

The Earth Observer

November – December 2022. Volume 34, Issue 6

The Editor's Corner

Steve Platnick

EOS Senior Project Scientist

On December 16, 2022, at 3:46 AM Pacific Standard Time, the Surface Water and Ocean Topography (SWOT) satellite launched atop a SpaceX Falcon 9 rocket from Space Launch Complex 4E at Vandenberg Space Force Base in California—see photo on page XX of this issue.

After SWOT separated from the second stage of the launch vehicle, ground controllers successfully acquired the satellite's signal. The solar panel arrays that power the spacecraft began unfurling shortly thereafter. SWOT's primary instrument is the Ka_a-band Radar Interferometer (KaRIn) instrument, which is designed to capture precise measurements of the height of water in Earth's freshwater bodies and the ocean. KaRIn will see eddies, currents, and other ocean features larger than 20 km across. It will also collect data on lakes and reservoirs larger than 62,500 m² (2 ha) and rivers wider than 100 m across. Cameras aboard SWOT captured the unfurling of the large mast and the KaRIn antenna panels, which are located at both ends of the mast, 10 m apart from each other, over a four-day period ending December 22. A video of that process can be seen at go.nasa.gov/40W9gZF.

SWOT is now undergoing a series of checks and calibrations as engineers prepare the mission to begin collecting science data—expected to begin about six months after launch. SWOT will measure the height of water on over 90% of Earth's surface, providing a first of its kind, high-definition survey of our planet's surface water.

continued on page 2

After nearly 34 years as a NASA print publication

The Earth Observer is Going Green



Continue your subscription today!

Use the QR code, or subscribe online: eosps0.gsfc.nasa.gov/earth-observer-archive

See the box on page 35 to learn more.

In This Issue

Editor's Corner

Front Cover

Feature Articles

NASA Participates in Pecora 22 Symposium and Celebrates Landsat 50 th Anniversary	4
NASA Travels to Egypt for COP27 Climate Change Conference	10

Meeting Summaries

Summary of the Eighth DSCOVER EPIC and NISTAR Science Team Meeting	14
Summary of the Fifty-First U.S.–Japan ASTER Science Team Meeting	21

In the News

Phytoplankton May Be Abundant Under Antarctic Sea Ice, Study Suggests	25
NASA Satellite Precipitation Data Joins the Air Force	28
NASA to Cancel GeoCarb Mission, Expands Greenhouse Gas Portfolio	30

Also Included in this Issue

NASA Earth Science in the News	31
Earth Science Meeting and Workshop Calendar	34

Announcements

<i>The Earth Observer</i> is Going Green	35
--	----

SWOT is the latest mission in a more than three-decade collaboration between NASA and CNES on ocean altimetry missions that began in 1992 with TOPEX–Poseidon. The collaboration has been maintained continuously with the Jason series of missions, and now will continue with SWOT. Given the urgent—potentially existential—challenges posed to human society by climate change and sea level rise, researchers are excited for the science data from SWOT to begin flowing.¹ Congratulations to the entire SWOT team on the successful launch.

We turn now to updates on the Earth Observing System (EOS) Flagship missions. Over the past two decades, these three missions—Terra (launched in late 1999), Aqua (2002), Aura (2004)—have provided continuous, global observations of a wide range of geophysical parameters, thus providing long term data records that have become vital for documenting and understanding Earth system processes and climate change. While their record of accomplishments is evident, all three mission have long exceeded their planned six-year missions, and discussions have been underway within the NASA Earth Science Division (ESD) on the inevitable end of these missions.

All three Flagships have sufficient fuel and power to operate for at least a couple more years. However, to ensure adequate fuel for collision avoidance and perigee lowering maneuvers, all three missions have now ceased making *inclination adjustment maneuvers* required to maintain the platforms in tightly controlled equatorial Mean Local Time (MLT) polar orbits.

¹ The SWOT mission, and the SWOT Science Team, were topics of discussion in “The Editor’s Corner” of the September–October 2022 issue of *The Earth Observer* [Volume 34, Issue 5, pp. 2–3]. To learn more about SWOT visit, swot.jpl.nasa.gov.

The most recent (2020) Senior Review for NASA’s Earth science extended missions discussed the continued value of the Flagships, while also recommending further study on the consequences of orbital drift for Terra and Aqua.² In September 2022, NASA issued a Request for Information (RFI) for a *Terra, Aqua, and Aura Drifting Orbits Workshop* to gather community input on science and applications that will be uniquely enabled by observations made during the period of orbital drift.³ Community responses discussed observations that continue to be unique during orbital drift as well as observations that become unique because of the drift (e.g., diurnal sampling). RFI responses, due in October, provided input for the virtual workshop that took place November 1–2, 2022, which presented an opportunity for the Flagship user communities to gather and participate in discussions about the opportunities—as well as the challenges—presented by the drifting orbits of these missions. The workshop was well attended (there were 546 unique participants over the two days—not including workshop and instrument leads who convened at GSFC), with engaged discussions during the plenary presentations and breakout sessions.

² The 2020 Senior Review can be viewed and downloaded from go.nasa.gov/3YxcPnt.

³ The RFI and workshop were organized and led by **Lucia Tsaoussi** [NASA HQ, Earth Science Division—*Deputy Associate Director for Research*], **Kurt Thome** [GSFC—*Terra Project Scientist*], **Claire Parkinson** [GSFC—*Former Aqua Project Scientist, now Scientist Emeritus*], **Lazaros Oreopoulos** [GSFC—*current Aqua Project Scientist*], **Bryan Duncan** [GSFC—*Aura Project Scientist*], and **Steve Platnick** [GSFC—*EOS Senior Project Scientist*], with assistance from the deputy project scientists and instrument team leads. The RFI and related documents can be found through nspires.nasaprs.com (search on Drifting Orbits).



Photo. A SpaceX Falcon 9 rocket launches with the Surface Water and Ocean Topography (SWOT) spacecraft onboard, December 16, 2022, from Space Launch Complex 4E at Vandenberg Space Force Base in California. SWOT is the first satellite mission that will observe nearly all water on Earth's surface, measuring the height of water in the planet's lakes, rivers, reservoirs, and oceans.

Photo credit: Keegan Barber/NASA

Based on a workshop report submitted to NASA ESD by the workshop and instrument leads (listed in footnote 3) all three Flagships have been invited to participate in this spring's Earth Science Division Senior Review—albeit with significantly reduced budget guidelines.

On a related note, on October 12 and 19, 2022, NASA's Earth Science Mission Operations (ESMO) executed maneuvers that lowered the orbit of Terra by 5.5 km. A community virtual forum took place on December 8, 2022 to inform users about this change and the potential impact on science. The *Terra Lower Orbit Virtual Community Forum* was an opportunity to follow up on the discussions that began at the *Terra, Aqua, and Aura Drifting Orbits Workshop* and delve deeper into specific details of relevance to the Terra user community on the impact of the orbit lowering. The forum was well-attended, with 120+ registered participants and 100+ attendees throughout the entire three-hour forum.

The Earth Observer plans a more detailed summary of these two EOS-related workshops in a future issue.

There are also updates from two other long-lasting Earth science missions: CloudSat and CALIPSO. These "sister" missions launched on the same vehicle in 2006

continued on page 13

List of Undefined Acronyms Used in Editor's Corner and/or Table of Contents

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CALIPSO	Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations
CIRA	CSU's Cooperative Institute for Research in the Atmosphere
COP	Conference of the Parties
CSU	Colorado State University
DSCOVR	Deep Space Climate Observatory
EPIC	Earth Polychromatic Imaging Camera
GSFC	NASA's Goddard Space Flight Center
NISTAR	National Institute of Standards and Technology Advanced Radiometer
ROSES	Research Opportunities in Space and Earth Sciences

NASA Participates in Pecora 22 Symposium and Celebrates Landsat 50th Anniversary

Doug Bennett, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., doug.bennett@nasa.gov

Ginger Butcher, NASA's Goddard Space Flight Center/Science Systems and Applications, Inc., ginger.butcher-1@nasa.gov

Steve Graham, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., steven.m.graham-1@nasa.gov

Jim Irons, NASA's Goddard Space Flight Center [Retired, Emeritus], james.r.irons@nasa.gov

Laura Rocchio, NASA's Goddard Space Flight Center/Science Systems and Applications, Inc., laura.e.rocchio@nasa.gov

The Pecora 22 conference featured a range of remote sensing experts and scientists from federal agencies, nongovernmental organizations, universities, and industry.

Introduction

NASA celebrated 50 years of the NASA–United States Geological Survey (USGS) Landsat program by participating in the 2022 Pecora Memorial Remote Sensing Symposium (Pecora 22 Conference), held October 23–28, 2022, at the Hilton Denver City Center Hotel in Denver, CO. Pecora 22 is the latest in a series of symposia named after William T. Pecora, the USGS Director who helped initiate the Landsat program in the 1960s. The Pecora Symposium series was established by the USGS and NASA in the 1970s as a forum to foster the exchange of scientific information and results derived from applications of Earth observing data to a broad range of land-based resources, and to discuss ideas, policies, and strategies concerning land remote sensing.

NASA's Science Support Office (SSO) staff organized and supported the NASA exhibit and Hyperwall at Pecora 22.¹ The conference featured a range of remote sensing experts and scientists from federal agencies, nongovernmental organizations, universities, and industry. Attendance for the meeting was approximately 1000, as attendees welcomed the return to an in-person conference where they could interact and converse without using virtual meeting applications. This article summarizes some of the highlights from the Pecora 22 Conference, including a special panel session devoted to the *Ladies of Landsat* and a gala celebration in recognition of the fiftieth anniversary of the Landsat program—see *Landsat 50th Anniversary Gala* on page 9.

Program Highlights

The symposium kicked off on October 24, with five major workshops on climate observations that covered a range of topics, including remote sensing of water quality, the future of international Earth observations collaboration, using NASA Earth observations for climate change monitoring and impacts assessment, and demystifying synthetic aperture radar (SAR) for climate resilience and sustainable future initiatives.

The next four days of the symposium featured eight moderated technical sessions covering all aspects of land observing technology and science. Technical sessions were split into multiple sub-sessions with each containing between four and seven presentations on a range of topics, including advancing radiometric/geometric calibration, improving food security through crop yield forecasting, remote sensing of open water surface dynamics and quality, advancing vicarious calibration, advancing geospatial data science through data access and computing, preparing the next generation of remote sensing scientists, and much more. For more details about the Pecora 22 program, please refer to the full PDF program file, which can be found at pecora22.org/program.

¹ NASA's Hyperwall is a 10-screen high-resolution videowall used for sharing NASA science data visualizations and is often the centerpiece of NASA exhibits at conferences and meetings around the world.

A special panel session devoted to the “Ladies of Landsat” took place on October 25. “Ladies of Landsat” is a Twitter-based community that started officially in 2018 and is led by a group of women hoping to make the field of Earth observation (EO) more equitable and inclusive for underrepresented scientists. The group has now grown to over 8000 members who work to broaden the mission of EO fields by amplifying the representation of women and other underrepresented scientists in EO science. They are also leading top-down calls for action from leaders in power and allies who have the capacity to change the status quo when it comes to diversity, equity, justice, inclusion, and accessibility (DEJIA) in remote sensing activities.

Serving as moderators for the *Ladies of Landsat* panel session were the cofounders of the “Ladies of Landsat,” **Kate Fickas** [USGS] and **Morgan Crowley** [Natural Resources Canada]. Panelists included **Catherine Nakalembe** [University of Maryland, College Park, NASA Harvest], **Kass Green** [Kass Green & Associates], **Meghan Halabisky** [University of Washington, Digital Earth Africa], **Africa Flores-Anderson** [University of Alabama in Huntsville; McGill University; SERVIR],² **Keiko Nomura** [Climate Engine], and **Raha Hakimdavar** [Ball Aerospace].

In the past, barriers to mentorship, data accessibility, education, outreach, and collaboration limited the use of remote sensing data and EO activities by women and other underrepresented scientists. With time, these barriers continue to be removed with free and open cyberinfrastructure, open science, and accessible communication. Of importance is that with this progress there is an increase in representation among those using the data, thereby enabling women of all ages—and girls in particular—to see that people from all backgrounds, careers, and fields can be part of a broader EO community. *Ladies of Landsat*—women from different backgrounds, career stages, sectors, and geographic locations—discussed how EO data has helped address challenges, lower barriers, and open career opportunities for underrepresented groups around the world.

Barbara Ryan [World Geospatial Industry Council—*Executive Director* and 2018 *Pecora Award winner*] served as moderator for a featured session on “Advancing the State of the Art in the Next 50 Years” on the afternoon of October 25. The session drew upon the perspectives of international EO leaders. Their presentations and the accompanying question and answer session set the stage for widening the aperture of innovation and expanding the benefits of EO to all societies worldwide. The session was informed by participants from the October 24 workshop on international collaboration, which considered key programmatic and technical topics for enhanced land-imaging collaboration.

The **Landsat Education and Public Outreach (EPO)** team—shown in **Photo 1** (on page 6) along with five former Landsat Project Scientists—supported the conference’s accompanying science, technology, engineering, art, and mathematics (STEAM) event for local students on October 25. The STEAM event was organized by AmericaView and funded by USGS. Other partners included NASA, the National Oceanic and Atmospheric Administration (NOAA), and Bentley Systems—a provider of infrastructure software with a strong education and outreach component to their mission, and a contributor to the symposium. Approximately 85 middle and high school students from the American Indian Academy of Denver and the Compass Academy attended the STEAM event, which provided opportunities for students to learn about Earth observation and remote sensing through interactive, hands-on exhibits.

² SERVIR is not an acronym. The program’s name is derived from the Spanish word meaning “to serve.” A joint initiative of NASA, the United States Agency for International Development (USAID), and leading geospatial organizations in Asia, Africa, and Latin America, SERVIR partners with countries and organizations in these regions to address critical challenges in climate change, food security, water and related disasters, land use, and air quality. Using satellite data and geospatial technology, SERVIR codevelops innovative solutions through a network of regional hubs to improve resilience and sustainable resource management at local, national, and regional scales.

Ladies of Landsat—women from different backgrounds, career stages, sectors, and geographic locations—discussed how EO data has helped address challenges, lower barriers, and open career opportunities for underrepresented groups around the world.

On October 26, **Jim Irons** [GSFC, Earth Sciences Division (ESD)—Former *Landsat 8 Project Scientist*, now *Scientist Emeritus*] led a plenary session titled “A Half-Century of Discovery: The Scientific Discoveries and Technical Innovations Enabled by Pecora’s Vision.” The 90-minute panel discussion featured Pecora Award winners (Landsat pioneers) who discussed “what we know now because of Landsat” via short presentations on major impacts and discoveries over Landsat’s 50-year history. The session included a Question and Answer period with the audience, which elicited many Landsat memories and testimonials. Panelists included **Kass Green**, **Barbara Ryan**, **Darrel Williams** [GSFC—Former *Landsat 7 Project Scientist*; currently *Chief Scientist* at *Global Science & Technology, Inc.*], **Curtis Woodcock** [Boston University—*Landsat Team Leader/Coleader* since 2006], and **Vince Salomonson** [GSFC, ESD—Former *Landsat 4 and 5 Project Scientist*, now *Scientist Emeritus*; currently *Research Professor, University of Utah*]. The Plenary Session was dedicated to the memory of **Tom Loveland**, the former Chief Scientist of the USGS’s Earth Resources Observation and Science (EROS) Center. Tom was a Program Chair for Pecora 22 and had intended to be one of the panel members. Sadly, however, he passed away in May before the Conference occurred. The Plenary Session concluded with a moving memorial from **Tim Newman** [USGS] who acknowledged Tom and several other prominent members of the EO community who passed away in recent years.

Also on October 26, **Ginger Butcher** [GSFC/Science Systems and Applications, Inc. (SSAI)] moderated a Technical Session on “Education & Outreach—Preparing the

Photo 1. Five current and former Landsat Project Scientists with the Landsat Education and Public Outreach (EPO) team. Pictured here are [left to right]: **Mike Taylor** [GSFC/SSAI], **Vince Salomonson**, **Darrel Williams**, **Laura Rocchio** [GSFC/SSAI], **Jim Irons**, **Ginger Butcher**, **Chris Neigh** [GSFC—*Landsat 8 Project Scientist* and *Landsat 9 Project Scientist*], **Allison Nussbaum** [GSFC/SSAI], and **Bruce Cook** [GSFC—*Landsat Next Project Scientist*]. **Photo credit:** NASA



Next Generation of Remote Sensing Scientists” and gave a presentation on NASA’s contribution to Landsat education and public outreach since the 1970s.

During the plenary sessions there were numerous inquiries about the status of Landsat Next,³ including when the public would learn more details about the mission. Landsat Next—a joint mission of NASA and the USGS—is expected to look very different from its predecessors that have been observing Earth for 50 years.⁴ With a trio of smaller satellites that can each detect 26 wavelengths of light and thermal energy, Landsat Next is designed to provide more frequent, and finer resolution, data of the changing surface of Earth.

³ For more information about Landsat Next, please see “Next up to Continue NASA/USGS’s Landsat Legacy” published December 20, 2022, at landsat.gsfc.nasa.gov/article/next-up-to-continue-nasa-usgs-landsat-legacy.

