Over Thirty Years Reporting on NASA's Earth Science Program

The Earth Observer

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The Editor's Corner

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As *The Earth Observer* documented over the past year, NASA continues to excel despite the pandemic. As we begin to emerge from it, there is now a concise vision to guide the program's future mission endeavors. On May 24, NASA publicly announced plans for its next generation *Earth System Observatory* (ESO) where the Earth Science Division will develop a new set of integrated missions to study a broad range of Earth science themes, from climate to weather to disaster mitigation.[1]

The immediate focus of the ESO missions will include starting up projects for four targeted Designated Observables (DOs) identified in the 2017 Earth Science Decadal Survey[2]: Aerosols; Cloud, Convection, and Precipitation; Surface Biology and Geology; and Mass Change. In addition, as noted on the new ESO website (*go.nasa.gov/3wmt4pm*), "The trailblazer for the observatory is a NASA partnership with the Indian Space Research Organisation (ISRO) that brings together two different kinds of radar systems that can measure changes in Earth's surface to less than a half-inch. This mission, called the NASA–ISRO Synthetic Aperture Radar, or NISAR, will measure some of the planet's most complex processes, e.g., ice-sheet collapse and natural hazards such as earthquakes, volcanoes, and landslides."

[1] To learn more about ESO, see *www.nasa.gov/press-release/new-nasa-earth-system-observatory-to-help-address-mitigate-climate-change*. The quote from NASA Administrator Senator Bill Nelson on page 2 is taken from this release.

[2] The 2017 Earth Science Decadal Survey's "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space" can be downloaded from *www.nap.edu/catalog/249abl38/thriving-on-our-changing-planet-a-decadal-strategy-for-earth*.

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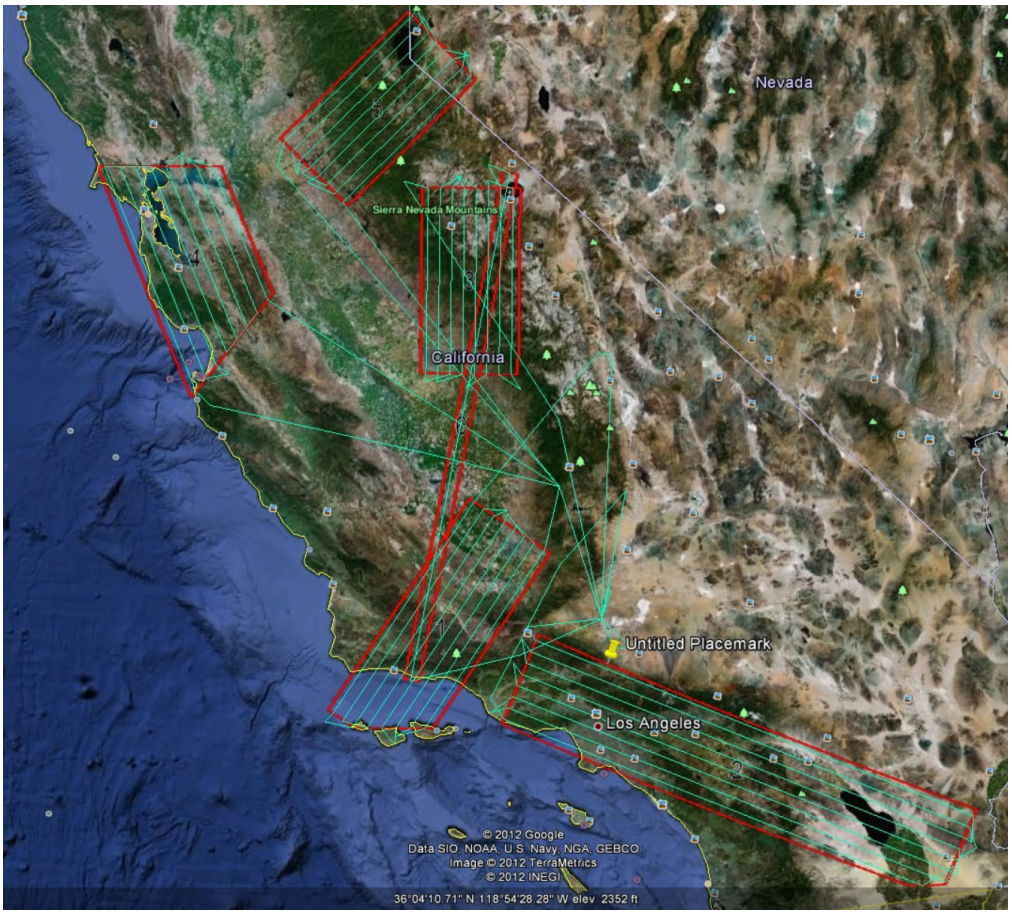

For the past nine years, NASA has conducted successful Western Diversity Time Series airborne campaigns across the state of California. The latest of these campaigns took place from February–April 2021. The NASA ER-2, equipped with the MASTER and AVIRIS-C airborne simulators, conducted a series of high-altitude flights observing the five large-area blocks and one long transect within the state of California and its immediate surroundings. These blocks cover a substantial fraction of the state and provide an excellent cross-section of California's terrestrial and marine systems. Results obtained from these flights are a unique asset for research and applications communities in the Golden State seeking to understand the influence of a changing water cycle on a variety of natural and human-dominated ecosystems. These data are also foundational for upcoming NASA missions such as EMIT (a Venture Class mission) and Surface Biology and Geology Change (an Earth System Observatory mission/Designated Observable). **Image credit:** NASA.

editor's corner

In This Issue

Beyond the DOs, the 2017 Decadal Survey also classified several additional targeted observables as Explorers (mid-size missions); these include greenhouse gases, ice elevation, ocean surface winds and currents, ozone and trace gases, snow depth and snow water equivalent, terrestrial ecosystem structure, and atmospheric winds. The plan is for three of these to be competitively selected for development into Earth System Explorer missions that will be part of the ESO.

The ESO will be built with application and user community needs being an upfront part of each mission, and with improved access through an integrated open science initiative to accelerate data usage. As mentioned on the Earth Science Division website, "NASA's Open Source Science strategy is the key to bringing the data from these missions together into a single observatory to help understand the Earth as a system and accelerate our ability to use this understanding."[3]

NASA Administrator Senator Bill Nelson stated: "Over the past three decades, much of what we've learned about the Earth's changing climate is built on NASA satellite observations and research. NASA's new Earth System Observatory will expand that work, providing the world with an unprecedented understanding of our Earth's climate system, arming us with next-generation data critical to mitigating climate change, and protecting our communities in the face of natural disasters."

In addition to initiating development of ESO, NASA's FY22 President's budget also includes support for the continued cadence of Venture Class solicitations as well as for the PACE and CLARREO Pathfinder missions.

To learn more about the ESO, there is a four-minute "Science in Seconds" segment that features **Thomas Zurbuchen** [NASA Headquarters—*Associate Administrator for the Science Mission Directorate*] and **Karen St. Germain** [NASA Headquarters—*Director of the Earth Science Division*] that can be viewed at *www.youtube.com/watch?v=aasS2rbxH_w*.

Despite COVID-19's continued impact on in-person meetings, NASA's 20+ year Southern Hemisphere Additional Ozonesondes (SHADOZ)[4] project has continued to make progress over the last year. The GSFC SHADOZ leadership team has come up with an innovative way to strengthen connections even when in-person gatherings are impossible—via virtual Regional SHADOZ Meet-Ups. To date, three of these Meet-Ups have taken place. Meanwhile, in November 2020, NASA and LAPAN signed an agreement to resume SHADOZ ozonesonde launches at the Watukosek, Java, Indonesia station (active 1998–2013). Also in 2021, the SHADOZ project is working with two formerly inactive stations (Watukosek, Java, Indonesia and San Cristobal, Galapagos, Ecuador) on restarting regular ozonesonde launches through renewed international partnerships.

