Over Thirty Years Reporting on NASA's Earth Science Program

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The Editor's Corner

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Despite all the disruptions caused by the COVID-19 pandemic in the past two years—including at NASA Centers—the agency's fleet of Earth observing satellites have continued their observations of our home planet without disruption. This achievement is a tribute to the resiliency of our NASA and contractor workforce. Maintaining long-term continuity of measurements is vitally important to study changes in climate. There are updates to share on two of these long-running datasets: sea level height and solar irradiance.

On March 22, the U.S.–European Sentinel-6 Michael Freilich (S6MF) mission became the official *reference satellite* for global sea-level measurements—replacing Jason-3 in this role. This means that sea-surface-height data collected by other satellites will be compared to the information produced by S6MF to ensure their accuracy. S6MF carries on a nearly 30-year legacy started by the Ocean Topography Experiment (TOPEX)/Poseidon satellite, which began its mission to measure sea-surface height in the early 1990s. A series of successor satellites (Jason-1, -2, and -3) have carried on the effort since then, with S6MF being the most recent. (Its twin, Sentinel-6B, is slated to launch in 2025.)

As with any time series for climate studies, long-term records of sea-level height are needed to measure how much—and how fast—the oceans are rising. Shortly after its launch in November 2020, S6MF settled into orbit, flying 30 seconds behind its predecessor, Jason-3. Data were made public last year and are being used for tasks like weather forecasting, understanding changes in ocean currents and monitoring climate signals.

After data validation, the Sentinel-6 Validation Team (S6VT), and the set of Sentinel-6 Project Scientists endorsed S6MF as the reference mission. The official designation of reference mission was made by the Committee on Earth Observation Satellites (CEOS), with input from the S6VT, the Ocean Surface Topography Science Team (OSTST), and the Sentinel 6 Project Scientists, during a virtual OSTST meeting held on March 21-22.

Just as Jason-2 did when Jason-3 became the reference sea-level measuring mission in 2016, later this year Jason-3 will be moved into an *interleaved orbit*—meaning that, from its new position, the ground track for Jason-3 will run in between the ground tracks of successive orbits for S6MF. Jason-3 will keep measuring sea-level height from its new orbit. This measurement pattern effectively doubles the number

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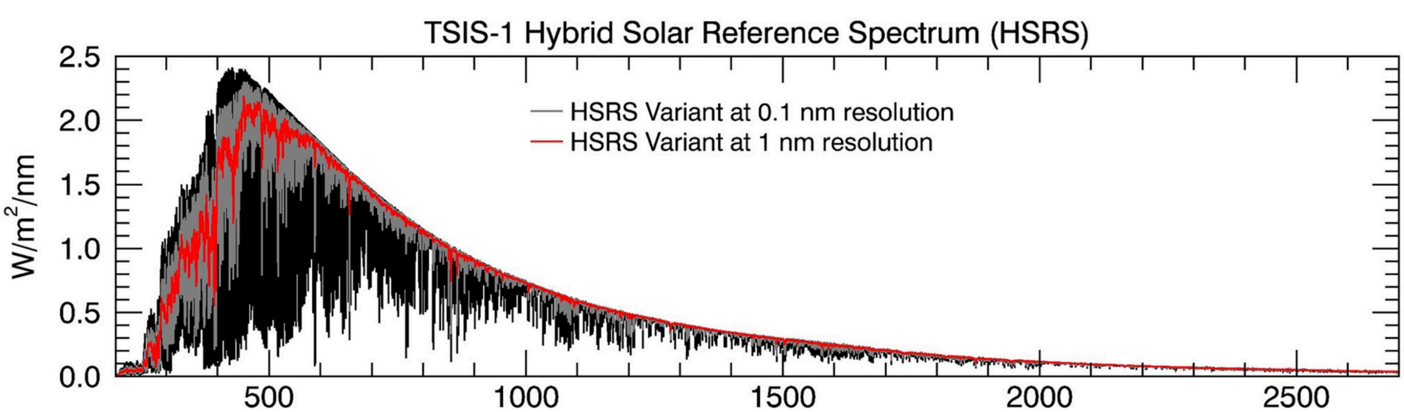

Figure. NASA's TSIS-1 mission continues to collect climate quality total solar irradiance (TSI) and solar spectral irradiance (SSI) data. The Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV) recently recommended the TSIS-1 Hybrid Solar Reference Spectrum (*lasp.colorado.edu/lisird/data/tsis1_hsrs*) become the new solar irradiance reference spectrum. Results are shown for two different variants: 0.1 nm resolution [gray] and 1 nm resolution [red]. **Image credit:** Laboratory for Atmospheric and Space Physics, University of Colorado Boulder.

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

of measurements collected by S6MF, helping to greatly increase the spatial resolution of sea-level measurements provided by both satellites.

Meanwhile, aboard the International Space Station, another crucial long-term climate record continues to grow. Now in its fifth year of continuous operation, the first implementation of NASA's Total and Spectral solar Irradiance Sensor (TSIS-1) continues to collect climate quality total solar irradiance (TSI) and solar spectral irradiance (SSI) data. TSIS-1 builds on the long-term, continuous measurements from the Solar Radiation and Climate Experiment (SORCE) mission that lasted over 17 years—ending in February 2020. TSIS-1 continues the TSI and SSI record with improved versions of the Laboratory for Atmospheric and Space Physics (LASP) Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM), both of which flew on SORCE. The TSIS-1 measurements secured the solar irradiance data record continuity for the near-term by achieving two years of operational overlap with SORCE during a period of solar minimum conditions and now continue into Solar Cycle (SC) 25. On March 23, the TSIS-1 based SSI reference spectrum was officially recommended by the CEOS Working Group on Calibration and Validation (WGCV)—see **Figure**.

The near future continuity of solar irradiance measurements is being secured as the instruments for the second implementation of NASA's Total and Spectral solar Irradiance Sensor (TSIS-2) are presently in final assembly and calibration with a launch readiness date in August 2024. TSIS-2 will launch on a free-flyer satellite (being built by General Atomics Electromagnetics Corporation) to achieve operational overlap with TSIS-1 (near the predicted SC 25 maximum) and will provide full TSI and SSI observational continuity.

On a related note, the next LASP–GSFC Sun-Climate Symposium is scheduled for May 16–20, 2022, in Madison, WI. The meeting focus is on, "Improved Climate-Record Reconstructions from Solar Variability and Earth System Observations." TSIS-1 results are expected to be featured prominently at this meeting.[1] *The Earth Observer* will summarize this meeting in an upcoming issue.

Related to future data acquisitions and processing, and in anticipation of the tremendous volume of data expected to be returned from the missions of the Earth System Observatory (ESO), NASA is actively working on data and information system plans (not unlike efforts that occurred as EOS was ramping up in the 1990s).[2]

The plan is for ESO to be an *open-source science* effort—with all activities, mission development, data processing, and mission results available without restriction. This is being done to ensure full transparency during the mission formulation process and to involve a wider,

[1] More information about the 2022 Sun–Climate Symposium, including a link to registration information, can be found at *lasp.colorado.edu/home/meetings/2022-sun-climate-symposium.*

[2] To read the story of the development and evolution of EOSDIS, see the "Perspectives on EOS" special issue of *The Earth Observer*, pp. 27–40—*go.nasa.gov/3vUL77f.*

more diverse community in the scientific process as close to the start of research activities as possible.[3]

To gather more input from the user community about their data requirements and explore potential ESO open-source science data processing architectures, NASA has established an Open Source Science for ESO Mission Science Data Processing Study, which is being co-led by NASA's ESDIS Project and JPL. The study team consists of a Steering Committee, which is managing the study, and a System Architecture Working Group (SAWG), which is responsible for conducting a Mission Data Processing System architecture trade study.

The study comprises three open workshops (in October 2021, March 2022, and August 2022)[4] to identify, assess, and review potential ESO data system architectures, with a four-month system architecture trade study conducted by the SAWG from April to July 2022. Additional stakeholder feedback will be solicited through public Requests for Information (RFI).

Turn to page 11 of this issue to read a summary of the first workshop.

The joint NASA–ISRO Synthetic Aperture Radar (NISAR) will be the initial ESO mission. NISAR will deploy two different kinds of radar systems to measure changes on Earth's surface to less than a half-inch, which will enable it to measure complex processes such as ice sheet collapse along with natural hazards including earthquakes, volcanoes, and landslides. It will also be an opportunity to test out data collection and processing techniques that will be used in subsequent ESO missions.[5]

Last but certainly not least, NASA recently participated in the Commodity Classic event in New Orleans, LA. This was NASA's first time participating in this event, which is one of the largest agricultural trade shows in the U.S.—"created for farmers, by farmers." NASA had a large presence in the exhibit hall and also offered a virtual participation option. Together, the *hybrid* meeting format—which seems to be becoming the "new normal" as the world slowly emerges from the COVID pandemic—was quite successful.

NASA has amassed vast amounts of environmental data, with satellite records going back decades. Through partnerships and the use of cutting-edge technology, the agency seeks to put that information, which is often not centralized in a single location, in the hands of organizations and individuals who can apply them to help solve real-world problems for the betterment of society, e.g., agriculture and farming.

NASA Administrator Sen. Bill Nelson and **Brad Doorn** [NASA Headquarters (HQ)—*Director of NASA's Water Resources and Agricultural Program*] both recorded welcoming remarks for the event. The Administrator's presentation was also shown during the in-person meeting to introduce **U.S. Secretary of Agriculture Tom Vilsack**, who gave the keynote address. Both presentations were accessible via NASA's virtual exhibit.

Karen St. Germain [NASA HQ—*Director of NASA's Earth Science Division*] attended the event and spoke at the NASA Hyperwall in the exhibit area. She also spoke to National Association of Wheat Growers (NAWG) board members and others about the agency's space assets and making them more readily available to farmers. "I think there's a natural partnership here because NASA is fundamentally a data agency," St. Germain said. "We already interact now, but what I really want to do is start the conversation on how we might do better together as we move forward into the future."