⁴ For an in-depth article about Landsat 9, including an archive of Landsat articles from *The Earth Observer* over the years, please see “The Legacy Continues: Landsat 9 Moves Landsat Toward a Golden Milestone” in the July–August 2021 issue of *The Earth Observer* [Volume 33, Issue 4, pp. 4–12—go.nasa.gov/3YniSLc].

NASA Exhibit Overview

NASA's exhibit encompassed a 20' x 30' floor space that prominently featured the Hyperwall, as well as tables where attendees engaged face-to-face to learn about NASA Earth Science. Tables in the exhibit area highlighted NASA's Landsat program, Applied Sciences initiatives, and Earth System Data. NASA and USGS staff and university partners delivered 14 presentations on NASA's Hyperwall over the three days of the conference, including **Karen St. Germain** [HQ—*Director of Earth Science Division*] on “NASA's Role in Understanding Climate Change” and **Lawrence Friedl** [NASA Headquarters—*Applied Sciences Program Director*] on “Earth Science in Action.” In addition, **Kate Fickas** conducted a “Ladies of Landsat” interview with **Barbara Ryan** regarding her instrumental role in pushing through Landsat's free and open-access data policy in 2008—see **Photo 2**.

Laura Rocchio [GSFC/SSAI] gave a Hyperwall presentation on “Five Fascinating Facts from a Half-Century of Landsat” which featured some of the stories uncovered while writing the *Landsat's Enduring Legacy* book—a seminal work on 50 years of



Photo 2. Kate Fickas [left] interviews Barbara Ryan [right] in front of NASA's Hyperwall. Photo credit: NASA

monitoring Earth's lands with Landsat. The presentation focused on the authoring team's work to find and conduct interviews with **Virginia Norwood**—“the mother of Landsat”; the unexpected success of the Multispectral Scanner System (MSS); the story of the first MSS image; the challenge of building a global archive before the existence of solid-state recorders; and the massive technological challenges behind the “next-generation” Landsat 4 and 5 satellite builds. The presentation was well attended, and audience members included three past and two present Landsat project scientists (shown in Photo 1), as well as **Lawrence Friedl**, **Kate Fickas**, and **Barbara Ryan**. In celebration of the Landsat program's fiftieth anniversary, the entire 586-page *Landsat's Enduring Legacy* book is available for free download.⁵

Steve Graham [GSFC/GST, Inc.] and **Heather Hanson** [GSFC/GST, Inc.] managed the NASA exhibit at Pecora 22. Graham served as operator and docent of the Hyperwall, while Hanson distributed a range of relevant publications and outreach materials and engaged with conference attendees. The complete Hyperwall schedule can be found at go.nasa.gov/3HOe1fb.

⁵ Download a free digital copy of the *Landsat's Enduring Legacy* book at my.asprs.org/landsat.

Awards and Recognition

The recognition of 2020 and 2021 Pecora Award recipients was delayed by the COVID pandemic, so they were recognized along with the 2022 Award recipients on the afternoon of October 26. One highlight from the three-year award period was that the Landsat 5 Flight Operations Team received the 2020 Pecora Group Award. Landsat 5 had already been honored by the Guinness Book of World Records as the “Longest Operating Earth Observation Satellite.” **Karen St. Germain** presented the 2020 Pecora Group Award to **Steve Covington** [GSFC/The Aerospace Corporation—*Systems Director*]—see **Photo 3**—stating that “The Landsat 5 Flight Operations Team is recognized for its engineering excellence and problem-solving ingenuity, which enabled long-term, continued Earth observations that significantly advanced the Landsat program and has greatly benefited humankind.”

Photo 3. Karen St. Germain presented the 2020 Pecora Group Award on October 26, 2022, to the Landsat 5 Flight Operations team. **Steve Covington** accepted the award on behalf of the team. **Photo credit:** Public Domain



The citation read by St. Germain recognized some of Landsat 5’s most noteworthy results—e.g., being the first satellite to detail the extent of tropical deforestation and to image the Chernobyl nuclear accident. In his remarks, Covington recognized the team who designed, built, launched, and operated the satellite, and the significance of Landsat 5. “The amazing thing that really makes it an interesting and important award for those of us on the team is the importance that Landsat 5 really was to the world. ...Of just a little over 10 million scenes in the Landsat archive, almost 4 million of them come from Landsat 5. Consider that. We’re on Landsat 9 right now—yet 40% of the images in the archive come from Landsat 5 alone.”⁶

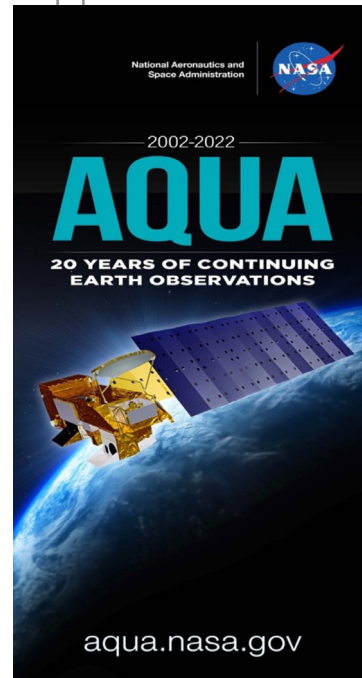
Other recipients of Pecora Awards bestowed during Pecora 22 included **Kass Green**—2020 Individual Award; **Frank Muller-Karger**—2021 Individual Award; **AmericaView**—2021 Team Award; the **Aqua Mission Team**—2022 Team Award (see **Kudos** on page 9); and **Susan Ustin**—2022 Individual Award. For more information regarding the 2020–2022 Pecora Award recipients, please see usgs.gov/news/featured-story/pecora-awards-honor-excellence-earth-observation.

⁶ The photo and citation quote for the 2020 Pecora Group Award were excerpted from usgs.gov/centers/eros/news/landsat-5-flight-operations-team-wins-pecora-award.

KUDOS

Aqua Mission Team Receives Pecora 2022 Group Award

The Aqua Mission Team was honored for its significant contributions to scientific studies of the Earth over twenty years and related applications of Aqua's satellite observations. **Claire Parkinson** [NASA's GSFC—then *Aqua Project Scientist*, now *Scientist Emeritus*] traveled to Denver to receive the Pecora 2022 Group Award on behalf of the Aqua Mission Team. Since its launch over two decades ago, the Aqua mission has delivered observations essential to improving our understanding of global dynamics and processes occurring on land and in the cryosphere, oceans, and atmosphere. The Aqua mission has addressed topics of national priority, including weather forecasting, homeland security, and natural resource management. The astonishing performance of the Aqua satellite is attributed to the well-designed and -operated Aqua mission, as well as the collective efforts of the instrument and science teams. Aqua is one of the most highly successful Earth observing satellites ever to have orbited our planet. The mission's free and open data policy has enabled a variety of application areas that generate societal value and support decision makers. As the Aqua satellite celebrates its twentieth year in space, its contributions continue to advance our knowledge of Earth's systems for the benefit of humanity.

**Landsat 50th Anniversary Gala**

A gala event to celebrate the fiftieth anniversary of the Landsat Program took place the evening of Wednesday, October 26. The event, held in the ballroom of the Pecora 22 conference hotel—Hilton City Center, in Denver—was subsidized by generous contributions from private industry.

Karen St. Germain and **Tanya Trujillo** [Department of the Interior—*Assistant Secretary for Water and Science*] gave brief remarks, as did representatives from the three Platinum sponsors of the conference—**Sarah Lipsy** [Ball Aerospace, Civil Space New Business—*Deputy Director*], **Rebecca Moore** [Google—*Director, Google Earth Engine*], and **Keith Kingston** [General Dynamics, Space Ground Solutions—*Director*]. Most of the evening was devoted to connecting with those present to celebrate the fiftieth anniversary of the Landsat program and build upon the Pecora 22 themes “to open the aperture to innovation and expand our collective understanding of a changing Earth.” The gala was successful, with attendance estimated at 200–250.

**Conclusion**

The Pecora 22 symposium was a tremendous success and comprehensively covered 50 years of Landsat's remarkable and enduring legacy through five major workshops, eight packed technical sessions, a *Ladies of Landsat* panel session, retrospective and forward-looking plenary sessions, award presentations, interview panels, a STEAM event for local students, and a gala celebration. In addition to the robust program already summarized in this article, other significant Landsat milestones highlighted during Pecora 22 included making the Landsat data archive open in terms of data use, information access, and economic benefit; the positive influence Landsat's open policy had on the European Space Agency's (ESA) decision to make data from its Copernicus Sentinel-2 mission open access; and the birth of Google Earth Engine as a direct result of the opening of the Landsat archive. All in all, Pecora 22 illustrated clearly how foundational Landsat has been—and continues to be—for Earth observation from space. ■

NASA Travels to Egypt for COP27 Climate Change Conference

Doug Bennett, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., doug.bennett@nasa.gov
 Tylar Greene, NASA Headquarters, tylar.j.greene@nasa.gov

The NASA Hyperwall was a main attraction at the U.S. Center.

Egypt hosted the 27th United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP27) in the resort town of Sharm El-Sheikh, from November 6–20, 2022. This annual conference brings the nations of the world together to address responses to climate change by negotiating formal commitments and forging agreements to limit greenhouse gas emissions. Each year the U.S. Department of State (DoS) sends a large delegation of negotiators to the COP meetings, along with a smaller team of outreach and communications staff to run the U.S. Center—a pavilion/exhibit where topical panel discussions and other presentations take place throughout the meeting to communicate U.S. positions outside the formal negotiation sessions.

NASA's Earth Science Division collaborated again with DoS to support the U.S. Center.¹ The NASA *Hyperwall*—the 10-screen video wall shown behind the presenters in **Photo 1** and **Photo 2**, both on page 11—was a main attraction at the U.S. Center. DoS representatives displayed visuals for their panel discussions and NASA Earth scientists presented two presentations per day on the Hyperwall, showing how NASA's global leadership in climate science and research helps model and predict ocean health, hurricanes, floods, heat waves, droughts, and wildfires.

All U.S. Center events were live-streamed and recorded on the U.S. Center at COP27 homepage,² and the U.S. Center *YouTube* channel.³ Events were organized around daily themes that included climate implementation, finance, science, youth and future generations, decarbonization, adaptation and agriculture, gender, water, Action for Climate Empowerment (ACE)⁴ and civil society, energy, biodiversity, and solutions.

In addition to NASA's Hyperwall, the U.S. Center featured an immersive virtual reality (VR) and augmented reality (AR) experience aimed at inspiring people to respect, protect, and restore our planet's biodiversity, and also included *Climate Conversations*—a forum where attendees could engage with prominent U.S. climate scientists, negotiators, and other experts. The Center also featured an exhibit highlighting the *First Movers Coalition*—a global initiative harnessing the purchasing power of companies to decarbonize hard to abate industrial sectors that currently account for 30% of global emissions—and an art and science climate action exhibit called *Voices and Visions: The Art and Science of Climate Action*, which highlighted youth engagement in various climate action themes, including connections between art and sustainable development.

¹ NASA has been a regular participant in the U.S. Center during recent COP meetings. For example, in 2022 the agency participated in COP26 in Glasgow, Scotland. To learn more see, "NASA Participates in United Nations Climate Change Conference," in the November–December 2021 issue of *The Earth Observer* [Volume 33, Issue 6, pp. 10–13—go.nasa.gov/3T6nPFC].

² To explore the U.S. Center at COP-27 homepage, see www.state.gov/u-s-center-at-cop27.

³ To view the U.S. Center YouTube channel, see youtube.com/user/TheUSCenter.

⁴ ACE stands for Action for Climate Empowerment—a term adopted by the United Nations Framework Convention on Climate Change (UNFCCC), which refers to Article 6 of the Convention (1992) and Article 12 of the Paris Agreement (2015), focusing on six elements: climate education and public awareness, training, public participation and access to information, and international cooperation. Each of the elements of ACE continue to be foundational tools for the implementation of climate goals by ensuring that everyone, across all walks of life, understands the causes and impacts of climate change, and is educated, equipped, and empowered to contribute to effective actions that drive mitigation, adaptation, and resilience. More information about ACE can be found at unfccc.int/ace.



Photo 1. Laura Lorenzoni [NASA Headquarters—*Ocean Biology and Biogeochemistry Program Scientist*] presents on NASA's Hyperwall, which was a focal point in the U.S. Center at COP27, held in Sharm el-Sheikh, Egypt. **Photo credit:** NASA

NASA's Science Support Office (SSO) staff members **Marit Jentoft-Nilsen** and **Eric Sokolowsky** [both from NASA's Goddard Space Flight Center/Global Science & Technology, Inc.] helped organize and support the NASA exhibit in the U.S. Center, along with **Susie Perez Quinn** [NASA Headquarters (HQ)—*Chief of Staff*] and **Tylar Greene** [NASA HQ, Office of Communications—*Earth Science Lead*]. **Kevin Conole** [NASA HQ, Office of International and Interagency Relations—*Senior Program Specialist*] led the overall planning for NASA's participation in COP27, although he did not attend in person.



Photo 2. Michael Falkowski [NASA Headquarters—*Terrestrial Ecology Program Scientist*] presents via the NASA Hyperwall in the U.S. Center at COP27. **Photo credit:** NASA.

*More photos of NASA's Hyperwall in the U.S. Center at COP27 can be found at [flickr.com/photos/eospso/albums/72177720303566696](https://www.flickr.com/photos/eospso/albums/72177720303566696).

SSO staff operated the Hyperwall, which featured 15 talks presented over two weeks by a team of NASA Earth scientists, including **Kate Calvin** [NASA HQ—*Chief Scientist and Senior Climate Advisor*], **Tahani Amer** [NASA HQ—*Earth Science Division Program Executive*], **Michael Falkowski** [NASA HQ—*Terrestrial Ecology Program Scientist*], and **Laura Lorenzoni** [NASA HQ—*Ocean Biology and Biogeochemistry Program Scientist*]. SSO staff operated the Hyperwall and worked with speakers prior to the meeting to prepare their Hyperwall presentations, which are listed in the **Table** on page 12.

The 15 Hyperwall presentations delivered by NASA senior climate scientists during COP27 highlighted how climate adaptation and mitigation efforts cannot succeed without robust climate observations and research.

Table. NASA Hyperwall presentations delivered at the U.S. Center during COP27. The presentations are available for viewing at the U.S. Center’s YouTube channel (youtube.com/watch?v=hE--kKSNtn0&list=PL8GloD-FU2CgzvdYk8QrZQYf6qwx3fl_W). Times indicating the start of each NASA Science talk are shown in the rightmost column of the Table.⁵

Presentation Title	Presenter	Date – Time
Satellite View of How Humans Are Changing the Earth	Kate Calvin	November 9 – 7:02:35
Satellite View of Earth’s Oceans	Tahani Amer	November 9 – 7:24:37
Introduction and Overview of NASA Earth Science	Kate Calvin	November 10 – 3:10:27
The GLOBE Program:* Engaging Youth and Citizen Scientists in Understanding our Environment	Tahani Amer	November 10 – 6:16:39
Carbon in Earth’s Atmosphere	Kate Calvin	November 11 – 3:40:18
Fires in a Changing World	Tahani Amer	November 12 – 3:42:45
A Global View of Agriculture	Kate Calvin	November 12 – 6:37:48
Viewing Earth’s Global Water Cycle from Space	Michael Falkowski	November 14 – 2:44:35
A Satellite View of Life in the Ocean	Laura Lorenzoni	November 14 – 5:48:56
Revealing Urban Pollution Patterns from a Bird’s Eye View	Laura Lorenzoni	November 15 – 3:33:55
Atmospheric Aerosols—Their Human and Natural Sources	Michael Falkowski	November 15 – 7:12:42
Connections Between Fire, Weather, and Climate	Michael Falkowski	November 16 – 3:20:12
Space and Aircraft Based Views of Biodiversity on Land and in Water	Laura Lorenzoni	November 16 – 7:21:23
New Climate for a Better Tomorrow: Earth Energy, Heat, and Water in a Changing Climate	Michael Falkowski	November 17 – 2:19:33
Science to Inform Solutions for a Healthy Planet	Laura Lorenzoni	November 17 – 6:00:45

*GLOBE stands for Global Learning and Observations to Benefit the Environment.

⁵ After navigating to the U.S. Center’s YouTube channel using the link above, be certain to fully expand your browser window—both horizontally to see the list of daily video streams (to the right) and vertically to see the “Show More” option (requires scrolling down). After clicking on the video stream for a particular day you want to view, scroll down and click “Show More” to see the full list of presentations (in chronological order) for that day. Click on the corresponding time stamps to jump directly to each presentation.

Conclusion

After the hybrid meeting approach employed during COP26 in Glasgow, Scotland (due to the COVID-19 pandemic), the SSO was able to fully resume its core mission of communicating NASA Science results face to face with individuals and groups from varying backgrounds at COP27. The 15 Hyperwall presentations delivered by NASA senior climate scientists during COP27 highlighted how climate adaptation and mitigation efforts cannot succeed without robust climate observations and research. In support of that goal, NASA's fleet of satellites and instruments provide critical information from their unique vantage point in space to advance understanding of our changing planet, including impacts from greenhouse gas emissions and warming, such as the decline of Arctic Sea ice, rising sea levels, more severe wildfires, and shifting animal migration patterns.