SHADOZ will have a leadership transition later this year. **Anne Thompson** [GSFC], who has been PI of

[3] See *science.nasa.gov/earth-science*.

[4] To learn more about the history and accomplishments of SHADOZ, see "SHADOZ at 20 Years: Achievements of a Strategic Ozonesonde Network" in the September–October 2019 issue of *The Earth Observer* [**Volume 31**, **Issue 5**, pp. 4–15—*go.nasa.gov/2RRAxOe*].

SHADOZ since its inception in 1998, transitioned in June to emeritus status at GSFC after a 26-year career as a NASA employee; **Ryan Stauffer** [GSFC] will be her successor. Stauffer started working with ozonesondes in 2010, when Thompson, then a professor at Penn State University, was his PhD advisor. He came to GSFC in 2016, working first as a NASA Postdoctoral Program Fellow, and is now a civil servant. Congratulations to Thompson and best wishes to Stauffer in his new leadership role. Turn to page 12 to learn more about the three Regional SHADOZ Meet-Ups and other recent project activity.

Meanwhile, from February through the beginning of April 2021, the NASA Airborne Science Program completed another successful Western Diversity Time Series airborne campaign across the state of California. These flights marked nine years of campaigns by NASA's high-altitude ER-2 aircraft carrying the Airborne Visible/Infrared Imaging Spectrometer-Classic (AVIRIS-C) and MODIS/ASTER Airborne Simulator (MASTER) instruments. The observation targets continue to be five large-area blocks and a long transect within the state of California and its immediate surroundings—see map on page 1. These blocks cover a substantial fraction of the entire state and provide an excellent cross-section of its terrestrial and marine systems. The powerful combination of visible to shortwave infrared imaging spectroscopy from AVIRIS-C and multispectral thermal infrared imagery from MASTER has captured change in multiple ecosystems across a wide range of elevational gradients through pre-drought, drought, early post-drought, and now back to drought conditions. The resulting data are a unique asset for research and applications communities seeking to understand the influence of a changing water cycle on a variety of natural and human-dominated ecosystems in one of the most biologically-diverse states in the Nation.

This unique time series serves as a vital precursor for both the upcoming Earth Surface Mineral Dust Source Investigation (EMIT)[5] on the International Space Station and the Surface Biology and Geology DO—discussed earlier. The fact that NASA successfully conducted the last two campaigns in 2020 and 2021 during a pandemic speaks to the incredible commitment and professionalism of the air and ground crews at AFRC, and the instrument teams at JPL and ARC.

One consequence of the ongoing COVID-19 pandemic has been the lack of in-person scientific meetings and events. NASA's Science Support Office (SSO, organizationally part of the EOS Project Science Office) has a long history of organizing domestic and international NASA exhibits (e.g., AGU Fall Meeting, JpGU, Earth Day). While there was some ability to participate in these exhibits virtually prior to March 2020, it tended to be the exception rather than the rule. It has been said that "necessity is the mother of invention," and this certainly proved true over the past year as virtual participation took a leap forward with organizations adopting virtual platforms to conduct meetings as well as exhibit activities.

NASA (including SSO staff) began thinking about how it might implement its own virtual conference platform to better allow the agency to host online meetings and events. In August 2020, the SSO began working closely with the Office of the Chief Information Officer's (OCIO) Web Service Office to conduct a thorough review of several candidate platforms. The analysis included a platform security assessment to ensure that all NASA data and security requirements were met and to minimize the collection of personal information. As a result of this review, on April 20, the NASA Web Service Office officially announced Communiqué[6] to be the NASA virtual event platform.

NASA's 2021 Virtual Earth Day Event was the first to use the Communiqué platform—and the results were impressive. The theme of the event was *Connected by Earth*, attracting 10,787 registered attendees from across the globe. The event's live days were April 21–24, with the platform accessible to registered attendees through May 31. Leveraging an incredible amount of teamwork across the agency, 70 individuals worked together to select a diverse group of speakers and stories for the event's live webinars and chat topics. The team collected interactive content to engage attendees from all backgrounds and ages. To learn more about NASA's Virtual Earth Day activities, see the feature article on page 4 of this issue.

The success of the inaugural NASA-hosted virtual event opens the door for future conferences to use the platform. As an example, the agency has confirmed the use of this platform for the upcoming National Space Symposium. ■

[5] EMIT is an Earth Venture Instrument–4 (EVI-4) selection scheduled to launch to the ISS in 2022. Learn more at *science.jpl.nasa.gov/projects/EMIT*.

[6] To learn more about the Communiqué platform, visit *www.communiqueconferencing.com*.

List of undefined acronyms used in Editorial and/or Table of Contents on page 11

feature article

Connected by Earth: Summary of NASA's 2021 Virtual Earth Day Event

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

To celebrate Earth Day 2021, NASA hosted its first virtual Earth Day event... The event attracted 10,787 registered attendees from around the globe.

Introduction

In 2020 the world celebrated the fiftieth anniversary of Earth Day during an unprecedented time as COVID-19 spread around the globe, ushering in widespread stay-at-home orders to help contain the virus. Because NASA could not participate in any face-to-face Earth Day celebrations in 2020, the agency made the decision to shift that year's celebration of Earth Day and similar science outreach conferences from the traditional in-person format—with a variety of hands-on activities to engage the public—to activities that could be carried out fully online. In doing so, NASA encouraged its web and social media followers to appreciate the wondrous beauty of our planet and the extraordinary science that helps us understand how it works—all from the relative safety of home.[1]

One year later, demand continues for online learning and communication tools to support society's seemingly never-ending drive to make online connections. To celebrate Earth Day 2021, NASA hosted its first virtual Earth Day event. The live event days were April 21–24, and the platform remained accessible to registered attendees through May 31, 2021.[2] The event attracted 10,787 registered attendees from around the globe.

Figure 1. This graphic depicts the welcome lobby for NASA's 2021 Virtual Earth Day Event, featuring seven rooms [clickable hexagons]. The event featured live content (i.e., webinar events and live chat rooms) from April 21–24 and remained accessible to registered attendees through May 31, 2021. Registration for the event was free and open to the public. **Image credit:** NASA

The theme of the event was *Connected by Earth*—as we are each part of Earth's gorgeous mosaic. The event was promoted through various NASA social media accounts (@NASA and @NASAEarth), the *nasa.gov/earthday* website, and various NASA education and public outreach outlets, including personal invitations sent directly to 1575 students in the U.S. On social media (e.g., Facebook and Twitter),

[1] To learn about NASA's home-based Earth Day 2020 celebrations, see "Earth Day at Home with NASA" in the May–June 2020 issue of *The Earth Observer*, **Volume 32, Issue 3**, pp. 4–12—*go.nasa.gov/2SGCu06*.

[2] Event registration was free and open to the public through May 31, 2021. While the live components (i.e., webinars, chat, and help desk) were only available April 21–24, attendees could access static content and recorded webinars through May 31, 2021.

NASA invited people around the world to join NASA's Virtual Earth Day Event and asked them to share aspects of their own relationship with Earth using the hashtag *#ConnectedByEarth* to celebrate how we are all connected by our home planet.

There were a variety of Earth Day activities available throughout seven rooms in the virtual environment—see **Figure 1** on page 4. Content included two live webinar events, nine topic-driven chat rooms staffed by NASA experts, a NASA Help Desk, games, videos, and roughly 100 downloadable resources such as posters, coloring pages, activity sheets, and books—see **Figures 2** and **3**. The event also featured an online scavenger hunt to kick off the agency's Grow for Launch initiative (*go.nasa.gov/3uQXFKF*) and a chance to learn more about plants grown in space and how you can start your own garden—see *Grow for Launch Scavenger Hunt* on page 10. A Guide to NASA's 2021 Virtual Earth Day Event is available at *go.nasa.gov/3uD0Beh*.

