Over Thirty Years Reporting on NASA's Earth Science Program

The Earth Observer

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The Editor's Corner

Steve Platnick
EOS Senior Project Scientist

NASA's Aqua mission celebrated the twentieth anniversary of its launch on May 4, 2022. The second EOS *flagship mission* (Terra, which launched in 1999, being the first) has amassed one of the longest near-continuous records of Earth observation data ever assembled. Aqua has orbited Earth more than 100,000 times over the past 20 years—far exceeding its planned six-year mission lifetime to the pleasant surprise of those involved in the mission.

Aqua, which is named after the Latin word for water, flies at an altitude of 705 km (438 mi) in a Sun-synchronous polar orbit. Aqua's six instruments (four of which remain active today) have collected and transmitted data about nearly every aspect of Earth's water cycle including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow covering Earth's terrestrial surfaces. Aqua also provides datasets that include Earth's radiative energy fluxes, aerosols, terrestrial vegetation, ocean color (e.g., phytoplankton and dissolved organic matter in the oceans), and temperatures on the land surface, the ocean surface, and throughout the atmosphere.

In addition to its own unique capabilities, Aqua was also the cornerstone mission in the Afternoon Constellation, or "A-Train," for nearly two decades until Aqua started slowly drifting earlier this year. The A-Train is an international constellation of satellites that closely follow within seconds to minutes of each other along the same (or slightly offset) orbital track, crossing the Equator in an ascending (northbound) direction at about 1:30 PM local time—see **Figure 2** on **page 6** of this issue. This allows near-simultaneous observations from a wide variety of instruments that are synergistically used to aid the scientific community in advancing a wide range of Earth-system science.

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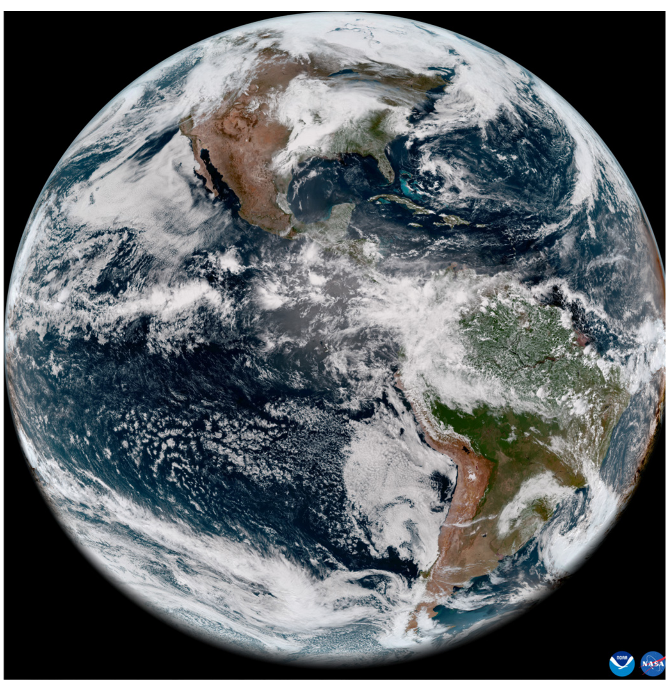


Figure. On May 11, 2022, NOAA shared the first images of the Western Hemisphere obtained by the Advanced Baseline Imager (ABI) on GOES-T (now GOES-18), which launched on March 1, 2022 from Cape Canaveral Space Force Station in Florida. ABI views Earth with 16 different channels, each measuring energy at different wavelengths along the electromagnetic spectrum to obtain information about Earth's atmosphere, land, and ocean.

NASA launches the GOES satellites for NOAA and performs the initial checkout of the spacecraft and instruents, and then NOAA takes command for daily operations—at which point the alphabetical designation (e.g., GOES-T) changes to a numeric one (e.g., GOES-18). This was the third of four planned launches of the GOES-R series. GOES-R (2016) and GOES-S (2018) proceeded GOES-T into orbit; GOES-U is planned for launch in 2024. **Image credit**: NOAA

In This Issue

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

This issue contains two articles related to Aqua's milestone anniversary. The first describes a hybrid celebration event held at the Visitor Center at GSFC. This event was sponsored by Aqua spacecraft developer Northrop Grumman and featured remarks from many past and present members of Aqua's science and mission teams, most of whom participated in person, with a few participating virtually. Turn to **page 4** to read this summary.

The second article describes the achievements of the Aqua mission, including descriptions of the contributions of each of its instruments and its participation in the A-Train. It includes quotes from the Aqua Project Scientist, Deputy Project Scientist, Mission Manager, and all current and some former science team leaders. Turn to **page 5** to read this summary.[1]

Another international A-Train member celebrated a milestone on May 18, as JAXA's Global Change Observation Mission—Water (GCOM-W1) or *SHIZUKU* (Japanese for droplet) mission marked 10 years in orbit. GCOM-W1 was the first launch in the Japanese GCOM series. GCOM—Climate (or C) followed in 2017. GCOM-W1 makes complementary measurements to those of Aqua. It carries the Advanced Microwave Scanning Radiometer 2 (AMSR2), which is a follow-on to the AMSR-E instrument on Aqua.

On May 11, 2022, NOAA released the first images of the Western Hemisphere from its GOES-T (now GOES-18) mission—see **Figure**, *on the cover.* The image comes from the Advanced Baseline Imager (ABI), which is a slight upgrade from the same instrument aboard the GOES-17 satellite currently positioned as GOES-West. Launched in March 2022, GOES-18 is the third of the GOES-R series of four advanced geostationary weather satellites built by NASA and operated by NOAA. In early 2023, GOES-18 will replace GOES-17 as the operational GOES-West satellite and will join GOES-16 (launched in 2016) currently in orbit as GOES-East.[2] In addition to the ABI, each GOES satellite includes a Geostationary Lightning Mapper (GLM) for detecting lightning flashes and multiple sensors that observe space weather and detect solar disturbances. The final satellite in the series [GOES-U (-19)] is scheduled to launch in 2024.

George Huffman [GSFC] has been selected to replace **Scott Braun** [GSFC] as GPM Project Scientist (PS). Braun had been GPM PS since 2018 and prior to

[1] This article was originally published on the *EarthData* website and is being reprinted (with some modification for the context of *The Earth Observer*) with the permission of the author. The original version appears at *go.nasa.gov/3OnZiJO.*

[2] At any given time, NOAA aims to have GOES satellites positioned at 75.2° W (referred to as GOES-East) and 137.2°W (GOES-West) to provide complete coverage of the Western Hemisphere. NOAA also maintains an on-orbit spare GOES satellite in the event of an anomaly or failure of GOES East or GOES West.

that he was TRMM PS from 2006–2017. This allows Braun to focus fully on his role as the Earth System Observatory's Atmospheric Observing System (AOS) PS and TROPICS PS.

Huffman, who had been GPM Deputy Project Scientist since 2014, brings a wealth of experience to his new role. He has been working at (or near) GSFC since 1988. Since the mid-1990s, Huffman's focus has been on the design, implementation, and extension of combined (satellite-gauge) estimates of global precipitation. The resulting datasets include the Global Precipitation Climatology Project (GPCP) monthly and daily products (carried out as a contribution to the World Climate Research Program, WCRP); the TRMM Multi-satellite Precipitation Analysis (TMPA); and its successor, the GPM mission's Integrated Multi-satellitE Retrievals for GPM (IMERG). Related to these efforts, he also collaborates on work that includes estimating errors and extreme precipitation event statistics.

Congratulations to George and Scott on their new positions, and many thanks to both for their years of service on previous endeavors.

In what is a sign of the times as the world emerges from the pandemic, this year, for the first time ever, NASA's Earth Day event was a hybrid affair. The event featured an in-person exhibit April 22–24 at Union Station in Washington, DC, as well as online content, including a "live" event held on April 22 (Earth Day) that featured webinars and an online exhibit—accessible via NASA's virtual exhibit space—that was open until May 2. There were 2336 unique participants online.

The three-day in-person event, which was free and open to the public, featured a 40-ft Earth dome tent and 18 hands-on activities inside Union Station's historic Main Hall—which is a major transportation hub with 25,000–30,000 people passing through daily, and thus an excellent place for NASA to showcase its activities. Three 60-minute webinar speakers were: **Don Thomas** [Former NASA Astronaut]; **Karen St. Germain** [NASA Headquarters—*Director of NASA's Earth Science Division];* and **Katherine Calvin** [NASA HQ—*Chief Scientist*]. Altogether 972 attendees watched the webinar events—which is nearly half of the online attendees.

Kudos to NASA's Science Support Office (SSO) staff for pulling together a diverse team of 100 individuals from across the agency to work together to plan and execute this event. Turn to page 14 of this issue to read a summary of the hybrid Earth Day event.

On June 12 an Astra Space rocket carrying the first two satellites of the Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) failed to reach orbit.[3] Everything started well as the rocket blasted off about 1:43 PM Eastern Daylight Time from Cape Canaveral Space Force Station in Florida. It successfully released its first stage and shed its faring. However, as the upper stage was raising the satellites to orbit, the engines shut off about a minute earlier than expected, which meant that the two CubeSats onboard could not be inserted into their proper orbit.[4]

Despite the loss of the first two CubeSats, TROPICS can still meet its science objective of providing rapid refresh microwave observations with the four remaining 3U CubeSats placed into two different inclined orbital planes. The launches of the remaining CubeSats were planned for later this summer (two CubeSats per launch) but will likely be delayed due to the Astra Space launch vehicle failure. ■

[3] TROPICS was selected as an Earth Venture Instrument (EVI-3) mission. The Earth Venture program element within the Earth System Pathfinder Program (ESSP) aims to produce science-driven, competitively-selected, low-cost missions that enhance our capability to better understand the current state of the Earth system and to enable continual improvement in the prediction of future changes.

[4] To learn more about this launch failure and the impact on TROPICS, see *go.nasa.gov/3HvQWxr*.

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

CO_2	Carbon Dioxide
EOS	Earth Observing System
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement
GISS	NASA Goddard Institute for Space Studies
AMSR-E	Advanced Microwave Sounding Radiometer for EOS
GSFC	NASA's Goddard Space Flight Center
NOAA	National Oceanic and Atmospheric Administration
JAXA	Japan Aerospace Exploration Agency
TRMM	Tropical Rainfall Measuring Mission

Aqua's 20 Years Honored with Celebration at Goddard's Visitor Center

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

Aqua—the second flagship of NASA's Earth Observing System (EOS)—celebrated the twentieth anniversary of its launch on May 4, 2022. An event was held that day at the Visitor Center at NASA's Goddard Space Flight Center (GSFC) to celebrate this impressive milestone. The Aqua spacecraft developer, Northrop Grumman, graciously sponsored the catered event. Attendees heard remarks from many past and present members of Aqua's science and mission teams, some of whom participated in person, while others participated virtually.

The evening kicked off with welcoming remarks from **Dennis Andrucyk** [GSFC—*Center Director*] and **Carl Martin** [Northrop Grumman—*Program Manager for Factory Operations*].

The next two presentations focused on Aqua's science achievements**. Claire Parkinson** [GSFC—*Aqua Project Scientist*] presented a brief overview of mission accomplishments, and **Steve Platnick** [GSFC—*EOS Senior Project Scientist* and *A-Train Project Scientist*] followed with a description of Aqua's role in the afternoon constellation, or "A-Train."[1]

Three speakers then gave the NASA Headquarters perspective on Aqua. These included: **Jack Kaye** [NASA HQ—*Associate Director for Research for the Earth Science Division*], **Ramesh Kakar** [NASA HQ, *retired—Former Aqua Program Scientist*], and **Will McCarty** [NASA HQ—*Aqua Program Scientist*].

George Morrow [NASA HQ, *Retired—Former Aqua Project Manager*] took the audience on a trip back in time to the mid-1990s (when the EOS missions and instruments were being developed and built) and discussed the challenges and accomplishments associated with building and launching Aqua.

Next, there were two presentations that offered perspective on Aqua mission operations. **Wynn Watson** [GSFC—*Project Manager for Earth Science Mission Operations*] and **Bill Guit** [GSFC—*Aqua Mission Director*] spoke on maintaining the health and safety of the mission over two decades, while at the same time ensuring the steady flow of high-quality data products.

The next group of presentations were from former and current Aqua instrument science team leaders, who remarked on the discoveries and accomplishments of each instrument. **Joao Teixeira** [NASA/Jet Propulsion Laboratory—*AIRS Science Team Leader*], **Norman Loeb** [NASA Langley Research Center—*CERES Science Team Leader*], **Vince Salomonson** [University of Utah—*Former MODIS Science Team Leader*], **Michael King** [University of Colorado, Laboratory for Atmospheric and Space Physics—*MODIS Science Team Leader*], and **Roy Spencer** [University of Alabama, Huntsville—*U.S. AMSR-E Science Team Leader*] all spoke about the impacts and benefits of the instrument they represented.

Turning to a crucial application of Aqua data, **Lou Uccellini** [National Oceanic and Atmospheric Administration, National Weather Service—*Former Director*] spoke about the improvements to weather forecasting made possible by data provided by Aqua's instruments.

Lazaros Oreopoulos [GSFC—*Aqua Deputy Project Scientist*] gave closing remarks. He displayed the first-light images from each of the instruments and then described Aqua's role in extending the observations of record—and their importance to the climate record.

The Aqua Twentieth Anniversary Celebration was extremely successful. Participants enjoyed the reminiscences about Aqua's history and scientific achievements, especially because for many of them, it was their first opportunity to see colleagues in person in two years. This celebration was the first event held at GSFC's Visitor Center after the pandemic restrictions had been lifted. ■

[1] To learn more about Aqua's achievements during its first two decades in orbit, see the article that begins on page 5 of this issue.

Aqua Turns 20

Joseph M. Smith, NASA's Goddard Space Flight Center/ADNET Systems, Inc., joseph.m.smith-1@nasa.gov

Introduction

On May 4, 2002, at 2:55 AM Pacific Time, a rocket carrying NASA's Aqua satellite—the second flagship satellite of the agency's Earth Observing System (EOS), shown in **Figure 1**—launched into space from Vandenberg Air Force Base, located in California.

Figure 1. NASA's Aqua satellite is depicted here in an artist's conception. The spacecraft design is similar to that used for Terra and identical to that used for Aura. **Image credit**: EOS Project Science Office website (*eospso.nasa.gov/missions/aqua)*

Since then, Aqua has orbited the Earth more than 100,000 times, and produced one of the longest near-continuous records of Earth observation data ever assembled. Its momentous Earth observation voyage has continued for more than two decades—far beyond anyone's expectations.

"It is remarkable," said **Claire Parkinson** [NASA's Goddard Space Flight Center (GSFC)—*Aqua Project Scientist*]. "The design life was six years, and although you expect to exceed the design life, getting 20 years has been great. If we knew we were going to have a spacecraft and instruments that would last 20 years, we might have put more fuel in it so that it would last even longer."

The Earth Observer has reported extensively on Aqua over its 20-year mission. Most notably, there was an article published for Aqua's tenth anniversary in 2012, which—while somewhat dated—is still a useful overview of the mission and its accomplishments over its first decade.[1] Beyond that, a search through the archives reveals summaries of numerous meetings of the science teams for Aqua's instruments [e.g., MODIS, CERES, AIRS/AMSU/HSB, AMSR-E (acronyms expanded below)], news stories related to Aqua, and numerous updates on the Aqua spacecraft and its instruments in the *Editor's Corner*.

This twentieth anniversary article was originally published on the *EarthData* website (*earthdata.nasa.gov/learn/articles/aqua-at-20*). The information has been slightly reorganized and modified in places to match the context and style of *The Earth Observer*.

