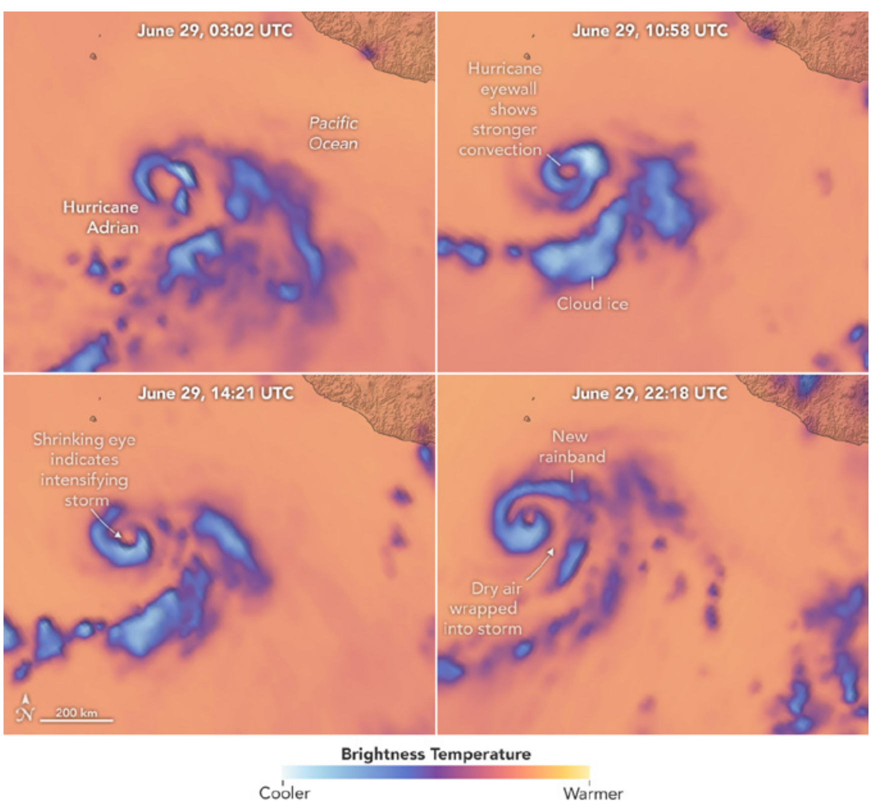


Figure. This series of still images, produced with data acquired by TROPICS, shows structural changes within Hurricane Adrian as the storm intensified. The first frame [*top left*] shows the storm's developed eye, visible as the warmer area surrounded by cooler areas associated with clouds and precipitating ice. (By the time of this image, NOAA's National Hurricane Center had already upgraded Adrian from a tropical storm to a category-1 hurricane. It continued to strengthen and remained a category 1 storm throughout this image series.) In the second frame [*upper right*], a reduction in cooler temperature (blue) indicates a weakening in convection, especially in the eyewall. By frame three, [*lower left*] the eyewall shows stronger convection, and the eye appears more compact—which often occurs as a storm intensifies. By frame four [*lower right*], strong convection is apparent south of the eye, a new rainband has developed on the north side, and the eye reaches its smallest size seen in the image series. **Figure credit: NASA Earth Observatory images** by Lauren Dauphin, using data provided by the TROPICS team.

In This Issue

newest storm-watching satellites, see the TROPICS news story on page 27 of this issue.[3]

Turning to upcoming missions, the **NASA–Indian Space Research Organisation (ISRO) Synthetic Aperture Radar** [NISAR] satellite is making progress toward its planned early 2024 launch. In June, engineers integrated the radar instrument payload onto the spacecraft bus in an ISRO clean room in Bengaluru, India.

A joint NASA–ISRO endeavor, NISAR will use advanced radar imaging to observe Earth's changing ecosystems, dynamic surfaces, and ice masses, providing information about biomass, natural hazards, the loss of glacial ice, groundwater, and a host of other applications. With a Sun-synchronous orbit (local time nodal crossing of 6 AM and 6 PM), the mission will observe land and ice-covered surfaces globally with a 12-day repeat, providing global coverage on average every six days for a baseline three-year mission. To learn more about the NISAR and its current testing phase, turn to the news story on page 29 of this issue.

Meanwhille, the **Plankton, Aerosol, Cloud, ocean Ecosystem** (PACE) mission is also making progress toward a planned early 2024 launch. In addition to collecting data on particles in the atmosphere, data from PACE will allow scientists to analyze the spectrum of reflected light emerging from the ocean to provide information on phytoplankton communities. The **Ocean Color Instrument** (OCI)—which will be able to observe more than 100 different wavelengths—is the first scientific instrument to do so daily on a global scale. OCI will make it possible to classify phytoplankton far more comprehensively and accurately than what can currently be accomplished.

PACE builds on a lengthy heritage of ocean color missions, including the **Coastal Zone Color Scanner** (CZCS, flown on **Nimbus 7**), the **Sea-viewing Wide Field-of-view Sensor** (SeaWiFS, flown on Orbview-2), **Terra**, **Aqua**, and the **Landsat series**, which have gathered data on phytoplankton abundances since the 1970s. PACE, which is being assembled at and managed by engineers at NASA's Goddard Space Flight Center, will significantly expand our ability to distinguish and track phytoplankton across the planet. To learn more about PACE's mission to study the world of phytoplankton, turn to page 31 of this issue.

With regard to the ongoing quest for continuity between the **Moderate Resolution Imaging SpectroRadiometer** (MODIS)[4] and **Visible Infrared Imaging Radiometer Suite** (VIIRS),[5] in early May 2023, the MODIS/VIIRS Science Team met to discuss the status of these two instrument suites and to hear updates on science results and efforts to ensure continuity of climate quality datasets once the Terra and Aqua missions end. These discussions continue those that were initiated at the November 2022 EOS Flagship Drifting Orbits Workshop,[6] which helped lead to the three Flagship missions being invited to the 2023 Earth Sciences Division (ESD) Senior Review. The Science Team meeting came just before the May 2023

[3] The **TROPICS mission website** was a source for the information in these paragraphs.

[4] MODIS instruments fly on NASA's Terra and Aqua platforms, both of which have been in service for over 20 years, and are approaching the end of their mission lifetime.

[5] VIIRS instruments fly on NASA's Suomi National Polar-orbiting Partnership (Suomi NPP) platform and the NASA–National Oceanic and Atmospheric Administration's (NOAA) Joint Polar Satellite System (JPSS) satellites. The JPSS-1 and -2 missions are now operational and known as NOAA-20 and -21, respectively.

[6] This meeting occurred November 1–2, 2022; to learn more, see **NASA Holds Discussions About the Future of the EOS Flagship Missions** in the January–February 2023 issue of *The Earth Observer* [**Volume 35**, **Issue 1**, pp. 13–17].

EOS Flagship data continuity workshop and provided a forum for the community to discuss the issues that would be the focus of the workshop.[7] Several themes emerged from the Science Team meeting including the importance of data stewardship in generating data continuity, the use of innovative ideas for merging different satellite datasets and bridging data gaps, and the need for additional support from Headquarters to continue to further refine and maintain quality data algorithms and products that will enable climate analysis across the MODIS and VIIRS eras. Turn to page 13 of this issue to learn more about the details of this workshop.

NASA's Earth Day event marked yet another successful demonstration of the "hybrid" exhibit framework. An in-person event was held April 20–21 at Union Station in Washington, DC, while a virtual Earth Day event went live simultaneously on April 20 and continued to host on-demand content through May 5, attracting over one thousand event attendees. The virtual event included an online exhibit featuring diverse content rooms, a live chat, live *Kahoot!* trivia games, and two online webinars featuring a number of presentations intended to showcase the activities of NASA's Science Mission Directorate—and of the Earth Science Division in particular. The two-day, in-person event, which was free and open to the public, featured a 40-ft Earth dome tent and 24 hands-on activities inside Union Station's historic Main Hall. As has been the case for several years, the major transportation hub of Union Station continues to attract large crowds at NASA's Earth Day event, with 25,000–30,000 people passing through daily. The Science Support Office (SSO) brought together a diverse team of 100 individuals from across the agency to work together to plan and execute this event. Turn to page 4 of this issue to read a summary of the hybrid Earth Day event.

Turning to personnel news, I'm pleased to report that **Joanna Joiner** [GSFC] has been named as the NASA Project Scientist for the **NOAA Geostationary Extended Observations** (GeoXO) satellite program, replacing **Joel McCorkel** [GSFC] in that role. Joanna has over 20 years of experience in satellite remote sensing, from the microwave to ultraviolet. She previously served as Deputy Project Scientist for NASA's **Aura** mission and as the U.S. Science Team Leader for the **Ozone Monitoring Instrument** (OMI) aboard Aura, and more recently as the GeoXO Atmospheric Composition Instrument (ACX) Scientist. Congratulations to Joanna on her new position and my thanks for her willingness to take on this important role that will extend the long history of NASA–NOAA geostationary partnerships into the next decade.

The Earth science missions outlined in this newsletter would not be possible without the decades of dedication and commitment provided by countless talented individuals who have served NASA throughout the years. Among these exceptional individuals is **Robert Wolfe** [GSFC], who retired from NASA on August 18, 2023 after almost 43 years at GSFC.

Robert worked in satellite remote sensing and computer science for over four decades, making major contributions to the design, development, deployment, and enhancement of data systems, including the **MODIS Advaptive Procesing System** (MODAPS), the **Level-1 and Atmospheric Archive and Distribution System** (LAADS), and the VIIRS Land **Science Investigator-led Processing System** (SIPS).

Within NASA, Robert is well known for his role as the Terra Deputy Project Scientist for Data—a position he has held for the last 17 years. He also played a key role in preparing multiple senior review mission extension proposals that justified extending the operation of Terra's five instruments to what is now a remarkable 23-year record.

Robert also led the development of advanced algorithms to geolocate MODIS data and to grid land science data using innovative techniques. He extended these techniques to process data from other instruments including VIIRS on Suomi NPP, NOAA-20, -21, and the **Advanced Baseline Imager** (ABI) on the NOAA–NASA **Geostationary Operational Environmental Satellite–R Series** (GOES)-16 and -17 satellites. My best wishes to Robert on his retirement. ■

[7] This workshop occurred May 23–25, 2023; to learn more see **The Editor's Corner** in the March–April 2023 issue of *The Earth Observer* [**Volume 35**, **Issue 2**, pp. 1–4].

A Pale Blue Dot in Washington: NASA's Earth Day Celebration at Union Station

Dalia Kirshenblat, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., dalia.p.zelmankirshenblat@nasa.gov
Heather Hanson, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., heather.h.hanson@nasa.gov

Photo 1. NASA's Earth Day event took place in Union Station's Main Hall in Washington, DC. A NASA Earth Day banner [*center*] greeted thousands of visitors throughout the two-day event. **Image credit:** NASA

Introduction

Organized by the Science Mission Directorate's Science Support Office (SSO), NASA hosted its eleventh annual Earth Day Celebration event. The second ever hybrid Earth Day Celebration,[1] offering both in-person and virtual components, was held April 20–21, 2023, at Union Station in Washington, DC and **online everywhere**.

The first Earth Day in 1970 famously inspired public awareness for environmental issues nationwide, providing an unprecedented platform for framing decisions that drive ecological conservation. NASA continues this decades-long tradition of igniting curiosity for and cognizance of our home planet's beauty and fragility each year at the Earth Day Celebration at Union Station. Through engaging the public in hands-on science activities and one-on-one conversations with NASA science experts, NASA continues to engage, enrich, and inspire widespread support for environmental protection.

The first Earth Day in 1970 famously inspired public awareness for environmental issues nationwide, providing an unprecedented platform for framing decisions that drive ecological conservation.

Leveraging the hybrid conference format that emerged during the COVID pandemic, the SSO continues to broaden participation for the agency's Earth Day Celebration event.

In-Person Earth Day Celebration

The two-day, in-person event, which was free and open to the public, featured a 40-ft (~12-m) Earth dome tent and 24 hands-on activities inside Union Station's historic Main Hall—see **Photo 1**. This central transportation hub is used by 25,000–30,000 people daily, enabling NASA to reach a large number of citizens.

On the first day of the event, more than 250 students from nine school groups from surrounding areas joined the general public to attend the event. The schools were Latin Public Charter School, Coolidge High School, University of Maryland Eastern Shore, Duvall High School, Prince George's County Virtual High School, Reid Temple Christian Academy, Upward Bound University of Maryland, homeschoolers,

[1] To read about the first hybrid Earth Day event at Union Station, see **Share the Science: Summary of NASA's First Hybrid Earth Day Celebration Event** in the May–June 2022 issue of *The Earth Observer* [**Volume 34**, **Issue 3**, pp. 14–18].

and NASA's Goddard Space Flight Center's (GSFC) STEM Pipeline Equity Inclusion and Diversity (SPEID) Program.[2]

The students and public gathered in front of a NASA stage at 10:00 AM ET for opening remarks. To kick off the event, **Trena Ferrell** [GSFC—*Earth Science Education and Public Outreach Lead*] welcomed attendees and introduced **Angie Ballentine** from **U.S. Congressman Glenn Ivey's** office, who encouraged the students to work hard and follow their dreams. Next **Julie Robinson** [NASA Headquarters (HQ)—*Deputy Director of the Earth Science Division*] welcomed participants and briefly explained how NASA uses the vantage point of space to study and monitor our home planet. She then introduced **NASA Astronaut** and **Former NASA Administrator Charles F. Bolden**, who delivered a special presentation and interacted with attendees for roughly 40 minutes. **Photos 2–5** highlight the kickoff opening reception.

Photo 2. Students gathered at Union Station for opening remarks by NASA representatives. **Image credit:** NASA

Photo 3. Julie Robinson [NASA HQ—*Deputy Director of the Earth Science Division*] welcomed participants. **Image credit:** NASA

[2] The SSO worked with Trena Ferrell, GSFC's Earth Science Education and Public Outreach Lead, to coordinate with local school groups attending the event.

Photos 4 and 5. NASA Astronaut and Former NASA Administrator **Charles F. Bolden** interacted with attendees. **Image credit:** NASA

Bolden enthusiastically welcomed the students, teachers, chaperones, and the public to the event. During his introductory remarks, Bolden engaged one-on-one with attendees, allowing several participants to speak into the microphone to share names and hometowns. He shared his story of where he grew up and what inspired his career at NASA, how his career started, and his long and impressive list of accomplishments. He also shared three pieces of advice with his young audience: always study and practice, never let anyone tell you that you're incapable of doing something, and allow yourself to make mistakes. Next Bolden provided responses to questions from the audience. To close, Bolden presented each school group with a signed lithograph of himself in a spacesuit. Following Bolden's remarks, the 250 students were divided into small groups that followed a rotation schedule, allowing every student access to various activity centers within the event. Each group completed several of the 24 hands-on activities.

In addition to the students, general public participants were also offered an activity passport listing the 24 hands-on activities. The exhibit met physical accessibility standards and featured topical NASA Science books in braille. After completing six or more activities, participants were able to redeem their passport for a NASA drawstring bag and choose from a wide range of NASA Science materials. This was a successful approach: Nearly 1200 activity passports were distributed to the public during the event. Student groups, families, and friends were encouraged to use a single passport during their visit; thus, the number of public participants (1200) and student participants (250) is estimated to be much higher than 1450. **Photos 6–9** highlight how participants engaged with NASA's activities during the Earth Day event. **More Earth Day photos** are available on the Earth Observing System Project Science Office's Flickr page. The **Table** below provides a full list of activities.

Table. Activities at NASA's 2023 In-Person Earth Day Celebration Event held in Washington, DC.