“NASA has a unique role in the global effort to continue understanding impacts of climate change and in addressing and mitigating those impacts,” said **NASA Administrator Bill Nelson**. “Beyond our Earth-observing satellites in space, instruments and research which provide an unparalleled understanding of our home planet, we are committed to working with our international partners to provide free and open data to the public. NASA is excited to be part of the discussions at COP27 to help answer the most pressing questions in addressing climate change.” ■

“NASA has a unique role in the global effort to continue understanding impacts of climate change and in addressing and mitigating those impacts...”

—**NASA Administrator Bill Nelson**

The Editor's Corner continued from page 3

and are approaching 17 years in orbit (April 28).⁴ In February 2018, CloudSat lowered its orbit out of the A-Train⁵ after technical issues that potentially affected the satellite's maneuvering capability. In September 2018, CALIPSO executed a series of maneuvers to join CloudSat's orbit, forming what is known as the C-Train. While the C-Train is considered part of the A-Train, CloudSat and CALIPSO fly 16.5 km below the A-Train and therefore follow a slightly different ground track—though it intersects the A-Train ground track about every 20 days allowing for regular simultaneity between A-Train and C-Train instrument observations.

CloudSat experienced the failure of a second reaction wheel in August 2020. After months of creative engineering by Ball Aerospace engineers, the satellite was able to return to science operations in December 2021. The new mode of operations for CloudSat is referred to as Attitude Control Through Two-Wheel Operations with Daylight-Only Operations, or ACT-TWO

DO-Op. CloudSat has operated in DO-Op mode since it experienced a severe battery anomaly in 2011—which is what eventually led to it needing to exit the A-Train in 2018.

In ACT-TWO DO-Op, the radar boresight is pointed slightly to the left of the nadir track during the ascending portion (daylight portion) of the orbit. A “Tiger Team” consisting of individuals from CSU/CIRA (CloudSat's Data Center) and other CloudSat algorithm scientists meets regularly to address the ACT-TWO radar geolocation issues. ACT-TWO operations are working well and CloudSat is being slowly moved back into the C-Train formation with CALIPSO.

Meanwhile, the CALIPSO lidar continues to operate and provide valuable profile observations of clouds and aerosols—although individual laser shots are increasingly affected by energetic particles in the exoatmosphere from solar events. The mission is expected to cease operations by Fall 2023 because the spacecraft will be unable to fully charge its batteries.

The two missions have a joint Science Team and have collaborated on many endeavors throughout their respective missions. Now CloudSat and CALIPSO will both enter *Phase F* (the Closeout Phase for NASA missions) at approximately the same time—both expected to do so early in Fiscal Year 2024. CloudSat may do some engineering characterizations prior to decommissioning, e.g., switching to the redundant, never-used extended interaction klystron (EIK) and a

⁴ To learn more about the achievement of CloudSat and CALIPSO over their first 10 years in orbit, see “A Useful Pursuit of Shadows: CloudSat and CALIPSO Celebrate Ten Years of Observing Clouds and Aerosols,” in the July–August 2016 issue of *The Earth Observer* [Volume 28, Issue 4, pp. 4–15—go.nasa.gov/2Wm2HcM].

⁵ The international Afternoon Constellation, or “A-Train,” is presently comprised of OCO-2, GCOM-W1, Aqua, and Aura, as well as CALIPSO and CloudSat—which lowered their orbit and are known as the “C-Train.” The instruments on these satellites are used synergistically to improve our knowledge of clouds, aerosols, atmospheric chemistry, and other elements critical for understanding Earth's environment and changing climate. To learn more about the A-Train and C-Train see svs.gsfc.nasa.gov/31049.

Summary of the Eighth DSCOVR EPIC and NISTAR Science Team Meeting

Alexander Marshak, NASA's Goddard Space Flight Center, alexander.marshak@nasa.gov

Adam Szabo, NASA's Goddard Space Flight Center, adam.szabo@nasa.gov

Introduction

The eighth Deep Space Climate Observatory (DSCOVR) Earth Polychromatic Camera (EPIC) and National Institute of Standards and Technology (NIST) Advanced Radiometer [NISTAR] Science Team Meeting (STM) was held virtually September 27–29, 2022. Over 50 people attended, most of whom were from NASA's Goddard Space Flight Center (GSFC), with several participating from other NASA field centers, U.S. universities, and U.S. Department of Energy laboratories. There were also several international participants from France and Estonia. A full overview of DSCOVR's Earth observing instruments was given in the summary of the 2018 DSCOVR STM and will not be repeated here.¹ This article presents the highlights of the 2022 meeting; the meeting agenda and full presentations can be downloaded from go.nasa.gov/3XoDodb.

Opening Presentations

The opening session consisted of a series of presentations from DSCOVR mission leaders and representatives from GSFC, who gave updates on the mission and the two Earth-viewing science instruments on board. **Alexander Marshak** [GSFC—*DSCOVR Deputy Project Scientist*] opened the meeting. He discussed the agenda for the meeting and mentioned that both Earth science instruments on DSCOVR are functioning normally. He reported that the EPIC website (epic.gsfc.nasa.gov) includes a list of more than 90 papers that have been published related to DSCOVR. Marshak also mentioned that the Special Issue of *Frontiers in Remote Sensing* titled “DSCOVR EPIC/NISTAR: 5 years of Observing Earth from the First Lagrangian Point,” which contains 23 papers, has recently been published.

Adam Szabo [GSFC—*DSCOVR Project Scientist*] welcomed the STM participants and briefly reported that the spacecraft, located at the first *Lagrange point*

“L1”,² was still in good health and the EPIC and NISTAR instruments continue to return their full science observations. He emphasized the importance of making the Earth Science community more aware of the availability of the various EPIC and NISTAR science data products. Szabo also reminded the participants that DSCOVR will participate in the next Earth Science Senior Review, which is coming up in the spring of 2023.³

Thomas Neumann [GSFC—*Deputy Director of GSFC's Earth Sciences Division (ESD)*] welcomed meeting participants on behalf of the ESD. Neumann noted the impressive engineering that has led to seven and a half years of DSCOVR operations and counting; he also commended the team on the continuing important science results from these instruments—with nearly 100 papers in the peer-reviewed literature.

Following on Neumann's remarks, **Steve Platnick** [GSFC—*Deputy Director for Atmospheres in ESD*] also welcomed the members of the DSCOVR Science Team and all friends of EPIC and NISTAR observations. He thanked NASA Headquarters (HQ) for its continued strong interest in the mission. Platnick also expressed his appreciation for the mission team members who have worked hard to maintain operation of the DSCOVR satellite and instruments during this challenging time.

Updates on DSCOVR Operations

The DSCOVR mission components continue to function nominally—with progress reported on several fronts, including data acquisition, processing, archiving, and release of new versions of several data products. The number of users of DSCOVR data is increasing, with a new Science Outreach Team having been put in place to aid users in several aspects of data discovery, access, and user friendliness.

² There are five Lagrange points in the Sun–Earth system where the gravitational pull of Sun and Earth masses precisely equals the centripetal force required for a small object to move with them. DSCOVR is positioned between Earth and the Sun at L1, which is about 1.5 million km (~930,000 mi) from Earth. This affords the spacecraft an uninterrupted view of both the Sun and Earth. (For comparison, the James Webb Space Telescope is positioned at L2, which is 1.5 million km “behind” Earth as viewed from the Sun.)

³ NASA Headquarters (HQ) periodically conducts reviews of its missions to assess their current state and their worthiness for continued operation. Historically, this has occurred every two years for Earth Science.

¹ See “Summary of DSCOVR EPIC and NISTAR Science Team Meeting” in the November–December 2018 issue of *The Earth Observer* [Volume 30, Issue 6, pp. 16–22—go.nasa.gov/37c0M5s].

Carl Hostetter [GSFC] described the DSCOVER Science Operations Center (DSOC)'s EPIC and NISTAR data flow—from the spacecraft, through the receiving ground station(s), to the Science Planetary Operations and Control Center (SPOCC)—and the subsequent processing of these data to Level-1A (L1A) and L1B science data products, including their archiving and distribution to the public.

Marshall Sutton [GSFC] discussed processing of EPIC Level-2 (L2) science products for all EPIC science teams. A suite of twelve L2 data products are generated from L1 EPIC data.⁴ Three new products have been added: Aerosol Cloud Height and Sunlint. Sutton also reported that the DSCOVER ST used the high-performance computing capabilities offered through the NASA Center for Climate Simulations (NCCS)—including the Discover cluster—to store algorithms, download ancillary data, process the data, and upload the data from the Atmospheric Science Data Center (ASDC) data repository.⁵

Alexander Cede and **Gavin McCauley** [SciGlob] reported that the L1A processor version was updated with an extra parameter for stray light correction, and improved for determining on-target versus off-target pixels. They said that the charged coupled device (CCD) photon detector remains healthy, and no hot or warm pixels have developed. In addition, they confirmed that the current dark-count correction model still satisfactorily describes the dark count.

EPIC Calibration

Liang-Kang Huang [Science Systems and Applications, Inc. (SSAI)] reported that for some EPIC flat-field calibrations, EPIC lunar measurements were performed in 2021 and 2022. This included measurement of and corrections for lunar phase changes. The relative sensitivities with respect to the CCD center were found to be 2–4% lower at the CCD edge compared to its center. EPIC ultraviolet (UV) channel albedo calibration coefficients were updated with coincidence comparison with nadir measurements from the Ozone Monitoring Profiler Suite on the Suomi National Polar-orbiting Partnership (Suomi NPP). After nine months in safe mode due to a glitch in the satellite's attitude control system—ultimately fixed by a software patch—EPIC was placed back in science operations in February 2020, with none of its channels recording a sensitivity decrease of more than 0.65% over the last 28 months.

⁴ The products include: Ultraviolet (UV), Aerosols, Ozone, Sulfur Dioxide, Ozone/Sulfur Dioxide/Aerosol Index, Cloud, Atmospheric Correction, Vegetation, Ocean Product, Glint, UV Aerosol–Fast, Tropospheric Ozone, and Aerosol Optical Centroid Height. Information on each of these products can be found on the EPIC website (epic.gsfc.nasa.gov) under the Science tab in the upper right corner.

⁵ To clarify, the NCCS Discover cluster is not directly associated with the DSCOVER mission.

Igor Geogdzaev [NASA's Goddard Institute for Space Studies (GISS)/Columbia University] reported on an analysis of nonabsorbing EPIC visible–near infrared (VIS-NIR) channel calibrations using matching spectral channels of five low-Earth-orbiting (LEO) radiometers.⁶ The results showed that EPIC calibration was remarkably stable—which is consistent with independent published findings. An analysis using VIIRS data showed that EPIC scenes with extreme backscattering angles have minimal effect on calibration.

NISTAR Status and Science with its Observations

NISTAR remains fully functional and continues its uninterrupted data record. The presentations here include more details on specific topics related to NISTAR, or on efforts to combine information from both EPIC and NISTAR.

Steven Lorentz [L-1 Standards and Technology, Inc.] reported that NISTAR has been measuring the irradiance from the Sun-lit Earth in three bands for more than seven years. The bands measure the outgoing reflected solar and total radiation from Earth at a limited range of solar angles. These measurements assist researchers in answering questions addressing Earth radiation imbalance and predicting future climate change. NISTAR continues to operate nominally, and the team is monitoring any in-orbit degradation. Lorentz explained that NISTAR has proven itself to be an extremely stable instrument—with less than 0.1% deviation in shortwave (SW) measurements over seven years of operations. He also said that the investigation to characterize offsets and biases continues.

Clark Weaver [University of Maryland, College Park (UMD)] compared a new reflected SW energy estimate from EPIC with the Band-B reflected energy from the NISTAR instrument. This new product uses generic Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) aircraft observations over homogeneous scenes to spectrally interpolate between the coarse EPIC channels. It assumes the spectra from an EPIC pixel is a weighted combination of a solid cloud scene and the underlying (cloud-free) surface. For each pixel they bend the composite high-resolution spectrum from AVIRIS to exactly fit EPIC observations at six different wavelengths (ranging from 340–780 nm). A radiative transfer model is used to account for the different viewing/illumination geometry of the sensors. Although the total reflected energy for a single EPIC image can be $\pm 15 \text{ W/m}^2$ different than the NISTAR measurement, during 2017 there was, on average, less than 1 W/m^2 in offset bias between the two measurements.

⁶ The five LEO instruments include the Moderate Resolution Imaging Spectroradiometer (MODIS) on both Terra and Aqua, the Multiangle Imaging Spectroradiometer (MISR) on Terra, and the Visible Infrared Imaging Radiometer Suite (VIIRS) on both Suomi NPP and NOAA-20.

Andrew Lacis [GISS] discussed longitudinal slicing of the sunlit hemisphere for unique climate-scale model and data comparisons between similarly sampled global climate model (GCM) output and observational data.⁷ These comparisons of the EPIC and GISS ModelE2 planetary albedo variability have unambiguously diagnosed the land–ocean deficiencies in the longitudinal ModelE2 cloud distribution. The EPIC-derived planetary albedo variability has also proved capable of detecting La Niña-associated, planetary-scale standing waves in February and October 2017, as well as the intense Madden–Julian Oscillation (MJO)-type variability occurring during the summer months in 2020 and 2021 over the Western Pacific and Indian Oceans.

EPIC Products

The presenters in this section provided updates on specific EPIC data products and/or concerns related to them.

Total Column Ozone

Natalya Kramarova [GSFC] compared tropospheric column ozone (TCO) derived from EPIC, Ozone Mapping and Profiler Suite (OMPS) on Suomi NPP, and the Ozone Monitoring Instrument (OMI) on Aura (called “NASA Merged”), with TCO derived from the TROPOspheric Monitoring Instrument (TROPOMI) on the Copernicus Sentinel-5 Precursor satellite.⁸ TCO was derived by subtracting independently measured stratospheric ozone (O₃) columns obtained from assimilated data. [For OMPS and OMI, the latest version of the Modern-Era Retrospective Analysis for Research and Applications (MERRA-2) was used; for TROPOMI, the Belgian Assimilation System for Chemical Observations (BASCOE) was used.] from EPIC/OMPS/OMI/TROPOMI total O₃ measurements. There was a consistent offset of ~4 Dobson Units (DU) between TROPOMI and NASA TCO in the 2018 to early 2021 period, which increased up to 6–8 DU after July 2021 due to calibration adjustments in TROPOMI measurements. Comparisons with ground-based sondes at 40 stations demonstrated smaller biases of ±2–4 DU with NASA TCO, and mostly positive biases of +4–8 DU with TROPOMI. Analysis of daily TCO maps revealed positive anomalies in EPIC TCO in places with high aerosol pollution [Aerosol Index (AI) > 5].

⁷ Each EPIC image shows “weather-scale” cloud distributions over the sunlit hemisphere. For the longitudinal slicing analysis, a single “climate-scale” planetary albedo point is created, which averages out all the weather-scale variability and leaves behind a broad-brush measurement of seasonal climate-scale variability—but differentiated from decadal climate variability. These climate-scale averages are further averaged into monthly means.

⁸ Copernicus is an Earth observation program coordinated and managed for the European Commission by the European Union’s (EU) Agency for the Space Programme in partnership with the European Space Agency and EU Member States.

Jerrald Ziemke [Morgan State University] reported that NASA satellite combining measurements from EPIC, OMI, and OMPS show that spring–summer decreases in tropospheric O₃ reported throughout the Northern Hemisphere (NH) in 2020 were repeated in 2021. Decreases in tropospheric ozone in 2020 and 2021 averaged 7–8% (–3 DU) below normal in the NH in both years, with most decreases occurring over ocean. Tropospheric O₃ decreases in the NH in 2020 and 2021 produced the lowest recorded tropospheric O₃ in the NH since 2005, despite the presence of a long-term positive trend of some +1 DU per decade. NASA satellite measurements of NO₂ and aerosols further show that the NH tropospheric ozone losses in both 2020 and 2021 were largely of anthropogenic origin.

Ozone and Sulfur Dioxide Algorithm Improvements

Kai Yang [UMD] presented a physics-based algorithm for trace-gas retrievals from remote sensing observations and its application to EPIC. He highlighted advances in algorithm physics that improve the retrieval accuracy of EPIC O₃ and volcanic sulfur dioxide (SO₂) products. The high accuracy and long-term consistency of the EPIC O₃ product are validated through time-series comparisons with coincident ground-based ozone measurements from a network of Brewer spectrophotometers. Yang described the unique observations of recent (2021–2022) volcanic eruptions, including the long-duration eruptions of Cumbre Vieja (La Palma Island, Spain) and Wolf (Galápagos Islands, Ecuador) volcanos, and the eruptions of submarine volcanos: Fukutoku–Oka-no-Ba (Japan) and Hunga Tonga–Hunga Ha’apai (HT-HH, Tonga). Using EPIC’s successive views of the volcanic plume from the January 15, 2022, HT-HH eruption, he estimated the SO₂ injection height to be 30–35 km (18.6–21.4 mi).

Simon Carn [University of Michigan] showed EPIC observations of the HT-HH eruption. The high-cadence EPIC SO₂ measurements provided new insight into the dynamics of the stratospheric umbrella cloud produced during the eruption. Carn also reported that ground-based SO₂ measurements from Brewer and Pandora UV spectrometers on Tenerife (Canary Islands) were used to validate EPIC volcanic SO₂ retrievals during the 2021 Cumbre Vieja eruption (La Palma) with promising results.