Aqua in the Context of EOS History and the A-Train

NASA's EOS was established to acquire a long-term record of Earth observations to enhance understanding of the total Earth system and the effects of natural and human-induced changes on the environment. Conceived of in the 1980s and implemented in the 1990s and early 2000s, EOS includes three flagship satellite missions—Aqua, its predecessor Terra, which launched in 1999, and Aura, which launched in 2004—and several smaller missions, plus the EOS Project Science Office (which was established to oversee development of EOS) and a data system, NASA's Earth Observing System Data and Information System (EOSDIS).[2]

Named after the Latin word for water, *Aqua* has spent the past twenty years in a Sun-synchronous polar orbit 705 km (438 mi) above Earth's surface, collecting and transmitting data about Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow covering Earth's terrestrial surfaces. At the same time, Aqua obtains measurements of Earth's radiative energy fluxes, aerosols, terrestrial vegetation, ocean color (i.e., phytoplankton and dissolved organic matter in the oceans), and temperatures on the land surface, the ocean surface, and throughout the atmosphere.

In addition to being one of three flagship EOS satellites, Aqua has been a cornerstone of the "A-Train," a moniker given to the international constellation of satellites that closely follow one another (within seconds to minutes of each other) along the same orbital track, crossing the Equator in an ascending (northbound) direction at about 1:30 PM local time—see **Figure 2**. This allows near-simultaneous observations from a wide variety of instruments that are synergistically used to aid the scientific community in advancing a wide range of Earth-system science.[3]

[1] See "Aqua 10 Years After Launch," in the November–December 2012 issue of *The Earth Observer* [**Volume 24**, **Issue 6**, pp. 4–17—*go.nasa.gov/3Qap99A*].

[2] A useful resource to learn more about the history of EOS—from the standpoint of the individuals who were involved—is the "Perspectives on EOS" series of articles that ran in *The Earth Observer* from 2008–2011. These articles have been compiled into a single volume available at *go.nasa.gov/2Jciu0X*.

[3] To learn more about the A-Train, visit *atrain.nasa.gov*.

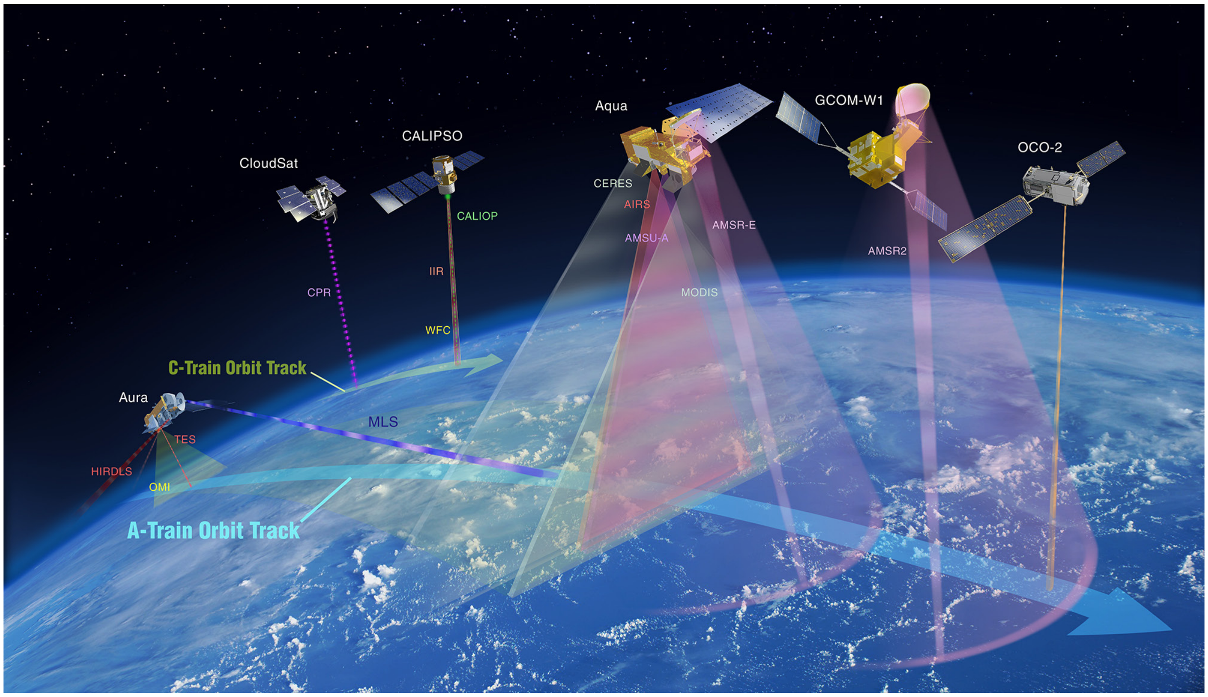


Figure 2, For almost 20 years, Aqua was the cornerstone of the Afternoon Constellation, or "A-Train," an international grouping of satellites that closely follow one another along the same orbital track, crossing the Equator going northward at about 1:30 PM local time and going southward at about 1:30 AM local time. This diagram illustrates the configuration of the A-Train in 2018—with Aqua still in the formation, and before CloudSat and CALIPSO lowered their orbit to create the "C-Train." See *atrain.nasa.gov* for more details. **Image credit**: Sally Bensusen, formerly of GSFC/Global Science and Technology, Inc.

In January 2022 Aqua descended from the A-Train when, due to its limited remaining fuel supply, it transitioned from its tightly controlled orbit to a free-drift mode, wherein its equatorial crossing time is slowly drifting to later times.

The Aqua mission is a joint endeavor among the U.S., Japan, and Brazil. NASA provided the spacecraft bus and four of its six instruments: the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Microwave Sounding Unit (AMSU)—both built under the management of GSFC; the Atmospheric Infrared Sounder (AIRS)—built under the management of NASA/Jet Propulsion Laboratory (JPL); and the Clouds and the Earth's Radiant Energy System (CERES)—built under the management of NASA's Langley Research Center (LaRC). Japan's National Space Development Agency (now the Japan Aerospace Exploration Agency, or JAXA) provided the Advanced Microwave Scanning Radiometer for EOS (AMSR-E). The Instituto Nacional de Pesquisas Espaciais (INPE) [Brazilian National Institute for Space Research] provided the Humidity Sounder for Brazil (HSB). Aqua began broadcasting data from these instruments in the weeks following its 2002 launch and, notwithstanding the failure of HSB (2003) and AMSR-E (2011), and other occasional disruptions to other instruments, it hasn't stopped since. **Figure 3** shows the location of each instrument on the Aqua spacecraft.

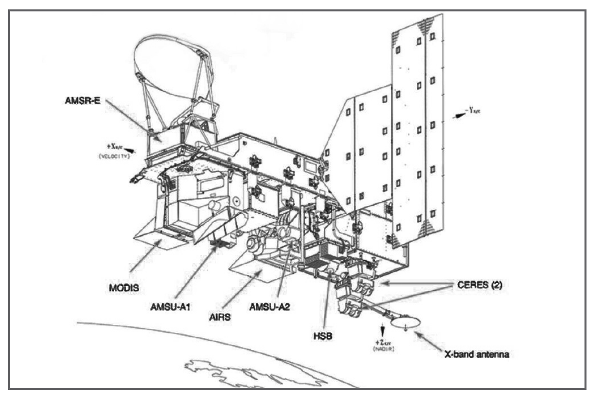


Figure 3. This schematic of the Aqua satellite shows the number and location of the spacecraft's six instruments. **Image credit**: Modified from version posted on Aqua Project Science Website (*go.nasa.gov/2VgjWjj*)

Parkinson attributes Aqua's longevity to the engineering expertise of NASA and its industry partners, who produced such a "well-constructed" spacecraft and instruments. She also credits NASA's Earth Science Mission Operations (ESMO) team, which has operated the systems that command and control the Aqua satellite, "with great skill and care," during the past two decades.[4]

[4] To learn more about the important role ESMO has played in the longevity of the Aqua mission, see *go.nasa.gov/3mD3ucG*. To learn more about ESMO, see "Earth Science Mission Operations, Part I: Flight Operations—Orchestrating NASA's Fleet of Earth Observing Satellites," in the March–April 2016 issue of *The Earth Observer* [**Volume 28**, **Issue 2**, pp. 4–13—*go.nasa.gov/3H66QhL*].

She is not alone in this assessment.

"[Aqua's longevity] is a testament to the high quality of engineering design and build that went into the instruments, the dedication of the ESMO team in quickly addressing anomalies, the expertise of the calibration scientists who ensured good characterization of the instruments so that consistent measurements can be made over many years, and NASA Headquarters, which recognized Aqua's success on multiple fronts and provided sustained funding for the mission," said **Lazaros Oreopoulos** [GSFC—*Aqua Deputy Project Scientist*].

Yet, Aqua's longevity is noteworthy for reasons beyond its mere stamina in the harsh conditions of space. Aqua's ability to endure in orbit is significant because it was intended to be the first in a series of three nearly identical EOS afternoon satellites.

"Originally, [the first two flagship EOS satellites] weren't called Aqua and Terra. They were called EOS AM, which became Terra, and EOS PM, which became Aqua, and there were to be two more versions of each satellite," Parkinson said. "The plan was that, after six years, we'd launch the next one. However, the budget for the EOS program was cut and the size of the program was reduced. Well, both Aqua and Terra have lasted 20 years, so it turns out we've more than covered the 18-year time frame that was going to be covered by both three-satellite sequences."

During that time, Aqua and its companion EOS satellites have given the Earth-science and remote sensing communities a treasure trove of data that have been incorporated into weather prediction models, processed into an array of data products for use in a wide variety of scientific research, and used in near-real-time (NRT) applications to monitor and manage natural and anthropogenic hazards and disasters, such as storms, wildfires, and volcanic eruptions.[5]

The Aqua Data Record

The Aqua data record represents one of the longest, single-satellite climate data records ever compiled. Each time Aqua orbits the Earth its data are transmitted from the spacecraft through two processes: *direct downlink* and *direct broadcast*. The direct downlink, which is routinely done after each orbit, transmits the data from an onboard, solid-state recorder (SSR), which has the capacity to hold up to 2.5 orbits of data, to polar ground stations in Poker Flats, AK and Svalbard, Norway. When direct downlink is not taking place, the direct-broadcast system is generally in operation and allows anyone with a direct-broadcast receiver to receive the raw Aqua data when the satellite is overhead.

[5] To learn more about Aqua data products, see *go.nasa.gov/3zsZzGH*.

From the polar ground stations, the downlinked data are transmitted to GSFC, where the data processing is done for the MODIS, AIRS, and AMSU-A data. CERES data are sent to LaRC for processing and, while it was operational, AMSR-E data were sent to Japan's Earth Observation Center (EOC) for initial processing, followed by further processing at Remote Sensing Systems (a private company) and at NASA's Marshall Space Flight Center (MSFC). After processing, Aqua instrument data are made available through several discipline-specific EOSDIS Distributed Active Archive Centers (DAACs).

According to figures from the Earth Science Data and Information System (ESDIS) Project's Metrics System, approximately 9.7 petabytes (PB) of Aqua data resided in the EOSDIS collection at the end of 2021, making up roughly 16.4% of the approximately 59-PB EOSDIS data collection. During Fiscal Year (FY) 2021, which ran from October 1, 2020, to September 30, 2021, 8.6 PB of Aqua data were distributed. Since 2002 the year the first Aqua data were available, approximately 55.2 PB of Aqua data have been distributed to data users, globally. Distribution of data from the Aqua and Terra MODIS instruments remains the highest of any instrument data in the EOSDIS collection, with 14 PB of MODIS data (7.5 PB from Aqua and 6.5 PB from Terra) distributed during FY 2021.

Statistics, of course, tell only part of the Aqua story. Aqua's impressive data record is composed of observations from each of its instruments: and the data they provide—both individually and in concert—offer a more detailed picture of the contributions the mission has made to the remote sensing and Earth science communities over the past 20 years.

MODIS

With 36 spectral channels, a swath of 2330 km x 10 km (1448 mi x 6 mi), and spatial resolution ranging from 250 to 1000 m (820 to 3280 ft), depending on the channel, the MODIS instrument is among the most celebrated of any satellite instrument in orbit. The first MODIS went into orbit aboard Terra in 1999 and, in conjunction with the MODIS sensor on Aqua, the pair have reliably and consistently provided the Earth science and remote sensing communities with an array of global Earth system observations, including interactions between the land, ocean, and atmosphere, for more than two decades.

The MODIS instrument aboard Aqua has proven especially useful in the satellite's mission to collect data about Earth's water cycle.

"Clouds are important elements of the water cycle and the MODIS instrument on Aqua has contributed a great deal to our understanding of the optical properties of clouds," said **Michael King** [University of Colorado, Laboratory for Atmospheric and Space Physics—*MODIS Science Team Leader*]. "And with Aqua being part of the A-Train, there were also a lot of opportunities to compare MODIS cloud property measurements with those from CloudSat and CALIPSO to help validate them."[6]

The Earth science and remote sensing communities also benefited from having a pair of MODIS instruments in different orbits (i.e., morning and afternoon), which offered complementary observations of high-priority features of Earth's atmospheric, oceanic, and terrestrial components—see **Figure 4**. "The second MODIS was very helpful in looking at morning and afternoon differences in the Earth system," said King. "For example, we observed that there were more clouds over land in the afternoon, which is partly why Terra was flown in an earlier orbit—to minimize cloud obscuration of the land during the morning. However, the reverse is true for the ocean, where there are more clouds in the morning and fewer in the afternoon. Having two MODIS instruments also enabled studies to investigate changes in other phenomena, such as aerosol concentrations (i.e., optical thickness), in the morning versus the afternoon."

[6] King, who was also EOS Senior Project Scientist from 1992–2008, wrote an article on his experiences with Terra that is included as part of the "Perspectives on EOS" series compilation referenced in footnote 2. To read King's article, see *go.nasa.gov/39hyETL*.

Having two MODIS instruments in orbit has also provided a greater chance of cloud-free observations and allowed a better assessment of fire regimes, and enabled the creation of the Bidirectional Reflectance Distribution Function (BRDF)-Adjusted Land Surface Reflectance dataset. This data product uses 16 days of 500-m (1640-ft) resolution MODIS data from both Terra and Aqua to measure surface albedo, or the percentage of radiant energy scattered up and away from the Earth's surface.

Further, several low-latency, NRT MODIS data products are available through NASA's Land, Atmosphere Near Real-time Capability for EOS (LANCE), typically within three hours of observation. Although NRT products undergo less processing than the MODIS data products used in scientific research, their near-immediate availability make them valuable tools for monitoring ongoing events like wildfires, flooding, volcanic eruptions, and other hazards.