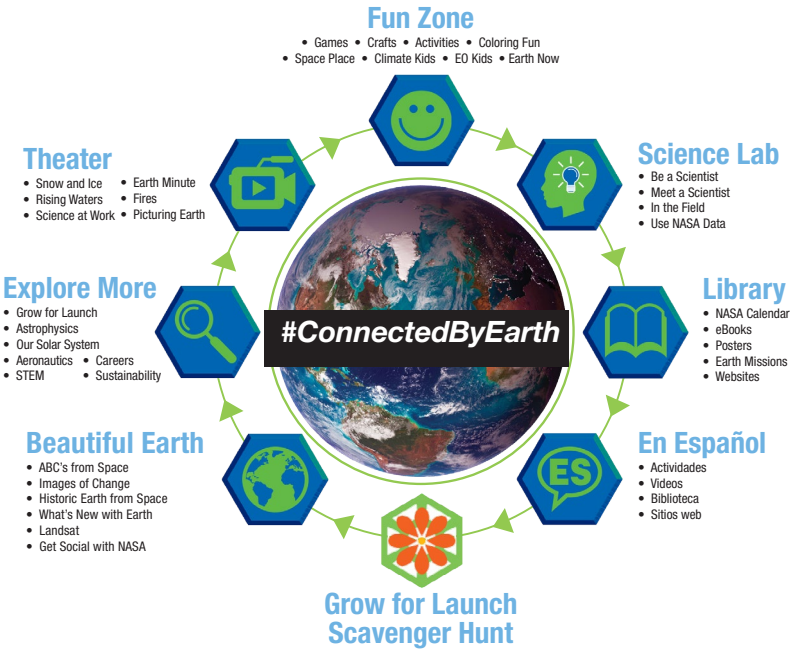

Figure 2. This graphic depicts the various content topics found in each of the seven rooms and available through the virtual environment. **Image credit:** NASA

A Guide to NASA's 2021 Virtual Earth Day Event is available at go.nasa.gov/3uD0Beh.

Figure 3. The NASA Help Desk featured links to various live events and chats, a guide to navigating the virtual Earth Day experience, and navigational links to NASA's seven virtual activity rooms. **Image credit:** NASA

feature article

Live Webinar Events in the Theater

The virtual event featured two 90-minute webinar events, *Connected by Earth: Water,* on April 21 from 10:30 AM to 12:00 PM EDT, and *Connected by Earth: Earth Day Celebration,* on April 22 (Earth Day) from 1:00 PM to 2:30 PM EDT. The *Water* event had 348 live viewers and the *Earth Day Celebration* event had 733 live viewers. Recordings of both events were made available on demand through the virtual platform, including closed captioning, within 72 hours. Also on April 22, the virtual event streamed a live downlink from the International Space Station (ISS) with special host **Shawn Mendes** via NASA Television—see *Downlink from the International Space Station with Special Host Shawn Mendes* on page 10. Summaries of presentations during these events are provided here.

The Water *event had 348 live viewers and the* Earth Day Celebration *event had 733 live viewers.*

Connected by Earth: Water

Trena Ferrell [NASA's Goddard Space Flight Center (GSFC)—*Education Specialist*] served as the moderator and first speaker for the Water event, opening with a message about how water is a resource that connects us all—see **Figure 4**. Then she demonstrated a dendrochronology activity using a piece of paper and pencil at home to show the impact of water availability on tree ring thickness. Next NASA Astronaut **Ricky Arnold** [University of Maryland Center for Environmental Science (UMCES)—*Director of STEM Engagement*] joined colleagues **Bill Dennison** [UMCES—*Vice President for Science Applications*], **Julia Beck** [Project WET Foundation[3]—*Vice President of Networks*], and **Crystal Nichols** [UMCES—*Science Communication Intern*] to talk about the key to managing our most precious resource—water—and how we're managing this resource using Earth observations from space combined with ground-based data—see **Figure 5**. Following Nichols' presentation, the four speakers answered questions from student participants in a panel discussion format.

Figure 4. Trena Ferrell shows a glass of water from her home to introduce the water theme for the first live webinar event, *Connected by Earth: Water*. **Image credit:** NASA

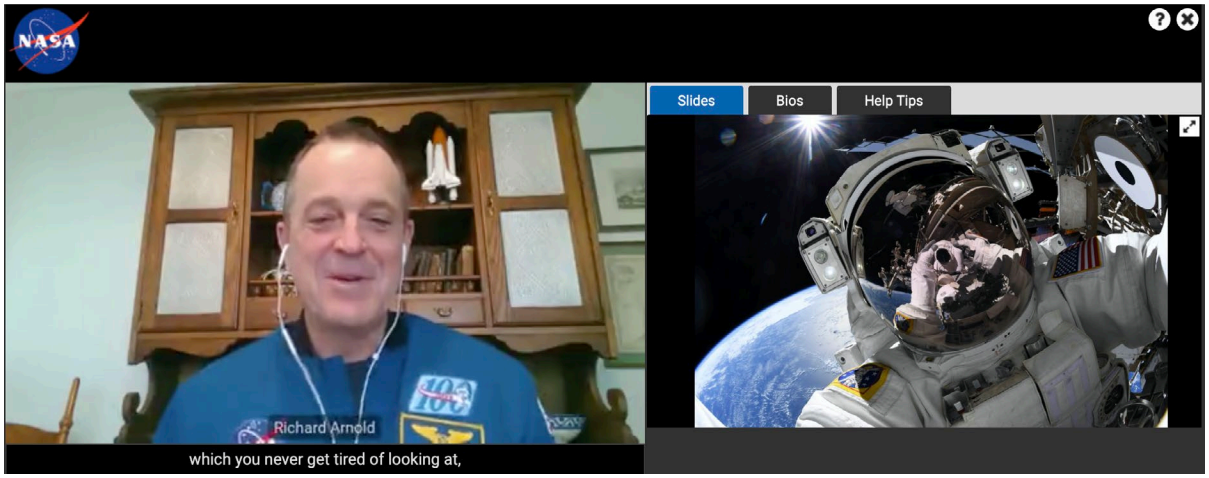

Figure 5. NASA Astronaut **Ricky Arnold** shows a picture of himself in space with the Sun coming up over his right shoulder, while describing the body of water close to his home on the Eastern Shore of Maryland—the Chesapeake Bay. **Image credit:** NASA

[3] WET stands for Water Education Today, a group that works to advance water education seeking to understand global challenges and promote local solutions. Learn more at *www.projectwet.org*.

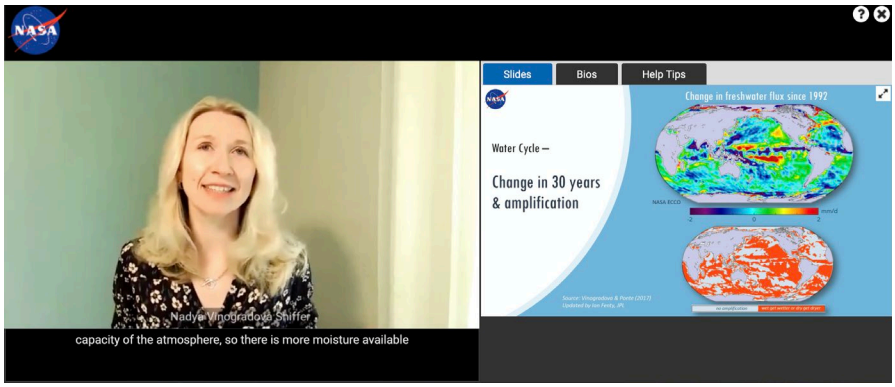

Figure 6. Nadya Vinogradova-Shiffer shows how the water cycle has changed over the last 30 years. She pointed out areas where the ocean is getting fresher, either due to more rainfall (such as in the tropics and Pacific Ocean), or because of less evaporation (in the South Pacific Ocean). And she pointed out areas where the ocean is losing freshwater, either because it rains less (such as in California) or because of more evaporation (Western Australia). She stated that overall, most wet areas are getting wetter and dry areas are getting dryer. **Image credit:** NASA