Activity Title	Description
Earth at Night	Participants interacted with a large, backlit Earth at Night display and were encouraged to download a copy of NASA's 200-page eBook, *Earth at Night*.
Dynamic Planet	Participants used this touchscreen interface to drive a spherical display that showed a variety of remote sensing satellite datasets.
Science Gallery	Participants walked through a colorful array of images that told science stories as only NASA can.
NASA Trivia	Participants tested their knowledge about Earth, the Moon, our Sun, and technology by answering 10 questions about each topic.
Virtual Earth Day Selfie Station	Participants took selfies as they stepped into NASA's virtual Earth Day event to celebrate Earth Day with NASA representatives and people all around the world.
The GLOBE Program	Participants learned how to be a citizen scientist and observe the environment around them under the auspices of the Global Learning and Observation to Benefit the Environment (GLOBE) program and using the GLOBE Observer app.
Pew, Pew, Pew: ICESat-2 Lasers Measure Earth's Height	Participants explored ICESat-2 mission science through interactive puzzles, augmented reality, and hands-on activities, such as the ICESat-2 Microenvironment, 3D Antarctic glacier puzzle, Augmented Reality Satellite interactive, digital elevation models, and a 3D ice display with accompanying braille text.
Hubble Augmented Reality Experience	Hubble Space Telescope photos came to life with the Augmented Reality Experience, where participants used their hands to manipulate a 3D hologram of Hubble.
Connect the Drops	Participants engaged in a variety of hands-on activities and learned how and why NASA measures global precipitation.
Explore Your World with NASA Worldview	Participants interactively explored and visualized NASA's Earth Science imagery to see hurricanes forming, wildfires spreading, icebergs drifting, and city lights illuminating.
Earth's Place in Our Solar System	Participants used NASA's Eyes and other tools to explore Earth's place in the Solar System, received sky-watching tips, and learned to track upcoming eclipses.
Phytoplankton Demo	Participants learned about phytoplankton and how NASA detects life from space.
Earth Science Technology	Participants explored the technologies NASA is advancing to observe and understand our home planet, from tiny satellites and smart sensors to artificial intelligence and machine learning.
Measuring Light, the Landsat Way	Participants learned how Landsat utilizes the electromagnetic spectrum and spectral signatures to better understand Earth's systems.
Viewing Earth from above with Landsat	Participants created a sticker mosaic of a Landsat scene and learned how Landsat satellite imagery is made.
To Bennu & Back: NASA's OSIRIS-REx Asteroid Sample Return Mission	Participants learned about the OSIRIS-REx mission and were able to launch a miniparachute to carry a model space capsule to a targeted landing zone.
GEDI* Knights Measure Forests from Space	Participants explored how observing the 3D structure of Earth from space can help us understand climate change and protect biodiversity.
Ask a Scientist with the American Geophysical Union	Participants were encouraged to use their investigative skills and act as a journalist with the American Geophysical Union (AGU) to interview a scientist.
Art and Science with the American Geophysical Union	Participants added to the Community Earth Day Poem and spent time coloring AGU coloring sheets.
Space Robots!	Participants were able to pilot small robotic arms built by NASA interns, mimicking the larger versions NASA develops to service, assemble, and manufacture things in space.
How Old Was the Tree?	Participants learned about how JPSS** satellites help track wildfires and how to calculate the age of a tree while making an artistic print of a tree's rings.
Meteorite Map Challenge and Space Rock Detective	Participants used clues to identify meteorite-related locations around the world while learning fun facts about meteorites and Earth and were challenged to match "space rock cards" with samples from Earth and beyond.
Ready, Set, Eclipse!	Participants learned about how NASA is preparing for the Helio Big Year*** and learned about eclipses, the Sun, and were able to make related items to take home.
NASA Flight Opportunities	Participants learned how to build and run an experiment on a suborbital flight.

*Global Ecosystem Dynamics Investigation (GEDI) is a NASA mission to measure how deforestation has contributed to atmospheric carbon dioxide concentrations.

**Joint Polar Satellite System (JPSS) is a series of polar-orbiting environmental satellites jointly managed by NASA and NOAA. The two satellites currently on orbit are known as NOAA-20 and -21.

***The Helio Big Year begins with the annular eclipse (October 2023) and ends with the Parker Solar Probe's closest approach to the Sun (December 2024). It will include the total solar eclipse (April 2024) and citizen science opportunities to explore aurorae leading up to the solar maximum in 2025.

Photo 6. Participants at *GLOBE Program* activities learned how to observe the environment as a citizen scientist through hands-on activities. One activity was the "cloud in a bottle" demonstration. The participants filled a bottle with about two inches (five cm) of hot water and stir. A match is then lit, blown out, and dropped into the bottle. Once the smoke clears, ice is placed on top of the bottle, and participants watch as a cloud forms. **Image credit:** NASA

Photo 7. Participants at the *Connect the Drops* activity learned how data from NASA's Global Precipitation Measurement (GPM) Mission are used in a variety of real-world applications to improve life around the world. **Image credit:** NASA

Photo 8. Participants engage with NASA staff in front of the backlit *Earth at Night* display. **Image credit:** NASA

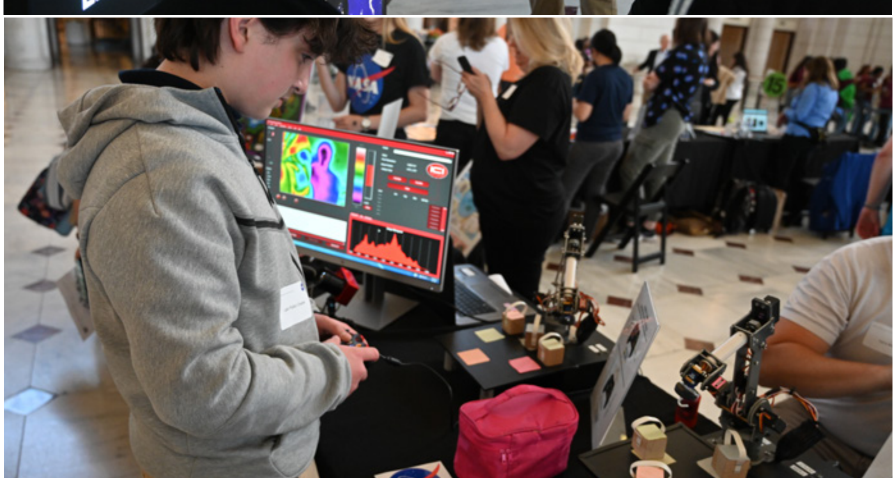


Photo 9. Participants piloted small robotic arms built by NASA interns, mimicking the larger robotic arms NASA develops to service, assemble, and manufacture materials in space. **Image credit:** NASA

Virtual Earth Day Event

The **virtual Earth Day event** went live on April 20 and continued to host on-demand content through May 5, attracting a grand total of 1407 event attendees. The online platform featured five content rooms (Art Gallery, Watch and Learn, Earth Science Booth, Planetary Booth, and Science Activation Booth), as well as an introductory video and portals to additional NASA resources including Home & City, NASA Kids Club, NASA Eyes, a live chat, and a help desk—receiving 4205 total content views—see **Figure 1**. The live online Earth Day celebration featured two live webinar events, with the second webinar followed by *Kahoot!* game challenges in the Science Theater on April 20—see **Figure 2**. The live sessions were recorded and made available on demand, along with all the other content hosted on the virtual platform through May 5. Webinar One hosted 112 attendees and Webinar Two had 83 attendees, featuring web accessibility and closed captioning during webinar events.

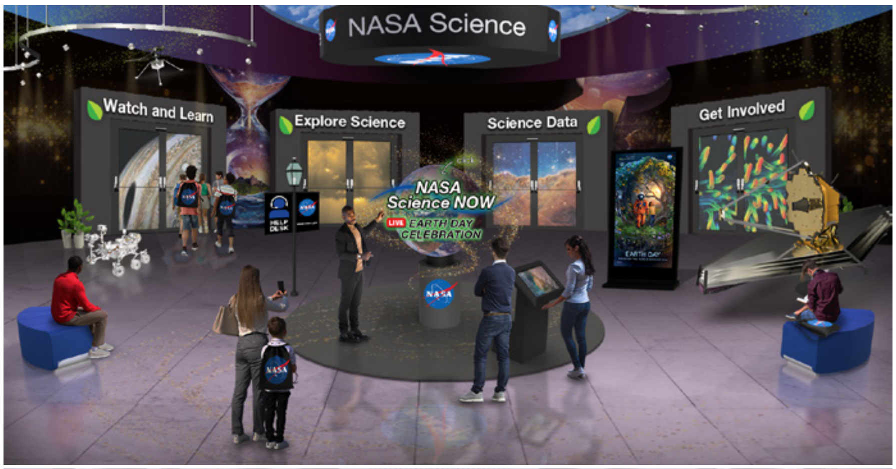


Figure 1. This graphic depicts the *Welcome Lobby* for NASA's 2023 Virtual Earth Day event, featuring five clickable areas. The event featured live events (i.e., webinar events and chat) on April 20 that were recorded and accessible to registered attendees through May 5, 2023. Registration for the event was free and open to the public. **Image credit:** NASA

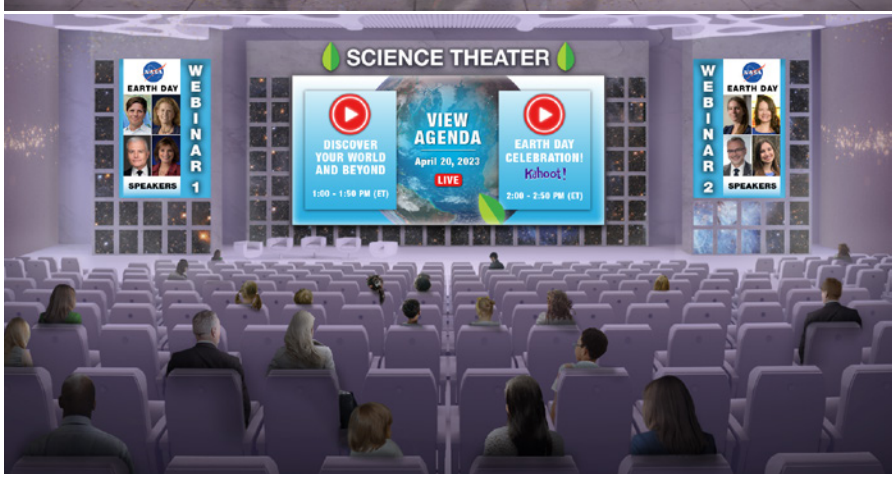


Figure 2. The *Science Theater* room featured two live webinar events. **Image credit:** NASA

The two 50-minute webinar events: "Discover Your World and Beyond" and "Earth Day Celebration" included presentations given by: **Kevin Murphy** [GSFC—*NASA Chief Science Data Officer*]; **Lori Glaze** [NASA HQ—*Director of NASA's Planetary Science Division*]; **Eric Smith** [NASA HQ—*Associate Director for Research in the Science Mission Directorate's Astrophysics Division*]; **Diane Malarik** [NASA HQ—*Acting Director of NASA's Biological and Physical Sciences*]; **Katherine Calvin** [NASA HQ—*NASA Chief Scientist* and *Senior Climate Advisor*]; **Kelly Korreck** [NASA HQ—*NASA Heliophysics Program Manager*]; and **Jim Free** [NASA HQ—*Associate Administrator for NASA's Exploration Systems Development Mission Directorate*]. These presentations are described in the captions of **Figures 3–9** on pages 10–12.

After each speaker's presentation, attendees were encouraged to join the others online to play Kahoot! games, including *Earth at Night* and *Earth, Sun, and Moon*. Over the course of the live-activities day on April 20, 83 attendees played the two Kahoot! games. These and other **NASA Kahoot! games** are available online.

Figure 3. Kevin Murphy [GSFC—*NASA Chief Science Data Officer*] talked about the large number of Earth observing missions under NASA's control and the myriad science applications these satellite data support, including tracking wildfires, monitoring climate change, and tracking global air quality and public health, and how these data are used to provide a better understanding of environmental issues and support environmental decision making. **Image credit:** NASA

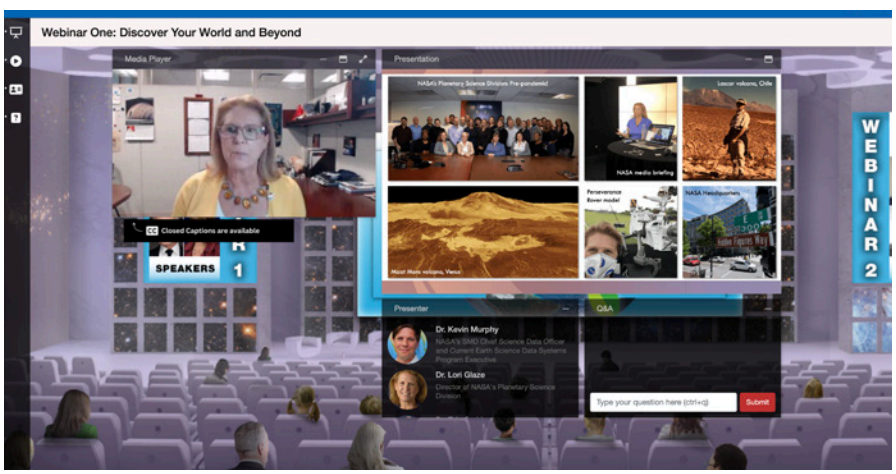


Figure 4. Lori Glaze [NASA HQ—*Director of NASA's Planetary Science Division*] gave an overview of NASA's Planetary Science missions that explore the Solar System from Mercury to Pluto, expressing how these missions continue to revolutionize our understanding of the origin and history of the Solar System. Glaze also touched upon NASA's robotic explorers and how they gather data to help scientists understand how the planets formed, what triggered different evolutionary paths among the planets, what processes have occurred and those that are active, and how Earth—so far alone among the Solar System's planets—became habitable. **Image credit:** NASA

Figure 5. Eric Smith [NASA HQ—*Associate Director for Research in the Science Mission Directorate's Astrophysics Division*] discussed how and why we study exoplanets, and the potential for exoplanetary systems to help scientists learn more about life on Earth. Smith highlighted one of the James Webb Space Telescope's objectives to follow up on previous discoveries of distant exoplanets to better discern their potential for developing life. **Image credit:** NASA

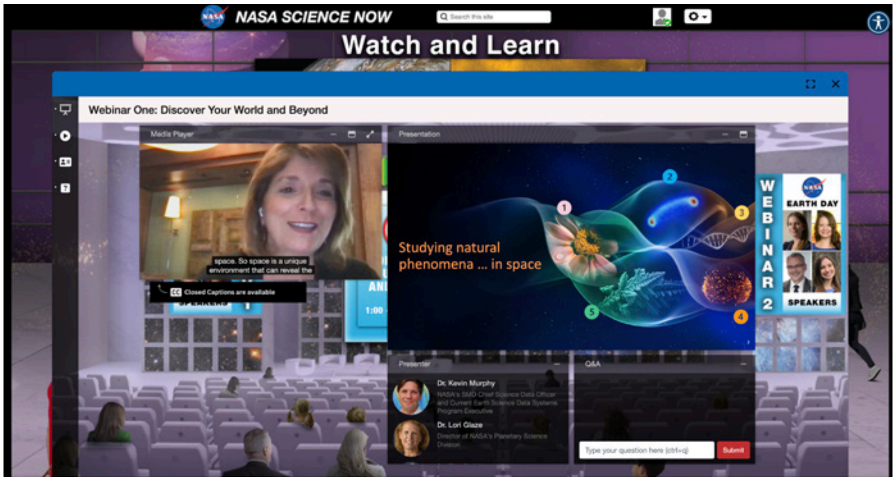


Figure 6. Diane Malarik [NASA HQ—*Acting Director of NASA's Biological and Physical Sciences*] discussed NASA's Biological and Physical Sciences program, and the work they do to study natural phenomena in space. Malarik discussed agriculture in space, how biology responds and adapts to the space environment, and the practical applications of this research for the benefit of life on Earth. **Image credit:** NASA

Figure 7. Katherine Calvin [NASA HQ—*NASA Chief Scientist and Senior Climate Advisor*] greeted the virtual audience with a short message to kick off the second webinar. She shared visualizations of the Earth's changing climate and provided a brief overview of NASA's Earth-related initiatives like the 2022 launch of the Surface Water and Ocean Topography (SWOT) satellite, NASA's various partnerships with the aviation industry to help reduce energy use and emissions, and the anticipated SCEPTOR Distributed Electric Propulsion Aircraft mission to test an all-electric airplane later this year. **Image credit:** NASA

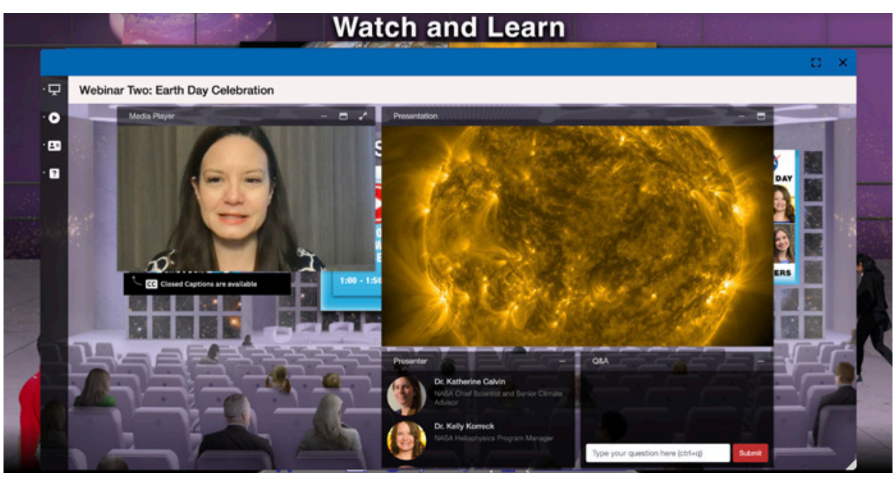


Figure 8. Kelly Korreck [NASA HQ—*NASA Heliophysics Program Manager*] discussed two upcoming solar eclipses: an annular solar eclipse in October 2023 and a total solar eclipse in April 2024. Korreck emphasized NASA's Heliophysics Big Year, a global celebration of solar science and the Sun's influence on Earth and the entire Solar System, which will begin with the annular eclipse in October 2023 and end with Parker Solar Probe's closest approach to the Sun in December 2024. **Image credit:** NASA

Figure 9. Jim Free [NASA HQ—*Associate Administrator for NASA's Exploration Systems Development Mission Directorate*] discussed how the planned Artemis missions to the moon will reveal hidden secrets of the Solar System and tell us more about the early history of the Earth–Moon system. Free also emphasized Artemis' planned orbiting lunar laboratory, Gateway, which will focus on biology, geology, astrophysics, and climate research. While studying the moon, astronauts will study the history of water in the inner Solar System, which has the potential to help scientists understand more about the beginnings of life on Earth. **Image credit:** NASA

Figure 10. The *Fun Zone* featured on-demand science games and links to other NASA resources, such as NASA's Eyes and Home & City. **Image credit:** NASA

In addition to the three live webinar events, virtual attendees could chat with NASA experts by visiting the Help Desk, which received 91 chat views and 17 questions. Last but not least, another popular and highly interactive component of the virtual event was the Fun Zone, which featured on-demand science games and interactives—see **Figure 10**.