Turn to page 4 of this issue to read a summary of NASA's participation in the hybrid Commodity Classic event. ■

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

EOS	Earth Observing System
ESDIS	Earth Science Data and Information System
GSFC	NASA's Goddard Space Flight Center
ISRO	Indian Space Research Organisation
JPL	NASA/Jet Propulsion Laboratory

[3] For a broad discussion of NASA open-source science efforts, see "Open-Source Science: The NASA Earth Science Perspective" in the September–October 2021 issue of *The Earth Observer* [**Volume 33**, **Issue 5**, pp. 5-9, 11—*go.nasa.gov/3KBrsj8*].
[4] To learn more about the workshops and other components of the Open Source Science for ESO Mission Science Data Processing Study, see *go.nasa.gov/3vYbYiF*.
[5] To learn more about NISAR, visit *nisar.jpl.nasa.gov*.

NASA Earth Science Data: A Valuable New Commodity for America's Farmers

Alan B. Ward, NASA's Goddard Space Flight Center/Global Science & Technology, Inc. alan.b.ward@nasa.gov

The Commodity Classic event was NASA's second full venture into the world of hybrid events—the "new normal," where some participants attend in person at a particular location (in this case, New Orleans) while others engage online.

Introduction

From America's "breadbasket" (the Midwest U.S.) to the Central Valley of California to the African Savannahs, and in many other places around the world, NASA data are delivered to decision makers to help them make critical decisions that impact our world's agricultural productivity. Based on such data, NASA and its many domestic and international partners work together to find the best ways to rethink and reshape our food and agriculture systems.

For the first time, NASA participated in the Commodity Classic event meeting held March 10–12, 2022, in New Orleans, LA—and online everywhere March 8–12. Describing itself as being, "Created by farmers for farmers," this meeting is the largest farmer-led, farmer-focused educational and agricultural experience in the U.S.[1] In-person attendance was 7862 people—3359 of which were farmers.[2]

Agency representatives, including **Karen St. Germain** [NASA Headquarters—*Director of NASA's Earth Science Division*], attended the meeting in person to discuss information, tools, and resources drawn from NASA's Earth-observing satellites and scientific research. Farmers and others regularly make decisions about water management, planting, and market decisions based on NASA data delivered by partner agencies and organizations, such as the U.S. Department of Agriculture (USDA). St. Germain participated in various speaking events and meetings and delivered a presentation at the NASA exhibit in front of the Hyperwall during the meeting—see **Photo 1.**

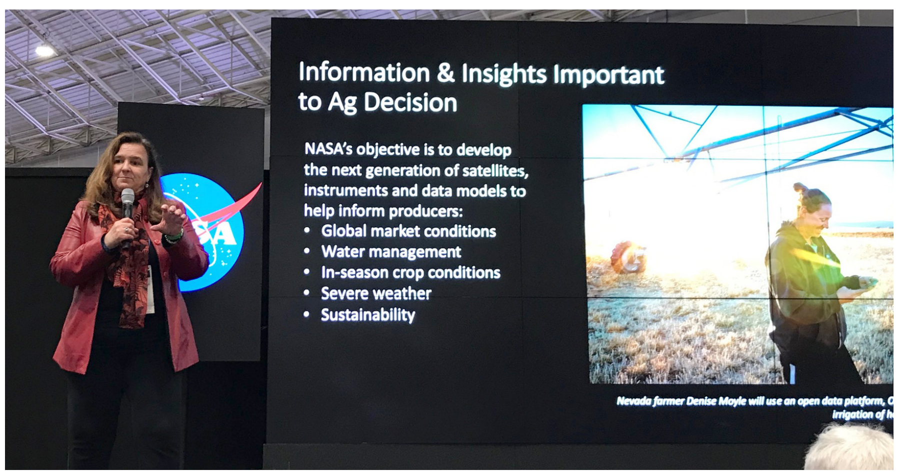

Photo 1. **Karen St. Germain** [NASA HQ—*Director of the Earth Science Division*] spoke in front of the Hyperwall at the in-person NASA exhibit at the Commodity Classic event. During the meeting, St. Germain and other NASA representatives interacted with farmers and others in attendance to learn more about their needs and how the agency's current and future data resources might be able to help address those needs. **Photo credit**: Kim Locke/ NASA's Goddard Space Flight Center (GSFC)

Building on the success of the fall 2021 meeting of the American Geophysical Union,[3] the Commodity Classic event was NASA's second full venture into the world of *hybrid* events—the "new normal," where some participants attend in person at a particular location (in this case, New Orleans) while others engage online. Staff from NASA's Science Support Office (SSO) traveled to support in-person activities at the NASA booth in the vast exhibit hall—which covered almost the entire 1.1 million ft^2 (~102,000 m^2) area of the Ernest N. Morial Convention Center—the largest contiguous-space exhibit hall in the U.S.

[1] To learn more about the Commodity Classic event, visit *commodityclassic.com*.
[2] For more detailed statistics on the 2022 Commodity Classic event, visit *commodityclassic.com/for-exhibitors/show-statistics*.
[3] To learn more about NASA's participation in the Fall 2021AGU meeting, see "NASA Science at the First Hybrid AGU Fall Meeting" in the January–February 2022 issue of *The Earth Observer* [**Volume 34**, **Issue 1**, pp. 16–19—*go.nasa.gov/3tUxqW9*].

Meanwhile, via NASA's Virtual Event Platform, online participants explored the connection between NASA Science and agriculture from afar. In coordination with NASA's Applied Sciences Program, SSO staff designed and oversaw the virtual exhibit, offering technical and logistical support as needed.

The following summary describes NASA's participation in the Commodity Classic event in an attempt to demonstrate NASA's new "commodities" and to give the flavor of this hybrid experience.[4]

Words of Welcome

NASA Administrator Sen. Bill Nelson and **Brad Doorn** [NASA Headquarters—*Director of NASA's Water Resources and Agricultural Program*] both recorded welcoming remarks for the Commodity Classic event. The Administrator's presentation was shown during the in-person meeting to introduce **U.S. Secretary of Agriculture Tom Vilsack**, who gave the keynote address. Both presentations were accessible via the virtual exhibit.[5]

Nelson spoke about how NASA's Earth-observing satellites provide a unique vantage point in space that enables continuous global observations of Earth's various systems, how they behave, and how they interact over long periods of time—which is key to studying climate. NASA is now joining its long record (over 50 years) of Earth observations together with cutting-edge technologies and collaboration, to put these data in the hands of users around the world who can apply them to help solve real-world problems for the betterment of society.

NASA is now joining its long record (over 50 years) of Earth observations together with cutting-edge technologies and collaboration, to put these data in the hands of users around the world who can apply them to help solve real-world problems for the betterment of society.

Nelson spoke about the upcoming Earth System Observatory missions that will collect even more detailed information about the physical processes that impact the health of our home planet. He explained that NASA will continue working to put this information, as quickly and efficiently as possible, in the hands of those who need it. Notably among these are farmers, among these are farmers, who can use NASA data to develop agricultural practices that better support the global food system.

Nelson stressed that collaboration is at the core of NASA's efforts—which is why NASA supports events like the Commodity Classic event. NASA can design better tools to enable more informed decision making by learning more about the requirements of its various constituent communities. Through its collaboration with the USDA and other organizations, NASA provides farmers and industry with essential data for crop reports, drought assessments, extreme weather prediction, and—eventually—predicting the impact of climate change on the food supply.[6]

"From the heavens to the heartlands, NASA's story is filled with breakthroughs and inventions that help humanity. Onward and upward!"

—NASA Administrator Sen. Bill Nelson

Doorn also welcomed participants to the meeting, focusing his remarks on the capabilities afforded by the virtual exhibit. He gave a quick overview of the content of the five "rooms" (described here) and noted that NASA's goal is to develop tools needed to work toward a more sustainable, resourceful, and profitable agricultural industry in the U.S. Toward that end, Doorn emphasized that NASA seeks feedback from participants at the Commodity Classic event (both in person and virtual) about what more the agency can do to support agricultural activities. He concluded by saying, "From seed to market, NASA supports our nation's agricultural industry," and he encouraged participants to enjoy exploring the in-person and virtual exhibits.

[4] To see examples and learn more about NASA's Applied Science Program, see *go.nasa.gov/35sweQl*.

[5] To view the NASA Administrator's full presentation (and a continuous playlist of Commodity Classic event presentations), see *www.youtube.com/watch?v=MlxLRjpzLjU&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=1*.

[6] NASA and USDA signed a Memorandum of Understanding in 2020 aimed at strengthening their longstanding partnership on space-based assets benefitting life on Earth. The details of this collaboration are summarized at *go.nasa.gov/3qQcOw5*.

Overview of Meeting Elements

Once registered, NASA employees used their NASA Personal Identification Verification (PIV) card, while non-NASA employees provided an email address and password, to gain access to the virtual exhibit. They "entered" via the *Lobby,* which had seven options that allowed them to explore the virtual content—see **Figure** below.

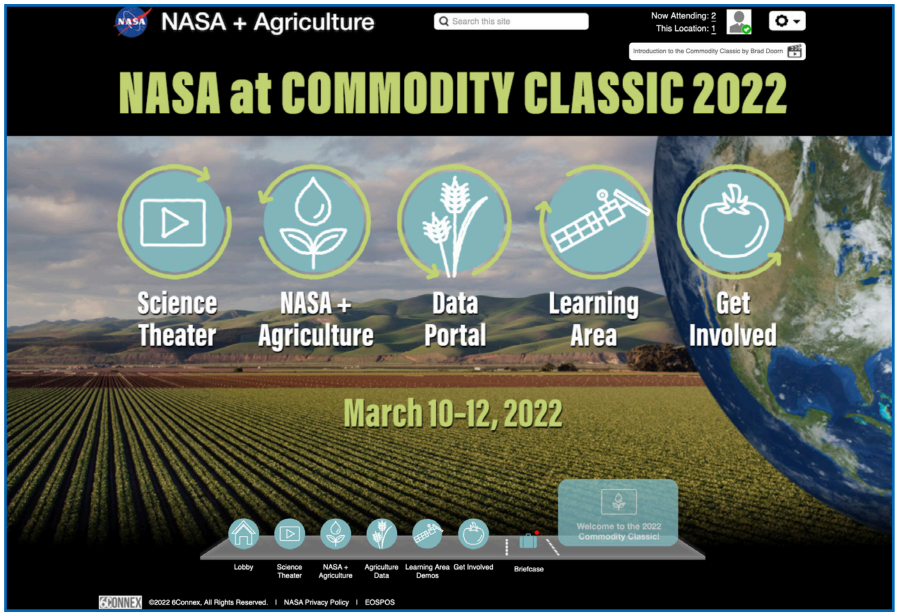

Figure. A screenshot of the *Lobby* for NASA's virtual exhibit at the Commodity Classic event. Buttons connected to five topic-centered rooms that online participants could explore, as well as a link to a *Briefcase*, which allowed participants to gather important content for the meeting in a single location, and a *Help Desk*, which enabled participants to chat with NASA scientists and receive technical support on using the website. **Image credit**: NASA

A *Help Desk* button provided links to chatrooms, where participants could interact in real time with NASA scientists during certain hours, as well as website technical support. There were also links to the chatrooms from other sections.