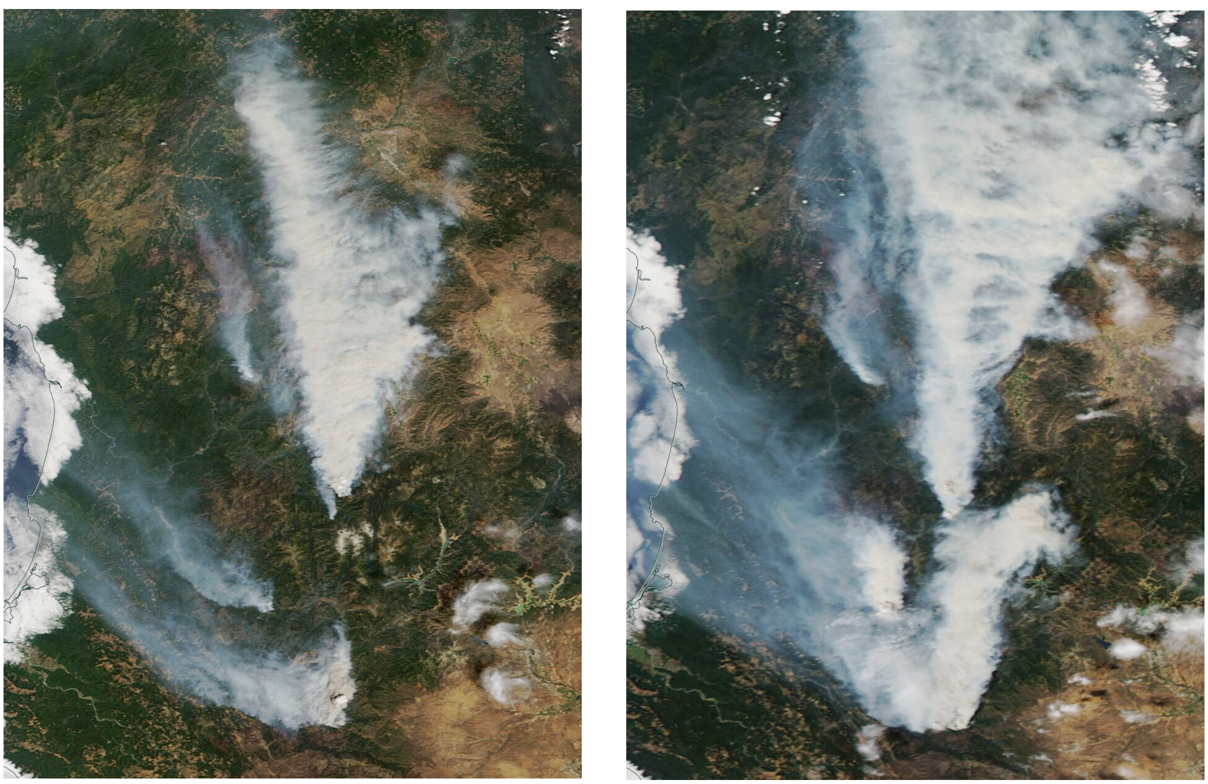


Figure 4. Having two MODIS instruments in orbit has provided a greater chance of cloud-free observations and better assessment of fire regimes. Shown here are two images of the River Complex fire burning in northern California on August 2, 2021, one obtained by MODIS on Terra in the morning (10:30 AM Mean Local Time, or MLT) [*left*] and the other by MODIS on Aqua in the afternoon (1:30 PM MLT) [*right*]. **Image credit**: NASA Worldview

Given the multidisciplinary nature of MODIS data, they are archived at and distributed from different EOSDIS DAACs:

- Land products are available from NASA's Land Processes DAAC (LP DAAC),
- Atmosphere products are available from NASA's Level-1 and Atmosphere Archive and Distribution System DAAC (LAADS DAAC),
- Snow and ice products are available from NASA's National Snow and Ice Data Center DAAC (NSIDC DAAC),
- Ocean color products are available from NASA's Ocean Biology Distributed Active Archive Center (OB.DAAC), and
- Sea surface temperature data are available from NASA's Physical Oceanography DAAC (PO.DAAC).

CERES

The CERES instrument was designed to help scientists better understand Earth's *radiation budget*—the balance (or imbalance) between Earth's incoming and outgoing energy. As Aqua orbits Earth, CERES measures the energy radiated and reflected from the top of the atmosphere, and the CERES Science Team combines the CERES measurements with other satellite data to calculate the radiated and reflected energy within the atmosphere and at the surface. Together, these data sets are used to better our understanding of the energy flows within the climate system—see **Figure 5**.

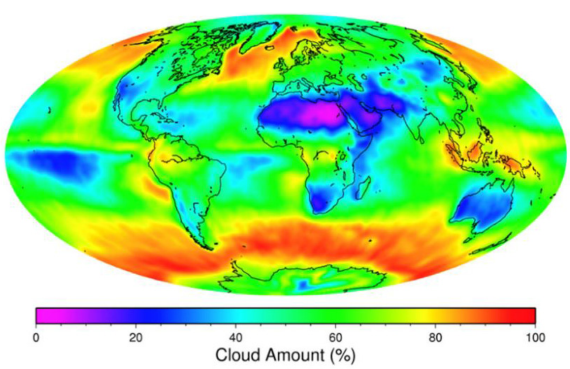


Figure 5. One of the greatest challenges in predicting how much Earth will warm in response to a doubling of atmospheric CO_2 involves the representation of clouds and their interactions with the Earth Radiation Budget (ERB) in climate models. The CERES Science Team has merged CERES and auxiliary data to develop data products that meet this challenge by providing a comprehensive suite of variables that describe clouds and their influence on ERB. As an example, shown here is the annual mean cloud fraction in percent. **Image credit**: Takmeng Wong and Norman Loeb/both at LaRC

For **Norman Loeb** [LaRC—*CERES Principal Investigator*], obtaining basic measurements of the amount of energy coming in and going out is critical to understanding both Earth's climate and climate change.

"From these measurements, we are able to assess the *heat budget* of the planet, meaning, how much energy is absorbed and how much is emitted," said Loeb. "It's important because, over time, if more energy is absorbed than emitted, the Earth will heat up, more ice and snow will melt over land, which will eventually find its way to the ocean and raise sea level, and heat the ocean, which will also cause sea level rise."

CERES data are also used in conjunction with data from other instruments aboard Aqua, particularly MODIS and AIRS, to investigate how atmospheric parameters and surface characteristics might impact Earth's radiation budget. "We use MODIS quite a bit, which enables us to look at properties in the atmosphere and at the surface that are driving the changes in radiation at the top of the atmosphere. So, we use the two synergistically, to provide a lot more information than one alone can provide," Loeb added. "We make use of AIRS as well to help us constrain the upper tropospheric humidity, which we need to make calculations of the surface radiative fluxes. AIRS provides us with a way of making those calculations more accurate."

Currently, there are six CERES instruments in orbit—one on the Joint Polar Satellite System's National Oceanic and Atmospheric Administration (NOAA)-20 satellite, one on the joint NASA/NOAA Suomi National Polar-orbiting Partnership satellite (Suomi NPP), two on Terra, and two on Aqua. Of note is that the last four have been operational for 20 or more years.

Having that long of a data record has been "incredible," according to Loeb.

"With the combination of Terra and Aqua both lasting this long we've learned a lot about the changes that are going on and we have had surprises," Loeb said. "We've learned that there's more energy coming in than going out and that this imbalance has actually doubled over the Aqua period. It's a truly incredible thought given the implications I mentioned earlier. We wouldn't have learned this had the missions lasted only as long as their six-year expected lifetimes."

CERES data are available through NASA's Atmospheric Science Data Center (ASDC), which archives and distributes EOSDIS data related to Earth's radiation budget, clouds, aerosols, and tropospheric composition.

AMSR-E

Provided by JAXA, AMSR-E was designed to measure a variety of processes over land and ocean using natural emissions of microwave radiation from Earth. Over land it measured precipitation, soil moisture, vegetation cover, and snow cover. Over the ocean,

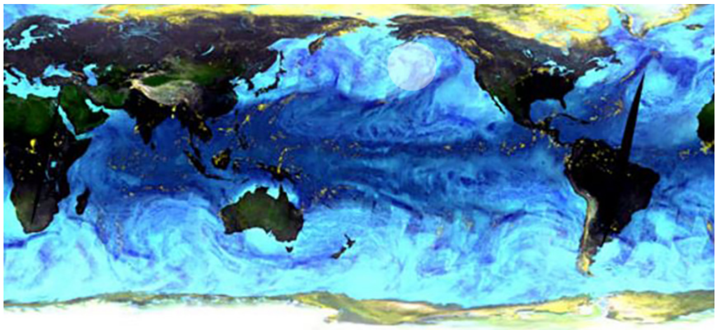


Figure 6. The Japan Aerospace Exploration Agency's Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) has delivered impressive pictures of the planet, illustrated here with a global image. **Image credit**: AMSR-E Science Team

its measurements included sea surface temperature (SST), surface wind speed, total atmospheric water vapor, cloud water content, precipitation, and sea ice—see **Figure 6**.

"Since AMSR-E measured at microwave frequencies, the instrument had the advantage of being able to 'see' many processes through cloud cover, somewhat like a radar," said **Roy Spencer** [University of Alabama, Huntsville—*U.S. AMSR-E Science Team Leader*]. "These measurements complemented the MODIS, AIRS/AMSU, and CERES instruments for the monitoring of the global hydrologic cycle."

For example, AMSR-E's measurements of precipitation over the land and ocean have provided scientists with better estimates of Earth's precipitation rates, as well as insights into the scattering effects of large ice particles, which later melt to form raindrops. Both these measurements have been used to improve cloud and weather modeling. Further, AMSR-E data enhanced the scientific community's ability to monitor SST fluctuations, which are known to have a profound impact on weather patterns across the globe, and its measurements of atmospheric water vapor over the ocean provided insights into how this compound cycles through the atmosphere.

AMSR-E suffered a major anomaly in October 2011. Although it was able to transmit reduced data for several more years, it was ultimately powered off in March 2016. Nevertheless, it lasted long enough to make significant contributions to the Earth science and remote sensing communities and paved the way for the development of new instruments.

"AMSR-E was the most advanced instrument in its class during the nine years it operated, building upon a long history of NASA and Department of Defense microwave radiometers that began flying in the early 1970s," said Spencer. "A follow-on instrument, called AMSR2, on the GCOM-W1 mission, designed and built by Japan, carried on the AMSR-E measurements from 2012 onward."

AMSR-E data are archived and distributed by NSIDC DAAC.

AIRS, AMSU, and HSB

Before Aqua, NOAA relied on satellite data from legacy sensors and land-launched weather balloons to update weather forecasts. The reliance on balloons left large portions of the world's surface (e.g., areas of open ocean) without data coverage. To improve weather forecasting, more-frequent and -detailed information about the atmosphere was necessary.

The AIRS instrument, working in conjunction with AMSU and HSB, was designed to meet this need and, together, the three instruments comprised the most advanced and accurate atmospheric sounding system ever deployed in space.

Every 2.67 seconds, AIRS probes a column of air—from the top of the atmosphere to Earth's surface—collecting measurements of humidity, temperature, cloud properties, and greenhouse gases with its 2378 infrared spectral channels and four visible/near-infrared channels. Each of these channels is associated with particular atmospheric properties, or combinations of them, and with particular heights or levels in the atmosphere. For example, **Figure 7** shows AIRS carbon monoxide measurements over parts of Africa. With so many channels, AIRS has been able to greatly improve the accuracy and vertical resolution of atmospheric profiles. The result of these improved soundings has been more reliable climate prediction, and improved weather forecasts.

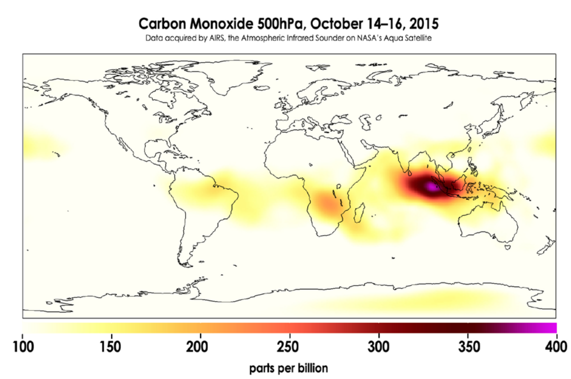


Figure 7. This image is taken from a visualization of AIRS data. It shows carbon monoxide in the middle troposphere at 500 hPa (or mb) [which is 18,000 ft, (~5500 m)] observed October 14–16, 2015. The largest source of CO during this time are fires burning over Indonesia. **Image credit**: AIRS Science Team

"AIRS revolutionized weather prediction by providing—for the first time—a three-dimensional picture of the atmosphere," said **Joao Teixeira** [JPL—*AIRS Science Team Leader*]. "Now there are a few infrared sounders in orbit, but AIRS still is one of the key sensors, and for the first few years it was the only one."

Part of what made AIRS so groundbreaking is its ability to provide high-resolution observations of both temperature and water vapor.

"Temperature is a very fundamental variable in atmospheric physics and for climate," said Teixeira. "Water vapor also plays a very large role, because it is responsible for clouds, which are condensed water vapor in the atmosphere, and water vapor essentially controls how many clouds there are and how much precipitation there is. Water vapor also interacts with the radiation emitted by the planet, and that's why we can detect it with this instrument. It also plays a role in how much the atmosphere is mixing vertically and the processes that promote it."

While AIRS cannot "see" through clouds, AMSU is particularly useful in an auxiliary role on Aqua for obtaining temperature profiles in the atmosphere. HSB was designed to measure the amount of water vapor in the atmosphere, but it suffered a catastrophic failure when its scan mirror motor failed in early 2003. Nevertheless, AIRS and AMSU have continued to provide atmospheric temperature and water vapor measurements that are much more accurate than previous space-based measurements.

Beyond enhancing weather forecasts, AIRS measurements of carbon dioxide and other greenhouse gases have also helped climatologists better understand climate variation trends and how increased concentrations of atmospheric greenhouse gases are impacting Earth's climate system.

In fact, today AIRS and AMSU play a more important role in climate science than in weather science, Teixeira said.

"We know that many of the key aspects of climate change have changed dramatically. Now we have instruments that last 20 years and are stable, meaning they are able to look at the atmosphere and the planet the same way year after year, and we can estimate how the degradation of certain components affects the measurements," he said. "We can also study the different channels of radiation that we measure, and we know that many of them are not degrading at all. So, the signal you're measuring is the signal of climate change."

The ability to capture these signals of climate change is what makes Aqua and its instruments unique, and solidifies their legacy in the history of satellite remote sensing, said Teixeira.

"You have these instruments at the same time you have the most dramatic change in climate, and we can measure it, but this was not what people necessarily planned in the early 1980s," he said. "They knew climate was changing, but climate change was not the main preoccupation. They wanted to study the Earth system. It turns out we launched these instruments exactly at the time this [was] all happening."

AIRS and AMSU-A data are archived and distributed through NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC).[7]

Aqua's Future and Legacy

Although there is no doubt the Aqua mission has enhanced our understanding of the Earth system and how it's changing, how much longer it will keep providing data is unclear. Due to limited fuel reserves, Aqua completed all mission maneuvers related to maintaining a 1:30 PM equatorial crossing time and 705-km orbit altitude in December 2021. Since then, it has begun drifting to later equatorial crossing times, and by February 2023 the satellite is expected to reach, and possibly exceed, an equatorial crossing time of 1:45 PM—see **Figure 8**.

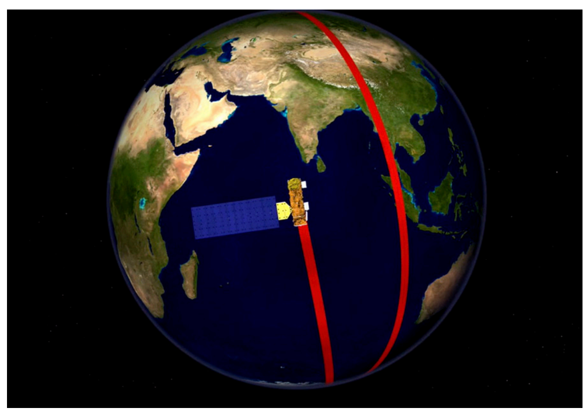


Figure 8. Due to limited fuel reserves, Aqua completed all mission maneuvers related to maintaining a 1:30 PM equatorial crossing time and 705-km orbit altitude in December 2021. Since then, it has begun drifting to later equatorial crossing times. This still image comes from a visualization that can be downloaded from *go.nasa.gov/39aSu33*. **Image credit**: NASA's Scientific Visualization Studio

Nevertheless, Aqua will continue to transmit extremely valuable data as its equatorial crossing time drifts. In fact, Parkinson said that "If funded, Aqua will likely be able to collect good quality science data until August of 2026."

"We are optimistic that we will be able to collect science-quality data for the next few years, despite the progressive drift of Aqua's orbit to crossings at later afternoon times, until spacecraft hardware limitations (i.e., power and fuel) will force mission termination,

[7] To learn more the bounty of data that AIRS has produced in 20 years of operations, see *go.nasa.gov/3aIdoH4*.

circa mid-2026," said Oreopoulos. "While the drift is disruptive to the consistency of the climate record of certain geophysical observables with considerable diurnal variation, many scientists have expressed excitement at the prospect of observations under different geometries and at different times of the day where some phenomena are more intense."

Among those scientists is Joao Teixeira, who said Aqua's departure from its traditional orbit will provide an opportunity for AIRS to collect valuable new data.

"The value of these observations by a hyperspectral sounder such as AIRS has never been explored and will present a unique opportunity to assess the impact on forecast quality of having infrared sounders at these local times," Teixeira said. "Discussions are currently underway between the AIRS project and some key weather centers to prepare for these impact studies, which will be essential for the design of new infrared sounders to inform decisions related to sampling of the diurnal cycle."

The same is true for the CERES science team, said Norman Loeb.