Conclusion

NASA's Earth Day Celebration is the largest event organized annually by the SSO. Each year, months of planning calls, cross-divisional coordination, and intensive activity design—carried from conceptualization through numerous revisions to implementation—result in thousands of visitors from a broad spectrum of ages and backgrounds coming together to enjoy NASA science. From young students accompanying their school groups to random passersby stumbling upon a giant inflatable Earth dome while bounding through the Main Hall on the way to catch a train, Earth Day at Union Station means shaking hands with an astronaut, touching a meteorite for the first time, or making a cloud in a bottle. NASA's SSO pulled together a team of some 100 individuals from across the agency to work together, plan, and execute these interactive activities synchronously. This event would not have been possible were it not for the incredible efforts and collaboration put forth by so many of NASA's outreach professionals. With in-person and virtual components, NASA was able to engage and celebrate Earth Day with roughly 3000 individuals directly—though the number of actual participants is estimated to be much higher due to school, family, and friend groups counted as a single contact (i.e., one activity passport at the in-person event or one computer login for the virtual event). The **Earth Day 2023 poster** is available for download. The link to the poster also contains more details about how NASA celebrated Earth Day 2023. ■

Continuing the Continuity Conversation: Summary of the 2023 MODIS/VIIRS Science Team Meeting

Nyssa Rayne, NASA's Goddard Space Flight Center/Global Science &Technology, Inc., nyssa.rayne@nasa.gov
Joanne Howl, Science Systems and Applications, Inc., joanne.howl@ssaihq.com

Photo 1. In-person attendees of the 2023 MODIS–VIIRS Science Team meeting. **Photo credit:** Mako Komoda/Japan Space Systems

Introduction

For the first time since 2019,[1] when live gatherings were interrupted by the COVID pandemic, the annual **Moderate Resolution Imaging SpectroRadiometer** (MODIS)[2] and **Visible Infrared Imaging Radiometer Suite** (VIIRS)[3] [hereinafter MODIS/VIIRS] Science Team Meeting (STM) was held May 2–4, 2023, at The Hotel at the University of Maryland in College Park, MD. The meeting drew 113 in-person participants—see **Photo 1**—and the hybrid option allowed over 100 more to participate virtually via WebEx livestream.

The three-day meeting had five sessions, each with panel discussions, some with plenary and individual presentations, and all followed by question-and-answer (Q&A) sessions. Time for Q&A (referred to as *Discussion* in the summary below) was intentionally built into the meeting to promote lively discussions among meeting participants, to help advance subject matter knowledge, and to formulate future goals. In addition, evenings of the first and second days (May 2 and 3) gave access to the poster session with **30 posters**. A detailed day-by-day summary of the STM meeting follows. In addition, a MODIS/VIIRS Calibration Workshop preceded the STM on May 1, 2023. The 19 presentaitions, each 20 minutes in length, are briefly summarized in the next secton. Following that, the reamainder of the article summarizes the MODIS/VIIRS STM.

The full agendas for both the **Science Team Meeting** and **Calibration Workshop**, along with downloadable slide decks and selected presentation recordings, are posted on the **MODIS website**.

MODIS/VIIRS Calibration Workshop Summary

The 2023 MODIS/VIIRS Calibration Workshop was held on May 1, 2023, at The Hotel at the University of Maryland, in College Park.

Jack Xiong [NASA's Goddard Space Flight Center (GSFC)] provided opening and closing remarks, as well as an agenda-based overview for the MODIS and VIIRS Calibration Workshop. **Sarah Schwenger** [GSFC] gave a brief introduction and status update of

[1] To read a summary of the most recent in-person meeting, see **The Continuity Quest Continues: Summary of the 2018 MODIS–VIIRS Science Team Meeting** in the January–February 2019 issue of *The Earth Observer* [**Volume 31**, **Issue 1**, pp. 7–16, 23].

[2] MODIS instruments fly on NASA's Terra and Aqua platforms, both of which have been in service for over 20 years, and are approaching the end of their mission lifetime.

[3] VIIRS instruments fly on NASA's Suomi National Polar-orbiting Partnership (Suomi NPP) platform and the NASA–National Oceanic and Atmospheric Administration's (NOAA) Joint Polar Satellite System (JPSS) satellites. The JPSS-1 and -2 missions are now operational and known as NOAA-20 and -21, respectively. JPSS-3 and -4 are scheduled for future launch, with JPSS-4 (which will become NOAA-22 after launch) planned for 2027 and JPSS-3 to be held in storage for the time being. For more details on the decision to switch the order of the JPSS launches, see **Jim Gleason**'s explanatory remarks in the Panel 2 Discussion on page 18.

the MODIS and VIIRS instruments and their respective satellite platforms (covered in the main text of this article), including an overview of the planned future operational maneuvers and platform decommission timeframes. **Sadashiva Devadiga** [GSFC] and **Xu Geng** [GSFC/Science Systems and Applications, Inc. (SSAI)] provided a summary of MODIS and VIIRS Level-1 Data Products as well as an update on—and future timeline for—additional data processing and reprocessing.

The workshop started off with several presentations about calibrating the instruments for specific spectral bands, e.g., shortwave reflective solar or longwave thermal emissive bands (TEB). **Emily Aldoretta** and **Keven Twedt** [both GSFC/SSAI] provided details on recent MODIS reflective solar band (RSB) calibration activities, followed by **Tiejun Chang** [GSFC/SSAI], who discussed TEB calibration activities and related crosstalk calibration improvements for MODIS instruments.

Ning Lei, **Amit Angal**, and **Junqiang Sun** [all at GSFC/SSAI] presented corresponding updates on VIIRS calibration activities related to RSB on-orbit calibration, TEB calibration, and day-night band (DNB) calibration, respectively. **Aisheng Wu** [GSFC/SSAI] then presented results on his team's work to assess the calibration consistency among similar instruments on Suomi National Polar-orbiting Partnership (Suomi NPP) and the four NASA–National Oceanic and Atmospheric Administration (NOAA) Joint Polar Satellite System (JPSS) satellites (of which NOAA-20 and -21 are operational at this time). They found that the stability of Suomi NPP and NOAA-20 missions is within 2%—but that NOAA-20 reflectances are lower than those from Suomi NPP, with a 4–7% difference in shortest wavelength bands and a 2–4% difference for other bands. Similarly, the VIIRS instruments on NOAA-20 and NOAA-21 align within 2% for the visible and infrared bands—but have significant inconsistencies greater than 5% in the shortwave/IR bands.

Later in the workshop, **Eric Vermote** [GSFC] presented a complete approach for instrument harmonization across multiple radiation bands using spatially diverse surface sites [BEnchmark Land Multisite ANalysis and Intercomparison of Product (BELMANIP) 2] and algorithms for deep convective clouds and sun glint, a combination that minimizes spectral response differences between sensors.

In response to the Terra and Aqua satellite's recent and ongoing oribital drift and altitude changes (see footnote 5 on page 15), **Gary Lin** [GSFC] presented information on geometric calibration processes and geolocation accuracy assessments for both MODIS and VIIRS instruments. He also provided an update on the minor changes to MODIS swath width and scan gaps resulting from the changes in orbits.

Additionally, because Terra and Aqua will reach the end of their lives within the next five years, many presenters focused on the evolving issue of *data continuity* and the calibration methods that will be needed to bridge the gap between MODIS and VIIRS in order to extend the Earth Observing System's (EOS) over twenty years of data records using data from Suomi NPP and JPSS. As an example, **David Doelling** [NASA's Langley Research Center (LaRC)] presented updates from the **Clouds and the Earth's Radiant Energy System** (CERES) instrument and from the Geostationary Calibration group, including the team's recent transition (as of April 2022) from using MODIS input data for their Energy Balanced and Filled (EBAF) product to using only VIIRS/NOAA-20. He also shared the team's newly determined RSB radiometric-scaling factor to rationalize differences between instrument responses on Suomi NPP and NOAA-20.

Several presentations focused on nontraditional and novel calibration approaches. **Kevin Turpie** [GSFC/University of Maryland, Baltimore County's Joint Center for Earth Systems Technology (JCET)] gave an overview and update of the Airborne Lunar Spectral Irradiance (Air-LUSI) campaign, and **Rajendra Bhatt** [LaRC] shared information about the upcoming Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder [CPF] mission, launching in spring 2025, that will provide intercalibration with VIIRS. **Jeffry Czapla-Myers** [University of Arizona] explained that, while not new, the Radiometric Calibration Test Site (RadCaTS) has also been used to calibrate and validate MODIS and VIIRS data. Planned future initiatives will incorporate novel techniques, such as drones and student-engineered radiometers.

Finally, many presentations focused on calibration continuity as related to specific science disciplines, with ocean, land, and atmosphere groups represented. **Gene Eplee** [GSFC/SAIC] presented the Ocean Biology Processing Group's calibration efforts and status updates for Suomi NPP and JPSS. **Kerry Meyer** [GSFC] presented work by members of the atmosphere discipline to intercalibrate MODIS with VIIRS instruments via their newly derived Suomi NPP and VIIRS/NOAA-20 adjustment factors. While this intercalibration process has been used to create an online tool that monitors near-real-time (NRT) relative radiometry, the team stressed a need to monitor future product continuity and correct the radiometric adjustment factor as needed.

Alexei Lyapustin [GSFC] presented a continuity analysis for both atmosphere and land MODIS algorithms, e.g., the **Multi-Angle Implementation of**

Atmospheric Correction (MAIAC)—used for aerosol optical depth (AOD) and a proxy for air quality—and the Normalized Difference Vegetation Index (NDVI)—used to characterize different land types. Both of these algorithms showed better agreement with MODIS/Aqua data than with Suomi NPP and NOAA-20/VIIRS data. **Virginia Sawyer** [GSFC/SSAI] also presented AOD results from the Dark Target Aerosol Retrieval Algorithm group. This group is working to extend the MODIS record rough calibration and application of the Dark Target algorithm to Suomi NPP and NOAA-20 datasets. She reported that a major update to the product is expected later this spring or early summer.[4]

DAY ONE—May 2, 2023

Session 1: MODIS/VIIRS Instrument Status and Continuity Updates

Miguel Román [Leidos Civil Group–*MODIS–VIIRS Science Team Leader*]—shown in **Photo 2**—served as moderator for this session and gave opening remarks. He welcomed the participants and explained that the meeting's *Davos-style* format, which centered on brief panel presentations followed by discussions, was selected to encourage participant engagement and sharing of ideas.

The first session took up about two-thirds of the first day of the meeting. It included four panel discussions and one plenary presentation.

Panel 1: NASA Headquarters' Perspective on MODIS and VIIRS

Mike Falkowski [NASA Headquarters (HQ)] provided the HQ perspective on MODIS and VIIRS. He congratulated the community on its hard work and diligence, which resulted in Terra and Aqua representatives being invited to the 2023 Earth Sciences Division (ESD) Senior Review (SR). Falkowski said that the November 2022 Drifting Orbits Workshop,[5] which resulted in several new science efforts based on Terra's drifting orbit, was a major reason for the SR invitation. The major challenge for NASA HQ is a decreased budget brought about by Congressional appropriations falling short of anticipated funding outlined in the President's Budget Request, as well as overruns in some programs. So far, the 15% shortfall has not resulted in programmatic cuts but has been addressed through funding timing.

Photo 2. Miguel Román [*MODIS–VIIRS STM Leader*]. **Photo credit:** Brandon Maccherone/SSAI

Looking ahead, the solicitation formerly for Terra/Aqua/Suomi NPP will likely occur next year—but will be broadened to include more than just those platforms. There are also ongoing discussions occurring regarding offering a joint solicitation with NOAA for data-project funding for Suomi NPP and the JPSS satellites (which includes the existing NOAA-20 and -21 missions and future JPSS-3 and -4 missions).

A new—and important—emphasis from NASA leadership seeks to increase knowledge and visibility of NASA's role in all the information produced to inform critical decisions. Other agencies often leverage the information that NASA produces, but the fact that NASA is the source of this information—and the agency's vital role in developing such useful information—is often lost on Congress, the executive branch, and the public. To that end, a new *Earth Action Strategy*—illustrated in **Figure 1**—will increase NASA's efforts to bring its data to decision makers in key areas. Initial focus areas will include greenhouse gas accounting and wildfire monitoring and mitigation.

Falkowski also discussed the NASA Earth Information Center (EIC).[6] He explained that a new physical space at HQ has been opened and features various MODIS and VIIRS products and services such as **Fire Information for Resource Management System** (FIRMS) and **Black Marble** (nighttime lights) products. The resource is an immersive experience where participants—which includes legislative visitors to NASA HQ—can see some of the amazing things NASA does with the data its

[4] **UPDATE:** The Dark Target Aerosol algorithm has been updated, but the data are not yet available to the public due to problems with the MODIS Adaptive Processing System (MODAPS) Services website.

[5] To learn more, see **NASA Holds Discussions About the Future of the EOS Flagship Missions** in the January–February 2023 issue of *The Earth Observer* [**Volume 35**, **Issue 1**, pp. 13–17]

[6] To learn more about the EIC, see **A New Way to Explore Climate Data: NASA Opens the Earth Information Center** in the May–June 2023 issue of *The Earth Observer* [**Volume 35**, **Issue 3**, pp, 24–25].

Figure 1. Pyramid depiction of NASA's Earth Action Strategy. On the left side of the pyramid, two arrows loop to show a cycle from Earth Science [*bottom*] to Action [*top*], and four levels of examples, including [*bottom to top*] Earth System Observations, Applications, Solutions, and Communication via the New Earth Information Center. **Figure credit:** Miguel Román

satellites, aircraft, and ground observations collect, i.e., applying it to science and technology that benefit society.

Panel 1 Discussion

The discussion encompassed several topics. Some participants raised concerns about the relationship between Earth Action and EIC efforts, particularly in light of the **2017 Earth Science Decadal Survey**'s call for increased NASA data applications. The panelists clarified that resource-sharing between programs will be a point of emphasis. Another audience member noted the increase in HQ funding for commercial data purchases and simultaneous cut in the NASA Earth Science data budget. In light of this, the person questioned the efficacy and cost-effectiveness of purchased data compared to NASA-developed data. This led to further clarification of the purchase process, pointing to a funding solicitation for commercial dataset evaluation. Additional topics of discussion centered on efforts to continue NASA data products into the JPSS era. Specifically, there is some concern about the future transition from Suomi NPP data to NOAA-20 and -21 data, due to differences between NOAA's and NASA's data requirements. Participants emphasized the need to set up a working group to address these issues before development of joint solicitations, along with the importance of data continuity and distribution planning, which **Mike Falkowski** agreed (on behalf of NASA HQ) to pursue as an action item.