Aerosols

Omar Torres [GSFC] reported that the EPIC near-UV aerosol record shows an unprecedented increase in atmospheric aerosol load on a global scale over the last five years. The main sources accounting for the increase appear to be enhanced carbonaceous aerosol production at the well-known biomass burning sources in the tropics, and an extraordinary increase in the

amount of Saharan desert dust aerosols transported across the Atlantic Ocean during this period. The EPIC UV aerosol record shows that—over the last five years—the occurrence of hemispheric-scale wildfires over the U.S., Canada, and Siberia have become annual phenomena. Major EPIC aerosol algorithm improvements currently underway include deriving aerosol layer height from oxygen (O_2) B-band observations and retrieving aerosol optical depth and single-scattering albedo in the visible spectral region.

Hiren Jethva [Morgan State University] reported that the EPIC near-UV aerosol algorithm (EPICAERUV) retrievals of aerosol-corrected and apparent cloud optical depths were used to estimate the direct aerosol radiative effects (DARE) over clouds. The top of atmosphere (TOA) SW flux versus cloud optical depth polynomials allowed estimating TOA flux for scenes with and without aerosols above clouds. The observation-based, instantaneous DARE product from EPIC will help constrain and improve the model simulation of aerosol–cloud radiative interactions.

Alexei Lyapustin [GSFC] presented a new algorithm to simultaneously retrieve aerosol optical depth, spectral absorption, and layer height from EPIC's measurements in the UV, visible, and O_2 A- and B-band regions. The initial evaluation of aerosol layer height using the Cloud–Aerosol Lidar with Orthogonal Polarization (CALIOP) on the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite is promising—but shows a need to reevaluate EPIC's calibration in the O_2 A- and B-bands. These new capabilities will be integrated into version 3 of the Multi-Angle Implementation of Atmospheric Correction algorithm for EPIC (MAIAC EPIC v3).⁹

Sujung Go [University of Maryland, Baltimore County (UMBC)] presented an algorithm and retrieval results of two iron-oxide species (hematite and goethite) in airborne mineral dust from EPIC observations. Results show a significant seasonal and spatial variability over the main dust-source regions and agree well with the published range of hematite and goethite content based on *in situ* soil samples—see **Figure 1**. Retrieved volume

⁹ To learn more about MAIAC, see ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/maiac.

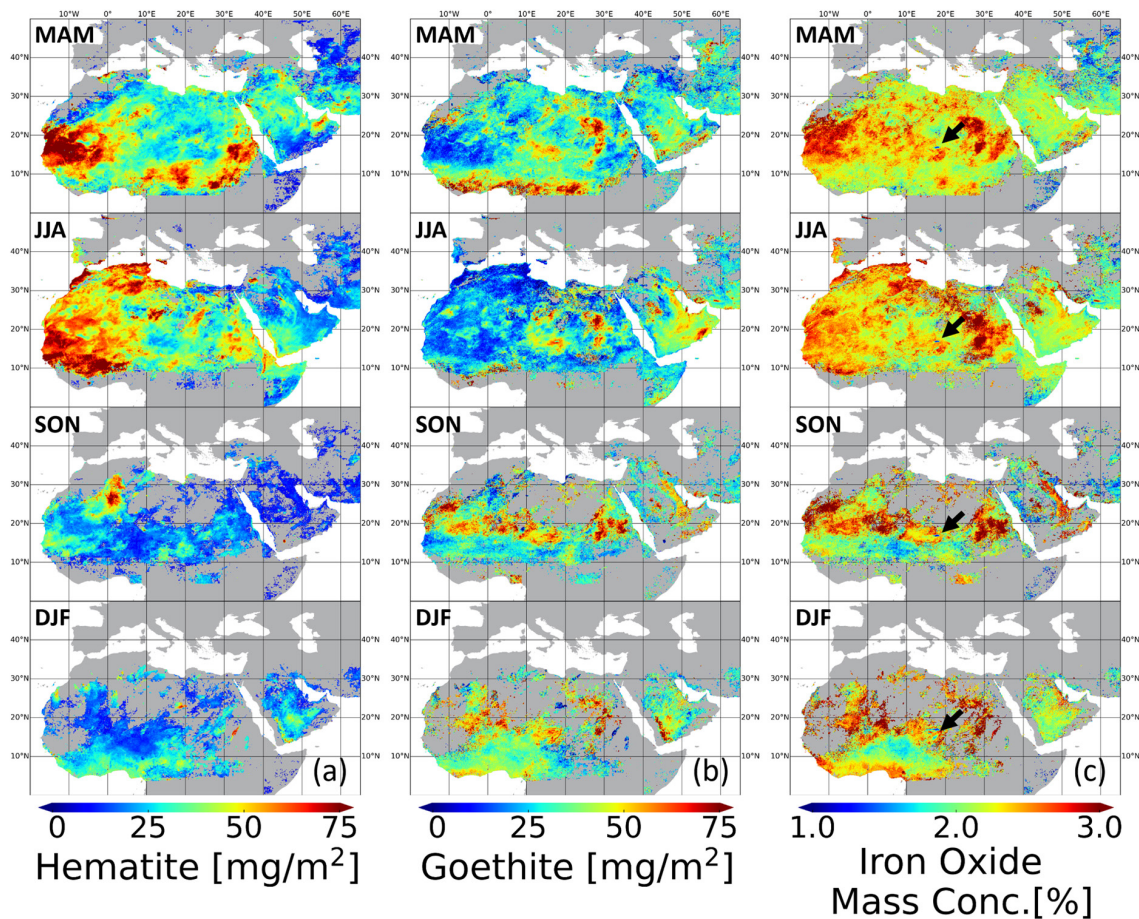


Figure 1. Seasonally averaged iron oxide content in airborne mineral dust for Sahara–Sahel, Arabian Peninsula, and Middle East dust-source regions generated from one year (2018) of MAIAC EPIC data. Shown are mass concentrations (mg/m^2) of hematite [left column] and goethite [middle column], and total iron-oxide (by weight, %) [right column]. The black arrows in the last column are pointing at the Bodélé Depression area, which was once the floor of a larger Lake Chad and now is a major source of fertile dust that gets transported across the Atlantic and supports growth in the Amazon rain forest. Acronyms Used in Figure 1: *MAM*—March, April, May (Spring); *JJA*—June, July, Aug (Summer); *SON*—September, October, November (Fall); and *DJF*—December, January, February (Winter). **Image credit:** Sujung Go/UMBC

and mass fractions of iron-oxide species will be part of the MAIAC EPIC v3 operational product, providing essential information on direct radiative effects of SW dust for use in climate modeling.

Jun Wang [University of Iowa] presented the description of the EPIC aerosol optical centroid height (AOCH) product, including the development progress and applications of this product. He showed that the routine production of AOCH product is on the way via collaboration with Marshall Sutton and his team at GSFC. Wang also discussed the algorithm that has been developed to retrieve AOCH over bright surfaces and showcased the application of EPIC AOCH data to study the diurnal variation of Saharan dust layer height over the Atlantic Ocean. In the future, the utility of hourly EPIC AOCH can serve as a self-consistent reference dataset to evaluate and cross-compare the hourly AOCH product from other geostationary satellite platforms.¹⁰

Olga Kalashnikova [NASA/Jet Propulsion Laboratory (JPL)] discussed brown-carbon (BrC) evolution assessments with EPIC products. She discussed roles of BrC

¹⁰ For example, three geostationary instruments, one currently in orbit and two more soon to be launched, will form a virtual air quality constellation in the coming years: the Geostationary Environment Monitoring Spectrometer (GEMS) instrument on the Korean Aerospace Research Institute's (KARI) Geostationary Korea Multi-Purpose Satellite-2B (GEO-KOMPSAT-2B) satellite, launched in February 2020; the NASA Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission to be launched on the commercial Intelsat 40e satellite, scheduled for launch in 2023; and the Ultraviolet–Visible–Near-infrared (UVN) sounder on Sentinel-4, scheduled for launch in 2024.

processes of aging and mixing in the climate-relevant and air-quality-relevant properties of smoke, focusing on understanding large-scale BrC evolution processes in the western U.S. and Canada. The approach was introduced to evaluate BrC evolution with a newly developed Weather Research and Forecasting coupled with Chemistry (WRF-Chem) parametrization that incorporates BrC time-resolved photobleaching. The EPIC MAIAC BrC products provided constraints for the model, which were evaluated with collocated satellite products of smoke plume vertical distributions for a set of fire cases where smoke plume could be tracked through multiple DSCOVR images.

Michael Garay [JPL] discussed how to use observations from polar orbiting satellites to test aerosol retrievals from DSCOVR/EPIC. Aerosol retrievals for smoke plumes from wildfires in the western U.S., developed using the original MAIAC algorithm applied to EPIC, were compared to collocated aerosol retrievals from the Multi-angle Imaging Spectroradiometer (MISR) instrument on the Terra satellite. The initial agreements were good. Smoke plumes were found to range in altitude from 1–4 km (–0.6–2.5 mi) based on MISR stereo height retrievals, so parallax effects need to be taken into account for detailed (pixel-to-pixel) comparisons. Future work will be done using the newly released EPIC MAIAC aerosol product.

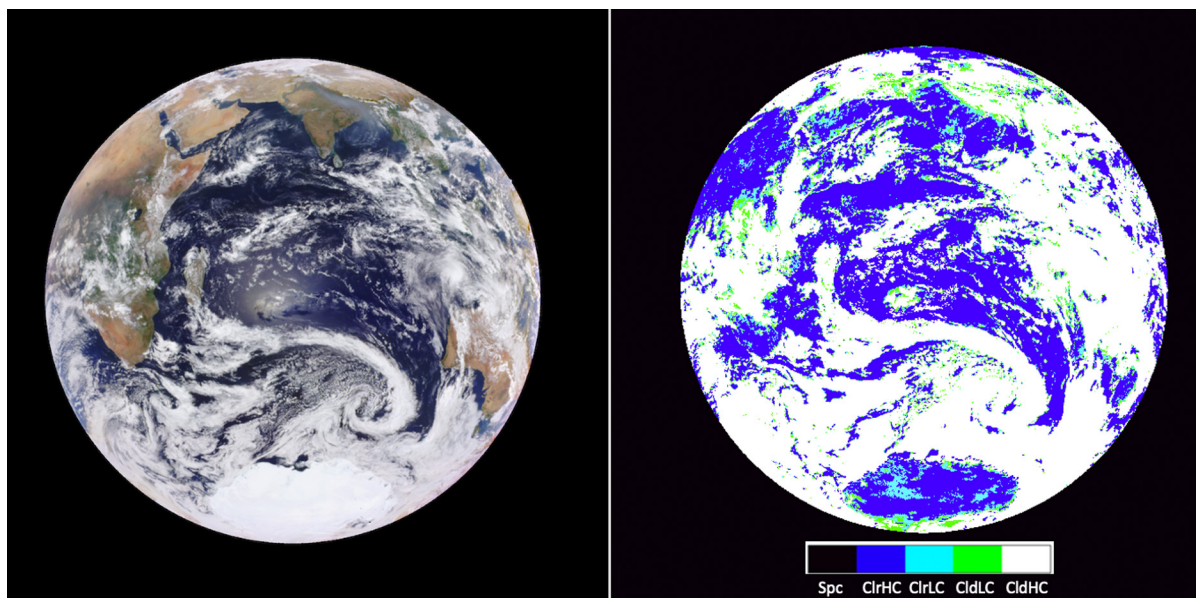


Figure 2. Example of EPIC Oxygen A- and B-band application on cloud identification over snow/ice and sunglint. The left panel shows an EPIC image taken on December 22, 2016. Notice the Antarctic ice sheet at the bottom and the ocean sunglint at the middle. The right panel shows the corresponding EPIC cloud mask. The labels used on the Cloud Mask color bar are defined as follows: *Spc*—Space; *ClrHC*—Clear (High Confidence); *ClrLC*—Clear (Low Confidence); *CldLC*—Cloudy (Low Confidence); and *CldHC*—Cloudy (High Confidence). **Image credit:** Yuekui Yang/GSFC

Clouds

Yuekui Yang [GSFC] provided updates on the EPIC Level-2 (not be confused with Lagrange 2) cloud products and presented the essential role of the EPIC O₂ A- and B-bands in EPIC cloud retrievals. Data from those bands form the basis of EPIC cloud height retrievals, and also provide solutions to cloud identification over bright surfaces, e.g., snow, ice, and sunglint—see **Figure 2**.

Yaping Zhou [UMBC] showed that the South Pole provides a good monitoring site for O₂ A- and B-band retrievals of cloud height because of its uniform, high surface albedo, thinner atmosphere, and available ground and *in situ* atmospheric observations. The O₂ A- and B-band reflectances have shown small but significant trends over the past seven austral summers, among other small fluctuations. Radiative transfer model simulations and sensitivities have been conducted to understand these trends and fluctuations.

Elizabeth Berry [Atmospheric and Environmental Research (AER)] reported on collocation of cloud retrievals from EPIC with active remote sensing measurements from the Cloud Profiling Radar (CPR) on CloudSat. The coincident data enable a simultaneous look at the three-dimensional structure of clouds and the column-derived cloud properties from DSCOVR. This effectively adds a vertical dimension to the DSCOVR-observed clouds for a subset of EPIC images.

Anthony Davis [JPL] described new research that was inspired by EPIC's cloud height products from its O₂ A- and B-band absorption channels. He showed that with sufficient spectral resolution or angular diversity, in theory one can derive a two-dimensional field of parametrized cloud profiles. Specifically, at each pixel it is possible to estimate an unbiased cloud-top height, that is, of cloud geometrical thickness. This can be done even under cloudy conditions (for cloud optical thickness values greater than 50)—where the standard cloud reflectivity-based retrieval method loses its sensitivity.

Afonso Delgado Bonal [UMBC] discussed an analysis of diurnal evolution of cloud properties using EPIC—which is the only sensor capable of capturing daytime evolution of cloud properties for the entire sunlit side of Earth. Statistical analysis of EPIC imagery shows that optical thickness peaks around local noon for liquid clouds independent of the underlying surface. For ice clouds, the optical thickness over land increases in the afternoon but remains mostly unchanged over oceans. A detailed latitudinal zone analysis reveals that liquid clouds are thicker in northern latitudes, while ice cloud thickness increases in the tropics.

Sunglint

Tamás Várnai [UMBC] described ongoing updates to the EPIC L2 glint product—the first satellite data product dedicated to sunglint. The presentation discussed the analysis of EPIC observations of sunglint, focusing on glints caused by horizontally oriented ice crystals occurring in clouds. Among other findings, the analysis revealed the impact of glints on EPIC operational data products (e.g., cloud optical depth and cloud height) and is expected to yield additional new insights about the microphysical and radiative properties of ice clouds.

Alexander Kostinski [Michigan Technology University] discussed interplay between the basic optics and fluid mechanics of EPIC glints. In particular, he focused on how placing observational constraints on the angular width of the glints yield constraints on the orientation spread of ice plates. If the plates are too small, Brownian motion and diffraction would cause the glints to broaden beyond observations. If the plates are too large, wobbling at higher settling speed would do likewise.

Ocean

Robert Frouin [Scripps Institution of Oceanography, University of California] discussed ocean surface radiation products from EPIC data. He reported that algorithms were developed to estimate daily-averaged downward planar and scalar irradiance and average cosine for total light just below the surface in several EPIC spectral bands, and integrated values over the Photosynthetically Active Radiation (PAR) and UV-A spectral ranges. These quantities are important to address science questions pertaining to biogeochemical cycling of carbon, nutrients, and oxygen, as well as mixed-layer dynamics and circulation. The subsurface quantities are obtained from the daily mean planar flux using a reduced set of parameters, i.e., location, cloud influence, and wind speed. Radiative transfer simulations were used to establish the feasibility of these ocean products. Frouin showed examples of global products.

Vegetation

Yuri Knyazikhin [Boston University] reported on the status of the Vegetation Earth System Data Record (VESDR) and discussed science results achieved using the VESDR product. A new version of the VESDR software has been delivered to NCCS. In this version, the ambiguity in quality assurance (QA) information about the reason for the algorithm failure has been fixed. The new software will be used to generate the VESDR product for 2022 and beyond. A new model for the hotspot signature of equatorial forests has been developed from synergistic analyses of DSCOVR EPIC and MISR data. The model can accurately reproduce

both MISR angular signatures acquired at 10:30 AM local solar time and diurnal courses of EPIC reflectance. Analyses of observed reflectance suggest that VESDR has the ability to unambiguously detect seasonal changes in equatorial forests.

Jan Pisek [University of Tartu/Tartu Observatory, Estonia] reported on verifying the expected link between the new, unique parameter called Earth Reflector Type Index (ERTI) from the EPIC VESDR product, foliage clumping, and canopy cover with empirical data. The results suggest that the ERTI parameter can deliver information about *photon recollision probability*—the probability that a photon scattered by material in the canopy will interact with matter in the canopy again—a useful concept for modeling the radiation regime of canopies. Note that this was done with EPIC data over study sites in Australia that included types of forests that are still relatively unexplored using spectral invariants theory.