"For CERES specifically and for future Earth-radiation satellites, we certainly would like to place the instrument in a different mode than it's currently in," he said. "We haven't had data from as full a range of solar zenith angles because we've been fixed in mean local time. Having the orbit drift allows us to extend our angular information to other solar Earth-viewing geometries."

In addition, Loeb noted that, when compared to other satellites with a 1:30 PM equatorial crossing, Aqua's drifting may provide some insight into how mean-local-time drifts can be corrected for in long-term data records.

"There is a long record of satellite instruments that have flown for 40+ years and they have had mean-local-time drifts too," said Loeb. "It's been a struggle for the community to try to come up with climate data records when the orbits drift. So, having Aqua drift and Suomi NPP and NOAA-20 in a fixed local time provides a way of better understanding how these mean-local-time drifts can be corrected, and this information can then be used to improve the long, 40+ year records."

Yet, regardless of when the instruments aboard Aqua stop collecting data, the legacy of the spacecraft will continue to live on both within NASA and in the larger Earth observation community.

For example, the conjoined measurement strategies of the A-Train constellation are, according to Oreopoulos, leaving a lasting influence on the design of future missions such as the Atmospheric Observing System of the Earth System Observatory.[8]

"Aqua has been for many years the cornerstone of the A-Train, which also included the CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellites, and in later years, GCOM-W1, among others.[9] The simultaneous views of cloud, precipitation, and aerosol fields with instruments aboard these satellites of different capabilities and sensitivities enabled us to obtain more holistic perspectives of their structures and interactions," Oreopoulos continued. "It also allowed us to cross-validate their measurements, better understand their limitations, and the degree to which consistency in the retrieved properties of these fields can be achieved."

Aqua's legacy will live on in the annals of weather prediction as well.

"Over the past 20 years, every decision that anyone on the planet made based on weather prediction has a little bit of AIRS in it," Teixera said. "Most NASA missions produce data, but it's not out there immediately. It takes a while. MODIS and AIRS data are out there immediately. This was a requirement from the weather prediction community. If the data couldn't be available quickly then they couldn't be used for weather prediction."

Conclusion

Ultimately, Aqua's legacy will be evident in the myriad data products that members of the remote sensing communities will continue to use in their research on Earth's atmosphere, cryosphere, lands, and oceans, long after 2026.

"In contrast to some missions, where there's a single or central goal, the Aqua mission collects data on all sorts of different variables, and so it has provided a wide range of datasets that can be used by a large number of scientists and others," said Parkinson. "More than 20,000 scientific papers have incorporated Aqua data, and the data have been used in weather forecasting and numerous other practical applications, making Aqua a mission of significance for both the global remote sensing science community and society in general." ■

[8] To learn more about NASA's plans for the Earth System Observatory (ESO), see *go.nasa.gov/3wmt4pm*. The Atmospheric Observing System (AOS) combines the Aerosols and Cloud, Convection and Precipitation focus areas into a single ESO mission. To learn more about AOS, see *aos.gsfc.nasa.gov*.

[9] In addition to all of the A-Train members pictured in Figure 2, the French Centre National d'Études Spatiale's (CNES) Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar (PARASOL) mission was part of the A-Train from 2004 until 2009.

Cynthia Rosenzweig of GISS Receives "Nobel Prize for Food and Agriculture"

Dr. Cynthia Rosenzweig [NASA Goddard Institute for Space Studies (GISS)—*Senior Research Scientist* and Columbia Climate School—*Adjunct Senior Research Scientist*] received the 2022 *World Food Prize* from the World Food Prize Foundation. Conceived of as the "Nobel Prize for Food and Agriculture," this prestigious international award seeks to elevate innovations and inspire action to sustainably increase the quality, quantity, and availability of food for all.

Cynthia is being recognized for her achievements as the founder of the Agricultural Model Intercomparison and Improvement Project (AgMIP), a globally integrated, transdisciplinary network of climate- and food-system modelers. AgMIP is dedicated to advancing methods to improve predictions of the performance of agricultural and food systems in the face of climate change, and to provide the evidence base for effective food-system transformation. Her leadership of AgMIP has directly helped decision makers in more than 90 countries enhance their country's resilience to climate change.

Cynthia Rosenzweig. **Photo credit:** Courtesy of Kisha Bari

Cynthia's work with AgMIP is just one accomplishment in a distinguished career that has spanned four decades and includes having made seminal contributions to international efforts to address climate change. More information on Cynthia's career achievements can be found at *www.worldfoodprize.org/index.cfm?nodeID=96584&audienceID=1*.

In addition to being a research scientist, Cynthia was also a farmer. She was born in Scarsdale, NY, but she and her husband Arthur moved to Tuscany, Italy, and started a farm there. Later, the couple returned to New York, and after Cynthia obtained a two-year degree in agriculture from a technical college on Long Island, they started Blue Heron Farm in Thompson Ridge, NY. Getting the soil of two different continents under her nails no doubt heightened Cynthia's personal connection to and passion for the work she did at GISS.

In the words of **Barbara Stinson** [World Food Prize Foundation—*President*], Cynthia understands the importance of "centering farmers in agricultural research." Stinson's comment came in remarks she gave during a ceremony at the U.S. Department of State on May 5, 2022, to announce the winner of the 2022 World Food Prize (*www.worldfoodprize.org/en/events/laureate_announcement*). Cynthia will officially receive her award in a ceremony on October 20 in Des Moines, IA.

The Earth Observer staff would like to congratulate Cynthia for receiving this prestigious award. Learn more about the World Food Prize at *www.worldfoodprize.org/index.cfm?nodeID=87515&audienceID=1*.

feature articles

Share the Science: Summary of NASA's First Hybrid Earth Day Celebration Event

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

Introduction

Organized by the Science Mission Directorate's Science Support Office (SSO), NASA hosted its first Earth Day Celebration Event offering both in-person and virtual components. Coined a *hybrid* event, the 2022 Earth Day Celebration was held April 22–24, at Union Station in Washington, DC, and online everywhere.

The last two years (2020 and 2021), NASA's annual Earth Day Celebration activities have taken place online only, hosting its first virtual-only event in 2021 (i.e., no in-person component).[1] Leveraging the hybrid conference format that emerged during the COVID pandemic, the SSO continues to broaden participation for the agency's Earth Day Celebration Event.

In-Person Earth Day Celebration Event

The three-day in-person event, which was free and open to the public, featured a 40-ft Earth dome tent and 18 hands-on activities inside Union Station's historic Main Hall—see **Photo 1**. This central transportation hub is used by 25,000 to 30,000 people daily, enabling NASA to reach a large number of citizens. The **Table** below provides a full list of activities.

Photo 1. NASA's Earth Day Event took place in Union Station's Main Hall in Washington, DC, featuring activity tables [*left*] and a 40-ft Earth dome tent [*right*]. **Photo credit:** NASA

[1] To read about the first virtual-only Earth Day Celebration Event, see "Connected by Earth: Summary of NASA's 2021 Virtual Earth Day Event" in the May-June 2021 issue of *The Earth Observer* [**Volume 33, Issue 3**, pp. 4-11—*go.nasa.gov/35lpjaY*].

Table. Activities at NASA's 2022 In-Person Earth Day Celebration Event held in Washington, DC.

Activity Title	Description
Earth at Night	Participants interacted with a large, backlit Earth at Night display and were encouraged to download a copy of NASA's 200-page eBook, *Earth at Night.*
Earth's Ocean–Phytoplankton Connection	Participants learned about phytoplankton and how NASA detects life from space.
Earth Science Technology	Participants explored the technologies NASA is advancing to observe and understand our home planet, from tiny satellites and smart sensors to artificial intelligence and machine learning.
Explore Your World with Worldview	Participants interactively explored and visualized NASA Earth science imagery to see hurricanes forming, wildfires spreading, icebergs drifting, and city lights illuminating.
Ask a Scientist with the American Geophysical Union*	Participants were encouraged to use their investigative skills and interview a scientist as a journalist with the American Geophysical Union would do.
Viewing Earth from Above	Participants helped create a sticker mosaic of a Landsat scene and discover the benefits of Landsat, pixel by pixel.
Spectral Signatures	Participants learned how Landsat utilizes the electromagnetic spectrum and spectral signatures to better understand Earth.

*AGU partnered with NASA to offer in-person engagement activities at the NASA Earth Day Event.

Table (*cont.*). Activities at NASA's 2022 In-Person Earth Day Celebration Event held in Washington, DC.

Activity Title	Description
Global Ecosystem Dynamics Investigation (GEDI) Knights Measure Forests from Space	Participants explored how observing the three-dimensional structure of Earth from space can help us understand climate change and protect biodiversity.
Ice, Cloud and land Elevation Satellite-2 (ICESat-2), Lasers, and Measuring the Height of Our Planet, One Photon at a Time	Participants learned about how the NASA ICESat-2 mission uses lasers to measure the height of objects on Earth, like ice and trees.
Connect the Drops	Participants engaged in a variety of hands-on activities and learned how and why NASA measures global precipitation.
The GLOBE Program	Participants learned how to observe the environment around them as a citizen scientist with the GLOBE Program and using the GLOBE Observer app.
Virtual Earth Day Selfie Station	Participants took selfies as they stepped into NASA's virtual Earth Day Event to celebrate Earth Day with NASA and people all around the world.
Science Gallery	Participants walked through a colorful array of images that tell science stories as only NASA can.
Science Visualizations	Participants watched stunning science visualizations—created using NASA data—to learn about Earth and space.
Earth's Place in Our Solar System	Participants explored NASA's Eyes (*eyes.nasa.gov*) and other tools to explore Earth's place in our solar system.
Sun-Earth Connection	Participants explored the Sun–Earth connection and how the Earth's magnetic field interacts with the Sun's solar wind.
Dynamic Planet	Participants used this touchscreen interface to drive a spherical display that showed a variety of remote sensing satellite datasets.
NASA Trivia	Participants tested their knowledge about Earth, the Moon, our Sun, and technology, by answering 10 questions about each topic.

Event participants were given an activity passport listing the 18 activities. After completing six or more activities, participants could redeem their passport to receive a NASA drawstring bag and choose from a wide range of NASA Science materials. This was a successful approach: Nearly 1500 activity passports were distributed during the event. Student groups, families, and friends were encouraged to use a single passport during their visit; thus, the number of actual participants is estimated to be much higher than 1500. **Photos 2–5** highlight how participants engaged with NASA's activities during the Earth Day event.[2]

[2] To view more photos from the event, visit *https://www.flickr.com/photos/eospso/albums/72177720298587694/with/52046113865*.

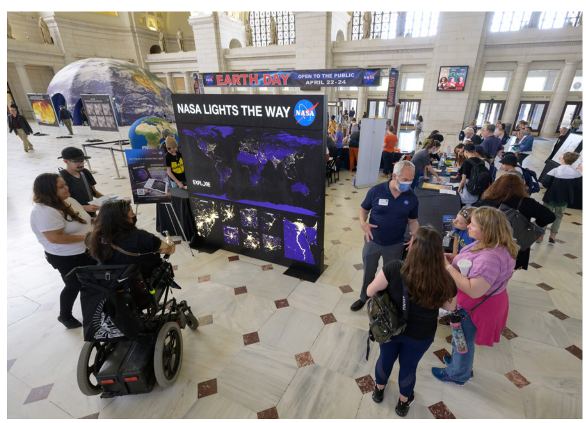


Photo 2. Participants can be seen engaging with NASA staff in front of the backlit *Earth at Night* display [*center*]. **Photo credit:** NASA

Photo 3. Two young Earth Day participants express joy for NASA and science while standing in front of an inflatable Earth display. **Photo credit:** NASA

Photo 6. NASA Administrator Sen. Bill Nelson posed for a photo at the *Virtual Earth Day Selfie Station* activity that promoted the virtual Earth Day event. **Photo credit:** NASA

Photo 4. Participants at the *Connect the Drops* activity learned how data from NASA's Global Precipitation Measurement (GPM) Mission are used in a variety of real-world applications to improve life around the world. **Photo credit:** NASA

Photo 7. NASA Administrator Sen. Bill Nelson talked with NASA staff in front of the Virtual Earth Day Selfie Station. **Photo credit:** NASA

Photo 5. Participants at the *GEDI Knights Measure Forests from Space* activity explored how observing the three-dimensional structure of Earth from space can help us understand climate change and protect biodiversity. **Photo credit:** NASA

NASA Administrator Sen. Bill Nelson visited the event on April 22 (Earth Day), accompanied by several NASA staff members, who guided him as he explored the variety of activities offered—see **Photos 6–7**. Nelson enjoyed his visit to Union Station. He enthusiastically engaged with several activities at the learning stations, and spent significant time at each activity he visited.

In addition to the activities open to the public in Union Station's Main Hall, NASA partnered with the American Geophysical Union (AGU) to host an invitation-only Science Roundtable Conversations event on April 22 in the Columbus Club at Union Station—see *NASA-AGU Earth Day Science Roundtable Conversations* on page 18.

Virtual Earth Day Event

NASA's complementary Virtual Earth Day Event was held online using the agency's virtual platform tool. The event attracted 2336 unique attendees from around the globe. It featured five content rooms (Science Theater, Fun Zone, Learning Area, Get Involved, Explore Science), a live chat, and a help desk—receiving 19,120 total content views—see **Figure 1**. The live online Earth Day celebration featured three live webinar events, each followed by *Kahoot!* game challenges,[3] in the Science Theater on April 22—see **Figure 2**. The live sessions were recorded and made available on demand, along with all the other content hosted on the virtual platform, through May 2.

[3] *Kahoot!* is a game-based learning platform. In November 2021, NASA produced a collection of ready-to-use Science, Technology, Engineering, and Math (STEM)-related *Kahoot!* games for use by everyone.

Figure 1. This graphic depicts the welcome lobby for NASA's 2022 Virtual Earth Day Event, featuring six areas (clickable squares). The event featured live events (i.e., webinar events and chat) on April 22 that were recorded and accessible to registered attendees through May 2, 2022. Registration for the event was free and open to the public. **Image credit:** NASA

The three 60-minute webinar events were: "One Earth," by **Don Thomas** [*Former NASA Astronaut*]; "Studying Our Home Planet," by **Karen St. Germain** [NASA Headquarters—*Director of NASA's Earth Science Division*]; and "Climate Research at NASA," by **Katherine Calvin** [NASA HQ—*Chief Scientist*]—see **Figures 3-5**. Nearly half the virtual Earth Day attendees watched the webinar events—972 to be exact.

Figure 2. The Live Events room featured three live webinar events. **Image credit:** NASA

After each speaker, attendees were encouraged to join the other attendees online to play *Kahoot!* games, including Unfold the Universe with NASA's Webb Space Telescope; Earth at Night; and Earth, Sun, and Moon. Over the course of the live-activities day (April 22) 944 unique attendees played the three *Kahoot!* games. To play these and other NASA *Kahoot!* games, visit *create.kahoot.it/profiles/47774408-45c3-48ba-8469-e2b65e31740d*.