A *Briefcase* button gave participants access to key information about the meeting in one convenient location. The Briefcase included links to a *Commodity Classic event How-To Guide* that covered how to register for, enter, and navigate the virtual exhibit; a *Science Theater Speaker List*; and a brief one-minute overview presentation called *NASA and Agriculture: From Seeds to Satellite*. There were also links to the welcoming words from the NASA Administrator and Brad Doorn, summarized in the previous section.

Each of the five other buttons in the Lobby of the virtual exhibit led to a room with information about various aspects of NASA and its support of applications related to agriculture. These rooms included: Science Theater, NASA + Agriculture, Data Portal, Learning Area, and Get Involved. This being a hybrid meeting, some of the content of these online rooms overlapped with elements of the in-person exhibit. The subsections that follow elucidate these connections.

Hyperwall (In Person)

As is the case at most in-person meetings where it has been installed, NASA's *Hyperwall*—a nine-screen video wall—was the centerpiece of the in-person NASA exhibit. There was a full schedule of speakers throughout the three days of the meeting, and the frequent use of high-resolution imagery was always a draw for people passing through the exhibit hall. See **Table 1** on pages 7–8 for a list of presentations.

Science Theater (Virtual)

Essentially the equivalent of the Hyperwall in the virtual exhibit, the Science Theater contained links to 10 prerecorded online presentations listed in Table 1. In addition to these presentations, there was another button that linked to the *NASA and Agriculture: From Seeds to Satellite* summary video, which was also included in the Briefcase.

(Text continues on page 9)

Table 1. List of Hyperwall (in-person) and/or Science Theater (virtual) Presentations and Speakers at the Commodity Classic event.

Title	**Presenter** [Affiliation—*Title*]	URL
Exploring the Value of Partnerships: NASA and American Agriculture	**Karen St. Germain** [NASA Headquarters—*Director of Earth Science Division*]	In-person Only
Help from Above: How NASA Is Supporting Advances in Agriculture Monitoring and Forecasting	**John Bolten** [NASA's Goddard Space Flight Center (GSFC)—*Associate Program Manager of Water Resources for NASA's Applied Sciences Program*]	In-person Only
How Satellite Data Can Help Farmers Capitalize on the Regenerative Agriculture Revolution	**Alyssa Whitcraft** [University of Maryland, College Park (UMD)—*Associate Director and Program Manager of NASA's Harvest Consortium*]	*www.youtube.com/watch?v=-UYorkjKPFA&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=3*
Earth Information for Agricultural Modeling Applications	**Alex Ruane** [NASA's Goddard Institute for Space Studies—*Co-Director of the Climate Impacts Group*]	*www.youtube.com/watch?v=OqZNfhUbaEw&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=2*
The GEOGLAM[#] Crop Monitors: A NASA Harvest Product	**Brian Barker** [UMD—*Lead Author of GEOGLAM Crop Monitor*]	*www.youtube.com/watch?v=nQaUqRADkgE&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=4*
NASA's Short-term Prediction Research Center (SPoRT) Center: Translating Research to Improve Operation Decision-Making	**Christopher Hain** [NASA's Marshall Space Flight Center—*SPoRT Project Scientist*]	*www.youtube.com/watch?v=uu8nR0Hoklc&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=12*
Earth Observations for Monitoring and Anticipating AgroClimatic Conditions	**Greg Husak** [University of California, Santa Barbara—*Principal Investigator for the Climate Hazards Center*]	*www.youtube.com/watch?v=1L5-6J_S1eo&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=5*
Interpreting Agricultural Data with Machine Intelligence	**Hannah Kerner** [UMD—*Harvest Hub Researcher*]	In-person Only
Landsat and Agriculture: Past, Present, and Future	**Jeffrey Masek** [GSFC—*Landsat 9 Project Scientist*]	*www.youtube.com/watch?v=Ewzfgd6tESE&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=6*
Monitoring Cover Crops and Tillage from Field to Satellite	**Kaiyu Guan** [University of Illinois at Urbana–Champaign (UIC)—*NASA Harvest Partner*]	*www.youtube.com/watch?v=AIijpWyJ30A&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=7*
Monitoring Drought: From Local to Global.	**Mark Svoboda** [University of Nebraska, Lincoln—*Director of National Drought Mitigation Center*]	*www.youtube.com/watch?v=SdQEWjILPRE&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=8*
Monitoring and Forecasting Groundwater and Soil Moisture Conditions Using NASA's GRACE-Follow-On Satellites	**Matthew Rodell** [GSFC— *Acting Deputy Director of Earth Sciences for Hydrosphere, Biosphere, and Geophysics*]	*www.youtube.com/watch?v=iCSDCPyBGJ0&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=9*
How's it Growing? Using Earth Observations for Responsive Food Security	**Ritvik Sahajpal** [UMD—*NASA Harvest Crop Condition Co-Lead*]	*www.youtube.com/watch?v=BWBMuX5Z-iY&list=PL55HrL0eJVEbhosmRsD9cHR4y912ZayY7&index=11*

continued on page 8

Table 1 (*cont.*). List of Hyperwall (in-person) and/or Science Theater (virtual) Presentations and Speakers at the Commodity Classic event.

Title	Presenter [Affiliation—*Title*]	URL
NASA's Earth Information System (EIS): Providing Actionable Information for Water Resources Application	**Sujay Kumar** [GSFC—*Lead for NASA EIS Freshwater* and *Land Information System Teams*]	Not Available
Destination Conservation: Mapping Sustainability Across a Moving Landscape	**Laura Gentry** [UIC—*NASA Harvest*]	In-person Only
Regional-to-Global-Scale Cropland Modeling with Landsat Data	**Xiaopeng Song** [Texas Tech University—*NASA Harvest*] and **Matthew Hansen** [UMD—*NASA Harvest*]	In-person Only
OpenET: Supporting Water Resources Management and Precision Agriculture in the West with Satellite-Based Information Data	**Forrest Melton** [NASA's Ames Research Center (ARC)—*Program Scientist for NASA's Western Water Applications Office*]	In-person Only

GEOGLAM stands for Group on Earth Observations Global Agricultural Monitoring Initiative.

Learning Area (In Person and Virtual)

There was both an in-person Learning Area at the NASA booth (see **Photo 2** on page 9) as well as a dedicated room in the virtual exhibit. The in-person Learning Area presentations are listed in **Table 2**, below. The virtual Learning Area room was organized around four topics related to Agriculture: Crop Health, Soil Moisture, Crop Monitoring, and Weather. Each topic linked to a prerecorded presentation, and the four virtual Learning Area topics are mapped to a related in-person presentation in Table 2.

Table 2. List of In-Person Learning Area Presentations (and Corresponding Virtual Learning Area Topics) and Speakers at the Commodity Classic event.

Title (Corresponding Virtual Exhibit Topic)	Presenter [Affiliation—*Position*]	URL
CropCASMA:+ Mapping Soil Moisture and Crop Vegetation Conditions Across the U.S. (Soil Moisture)*	**Rajat Bindish** [GSFC]	Not Available
Landsat for Crop Health (Crop Health)*	**Mike Taylor** [GSFC]	*www.youtube.com/watch?v=mpdf5RPnxXI&list=PL55HrL0eJVEZ9F6d7VJeFuZ29mBdK9YMB&index=1*
Daymet: Geographic Information Systems (GIS) for Weather Monitoring*	**Cyndi Hall** [GSFC—*Community Coordinator for NASA's TOPS Program*] and **Michelle Thornton** [Oak Ridge National Laboratory DAAC]++	*www.youtube.com/watch?v=9FrXQF-scgY&list=PL55HrL0eJVEZ9F6d7VJeFuZ29mBdK9YMB&index=3*
NASA Harvest's Open Access Agricultural Monitoring Dashboards (Crop Monitoring)*	**Mike Humber** [UMD—NASA Harvest]	*www.youtube.com/watch?v=andpNcEsPH0&list=PL55HrL0eJVEZ9F6d7VJeFuZ29mBdK9YMB&index=2*
Earth Information System (EIS) Freshwater Project: Addressing Water Availability Issues through Cloud-Based Open Science	**Sujay Kumar** [GSFC]	In-person Only

continued on page 9

Table 2 (*cont.*). List of In-Person Learning Area Presentations (and Corresponding Virtual Learning Area Topics) and Speakers at the Commodity Classic event.

Title (Corresponding Virtual Exhibit Topic)	**Presenter** [Affiliation—*Position*]	**URL**
Data Visualization with NASA Worldview	**Cyndi Hall** [GSFC]	In-person Only
OpenET:[+++] Supporting Water Resources Management and Precision Agriculture in the West with Satellite-Based Information Data	**Forrest Melton** [ARC]	In-person Only

[*] The content of these in-person Learning Area presentations approximately maps to one of the topics (listed in parentheses) covered in the virtual Learning Area.

[+] CropCASMA stands for Crop Condition and Soil Moisture Analytics tool.

[++] TOPS stands for Transform to Open Science; DAAC stands for Distributed Active Archive Center.