More EPIC Science Results

Guoyong Wen [Morgan State University] discussed spectral properties of the data observed by EPIC. To understand spectral relations of global average reflectance, Wen analyzed EPIC data at five nonabsorbing bands and found that for the August 2016 observations, the near-hourly reflectance in the bands examined follows a closed loop relationship in the course of 24-hours of Earth's rotation. However, analysis of observations taken in March 2016 revealed a different trajectory. The difference is primarily due to the change of cloud amount for the two months. Wen also analyzed the daily average and associated variation of spectral reflectance and found that daily global average spectral reflectances are highly correlated. Typically, the daily average reflectance decreases at the lower end of the range examined and remains almost neutral midrange, with an increase toward the higher end. The Earth-rotation-induced variation decreases with wavelength.

Nick Gorkavyi [SSAI] proposed to deploy a wide-angle camera and a multislit spectrometer on the Moon's surface for whole-Earth observations to complement EPIC observations. Gorkavyi explained that the Moon's *libration*—the wagging and wavering of the Moon that Earth-bound observers of the Moon observe due to changes in perspective caused by latitude and longitude—causes Earth's center to vary in the Moon's sky within a limited angular field of view with two periods: 27 days and 6 years.

Benoît Tournadre [ParisTech] presented the application of the Heliosat-V method to estimate downwelling solar irradiance at Earth's surface from EPIC

imagery.¹¹ Comparative estimates were made from five EPIC channels and then compared with ground-based measurements, outputs from the European Centre for Medium-range Weather Forecasts' (ECMWF) fifth-generation reanalysis [ERA5], and satellite-based products from Clouds and Earth's Radiant Energy System (CERES)¹² and from EPIC cloud properties data. Estimates from two channels show similar performance—albeit with larger biases for two other channels—and perform well compared to other products.

Jay Herman [UMBC] explored whether clouds observed at 388 nm caused enhanced reflection, mostly at 45° S, at backscatter angles near 88° seen in the Southern Hemisphere (SH) during the December 2020 solstice. The absence of cloud brightening at 388 nm in the Northern Hemisphere (NH) during the 2021 June solstice for large backscatter angles greater than 88° suggests that the SH brightening was caused by a temporary increase in cloud amount.

Conclusion

At the end of the meeting **Alexander Marshak**, **Jay Herman**, and **Adam Szabo** led a discussion on how to make data from the EPIC and NISTAR instruments more visible in the community. One suggestion was to add new content to the EPIC website: e.g., daily fluctuations of different products (including cloud and aerosol properties, surface reflectance, and ozone), and the possibility of designing and making gridded L3 products available to the scientific community.

Overall, the meeting was quite productive; it provided an opportunity to learn the status of DSCOVR's Earth-observing instruments—EPIC and NISTAR—as well as the status of recently released L2 data products and the science results being achieved from the “L1” point. There are more and more users of DSCOVR data worldwide, and the Science Team hopes to hear from users and team members at its next meeting. The latest updates from the mission are found at epic.gsfc.nasa.gov. The next STM will be held in the fall of 2023. ■

¹¹ Learn more about the Heliosat-V method at presentations.copernicus.org/EGU2020/EGU2020-1630_presentation.pdf.

¹² There are currently six CERES instruments in orbit: Two fly on Terra, two on Aqua, one on Suomi NPP, and one on NOAA-20.

Summary of the Fifty-First U.S.–Japan ASTER Science Team Meeting

Michael Abrams, NASA/Jet Propulsion Laboratory/California Institute of Technology, mjabrams@jpl.nasa.gov
Yasushi Yamaguchi, Nagoya University/Japan Science and Technology Agency, yasushi@nagoya-u.jp

Introduction

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team (ST) organized a three-day workshop that took place November 7–9, 2022 at Japan Space System's (JSS) offices in Tokyo, Japan. Over 40 people from Japan and the U.S. participated in the in-person meeting—some of whom are shown in **Photo 1** below. This was the first ST meeting—and the first ASTER-related in-person meeting—since prior to the pandemic in 2019.¹ U.S. participation included representatives from NASA/Jet Propulsion Laboratory (JPL), NASA's Goddard Space Flight Center (GSFC), NASA's Land Processes Distributed Active Archive Center (LPDAAC), University of Arizona (UA), University of Pittsburgh (Pitt), and University of Washington (UW). Japanese participation included representatives from JSS, Ibaraki University (IU), Nagoya University (NU), University of Tokyo (UT), Tohoku University (TU), National Institute of Advanced Industrial Science and Technology (AIST), and University of Tsukuba (UTs).

The main objectives of this meeting were to discuss mission status; data products; science team projects; data calibration, validation, distribution, and applications; as well as end-of-mission plans.

Another topic of immediate concern was NASA Headquarters' (HQ) recent Request For Information

¹ To read a summary of the most recent meeting, see "Summary of the Fiftieth ASTER Science Team Meeting" in the September–October 2019 issue of *The Earth Observer* [Volume 32, Issue 5, pp. 21–25—go.nasa.gov/3XwBOBp].

(RFI) for new science that could be conducted as the orbits of Terra, Aqua, and Aura drift; and the associated Aqua, Aura, and Terra Drifting Orbits Workshop (held online November 1–2, 2022), where each instrument team discussed the appropriate submissions with their constituency, and sought additional ideas for new science. With the 2023 Senior Review coming up in the spring of 2023, NASA HQ has some important decisions to make regarding future funding for Terra, Aqua, and Aura. The information collected during the Drifting Orbits workshop is expected to help inform the decision making.²

Opening Plenary Session

The opening plenary session took place on the afternoon of the first day of the ASTER workshop and was devoted to general topics about mission operations, instrument status, and data distribution. **Yasushi Yamaguchi** [NU] and **Michael Abrams** [JPL]—the ASTER Science Team Leaders from Japan and the U.S., respectively—opened the meeting and welcomed participants.

The next three presenters gave updates on the status of the Terra spacecraft, the Terra Ground Data System, and the ASTER instrument, respectively.

Jason Hendrickson [GSFC—*Terra Flight Systems Manager*] reviewed the status of the Terra platform. He reported that all systems are functioning nominally. In September, ASTER agreed to completely turn off the **short-wave infrared (SWIR)** instrument, saving over

² To learn more about the topics discussed in this paragraph, see page 2 of "The Editor's Corner" in this issue.



Photo 1. Some of the attendees at the Fifty-First ASTER Science Team workshop. **Photo credit:** Akiko Arima/JSS

200 watts of power for the platform. In October, Terra executed two Morning Constellation-exit maneuvers,³ lowering the orbit by 5.5 km (~3.4 mi). Since its final inclination maneuver in February 2020, Terra has been drifting; the orbit reached 10:15 AM Equator crossing time (from 10:30 AM) in October, and will continue to drift earlier, reaching 9:00 AM in late 2026. Data capture—for all five instruments—continues at ~100%.

Akira Miura [JSS—*Deputy Director*] described the status of the Terra Ground Data System. After the October Morning Constellation-exit maneuver, the Level-1A (L1A) ASTER processing failed. JSS is investigating the cause of this failure. All acquired data are meanwhile being archived for later processing.

Hitomi Inada [JSS—*ASTER instrument Manager*] summarized the status of the ASTER instruments. All systems are performing nominally—with the SWIR instrument having been turned off in October. Telemetry of monitoring systems on ASTER report that systems are currently stable.

The next three presenters focused on issues related to ASTER data acquisition, storage, and distribution in the U.S. and Japan.

Frank Lindsay [GSFC] discussed the Earth Science Data and Information System (ESDIS), which manages NASA's DAACs and provides guidance for post-mission ASTER archive activities. He showed several documents during his presentation that describe the required standards for information archiving. These documents can be viewed at go.nasa.gov/3lFn7mQ.

Chris Torbert [LPDAAC] presented the status of ASTER data processing at the LPDAAC. In Fiscal Year 2022, LPDAAC distributed eight million files of Global Digital Elevation Model (GDEM) data, and six million files of ASTER L1 data.

Koki Iwao [AIST] summarized ASTER data processing at AIST. He reported that the number of scenes had reached four million this year. AIST continues to distribute ASTER DEMs and pseudo-true-color composites. The LPDAAC, along with other NASA organizations, is moving data sets to the Earthdata Cloud, for processing and distribution.

The plenary session ended with a series of presentations where the speakers highlighted other missions of interest to the ASTER ST. **Osamu Kashimura** [JSS] reported that data from the Japanese Ministry of Economy, Trade, and Industry's (METI) Hyperspectral Imager Suite (HISUI) on the International Space

Station (ISS), would be released to the public in 2023. **Michael Abrams** presented an update on the joint NASA–U.S. Geological Survey (USGS) Landsat program, and on NASA's Earth Surface Mineral Dust Source Investigation (EMIT) hyperspectral instrument, also on ISS. **Simon Hook** [JPL] described the status of the multispectral thermal infrared (TIR) on the ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), and also spoke about NASA's future Surface Biology and Geology (SBG) mission—which is part of the planned Earth System Observatory.

Applications Working Group

The applications session provided a sampling of the wide variety of applications that make use of data from ASTER, as summarized below.

ASTER has proven to be a workhorse when it comes to applications, which, over the last two decades, have run the gamut from social phenomena, e.g., monitoring urban sprawl and slum growth, to geochemical and geophysical phenomena, e.g., deriving thermal inertia for geologic mapping, volcanism, and its consequences—including near-real-time (NRT) monitoring of ash- and sulfur dioxide (SO₂)-rich volcanic plumes—see **Figure 1** below—and seismic events. The presentations in this session highlighted a host of other applications as well, clearly demonstrating the wide and deep utility of ASTER applications.

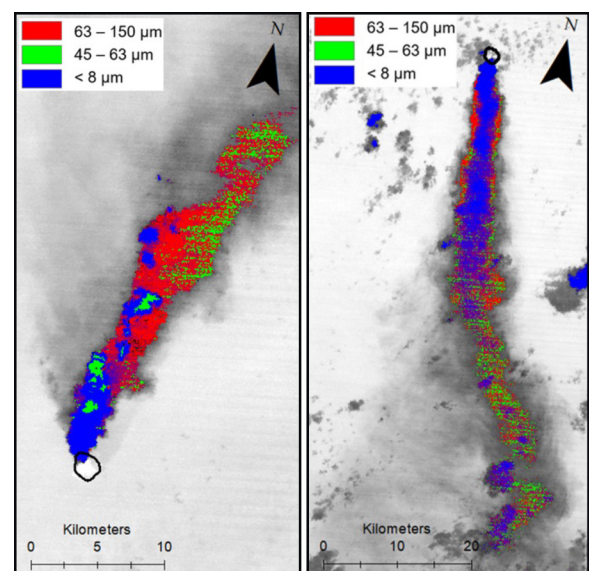


Figure 1. Particle size distribution of Nishinoshima eruption ash plume based on ASTER daytime thermal data acquired July 24, 2020 [left]; and on ASTER nighttime thermal data acquired July 31, 2020 [right]. The island is at the bottom of image on the left and the top of the image on the right. **Figure credit:** Daniel Williams/Pitt

³Terra was part of the Morning Constellation, a formation of satellites that had Equator crossings in the late morning around 10:30 AM (and late evening, at about 10:30 PM) Landsat-8 and -9 are still in the Morning Constellation.

Calibration/Validation Working Group

This working group is responsible for monitoring the radiometric performance of ASTER’s visible-near-infrared (VNIR) and TIR instruments. For the VNIR, calibration and validation are performed by analysis of onboard calibration lamps and measurements of pseudo-invariant ground targets during field campaigns.

Reports on ASTER calibration and validation activities covered a wide range of activities. There were reports that Level-1 (L1) data processing is progressing, that L2 production is up to date, that calibration lamp trends are largely consistent, that the blackbody source onboard Terra is stable, and on aspects of lunar calibration. There were also presentations about the eight successful TIR field campaigns that have occurred since the last meeting in June 2019, and how onboard calibration is keeping the designed accuracy to less than 1 K—see **Figure 2** below. Of note is that, to date, over 100 million GDEM files have been ordered—clear testimony to the utility of ASTER’s calibrated and validated data.

Temperature-Emissivity Working Group

This group is concerned with ASTER’s kinetic temperature and emissivity (T-E) products. They also discuss applications of these products and review the status of the nighttime TIR global map program. Activities in this area include developing microbolometer TIR

cameras—now with one for high temperatures, and one for lower. Comparing spaceborne temperature versus *in situ* measurements using LandBrowser (a new tool to search, browse, and download satellite data that can be accessed at gsrt.digiarc.aist.go.jp) revealed systematic differences between the two sources—see **Figure 3** on page 24. Researchers noted that there have been problems with emissivity retrievals in volcanic plumes, and, as a consequence, the T-E Separation algorithm sometimes gives anomalous results in ash-rich clouds. Data processing and algorithm development continue, including developing a VIIRS⁴–ASTER 375-m near-real-time land-surface temperature algorithm using ASTER emissivity for corrections. The precision of nighttime ASTER emissivity images, which involved a comparison ASTER emissivity using NCAR–NCEP and MOD07 water profiles,⁵ showed increased errors with increased water vapor. In a new approach, research is underway to evaluate the performance of generative adversarial network (GAN) for pseudovisible color transformation of TIR images.

⁴ VIIRS stands for Visible Infrared Imaging Radiometer Suite, which flies on the Suomi National Polar-orbiting Partnership (Suomi NPP), as well as on NOAA-20 and NOAA-21.

⁵ NCAR–NCEP stands for National Center for Atmospheric Research (NCAR)–National Centers for Environmental Prediction (NCEP). They provide a joint globally-gridded water profile that is continually updated. MOD07 is a water profile product using data from the Moderate Resolution Imaging Spectroradiometer (MODIS).

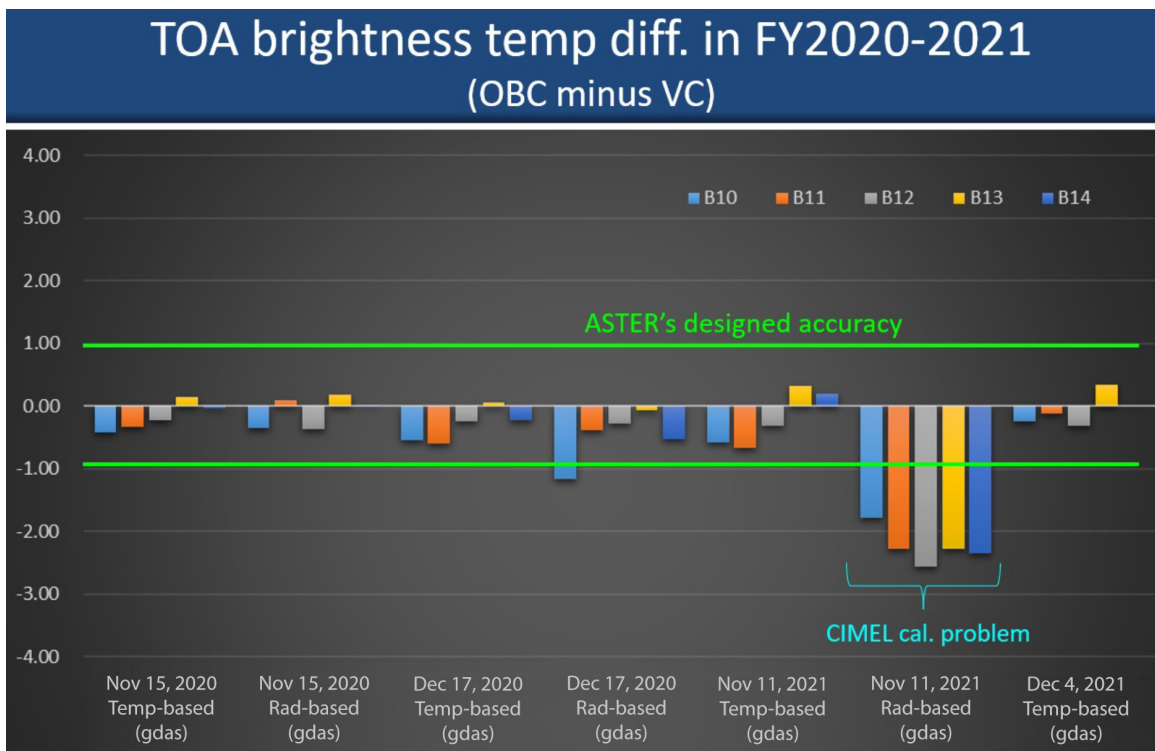


Figure 2. Validation of ASTER TIR bands at Lake Kasumigaura, Japan. Comparison of *onboard* calibration (OBC) minus *vicarious* calibration (VC) via *in situ* measurements obtained by a CIMEL Electronique (CIMEL) radiometer observing the lake surface. With the exception of November 11, 2021—when the CIMEL malfunctioned—the matchup is well within ASTER’s performance specifications. **Figure credit:** Hidoyuki Tonooka/IU

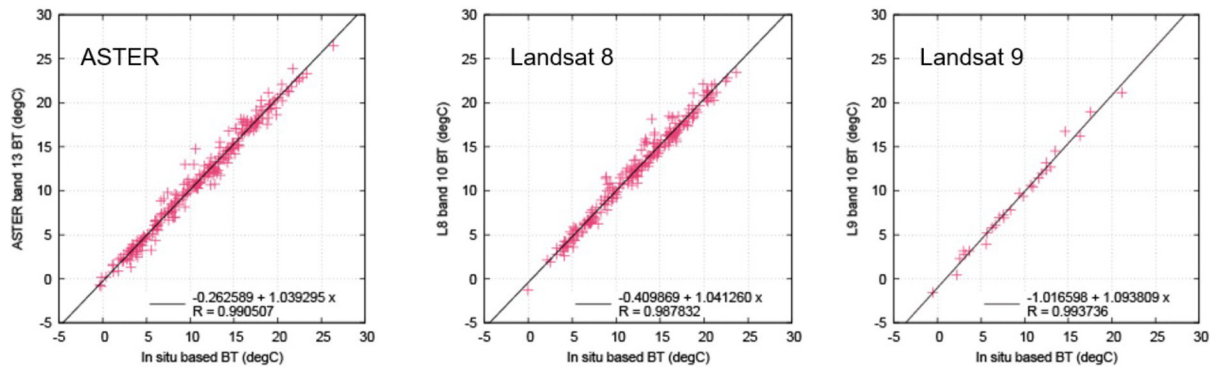


Figure 3. Top of atmosphere brightness temperature (BT) versus 10 μm bands for ASTER [*left*], Landsat 8/Thermal Infrared Sensor (TIRS) [*center*] and Landsat 9/TIRS-2 [*right*]. Negative offset and slope less than 1 imply that *in situ* BT is overestimated at lower temperatures and underestimated at higher temperatures. **Figure credit:** Shunyu Suzuki/IU

Operations and Mission Planning Working Group

This working group oversees and reviews the acquisition programs executed by the ASTER scheduler. Because ASTER data acquisitions have to be scheduled every day (due to ASTER's average 8% duty cycle), an automatic program was developed to select ~600 daily scenes from the possible 3000+ in the request archive. **Tetsushi Tachikawa** [JSS] reviewed the status of acquisition scheduling. Urgent observations receive the highest priority and can be scheduled close to acquisition time. Approximately 70 scenes are programmed per month, with over 95% acquisition success.