Next, **Nadya Vinogradova-Shiffer** [NASA Headquarters—*Program Scientist and Program Manager of Physical Oceanography*] explained that there are two major players in the water cycle—evaporation (water leaves Earth's surface) and precipitation (water enters Earth's surface), with the long-lasting supplier of moisture on our planet being Earth's ocean. She spoke about how NASA uses satellite observations from space and climate models to monitor changes in evaporation, precipitation, and salinity around the globe. She stated that the water cycle intensified over the past 30 years, with the mean climatological patterns amplifying as the wet areas are getting wetter and dry areas are getting drier, showing where the ocean is gaining and losing fresh water—see **Figure 6**. **Josh Willis** [NASA/Jet Propulsion Laboratory—*Climate Scientist*] talked about how NASA—in order to better predict sea-level rise around the globe—monitors not only how ice on our planet is changing, but also how the ocean water around Earth's ice is changing—see **Figure 7**. **Dalia Kirschbaum** [GSFC—*Chief of the Hydrology Sciences Laboratory*] explained how she uses satellite data collected from instruments 450 mi (724 m) above the Earth to tell her about the weather and climate in her backyard—see **Figure 8**. The live event ended with a 15-minute panel discussion among the presenters, answering questions received via the webinar chat tool.

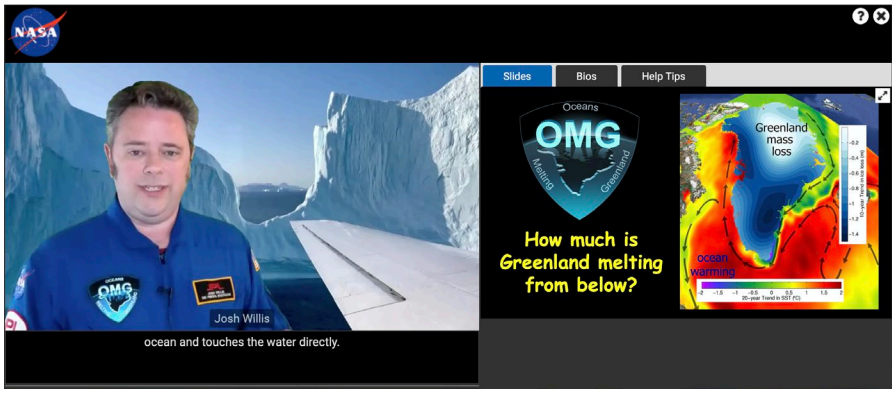

Figure 7. Josh Willis showed that as the planet warms and glaciers in Greenland melt, some of the water trickles down through the glacier and travels along the bedrock before exiting into the ocean. This melt water plume rises up to the surface pulling in warm water from the deep, which causes glaciers to melt from the bottom up, accelerating glacier retreat. **Image credit:** NASA

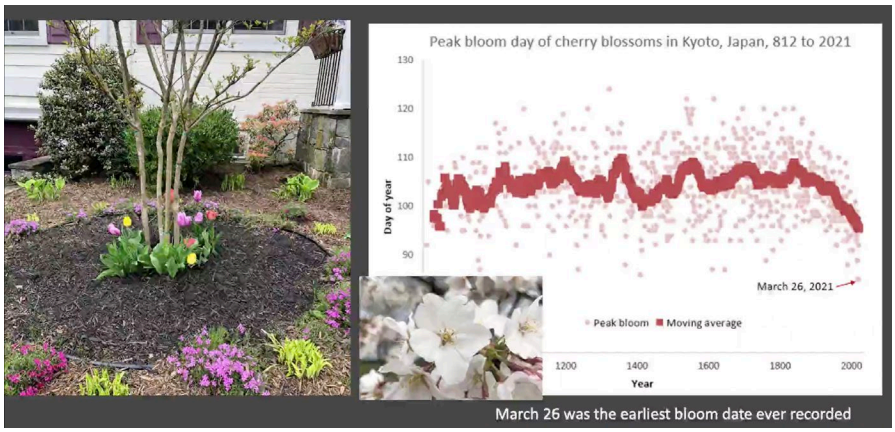

Figure 8. Dalia Kirschbaum spoke about changes in bloom patterns in our own backyards, showing that due to changes in climate, March 26, 2021, was the earliest bloom date ever recorded for cherry blossoms in Kyoto, Japan. **Image credit:** NASA

feature article

Connected by Earth: Earth Day Celebration

On Earth Day, April 22, **Leslee Scott** [GSFC—*Public Affairs Specialist*] welcomed guests to the event and served as the event moderator. **Karen St. Germain** [NASA Headquarters—*Director of the Earth Science Division*] explained the theme of this year's NASA's Earth Day event—*Connected by Earth*—stating that all of Earth's systems are connected to one another and that we as humans are all connected by what Earth provides us and how we care for our planet. As an example of Earth's connected systems, she showed a series of satellite images that revealed dust particles (i.e., aerosols) being carried through the atmosphere from West Africa across the Atlantic Ocean. She explained how NASA and other U.S. agencies use satellite data to track air quality, measure the impact of dust on the ocean, and study the effect of dust on storms and climate measurements—see **Figure 9**.

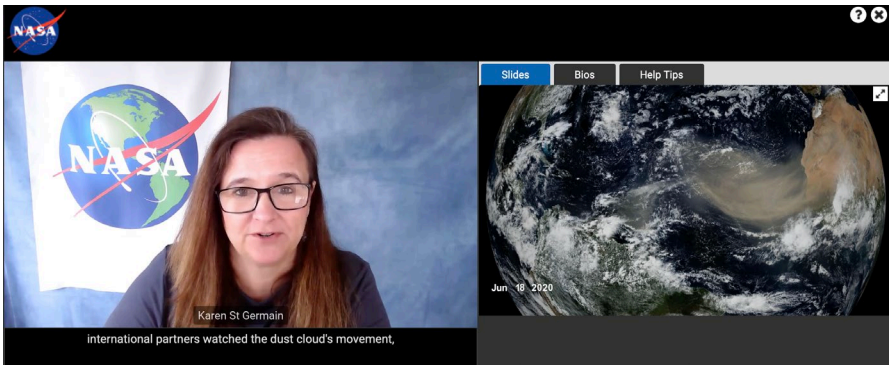

Figure 9. Karen St. Germain showed how NASA satellite images can be used to track dust storms across the Atlantic Ocean, noting that African dust can have many impacts along the way, including fertilizing soil in the Amazon, helping build beaches in the Caribbean, impacting air quality, and suppressing the intensification of tropical cyclones. **Image credit:** NASA

Gavin Schmidt [NASA's Goddard Institute for Space Studies (GISS)—*NASA Senior Climate Advisor* and *GISS Director*] spoke next, providing highlights about how we can "see" climate change from space, showing Landsat images of glacial retreat in Alaska, ice-loss trends in Antarctica and Greenland, declining sea-ice extent in the Arctic Ocean, global sea-level rise, and increasing global surface temperatures over the last 50–60 years. He explained that the trends we're seeing in climate model data are driven by human activities, the chief among these being increases in greenhouse gases mainly from the burning of fossil fuels. To close, he showed changes in surface temperature since the first Earth Day in 1970—see **Figure 10**.