[+++] Open ET stands for open evapotranspiration

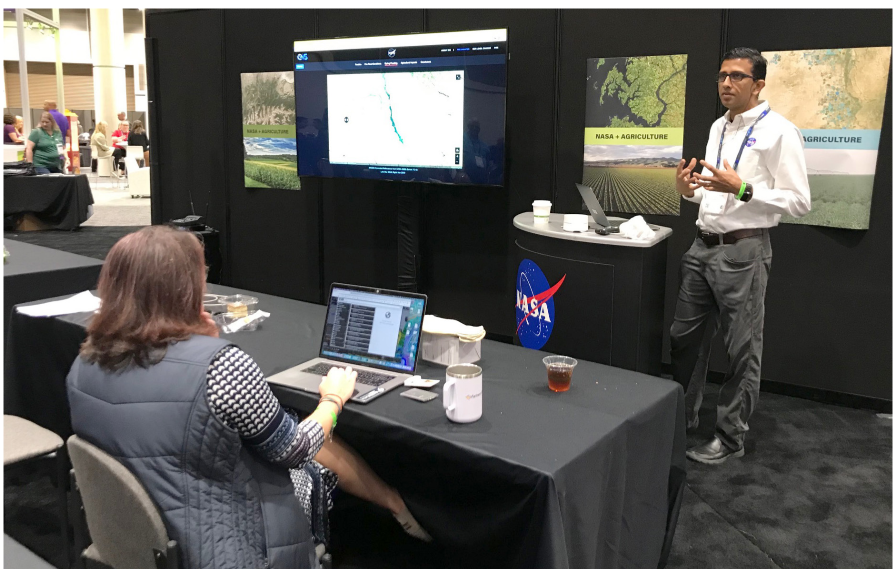

Photo 2. **Sujay Kumar** [GSFC] gave a presentation at the in-person Learning Area. **Photo credit**: Kim Locke/ GSFC

NASA + Agriculture (Virtual)

This room contained links to several fact sheets that illustrated how NASA data are being connected to different agricultural applications. Each fact sheet included several images with captions and links to videos. The options included: Land + Crops, Water Management + Drought, Weather + Changing Extremes, Conservation + Carbon, Markets + Farm Economics, and NASA + Agriculture.[7]

Data Portal (Virtual)

This room focused on NASA data that are being applied to agricultural applications. The "Introduction to Data" and "Online Training" buttons linked participants to information on the NASA Applied Sciences Division's Applied Remote Sensing Training (ARSET) program,[8] which offers online and in-person training in the use of NASA data for beginners and more seasoned practitioners alike.

[7] This last link was not to a fact sheet like the others in this room, but to information about NASA's involvement in the Commodity Classic event, including the schedules for the Hyperwall and in-person Learning Area.
[8] To learn more about ARSET, see *go.nasa.gov/3NFx9Or*.

The other three buttons in this section connected with several *Data Pathfinders*—commonly used datasets and associated tools across NASA's Earth science data collections—related to agricultural applications including: Agriculture and Water, Disasters, and Water Quality. There are many more such found at the Data Pathfinders site.[9]

Get Involved (Virtual)

This room had an educational focus, with links to various ways to get more connected and involved with NASA. Buttons included: Internships & Fellowships, NASA Earth, NASA Landsat, NASA Harvest, Citizen Science, Applied Sciences, and NASA + Agriculture.

It may seem odd for NASA, an agency associated with sending satellites into space, to participate in a meeting whose primary audiences are farmers and agribusinesses. However, NASA's Earth Science missions and the data resources they provide are becoming more and more familiar to today's agriculturalists—and to scores of other users.

Conclusion

It may seem odd for NASA, an agency associated with sending satellites into space, to participate in a meeting whose primary audiences are farmers and agribusinesses. However, NASA's Earth Science missions and the data resources they provide are becoming more and more familiar to today's agriculturalists—and to scores of other users. NASA had a major presence at the Commodity Classic event, and by all accounts, thanks to the contributions of many individuals, the agency's inaugural foray into this event was successful.

The hybrid meeting format worked well. Both the in-person and virtual exhibits were well attended. The variety and depth of the content provided just a sample of the practical support NASA can offer this audience. As **Karen St. Germain** said in her remarks to the National Association of Wheat Growers (NAWG), "My hope is that this is the start of a conversation between NASA Earth Science and wheat growers [and farmers] and other agricultural industry folks." ■

[9] To learn more about Data Pathfinders, see *go.nasa.gov/3NFxfWj*.

Summary of the First NASA Open Source Science for the Earth System Observatory Mission Science Data Processing Workshop

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Introduction

NASA is formulating the Earth System Observatory (ESO), a set of missions to provide key information to guide efforts related to monitoring climate change, mitigating disasters, fighting forest fires, and improving real-time agricultural processes—see **Figure** below.[1] Under the guidelines set forth in the 2017 Decadal Survey,[2] all data, software, and algorithms developed as part of the ESO will be openly available as early as feasible in the mission process, and publications resulting from this work will be available without restriction. As a result, ESO missions will develop algorithms for all stages and levels of data processing, software, and documentation openly from their inception.

NASA's Science Mission Directorate (SMD) and Earth Science Data Systems (ESDS) Program define *open science* as a collaborative culture enabled by technology that empowers the open sharing of data, information, and knowledge within the scientific community and to the wider public, to accelerate scientific research and understanding.

Developing and conducting the ESO as an open science effort—with all activities, mission development, data processing, and mission results available without restriction—will ensure full transparency during the mission formulation process and engender trust in ESO missions and the resulting data and data products.

Open-source science, which is a developing paradigm within open science, builds on concepts from the open-source software revolution that expanded participation in code development to a wider community of practitioners and applies these concepts to the scientific process to accelerate discovery through open science, from project initiation through implementation. One intended result is the inclusion of a wider, more diverse community in the scientific process as close to the start

[1] For more information, visit *go.nasa.gov/3i79uYV*.
[2] More information about the Decadal Survey is available at *go.nasa.gov/3tgaXm5*.

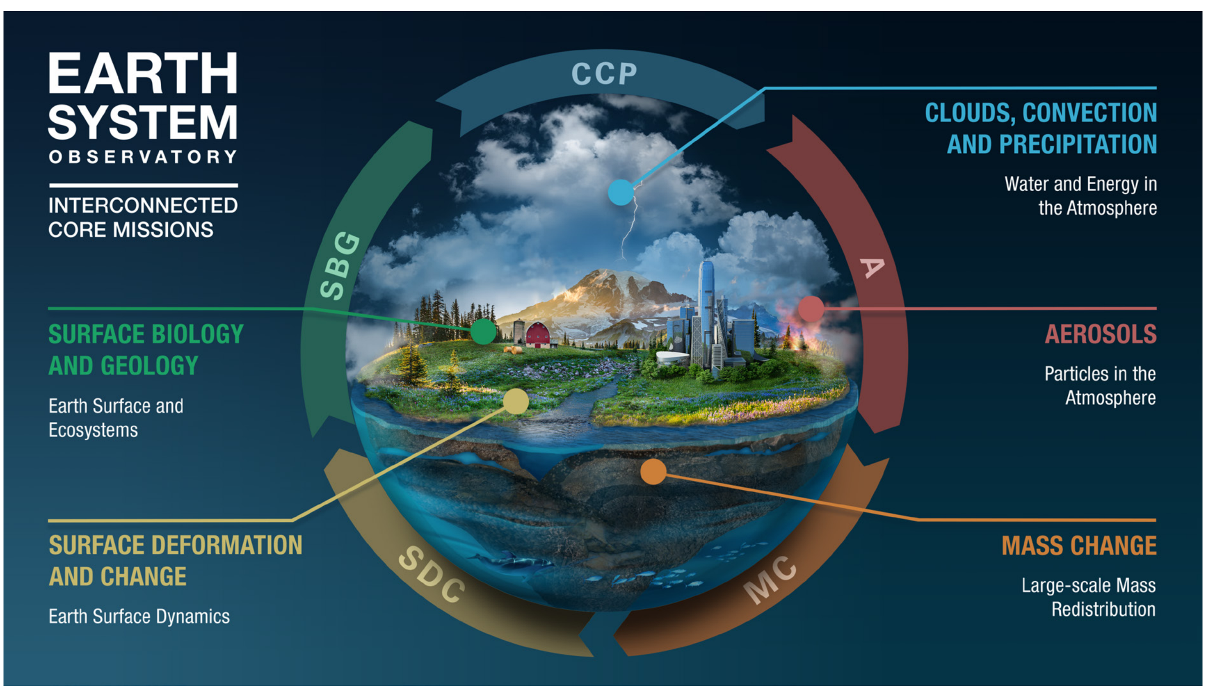


Figure. The core of the Earth System Observatory consists of five NASA missions that will acquire data on multiple Earth processes. These data will be integrated into a single observatory to provide a holistic, three-dimensional view of Earth processes. **Image credit**: NASA of research activities as possible.[3] Since 1994, NASA Earth science data have been open to all users for any purpose, and since 2015 all data systems software developed through NASA research and technology awards have been made available as open-source software.[4]

Open-Source Science Study and Workshop Overview

To explore potential ESO open-source science data processing architectures, an Open Source Science for ESO Mission Science Data Processing Study was established. Sponsored by **Kevin Murphy** [NASA Headquarters—*Chief Science Data Officer for SMD* and *Program Manager for NASA's Earth Science Division (ESD)*], the study is being co-led by NASA's Earth Science Data and Information System (ESDIS) Project and NASA's Jet Propulsion Laboratory (JPL). The motivation for the study stems from the recognition that barriers to accessing science mission algorithms, workflows, computing, and analytics can hinder the broader participation in NASA science. It also builds on SMD's *Strategy for Data Management and Computing for Groundbreaking Science 2019–2024*, which was released in December 2019.[5]

Specific objectives of the ESO data study are to identify data processing architectures that best:

- meet ESO mission science data processing objectives;
- enable data system efficiencies;
- support Earth system science and applications; and
- promote open science principles to expand participation in mission science beyond funded science teams.

The study team consists of a Steering Committee, which is managing the study, and a System Architecture Working Group (SAWG), which is responsible for conducting a Mission Data Processing System architecture trade study.

The study comprises three open workshops (in October 2021, March 2022, and August 2022) to identify, assess, and review potential ESO data system architectures, with a four-month system architecture trade study conducted by the SAWG from April to July 2022. Additional stakeholder feedback will be solicited through public Requests for Information (RFIs). This article focuses on the initial study workshop (hereinafter Workshop One).