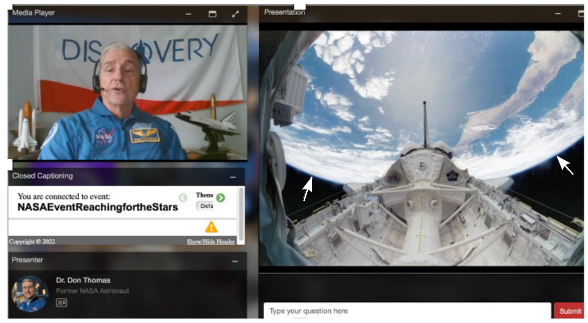


Figure 3. Don Thomas [*Former NASA Astronaut*] talked about his view of Earth, orbiting 200 mi (~322 km) above the planet. He highlighted the "paper thin" appearance of Earth's atmosphere with an edge-on view from space [*two white arrows in the image on the right*]. The peninsula region [*top right*] is the Baja California peninsula. **Image credit:** NASA

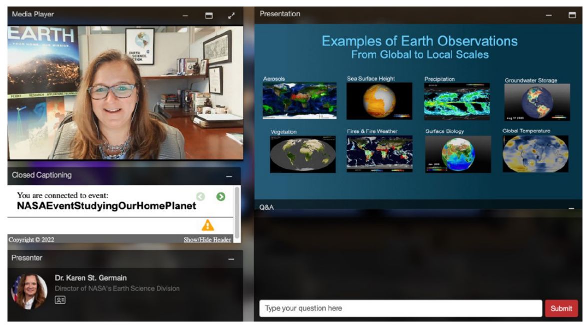


Figure 4. Karen St. Germain [NASA Headquarters—*Director of NASA's Earth Science Division*] stated that every day is Earth Day at NASA and that with its 24 Earth-observing missions in space, NASA leads the world in Earth science discovery, sharing examples of Earth observations from global-to-local scales. **Image credit:** NASA

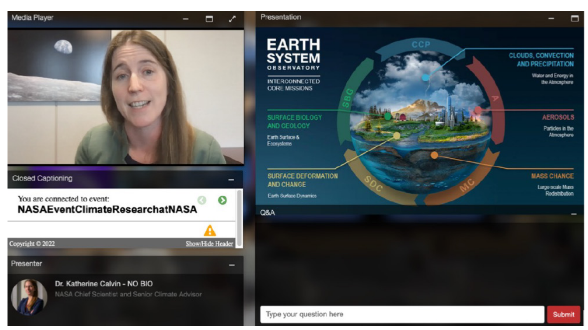


Figure 5. Katherine Calvin [NASA HQ—*Chief Scientist*] spoke about NASA's role in studying climate using data from more than two dozen satellites and instruments in orbit, including several on the International Space Station. She stated that NASA is developing technologies that can help mitigate or adapt to climate change, like sustainable aviation technologies. Calvin shared that NASA is working to launch a new era of Earth observations, called the Earth System Observatory, which will provide a holistic view of Earth. **Image credit:** NASA

In addition to the three live webinar events, virtual attendees could chat with NASA experts by visiting the Help Desk and entering the virtual "Science Chat." The chat had 753 total views, with 296 unique views. Seven NASA experts from a variety of fields helped staff the

NASA-AGU Earth Day Science Roundtable Conversations

On April 22 NASA and the American Geophysical Union (AGU) hosted an invitation-only Science Roundtable Conversations event, held in the Columbus Club at Union Station in Washington, DC. With roughly 30 participants, the event included NASA scientists, AGU leadership, graduate students, university professors, and high school educators—see photo.

The three roundtable conversation topics were:

1. *Community Science*. To address equitable collaboration in science activities aimed at beneficial outcomes for communities;
2. *Open Science*. To focus on open sharing of data, information, and knowledge within the scientific community; and
3. *Data Visualization*. To discuss using creative ways to use visualization to present complex problems in Earth and space science.

At the conclusion of the event and after an hour-long discussion, the topic moderators exchanged summary remarks on behalf of each table. The event was effective at generating fruitful discussions about the three main topics, and fostering new face-to-face connections.

Participants at the Science Roundtable Conversations event held in the Columbus Club at Union Station in Washington, DC, on Earth Day, April 22, 2022. **Photo credit:** NASA

chat, with representatives available for live chat on April 22. Another popular and highly interactive component of the virtual event was the Fun Zone, which featured on-demand science games, activities, and interactives—see **Figure 6**.

Figure 6. The Fun Zone featured on-demand science games, activities, and interactives. **Image credit:** NASA

Conclusion

NASA's 2022 Earth Day Celebration was a successful hybrid event. With in-person and virtual components, NASA was able to engage and celebrate Earth Day with roughly 4000 individuals directly—though the number of actual participants is estimated to be much higher due to school, family, and friend groups counted as a single contact (i.e., one activity passport at the in-person event or one computer login for the virtual event). NASA's SSO pulled together a team of some 100 individuals from across the agency to work together, plan, and execute the events synchronously. This event would not have been possible if not for the incredible efforts and collaboration put forth by so many of NASA's outreach professionals.

To download the Earth Day 2022 poster and learn more about how NASA celebrated Earth Day 2022, visit *https://science.nasa.gov/2022poster*. ■

Summary of the 2022 NASA Airborne and Field Data Workshop

Sara Lubkin, NASA's Goddard Space Flight Center, sara.h.lubkin@nasa.gov
Deborah Smith, NASA's Marshall Space Flight Center/University of Alabama in Huntsville, deborah.smith@uah.edu

Introduction

NASA is well known for its satellite-based observations of Earth's systems, but the agency also routinely collects information from aircraft and field campaigns. NASA's Airborne Science Program is responsible for providing the aircraft systems used in these suborbital and/or ground-based investigations.[1] The data resulting from these endeavors are traditionally used to validate and ensure the quality of NASA satellite data products. However, airborne and field campaign data products also support a wide range of research and applications research in NASA's six Earth Science focus areas: Atmospheric Composition, Weather and Atmospheric Dynamics, Climate Variability and Change, Water and Energy Cycle, Carbon Cycle and Ecosystems, and Earth Surface and Interior.[2] The highly diverse, heterogeneous, and cross-disciplinary nature of these data provides unique challenges for those who want to use NASA's airborne and field observations.

As part of an ongoing effort to improve the accessibility and (re)usability of NASA's Airborne data holdings, NASA's Airborne Data Management Group (ADMG) acts as a facilitator for the NASA airborne science community: airborne data producers, Distributed Active Archive Centers (DAACS), and users of data from airborne instruments—see **Figure 1**. The ADMG gathers and organizes relevant contextual information about airborne and field campaigns for existing and past airborne projects, enhancing user access to the rich multidecade history of suborbital (anything other than satellite) NASA Earth science research.

The ADMG, the Earth Science Data and Information System (ESDIS) Project, and several DAACs teamed up to host a two-day virtual workshop which took place March 29–30, 2022, with the goal of understanding how NASA can help researchers realize the full value of its airborne and field data assets. This was an opportunity to hear from data users and producers, who shared comprehensive and constructive suggestions for improving discovery, access, and usability of NASA's airborne and related field data.

The workshop was well attended, with over 250 registrants, more than 115 confirmed attendees on Day One, and over 70 attendees on Day Two. Represented among the participants were data users, data producers, those who consider themselves both a data user and producer, and personnel from various DAACs, NASA Headquarters (HQ), ADMG and ESDIS—see **Figure 2** on page 20. The attendees represented a wide range of scientific fields, including atmospheric science, terrestrial ecology, physical oceanography, ocean biology, and cryospheric science—see **Figure 3**, on page 20. Roughly 40% of attendees identified as students or early-career researchers and 35% identified as being in midcareer.

[1] To learn more about the history of NASA's Airborne Science Program (ASP), the aircraft that are currently flying (as of 2020), and examples of how the ASP assists with field campaigns, see "Flying in the 'Gap' Between Earth and Space: NASA's Airborne Science Program" in the September–October 2020 issue of *The Earth Observer* [**Volume 32**, **Issue 5**, pp. 4–14—*go.nasa.gov/2KSPTy5].*

[2] Learn more about these six focus areas at *go.nasa.gov/3Juvl8I*.

Image credit: NASA's Earth Science Data and Information System (ESDIS)

The workshop agenda is located online at *go.nasa.gov/3N31uVO* and includes presentation slides and workshop recordings. The remainder of this article presents a summary of the workshop.

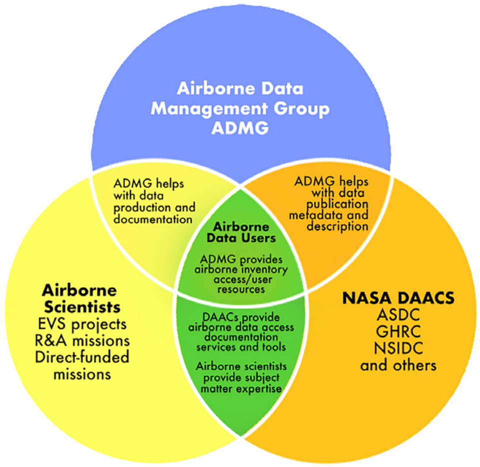


Figure 1. This Venn diagram illustrates the specific roles that NASA's Airborne Data Management Group plays as it seeks to help facilitate interactions between airborne scientists (data producers), NASA's DAACs, and users of data obtained by airborne and field instruments. **Image credit**: NASA ADMG

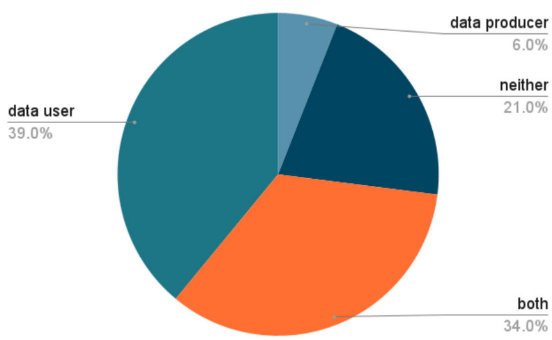


Figure 2. Pie chart showing self-described roles of workshop participants. More than one-third of participants considered themselves both data users and data producers. **Image credit**: NASA Airborne and Field Data Working Group

DAY ONE

The workshop commenced with welcomes from **Kevin Murphy** [NASA HQ—*Chief Science Data Officer for the Science Mission Directorate*] and **Melissa Martin** [NASA's Langley Research Center (LaRC)—*Deputy Director of the Airborne Science Program* and *Earth System Science Pathfinder Program Office (ESSPPO) Earth Venture Suborbital (EVS) Mission Manager*]. They emphasized the importance of these discussions for the development of the ESO data processing system, thanked all attendees for particpating, and thanked the speakers for offering their insights to the conversations.

The first day of the workshop focused on the needs and concerns of data users. To set a solid foundation of understanding for all attendees, **Deborah Smith** [NASA's Marshall Space Flight Center (MSFC), Interagency Implementation and Advanced Concepts Team (IMPACT)—*ADMG Lead*] introduced the purpose and activities of ADMG (summarized earlier, in the *Workshop Motivation and Objectives* section) and **Frank Lindsey** [NASA's Goddard Space Flight Center (GSFC)—*ESDIS DAAC Operations Engineer]* shared information about ESDIS.

Session 1: The Airborne-Data User Community Shares their Experiences

The first session highlighted four invited speakers who were asked to share their experiences using NASA airborne and field data in their research. Each speaker answered a series of questions aimed at identifying what works well for data users and what improvements might facilitate finding, accessing, and using airborne and field data. Formative questions included:

- From your perspective, what does it mean to you to be a "user of airborne and field data?"
- What does a generalized access-to-data workflow look like for you and what are the challenges to data access within that workflow?

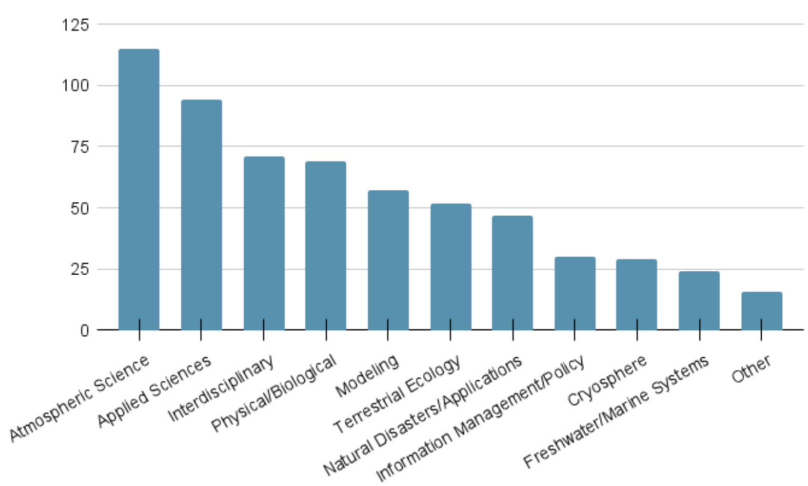


Figure 3. Chart showing the number of registered participants identifying their primary area(s) of interest within a variety of communities. **Image credit**: NASA Airborne and Field Data Working Group

- With respect to airborne and field data, what works for you that you would be willing to share with your research community?
- What are the challenges associated with using the search tool on the EarthData website (Earthdata Search)?

Phil Townsend [University of Wisconsin, Madison, Environmental Spectroscopy Laboratory], described his work to combine Airborne Visible InfraRed Imaging Spectrometer–Next Generation (AVIRIS-NG) data with data from the National Ecological Observatory Network (NEON) to characterize fine-scale vegetative function at the continental scale. Townsend shared examples of AVIRIS-NG data and ground sampling used by NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) to understand boreal vegetation. Townsend described his experience with using data from many different instruments [e.g., AVIRIS-NG, MODIS/ASTER[3] Airborne Simulator (MASTER), NEON Airborne Observation Platform (AOP), unmanned aerial vehicle (UAV) lidar], which provided valuable insight into using large, complicated datasets from cloud sources. For example, he uses a Python image-processing workflow when working with large data volumes, but he recommended developing tools that lower barriers to access for the inexperienced data user.

Subsequent speakers raised similar issues regarding large data volumes and data access, and agreed that more-mature data products are needed for non-experts. Other invited speakers were **Qing Liang** [GSFC], **Mark Tschudi** [University of Colorado Boulder (UCB)], and **Timothy Lang** [MSFC].

Liang, an atmospheric modeler in the Atmospheric Chemistry and Dynamics Laboratory at GSFC, mentioned the difficulty with locating data, given that airborne and field data are located across many DAACs, the need for more airborne data in Earthdata Search, and the need to locate data using special filters, such as finding data products by measured variable.

Tschudi, a senior scientist at UCB, spoke about the need for a better notification system to inform users when data are updated or improved. He also mentioned the need for improved access to aircraft camera data.

Lang, who identified himself as both a data user and a data producer at MSFC, commented on the greater requirements placed on teams without additional support, and the need for greater consistency across DAACs with respect to documentation, data access, data product and file naming, and data organization and access.

Kenton Ross [LaRC—*Chief Scientist of NASA's DEVELOP Program*] highlighted uses of airborne data for applied science. He described several 10-week feasibility projects conducted by DEVELOP participants who used airborne data to detect invasive species, monitor ecosystem health, identify permafrost subsidence, and locate methane emissions.

Next came an Airborne Data User Panel. The panelists were: **Elizabeth Hoy** [GSFC], **Sean Serbin** [Brookhaven National Lab], **Stephen (Joe) Munchak** [Tomorrow.io], **Owen Cooper** [UCB], **K. Fred Huemmrich** [University of Maryland, Baltimore County], **Alexey Shiklomanov** [GSFC], **Tim Bailey** [The Watershed Center], and **Rebecca Hornbrook** [National Center for Atmospheric Research (NCAR)].

Each panelist discussed how they access and use NASA data and the challenges they experience while doing their work. The consensus was that discovering data can be a problem because current search tools were designed for satellite data. They suggested that keyword searches with greater flexibility would be helpful, as well as the ability to search for data by time period and location or by attribute. They also suggested that more search and discovery, subsetting, and visualization tools for airborne and field data are needed. Available tools are often dataset specific and are not useful for researchers who want to utilize data from several sources.

Session 2: NASA Tools and Services for Airborne Data Users

The second half of the first day focused on NASA's existing and planned tools and services for airborne and related field data. **Bruce Wilson** [Oak Ridge National Laboratory (ORNL) DAAC] led off this session with a presentation on the evolution of the *Earthdata Cloud*, during which he discussed NASA's use of commercial cloud tools to enhance access to NASA Earth science data.[4] These efforts are focused on creating capabilities for users to have direct access to data, improving the efficiency of data system operations, and science-enabling tools that work across DAACs. Users will still be able to download and use data locally, but will gain the abilities to access data without downloading and to use tools like *Harmony*,[5] which allows users to work with data from multiple DAACs. NASA is currently focusing on migrating the most heavily used Earth Observing System data into Earthdata Cloud. Wilson noted that data from the ABoVE field campaign has already been migrated. While relatively little airborne data have been migrated at this time, migration efforts are in progress for data from several airborne instruments—notably AVIRIS and MASTER.

[3] MODIS stands for Moderate Resolution Imaging Spectroradiometer, which flies on NASA's Terra and Aqua platforms; ASTER stands for Advanced Thermal Emission and Reflection Radiometer, which flies on NASA's Terra platform.