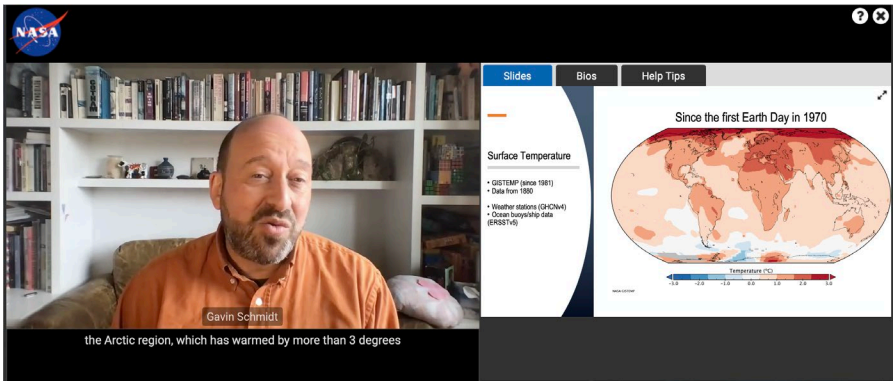

Figure 10. As an example of Earth's changing climate, **Gavin Schmidt** showed changes in surface temperature since the first Earth Day in 1970. He noted that the changes are larger in the Northern Hemisphere than they are in the Southern Hemisphere and that the changes are largest in the Arctic region, which has warmed more than 3 °C (almost 6 °F). **Image credit:** NASA

Gioia Massa [NASA's Kennedy Space Center—*Plant Scientist*] provided several main reasons to explain why NASA is growing plants in space: to provide nutrient-rich food for astronauts, to improve psychosocial wellbeing by having a piece of organic Earth in space and watching plants grow, and by recycling the atmosphere (converting carbon dioxide into oxygen) and water (transpiration and evaporation) onboard the ISS—see **Figure 11** on page 9. Growing plants in space helps NASA understand how astronauts might produce crops during future missions to the Moon and Mars.

After Massa's presentation, NASA Astronaut **Ricky Arnold** shared a hopeful message about how the ISS is a model for how things can work when human beings come together and find a higher plane of agreement. He noted that onboard the ISS the

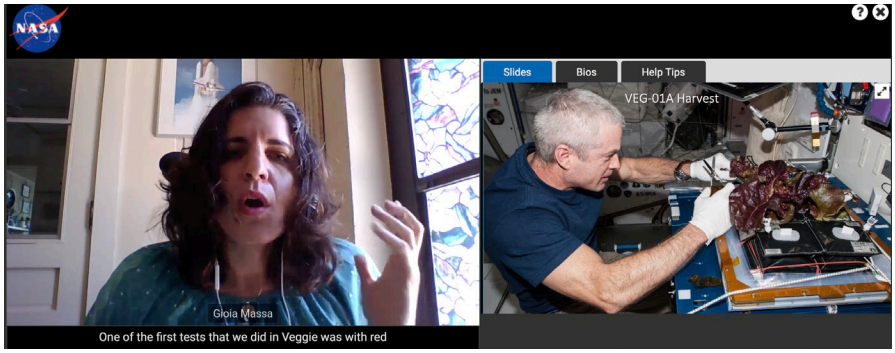

Figure 11. Gioia Massa shows a photo of NASA Astronaut **Steven Swanson** harvesting the first set of red romaine lettuce from the Vegetable Production System (Veggie) unit onboard the International Space Station. **Image credit:** NASA

international crew members speak many different native languages and come from many different cultural backgrounds to work together as one for common goals. He shared many inspiring sentiments about his time in space and answered questions from students about what it takes to become an astronaut, how cold it is in space, what astronauts eat in space, and how beautiful the view of Earth from space is.

The final speaker, **Jim Green** [NASA Headquarters—*Chief Scientist*] spoke about Earth's place in our Solar System. He explained the importance of understanding Earth's past so that we can better understand what's happening to our planet today, noting that changes in Earth's climate have always taken place, but the recent rate of change is accelerating. He explained that the Earth is warming faster than its natural cycle and greenhouse gases such as water vapor, methane, and carbon dioxide are the culprit—see **Figure 12**.

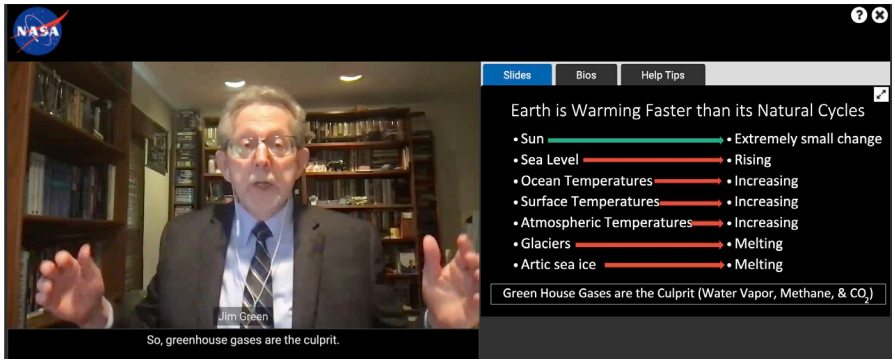

Figure 12. Jim Green explained that Earth's climate change is occurring at a faster rate than well-documented phenomena relating to Earth's orbit and orientation in space would predict. **Image credit:** NASA

Live Chat with NASA Experts in the Science Lab

Virtual attendees could chat with NASA experts by visiting the Science Lab and choosing from nine chat topics in the Ask a Scientist chat menu. Combined, the Ask a Scientist chat topics had 3933 total views, with 2032 unique user views—see **Table 1**. Altogether, 40 NASA experts helped staff the various chat topics, with representatives available for live chat April 21–23, 9:00 AM–6:00 PM EDT daily.

Table 1. Number of views (i.e., total) and unique viewers for the nine topic-driven chat areas.

Chat Topic	Number of Views	Unique Viewers
African Dust	555	351
Climate Change	574	277
Water Quality	445	261
Animals and Conservation	376	233
Vegetation	456	214
Ice and Sea Level Rise	378	202
Disasters	364	194
Sustainable Aviation	400	161
Citizen Science with GLOBE	385	139
Total	**3933**	**2032**

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Downlink from the International Space Station with Special Host Shawn Mendes

On April 22 at 11:00 AM EDT, Astronauts **Mike Hopkins**, **Shannon Walker**, **Victor Glover**, and **Mark Vandehei** [all from NASA], and **Soichi Noguchi** [Japan Aerospace Exploration Agency (JAXA)] participated in a live downlink from the International Space Station for a special Earth-focused Q&A with guest host, singer and songwriter **Shawn Mendes**! The live stream featured questions sent in from around the world. To listen to the full downlink event, visit *www.youtube.com/watch?v=kg5uxKK-7lI*.

Grow for Launch Scavenger Hunt

Another popular and highly interactive component of the event was the Grow for Launch virtual scavenger hunt. This Earth Day, NASA encouraged the public to start their own gardens—be they in a plot of Earth or a pot full of earth—using seeds similar to those taken to the ISS for the astronauts' garden, including romaine lettuce, radishes, and mustard. To play, participants had to find and click on the 11 space plants hidden throughout the virtual rooms to decipher an 11-character code word that would unlock the Grow for Launch greenhouse—see **Figures 14** and **15**. Inside the virtual greenhouse, attendees were greeted with a special video message from NASA Astronaut **Ricky Arnold**. They could then download a certificate of completion.