Workshop One Summary

Workshop One took place virtually October 19–20, 2021, and focused on gathering needs and considerations for evaluating open science data system architectures to support Earth system science and mission data system efficiencies. As an open science event, anyone was welcome to attend, and the 144 workshop participants provided input on requirements, constraints, recommendations, and opportunities for ESO science data processing.[6]

The goals of this workshop were to:

1. understand programmatic requirements, objectives, capability needs, and constraints driving ESO mission data processing systems;
2. seek opportunities to advance science data systems in the context of the data processing study objectives; and
3. establish programmatic and mission point of contacts to support the codevelopment of future ideas and concepts.

Day One of the two-day workshop focused on programmatic presentations from the managers of NASA Earth Science programs; Day Two featured presentations from ESO projects that are in pre-Phase A of mission development. After each group of presentations, the SAWG posed questions directly to the presenters for study input. Each day ended with an open discussion of the presentations. Individual workshop presentations are available on the Earthdata website, and workshop recordings are available through the Earthdata website and on YouTube.[7]

Workshop participants agreed on evaluation criteria for the ESO Data System. Specifically, it should:

- support mission needs, be portable to support deployment in a range of environments (e.g., on-premises, in-cloud, hybrid), have well-defined interfaces, be relatively mature before use, and be developed within existing budgets;
- support a *data lake*,[8] be flexible and efficient, accommodate varying compute needs, and encourage standard data formats;
- enable data/algorithm/tool sharing to facilitate advancing cross-ESO science goals; and

[3] For a broad discussion of NASA open-source science efforts, see "Open-Source Science: The NASA Earth Science Perspective" in the September–October 2021 issue of *The Earth Observer* [**Volume 33**, **Issue 5**, pp. 5-9, 11—*go.nasa.gov/3KBrsj8*].

[4] Additional information is available at the Earthdata Open Science webpage at *go.nasa.gov/3KNOXVC*.

[5] The strategy document is available at *go.nasa.gov/3u0bHuB*.

[6] Detailed information about this workshop, including links to workshop discussions and recordings, is available at *go.nasa.gov/3CSs54n*.

[7] Recordings are available on YouTube at *bit.ly/3tW6RAm*.

[8] A data lake is a storage repository that holds a vast amount of raw data in its native format until it is needed for analytics applications.

- provide a community-based, publicly-accessible analysis platform that provides the required levels of cybersecurity to protect NASA assets.

One exercise conducted during the meeting was a strengths, weaknesses, opportunities, and threats (SWOT)[9] analysis of existing NASA data systems. The results of this analysis are summarized in the **Table** below.

NASA Programmatic Priorities

From the NASA programmatic perspective, ESD priorities are to advance scientific discovery through open-source science and foster broad participation by NASA data users as early as feasible in the mission development process.

The Flight Program strives to meet the above-mentioned ESD priorities while still adhering to data system design constraints and flight requirements. This work entails maintaining compliance with existing concepts and investments along with enforcing the role of NASA Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs) as sources for discipline-specific EOSDIS data.

[9] This should not be confused with the Surface Water and Ocean Topography mission, which goes by the same acronym.

The Research and Analysis (R&A) Program sees the accommodation of the breadth of activities across many data sources as crucial in supporting the larger researcher community and enabling community-based, intra-team collaboration.

The Applied Sciences Program would like to expand access to mission data and services to enable codevelopment across disciplines within the broader community.

The Earth Science Technology Office (ESTO) supports on-premises *high-end computing* (HEC)[10] and cloud capabilities for data processing, archiving, and analysis; requires and implements Findable, Accessible,

[10] A high end computer, or "supercomputer," is a machine that connects a very large number of processors using hardware and software that lets the processors work together quickly and efficiently.

Table. Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis of Existing NASA Earth Science Data Systems.

Strengths
• Include activities to make NASA data accessible to a broad user base • Support large data and computational infrastructure • Have known costs and schedules
Weaknesses
• Can have limitations on community access to and use of existing infrastructure • Challenges with interoperability across computing infrastructure • Lack of broad user experience working with NASA data and data formats • Lack of equal recognition given to algorithm developers and software developers for converting science code to open-source software
Opportunities
• Encourage capacity building in the broader research community for open-source science and the use of NASA infrastructure • Gain champions of open-source science through early adopters • Standardize the value of open-source science • Encourage more efficient use of existing infrastructure • Develop open-source software and data tools
Threats
• Disconnect between open-source science policy and implementation within existing business models and cybersecurity policies • Potential to introduce inequity in terms of access, inclusion, and work effort • Cost-optimization inequalities in the cloud and across diverse geographic regions • Research community hesitancy to adopt cloud technology

Interoperable, and Reproducible (FAIR) principles for software and data; and sponsors technology advancements for future ESD needs.

Feedback from ESO Missions

The ESO Mission Program Offices see partnerships with external and international communities, access to many data sources, and support for Analysis-Ready Data (ARD) as crucial elements.

With regard to responses from specific ESO missions, the NASA–Indian Space Research Organisation (ISRO) Synthetic Aperture Radar [NISAR][11] and Surface Biology and Geology (SBG) Mission Program Offices are interested in lowering the bar for data product usage, as is the Mass Change (MC) Program Office—although they acknowledge that some MC algorithms are proprietary and may not be available for public dissemination.

More generally, ESO mission science teams would benefit from sharing data and algorithms, having an analysis platform (especially for Level 3 and higher data), and having access to the *Program of Record*,[12] which would lead to harmonization of ESO missions. The NISAR team stressed that open access to data—with quality metadata—is most conducive to scientific progress, while the Atmosphere Observing System (AOS)—formerly known as Aerosols–Clouds, Convection, and Precipitation (A-CCP)—office noted that they plan to use the ESO data analysis platform prior to launch, using simulated and airborne-collected data.

The ESO Mission Data Processing Systems have a need for a community supported on-demand processing system to generate higher level (Level 3+) products as ARD that enable harmonization. ESO mission data volumes range from small (with MC at <1 PB) to large (NISAR/SBG with 100+ PB). Because of this, variable processing and low-latency products, along with the ability to interface with data processing systems for non-ESO missions, are essential.

Other Stakeholder Considerations and Constraints

A Policy, Economics, Sociocultural Factors, and Technologies (PEST) analysis provides a means of capturing findings relevant to all stakeholders. The consensus was that cybersecurity intellectual property (IP), International Traffic in Arms Regulations (ITAR), and NASA SMD policies on data management and open-source science should be better aligned, which will help facilitate open-source science objectives.

The data system economics are cost-constrained by ESO budgets and limited by NASA's current investments in high performance computing (HPC)^13, and could be hindered by some in the community who feel it is more cost effective to buy their own systems.[13]

A key sociocultural concern is the science community's traditional "publish or perish" business model that is based on reward for being the first to discover or publish, which can disincentivize participation in collaborative, open-source science. Changing this model will require an intentional cultural shift to teach experienced researchers new practices, provide cloud/HPC training, and develop consistent open-source science guidelines across different centers.

Finally, on the technical side, there was concern about including the use of existing investments in infrastructure and mechanisms to enable broad community data contributions while limiting the proliferation of unvalidated data resulting from these community contributions.

The Way Forward: Workshops Two and Three and the SAWG Architecture Trade Study

Workshop Two took place March 1–4, 2022, and focused on understanding the state of the art in mission data processing systems and open science.[14] It was also an opportunity for the community to provide input on data system architectures. The broader community will provide additional information on the state of the art via invitation and an open RFI.

The next step is for the SAWG to conduct a system architecture trade study (April to July 2022) to evaluate potential data system and data processing architectures against ESO data system evaluation criteria. The SAWG will then communicate with stakeholders from the first workshop to inform assessment of architectures for meeting different evaluation criteria.

Workshop Three is planned for August 2022 and will be another virtual event. Candidate data architectures will be presented and a recommendation for an ESO data system will be made with an assessment against the evaluation criteria. NASA Headquarters will take into consideration the feedback from these workshops as it makes final decisions for the path forward.

[11] NISAR is intended to be an ESO pathfinder mission. It will take high-resolution measurements of changes on Earth's surface to measure complex processes. To learn more, visit *nisar.jpl.nasa.gov*.

[12] The 2017 Earth Science Decadal Survey referred to NASA's existing and already planned Earth observation missions as the *program of record*. Refer to the 2017 Decadal Survey (referenced in footnote 2) for more details.

[13] High performance computing (HPC) generally refers to the practice of aggregating computing power in a way that delivers much higher performance than one could get out of a typical desktop computer or workstation.

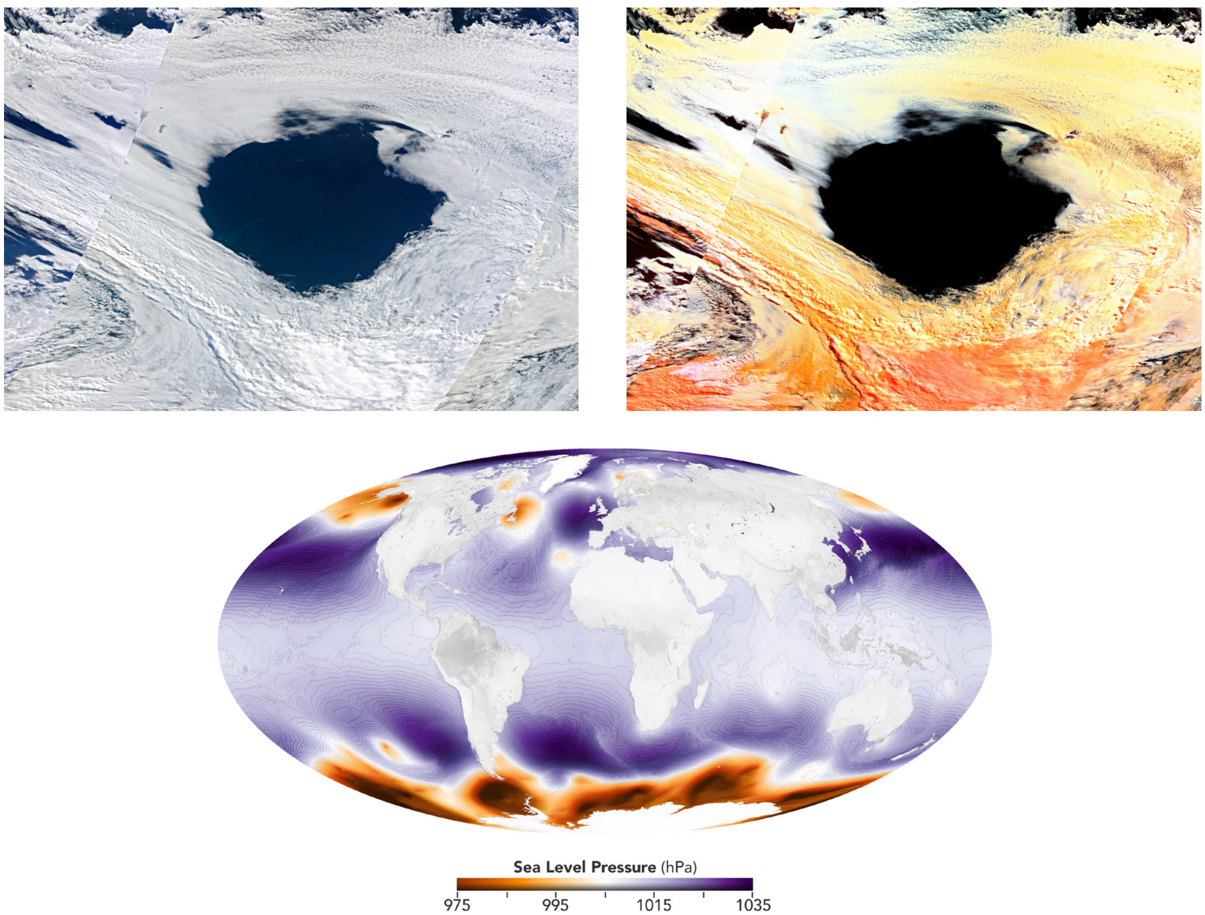
[14] Detailed information about this workshop, including links to workshop presentations and recordings, is available on the Earthdata workshop page (referenced in footnote 6).