[4] To learn more NASA's strategic vision to develop and operate multiple components of EOSDIS in a commercial cloud environment, visit *earthdata.nasa.gov/eosdis/cloud-evolution*.

[5] To learn about this tool that facilitates integrating data from different NASA data centers, visit *harmony.earthdata.nasa.gov.*

Table 1. Presentations on NASA airborne- and field-data-relevant tools.

Tool	Presenter [Affiliation]	URL	Description
Catalog of Suborbital Earth Science Investigations (CASEI)	**Stephanie Wingo** [ADMG]	*impact.earthdata.nasa.gov/casei*	An inventory of NASA's airborne and field campaigns for Earth Science
Sub-Orbital Order Tool (SOOT)	**Jennifer Tindell** [ASDC]	*asdc.larc.nasa.gov/soot/power-user*	Discover and access selected airborne and field campaign data archived at the ASDC
Soil Moisture Visualizer (SMV).	**Michele Thornton** [ORNL DAAC]	*airmoss.ornl.gov/visualize*	Integrates soil moisture data from AirMOSS* flights (see nnote below table for acronyms), SMAP, and selected ground sensors
Airborne Data Visualizer (ADV)		*daac.ornl.gov/tools/airborne-data-visualizer-project-list*	Visualize flight paths and in situ (atmospheric composition) data from ACT-America, ATom, and CARVE missions
Spatial Data Access Tool (SDAT)		*webmap.ornl.gov/ogc*	Visualize and subset gridded (GeoTIFF) data from missions held at the ORNL DAAC, including CARVE and AfriSAR.
Field Campaign Explorer (FCX)	**Geoffrey Steno** [GHRC]	*webmap.ornl.gov/ogc*	Discover and access selected airborne lightning data archived at the GHRC.

*__List of acronyms occurring in Table that are not defined in the text and their expansions__: AirMOSS—Airborne Microwave Observatory of Subcanopy and Subsurface; SMAP—Soil Moisture Active Passive (SMAP), ACT-America—Atmospheric Carbon and Transport–America ; ATom—Atmospheric Tomography Mission; and CARVE—Carbon in Arctic Reservoirs Vulnerability Experiment GHRC—Global Hydrometeorology Resource Center; and AfriSAR—African Synthetic Aperture Radar campaign.

Deborah Smith led off a series of presentations providing overviews of NASA tools for airborne and field data, as summarized in **Table 1**.

Session 2 concluded with an interactive activity where workshop participants highlighted their data discovery and data use needs that are not presently being met. A key challenge recognized is that data organization and presentation vary substantially based on when data were collected, the project that collected the data, and the DAAC that archived the data. Users find it difficult to locate airborne data relevant to a particular location and time, and to align data in space and time with related ground and satellite measurements. With the exception of the Catalog of Suborbital Earth science Investigations (CASEI),[6] the tools available are limited in that they apply only to a subset of the airborne data held at the DAAC that developed the tool. There is a clear need for tools that work across DAACs and for tools that enable integration of data from instruments on ground, airborne and satellite platforms, as well as modeling data. Users also expressed a desire for better visualization of flight tracks, including being able to see where tracks overlap and being able to zoom in to obtain data. There was also some discussion of the wide range of file formats used across holdings. Participants recognized that while a given format may be common for a portion of airborne users and an impediment to use by others, some formats are more amenable to analysis in place, as supported by the Earthdata Cloud.

[6] See Table 1 for summary and URL link for CASEI.

DAY TWO

The second day of the workshop focused on the needs of airborne and field data producers. The morning began with breakouts into smaller groups where participants discussed Day One activities and lessons learned. The purpose of discussions were to gauge if the appropriate data user topics were covered, to identify what knowledge or understanding was gained from Day One in comparison to the start of the workshop, and to determine which topic area within Day One was most applicable or meaningful to the workshop participants. There were many comments from the smaller groups which fell into these categories: e.g., the length of time from data measurement to when available to the public at the DAAC, the need for consistency, security issues with data access, data versioning, colocating data, and the need for more time for participant feedback. After the breakouts came several more sessions which are described on the following pages.

Session 3: The Airborne Data Producer Community Shares Their Experience

This session offered an opportunity for members of that community to share their perspectives. **Deborah Smith** moderated individual flash talks (as summarized in **Table 2)** by selected NASA-funded scientists involved in recent and ongoing airborne and field campaigns.

Workshop organizers provided a series of questions to guide Session 3 flash talks, which allowed data managers and producers to share their experiences. Guided questions included:

- Which datasets have you produced and which DAAC(s) have you worked with?
- What "pain points" did you encounter when working with the DAAC(s)?
- What works well and what suggestions do you have for improvement?
- What do you think is needed to encourage and support future use of your data product(s)?
- What support is needed from ADMG?

The data managers and producers from this session reported positive and responsive interactions when working with NASA's DAACs and provided meaningful suggestions and areas for improvement. Several speakers gave top priority to improving communications between NASA science team members (i.e., the data producers) and the DAACs. Good communications lead to better understanding of standardization in terms of file formats, naming conventions, metadata, and evaluating merge or higher-level products. Furthermore, a strong communications cycle has provided the opportunity for developing web-based, DAAC-hosted dataset catalogs and other enhanced discovery methods. Work is currently underway to fully capture and summarize the content from the flash talks.

Data producers also commented that there is often a field data repository (or archive) run by a project data manager that is used as an intermediate data store for scientists to share and access data among researchers before the DAACs produce publication-quality data and metadata—see **Figure 4** on page 24. Sharing these intermediate repositories with the DAACs facilitates open and effective communications between the science teams and DAACs. Such early communication

Table 2. Session 3 Flash Talk topics and speakers.

Mission	Panelist	Description
Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS)	**Stacy Brodzik** [University of Washington]	IMPACTS is an airborne field campaign to study the development of winter storms—and *Nor'easters* in particular—along the U.S. East Coast.
Alpha Jet Atmospheric eXperiment (AJAX)	**Emma Yates** [NASA's Ames Research Center]	AJAX is an airborne instrument that measures ozone (O_3), formaldehyde (HCHO), carbon dioxide (CO), methane (CH_4), and meteorological data over California and Nevada.
Delta-X/Airborne Visible InfraRed Imaging Spectrometer–Next Generation (AVIRIS-NG)	**Daniel Jensen**, [NASA/Jet Propulsion Laboratory]	Delta-X is a NASA airborne campaign that uses AVIRIS-NG and other observations to study soil accretion in Mississippi region coastal deltas. The data collected are used to improve the understanding of soil gain and loss processes using models.
Three Ocean Experiments in a Flash: S-MODE, SPURS-1 and 2, and SASSIE*	**Fred Bingham** [University of North Carolina at Wilmington]	S-MODE leveraged aircraft and ocean surface and subsurface instruments to study how small-scale ocean dynamics impact Earth's climate system. SPURS focused on identifying the mechanisms behind near-surface salinity variations in the oceans and SASSIE (an upcoming Surface Biology and Geology campaign) is a multiscale experiment to study upper ocean structure and the effects of sea ice melting.
Atmospheric Carbon and Transport America (ACT-America)	**Gao Chen** [NASA's Langley Research Center]	ACT-America conducted five airborne campaigns to study the impact of atmospheric carbon across three regions of the Eastern U.S.

*S-MODE stands for Sub-Mesoscale Ocean Dynamics Experiment; SPURS stands for Salinity Processes in the Upper Ocean Regional Study; and SASSIE stands for Salinity and Stratification at the Sea Ice Edge.

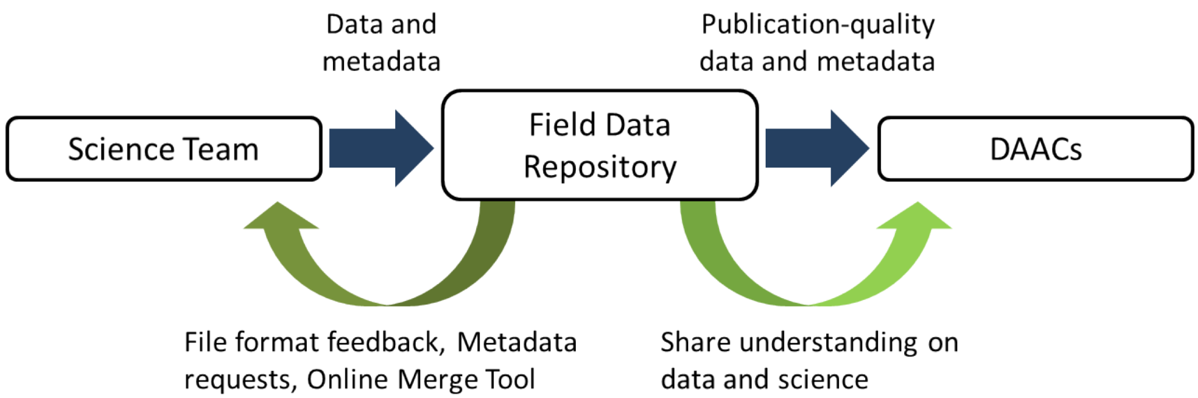


Figure 4. A schematic of the interactions between data producers and DAACs when a field data repository is used during an active mission. The field data repository is managed by a designated data manager for the campaign or activity. The data manager then functions as the primary contact for DAAC data transfer instead of each instrument scientist. **Image credit**: Gao Chen

ensures data-product quality, supports research activities both during missions and after data publication and, from the perspective of the data producers, improves the long-term curation in the form of digital object identifiers (DOIs), collaborative user guides, and NASA Earthdata outreach.

Finally, the participants recognized that many datasets are not widely supported by standard software code or tools. One suggestion to help mitigate this issue was to have the DAACs support the distribution of code and tools that data producers develop during the project as a means to make archived datasets more accessible and usable by the broader research community.

Directly following the flash talks, **Kasey Phillips** [ASDC)] wrapped up the session with a moderated *fish-bowl panel* (meaning it included all participants in the discussion) in which the flash-talk speakers responded to workshop participants' questions and comments.

Session 4: Working Together to Make Data Accessible

The final session focused on how NASA and data producers can work together to improve data accessibility, most notably most notably in the NASA Earthdata Cloud environment.

Amanda Leon [National Snow and Ice Data Center (NSIDC) DAAC], **Deborah Smith**, and **Bruce Wilson** provided focused presentations regarding project life cycle, ADMG and DAAC processes and responsibilities, and enhancing communication between the science teams, DAACs, and ADMG. The presentations emphasized:

- Collaborating through the entire project lifecycle, to include the project initiation, planning and data management plan (DMP) preparation, active data collection and delivery, and closeout—see **Figure 5**, on page 25;
- promoting two-way communications, including continuous and clear discussions regarding data and open-science requirements);
- formalizing the roles and responsibilities of the campaign science team, ADMG, and the assigned DAAC—see Figure 5;
- utilizing potential capabilities offered by a cloud environment (e.g., enabling user access to large-volume data holdings, removing barriers to cross-DAAC tools and data access, and enabling analysis);
- making NASA Earth Science data as "fair" as practical (e.g., by involving ESDIS and DAAC responsibilities such as data publication, data access, and user support).

Amanda Leon provided information regarding *Earthdata Pub*,[7] a data publication workflow intended to enhance interactions between the DAAC and the data producers during the data-publication process and to provide consistency across DAACs. She discussed the use of Earthdata Pub to provide a data-publication workflow in Earthdata Cloud with a common terminology and user interface. This would act as a centralized location of resources for data producers to help support the data-publication process, which will enable data producers to find instructions on how to publish, how to communicate with DAAC personnel, and how to provide data and related information to a DAAC.

Participants revisited the topic of collaboration in moderated breakout sessions that allowed continued small-group discussion. Topics covered included: Data Formats/Data Standards (e.g., commonly used data formats, pros and cons of specific formats), Earthdata Pub (e.g., transitioning to Earthdata Pub, the need to

[7] A summary poster about Earthdata Pub, with Amanda Leon as one of the authors, can be downloaded from *go.nasa.gov/3MNIvyw*.

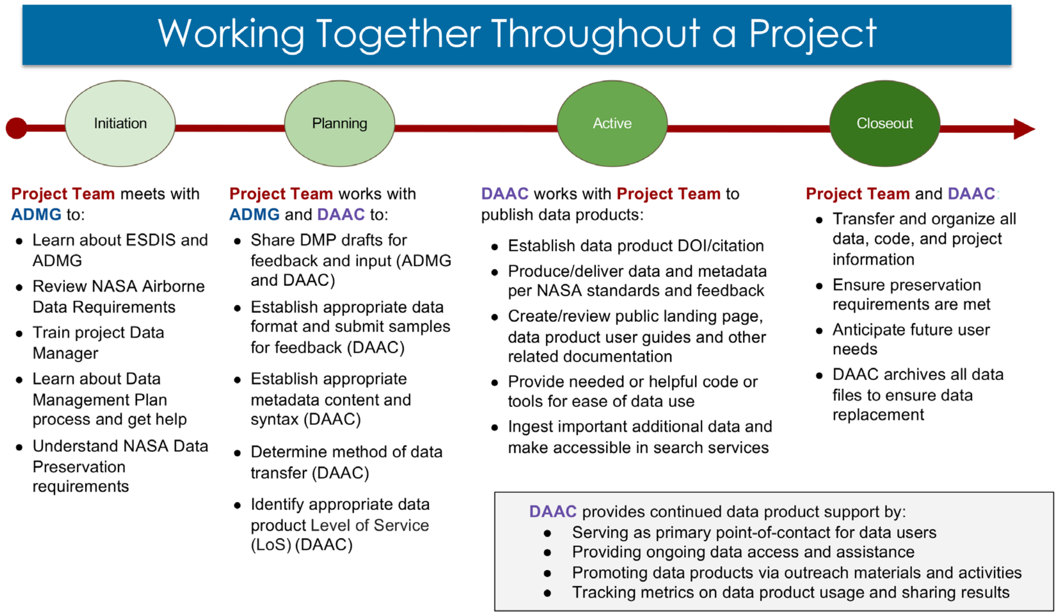


Figure 5. An outline of steps, roles, and responsibilities of project team, ADMG, and DAACs for communicating with each other throughout the life cycle of a project. **Image credit**: Amanda Leon and Deborah Smith.

train DAAC staff and scientists to use Earthdata Pub), Airborne Data in the Cloud [e.g., primarily regarding datasets in the cloud, a hybrid-approach discussion), Metadata [discussions regarding the Climate and Forecast (CF) metadata conventions and the Global Change Master Directory (GCMD) keywords], and Working with the DAACs, (e.g., highlighting the importance of open lines of communication between scientists and the DAACs to help streamline the data-publication process and to understand nuances within a project).

Participants in the breakout rooms identified several challenges that hinder airborne data access and (re)use, especially for legacy data. These challenges included difficulty in finding historical airborne and field data; limited public data access caused by delays in assigning a project to a DAAC; proliferation of heterogeneous domain-specific data file formats that make it difficult to use the data for cross-disciplinary applications; lack of standard data download protocols (i.e., different data sources require different scripts for download); and the need for appropriate contextual information from the start, regardless of the format used in the metadata and data files, in order to ensure long-term data use.

Joe Koch [ASDC] and **Siri Jodha Khalsa** [NSIDC] from the ESDIS Standards Coordination Office (ESCO) then gave a presentation regarding the role of ESCO, the critical role of standards throughout the entirety of the data product lifecycle, community standards (data formats and general recommendations), and the process of submitting a document through the ESCO process.

The meeting wrapped up with **Elena Steponaitis** [NASA HQ, Earth Science Data Systems (ESDS) Program] presenting an overview of "Open-Source Science at NASA." This presentation included a discussion on open science and open-source science, as well as related principles and best practices. NASA's Scientific Information Policy (SPD-41)[8] and the Transform to Open Science (TOPS) initiative's objectives were highlighted in relation to current and future efforts.[9]

Workshop Outcomes

The planning committee has started sifting through the vast amount of important feedback obtained from the data users and data producers. The initial findings of the workshop are summarized in four categories below. The goal is to capture and synthesize the findings in order to ensure future DAAC activities alleviate some of the issues identified.

The Importance of Communications Among all Stakeholders.