By contrast, global mapping data acquisitions receive the lowest priority and are used to fill in the scenes for the daily quota. ASTER's goal is to acquire at least one cloud-free image each season for every place on Earth. Due to persistent cloud cover, success is typically ~85% after several years, at which time the program is restarted. For example, on October 1, 2022, having achieved 83% success with acquisitions, ASTER was restarted. (The last such restart was exactly two years earlier on October 1, 2020.)

The thermal group submits areal requirements to acquire global nighttime coverage with the thermal bands. After the restart in October, the thermal group was asked to prepare new areas-of-interest acquisitions covering areas that were not imaged previously, either because of persistent clouds, or because their priorities were too low. Several other acquisition programs focus on islands, volcanoes, glaciers, and cloudy areas. The global volcano image acquisition program will continue with no change to the observation parameters. Acquisition of images of islands and over cloudy areas will also continue in current form. The global glacier acquisition program was modified to increase the imaging time window for some regions.

Closing Plenary Session

The chairpersons of each of the WGs presented summaries of presentations and discussions of their sessions. The overall consensus of participants was that ASTER continues to perform nominally, with no change since the 2019 meeting. Updates of the calibration coefficients took place in 2020, incorporating results from onboard calibration sources, the 2017 Deep Space Lunar Calibration Maneuver, and field-based validation measurements. The GDEM Version 3 and the new ASTER Water Body Dataset were released in July 2019. NASA and METI signed a Diplomatic Note, extending joint operation of the ASTER project for an additional seven years, until October 2026. The Science Team forwarded recommendations to the LPDAAC concerning which ASTER products to archive at the end of the Terra mission.

Conclusion

The fifty-first ASTER Science Team Meeting was a success, after an absence of face-to-face meetings for over three years. Attendance by almost the entire joint science team resulted in presentations of new ASTER science results, lively discussions, and resolution of future archiving issues. Plans were made for the fifty-second meeting in mid-to-late 2023, at the same Tokyo venue. ■

Acknowledgments

Work by the lead author of this article was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

Phytoplankton May Be Abundant Under Antarctic Sea Ice, Study Suggests

Michael Carlowicz, NASA Headquarters, michael.j.carlowicz@nasa.gov

in the news

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*.

A decade ago, scientists on a NASA-sponsored ocean expedition found massive populations of phytoplankton blooming beneath sea ice in the Arctic Ocean.¹ Now scientists using underwater instruments and a NASA satellite have found evidence of potentially significant blooms beneath the sea ice encircling Antarctica. The findings were recently published in the scientific journal *Frontiers*.²

Phytoplankton are to the ocean what grasses are to land: these floating, plant-like organisms soak up sunshine, sponge up mineral nutrients, and create their own food (energy) through photosynthesis. Phytoplankton grow just about anywhere there are open, sunlit patches of ocean. When conditions are right, these collections of microscopic cells can blossom to scales that are visible from space.³ They are a critical

food source for other life in the ocean and a key carbon recycler and disposer for the planet.

But until recent studies, the conventional wisdom was that ice cover prevented the growth of phytoplankton for most of the year in the ocean around Antarctica because very little sunlight could penetrate to the water below. However, new evidence shows there are just enough cracks, thin spots, and gaps to let sufficient daylight through the sea ice—e.g., see **Photo** below.

“Around Antarctica, the compact sea ice seems pretty impenetrable to light,” said **Chris Horvat** [Brown University], the lead author of the new study. In the wide and coarse views from most satellites, ice cover can appear uniform and sheet-like, reinforcing the idea that light would be too scarce and faint for plant-like life below.

But viewed from and below the ocean surface—and now with the laser eyes of NASA’s Ice, Cloud and land Elevation Satellite 2 (ICESat-2)—scientists see

¹ To learn more about the Arctic phytoplankton blooms, see go.nasa.gov/3XzSNr8.

² The full article can be viewed at go.nasa.gov/3YMQRg0.

³ Examples can be viewed at go.nasa.gov/3C2XXSi.

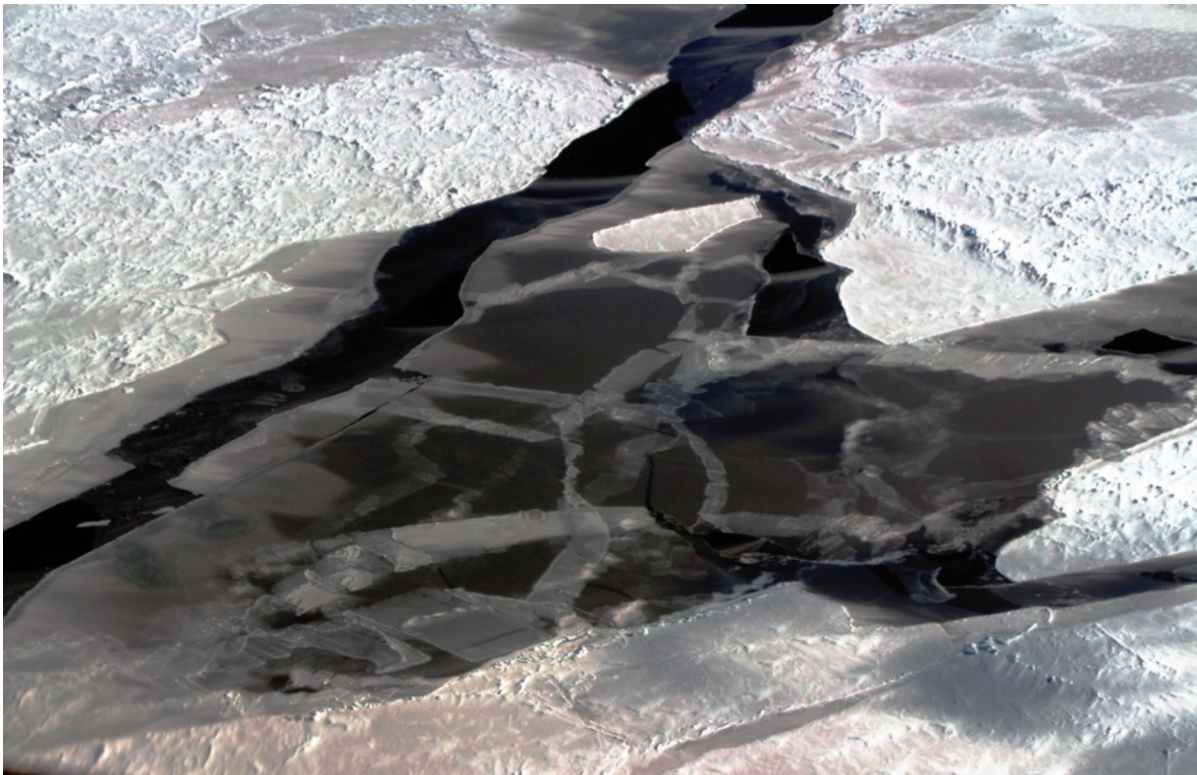


Photo. With underwater instruments, computer models, and NASA’s ICESat-2 satellite, scientists determined that phytoplankton are blooming under Antarctic sea ice. As can be seen in this close-up photograph of sea ice over the Weddell Sea in Antarctica, there are just enough cracks, thin spots, and gaps to let sufficient sunlight through the sea ice in the Southern Ocean to allow phytoplankton to grow. **Photo credit:** John Sonntag/NASA

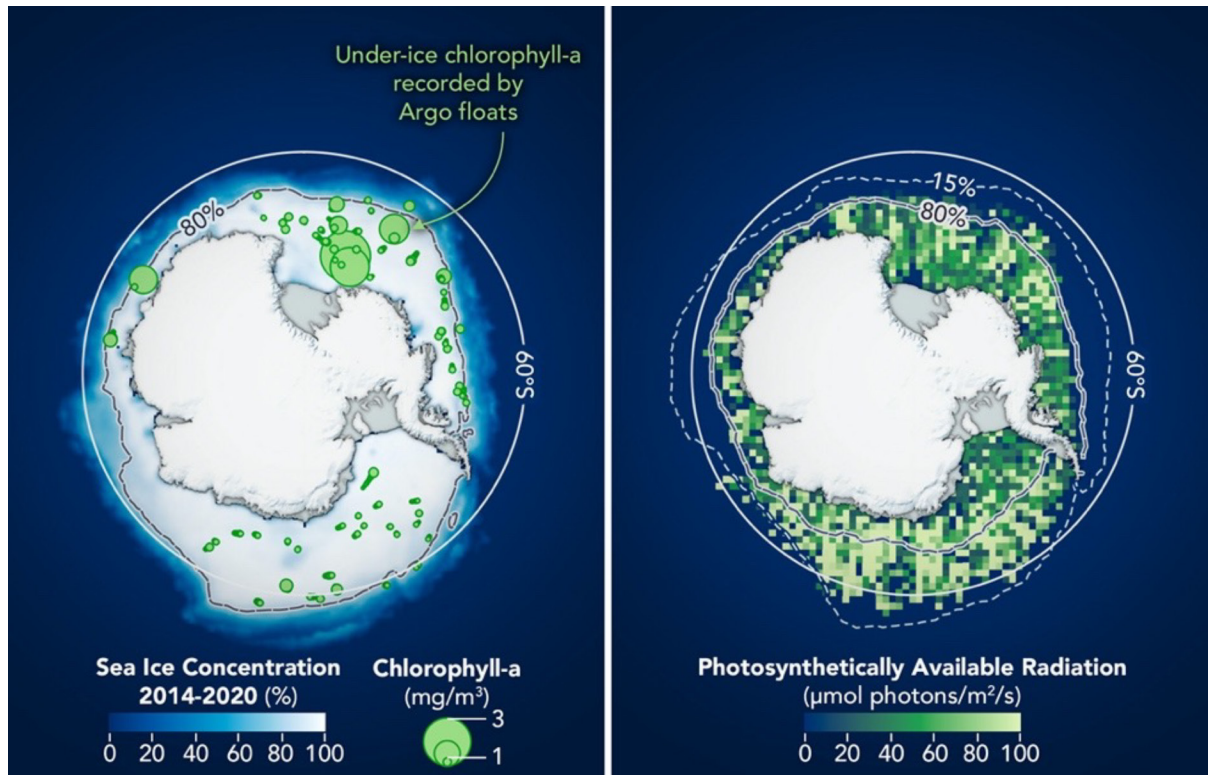


Figure. Based on data from underwater instruments and climate models, the left map shows the location and abundance of likely phytoplankton blooms and their position within the icepack from 2014–2020. The right map combines satellite data and models to show where there was likely enough light penetrating the ice to sustain blooms. **Figure credit:** Joshua Stevens/NASA Earth Observatory

that Antarctic sea ice is actually riddled with fractures and openings. Sunlight slips through the cracks and provides the energy for notable under-ice blooms in the Southern Ocean.

Horvat and colleagues pulled together three lines of evidence. First, they examined data collected by Argo floats—underwater instruments that measure different properties of the ocean from the surface to roughly 7000 ft (2000 m) in depth. The cylinder-shaped instruments drift with currents and rise and fall through the ocean, occasionally surfacing to relay their data back to land-based laboratories via satellite transmitters. Deployed since 2014 these floats can detect the presence of chlorophyll and particulate carbon in the water, both of which can indicate the presence of phytoplankton.

Examining data from more than 2000 under-ice dives over seven years, the research team found that nearly all measurements showed phytoplankton accumulating even before the sea ice had retreated in Southern Hemisphere spring and summer—see **Figure** above. In a quarter of those measurements, enough phytoplankton had amassed to suggest blooming events were underway.

Given those observations, the team analyzed ice conditions with ICESat-2 data to develop a picture of where and how much light was penetrating through the cracks and openings in Antarctic sea ice. The primary instrument on ICESat-2 is the Advanced Topographic Laser Altimeter System (ATLAS), which sends pulses of light toward Earth’s surface and then measures—to within a billionth of a second—how long it takes individual photons to return to the satellite. From this information scientists can derive the height of sections of ice—and also spot the cracks and gaps between them.

Finally, building off ice-cover models from the Coupled Model Intercomparison Project (CMIP) Phase 6,⁴ Horvat and colleagues estimated the location and thickness of Southern Ocean ice cover and how it moved. They also derived estimates of photosynthetically available radiation (PAR), a measure of the sunlight needed to sustain blooms in the ocean. They found 1.2 to 1.9 million mi² (3 to 5 million km²)—i.e., an area larger than India—of the ice-covered Southern Ocean could allow enough light to penetrate and support some under-ice blooms.

⁴ To learn more about CMIP, see wcrp-climate.org/wgcm-cmip.

“Scientists have talked about the potential for blooms here, but this is the first time we are seeing them under the ice in Antarctic waters,” said Horvat. “The blooms have probably always been there, we just haven’t had the capacity to observe them. This finding opens up a whole new way of thinking about life around and under the ice. Sea ice is more interesting and diverse than people think, and it can support a wide range of ecological communities.”

Horvat is part of a team that is developing new sea ice products from ICESat-2 to get an even better sense of the mosaic-like texture of sea ice. They also hope to follow up on the under-ice bloom study by investigating how extensive and how frequent the blooms are, and if there is seasonality to them.

“The paper describes some interesting observations in a relatively poorly studied region of the global ocean,” added **Michael Behrenfeld** [Oregon State University], who was not part of the study. “Under-ice blooms have earlier been reported in the Arctic, but this new study clearly documents these types of blooms in the Southern Ocean. An important difference between these two polar regions is that the total area of suitable conditions for under-ice blooms is much greater around Antarctica. Thus, when integrated over area, these Southern Ocean blooms may be a very large mass of plankton.” ■

The Editor’s Corner continued from page 13

high-voltage power supply (HVPS),⁶ with final decommissioning planned for no later than March 31, 2024, following a series of orbit-altitude lowering burns to ensure atmosphere re-entry within 25 years. Science Team activities will continue during Phase F for both missions, including reprocessing of the datasets, calibration and validation of data, and science research activities. Phase F will be fully closed out approximately two years after it begins..

The success of these and other Earth science missions has been made possible as a result of dedicated efforts of countless individuals over the past several decades. Few people embody the scientific commitment more than **Claire Parkinson** [GSFC], who retired from NASA December 31, 2022—after more than 44 years.

Within NASA, Claire is perhaps best known for her role as Aqua Project Scientist, which she held from May 1993 until her retirement. In that role, she participated in the development of the Aqua mission from its initial concept through various EOS concept redesigns. She effectively worked with Aqua instrument teams, mission operations, and the science community over the years and lead the mission through numerous Senior Reviews as Aqua (launched in 2002) continued well beyond its designed six-year life. Claire started at GSFC in 1978 as a climatologist, and had been a GSFC Senior Fellow since 2005.

Claire studies polar sea ice and its connections to the rest of the climate system. She has analyzed satellite data, created a computer model of sea ice, and trekked to both the Arctic and Antarctic to study polar ice up close. Claire has authored well over a hundred scientific papers, as well as atlases, books, and

technical memoranda. She is a member of the National Academy of Sciences, the National Academy of Engineering, the American Philosophical Society, and the American Academy of Arts and Sciences. To read Claire’s full biography see science.gsfc.nasa.gov/sed/bio/claire.l.parkinson.

Claire is one of the most hardworking people I know. My heartfelt congratulations on her retirement and sincere thanks for her years of exceptional service to NASA—and to the Aqua mission in particular. I wish her all the best in her future endeavors.