Conclusion

The ESO brings tremendous opportunities for applying open science and open-source science principles to NASA Earth science initiatives. The result will be the inclusion of a broader, more diverse community in the collaborative development of ESO missions and mission data. Through the Open Source Science for ESO Mission Science Data Processing Study, NASA's SMD is enabling the scientific community to provide insights into developing the ESO data processing system.

Acknowledgments

The authors recognize and express their gratitude for the contributions and input from the following individuals on this workshop summary: **Luke Dahl** [NASA/Jet Propulsion Laboratory (JPL)]; **Chelle Gentemann** [Farallon Institute]; **Sara Lubkin** [NASA's Goddard Space Flight Center]; and **Karen Yuen** [JPL].



A "Hole" in the Clouds. On April 3, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite happened to be in the right position to capture an image [*top, left*] of what appears to be a massive "hole" in the clouds over the normally turbulent seas south of the Cape of Good Hope. To the casual observer, the unusual phenomenon looks like a single feature, but analysis revealed that it was actually created by the convergence of two meteorological phenomena. A quick moving frontal weather system moved through between 50–60° S latitude at the same time a layer of more stationary, low clouds closer to the tip of Africa was being eroded by an area of High pressure. The sinking air associated with the High produced a semi-circular ring of clouds between 45–50 ° S latitude. When both of these weather phenomena lined up in latitude, it gave the illusion of a single giant hole in the clouds.

The false-color MODIS image [*top, right*] combines information from MODIS bands 3, 6, and 7. This combination of of blue and shortwave infrared light is useful for sorting out the heights of clouds, which helps to confirm the surface meteorological analysis. The low clouds in the northern (upper) half of the feature appear mostly white, indicating they are comprised of liquid droplets close to the surface. In contrast, the frontal clouds in the southern (lower) half of the feature appear red, a sign that they contain large numbers of ice particles that are higher in the atmosphere.

The global map [*bottom*] shows the position of the high-pressure area on April 3, 2022, about 90 minutes before the MODIS image of the cloud hole was acquired. Globally, the average sea-level pressure is about 1013 mb; at the center of the High, pressures topped 1035 mb. Stormy, low-pressure areas appear orange; calmer, high-pressure areas are purple.

Image/partial text credit: NASA's Earth Observatory

NASA Is Helping Fly Drones in the Arctic. Here's What That Means for Sea Ice and Sea Level Change

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

They've delivered groceries and performed light shows at the Olympics. But in the unforgiving Arctic climate, drones have struggled to fly for extended periods of time—at least, the kind that would allow researchers to fly scientific instruments safely to keep tabs on the region.

Now, a team led by NASA scientists is showing how a fixed-winged drone named *Vanilla* could fly for several days over the Arctic Ocean, carrying an instrument that uses radar to measure the depth of snow accumulating on top of sea ice.

By testing the drone and snow radar instrument together, the team wants to provide key data to more accurately track and project how Earth's polar regions are changing and influencing sea level.

Because snowfall puts an additional layer of snow over sea ice, even some of NASA's most powerful altimeter systems in space struggle to measure the thickness of the ice. Data from drones flying at low altitudes can help scientists measure this changing thickness more accurately as Arctic sea ice waxes and wanes with the seasons.

"The same technique could eventually be used to assess how freshwater melting from Greenland and Antarctica contributes to sea level rise," says **Brooke Medley** [NASA's Goddard Space Flight Center], who leads the project.

In other words, Medley sees in drones a path toward increasingly accurate projections of how sea level rise might reshape coastlines worldwide, and, for more temperate climates, a promising new tool to monitor wildfires, algal blooms, and other vital signals of change on Earth.

In November 2021, Vanilla flew for six hours over open ocean and sea ice more than 130 mi (222 km) from an airport in Deadhorse, AK, where a pilot controlled the aircraft and a scientist controlled the radar instrument—see **Photo**.

By flying in more temperate weather for eight days straight in 2021, Vanilla earned the world record for continuous flight without refueling by a remotely piloted aircraft with internal combustion engine. In Alaska, unusual precipitation prevented multiday flights, but early assessments show Vanilla could fly for nearly five days over Arctic sea ice.

Photo. Vanilla flying over sea ice off Alaska's North Slope in November 2021. Airborne campaigns to the polar regions often fly straight tracks, limited by the need to refuel in between flights. Drones like Vanilla have different needs and can offer a niche in Earth observations that scientists have traditionally struggled to explore with boots on the ground or instruments already in the air and space. **Credit:** Platform Aerospace

To earn its "Arctic wings," Vanilla flew with ice-detecting sensors, heating systems, and a special anti-icing coating to protect against fog and moisture that can quickly ice on its wings and propeller. The aircraft also runs on a diesel engine, which helps to regulate heat, unlike battery-operated drones.

"Drones have come a long way, enough that they can start to be more than just quadcopters flying locally and looking at your neighborhood," Medley says. "Flying drones is ultimately more green and safer than flying large planes, so this checks a lot of boxes."

Medley wants to survey sea ice in the Arctic and Southern Ocean with the drone. Ultimately, the idea is to fly over Greenland and Antarctica, Earth's two major ice sheets. Unlike expensive and labor-intensive airborne campaigns that rely on airplanes and crew, multiple drones could fly simultaneously, on a regular basis, and in multiday surveys of an entire ice sheet, Medley says.

NASA satellites have played a key role in detecting how ice sheets have lost mass in recent decades. But they have struggled to measure fine details about how variations in snow depth on the surface of the ice affect the thickness of these continental glaciers.

Scientists typically determine the health of an ice sheet by measuring changes in surface height that help assess whether the ice is thinning or thickening. But snow blows constantly all around an ice sheet and piles on its surface over several years like a multilayer cake that satellites struggle to track.

"We have to make sure the thickness changes we're seeing aren't just a single snowfall event or the lack of a single snowfall event," Medley says. "Then we can better interpret the changes that we're seeing from space, if we know how much snow is falling."

Because sea ice is already floating on the ocean, sea level does not rise significantly when that ice melts.

But snowfall that settles on the ice sheets eventually melts and deposits freshwater into the ocean. Stored as frozen water on the surface of an ice sheet, this snow can also stall an ice sheet's contribution to sea level rise, Medley says.

How exactly that accumulated snow influences sea levels is a poorly understood processes in studies of sea level rise.

"We need to monitor this snow accumulation," Medley says, "because small changes can actually end up playing a very large role in sea level change." ■

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- connect with attendees;
- share open-source data;
- grow your audience; and
- access valuable metrics.

Even as in-person events and conferences return, the *hybrid* model (combining in-person *and* online participation) is here to stay. NASA's Virtual Event Platform ensures NASA's continued presence at the heart of the scientific community—and provides both scientific and general audiences with easier access to NASA Science than ever before.

The landing page for NASA's Virtual Event Platform as it was set up for Earth Day 2022. **Photo Credit:** Kevin Miller/NASA's Goddard Space Flight Center's Science Support Office

Learn more about NASA's Virtual Event Platform at *go.nasa.gov/3KG7brt*

Or explore NASA's "Every Day Is Earth Day" virtual exhibit at *go.nasa.gov/EarthDayEvent2022*

Sea Level to Rise up to a Foot by 2050, Interagency Report Finds

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

NASA, NOAA, USGS, and other U.S. government agencies project that the rise in ocean height in the next 30 years could equal the total rise seen over the past 100 years.

Coastal flooding will increase significantly over the next 30 years because of sea level rise, according to a new report by an interagency sea-level-rise task force that includes NASA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and other federal agencies. Titled "Global and Regional Sea Level Rise Scenarios for the United States," the February 15, 2022, report concludes that sea level along U.S. coastlines will rise between 10 to 12 in (25 to 30 cm) on average above today's levels by 2050.[1]

The report—an update to a 2017 report—forecasts sea level to the year 2150 and, for the first time, offers nearer-term projections for the next 30 years. Agencies at the federal, state, and local levels use these reports to inform their plans on anticipating and coping with the effects of sea level rise.

"This report supports previous studies and confirms what we have long known: Sea levels are continuing to rise at an alarming rate, endangering communities around the world. Science is indisputable and urgent action is required to mitigate a climate crisis that is well underway," said **NASA Administrator Bill Nelson**. "NASA is steadfast in our commitment to protecting our home planet by expanding our monitoring capabilities and continuing to ensure our climate data are not only accessible but understandable."