Panel 2:* NASA *Project Scientists' Perspectives on MODIS and VIIRS

The project scientists for the missions represented at this meeting served as panelists, including: **Lazaros Oreopoulos** [*Aqua Project Scientist*], **Kurt Thome** [*Terra Project Scientist*], **Linette Boisvert** [*Aqua Deputy PS*], and **Jim Gleason** [*Suomi NPP* and *JPSS Project Scientist*], as well as **Robert Wolfe** [*Terra Deputy Project Scientist for Data*].[7] All were working at GSFC at the time of the meeting.

Oreopoulos explained that the 284-page Aqua SR proposal carried a substantially trimmed budget (about 50% less than optimal). It proposed to extend Aqua science operations for an additional three years, then three more years of Science Phase F, ending in 2029. The goal in the extended mission is to continue science and applications despite the drift and enable new science applications because of it. The hardware is in good shape—but Aqua is expected to run out of fuel by the end of summer 2026. Readjustment maneuvers have ceased in order to save fuel for exit maneuvers. Oreopoulos also discussed some of the challenges faced, e.g., data continuity.

Thome reminded the meeting participants of the great success story that is NASA's Terra mission. It carries five instruments including MODIS, sometimes called the "EOS Workhorse." Terra has long exceeded its planned lifetime and productivity, currently giving us 23 years of service, with over 100,000 orbits, 4.6 million users, 20,000 publications, 350,000 citations, and 83 **data products**. Terra is currently a healthy platform that is slowly approaching its end of life. The last inclination burns took place in March 2020 and Equator crossing time is changing to earlier times—expected to reach 10:15 AM in September 2023, compared with its initial 10:45 AM crossing time. Terra exited the 705 km (~437 mi) Morning Constellation in October 2022, and continues its crossing time drift, with its altitude slowly decaying. End of science is planned to arrive in February 2027, followed by perigee lowering and spacecraft passivation in September 2027. Operational budget cuts mean that there will be some Lights Out Operations (LOOPs) *lights-out* periods overnight, and there may be a lag time in responses to anomalies. Although there is high confidence from **Earth Science**

[7] **UPDATE: Robert Wolfe** officially retired from GSFC as of August 18, 2023, after a 43-year career (25 years as a contractor and 18 as a civil servant). He will continue as an emeritus at GSFC for the next three years.

Mission Operations (ESMO)[8] that data quality will remain the same, there inevitably may be some minor data gaps due to the new LOOPs schedule and process, and missing data will no longer be replayed from the spacecraft in attempts to fill these data gaps. Also, inclination maneuvers and drag makeup, processes that previously kept the satellite orbiting at a consistent orbital speed and height above the Earth, can no longer be performed—only risk mitigation maneuvers to avoid collision with space debris—which may impact some data samples.[9]

Wolfe discussed the key impacts the budget reduction will have on the **MODIS Characterization Support Team** (MCST) and MODIS Instrument Operations. Such reductions have a wide impact across almost all aspects of MODIS operations, including decreasing the frequency of operating MODIS instruments' on-board calibrators, reducing efforts the MCST can make to follow sensor response versus scan angle (RSV), and additional impacts on the Science Data Support Team (SDST) that result in production of Collection 7.1 (C7.1) instead of C8. There will also be negative impacts on the MODIS Administrative Support Team (MAST)—e.g., reduced web page support and fewer in-person Science Team meetings—and on the MODIS Science Investigator-led Processing System (SIPS).

Gleason began his remarks by emphasizing the importance of the upcoming EOS Continuity Workshop and community participation in the Request for Information (RFI).[10] The Workshop is a high-level discussion that looks to the 2030 time frame to define data continuity and address data product needs. EOS missions will reach end of life at the end of the 2020s, while VIIRS measurements will continue until at least 2040. NOAA is currrently deliberating its future plans. The fate of Suomi NPP is tied to other instruments—particularly CERES. The next CERES-like instrument is the **NOAA's Libera**, which will be on JPSS-4 (J4) to be launched in 2027—before J3. Gleason stressed the need to avoid falling into a single-point failure mode for getting overlapped by Libera and pointed out the critical need for maintaining the continuity of the ongoing data stream. It is the job of this team to convince NASA management of the benefits of making continuous multidecadal data products that answer high-priority Earth Science questions, as well as how the early EOS data record for MODIS is the anchor for that effort. Coordinated, highly focused communication efforts will be instrumental in developing focused discipline-specific reports to guide management to understand how money is spent efficiently in order to deliver the greatest scientific return.

Turning to Suomi NPP, Gleason stated that it is still functional—although, with very small margins for operations. Suomi NPP has lost about one-third of its solar array, leaving it in tight power conditions. Currently it is power positive, but another power issue will cause NOAA operations to deorbit the satellite. Health and safety are under NOAA control, and the organization is currently reviewing the potential impacts of operational changes to meet budgetary restraints. For example, the reduction of fuel-burning-maneuvers that stabilize Suomi NPP's orbital track has been discussed. This change would lead to small changes in satellite overpass time; however, this shift in time is not expected to be more than an hour over the next three years.

Panel 2 Discussion

This discussion covered several key topics, starting with the EOS Data Continuity Workshop and the Science Team's role. Some participants inquired about engaging NOAA to help generate and maintain long-term data records, while others discussed advocating for extended funding based on the significance of Terra and Aqua data. The participants discussed similarities and differences between European and American data acquisition approaches—highlighting the open-access nature of the American model—and touching on the potential scale of the proposed **Earth System Observatory** (ESO) in comparison to existing missions. This led to a discussion of "lessons learned" from EOS that were applicable to implementation of ESO, emphasizing accessible data through systems like EOSDIS and briefly addressing the impacts of cloud service providers. Participants asked about what led to the decision to launch J4 before J3. **Jim Gleason** explained that it is primarily a means to optimize satellite launches. Additional topics discussed include resource allocation strategies for data continuity; researcher concerns associated with potential gaps in direct data readout as Terra and Aqua approach end of life; and the critical aspect of morning orbit continuity for scientific observations.

For more discussion of this subject, see *Panel 3* of this summary.

Plenary 1: Terra and Aqua MODIS and VIIRS Instruments Status

Jack Xiong [GSFC] gave a plenary presentation—which was essentially a high-level summary of material presented at the MODIS–VIIRS Calibration Workshop (described in the previous section) regarding the

[8] To learn more about ESMO, see, **Earth Science Mission Operations, Part I: Flight Operations—Orchestrating NASA's Fleet of Earth Observing Satellites**, in the May–June 2016 issue of *The Earth Observer* [**Volume 28**, **Issue 2**, pp. 4–13].

[9] To learn more, the Terra website has a page on **Terra's orbital changes**.

[10] **UPDATE:** This virtual workshop took place on May 23–25, 2023. See "The Editor's Corner" in the **March–April 2023** issue of *The Earth Observer* [**Volume 35**, **Issue 2**, p. 2] for more details.

status of MODIS/Terra and Aqua and VIIRS/Suomi NPP, NOAA-20, and -21. All instruments continue to operate normally and are healthy. Strategies have been developed and implemented to address calibration challenges due to recent drifting orbits for Terra and Aqua, as described earlier. The MCST and VIIRS Characterization Support Team (VCST) support for the instruments will continue, including characterizing and monitoring sensor performance, to address issues identified and to derive and deliver calibration parameters to support sensor Level-1B (L1B) and science data processing and reprocessing.

Plenary 1 Discussion

This discussion addressed the future of the MCST and VCST teams, as they transition from mission support to a broader cross-mission role—with an emphasis on the importance of retaining skilled personnel through reassignment to new missions or roles. A participant asked a technical question about the polarization sensitivity in the VIIRS/Suomi NPP detectors, which **Jack Xiong** explained has been reduced in newer VIIRS instrument builds and also corrected for in the VIIRS ocean product. Discussion then turned to NOAA's reliance on NASA's VCST, which highlighted differences in operational philosophy and practices between NOAA's Center for Satellite Applications and Research (STAR) and NASA's VCST, and the importance of a working partnership and ongoing efforts from NOAA leadership to address disparities between the two entities.

Panel 3: Continuity of MODIS Terra Morning Observations

This panel discussed an ongoing three-part pilot study aimed at integrating and evaluating data continuity between the European Space Agency's (ESA) Copernicus **Sentinel 3** (S3) satellites with morning-crossing-time MODIS data from Terra. S3 is a polar-orbiting satellite with similar instruments and an Equator crossing time [10:00 AM, mean local time (MLT)] that is close to but not identical with Terra's 20+ year historical overpass time of 10:30 AM MLT.

Karen Michael [GSFC] shared the MODIS/S3 morning continuity project's three primary objectives of the pilot—see **Figure 2**. These are to integrate the S3 NRT fire products into the **Land Atmosphere Near real-time Capability for EOS** (LANCE), FIRMS, and **Worldview**, then evaluate them for continuity with the MODIS/Terra Active Fire/Thermal Anomaly product; to develop an NRT, S3 Corrected Reflectance (CR) product that is integrated into Worldview and evaluate it for continuity with the Terra MODIS CR product; and to prototype a standard S3 Land Surface Reflectance (LSR) product and evaluate it for continuity with the MODIS/Terra LSR product.

Sadashiva Devadiga [GSFC] updated the Science Team on the **Science Investigator-led Processing Systems** (SIPS) and summarized the data processing status. He stated that for L1 the SIPS are currently ingesting NRT and standard non-time-critical (NTC) L1 calibrated products from ESA. The standard L1 data are in the **Level-1 and Atmosphere Archive & Distribution System Distributed Active Archive** (LAADS DAAC), while NRT data are accessible from LANCE servers nrt3 and nrt4. Delivery of the science processing code for CR from L1 data from the **Sea and Land Surface Temperature Radiometer** (SLSTR) and the **Ocean and Land Colour Instrument** (OLCI) is complete as is testing and integration. Operational processing of both OLCI and SLSTR CR is expected in late May 2023.

Eric Vermote [GSFC] shared the LSR status, emphasizing the long-term efforts to gain continuity in the Land Climate Data Record, beginning with data from the **Advanced Very High Resolution Radiometer** (AVHRR) on several NOAA and European platforms beginning in the 1980s, then by MODIS on both Terra and Aqua. The community seeks new data sources to

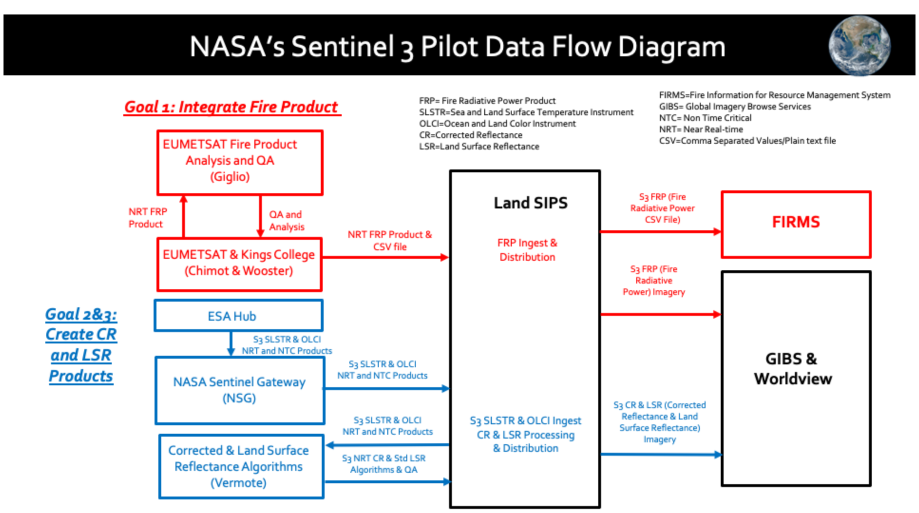


Figure 2. Overview of the MODIS/Sentinel-3 morning continuity project. **Figure credit:** Karen Michael

extend this continuity into the future. The emphasis is on *data consistency*—i.e., characterizing the data as opposed to degrading/smoothing it. Results show that when using only the ESA product the S3 product alone is inadequate. In August 2020 work began on a prototype product using the S3 L1 data directly then applying a MODIS-like algorithm to these data. This has led to promising results, which makes a strong case for developing heritage algorithms for S3 data.

Louis Giglio [UMD] discussed active fire detection. He explained that the focus is on the SLSTR instrument on S3A and S3B, which has 1-km (~0.6-mi) fire bands supplemented with bands that were not intended for fire detection. Two products have been evaluated: an NRT product from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and a science-quality product from ESA. The study focuses on the NRT product with the emphasis on getting the fire product into FIRMS. Results show that each SLSTR reports about three times as many fire pixels as MODIS/Terra. There are several reasons for this, including a more-aggressive algorithm, constrained pixel growth, and wavelength. While SLSTR has higher sensitivity, it also produces more "false alarms" than MODIS. There are also significant differences in distribution in fire radiative power (FRP) between SLSTR fire products and those for MODIS/Terra. This approach has several—but mostly manageable—product issues, e.g., cumbersome product format, large size of product, significant differences found between contents of standard vs. NRT products, and—most of all—proprietary software. The NRT fire product is not yet widely used but is actively being updated by EUMETSAT, and the research team has shared numerous recommendations. Going forward, the focus of the pilot study will be on reducing the number of "false alarms" with an eye toward filtering using FIRMS.

Panel 3 Discussion

The discussion began with a request for the Level 3 gridded products from the S3 pilot study. The panelists explained that the pilot's strategic aim is to create demand for a suite of the most-requested NASA-generated products, e.g., corrected reflectance, fire, and surface reflectance. Additional discussion focused on the differences between data products from ESA's Copernicus Programme versus NASA's EOS Program; the challenges of the formatting and reformatting process when combining different program datasets; and data quality disparities within NASA and MODIS heritage products. The Science Team also stressed the need for NASA HQ to support efforts to deal these data quality issues and to foster collaborations for science-quality improvements. Finally, the panelists shared the challenges of using proprietary code; the costs involved with code development and storage; and potential solutions to other problems experienced in the S3 pilot.

Panel 4: MODIS Collection V7 and End-of-Mission Processing

Miguel Román introduced this panel, explaining that its nature stems from internal discussions on future reprocessing efforts and understanding the need for open communication and coordination across science disciplines to ensure a timely response to efforts for Collection 7 (C7) and beyond.

Sadashiva Devadiga presented the *MODIS C7 Land Reprocessing Plan*, beginning with a retrospective on C6.1—which is the latest collection completed—to give a perspective on work required for C7—especially under conditions of reduced funding. Using C6.1, he illustrated difficulties and delays common to processing. He explained that it's not just processing, but other activities, e.g., integration, testing, and porting into the system, that are part of the work. Transitioning the system to the Ubuntu operating system, for example, took nearly a year to complete. There are still three or four more years of data from the **Multi-Angle Implementation of Atmospheric Correction** (MAIAC) to be processed, which should be completed by June 2023. In addition, Devadiga reported that Science Team determined that high-level Land products [e.g., downward shortwave radiation (DSR) and photosynthetically active radiation (PAR)] required additional science testing and initiated C6.2 reprocessing in May 2023.

The optimal start dates for C7—pending the outcome of the 2023 Senior Review—are as follows: L1B should begin in 2024; Atmosphere should begin in spring or summer 2024; and Land in fall 2024. That timetable would allow for three years of activity before the planned end of mission processing (Phase F), which requires finishing collection reprocessing and documenting the entire history of the mission, including collecting and archiving all the artifacts. It also includes creating C7.1—which will only have a calibration change—and/or C8, which would include calibration and discipline-specific science reprocessing. C7 is expected to take three years, bringing it to completion in 2026; it appears that it will be completed on time. Phase F, depending on the Senior Review and funding, should take until 2027 or 2029. Orbital drift (discussed earlier) is expected to have minimal impact.

Steve Platnick [GSFC—*MODIS Atmosphere Discipline Lead*] then gave a summary of the C7 development status and plans for the atmosphere Level-2 (cloud, aerosol, clear sky pixel-level) datasets and their Level-3 spatial and temporal aggregation—see **Platnick's full presentation** for specific product details. He noted that the C7 Cloud team science testing turnaround has slowed over the past couple of years, raising questions of the adequacy of SDST personnel to engage both the Atmosphere and Land algorithm teams. Notwithstanding those staffing concerns, with SDST help, the Amosphere Team created an alternative to the Optimum Interpolation Sea Surface Temperature (OISST) for C6.1 forward processing. Platnick noted that C7 will use the Global Modeling and Assimilation Office's Goddard Earth Observing model for Instrument Team, or GEOS-IT. Other good news is that the National Snow and Ice Data Center (NSIDC) Near-real-time Ice and Snow Extent (NISE) product is likely to be continued through MODIS lifetimes. Challenges include the change to Ubuntu and GitLab. Issues still arise with GitLab, the software development platform, such as creation of unit tests.