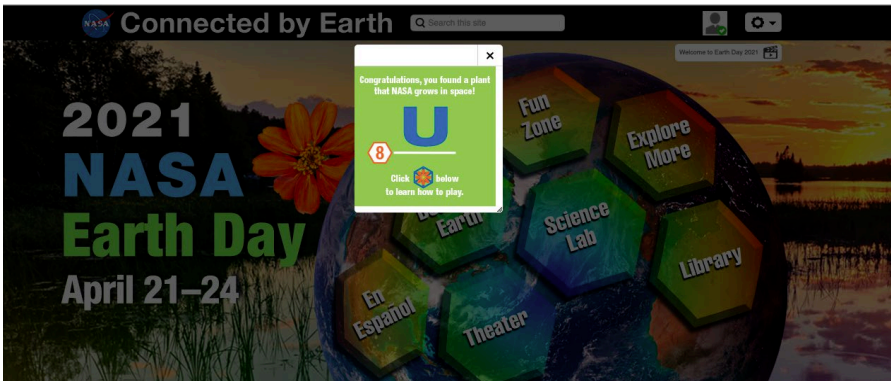

Figure 14. When participants clicked on the orange zinnia in the main lobby (see Figure 1), the letter U was shown to be the eighth letter in the 11-character code word. **Image credit:** NASA

Figure 15. The Grow for Launch greenhouse featured a video message from NASA Astronaut Ricky Arnold, a downloadable certificate of completion, and various content items related to growing plants in space and at home. **Image credit:** NASA

Conclusion

NASA's 2021 Virtual Earth Day Event was a successful online event. With registration free and open to the public, NASA was able to celebrate Earth Day with more than 7000 attendees around the globe. NASA's Science Support Office oversaw the event planning and execution, pulling together a team of some 70 individuals from across the agency to work together, build the event, and execute the live days. This event would not have been possible without incredible efforts and collaboration put forth by so many outreach professionals across the agency.

To download the Earth Day 2021 poster and learn more about how NASA celebrated Earth Day 2021, visit *www.nasa.gov/earth-day-2021*. ■

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

AFRC	NASA's Armstrong Flight Research Center
AGU	American Geophysical Union
ARC	NASA's Ames Research Center
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CLARREO	Climate Absolute Radiance and Refractivity Observatory
EOS	Earth Observing System
GSFC	NASA's Goddard Space Flight Center
JpGU	Japan Geophysical Union
JPL	NASA/Jet Propulsion Laboratory
LAPAN	Lembaga Penerbangan dan Antariksa Nasional (National Institute of Aeronautics and Space [Indonesian space agency])
MODIS	Moderate Resolution Imaging Spectroradiometer
PACE	Plankton, Aerosol, Cloud, ocean Ecosystem

meeting summaries

NASA's SHADOZ Team Makes Advances in 2021 Despite the Pandemic

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Introduction

Since 1998 NASA's Goddard Space Flight Center's (GSFC) Southern Hemisphere ADditional OZonesondes (SHADOZ; *tropo.gsfc.nasa.gov/shadoz*) has been coordinating balloon-borne ozonesonde launches from 14 sites in the tropics and subtropics through global international partnerships—see **Figure 1** and **Table 1**.[1] By the end of 2020, SHADOZ had archived more than 9000 sets of ozone and pressure–temperature–humidity (PTU) vertical profiles for the entire project period. In 2020 alone, more than 300 profile sets were archived—despite COVID-19-mandated work interruptions at 6 stations. The 2020 measurements, provided by 12 stations, are always in high demand for trend studies, ozone assessments, and satellite validation and model evaluation. More than 20 refereed journal publications used or referenced SHADOZ data in 2020.

The current GSFC SHADOZ team consists of **Anne Thompson** [*Principal Investigator*], **Ryan Stauffer** [*Field Coordinator*], and **Debra Kollonige** [*Data Archiver* and *Website Manager*].[2] Despite not being able to travel to conferences, technical workshops, or launch sites due to the pandemic, the GSFC SHADOZ team strengthened partnerships with international collaborators through outreach with its 14 stations. There were two key results from these activities:

- The restart of two stations that were inactive for a period of more than five years (Watukosek, Java, Indonesia; San Cristóbal, Galápagos, Ecuador) and the incorporation of Quito, Ecuador, into the SHADOZ project with support from NASA Headquarters, GSFC, and the National Oceanic and Atmospheric Administration (NOAA).
- The convening of three virtual regional station meetings (the first held in March, the second in April, and the third in May 2021) to foster improved communication with the stations' principal investigators (PIs) and staff.

These activities and their results are discussed in this article.

[1] To learn more about the history of SHADOZ and the accomplishments of the first 20 years of the program, see "SHADOZ at 20: Achievements of a Strategic Ozonesonde Network" in the September–October 2019 issue of *The Earth Observer* [**Volume 31**, **Issue 5**, pp. 4–15—*go.nasa.gov/3v0xdht*].

[2] This team and its roles were discussed in more detail in the 2019 feature article referenced in Footnote 1.

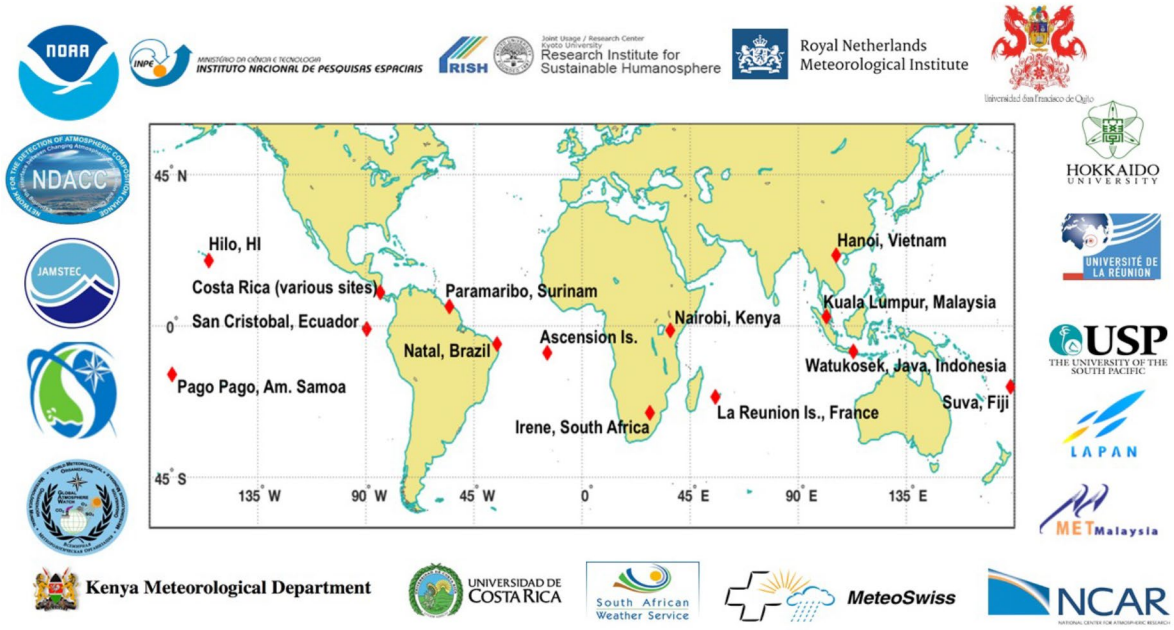

Figure 1. SHADOZ station map with partnership emblems indicated. Any undefined acronyms on the partner logos are defined in Table 1 and/or in the article text. **Image credit:** Debra Kollonige

Table. List of SHADOZ stations that have compiled at least 10 years of data.