I’m delighted to report that **Lazaros Oreopoulos** [GSFC] has replaced Claire as the Aqua Project Scientist. Lazaros served as Aqua Deputy Project Scientist since 2010, thus allowing for a seamless leadership transition. Lazaros brings over two decades of experience to the position, having been at GSFC since 1997. His research focuses on the modeling and remote sensing of clouds, their impact on the Earth’s Radiation Budget, aerosol-cloud interactions, and many aspects of atmospheric radiative transfer for climate applications.

Replacing Lazaros as the Aqua Deputy Project Scientist is **Linette Boisvert**, who came to GSFC in 2009 while working on her PhD at the University of Maryland, College Park (UMD). Linette has worked with Aqua data for nearly all her publications, so she is quite familiar with the mission and its products. Since 2020, she has been the Assistant Lab Chief for GSFC’s Cryospheric Sciences branch, and prior to that served as Deputy Project Scientist for the IceBridge mission from 2018 until it ended in 2020. Her research interests center around understanding sea ice–atmosphere interactions in the Arctic.

⁶ The EIV and HVPS are both parts of CloudSat’s instrument, the Cloud Profiling Radar.

NASA Satellite Precipitation Data Joins the Air Force

Erica McNamee, NASA's Goddard Space Flight Center/Telophase Corporation, erica.s.mcnamee@nasa.gov

EDITOR'S NOTE: This article is taken from [nasa.gov](https://www.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*.

Rain gauges are plentiful around the United States, but that's not the case elsewhere in the world—particularly over oceans and sparsely populated areas. That means scientists and other data users have to rely on satellite measurements—e.g., those provided by NASA's Global Precipitation Measurement (GPM) mission—to fill in the gaps.

The list of data users now includes the U.S. Air Force's 557th Weather Wing. For the first time, the Air Force meteorology unit has integrated the Integrated Multi-satellite Retrievals for GPM (IMERG) algorithm into its operational weather forecasts and advisories.

“The IMERG precipitation data are an invaluable input to global land surface characterization capabilities, as well as input to numerical models,” said **Maj. Kurtis A. Schubeck** [U.S. Air Force, Directorate of Weather Headquarters—*Chief of Weather Prediction and Modeling Strategy*].

NASA's IMERG product combines observations from a network of satellites affiliated with the GPM mission in order to estimate precipitation over most of Earth's surface. Using a data blending technique, IMERG pieces together observations from several different

satellites into one complete picture of global precipitation. See **Figure** for an example of IMERG data.

In some parts of the world, e.g., large sections of Africa, ground-based measurements of precipitation are minimal. That means estimates from satellite sources such as IMERG are sometimes the only way for the U.S. Air Force to obtain information on rainfall and precipitation in a region. IMERG allows precipitation estimates to be more comprehensive and available at near-real-time intervals.

According to **Jerry Wegiel** [Science Applications International Corp. (SAIC)—*Principal Investigator for the Department of Defense (DoD) and Intelligence Community components of the NASA Land Information System (LIS)*], “IMERG is a one-stop shop for how much precipitation is falling around the world and, arguably, it's one of the most accurate.”

Modeling tools managed by NASA and used by DoD quantify how the global water cycle is changing based on information from remote sensing. Reliable estimates of rainfall and other precipitation are vital for allowing the modeling system to determine where the water will go—whether flowing into rivers, evaporating back into the atmosphere, or soaking into soils.

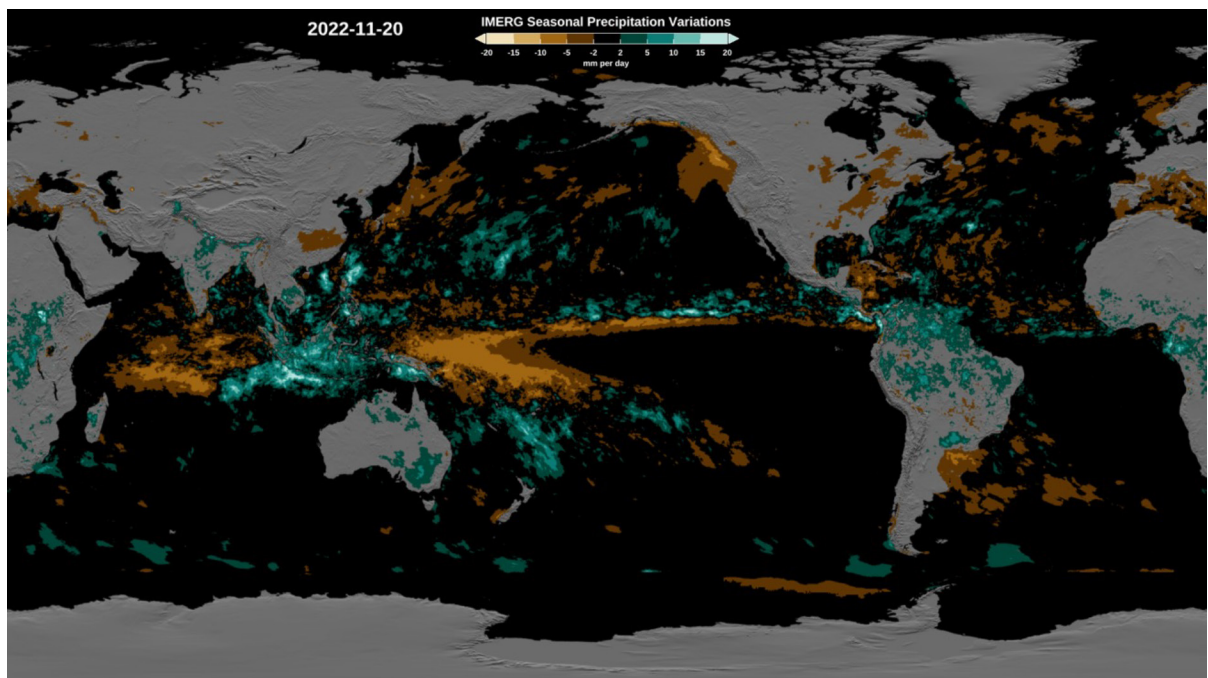


Figure. An image of the global precipitation variation from Integrated Multi-satellite Retrievals for GPM (IMERG) data, from Nov. 20, 2022. To learn more about this image and download supporting multimedia in high definition formats, see svs.gsfc.nasa.gov/4897. **Figure credit:** NASA's Scientific Visualization Studio

“Our land characterization estimates are critically reliant on precipitation inputs,” said **Sujay Kumar** [NASA’s Goddard Space Flight Center (GSFC)—*Principal Investigator for LIS*]. “Unless you have the right precipitation, you’re not going to be able to simulate downstream impacts on land surface states.”

With IMERG data now incorporated, the Air Force’s operational land surface models—which simulate changes in soil temperature, soil moisture, runoff, and snowpack across the globe in 10 km (6.2 mi) blocks—will have more accurate estimates. DoD will now be able to better plan mobility movements using more accurate hydrology and land-trafficability

estimates. “Incorporation of NASA data and algorithms within the Air Force weather forecasting represents an important demonstration of the value and quality of these data to support our federal partner’s operational requirements,” said **Dalia Kirschbaum** [GSFC—*Director of the Earth Sciences Division*]. “We look forward to continuing this engagement to providing key data to support and advanced our joint activities.” ■

The Editor’s Corner continued from page 27

My congratulations to Lazaros and Linette on their new positions and my thanks for their willingness to serve.

Finally, this issue provides coverage of two recent NASA Science Support Office (SSO) outreach events: Pecora 22 and COP-27. The Pecora 22 conference, which was held October 23–28, 2022, in Denver, CO, was the latest in a series of symposia named after William T. Pecora, the USGS Director who helped initiate the Landsat program in the 1960s. NASA’s Pecora 22 exhibit celebrated 50 years of NASA–USGS collaboration on Landsat. Turn to **page 4** to learn more about NASA’s participation in Pecora 22.

NASA’s Earth Science Division collaborated again with the U.S. Department of State to support the

U.S. Center at the 27th United Nations Framework Convention on Climate Change Conference of the Parties (COP27). The meeting took place November 6–20, 2022, in the resort town of Sharm El-Sheikh, Egypt. The NASA Hyperwall was a main attraction at the U.S. Center. DoS representatives used the Hyperwall to display visuals for their panel discussions and NASA Earth scientists gave two presentations per day. The 15 Hyperwall presentations delivered by NASA senior climate scientists during COP27 highlighted how climate adaptation and mitigation efforts cannot succeed without robust climate observations and research. Turn to **page 10** to learn more about NASA’s participation in COP27. ■

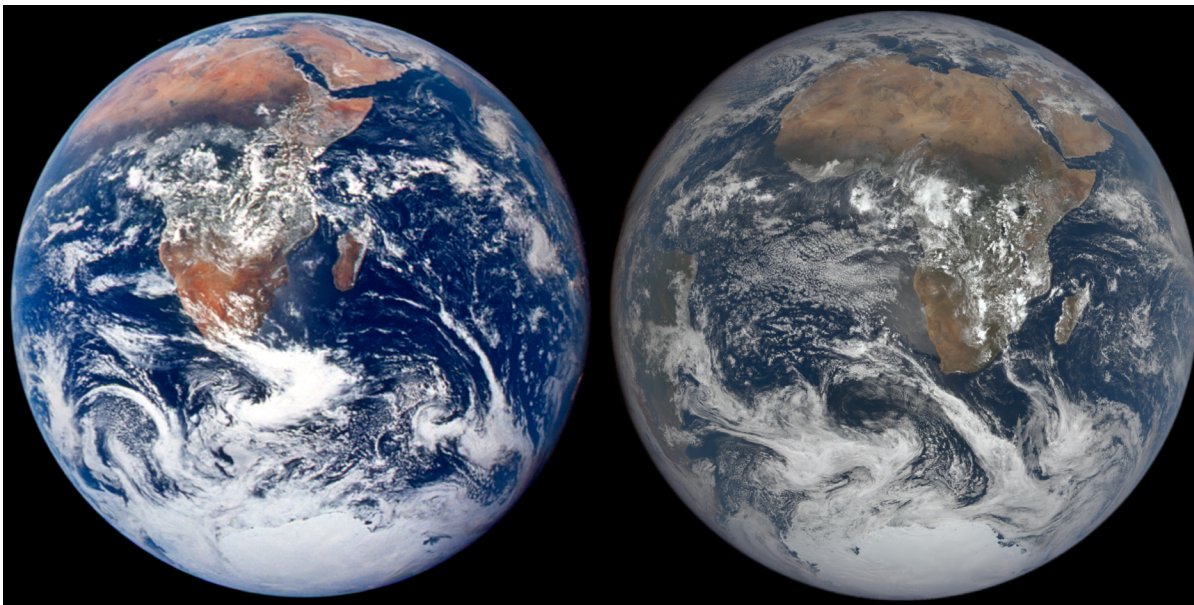


Photo. On December 8, 1972, Apollo 17 astronauts captured an image of the Earth that was destined to become an icon [*left*]. This first true-color image of the fully illuminated Earth became known as the “Blue Marble,” and has been replicated using data from Earth observing satellites over the past 50 years. On December 7, 2022, the Earth Imaging Polytechnic Camera (EPIC) on the National Oceanic and Atmospheric Administration’s (NOAA) Deep Space Climate Observatory (DSCOVR) mission obtained a series of images intended to replicate the original Blue Marble. Shown here [*right*] is the twelfth image in the series of twelve images taken at 10:39 UTC—the precise time that Apollo 17’s crew obtained the original Blue Marble photo. Turn to page 14 to read about the most recent DSCOVR Science Team Meeting. **Photo credit:** NASA

NASA to Cancel GeoCarb Mission, Expands Greenhouse Gas Portfolio

Tylar Greene, NASA Headquarters, tylar.j.greene@nasa.gov

Karen Fox, NASA Headquarters, karen.c.fox@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*.

On November 28, 2022, NASA announced that it intends to cancel development of its GeoCarb mission, and instead implement a plan for pursuing alternate options to measure and observe greenhouse gases.

Newer options to make key greenhouse gas measurements are emerging that were not previously available for the agency when considering GeoCarb. For example, NASA's newest instrument that launched in July to the International Space Station—the Earth Surface Mineral Dust Source Investigation (EMIT)—can measure methane.¹

“Decisions like this are difficult, but NASA is dedicated to making careful choices with the resources provided by the people of the United States” said **Thomas Zurbuchen** [NASA Headquarters—*Associate Administrator for Science*]. “We look forward to accomplishing our commitment to state-of-the-art climate observation in a more efficient and cost-effective way.”

NASA plans to augment its greenhouse gas observations by prioritizing a greenhouse gas mission as the first *Earth System Explorers* mission,² obtaining greenhouse gas data from international and commercial partners, extending the Orbiting Carbon Observatory-3 (OCO-3) mission aboard the International Space Station, and conducting additional airborne observations. Additionally, NASA's Earth System Observatory, slated to launch by the end of the decade, is the next generation of missions to observe Earth, and will provide a three-dimensional, holistic view of our planet to help better understand what its changes mean for humanity.

“NASA prioritizes understanding how our home planet is changing—and greenhouse gases play a central role in that understanding,” said **Karen St. Germain** [NASA HQ—*Director of the Earth Science Division*]. “We are committed to making key methane and carbon dioxide observations, integrating them with measurements

collected by other national, international, and private sector missions, and making actionable information available to communities and organizations who need it to inform their decisions.”

NASA reached the decision about GeoCarb because of technical concerns, cost performance, and availability of new alternative data sources—as well as to keep the Earth Science portfolio aligned with overall science priorities. GEOCarb sought to probe the natural sources and exchange processes that control carbon dioxide, carbon monoxide, and methane in the atmosphere over the Americas.³ NASA will collaborate with the principal investigator team at the University of Oklahoma to plan an orderly close out the project.

The current estimated life cycle cost estimate for GeoCarb is over \$600 million. This estimate is more than three times the life cycle cost at the time of selection, which was capped at \$170.9 million. The increased costs and delays of GeoCarb would have a detrimental impact on NASA's Earth Science portfolio, including delays of up to two years for the Earth System Observatory, which addresses the highest priorities for Earth Science as described by the National Academies. ■

¹ This capability was described in “The Editor's Corner” of the September–October 2022 issue of *The Earth Observer* [Volume 34, Issue 4, p. 3].

² UPDATE: The draft “Earth Explorers Announcement of Opportunity” was released on November 29, 2022, with comments of the draft due by January 20, 2023. The draft can be downloaded from nspires.nasaprs.com/external/solicitations/summary.do?solId=%7b07D045BC-6320-5E94-FBBB-C8C676365030%7d&path=&method=init.

³ GEOCarb traces its heritage back to the proposed GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission, which was identified as a Tier 2 mission in the the first (2007) Earth Science Decadal Survey. Tier 1 missions had highest priority for development, Tier 2 had medium priority, and Tier 3 had lowest priority. The 2007 report, “Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,” can be downloaded from go.nasa.gov/3lEqtXh.



NASA Earth Science in the News

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

EDITOR'S NOTE: This article is taken from [nasa.gov](https://www.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*.

Global Study Reveals Widespread Salt Marsh Decline, December 19, 2022, [mongabay.com](https://www.mongabay.com)

By analyzing satellite images from around the globe, NASA scientists determined that since the turn of the century an area of salt marsh twice the size of Singapore has disappeared. Severe storms were partially responsible for the loss, which resulted in “significant” carbon emissions, according to a study published in the journal *Nature* in November, which showed that between 2000 and 2019 the world lost 1055 mi² (2732 km²) of marsh and recovered 493 mi² (1277 km²)—some as a result of restoration by people. This resulted in a net loss of 561 mi² (1453 km²). Globally, salt marshes declined at a rate of 0.28% per year, according to the study.

Previously, up-to-date information on the rates and “hotspots” of salt marsh loss at the global level was limited, as were estimates of the resulting carbon emissions, according to **Anthony Campbell** [NASA's Goddard Space Flight Center (GSFC)/Biospheric Sciences Laboratory], the paper's lead author. Past estimates suggested much higher salt marsh losses of 1–2% per year. “We utilized the Landsat record to get at those numbers and then do an updated carbon budget for salt marshes, showing a decline in loss, but still significant emissions in salt marsh environments,” Campbell said. According to the study, salt marsh loss resulted in 16.3 million metric tons (16.3 Tg) of CO₂ emissions per year. That's the rough equivalent of the annual carbon output of around 3.5 million cars. The loss of marsh also reduced its capacity to store carbon.

The results are “sobering,” said **Peter Macreadie** [Deakin University (Australia), Blue Carbon Lab—*Director*], who was not involved in the study. “The results provide clarity about salt marsh distribution and extent. Unfortunately, salt marshes are losing ground, and future climate change will make these ecosystems more vulnerable.” Salt marshes are coastal wetlands that depend on tidal flows to maintain a delicate balance of seawater. They are found mainly in temperate regions around the globe, providing a range of ecosystem services. “This humble coastal vegetated [ecosystem] provides critical support for fish and fisheries; it provides habitat for some of the rarest species on the planet; it helps stabilize shorelines and prevents erosion;

and it is one of the most efficient and long-term carbon sinks on the planet,” Macreadie said.