Panel 4 Discussion

Several Science Team members shared issues they have encountered and potential solutions, and identified data-processing needs. These included challenges associated with manipulating data in the cloud, e.g., details regarding data processing and usability as well as cost-model issues—with negative consequences, regardless of approach. In other words, if data are downloaded from the cloud onto their local processing system, egress costs increase significantly for NASA. On the other hand, if the processing is done in the cloud, then the individuals and organizations running their algorithms accrue costs. Ideally, these concerns should be solved, or at least considered, sooner rather than later—i.e., resolved well before Phase F begins. **Miguel Román** developed a detailed list of items to be addressed by a working group or Tiger Team going forward.

Session 2: MODIS—VIIRS Ocean Science and Data Analysis

Bryan Franz, [GSFC—*Ocean Discipline Lead*] chaired this session, which took up the remainder of the first day and included a panel discussion and plenary presentation.

Panel 5: Seasonally Varying Bias in MODIS/Aqua Ocean Color Retrievals

Amir Ibrahim and **Gerhard Meister** [both from GSFC] participated in this panel and discussed seasonally varying bias in MODIS/Aqua ocean color retrievals and its potential relationship to polarization sensitivity. **Ibrahim** first discussed work focused on addressing a seasonal bias that was found, and Meister followed with a detailed discussion of cross-calibration efforts to find a resolution.

The crux of these two reports is that seasonal bias is found in all ocean color sensors to varying degrees—but is most pronounced in MODIS/Aqua. To address the issue, the investigators compared remote sensing reflectance measurements from MODIS/Aqua, VIIRS, the OrbView 2/Sea-viewing Wide Field-of-view Sensor (SeaWiFS), and Marine Optical Buoy (MOBY) measurements at different wavelengths. (MOBY is a vicarious calibration site off the island of Lanai in Hawaii with high-quality, *in situ* measurements.) Compared to SeaWiFS and VIIRS, there remains a strong seasonal bias in MODIS/Aqua in both 2018 and 2022 reprocessing. The 2022 reprocessing showed slight improvement in the red spectrum, but the bias persists in blue and green spectra. Despite the reliance on Aqua for cross calibration, MODIS/Terra does not show the same strong seasonal bias. To find the source of the bias, the team altered algorithms and developed polarization corrections. Each resulted in slight improvements, but also made it evident that neither the algorithm or polarization effects is the root cause of the issue in MODIS/Aqua. The Ocean team is working on cross-calibration-derived polar sensitivity—detailed in Meister's slides—but so far have not resolved the root cause of the seasonality bias in MODIS/Aqua.

Panel 5 Discussion

The questions that arose after this panel were aimed at obtaining more detailed understanding of the potential causes of the seasonality bias in MODIS/Aqua data. The panel explained that this is an issue that the international science community has seen and is also working on, without resolution to date, but confirmed that these efforts will continue.

Plenary 2

Brian Franz discussed the MODIS and VIIRS ocean color time series, including the impacts of the 2022 data reprocessing process as well as the Hunga Tonga–Hunga Ha'apai (HT-HH) eruption in 2022. Franz's group supports seven global missions and their product suites. He explained that in the past six months there has been an effort to reprocess data from all the ocean color missions his group supports—both current and heritage. The reprocessing includes updates to instrument and vicarious calibration, ancillary data sources, atmospheric correction methods and tables, pure seawater optical properties, masks and flags, and derived product algorithms.

The reprocessing shows that the remote sensing reflectance (Rrs) time series from VIIRS/Suomi NPP and VIIRS/NOAA-20 are in good agreement with MODIS on both Terra and Aqua, which indicates that VIIRS can be used to extend the SeaWiFS–MODIS time series for many key ocean color parameters. In addition, the 2022 Rrs and chlorophyll results are in good agreement with in situ measurements for all missions—see **Figure 3** on page 21. The VIIRS/NOAA-21 ocean color products are complete and now available through NASA's **Ocean Biology Distributed Active Archive Center** (OB.DAAC). Franz reported that there was a

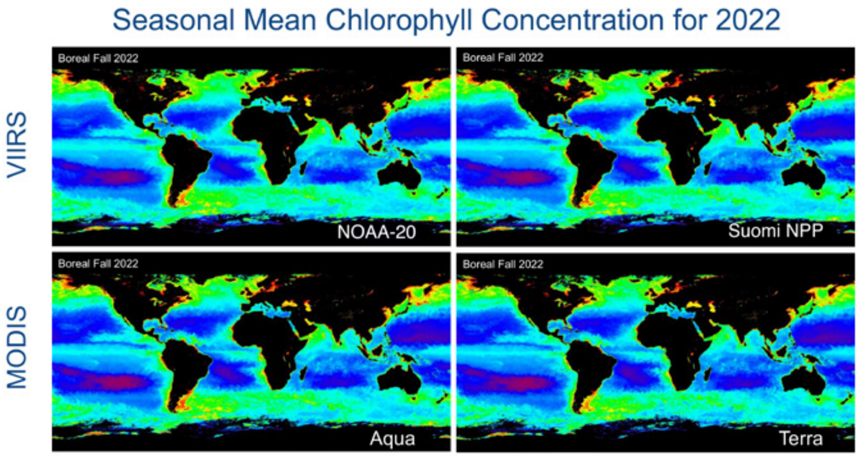


Figure 3. Seasonal mean chlorophyll concentrations for 2022 derived from VIIRS on NOAA-20 [*top left*] and Suomi NPP [*top right*] observations compared with the same derived from MODIS on Terra [*bottom left*] and Aqua [*bottom right*] observations. **Figure credit:** Bryan Franz

peak in the Southern Hemisphere Rrs in January 2022 in response to a phytoplankton bloom spurred by the extreme and widely spread Australian wildfires. The Ocean team discovered an anomaly in all ocean color missions in June–July 2022, which appears to have been caused by an atmospheric correction error associated with unresolved stratospheric aerosols from the HT-HH eruption. A detailed analysis of the error is underway and mitigation strategies are being developed.

Lorraine Remer (UMBC) spoke on how atmospheric dust aerosols nourish the global ocean. Her presentation summarized the findings released in a paper her team recently published in ***Science***. While most of the nutrients that fuel primary production come from water upwelled from ocean depth, atmospheric aerosols are also a potential source of nutrients. Remer reported on several challenges to completing this study, including the fact that methods used to measure atmospheric deposition were useful only on longer temporal scales (months to days) while the ocean response occurred temporally on the order of days. In addition, dust deposition often happens during rain, which implies cloud cover, which in turn reduces the ability to capture data. This study used a Goddard Earth Observing System (GEOS) model, which captures events but underestimates their magnitude. Responses measured include chlorophyll concentrations, phytoplankton carbon biomass, chlorophyll-to-carbon ratio response, and chlorophyll fluorescence quantum yield—all from MODIS/Aqua. Remer noted that fluorescence will be lost if VIIRS is used for continuity, as VIIRS does not capture that. She also pointed out that it is important to realize that "nutrition" is not just from iron ingestion; other nutrients, e.g., phosphorus, should be considered. Furthermore, this phenomenon needs to be looked at globally not just regionally. Also, Remer said that it is important to note that dust events are relative to background conditions—and that a small amount of dust can sometimes result in a large chlorophyll response change. Not only that, but the responses vary, e.g., increased biomass in one case or changing physiological properties in another. Finally, she said that atmospheric nutrients are a part of the ocean system and may respond differently to climate change. While the study has made headway in understanding atmospheric nutrient deposition, there is still much more to learn.

Plenary 2 Discussion

Topics covered in this discussion included the data reprocessing schedule for ocean color and dust products; the causes of phytoplankton response in the ocean; the identification of primary global aerosol sources; and the impact of the absence of a fluorescence band on VIIRS. Reprocessing the collection is typically triggered by algorithm advancements and is expected to coincide with the **Plankton, Aerosol, Cloud, ocean Ecosystem** (PACE) mission, scheduled for launch in 2024. Subsequent discussion clarified that ocean color response doesn't necessarily mean increased phytoplankton abundance due to nutrients, but rather differences in dynamic responses related to chlorophyll-to-carbon ratio. There was also conversation about primary aerosolized dust sources, which include the Sahara Desert and Arabian Peninsula. Another topic that came up was the absence of VIIRS fluorescence bands (which MODIS has), along with potential solutions, e.g., supplementing VIIRS data with S3 OLCI data and leveraging the upcoming PACE mission's fluorescence data gathering capabilities.

DAY 2—May 3, 2023

Session 3: MODIS/VIIRS Atmospheres Science and Data Analysis

The Atmosphere discipline leads for both VIIRS [**Bob Holz**, University of Wisconsin–Madison UWM)] and MODIS [**Steve Platnick**] moderated this session on the morning of the second day, which included two panel discussions and a plenary presentation.

Panel 6: Science Analysis

This panel comprised five, 15-minute science presentations divided among three research focus areas: Aerosols, Clouds, and Aerosols–Cloud Interface. A few cross-cutting themes emerged from these studies, e.g., the use of both emerging data processing techniques and multiple combined datasets, to better characterize more complex atmospheric processes.

Aerosols

Jing Wei [UMD] presented work performed with **Zhanquing Li** [UMD] that applied novel machine-learning approaches to a diverse set of atmospheric datasets—including MODIS Aerosol Optical Depth (AOD)—to reconstruct more detailed, higher-resolution particulate matter distributions with products for fine particulate matter (or aerosols) with diameters less than 2.5 µm ($PM_{2.5}$) for China and regions of the continental U.S. **Eric Wilcox** [Desert Research Institute (DRI)] then presented a summary of studies using temperature and aerosol data from both the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua satellite and MODIS on both Terra and Aqua to better differentiate the light-absorbing aerosols that cause warming from other aerosol types across both ocean and land regions like Africa and India, as well as at different levels in the vertical atmospheric column.

Clouds

Catherine Naud [NASA's Goddard Institute for Space Science (GISS)/Columbia University] presented results from an evaluation of multiple datasets and physical variables that drive other, more complex atmospheric processes to determine which had the largest impact by latitude on cloud development over different oceanic regions. Her group's findings suggest that different processes drive cloud development in subtropical regions versus extratropical regions—which highlights the challenge of accounting for these process differences in single-metric model parameterization and results in potential cloud disparities.

Aerosol–Clouds Interface

Further highlighting the complex interactions between both aerosols and clouds, **Sally Benson** presented her work with **Jay Mace** [both from University of Utah] on nonprecipitating low cloud formation over the Southern Ocean using the MODIS Level 2 Cloud Product. Using five summers of data, the team found a latitudinal band of the brightest clouds located south of 60°S latitude, a pattern related to proximity and time spent over land versus oceans, as well as the natural seasonal biogenic aerosol cycle that occurs in this region.

Tianle Yuan [UMBC] described how her team used MODIS/Aqua data to develop algorithms that automatically detect and analyze the indirect cloud forcing impacts from ship track emissions. The study found that changes in pixel cloud fraction (CF) accounted for the strongest indirect aerosol forcings. However, CF also changed based on background droplet size and cloud precipitation frequency, which makes it difficult to pin down the precise source of uncertainty in the calculations of the impact of CF on low-cloud total indirect forcing.

Plenary 3: Atmosphere SIPS/LAADS Data Access

Liam Gumley [UWM] provided an update on the **NASA Atmospheric Science Investigator-led Processing System** (ASIPS), which is responsible for the processing, reprocessing, production, and general assessments of the VIIRS/Suomi NPP Atmosphere Products. He gave updates about ASIPS personnel, services, and products. Gumley then briefly highlighted several online tools for data visualization and fusion, and analysis of a variety of data types and processing levels. He discussed some specific tools, e.g., the L3 Interactive Analysis workflow for science teams, which allows users to work closer to the data (i.e., virtually) in the cloud—without downloading entire dataset files—to generate exploratory data fusions in space and time quickly.

Panel 7: Continuity Products: Status, Challenges, Future Directions

Several themes stood out in all four of the presentations in this session, including details about future data reprocessing and the ongoing development of algorithms that incorporate additional satellite platforms and sensors.

Christina Hsu [GSFC] discussed the Deep Blue aerosol product (AERDB), highlighting the new V2.0 release for VIIRS/Suomi NPP and VIIRS/NOAA-20. This product is available in the LAADS DAAC and the **EarthData** website. Two highlights of the new release are improved accuracy of measured aerosol optical depth in regions with high elevations and brighter surfaces, as well as the development of a cross-calibration algorithm to support consistent aerosol records across low-Earth-orbiting (LEO) and geostationary orbiting (GEO) platforms for future MODIS Collection 7 reprocessing.

Rob Levy [GSFC] shared updates on the Dark Target Aerosol Product (AERDT), now available for VIIRS data in the LAADS DAAC, and highlighted the team's overall goal to incorporate as many sensors from as many different platform types as possible—while maintaining consistency in the MODIS/VIIRS long-term aerosol record—see **Figure 4** on page 23. As a result, the new Level 2 Dark Target package is *platform independent*—meaning it can be used for data from both

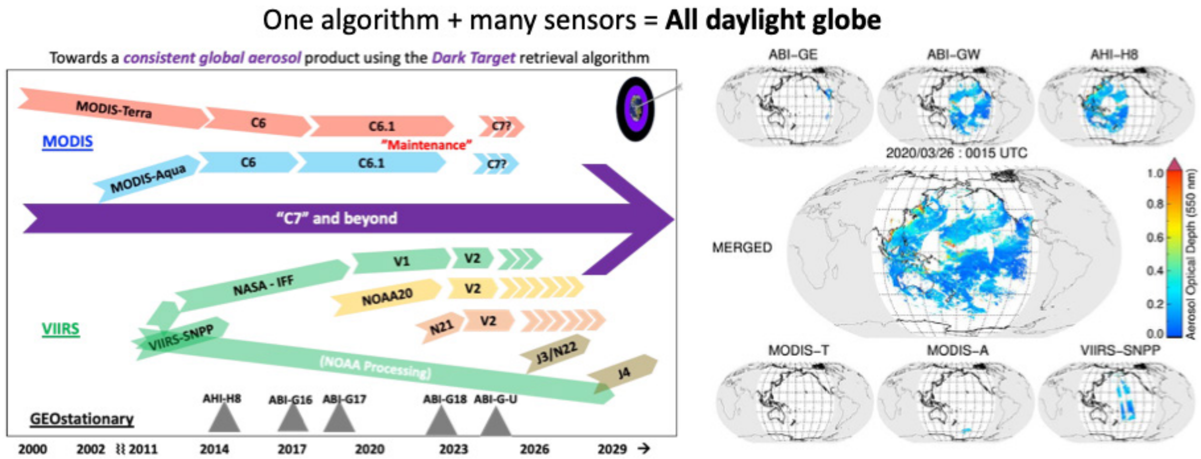


Figure 4. Overview of the Dark Target Aerosol Product (AERDT), including the datasets incorporated into this product [*right*] and an image of AOD from merged datasets for March 26, 2020 [*left*]. **Figure credit:** Rob Levy

MODIS and VIIRS, as well as from LEO and GEO satellites. However, Levy cautioned that some future challenges remain pertaining to calibration standardization and program support.

Kerry Meyer [GSFC] discussed VIIRS/MODIS cloud products, stressing the difficulty in applying the original MODIS algorithm to VIIRS data due to instrument band-detection differences, which led to developing multiple cloud mask continuity products. After providing the website link for **all known issues related to cloud continuity products**, Meyer presented an update on data continuity efforts by combining afternoon MODIS and VIIRS datasets, provided details on the new Version 2 Science updates, and elaborated on the team's ongoing development of algorithms that leverage multiple sensors and platforms to create additional cloud science continuity with these missions.

Éva Borbás [UWM/Space Science and Engineering Center] wrapped up the panel presentations with an overview of the recently released Version 2 VIIRS–**Cross-track Infrared Sounder** (CrIS)[11] Fusion product (FSNRAD), available via the LAADS DAAC. Unlike MODIS, VIIRS does not capture several infrared absorption bands associated with carbon monoxide and water vapor. However, data from these MODIS bands are important for generating accurate night and high-latitude cloud and moisture products. In response to this data need, the new VIIRS–CrIS product extends continuity of these bands using data from both VIIRS and CrIS on the Suomi NPP platform to derive the MODIS-equivalent, fusion-based radiances for VIIRS. Borbás presented examples of comparisons and accuracy testing, along with a guide to accessing and using the data for different science studies and applications.