The task force developed its near-term sea level rise projections by drawing on an improved understanding of how the processes that contribute to rising seas—such as melting glaciers and ice sheets as well as complex interactions between ocean, land, and ice—will affect ocean height. "That understanding has really advanced since the 2017 report, which gave us more certainty over how much sea level rise we'll get in the coming decades," said **Ben Hamlington** [NASA/Jet Propulsion Laboratory], one of the update's lead authors.

NASA's Sea Level Change Team, led by Hamlington, has also developed an online mapping tool to visualize the report's state-of-the-art sea level rise projections on a localized level across the U.S.[2] "The hope is that the online tool will help make the information as widely accessible as possible," Hamlington said.

The Interagency Sea Level Rise Task Force projects an uptick in the frequency and intensity of high-tide coastal flooding—a.k.a., *nuisance flooding*—because of higher sea level. It also notes that if greenhouse gas emissions continue to increase, global temperatures will rise even higher, leading to a greater likelihood that sea level rise by the end of the century will exceed the projections in the 2022 update.

"It takes a village to make climate predictions. When you combine NASA's scenarios of global sea level rise with NOAA's estimates of extreme water levels and the USGS's impact studies, you get a robust national estimate of the projected future that awaits American coastal communities and our economic infrastructure in 20, 30, or 100 years from now," said **Nadya Vinogradova-Shiffer** [NASA Headquarters], who directs the NASA Sea Level Change Team.

"This is a global wake-up call and gives Americans the information needed to act now to best position ourselves for the future," said **NOAA Administrator Rick Spinrad**. "As we build a Climate Ready Nation, these updated data can inform coastal communities and others about current and future vulnerabilities in the face of climate change and help them make smart decisions to keep people and property safe over the long run."

Building on a Research Legacy

The Global and Regional Sea Level Rise report incorporates sea level projections from the latest Intergovernmental Panel on Climate Change (IPCC) assessment, released by the United Nations in August 2021. The IPCC reports, issued every five to seven years, provide global evaluations of Earth's climate and use analyses based on computer simulations, among other data.

A separate forthcoming report known as the Fifth National Climate Assessment, produced by the U.S. Global Change Research Program, is the latest in a series summarizing the impacts of climate change on the U.S., and it will in turn use the results from the Global and Regional Sea Level Rise report in its analysis. The Climate Assessment is slated to be published in 2023. ■

[1] To read the report, visit *oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html*.
[2] The tool is available at *go.nasa.gov/35u7DKQ*.

New Space-Based Weather Instruments Start Gathering Data

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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*.

Innovative mini instruments on the International Space Station have produced their first maps of global humidity and ocean winds.

After being installed on the International Space Station, two small instruments designed and built at NASA/Jet Propulsion Laboratory (JPL) were powered up January 7 and began collecting data on Earth's ocean winds and atmospheric water vapor—critical information required for weather and marine forecasts. Within two days, the Compact Ocean Wind Vector Radiometer (COWVR) and Temporal Experiment for Storms and Tropical Systems (TEMPEST) instruments had gathered enough data to begin producing maps.

COWVR and TEMPEST launched on December 21, 2021, on SpaceX's twenty-fourth commercial resupply mission for NASA. Both instruments are microwave radiometers, measuring variations in natural microwave emissions from Earth. Part of the U.S. Space Force's Space Test Program-Houston 8 (STP-H8), the instruments were designed to demonstrate that they can collect data comparable in quality to the larger instruments currently operating in orbit.

Created using COWVR data, the map in **Figure 1** shows microwave emissions from Earth at 34 GHz through all latitudes visible to the space station (52 °N to 52 °S). This particular microwave frequency provides weather forecasters information on the strength of winds at the ocean surface, the amount of water in clouds, and the amount of water vapor in the atmosphere.

Medium gray and white shades on the map indicate higher water vapor and clouds, while dark gray over the ocean indicates drier air and clear sky. The image captures typical weather patterns, such as tropical moisture and rain (the medium gray band stretching across center of map) and mid-latitude storms moving across the ocean.

"We're off to a great start," said **Shannon Brown** [JPL], the technologist who designed the COWVR instrument. "Seeing this quality of data so early into the mission sets the stage for very exciting things to come."

COWVR is a complete rethinking of a classic instrument design, while TEMPEST is the product of a long advance toward miniaturizing instrument components. If they continue to prove successful, they will crack open the door to a new era where lower-cost satellites complement the existing weather satellite fleet.

How the Instruments Work

Radiometers need an antenna that rotates so that they can observe a wide swath of Earth's surface instead of just a narrow line. In all spaceborne microwave radiometers to date, not only the antenna but also the radiometer itself and the companion electronics rotate about 30 times a minute. There are good scientific and engineering reasons for a design with so many spinning parts—but keeping a spacecraft stable when there's that much moving mass can present challenges. Also, the mechanism that passes power and data between the spinning and the stationary sides of the instrument has proven to be time-consuming and difficult to build.

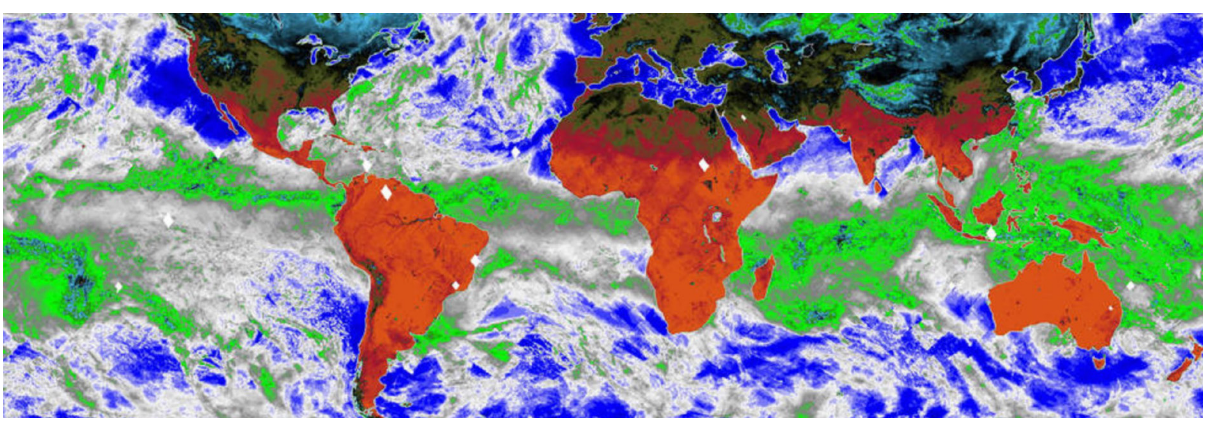

Figure 1. This map, made using COWVR's new observations, shows Earth's microwave emissions at 34 GHz—a frequency that provides information on the strength of winds at the ocean surface, the amount of water in clouds, and the amount of water vapor in the atmosphere. **Credit:** NASA/JPL-Caltech

Weighing about 130 lb (~59 kg), COWVR has less than one-fifth the mass of WindSat—the microwave radiometer the U.S. military currently uses to measure ocean winds. Less than one-third of COWVR's mass rotates. To avoid the need for a separate mechanism that transfers power and data from the spinning to the stable parts, Brown mounted everything that spins on a turntable.

Brown and his team enabled other design innovations by increasing the complexity of the data processing required—i.e., finding software solutions to hardware challenges. For example, the team replaced a part of the instrument called a *warm target*, used to calibrate the radiometer's polarization measurements, with a noise source that generates known polarized signals. When the calibration is complete, these known signals can be removed like any other noise in a data transmission.

Meanwhile, COWVR's companion instrument, TEMPEST, is the product of decades of NASA investment in technology to make space-bound electronics more compact. In the mid-2010s, NASA engineer **Sharmila Padmanabhan** [JPL] pondered what scientific goals could be accomplished by packaging a compact sensor in a *CubeSat*—a type of very small satellite often used for testing new design concepts inexpensively.[1] "We said, 'Hey, if we can actually manage to compactly package a sensor inside a CubeSat, we can get measurements of clouds, convection, and precipitation over time,'" Padmanabhan remembered. Those measurements would provide more insight into how storms grow.

[1] To learn more about how NASA is using CubeSats to study Earth science, see "CubeSats and Their Roles in NASA's Earth Science Investigations," in the November–December 2020 issue of The Earth Observer [**Volume 32**, **Issue 6**, pp. 5–17—*go.nasa.gov/3tmwAig*]. Page 14 of this article shows an image obtained from TEMPEST-D.

Padmanabhan's design was first tried out in space from 2018 to June 2021. That CubeSat, known as TEMPEST-D ("D" for "demonstration"), measured water vapor in the atmosphere and captured images of many major hurricanes and storms.[2] The newly deployed TEMPEST is about the size of a large cereal box and weighs less than 3 lbs (1.3 kg), with an antenna about 6 in (15 cm) in diameter.

The antenna size dictates that TEMPEST can best observe only the shortest microwave wavelengths sensitive to water vapor—about 10 times shorter than the ones COWVR senses. A smaller antenna *matches* short wavelengths better, similar to the way the short air column of a flute is suitable for short wavelengths of sound (high notes), while the long air column of a tuba is better for the long wavelengths of low notes.

COWVR and TEMPEST's combined data provide most of the same measurements available from large microwave radiometers used for weather observations. The instruments were funded by the U.S. Space Force and Navy, but users from other agencies, universities, and branches of the military are also interested. These scientists are already working on mission concepts that would take advantage of the new low-cost microwave sensor technologies to study long-standing questions such as how heat from the ocean fuels global weather patterns. ■

[2] See page 14 of the article referenced in footnote 1 to see an image obtained by TEMPEST-D combined with data from RainCube (another CubeSat).