Participants acknowledged the existing high quality of communications between DAACs and the science teams, and appreciated the DAAC involvement with the campaign science team from the beginning. However, instrument teams would like additional help from the DAACs concerning metadata and data format checking, as campaign teams have tight budgets for science, leaving less time for data production and

[8] This policy describes how data (and other information) produced by NASA's Science Mission Directorate is being shared. The policy can downloaded from *go.nasa.gov/2ZCCBgE*.

[9] To learn more, 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—*go.nasa.gov/3ElvLM9*].

formatting. Looking forward, the community would like more information about open-source science and SPD-41 requirements to assist teams with meeting the future requirements laid out in the policy.

The Need for Cross-DAAC Consistency in Handling Data.

Historically, DAACs have handled data publication differently, as each evolved from serving a particular science community. Airborne and field data producers and users whose data may cross scientific domains, often work with several different DAACs, each with their own approach to data publication—an inefficient and possibly counterproductive process. Users would like to see more consistency in terms used, metadata, data formats, and data-variable names. However, it was also noted that different disciplines have different needs and standards. Participants cautioned data centers to consider those and not apply a one-size-fits-all approach.

Improved Data Discovery, Access, and Use

Several suggestions were made to improve the discovery of, access to, and use of airborne and field data. Suggestions included focusing on simplified user interfaces, consistency in data and documentation, better bulk-data access, improved cross-DAAC data accessibility, unique filtering mechanisms relevant to airborne data (e.g., finding data by altitude, specific variable, or flight number), improved spatiotemporal searching, and discovery of data coincident with satellite overflights. Participants also expressed the need for datasets to include data version information and notification when new versions are released. Since airborne data have been collected since the early 1970s, much of the data have yet to be assigned to a DAAC and made available to the public. Scientists would like to see improved access to these legacy data. Some users proposed storing data from all airborne campaigns at a single DAAC rather than the present system of assigning each airborne campaign to a different DAAC based on scientific themes. They also identified a need for data-translation tools that would allow for easier data use (e.g., conversion of International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) file format to Network Common Data Form (NetCDF) format).[10]

Provision of Additional Information and Resources

Both data producers and users wanted more information and resources to lower the barriers to airborne and field data for nonexpert data users. This is especially important for interdisciplinary scientists, modelers, students, and others who may not be familiar with the campaign details. By offering more mature data products, users beyond the campaign team will find it easier to use common formats, find improved data clarity, and have access to better within-file documentation. More guidance is needed to show users how to work with the data and which tools and services are available, especially once the data are placed in the Earthdata Cloud.

Some users emphasized the need for camera or video environmental information to aid in interpreting data collected on the flight. This type of alternative data must be preserved and made easily accessible to all users along with other important campaign information that can be hard to find after a campaign has ended. For instance, campaign, instrument, and variable "landing pages" could be used to summarize which data and information are available and to provide links to documentation from a single location, thereby speeding and simplifying data and information access.

Conclusion

Over the two days of the workshop, more than 100 attendees shared their experiences using and producing NASA airborne and field data. Participants of varied backgrounds and experience levels gave feedback and provided suggestions for improvement through community members' presentations, breakout rooms, chats, discussions, and Slido polls.[11]

The workshop conveners plan to complete a more thorough analysis of the feedback in the coming months and share the findings with the community through a formal workshop report as well as presentations at the Earth Science Information Partners (ESIP) Summer Meeting and the American Geophysical Union (AGU) Fall Meeting. In addition, the findings will be used by ADMG, ESDIS, and the DAACs to guide activities and improvements in the coming years.

If you would like to join the ongoing effort to improve airborne and field data management, reach out to Deborah Smith and Sara Lubkin of the airborne workshop planning committee.

Acknowledgements

The authors wish to thank the following individuals for their helpful contributions to this article: **Kasey Phillips** [NASA's Langley Research Center]; **Ge Peng** [NASA's Marshall Space Flight Center/University of Alabama in Huntsville]; and **Bruce E. Wilson**; and **Michele Thornton** [both at Oak Ridge National Laboratory].

[10] The ICARTT fie format was developed for the ICARTT campaign in 2004 and is now widely used among the atmospheric composition community and used in recent NASA airborne studies; NetCDF is considered the "common" format for storing multidimensional meteorological data (e.g., temperature, humidity, pressure, wind speed, and direction).

[11] Slido is an easy-to-use online polling program, a useful resource for online and hybrid meetings. Learn more at *www.sli.do*.

NASA Rocket Endures Flight from Norway

Keith Koehler, NASA's Wallops Flight Facility, keith.a.koehler@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*.

A NASA suborbital rocket carrying instruments to measure Earth's electric potential—and provide a clue as to why the planet supports life successfully—launched at 9:31 PM EDT on May 10, 2022, from Andøya Space's Ny-Ålesund, Svalbard Launch Facility in Norway—see **Photo 1**.

Photo 1. An Oriole IIIA rocket launched on May 10, 2022, from Andøya Space's Ny-Ålesund Svalbard Launch Facility in Norway, carrying the *Endurance* suborbital rocket into orbit. This NASA (Planetary Science) mission carries instruments that will measure Earth's electric potential and may provide clues as to why Earth's atmosphere supports life while those of other planets do not. **Photo credit**: NASA

The three-stage Oriole IIIA carried the instruments to an altitude of 475 mi (764 km) before descending and splashing down in the Greenland Sea. The rocket obtained good data during it flight—and some specular photos of the northern polar ice cap (see Photo 2.)

The Endurance mission is measuring Earth's global electric potential, or how much Earth's electric field "tugs" at electrically charged particles in our air. This electric potential is expected to be very weak, making it difficult to measure—and one reason Earth can support life.[1]

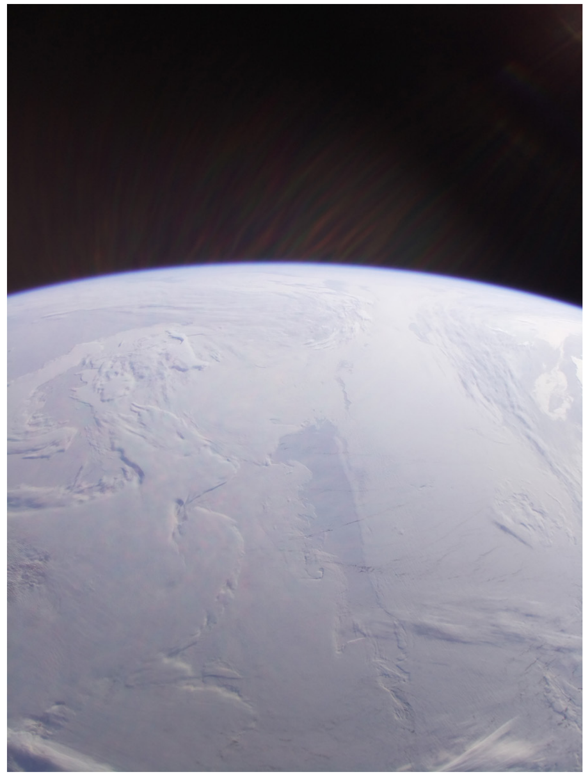


Photo 2. As the Endurance rocket reached its peak altitude or apogee of 475 mi (764 km), it obtained this photo of Earth's northern polar regions. **Photo credit**: NASA

"The flight was spectacular! After six years of hard work, watching Endurance take flight was a dream come true," said space scientist **Glyn Collinson** [NASA's Goddard Space Flight Center—*Endurance Principal Investigator*].

Endurance is a NASA-funded mission conducted through the Sounding Rocket Program at the Wallops Flight Facility. The Svalbard Rocket Range is owned and operated by Andøya Space Center.

The European Incoherent Scatter Scientific Association (EISCAT) Svalbard radar, located in Longyearbyen, made ground-based measurements of the ionosphere critical to interpreting the rocket data. The United Kingdom Natural Environment Research Council (NERC) and the Research Council of Norway (RCN) funded the EISCAT radar for the Endurance mission. EISCAT is owned and operated by research institutes and research councils of Norway, Sweden, Finland, Japan, China and the United Kingdom (the EISCAT Associates). ■

[1] Learn more about the Endurance mission at *go.nasa.gov/37j93Ja*.

NASA Science Enables First-of-its-Kind Detection of Reduced Human CO_2 Emissions

Jessica Merzdorf Evans, NASA's Goddard Space Flight Center, jessica.v.merzdorf@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*.

For the first time, researchers have spotted short-term, regional fluctuations in atmospheric carbon dioxide (CO_2) across the globe due to emissions from human activities.

Using a combination of NASA satellites and atmospheric modeling, Scientists have performed a first-of-its-kind detection of human CO_2 emissions changes. The new study uses data from NASA's Orbiting Carbon Observatory-2 (OCO-2) to measure from space reductions in CO_2 emissions during the COVID-19 pandemic. With daily and monthly data products now available to the public, this opens new possibilities for tracking the collective effects of human activities on CO_2 concentrations in near-real time.[1]

Previous studies investigated the effects of lockdowns early in the pandemic and found that global CO_2 levels dropped slightly in 2020. However, by combining OCO-2's high-resolution data with modeling and data analysis tools from NASA's Goddard Earth Observing System (GEOS), the team was able to narrow down which monthly changes were due to human activities and which were due to natural causes at a regional scale. This confirms previous estimates based on economic and human activity data.

The team's measurements showed that in the Northern Hemisphere, human-generated growth in CO_2 concentrations dropped from February through May 2020 and rebounded during the summer, consistent with a global emissions decrease of 3–13% for the year.

The results represent a leap forward for researchers studying regional effects of climate change and tracking results of mitigation strategies, the team said. The method allows detection of changes in atmospheric CO_2 just a month or two after they happen, providing fast, actionable information about how human and natural emissions are evolving.

Discerning Subtle Changes in Earth's Atmosphere

CO_2 is a greenhouse gas present in the atmosphere and its concentration changes due to natural processes

[1] To watch a video related to this topic, visit *https://youtu.be/mBXeA3v1NLY*. The part pertaining to the research discussed in this article begins **~1:30** into the video.

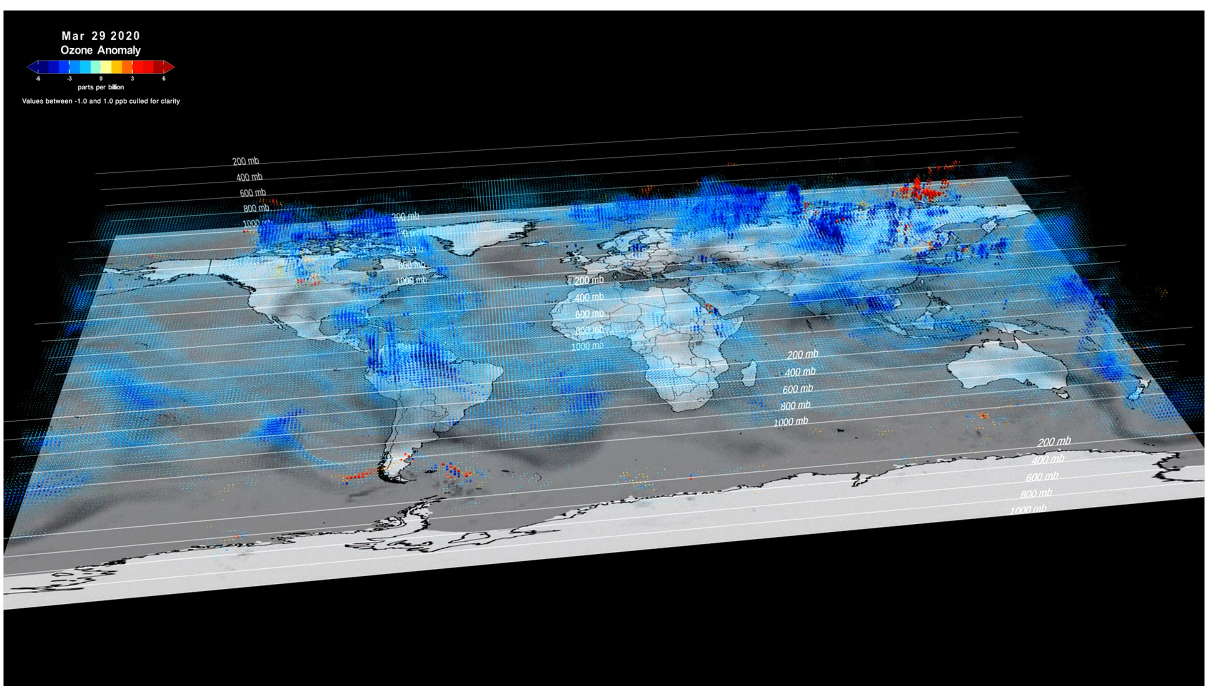


Figure. The COVID-19-related lockdowns granted scientists an unexpected and detailed glimpse as to how human activities impact atmospheric composition. Two recent studies, one focusing on nitrogen oxide and the other examining CO_2 concentrations, were able to detect the atmospheric 'fingerprint' of the lockdowns in unprecedented detail. **Credits: NASA/Katie Jepson**

like respiration from plants, exchange with the world's oceans, and human activities like fossil fuel combustion and deforestation. Since the Industrial Revolution, the concentration of CO_2 in the atmosphere has increased nearly 49%, passing 400 parts per million for the first time in human history in 2013.

When governments asked citizens to stay home early in the COVID-19 pandemic, fewer cars on the road meant steep drops in the amount of greenhouse gases and pollutants released into the atmosphere. However, as **Lesley Ott** [NASA's Goddard Space Flight Center (GSFC) Global Modeling and Assimilation Office] explained, with CO_2, a "steep drop" needs to be put in context. This gas can last in the atmosphere for up to a century after it is released, which is why short-term changes could get lost in the overall global carbon cycle—a sequence of absorption and release that involves natural processes as well as human ones. The lockdowns of early 2020 are one small part of the total CO_2 picture for the year.

"Early in 2020, we saw fires in Australia that released CO_2, we saw more uptake from plants over India, and we saw all these different influences mixed up," Ott said. "The challenge is to try to disentangle that and understand what all the different components were."

Up until recently, measuring these kinds of changes wasn't possible with satellite technology. However, NASA's OCO-2 satellite has high-precision spectrometers onboard that were designed to pick up even smaller fluctuations in CO_2 than those observed during COVID. When these highly precise observations are input into the comprehensive GEOS Earth system model, it provided the means to spot the pandemic-related changes.

"OCO-2 wasn't designed for monitoring emissions, but it is designed to see even smaller signals than what we saw with COVID," said lead author and research scientist **Brad Weir** [GSFC/Morgan State University]. Weir explained that one of the OCO-2 mission research goals was to track how human emissions shifted in response to climate policies, which are expected to produce small, gradual changes in CO_2. "We hoped that this measurement system would be able to detect a huge disruption like COVID."

The team compared the measured changes in atmospheric CO_2 with independent estimates of emissions changes due to lockdowns. In addition to confirming those other estimates, the agreement between emissions models and atmospheric CO_2 measurements provides strong evidence that the reductions were due to human activities.

GEOS contributed important information on wind patterns and other natural weather fluctuations affecting CO_2 emission and transport. "This study really is bringing everything together to attack an enormously difficult problem," Ott said.

Taking a Closer Look at Greenhouse Gases

The team's results showed that growth in CO_2 concentrations dropped in the Northern Hemisphere from February through May 2020, which agreed with computer simulations of how activity restrictions and natural influences should affect the atmosphere.

The signal wasn't as clear in the Southern Hemisphere, thanks to another record-breaking climate anomaly: The Indian Ocean Dipole (IOD). The IOD is a cyclical pattern of cooler-than-normal oceans in Southeast Asia and warmer-than-normal oceans in the eastern Indian Ocean (*positive phase*) or the reverse (*negative phase*). In late 2019 and early 2020, the IOD experienced an intense positive phase, yielding a plentiful harvest season in sub-Saharan Africa and contributing to the record-setting Australian fire season. Both events strongly affected the carbon cycle and made detecting the signal of COVID lockdowns difficult, the team said—but also demonstrated GEOS/OCO-2's potential for tracking natural CO_2 fluctuations in the future.