Panel 7 Discussion

The discussion focused on the challenges of funding and time constraints in developing algorithms for various platforms and instruments. The **Making Earth Science Data Records for Use in Research Environments** (MEaSUREs) Program has been an important funding source for these efforts; however, artificial barriers like contracting issues and program priorities hinder efficient utilization of existing infrastructure for processing data from geostationary platforms. Panelists stressed the importance of engaging NASA HQ program managers to provide guidance for generating new data products, establishing a repository for these new datasets, and sharing these datasets publicly in an accessible format. There was also dialogue about integration of Low Earth Orbit (LEO) and Geostationary Orbit (GEO) products, which highlighted the need for international collaboration. Discussion participants advocated for additional funding and support in developing open-source algorithms and data; however, they raised concerns about the time and effort needed to evaluate user-developed products, especially considering recent mission funding reductions. Participants also emphasized that institutional and industry partnerships have historically played key roles in successful NASA programs (e.g., EOS) and for achieving future long-term goals. Another key point that came up in discussion was that data stewardship is critical for developing long-term continuity between MODIS and VIIRS datasets.

[11] Like VIIRS, CrIS flies on Suomi NPP and the JPSS satellites. Similar to the relationship between MODIS and VIIRS explored in this article, CrIS is the JPSS "successor" to the EOS sounder suite on Aqua, which consists of the Atmospheric Infrared Sounder (AIRS), Advanced Microwave Sounding Unit (AMSU), and the defunct Humidity Sounder for Brazil (HSB). For a recent historical perspective and update on the activities of these missions, see **A Celebration of 20 Years of AIRS History and Observations** in the September–October 2022 issue of *The Earth Observer* [**Volume 34**, **Issue 5**, pp. 4–11].

Session 4: MODIS/VIIRS Land Science and Data Analysis

Chris Justice [UMD—MODIS *Land Discipline Lead*] was moderator for this session, which took place during the afternoon of the second day, and included two more panel discussions and a plenary presentation.

Panel 8: New Land Science Products in Development

Jun Wang [University of Iowa] gave an overview of the **Fire Light Detection Algorithm–Version 2** (FILDA-2), which uses **Black Marble** data along with VIIRS visible and radiative properties of detected fires to estimate combustion efficiency and thus differentiate burning versus smoldering areas within wildfire footprints.

Huilin Gao [Texas A&M University] shifted the focus from fire to water, presenting information on the **MODIS/VIIRS Global Water Reservoir** (GWR) Product, created to monitor the status of global water resources in an automated, open-science format, with products incorporating VIIRS scheduled for release later in 2023.

Volker Radeloff [UWM] discussed the **Dynamic Habitat Indices** product—a biodiversity habitat product that incorporates MODIS and VIIRS data to differentiate the impacts of available energy, environmental stress, and environmental variability in explaining the species richness, globally.

Karl Ritter [University of Colorado Boulder] presented information about an experimental product that characterizes snow properties like snow cover, albedo, and radiative forcing and included information about the NSIDC's new interactive **Snow Today** website tool for easy product access and analysis.

Panel 8 Discussion

The discussion raised questions from the participants about product readiness. It also identified a need to characterize the users of these products, foster new potential research collaborations, and discuss the advantage of open science to support data continuity, e.g., via documentation of product-specific users' needs, including information about the strengths and limitations of each.

Panel 9: MODIS/VIIRS Interdisciplinary Science

Dorothy Hall [UMD] presented her team's work using MODIS Environmental Science Data Records (ESDR) to study complexities of terminal lake desiccation in the Western U.S., e.g., studying trends in surface temperature, snow cover, water quality, and evapotranspiration. She also highlighted new MODIS and VIIRS data products developed to characterize visible differences in water content from chlorophyll, suspended material, and organic matter, using the Black Marble product and other urban-growth datasets.

Srija Chakraborty [NASA/Universities Space Research Association (USRA)] described her team's efforts to study global electricity infrastructure and evaluate future energy needs using learning techniques.

Luigi Boschetti [University of Idaho] presented work evaluating trends in global burned area using harmonized MODIS and VIIRS fire products.

Mark Friedl [Boston University] described his team's work to model global growing season changes and the impact these changes have on carbon flux seasonally, using 22 years of MODIS data in conjunction with other ecosystem information.

Panel 9 Discussion

This discussion included questions about how NASA can balance goals of data continuity with doing process-driven science, the restrictions that shorter record lengths create for the process of evaluating changes in climate, and the importance of standardizing datasets for future harmonization.

Plenary 4: MODIS/VIIRS Land: A Retrospective and Prospective View

Chris Justice closed Day 2 with a historical overview of MODIS land applications, describing the design and development of the instrument. This included detection bands, the instrument's science objectives and initial leadership, and the original plans for data processing and storage with considerably less-than-modern technology. He discussed several other details about MODIS planning, e.g., the original intent for all data to be publicly available from the time of its collection, the complexities of meeting the requests of multiple science disciplines for specific absorption bands, and the original plan for MODIS data processing and product development.

Following the launch of Terra in 1999 the team made adjustments due to known biases and issues, worked on calibrating and validating data, and developed new ways to collaborate scientifically and disseminate information more quickly through the MODIS Rapid Response Project, and—eventually—the NRT LANCE capability. Moving into the more recent era, the MODIS land team has shifted focus towards platform end-of-life data processing and management, as well as data record continuity via synthesis with VIIRS and other instruments.

DAY 3—May 4, 2023

Session 5: End-User Perspectives and Closing Plenary

Miguel Román opened the final half-day of the meeting with a discussion about the challenges that will arise if the proposed budgetary cuts are implemented—and in particular, the earlier timeline for retirement of the Terra, Aqua, and Aura platforms. As a result of these announced timeline changes, Román referred to an article published in ***Science Advances*** to highlight the novel remote sensing research that could be done with such a diverse set of drifting instruments; however, he stressed the need for a large community of invested experts working together to reach this goal. Román also highlighted the need for additional collaboration with NOAA partners to support the complex processes of monitoring, validating, and producing products related to MODIS and VIIRS, without sacrificing specific important non-negotiable actions, e.g., product quality control and a PI-driven science processing element. He explained that while there is already some support for these activities across a wide range of NASA programs, the processes could move faster if there was even more support. Román also discussed the critical role of data continuity in the ongoing push for open science, as well as NASA's new Earth Action Strategy. Lastly, he stressed the role that MODIS/VIIRS continues to play in pressing social issues our nation faces and the need for continued science advocacy and federal stakeholder buy-in.

Panel 10: MODIS/VIIRS End-User Perspectives

Miguel Román introduced this panel, which explored end-user experiences. Panelists included representatives from several different agencies' activities in this area and the tools that ingest data from MODIS and VIIRS.

Everett Hinkley and **Brad Quayle** [both from U.S. Forest Service (USFS)] gave an overview of the MODIS/VIIRS Operational Use Applications developed by USFS and highlighted the USFS wildfire detection and forest health-monitoring tools that incorporate MODIS and VIIRS data along with other visualization and cloud computing techniques. They stressed the need for MODIS-like data continuity, including for the morning observations that Terra currently provides.

Ed Hyer [U.S. Naval Research Laboratory (NRL)] explained that the visibility weather forecasting group at NRL built their system using foundational input from MODIS data and lauded NASA's commitment to both establishing a long-term, accurate Earth system data record and efforts to make this data accessible and easy to incorporate into other applications.

Arlindo Da Silva [GSFC/Global Modeling and Assimilation Office (GMAO)] explained the myriad ways that the GMAO has implemented MODIS aerosol data, including via Dark Target and Deep Blue Aerosol products discussed previously at this meeting. He highlighted the ways in which GMAO continues to incorporate the new VIIRS versions of MODIS products, but also stressed the need for morning observations along with the long-term commitment to develop algorithm-based solutions to this temporal data gap.

Panel 10 Discussion

The discussion focused on funding challenges, near real-time data products, and a summary of the top programmatic and technical priorities to ensure data continuity moving forward. There was also a conversation about capacity building for future national and international collaborations, e.g., ways to receive inputs from these sources on furthering data continuity.

Closing Plenary

Miguel Román gave the closing presentation. He introduced a new framework on Recurrent Acute Disasters (RADs) based on the Human Ecosystem Model (HEM). He stressed the need to strategize new ways that MODIS and VIIRS data can actively help at-risk communities—which are disproportionately harmed by the legacy conditions of frequent, more intense, and expansive events—in a way that prioritizes critical resources while focusing on the flow of keystone elements, including information, capital, and people after these disasters.

As a case study, Román described how MODIS and VIIRS data empowered him to advocate for the needs of persons affected by a series of disasters in the U.S. Territory of Puerto Rico following the 2017 Hurricane season. In this study, NASA's Black Marble product allowed the Science Team to evaluate the actual electricity restoration progress versus what was officially reported. This revealed major discrepancies, especially for rural areas where the data showed an even slower restoration rate compared to adjacent urban areas—see **Figure 5** on page 26.

Further, the team generated Black Marble maps that showed the extent of damage and used the data to advocate for more aid.

Román wrapped up his presentation with a call for more research that both acknowledges the interconnectedness of RAD events and supports those individuals most harmed by these events through the novel use of NASA data, helping promote the agency's role as a catalyst for equity, transparency, and accountability.

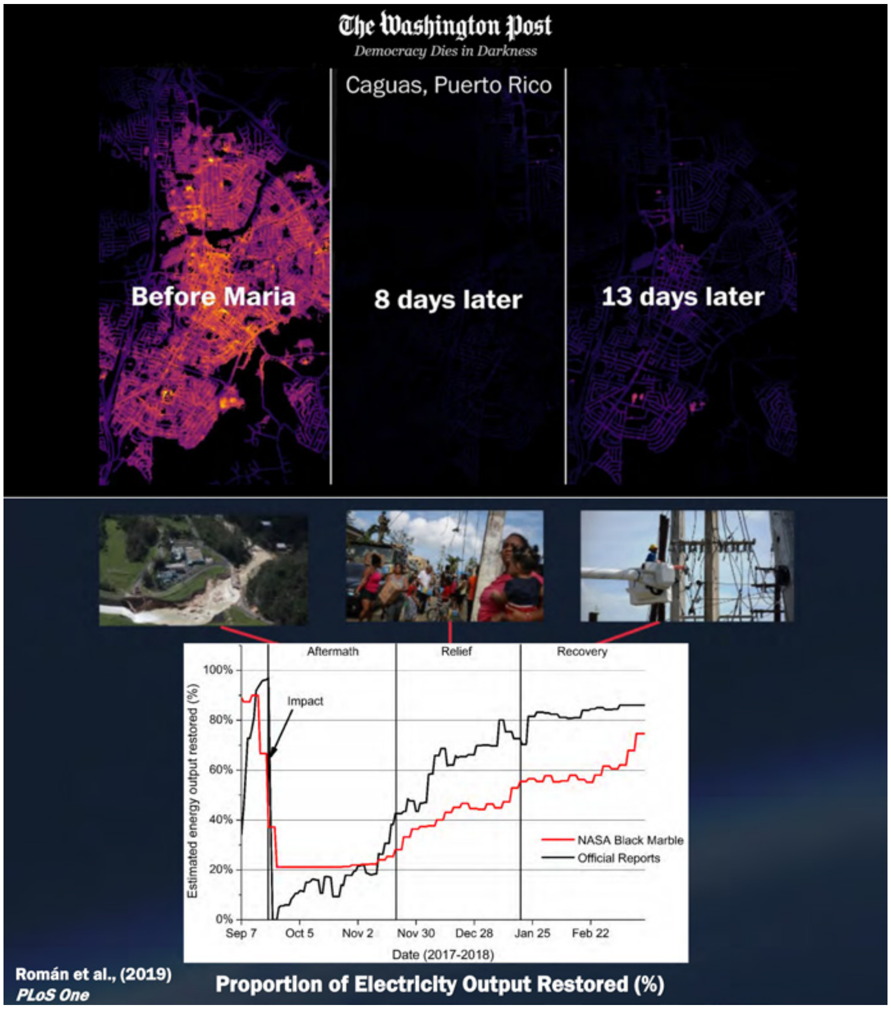


Figure 5. *Top*: NASA's "Black Marble" VIIRS imagery of light sources in Caguas, Puerto Rico, before [*left column*], eight days after [*middle column*], and 13 days after [*right column*] Hurricane Maria made landfall on September 20, 2017. *Bottom*: Graph showing the "official" percentage of restored electricity (black line) versus the much lower, actual data detected by NASA's Black Marble imagery (red line) over several months after Maria made landfall, broken into three event periods with corresponding images representing each: the storm aftermath, the relief phase, and the later recovery phase. The chart data show that when compared with the officially-reported electricity restoration (represented as the black line), the actual nightlight data detected by NASA's Black Marble imagery (red line) indicates a much lower restoration percentage throughout all three designated periods. **Figure credit:** Miguel Román

Conclusion

The recent MODIS/VIIRS Science Team meeting was a significant milestone, potentially marking one of the final in-person events—due to budget constraints. This gathering provided a platform for robust discussions on various critical topics pertaining to the evolving Earth-observing satellite landscape.

Data stewardship emerged as a paramount concern, as participants recognized that meticulous care in the managing and transitioning of data is crucial for preserving the invaluable legacy of MODIS and ensuring its continuation and usefulness into the VIIRS era. As such, the team emphasized the need for increased investment in the future management and transition of these data, including support for the technical experts leading these tasks. This emphasis on data stewardship also reflects the community's expressed need for a seamless transition between EOS and JPSS instruments, ensuring that Earth science data remains consistent and reliable. Moreover, the upcoming AGU Fall Meeting in December 2023 promises to further underscore the significance of data continuity in the MODIS/VIIRS scientific community and will serve as an opportunity to expand on the discussions initiated during the Science Team meeting.

Another central meeting theme was the urgent need for greater NASA HQ funding of data algorithm development and refinement, as well as products that support the transition from MODIS to VIIRS. Such investment is crucial for maintaining the high quality of Earth science data that researchers have come to expect from these missions.

Lastly, participants noted the need to raise additional community and public awareness about the approaching wrap-up of the Terra and Aqua missions. With—at most—four years left before these missions are passivated, many researchers may not realize the need to transition to VIIRS data, or that when Terra concludes its mission, NASA will no longer have a similar morning daily polar-orbiting imagery source, details that will both impact various data applications. Moving forward, there is an urgent need for MODIS data users to adapt and prepare for these impending changes in satellite data sources and to continue seeking additional solutions for the future data gaps caused by this transition. ■

NASA's TROPICS Offers Multiple Views of Intensifying Hurricanes

Kathryn Hansen, NASA's Earth Observatory, kathryn.h.hansen@nasa.gov

EDITOR'S NOTE: This article is taken from a *nasa.gov* news release and is based on an original **NASA Earth Observatory story**. While this material contains essentially the same content as the original release, it has been rearranged and edited for the context of *The Earth Observer*.

NASA's newest storm-watching satellites have collected their first views of hurricanes, offering scientists a new tool for understanding the inner workings of storms over shorter time spans.

Data from the **Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats** (TROPICS) mission will help weather researchers learn more about the environmental factors contributing to hurricane structure and intensity. Such information could prove useful for NOAA, the U.S. Joint Typhoon Warning Center, and international agencies responsible for developing hurricane, typhoon, and cyclone forecasts.

In late June 2023, the TROPICS mission acquired data for images of the first named storms of the Eastern Pacific hurricane season. Hurricane Adrian developed near the west coast of Mexico but steered away from land. The animation—see **Figure**—and stills—shown on the **front cover** of this issue—show the evolution of the storm's clouds from the morning of June 28, 2023 to the afternoon of June 29, 2023. (The images shown were curated from nearly two dozen taken by the satellites in that time.) Nearby, Beatriz was developing into a tropical storm, visible in these images as the less-organized clouds closer to the coast.

"As communities throughout the world are experiencing the growing impacts of increased extreme weather, it's never been more important to get timely data to those who need it most to save livelihoods and lives," said **NASA Administrator Bill Nelson**. "TROPICS will deliver vital information for forecasters, helping us all better prepare for hurricanes and tropical storms."