NASA Earth Science in the News

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

NASA Satellite Sees Arctic Sea Ice Thinning at "Frightening" Rate, March 11, *cnet.com*. Scientists have warned that, for the first time since record keeping began, the Arctic Ocean could be totally ice free in late summer as soon as 2035. New research shows Arctic sea ice, including some of the oldest hunks, is thinning and disappearing at a surprising rate. NASA-supported research, using observations from NASA's Ice, Cloud, and land Elevation Satellite–2 (ICESat-2) and the European Space Agency's CryoSat-2 satellite, found the Arctic Ocean has lost about a third of its winter sea-ice volume over the past two decades. Much of this loss is occurring because so-called *multiyear ice* that lasts for several seasons is being replaced by thinner *seasonal ice* that completely melts each summer. A recent study, published in the journal *Geophysical Research Letters*, found multiyear ice in the Arctic lost about 1.5 ft (~0.5 m) of thickness since ICESat-2 began operating in 2019—that's 16% of the Arctic's total ice thickness in about three years.[1] "We weren't really expecting to see this decline, for the ice to be this much thinner in just three short years," said **Sahra Kacimi** [NASA/Jet Propulsion Laboratory], lead author of the study and a polar-regions scientist. The study used satellite radar and lidar data to measure ice thickness and snow depth and found previous estimates overestimated sea-ice thickness by as much as 20%. The switch from the legacy of multiyear ice to more seasonal ice is the latest in a series of impacts the Arctic has felt from climate change in recent decades.

*__NASA Takes Off at Commodity Classic__, March 14, *dtnpf.com*. Leaders from the U.S. agency normally associated with rocket launches and space travel—NASA—spent time in early March showing farmers and people in agribusiness its satellite data resources, which are already being used to help the U.S. Department of Agriculture (USDA) and others forecast crop production and weather conditions on the ground. This was the first year that NASA participated in the annual Commodity Classic event, the largest trade show in the U.S. for and about farmers. The agency had a large exhibit in the expo hall, providing the venue for a series of presentations about crop modeling, weather, and partnerships, such as the U.S. Drought Monitor. **Karen St. Germain** [NASA Headquarters—*Director of the Earth Sciences Division*] spoke to National Association of Wheat Growers (NAWG) board members and others about the agency's space assets constantly looking back at the planet. "My hope is that this is the start of a conversation between NASA Earth Science and wheat growers and other agricultural industry folks," St. Germain said, stating that she thinks agriculture is perhaps one of the most data-intensive industries in the country. She then highlighted how NASA has a range of data tools that are "all free and all freely available." NASA maintains the largest holdings of environmental data in the world, with satellite records going back decades. Through partnerships and the use of cutting-edge technology, the agency seeks to put that information, which is often not centralized in a single location, into the hands of organizations and individuals who can apply them to help solve real-world problems for the betterment of society, e.g., agriculture and farming. "I think there's a natural partnership here because NASA is fundamentally a data agency," St. Germain said. "We already interact now, but what I really want is to start the conversation on how we might do better together as we move forward into the future."

International Sea Level Satellite Takes Over from Predecessor, March 23, *spacedaily.com*. On March 22, the newest U.S.–European sea-level-measuring satellite, named Sentinel-6 Michael Freilich, became the official *reference satellite* for global sea-level measurements—replacing Jason-3 in this role. This means that sea-surface-height data collected by other satellites will now be compared to the information produced by Sentinel-6 Michael Freilich to ensure their accuracy. Launched from Vandenberg Space Force Base in November 2020, the satellite is continuing a nearly 30-year legacy started by the Ocean Topography Experiment (TOPEX)/Poseidon satellite, which began its mission to measure sea-surface height in the early 1990s. A series of successor satellites (Jason-1, -2, and -3) have carried on the effort since then, with Sentinel-6 Michael Freilich being the most recent. (Its twin, Sentinel-6B, is slated to launch in 2025.) "These missions, of which Sentinel-6 Michael Freilich is the

[1] To read the study, visit *agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL097448*.

*See feature article on page 4 to learn more about this topic.

latest, are the gold standard when it comes to sea level measurements, which are critical for understanding and monitoring climate change," said **Josh Willis** [NASA/Jet Propulsion Laboratory—*Sentinel-6 Michael Freilich Project Scientist*]. Long-term records of sea-level height are key to monitoring how much—and how fast—the oceans are rising in a warming climate. "We can't lose track of how much sea level has gone up because if we do, it's hard to predict what's going to happen in the decades to come," Willis added. After Sentinel-6 Michael Freilich launched, it settled into orbit flying 30 seconds behind its predecessor, Jason-3. Science and engineering teams have spent the time since launch making sure Sentinel-6 Michael Freilich was collecting the intended data and that the information was accurate. Some of the initial data were made available last year for use in tasks like weather forecasting. After further validation, the scientists agreed that Sentinel-6 Michael Freilich should become the reference satellite for sea-level measurements. Later this year, teams will move Jason-3 into an *interleaved orbit*—meaning that, from its new position, the ground track for Jason-3 will run in between the ground tracks of successive orbits for Sentinel-6 Michael Freilich. Although it will no longer serve as the official reference sea-level-measuring satellite, Jason-3 will keep measuring sea-level height from the interleaved orbit. By continuing to collect sea-level data, Jason-3 will essentially double the number of measurements seen by each pass of Sentinel-6 Michael Freilich, helping to greatly increase the spatial resolution of sea-level measurements provided by both satellites.

NASA Warns Thawing Permafrost Could Free Microbes Locked Away for Thousands of Years, March 10, *msn.com*. *Permafrost*—defined as any ground that remains completely frozen for at least two years straight—covers large portions of our planet, including almost 25% of land in the Northern Hemisphere. A gradually warming climate will cause permafrost to melt over time, potentially causing a multitude of problems for humans. Thawing permafrost releases vast pockets of carbon dioxide, which is a greenhouse gas.[2] Perhaps less known—but more ominous—is the danger posed to public health by the release of ancient microbes, frozen in the permafrost as natural time capsules, sometimes for hundreds of thousands of years. For example, more than 100 diverse microorganisms in Siberia's permafrost are resistant to antibiotics. Permafrost is home to untold amounts of microbes and other chemicals, NASA said, with large regions of frozen ground melting at an increasing rate. **Kimberley Miner** [NASA/Jet Propulsion Laboratory], a climate researcher, is working to characterize microbes frozen in permafrost. "Everyone is racing as fast as they can to understand what's going on at the poles," she said in a press release.[3] "The more we understand, the better prepared we will be for the future." Contact with such potential biological hazards would not be impossible or even necessarily difficult. Settlements, industrial sites, and military projects have all been built on permafrost in recent decades. "These are microbes that have co-evolved with things like giant sloths or mammoths, and we have no idea what they could do when released into our [present-day] ecosystems," Miner said in October last year. "We have a very small understanding of what kind of *extremophiles*—microbes that live in lots of different conditions for a long time—have the potential to re-emerge."

NASA's New Climate Change GIF Made the Internet Go Crazy, March 17, *bgr.com*. NASA has released an updated visual showcasing the temperature changes from 1880 to 2021—see **Figure**.[4] The climate change GIF took off on Reddit, garnering over 48,000 upvotes on one of its many subreddits. The GIF was pulled from a video that NASA shared on March 15, 2022, that showcases how global temperatures have warmed due to human activities over time. The original video appeared on NASA's climate change YouTube channel in mid-March. **Ed Hawkins** [University of Reading, National Centre for Atmospheric Science] is the climate scientist who created the visualization.

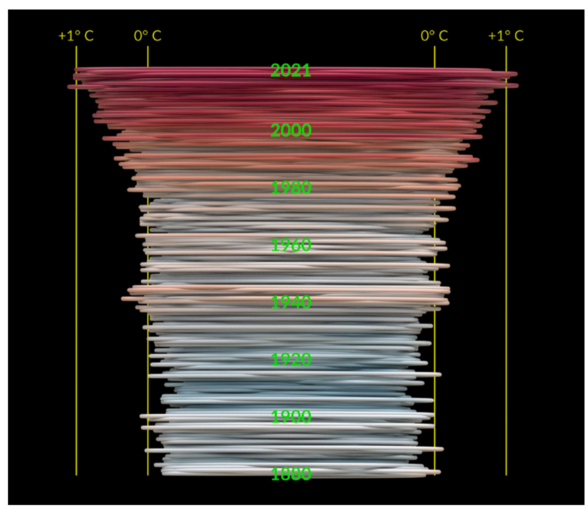

Figure. This image—pulled from *svs.gsfc.nasa.gov/4975*—presents monthly global temperature anomalies between the years 1880 and 2021. These temperatures are based on the Goddard Institute for Space Studies (GISS) Surface Temperature Analysis (GISTEMP), an estimate of global surface temperature change. Anomalies are defined relative to a base period of 1951–1980. To watch the visualization, visit *svs.gsfc.nasa.gov/4975*. **Credit:** NASA's Scientific Visualization Studio.

[2] The permafrost in the Arctic alone is estimated to store around 1700 billion metric tons of carbon including carbon dioxide and methane. If this amount were to be released all at once, it would equal more than 50 times the amount of fossil fuel emissions the world produced in 2019.

[3] To read more, visit *go.nasa.gov/3rc5P0V*.

[4] To find additional background on this Figure and to view the visualization, visit *go.nasa.gov/3v5CRAF*.

Earth Science Meeting and Workshop Calendar

NASA Community

May 16–20, 2022
2022 Sun–Climate Symposium, Madison, WI
lasp.colorado.edu/home/meetings/2022-sun-climate-symposium

October 18–20, 2022
Land Cover and Land Use Change Science Team Meeting and Silver Jubilee, Bethesda, MD
lcluc.umd.edu/meetings/2021-22-nasa-lcluc-science-team-meeting-silver-jubilee-celebration?page=

October 31–November 4, 2022
Ocean Surface Topography Science Team Meeting, Venice, Italy
ostst-altimetry-2022.com

Global Science Community

May 22–27, 2022
Japan Geoscience Union Meeting, *hybrid*
Makuhari, Chiba, Japan
www.jpgu.org/meeting_e2022

May 23–27, 2022
EGU General Assembly, *hybrid*
Vienna, Austria
www.egu22.eu

May 23–27, 2022
2022 Living Planet Symposium,
Bonn, Germany
lps22.esa.int/frontend/index.php

June 21–24, 2022
Global Council for Science and the Environment, *virtual*
www.gcseconference.org

July 16–24, 2022
COSPAR 2022,
Athens, Greece
www.cosparathens2022.org

July 17–22, 2022
IGARSS 2022,
Kuala Lumpur, Malaysia
www.classic.grss-ieee.org/conferences/future-igarss

August 1–5, 2022
AOGS 18th Annual Meeting, *virtual*
www.asiaoceania.org/aogs2021/public.asp?page=home.html

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