Station [latitude, longitude]	Partner Organization	Years Operational	Number of Profiles*
Pago Pago, American Samoa [14.3° S, 170.71° W]	American Samoa Observatory [National Oceanographic and Atmospheric Administration (NOAA)/Global Monitoring Lab (GML)]	1998–Present	821
Hilo, HI, U.S. [19.72° N, 155.05° W]	Mauna Loa Observatory (NOAA/GML)	1998–Present	1148
San Cristóbal, Galapagos, Ecuador [0.9° S, 89.6° W]	University of San Francisco Quito (USFQ) in Quito, Ecuador, and NOAA/GML	1998–2008; 2012–2016; 2021–Present	442
San Pedro, Costa Rica [10° N, 84° W]	University of Costa Rica (at several locations)	2005–Present	649
Paramaribo, Suriname [5.81° N, 55.21° W]	Meteorological Service of Suriname and Koninklijk Nederlands Meteorologisch Instituut (KNMI) [Royal Netherlands Meteorological Institute]	1999–Present	822
Ascension Island [7.97° S, 14.4° W]	U.S. Air Force and GSFC	1998–2010; 2016–Present	755
Natal, Brazil [5.8° S, 35.2° W]	Instituto Nacional de Pesquisas Espaciais (INPE) [Brazilian National Institute for Space Research], GSFC, and NASA's Wallops Flight Facility	1998–2011; 2013–Present	714
Irene, South Africa [25.9° S, 28.22° E]	South African Weather Service	1998–2008; 2012–Present	396
Nairobi, Kenya [1.3° S, 36.76° E]	Kenyan Meteorological Department and Météoswiss	1998–Present	947
La Réunion, France [20.89° S, 55.48° E]	Université de la Réunion, Météo-France, and Centre National de la Recherche Scientifique (CNRS)	1998–Present	759
Kuala Lumpur, Malaysia [2.73° N, 101.7° E]	Malaysian Meteorological Department (Malaysian Met)	1998–2010; 2012–Present	465
Hanoi, Vietnam [21.02° N, 105.8° E]	Vietnam Meteorological and Hydrological Administration and Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	2004–Present	338
Watukosek, Java, Indonesia [7.57° S, 112.65° E]	Lembaga Penerbangan dan Antariksa Nasional (LAPAN) [Indonesian National Institute of Aeronautics and Space] and NOAA/GML	1998–2013; 2021–Present	343
Suva, Fiji [18.15° S, 178.4° E]	University of the South Pacific (NOAA/GML)	1998–Present	471

*The number of profiles as of the end of 2020.

Reactivation of Two SHADOZ Stations in Indonesia and Ecuador

With the current increasing demand for SHADOZ ozone and PTU vertical profiles for use in satellite validation and in upcoming ozone trend assessments, the SHADOZ team has worked diligently to avoid data gaps in the ozonesonde records at its current stations. These efforts include renewing an old partnership with the Lembaga Penerbangan dan Antariksa Nasional (LAPAN) [Indonesian National Institute of Aeronautics and Space] and starting a new partnership with the University of San Francisco Quito for the restarts of the Watukosek and San Cristóbal stations,[3] respectively, in 2021.

[3] The restart of the San Cristóbal station is supported with funding from NASA's Upper Atmospheric Composition Observations (UACO) program.

SHADOZ in Southeast Asia: Watukosek, Java, Indonesia (1998–2013; 2021–Present)

Ozonesonde launches began at Watukosek, Java, Indonesia in 1993 as a cooperative arrangement between LAPAN, the National Space Development Agency of Japan (NASDA),[4] and the University of Tokyo. Watukosek became a SHADOZ station in 1998 and provided essential ozone data for the region. Both Watukosek sounding and satellite data were used to study the environmental impacts of the massive fires that developed over Indonesia, Malaysia, and nearby nations as a result of a drought during the 1997–1998 El Niño-Southern Oscillation and Indian Ocean Dipole events. Using what were, at that time, new ozone and aerosol products, the Total Ozone Mapping Spectrometer–Earth Probe (TOMS-EP; launched in 1996 and operational until 2006) showed that the amount of smoke pollution in the atmosphere above populated areas remained high, whereas upper-level winds pushed high concentrations of ozone westward, over the ocean toward India.[5] Ozone profiles from the Watukosek ozonesonde launches confirmed elevated ozone from fires in the area during this period.

Ninong Komala [LAPAN—*SHADOZ Co-Investigator (Co-I)*] supplied high-quality Watukosek ozonesonde data to the SHADOZ archive (active 1998–2013) for more than 15 years. In November 2020 representatives from NASA and LAPAN signed an agreement to resume SHADOZ ozonesonde launches at the Watukosek station with Komala serving as the technical point of contact.[6] In honor of this occasion, a member of the U.S. Consulate in Surabaya, East Java, Indonesia, attended one of the first balloon launches at Watukosek in March 2021—see **Figure 2**. Komala and the LAPAN staff will continue twice-monthly ozonesonde launch operations as a part of the SHADOZ project.

SHADOZ Activity in the Equatorial Americas Region: Costa Rica and Ecuador

In February 2021 NASA Headquarters funded **Ryan Stauffer** [GSFC—*Research Aerospace Technology (AST)*] to:

- support ozonesonde and water-vapor sonde launches in Costa Rica—an active SHADOZ station (at various locations) since 2005 that is operated by **Jorge Andrés Diaz** [Universidad de Costa Rica (UCR)—*Professor* and *SHADOZ Co-I*];
- restart launch operations at San Cristóbal, Ecuador—a SHADOZ station from 1998 to 2016 that was founded by a partnership between NOAA and the Instituto Nacional Meteorologia e Hidrologia (INAMHI) [National Meteorological Agency of Ecuador]; and

[4] NASDA was the predecessor to today's Japan Aerospace Exploration Agency (JAXA).

[5] To learn more on this topic see the 2001 *Science* article, "Tropical Tropospheric Ozone and Biomass Burning", by Thompson *et al.,* at *go.nasa.gov/2T90n0h*. This topic was also discussed on page 11 of the September–October 2019 feature article referenced in Footnote 1.

[6] This new agreement was featured in the SHADOZ Newsletter that can be downloaded from *go.nasa.gov/3uXbhDH* and in a GSFC web feature at *go.nasa.gov/3pvwtjh*.

Figure 2. The photo on the left shows **Ninong Komala** [*middle*] with staff from the LAPAN Watukosek SHADOZ station. The top right photo shows **Theodore Kulongoski** [U.S. Consulate representative, *second from right*] in Surabaya, Indonesia, pictured with staff as they launch an ozonesonde from the LAPAN Watukosek station in March 2021. The bottom right photo shows LAPAN ozonesonde launch operations in action. **Photo credit:** LAPAN

- add a new SHADOZ station at Quito, Ecuador—which already has ozonesonde profiles dating back to 2014—to be led by former GSFC postdoctoral fellow **María Cazorla** [Universidad San Francisco de Quito (USFQ)—*Professor* and *SHADOZ Co-I*].[7]

These activities are illustrated in **Figure 3**.

Contrasts between Quito and San Cristóbal ozone are expected to reflect the more urban environment of Quito and the different local atmospheric dynamics due to its location at 3.2 km (~2 mi) altitude. New arrangements with UCR (San Pedro) and USFQ provide the infrastructure needed to have these three stations as a part of the SHADOZ Equatorial Americas region in 2021.

SHADOZ Regional Station Virtual Meet-Ups

Travel restrictions during the COVID-19 pandemic inspired the SHADOZ GSFC team to host virtual regional station meetings, or Meet-Ups, in 2021 as a way to communicate with currently operating stations and coordinate future launch efforts with the reactivated stations. So far, using the *Microsoft Teams* platform, the SHADOZ leaders have organized and hosted monthly Meet-Ups in March–May for the Southeast Asia, Equatorial Americas, and NOAA Pacific stations, respectively. The general goals for these Meet-Ups have been to:

- acquaint regional SHADOZ members with each other to foster stronger communications amongst the stations and with the GSFC Team and with partners **Bryan Johnson** and **Patrick Cullis** [both from NOAA/Global Monitoring Laboratory (GML)];
- allow the GSFC team to provide an overview of current activities, such as capacity building and data quality assurance;
- provide an opportunity for respective station PIs and staff to provide updates on operations at the SHADOZ stations;
- facilitate discussion of logistical issues at stations; and
- enhance SHADOZ station representation at the upcoming Quadrennial Ozone Symposium (QOS) in October 2021 (*qos2021.yonsei.ac.kr*), where each group is encouraged to showcase its accomplishments.

[7] The USFQ launches in the past year have been partially supported by the United Nations Environmental Programme/Vienna Convention Trust Fund (*go.nasa.gov/3cmL76M*).