TROPICS is a constellation of four identical CubeSats designed to observe tropical cyclones. The cost-effective,

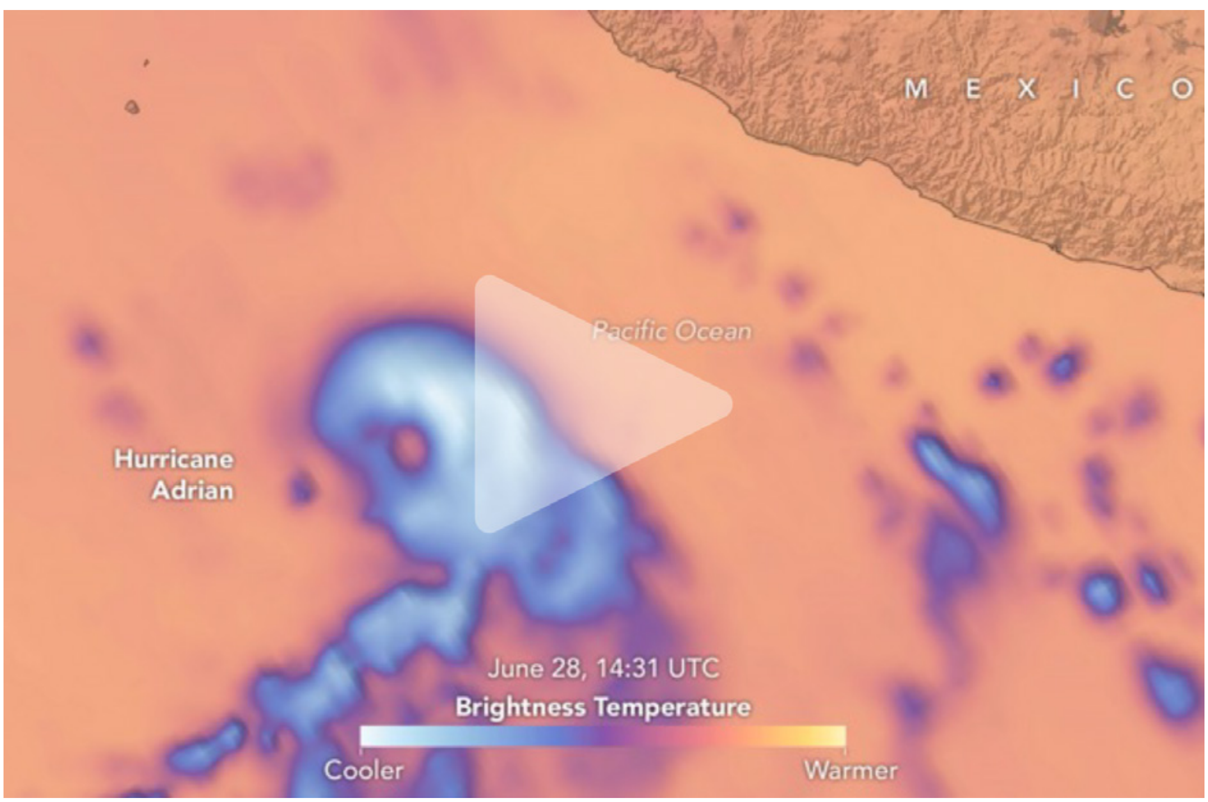


Figure. This animation shows the evolution of Hurricane Adrian between 8:31 AM local time on June 28, 2023, and 4:18 PM local time on June 29, 2023. Data for the animation were acquired by the TROPICS mission, NASA's newest constellation of storm-watching satellites. **Figure credit:** NASA Earth Observatory images by Lauren Dauphin, using data provided by the TROPICS team milk carton-sized satellites were launched in May 2023 by Rocket Lab. Each TROPICS CubeSat contains a microwave radiometer that collects data across 12 channels to detect temperatures, moisture, and precipitation around and within a storm.

The images in the animation were built from data collected by a single channel (205 GHz) that is sensitive to ice in the clouds. Each scene shows the *brightness temperature*—the intensity of radiation detectable at that channel frequency moving upward from the cloud layers and toward the satellites.

Cold brightness temperatures (*blue*) represent radiation that has been scattered by ice particles in the storm clouds. The colder the temperature, the more ice there is likely to be in a column of the atmosphere. Ice in the clouds is an indication of intense movement of heat and moisture (convection) in a storm, noted **Will McCarty** [NASA Headquarters (HQ)—*TROPICS Program Scientist* and *Program Manager for Weather and Atmospheric Dynamics*].

Scott Braun [NASA's Goddard Space Flight Center (GSFC)—*Research Meteorologist* and *TROPICS Project Scientist*] explained that patterns observed in the brightness temperature data can indicate the location of rain bands, the intensity of convection, whether the storm has formed an eye, and how those structures are changing over time. All are important to understanding how storms will evolve.

"Structural changes in brightness temperature can help tell us whether a storm is intensifying or weakening," said **Patrick Duran** [NASA's Marshall Space Flight Center (MSFC)—*TROPICS Deputy Program Applications Lead*]. These structural changes are less apparent in **natural-color images**, which primarily show the tops of clouds. Some features, such as the eye, often show up in microwave images before they are detected by infrared sensors on other satellites.

Similar microwave measurements can be made with other satellites, such as the Global Precipitation Measurement (GPM) mission. TROPICS, however, has a time advantage. Whereas the orbits of most science satellites only permit observations of a storm every 6 to 12 hours, the low-Earth orbit and multiple satellites of TROPICS can allow storm imaging about once an hour. That's a big advantage when trying to understand a rapidly evolving storm.

"The high-revisit observations from TROPICS show detailed structure in the inner eye and rain bands of tropical cyclones," said **William Blackwell** [Massachusetts Institute of Technology (MIT) Lincoln Laboratory—*TROPICS Principal Investigator*]. "Rapidly updated data provided by TROPICS uniquely show the dynamic evolution of the storm structure and environmental conditions." ■

Earth Science Meeting and Workshop Calendar

NASA Community

September 12–13, 2023
ROSES SAGE III/ISS Science Team Meeting
Atlanta, GA

September 18–22, 2023
PMM Science Team Meeting
Minneapolis, MN

October 16–18, 2023
DSCOVR Science Team Meeting
NASA/GSFC, Greenbelt, MD

October 17–19, 2023
CERES Science Team Meeting
NASA/GISS, New York, NY

November 7–11, 2023
OST Science Team Meeting
San Juan, Puerto Rico

Global Science Community

October 11–15, 2023
Historically Black Colleges and Universities (HBCU) Climate Change Conference
New Orleans, LA

October 15–18, 2023
Geological Society of America (GSA)
Pittsburgh, PA

October 23–27, 2023
World Climate Research Programme (WCRP) Open Science Conference (OSC) 2023
Kigali, Rwanda

November 30–December 12, 2023
United Nations Framework Convention on Climate Change Conference of the Parties 28 (UNFCCC COP28)
Dubai, United Arab Emirates

December 11–15, 2023
American Geophysical Union (AGU) Fall Meeting
San Francisco, CA

Powerful NASA-ISRO Earth Observing Satellite Coming Together in India

Jane J. Lee, NASA/Jet Propulsion Laboratory (JPL), jane.j.lee@jpl.nasa.gov
Andrew Wang, NASA/JPL, andrew.wang@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*.

Two major components of the **NASA–ISRO Synthetic Aperture Radar** (NISAR) satellite have been combined to create a single spacecraft in Bengaluru, India. Set to launch in early 2024, NISAR is a joint effort between NASA and the Indian Space Research Organisation (ISRO) that will track movements of Earth's land and ice surfaces in extremely fine detail. As the satellite monitors nearly every part of our planet at least once every 12 days, NISAR will also help scientists understand, among other observables, the dynamics of forests, wetlands, and agricultural lands.

About the size of a sport utility vehicle and partially wrapped in gold-colored thermal blanketing—see **Photo 1** below—the satellite's cylindrical radar instrument payload contains two radar systems. The S-band radar is particularly useful for monitoring crop structure and the roughness of land and ice surfaces, while the L-band instrument can penetrate denser forest canopies to study the woody trunks of trees, among other observables. The wavelengths of the S-band and L-band signals are about 4 in (10 cm) and 10 in (25 cm), respectively, and both sensors can see through clouds and collect data day and night.

The payload took a roundabout journey to get to this point. The S-band radar was built at the Space Applications Centre in Ahmedabad in western India, then flown in March 2021 to NASA/Jet Propulsion Laboratory (JPL), where engineers had been developing NISAR's L-band radar. Once at JPL, the two systems were fixed to the payload's barrel-like frame before being flown to the U R Rao Satellite Centre (URSC) in the southern Indian city of Bengaluru in March 2023.

In the meantime, engineers and technicians at URSC, collaborating with teams from JPL, were busy developing the spacecraft's main body, or *bus*, which is covered in blue blanketing that protects it during assembly and testing prior to launch. The bus—see **Photo 2** on page 30—which includes components and systems

Photo 1. Engineers joined the two main components of NISAR—the spacecraft bus and the radar instrument payload—in an ISRO clean room in Bengaluru, India, in June. The payload arrived from NASA's Jet Propulsion Laboratory in Southern California in March, while the bus was built at the ISRO facility. **Photo credit:** VDOS-URSC

Photo 2. In June, engineers used a crane to align NISAR's radar instrument payload—seen partially wrapped in gold-colored thermal blanketing—with the satellite's spacecraft bus, which is inside the blue blanketing. **Photo credit:** VDOS-URSC

developed by both ISRO and JPL, will provide power, navigation, pointing control, and communications for the mission.

Since the radar payload and bus were joined in a URSC clean room in mid-June, NASA and ISRO teams have been working together to route thousands of feet of cabling between them. Still to be attached: the satellite's solar panels, as well as the drum-shaped, wire-mesh reflector that will unfold from the end of a 30-ft (9-m) boom. At nearly 40-ft (12-m) in diameter, the reflector will be largest radar antenna of its kind ever launched into space.

The NISAR satellite is currently undergoing performance testing, to be followed by several rounds of environmental testing to ensure it can withstand the rigors of launch and meet all of its operational requirements once in orbit. Then it will be transported about 220 miles (350 km) eastward to Satish Dhawan Space Centre, where it will be inserted into its launch fairing, mounted atop ISRO's Geosynchronous Satellite Launch Vehicle Mark II rocket, and sent into low Earth orbit. ■

NASA Wants to Identify Phytoplankton Species from Space. Here's Why.

Erica McNamee, NASA's Goddard Space Flight Center (GSFC), erica.s.mcnamee@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*.

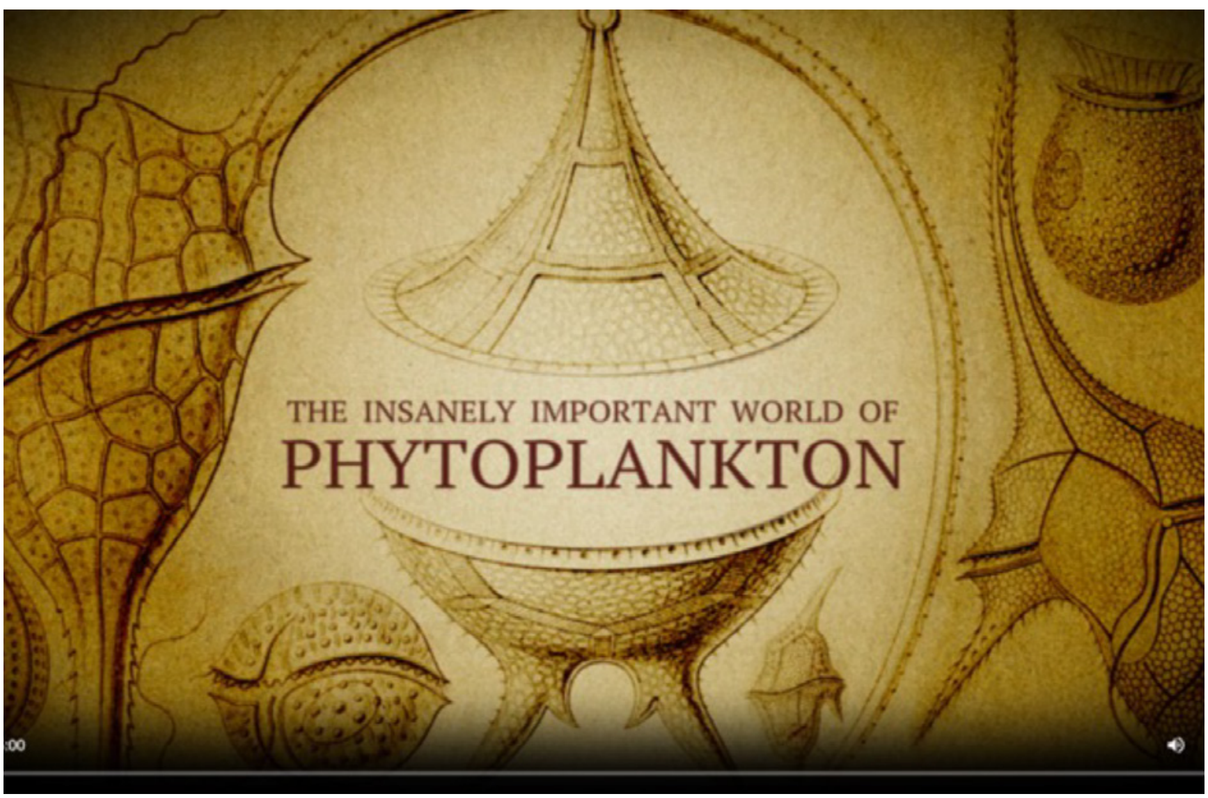
They're small, but they're mighty. From producing oxygen we breathe and soaking up carbon we emit, to feeding fish we eat, tiny phytoplankton are a crucial part of ocean ecosystems and essential to life as we know it on Earth. To give us a new view of these extraordinary aquatic organisms, NASA is launching a satellite in early 2024.

Instruments on the **Plankton, Aerosol, Cloud, and ocean Ecosystem** (PACE) satellite will peer down at the ocean and collect data on the colors of light reflecting off it, telling us where different types of phytoplankton are thriving. The Ocean Color Instrument (OCI) will be able to observe more than 100 different wavelengths and is the first scientific satellite to do so daily on a global scale. This "hyperspectral" instrument will make it possible to identify phytoplankton by species for the first time from space—see **Video**.

Phytoplankton and Photosynthesis

Phytoplankton are tiny organisms that float on the surface of the ocean and other water bodies. Like land-based plants, phytoplankton use photosynthesis to absorb sunlight and carbon dioxide (CO_2) and generate oxygen (O_2) and carbohydrates, which are carbon-filled sugars. These sugars make phytoplankton the center of the ocean food web: They nourish larger animals—from zooplankton to shellfish to finfish—that are then eaten by even larger fish and marine mammals. The creation of those sugars from sunlight is called *primary production*.

Even though phytoplankton make up less than 1% of the total biomass on Earth that can photosynthesize—they deliver about 45% of global primary production. Without phytoplankton, most oceanic food webs would collapse, which would be devastating for both marine life and humans who rely on fish for food.