Alongside other coastal ecosystems, however, salt marshes are under pressure from human activities. A study released earlier this year estimated that only 15.5% of the world's coastlines remain unaffected by human interference; a previous study showed that salt marshes in particular have lost 25–50% of their historic global coverage. Climate change is one of the greatest threats they face. Sea level rise can outpace the ability of salt marshes to adapt or it can push them further inland, where human-made barriers can block their expansion and ultimately reduce their extent in a process known as *coastal squeeze*. Other threats contributing to the global marsh decline include conversion to aquaculture, coastal erosion, eutrophication, drainage, mangrove encroachment, and invasive species.

By analyzing historical satellite images and comparing them over time, Campbell and his team found that the majority—64%—of salt marsh losses occurred in the U.S. and Russia, often as a result of hurricanes and coastal erosion. The largest loss of marshes ever documented occurred in North America between 2005 and 2009: about 109 mi² (282 km²) succumbed—much of it in areas battered by hurricanes. Some of the uncertainties that still remain include determining the full extent of salt marsh ecosystems around the world, whether factors in addition to coastal erosion explain marsh loss in the Arctic, and the extent of mangrove encroachment in areas such as Oceania. “Further analyses of satellite imagery are needed to fill such knowledge gaps,” Campbell said.

Salt marshes are recognized for their potential role as a nature-based solution to climate change, and as a way to mitigate some of its effects. Efforts are underway to restore and conserve them, as well as other coastal environments, to harness their ecosystem services. Restoring tidal flows, returning vegetation, and reducing coastal erosion are some of the techniques that are being implemented. “Currently, it's difficult to tell whether marshes collectively still serve as a carbon sink or are undergoing enough loss to become a net carbon emitter,” Campbell said. Whether humanity will be able to turn around the global decline to return them

definitively to being a carbon sink remains unclear. “One reason is the uncertainties about marshes’ carbon-storage capacity,” Campbell said.

William Austin [University of St Andrews (Scotland)] said it is “speculative” that improving the condition of marshes through “management interventions” would reduce emissions and strengthen marshes’ ability to store carbon. Even so, he said the paper does stake a claim for protecting salt marshes. “While we still probably lack adequate monitoring data to support the implementation of such policy change at scale, this seems a very significant nature-based solution that

would both support the case for carbon *and* nature,” he wrote. Tracking salt marshes and other coastal environments, such as seagrass meadows, with satellite technology is essential to “safely and consistently monitor these important blue carbon systems,” Campbell said. “With the spatial awareness of where they are and how they’re changing, we have a better ability to protect them and address areas that are hotspots of change,” he said. ■

NASA’s EMIT: Dust Detective Delivers First Maps from Space for Climate Science, October 17, 2022, *scitechdaily.com*

NASA’s Earth Surface Mineral Dust Source Investigation (EMIT)¹ mission aboard the International Space Station (ISS) produced its first mineral maps, providing detailed images that show the composition of the surface in regions of northwest Nevada in the U.S. and Libya in the Sahara Desert. Windy desert areas are the sources of fine dust particles that, when lifted by wind into the atmosphere, can heat or cool the surrounding air. But researchers haven’t been able to assess whether mineral dust in the atmosphere has overall heating or cooling effects at local, regional, and global scales. EMIT’s measurements will help them to advance computer models and improve our understanding of dust’s impacts on climate.

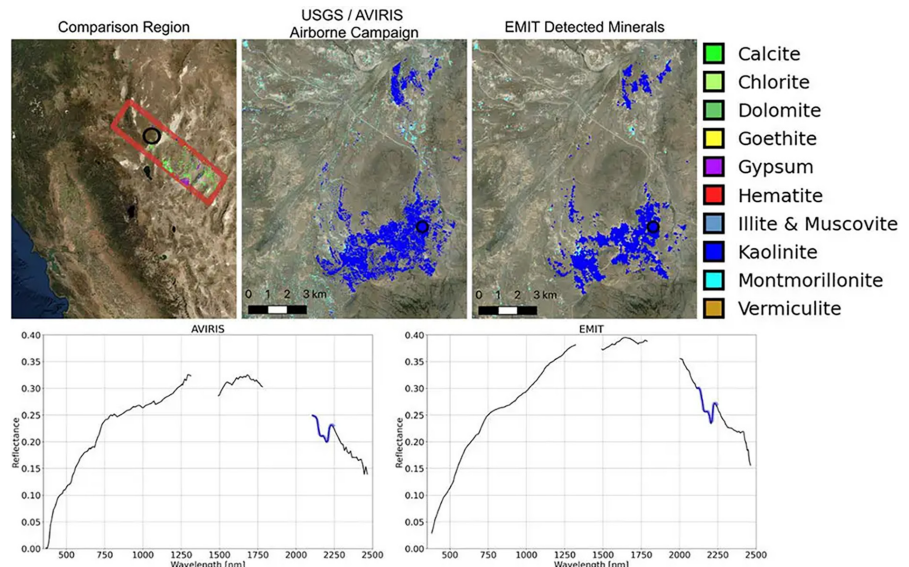
EMIT scientists at NASA/Jet Propulsion Laboratory (JPL) and the U.S. Geological Survey (USGS) created the maps to test the accuracy of the instrument’s

measurements, a crucial first step in preparing for full science operations. EMIT is the first of a new class of high-fidelity imaging spectrometers that collect data from space and produce better-quality data at greater volumes than previous instruments. “Decades ago, when I was in graduate school, it took 10 minutes to collect a single spectrum from a geological sample in the laboratory. EMIT’s imaging spectrometer measures 300,000 spectra per second—with superior quality,” said **Robert Green** [JPL—EMIT Principal Investigator].

“The data we’re getting from EMIT will give us more insight into the heating and cooling of Earth and the role mineral dust plays in that cycle. It’s promising to see the amount of data we’re getting from the mission in such a short time,” said **Kate Calvin** [NASA Headquarters—Chief Scientist and Senior Climate Advisor]. “EMIT is one of seven Earth science instruments on the ISS giving us more information about how our planet is affected by climate change.”

EMIT analyzes light reflected from Earth, measuring it at hundreds of wavelengths from the visible to the infrared range of the spectrum. Different materials

Figure 1: NASA’s EMIT mission recently gathered mineral spectra [right image, left graph] in northwest Nevada [left image] that match what the agency’s Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) instrument found in 2018 [middle image, left graph], helping to confirm EMIT’s accuracy. Both instruments found areas dominated by kaolinite, a reflective clay mineral whose particles can cool the air when airborne. **Credit:** NASA/JPL-Caltech/USGS



reflect light in different wavelengths. Scientists use these patterns, called spectral fingerprints, to identify surface minerals and pinpoint their locations.

The Nevada map (**Figure 1**) focuses on a mountainous area about 130 mi (209 km) northeast of Lake Tahoe, revealing locations dominated by kaolinite, a light-colored mineral whose particles scatter light upward and cool the air as they move through the atmosphere. The map and spectral fingerprint closely match those collected from aircraft in 2018 by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)—data that was verified at the time by geologists. Researchers are using this and other comparisons to confirm the accuracy of EMIT’s measurements.

The other mineral map (**Figure 2**) shows substantial amounts of kaolinite as well as two iron oxides, hematite, and goethite, in a sparsely populated section of the Sahara about 500 mi (800 km) south of Tripoli, in Lebanon, overlooking the eastern Mediterranean Sea. Darker-colored dust particles from iron oxide-rich areas strongly absorb energy from the Sun and heat the atmosphere, potentially affecting the climate.

Currently, there is little or no information on the composition of dust originating in parts of the Sahara. In fact, researchers have detailed mineral information of only about 5000 soil samples from around the world—requiring that they make inferences about the composition of dust. EMIT will gather billions of new spectroscopic measurements across six continents,

closing this gap in knowledge and advancing climate science. “With this exceptional performance, we are on track to comprehensively map the minerals of Earth’s arid regions—about 25% of the Earth’s land surface—in less than a year and achieve our climate science objectives,” Green said.

EMIT’s data also will be freely available for a wide range of investigations, including, for example, the search for strategically important minerals such as lithium and rare-earth elements. What’s more, the instrument’s technology is laying the groundwork for the future Surface Biology and Geology (SBG) satellite mission—part of NASA’s Earth System Observatory, a set of missions aimed at addressing climate change. “The technology took directions that I would never have imagined,” said **Gregg Vane** [JPL], the researcher whose graduate studies in geology helped inspire the idea for the original imaging spectrometer. “Now with EMIT, we’re using it to look back at our own planet from space for important climate research.”

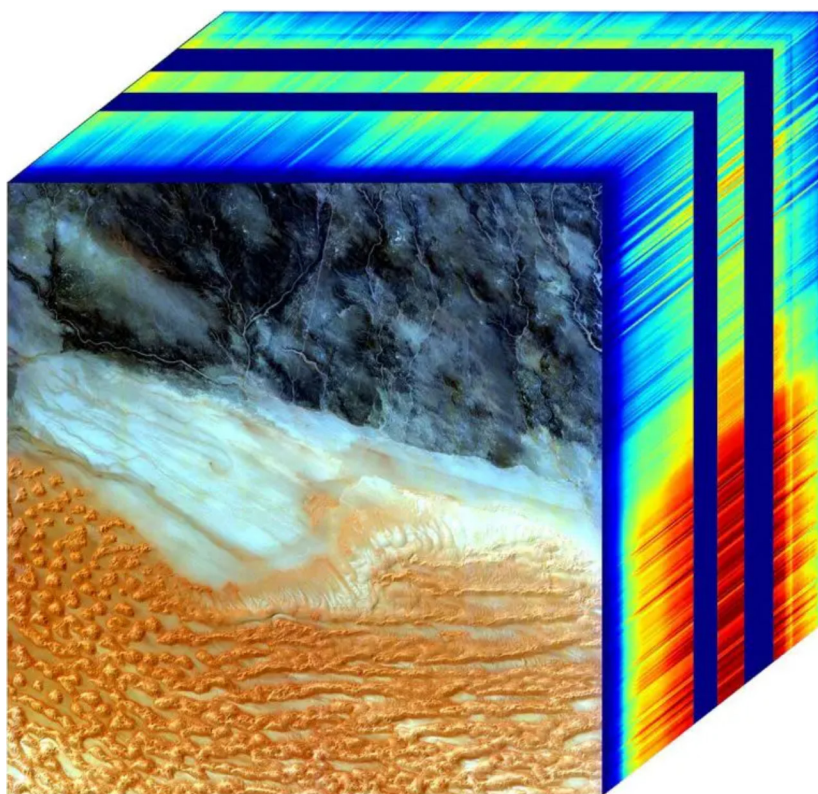


Figure 2: The image cube’s front panel is a true-color view of part of southwestern Libya observed by NASA’s EMIT mission. The side panels depict the spectral fingerprints for every point in the image, showing kaolinite, a reflective clay mineral, and goethite and hematite, iron oxides that absorb heat. **Credit:** NASA/JPL-Caltech

Earth Science Meeting and Workshop Calendar

NASA Community

April 20–21, 2023

Earth Day
Washington, DC and Online

Global Science Community

March 9–11, 2023

Commodity Classic
Orlando, Florida
commodityclassic.com

April 23–28, 2023

European Geosciences Union (EGU)
2023 General Assembly
Vienna, Austria, and Online
egu23.eu

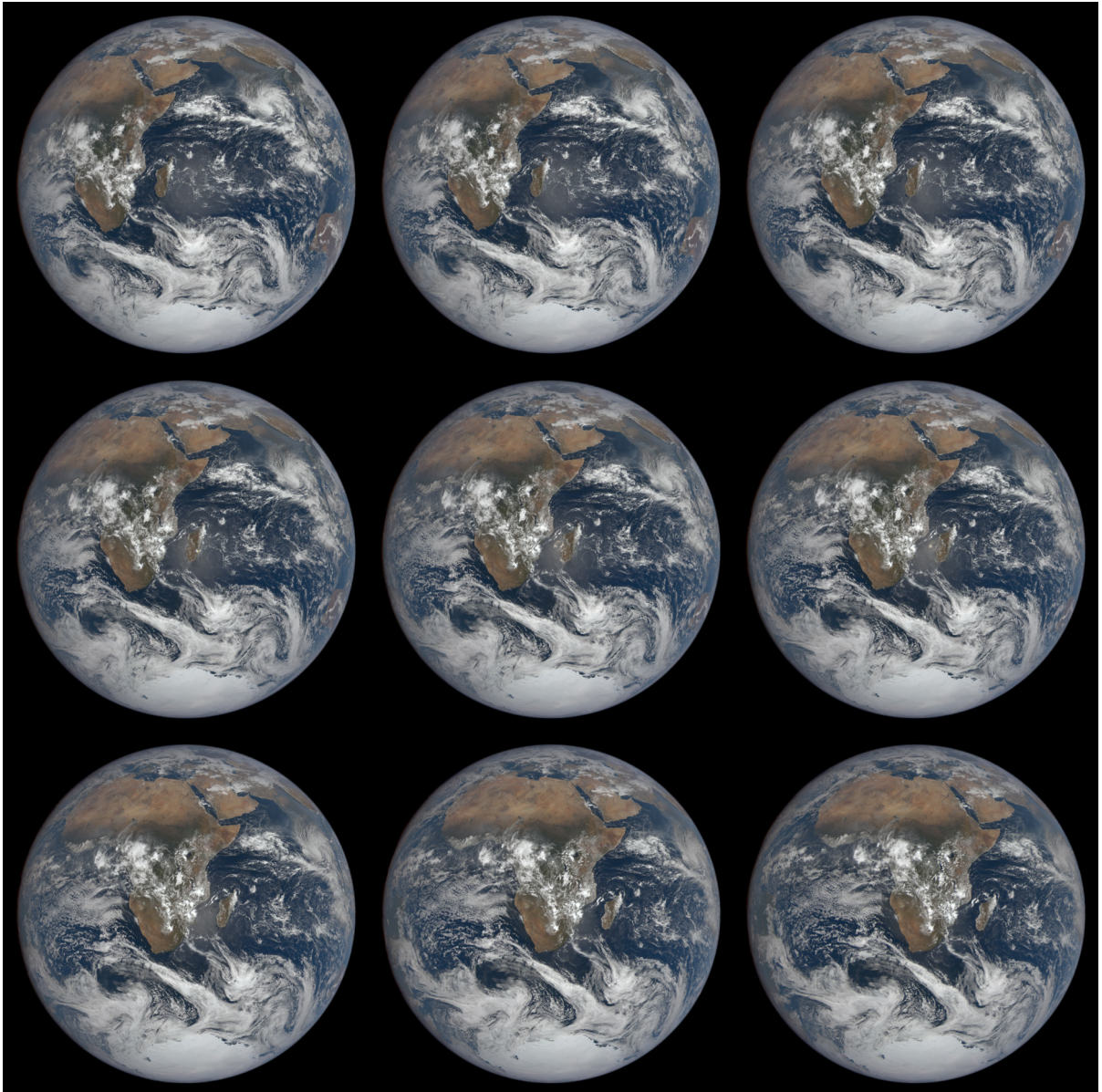


Photo. Shown here are nine of the twelve images taken on December 7, 2022 of the “blue marble” photo shoot as described on page 29. While the Apollo 17 image was taken from 18,000 mi (29,000 km) away from Earth, the DSCOVR photos are almost 1 million mi (1.6 million km) away at the L1 Lagrange point between the Earth and the Sun. To view all the EPIC images see go.nasa.gov/3S4qP5X. **Photo credit:** NASA

After nearly 34 years as a NASA print publication

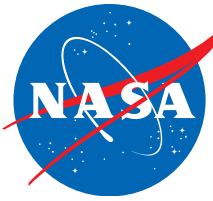
The Earth Observer is Going Green

In light of rising printing costs and ongoing efforts to reduce our carbon footprint, the NASA Science Support Office will discontinue publishing and mailing the print version of *The Earth Observer* newsletter. Starting with the January–February 2023 issue [**Volume 35, Issue 1**] a color/508-compliant PDF version will be published and posted exclusively online. To receive an email alert when each new issue is available, all current subscribers who haven't already done so must subscribe online using the QR code or link below.



Continue your subscription today!

Use the QR code above, or subscribe online:
eosps.nasa.gov/earth-observer-archive



Code 610
National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

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

Official Business
Penalty for Private Use: \$300

eospso.nasa.gov

The Earth Observer

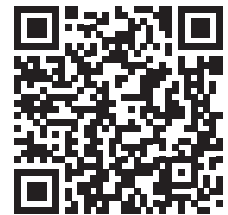
The Earth Observer is published by the Science Support Office, Code 610, NASA's Goddard Space Flight Center (GSFC), Greenbelt, MD 20771, and is available at *eospso.nasa.gov/earth-observer-archive*.

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, and point of contact if applicable. 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.

Beginning with the January–February 2023 issue *The Earth Observer* will **Go Green**. 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

Executive Editor:	Alan B. Ward (<i>alan.b.ward@nasa.gov</i>)
Associate Editor:	Doug Bennett (<i>doug.bennett@nasa.gov</i>)
Assistant/Technical Editor:	Mitchell K. Hobish (<i>mkh@sciential.com</i>)
Technical Editor:	Ernest Hilsenrath (<i>hilsenrath@umbc.edu</i>)
Design, Production:	Mike Marosy (<i>mike.marosy@nasa.gov</i>)



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