GEOS/OCO-2 data power one of the indicators in the COVID-19 Earth Observing Dashboard (*eodashboard.org*), a partnership between NASA, the European Space Agency, and the Japan Aerospace Exploration Agency. The dashboard compiles global data and indicators to track how lockdowns, dramatic reductions in transportation, and other COVID-related actions are affecting Earth's ecosystems.

The GEOS-OCO-2 assimilated product is available for free download, making it accessible to researchers and students who want to investigate further.

"Scientists can go to this dashboard and say, 'I see something interesting in the CO_2 signal; what could that be?'" said Ott. "There's all kinds of things we haven't gotten into in these data sets, and I think it helps people explore in a new way."

In the future, the new assimilation and analysis method could also be used to help monitor results of climate mitigation programs and policies, especially at the community or regional level, the team said.

"Having the capability to monitor how our climate is changing, knowing this technology is ready to go, is something we're really proud of," Ott said. ■

NASA Scientist Discovers New Means to Measure Snow Depth from Space

Joe Atkinson, NASA's Langley Research Center, joseph.s.atkinson@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*.

A NASA scientist is adding a new dimension to the climate-observing powers of a satellite instrument whose main mission is to measure the height of Earth's ice sheets and sea ice. And the inspiration for this new method comes from how ants walk around their colonies.

Using a concept adapted from the mathematics and biology communities, **Yongxiang Hu** [NASA's Langley Research Center] developed a method to directly measure snow depth using lidar measurements from the Ice, Cloud and land Elevation Satellite-2 (ICESat-2). (The **Figure** below shows a scene from ICESat–2 as well as an illustration of the satellite in orbit.) Lidar uses pulses of laser light to make measurements, similar to how sonar uses sound. Hu worked with other scientists at NASA, the University of Arizona, Stevens Institute of Technology, and Ball Aerospace.

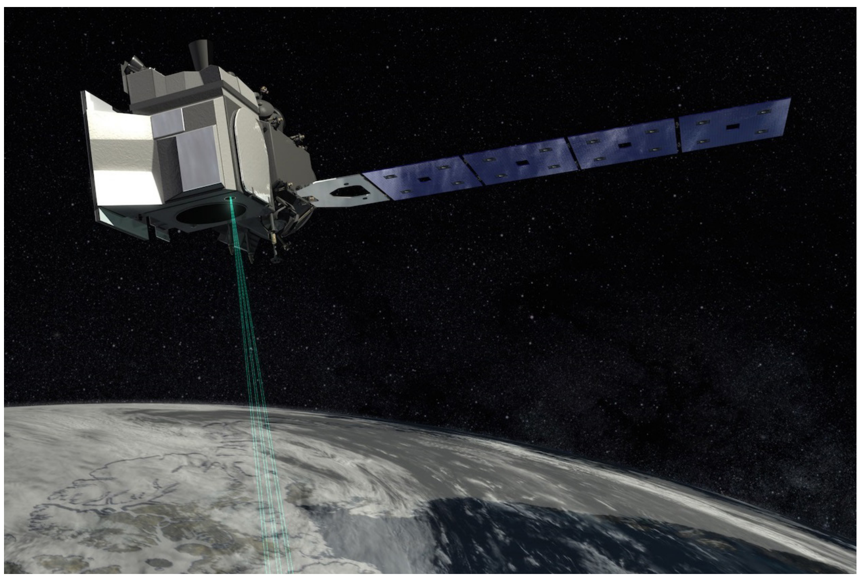


Figure. Using a concept adapted from the mathematics and biology communities, a scientist at NASA's Langley Research Center developed a method to directly measure snow depth using lidar measurements from the Ice, Cloud and land Elevation Satellite-2 (ICESat-2). **Image and text credit**: NASA

Snow depth is an important measurement in understanding climate, weather, and Earth's water cycle, but there are limits to current measurement methods. To determine how to use ICESat-2's laser to directly measure snow depth, Hu turned to a principle he adapted from biologists and physicists who figured out the average length of the path an ant travels inside its colony before coming back out. What those scientists came up with is that the average time an ant walks around inside the colony before coming back is roughly four times the volume of the colony divided by its surface area.

Similar to an ant disappearing into a colony and walking around randomly, a photon of light from a lidar enters the snow and bounces around as it is scattered by the snow particles until it exits and is collected by the telescope on ICESat-2. All this happens very fast—at the speed of light.

Using a special model simulation and an equation almost identical to the one from the ant problem, Hu discovered he could measure the average distance a photon traveled inside the snow before it's eventually measured by the lidar and determined the snow depth is half of that average distance.

"The model suggests that the photon is traveling inside the snow almost exactly the way the ant travels inside its colony," said Hu.

Hu's use of ICESat-2 to make snow depth measurements directly would overcome limitations of existing methods that use airborne and space platforms. Airborne measurements can only cover limited areas. Historically, satellite measurements have been limited by the low resolution of passive sensors. More recently, scientists have used ICESat-2 to measure the top of the snow layer on sea ice and CryoSat-2's radar to "see" the top of the sea ice beneath the snow layer. However, geolocation differences of just 10 ft (~3 m) or so in where these two satellites take measurements can introduce significant inaccuracies to inferences of snow depth.

Direct measurements of snow depth would increase understanding of the water cycle and snowfall, and satellite estimates of sea ice thickness, since so much sea ice is covered by snow. It is a critical measurement, especially as climate change intensifies.

"In general, snowpack has been decreasing and the snow season has been shortened in the contiguous U.S. during the last 50 years," said Hu. "Predicting regional changes in snowfall has been difficult."

Snow plays an important role in regulating climate because it reflects the Sun's energy back out into space and helps keep the planet cool. Less snow on the ground equals less reflectivity and more warming. Less snow on sea ice removes an insulating layer that prevents heat from the relatively warm ocean from escaping to the much colder atmosphere.

According to Hu, if carbon dioxide doubles from current levels, most climate models consistently predict an increase in global rainfall of anywhere between 3–7%. Inversely, though, snowfall may decrease significantly in mid-latitude regions. Accurate snow measurements can help constrain the models.

The innovation of Hu's team will advance climate scientists' abilities to better understand and interpret difficult-to-make snow depth measurements from space. Launched in 2018, ICESat-2 fires 10,000 laser pulses a second and measures the elevation of sea ice, ice sheets, forests and more in unprecedented detail.

Their findings were published recently in the journal *Frontiers in Remote Sensing*.[1] ■

[1] To read the study, visit *https://www.frontiersin.org/articles/10.3389/frsen.2022.855159/full*.

Step Into NASA Science Via NASA's Virtual Exhibit Platform

The *NASA Virtual Event Platform* recreates the excitement, convenience, and functionality of an in-person event in a fully customizable, online environment—and it's now free to use agency-wide in the development of virtual events for the public and others.

Whether planning a public-engagement event or attending an upcoming scientific conference, the platform offers NASA and its partners an interactive and engaging way to "share the science" in today's digital world. Via the platform, users can:

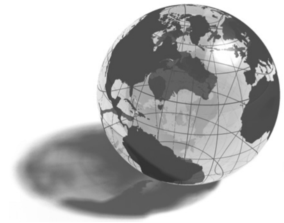
- Host live events;
- connect with attendees;
- share open-source data;
- grow their audience; and
- access valuable metrics.

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/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*



NASA Earth Science in the News

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

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

[*]**How Ants Inspired a New Way to Measure Snow with Space Lasers**, May 31, *wired.com*. After reading the results of a study about the gross behavior of ant colonies, which determined that the average time any one ant might wander around underground before resurfacing can be predicted with some certainty, NASA physicist **Yongxiang Hu** [NASA's Langley Research Center] got to wondering if a similar predictive formula might be applied to *photons* traveling through a snowpack. If so, that would let scientists estimate snow depth *directly*, using a laser pulse from an orbiting satellite—and potentially provide a powerful new way to monitor water supplies and the health of sea ice in the Arctic. (Current methods use *indirect* measurement techniques to calculate snowpack.) NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2) uses lidar to send photons at Earth's surface, then analyzes what bounces back to the satellite, with the heights of different surface structures (e.g., mountains vs. valleys) giving different return times. The same thing happens when a lidar pulse travels through a snowbank. "We can measure that distance of each individual photon traveling inside the snow," says Hu. Penetrating to different pack depths results in pack thickness The nonlinear paths of the photons—both through and within the pack make for noisy data, but patterns may be discerned. With an appropriate mathematical formulation in hand, the team was able to estimate snow depth all over the planet using global lidar data from ICESat-2. Then they compared those estimates to snow depth measurements of the same areas taken by airplane-based radar. "They compare very well," says Hu of the methods. "We're very happy that the theory worked."

NASA Scientists Available for 2022 Hurricane Season Interviews, June 1, *apnews.com*. The Atlantic Ocean hurricane season began on June 1 and runs through November 30. NASA is once again prepared to help understand and monitor storms from the unique vantage point of space, as provided by satellite-borne instruments. As the 2021 hurricane season brought the third-highest number of named storms on record, the public wonders what the 2022 season will bring. NASA experts are available for interviews throughout the 2022 season. The agency plays a foundational role in the science of hurricanes, using data from its over 20 Earth-observing satellites, including several that are important for tropical cyclone monitoring: Sentinel-6 Michael Freilich, Global Precipitation Measurement (GPM), Cyclone Global Navigation Satellite System (CYGNSS), and the soon-to-be launched Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission.[1] "Along with millions of Americans, I know firsthand the devastation caused by hurricanes. These climate-related events are growing more frequent and powerful, underscoring the need for greater action to improve our nation's response and resilience to hurricanes," said **NASA Administrator Bill Nelson**. "Addressing and mitigating the effects of climate change [and their influences on phenomena] like hurricanes are at the core of NASA's mission. From the agency's upcoming TROPICS mission that will help scientists understand the factors driving storm intensification and contribute to weather-forecasting models, to the creation of the Earth Information Center to ensure game-changing NASA climate data are accessible and understandable to decision makers, NASA will continue to help communities better prepare for and recover from these weather events." NASA's goal for American disaster preparedness, response, mitigation, and recovery is bringing data to people who need it. Before, during, and after a hurricane makes landfall, NASA satellites are in prime positions to identify impacts.[2]

Why NASA Is Measuring Dust on Earth from Space, June 5, *slashgear.com*. Space agencies like NASA are in an ongoing fight with a tiny enemy: dust. From dust covering up the solar panels of Mars landers like InSight and rovers like Opportunity to tricky sharp moon dust that gets into components and eats away at them, the problems presented by these small particles are many. But NASA isn't only interested in dust out on other planetary bodies and in the depths of space, the agency is also interested in the dust right here on Earth.

[1] UPDATE: Regrettably the first two satellites in this mission failed to reach orbit. Read details in the Editor's Corner column in this issue.

[2] For more information and to see a list of NASA scientists who are available for interview, visit *go.nasa.gov/3MCr83n*.

As part of its suite of Earth-monitoring tools and experiments, NASA will soon be launching an experiment to the International Space Station (ISS) to measure dust in Earth's atmosphere. The Earth Surface Mineral Dust Source Investigation (EMIT) instrument analyzes dust to see its composition. This allows researchers to pinpoint particular minerals and to determine the dust's composition. The idea is to point the instrument at Earth and to study desert regions in particular—because these are the sources of a large amount of mineral dust in the atmosphere. According to NASA, the total amount of mineral dust carried out of desert regions and into the atmosphere is more than a billion metric tons per year. Researchers want to measure how this dust moves through the atmosphere and what effect it has on the climate.

Human-Triggered California Wildfires Are More Severe than Natural Blazes, June 6, *phys.org*. Human-caused wildfires in California are more ferocious than blazes sparked by lightning, a team led by scientists from the University of California, Irvine (UCI) reported recently in the journal *Nature Communications*.[3] The research could help scientists better understand fire severity and how likely a blaze is to kill trees and inflict long-term damage on an ecosystem in its path. California is no stranger to wildfires: in 2020 alone, over 4 million acres (~16,200 km^2) burned across the state, including the million-acre August Complex Fire. But what's been unclear until now was whether there was any difference in severity between wildfires that start naturally, from lightning strikes, versus those touched off by humans. "Human-ignited fires grow more rapidly and release more energy as they're growing because they're often sparked under conditions that are hotter and drier," which makes them, "more ferocious," said **James Randerson**, co-author of a separate paper published in *Scientific Data*.[4] The work was made possible by UCI advances in fire modeling that enable scientists to better understand the forces that govern how fast blazes move. This two-study effort was also one of the first times scientists have been able to link a fire's speed and energy release to its long-term effects on ecosystems—which can last for decades or even centuries. Both new studies have special relevance for California, where increasing fire severity is leading to more and more property damage, civilian and firefighter fatalities, ecosystem degradation, and poor air quality. Co-author **Douglas Morton** [NASA's Goddard Space Flight Center (GSFC)] and visualization engineer **Cynthia Starr** [GSFC] created animations of these new data for the Caldor fire and the Dixie fire—see **Figure**.[5] These two fires had devastating impacts on several California communities in the Sierra Nevada Mountains during the 2021 wildfire season. The data visualizations for these fires illustrate how quickly fire behavior can change day-to-day, as a result of variations in weather and the fires burning into new areas with different levels of fuel accumulation. The two studies included contributions from researchers at GSFC, Universidad del Rosario (in Bogotá, Colombia), and Cardiff University (U.K.)

*See News Story in this issue to learn more.

[3] To read the study, visit *www.nature.com/articles/s41467-022-30030-2.*

[4] To read the study, visit *https://www.nature.com/articles/s41597-022-01343-0.*

[5] To watch a visualization of the Dixie fire, visit *svs.gsfc.nasa.gov/4993*. To watch a visualization of the Caldor fire, visit *svs.gsfc.nasa.gov/4992.*

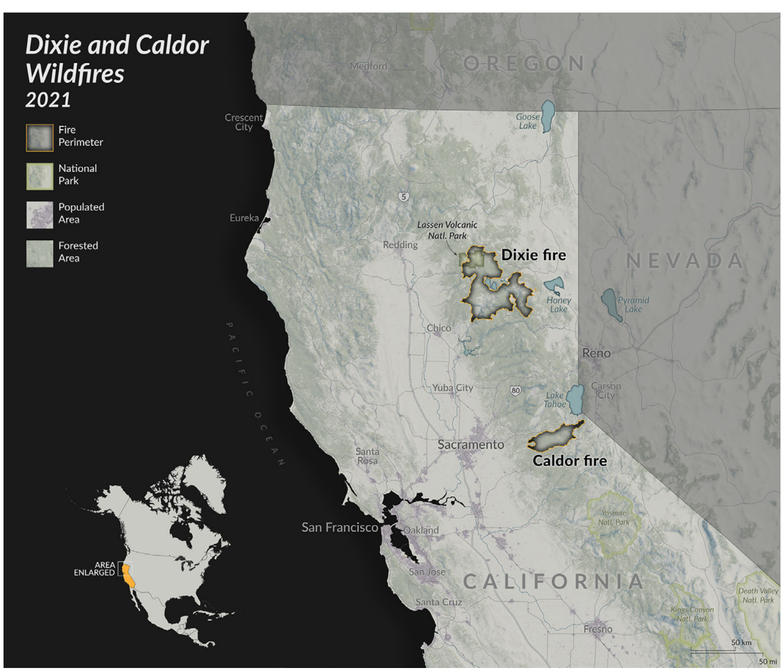


Figure. This map shows the perimeter of the Dixie and Caldor wildfires located in California on October 22, 2021. This and other maps of the two fires are available at *svs.gsfc.nasa.gov/5009.* **Credit:** NASA's Goddard Space Flight Center/Scientific Visualization Studio

Earth Science Meeting and Workshop Calendar

NASA Community

September 14–15, 2022
PACE Applications Workshop, *virtual*
www.eventbrite.com/e/pace-applications-workshop-2022-tickets-321347487987?aff=newsletter

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

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

September 29–30, 2022
History of NASA and the Environment Symposium, *hybrid*
Washington, DC
go.nasa.gov/3Ne8lMg

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Article submissions, contributions to the meeting calendar, and other suggestions for content are welcomed. Contributions to the calendars should contain date, location (if meeting in person), URL, and point of contact if applicable. Newsletter content is due on the weekday closest to the first of the month preceding the publication—e.g., December 1 for the January–February issue; February 1 for March–April, and so on.

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