Video. Ivona Cetinić [NASA's Goddard Space Flight Center (GSFC)—*Science Lead for Ocean Biogeochemistry for PACE*] describes the weird, wonderful, and important world of phytoplankton and why it's important for the PACE mission to study these tiny creatures. **Video credit:** NASA/GSFC/Scientific Visualization Studio

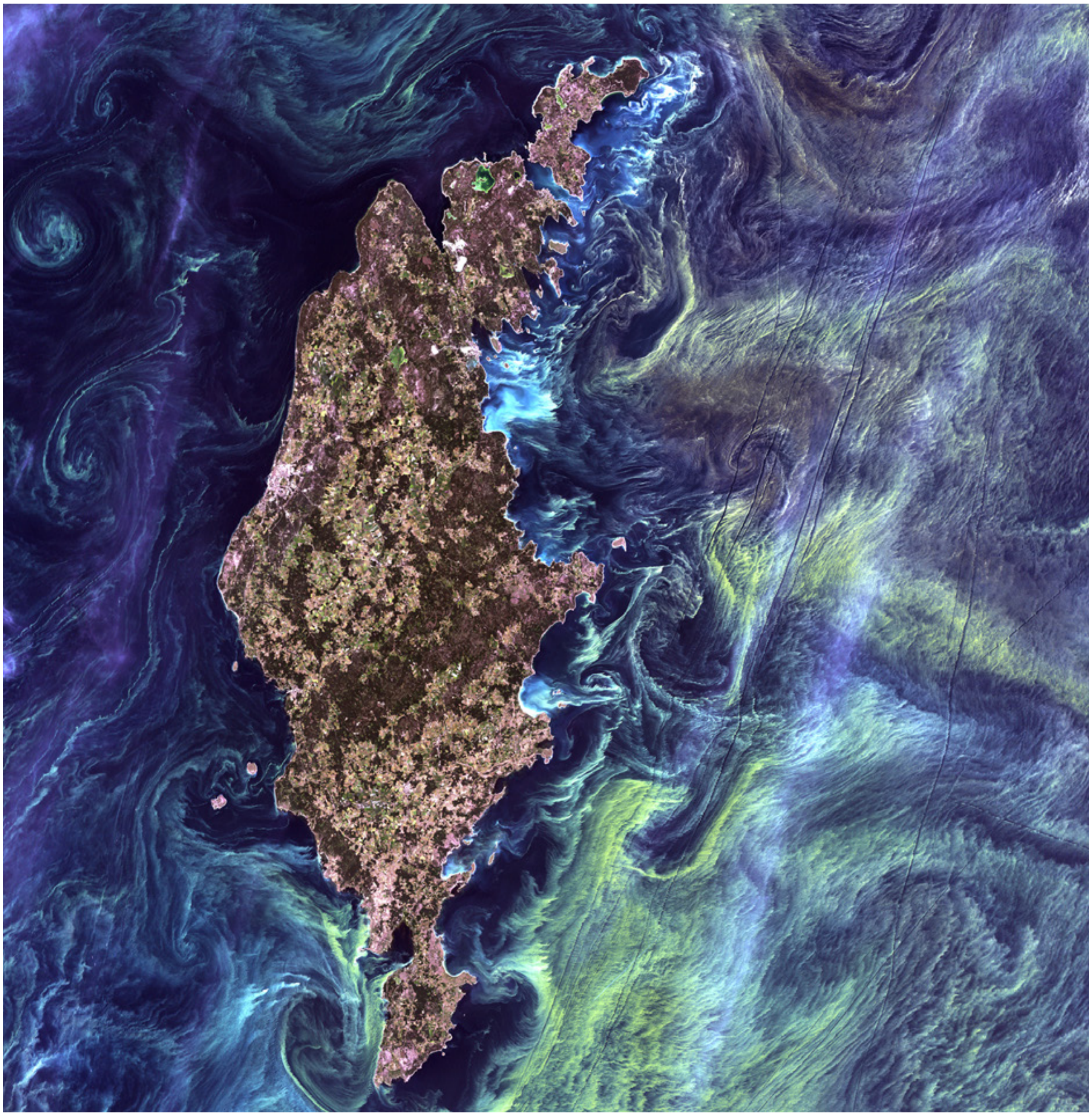


Figure. This Landsat 7 image was captured on July 13, 2005, and shows green blooms of phytoplankton swirling in the dark water around Gotland, a Swedish island in the Baltic Sea. Phytoplankton are microscopic marine plants that form the first link in nearly all ocean food chains. Population explosions, or blooms, of phytoplankton, like the one shown here, occur when deep currents bring nutrients up to sunlit surface waters, fueling the growth and reproduction of these tiny plants. **Figure credit:** United States Geological Survey (USGS) and NASA/Landsat 7

The tiny organisms provide more than just nutrients. Through photosynthesis, phytoplankton create O_2, which is released into the ocean and atmosphere. In fact, since they began photosynthesizing over three billion years ago—more than two billion years before land plants and trees—phytoplankton have made about 50% of all the O_2 that has been produced on Earth.

Photosynthesis gives them a key role in the global carbon cycle as well, as they soak up CO_2 from the atmosphere. What phytoplankton do with that carbon depends on the species.

"Like plants on land, phytoplankton are highly diverse," said **Ivona Cetinić** [NASA's Goddard Space Flight Center (GSFC) *Ocean Ecology Lab—Biological Oceanographer*]. "Each of these diverse species has different characteristics that allow them to take on different jobs in Earth's carbon systems."

Phytoplankton like *Emiliana huxleyi* incorporate carbon into their shell-like outer coating. When they die, the shells sink and sequester the carbon in the ocean depths. Other phytoplankton species fit a certain niche for picky eaters like oysters, which only eat phytoplankton of a certain size. Still other species of phytoplankton may capture carbon through photosynthesis, where it then remains on the ocean surface until the organisms decompose, releasing the carbon back into the atmosphere as carbon dioxide.

"I hope that PACE, once it gives us a view of ocean phytoplankton diversity, can tell us so much more about global carbon flow in oceans, now and in the future," Cetinić said.

Phytoplankton in the Cold

Even in colder waters at higher latitudes, phytoplankton are crucial to ocean life. In polar regions, *phytoplankton blooms*—when the organisms grow and multiply in vast numbers visible from space—can follow the cycle of sea ice melt—see **Figure** on page 32.

When sea ice cover recedes, sunlight can reach the surface of the ocean and the phytoplankton that float on it, allowing them to photosynthesize and thrive after a long period of being covered. This produces fuel for other species. Polar species from clams and krill all the way up to walruses and whales rely on these timely blooms for their food sources.

"Without phytoplankton, we may not be able to breathe or eat sushi," said **Aimee Neeley** [GSFC—*Biological Oceanographer*]. "An alteration of the timing of the blooms impacts the entire ecosystem."

As the timing and extent of sea ice retreat changes in a warming climate, PACE will be able to track changes to the timing of blooms, providing insights into the wider impacts to the ecosystem.

Identifying Harmful Phytoplankton

Not all phytoplankton are beneficial for ecosystems. Some species can produce toxins that are dangerous for humans or other marine species. These harmful algal blooms can disrupt ecosystems as well as daily life for people near coasts, lakes, and rivers. Blooms of cyanobacteria, for example, can spoil drinking water and recreational water use with the toxins they generate.

Scientists have been using some satellite data to track and monitor these blooms and the conditions that cause them. PACE should make it easier to decipher these species and conditions, allowing people to develop ways to mitigate the impacts and prevent future blooms.

"Not all phytoplankton create harmful algal blooms, so if we can use the satellite data to better separate harmful from non-harmful blooms, that would be helpful for water managers and scientists that are trying to understand phytoplankton communities in a region," said **Bridget Seegers** [GSFC—*Oceanographer*].

PACE will not be the first satellite to let us see phytoplankton from space. It is a successor to missions like **Terra**, **Aqua**, the **Landsat series**, and the **Sea-viewing Wide Field-of-view Sensor** (SeaWiFS, which flew on Orbview-2), which have gathered data on phytoplankton since the 1990s. PACE, which is being assembled at and managed by engineers at GSFC, will significantly expand our ability to distinguish and track phytoplankton every day, all over the planet.

"Hopefully, the hyperspectral nature of the Ocean Color Instrument will allow us to better tease apart the phytoplankton types from each other and from non-phytoplankton particles," Neeley said. "To me, the opportunities for research will be endless." ■

NASA Earth Science in the News

Doug Bennett, NASA's Goddard Space Flight Center, doug.bennett@nasa.gov
Jenny Marder-Fadoul, NASA's Goddard Space Flight Center, Earth Science News Team, jennifer.m.fadoul@nasa.gov

EDITOR'S NOTE: Presented in this column are summaries of articles that have been published on *nasa.gov* that have subsequently been reported on by other media outlets.

Global Collaboration Leads to New Discoveries in Lightning Research, August 16, 2023, *rockymount-telegram.com*.[1] An international group of researchers completed a month of flights to study lightning and the vast energy fields around thunderclouds in our atmosphere. These new observations will help scientists gain further insight into how lightning forms and to improve predictions of when storms could turn severe. The **Airborne Lightning Observatory for Fly's Eye GLM Simulator (FEGS) and Terrestrial gamma-ray flashes** [ALOFT][2] field campaign logged approximately 60 hours of flight time across Central America and the Caribbean. The team used the NASA Armstrong Flight Research Center (AFRC) **ER-2** aircraft—see **Figure 1**—to fly near thunderclouds as tall as 18 km (10 mi) in altitude to measure gamma-ray glows and flashes produced by the thunderclouds' electric fields. The campaign included researchers and flight crews from the University of Bergen (Norway), the U.S. Naval Research Laboratory (NRL), and NASA's AFRC, Marshall Space Flight Center (MSFC), and Goddard Space Flight Center (GSFC).

Led by **Nikolai Ostgaard** [University of Bergen, Norway—*Principal Investigator*], the team was able to capture the most detailed airborne analysis of gamma-rays and thunderclouds ever recorded. The project used the University of Bergen-Bismuth-Germanium-Oxide (UIB-BGO) gamma-ray detector instruments, which collected and downloaded real-time data, allowing researchers to instruct the ER-2 pilot to return to a glowing thunder cell if it continued to glow. Teams from MSFC and GSFC also added instrumentation to the ER-2 aircraft to observe other radiation emitted

[1] The link to the story published on *rockymounttelegram.com* is no longer working. Please refer to the original **NASA news release** for more information.
[2] In the link in this sentence, GLM stands for Geostationary Lightning Mapper (GLM), which flies on the Geostationary Operational Environmental Satellite—Series R (GOES-16, -17, and -18) missions.

Figure 1. The joint team that worked on the ALOFT field campaign in front of NASA Armstrong's ER-2 aircraft following its safe return from a mission on July 24, 2023. **Photo credit:** NASA

at other wavelengths from thunderclouds. **Timothy Lang** [MSFC—*Project Scientist*] and **Mason Quick** [MSFC—*Deputy Project Scientist*], with support from the University of Alabama Huntsville and partners, flew FEGS—which has been substantially upgraded since it was last flown in 2017. "FEGS optical sensors capture different wavelengths, such as near infrared and ultraviolet radiation from lightning, that are not captured by current satellites," said Lang. "These smaller, less dense flashes are known as precursors of when storms are turning severe. FEGS could help scientists see when storms are strengthening and provide extra lead time of information to keep the public safe from the threat of lightning." ■

NASA Maps Key Heat Wave Differences in Southern California, August 22, 2023, *enn.com*. Southern California is no stranger to hot weather. However, the adage has been that "it's a dry heat"—meaning that humidity levels are relatively low—and thus the heat is more tolerable. More recently, though, Southern California has experienced increasing levels of humidity accompanying heat waves, which tests the adaptability of its residents. Heat waves are expected to become increasingly common in the future due to Earth's changing climate. In California, some of these heat waves will feel more like conditions more typical in Florida or eastern Texas—although the impacts won't be felt evenly by everyone in that area. To begin to understand what these changes could mean across the greater Los Angeles area, scientists at NASA/Jet Propulsion Laboratory (JPL) mapped how extreme heat and humidity patterns vary with regional geography. The results underscore how air temperature alone does not tell the full story of dangerous heat—see **Figure**. "We can't just look at air temperature when we talk about heat wave impacts," said study author **Anamika Shreevastava** [JPL—*Postdoctoral Fellow*]. "People tend to get acclimatized to where they live. We have to understand how anomalous conditions are making a difference in what people are used to." ■

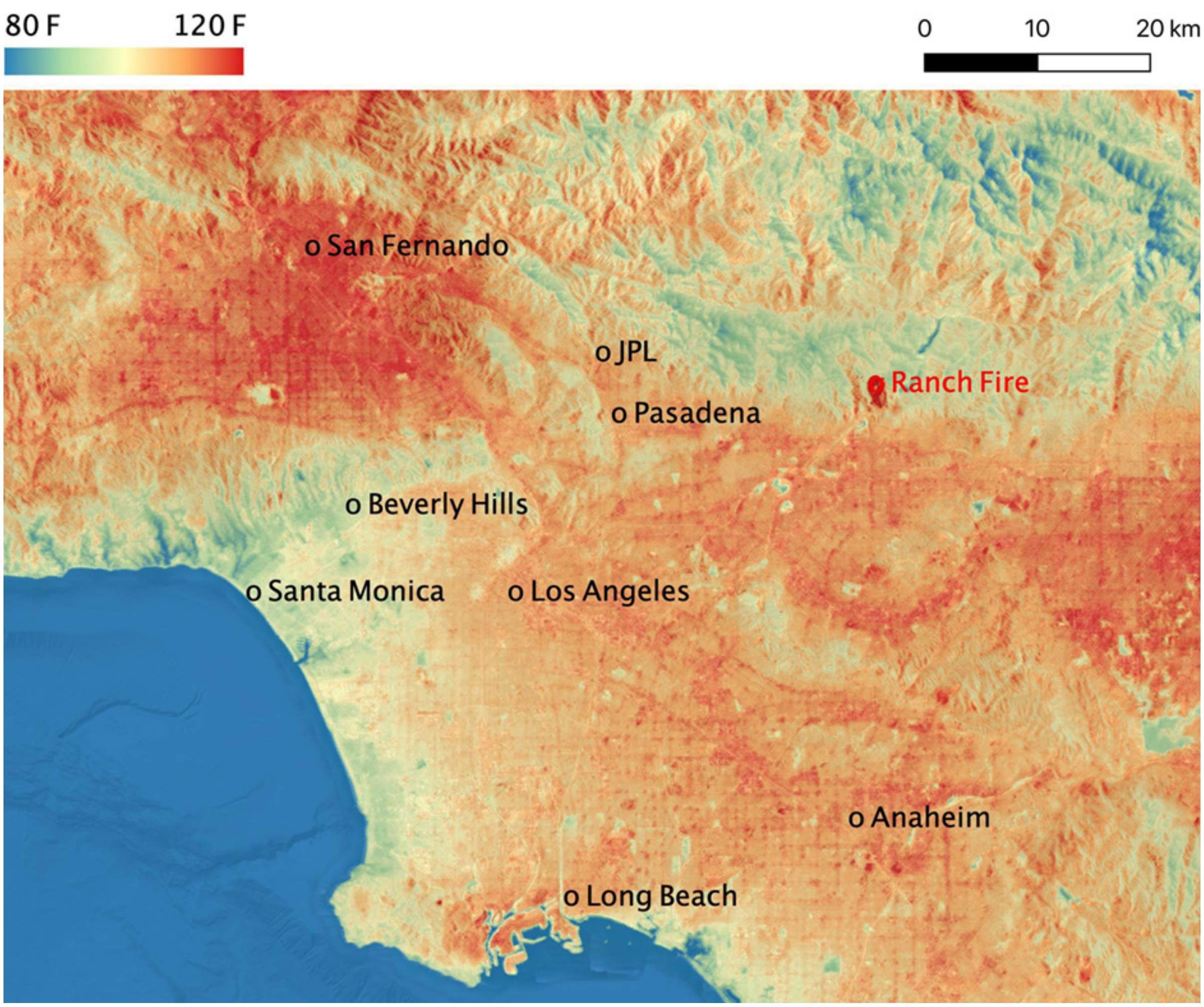


Figure. Made using NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) mission, this map shows *land-surface temperatures*—or how hot the land is to the touch— in much of Los Angeles County on August 14, 2020. Peak land-surface temperature in the San Fernando Valley hit 128.3 °F (53.5 °C), while coastal areas stayed cooler. **Figure credit:** JPL

Photo 2. A drone image captures a grateful message scrawled in a vineyard in the Lodi, CA, region by growers who collaborated with NASA's Jet Propulsion Laboratory on research to detect a crop-destroying virus. **Photo credit:** Aaron Lange/Lodi Winegrape Commission

NASA Technology Can Spot Wine Grape Disease from the Sky. The World's Food Supply Could Benefit, September 5, 2023, *latimes.com*. Cutting-edge NASA imaging technology can detect early signs of a plant virus that, if unaddressed, often proves devastating for wineries and grape growers, **new research** has found. While the breakthrough is good news for the wine and grape industry, which loses billions of dollars a year to the crop-ruining disease, it could eventually help global agriculture as a whole. Using intricate infrared images captured by airplane over California's Central Valley, researchers were able to distinguish Cabernet Sauvignon grape vines that were infected by a disease called *grapevine leafroll-associated virus complex 3* (GLRaV-3)—but not showing symptoms—before the point at which growers can spot the disease and respond. The technology, coupled with machine learning and on-the-ground analysis, successfully identified infected plants with almost 90% accuracy in some cases. "This is the first time we've ever shown the ability to do viral disease detection on the airborne scale," said **Katie Gold** [Cornell University—*Assistant Professor*], a lead researcher on the project. "The next step is scaling to space." As NASA's Jet Propulsion Laboratory works on sending its airborne imaging instrument—a spectrometer known as the **Airborne Visible/InfraRed Imaging Spectrometer—Next Generation** (AVIRIS-NG)—into space, the research team is hopeful more routine aerial images and data from the launched machine could be used to more widely monitor crops, which grape growers appreciate—see **Photo 2**. "The ultimate vision is to be able to do this from space—and not just for grapes and not just this one disease and not just a few places in California, but to be able to do this for farmers all over the world, for many different crops and many different diseases and pests," said **Ryan Pavlick** [JPL—*Research Technologist*], who worked on the project. ■

Code 610
National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

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, MD 20771. PDFs of previous issues (from March–April 1997 to the present) are available 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. Also indicate if the meeting is *hybrid* (combining online and in person participation) or *virtual* (online only). Newsletter content is due on the weekday closest to the fifteenth of the month preceding the publication—e.g., December 15 for the January–February issue; February 15 for March–April, and so on.

Please be certain to register your email address using the QR code below to receive notifications when new issues are published online.

The Earth Observer Staff

Scan code to register to receive *The Earth Observer* and access the online archive.