Figure 3. The left and top middle photos show **María Cazorla** [USFQ] with her students launching ozonesondes from the rooftop at USFQ in Quito, Ecuador. The bottom middle photo shows **Anne Thompson** [SHADOZ PI] and **María Cazorla** [*right*] in front of a Thermo Environmental Instruments (TEI) surface ozone instrument at the USFQ Institute of Atmospheric Research laboratory during a 2017 visit. The top right photo shows UCR staff launching an ozonesonde in 2019. The bottom right photo shows the Ticosonde project team during a 2019 annual visit. The Ticosonde project is a participating SHADOZ station that is unique in that it launches specialized water-vapor instrumentation and is supported entirely by NASA Upper Atmospheric Composition Observations (UACO) funding. **Photo credits:** USFQ for left and middle photos; UCR for photos on right

meeting summaries

Regional Meet-Up #1: Southeast Asia Stations

On March 24 the GSFC SHADOZ team hosted the first-ever SHADOZ Regional Meet-Up, with members from the three Southeast Asian stations: Kuala Lumpur, Malaysia; Hanoi, Vietnam; and Watukosek, Indonesia (discussed earlier). Total attendees for the two-hour session numbered 16, including Asian program managers, SHADOZ station PIs, data contacts, and field operators. **Figure 4** is a screenshot of the Meet-Up attendees.

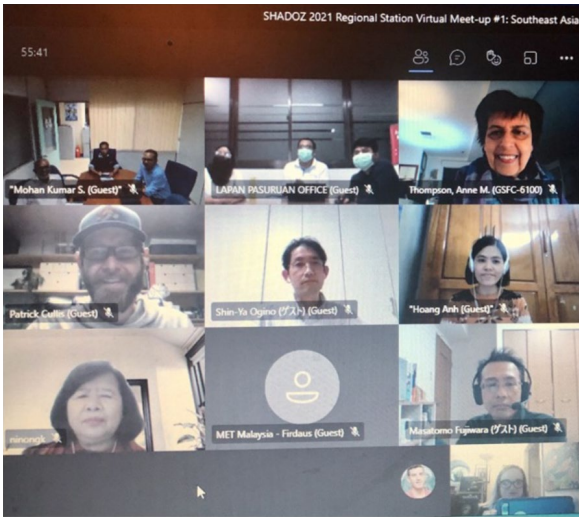

Figure 4. Screenshot from SHADOZ Regional Virtual Meet-Up #1, with attendees from the Southeast Asia stations. **Photo credit:** Debra Kollonige

The Meet-Up began with three overview presentations given by the GSFC SHADOZ team. **Anne Thompson** discussed Assessment of Standard Operating Procedures for OzoneSondes (ASOPOS) capacity building (see next section for a more detailed discussion of ASOPOS); **Ryan Stauffer** discussed ozonesonde data quality assurance; and **Debra Kollonige** described current requirements for SHADOZ data and metadata archiving.

Thompson outlined the history of ASOPOS activities and materials available (e.g., manuals, instructional videos) to assist with following ASOPOS-recommended ozonesonde best practices. Stauffer's and Kollonige's presentations detailed the steps from data delivery by the stations to the final upload of SHADOZ Version-06 format data to the NASA SHADOZ archive by the GSFC SHADOZ team, including the recording of accurate metadata and the application of data quality checks with satellite- or ground-based ozone measurements.

After the SHADOZ overview, three Southeast Asian station PIs gave a summary of recent activity at their location: **Ninong Komala** [LAPAN] for Watukosek; **Ahmad Fairudz Jamaluddin** [Malaysian Meteorological Department (MMD)] for Kuala Lumpur; and **Hoang Anh Nguyen Thi** [Vietnam Meteorological and Hydrological Administration] for Hanoi. These presentations included information about each station and their staff, current ozonesonde launch status and operations in 2021, future plans for the station (e.g., colocated measurements or upcoming campaigns), and plans for or interest in the upcoming QOS.

The Southeast Asian participants were enthusiastic about participating and it was most gratifying to see the operator team from Watukosek and the leaders from Malaysian Meteorological Department, new to SHADOZ since the 2019 retirement of the first station PI Maznorizan bt' Mohamad, who provided high-quality data to the archive for 21 years (1998–2019).

Regional Meet-Up #2: Equatorial Americas Stations

The second GSFC-hosted Regional Meet-Up, on April 22, included the NOAA/GML partners and members from five stations in the Equatorial Americas: Natal, Brazil; San Pedro, Costa Rica; Paramaribo, Suriname; San Cristóbal, Ecuador (Galapagos); and Quito, Ecuador. Total attendees for Meet-Up #2 numbered 15, including station PIs and sponsors from two universities (UCR, USFQ), the Instituto Nacional de Pesquisas Espaciais (INPE) [Brazilian National Institute for Space Research], the Meteorological Service of Suriname, and the Koninklijk Nederlands Meteorologisch Instituut (KNMI) [Royal Netherlands Meteorological Institute], which sponsors Paramaribo operations, and the Meteorological Service of Suriname. In addition to SHADOZ affiliation, the Natal and Paramaribo stations host other atmospheric-composition ground-based instruments as part of the Network for the Detection of Atmospheric Composition Change (NDACC).[8]

Figure 5 displays several of the meeting attendees for Meet-Up #2. The GSFC leads and the station managers shared presentations as they did for the first SHADOZ Meet-Up, with similar objectives. For example, **María Cazorla** described her Quito, Ecuador ozonesonde operations, and the restart plans for the San Cristóbal station (discussed earlier). **Ryan Stauffer** invited participants to an upcoming environmental webinar on NASA's networks and satellite data that will be sponsored by U.S. Embassy personnel in Costa Rica and Peru.

[8] To learn more about the history and achievements from the first 25 years of NDACC, see "The Network for the Detection of Atmospheric Composition Change: 25 Years Old and Going Strong " in the September–October 2016 issue of *The Earth Observer* [**Volume 28**, **Issue 5**, pp. 4–15—*go.nasa.gov/34VROZB*].

Figure 5. Screenshot from SHADOZ Regional Virtual Meet-Up #2, with attendees from the Equatorial Americas stations. **Photo credit:** Debra Kollonige

Figure 6. Screenshot from SHADOZ Regional Virtual Meet-Up #3, with attendees from the NOAA Pacific stations. **Photo credit:** Debra Kollonige

Because SHADOZ has a 12-year formal affiliation with the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW), the team looks forward to promoting the visibility of SHADOZ stations and station PIs in the WMO and similar communities as part of capacity building. As part of the GSFC-led Aerosol Robotic Network (AERONET),[9] a sun photometer has been installed at San Cristóbal; more are expected to be installed in the future at other SHADOZ stations along with Pandoras[10] from the NDACC-affiliated Pandonia Global Network (PGN).[11]

Regional Meet-Up #3: NOAA Pacific Stations

The third GSFC-hosted Regional Meet-up, held on May 19, included the NOAA/GML partners, station contacts, and field operators from NOAA's three stations in the Pacific: Hilo, HI; Suva, Fiji; and Pago Pago, American Samoa. **Figure 6** is a screenshot of some of the attendees; there were 13, including NASA Headquarters representation from **Henry Selkirk**, who is pictured in the middle of the top row in Figure 6. The GSFC team leads (**Anne Thompson**, **Ryan Stauffer**, and **Debra Kollonige**) presented similar updates as they did in the first two Meet-Ups. **Bryan Johnson** [NOAA/GML], pictured in the middle photo of **Figure 5**, delivered an overview presentation on NOAA's history of ozone measurements in the Pacific region. Individual stations shared pictures and updates on their operations including current launch statuses under COVID-19 pandemic restrictions.

[9] AERONET is a federation of Cimel sunphotometers joined in a large, ground-based network operated and hosted at NASA's Goddard Space Flight Center. To learn more, see *aeronet.gsfc.nasa.gov*.

[10] Pandora is a passive ultraviolet/visible grating spectrometer designed for Sun, sky, and lunar observations.

[11] The Pandonia Global Network is a partnership between NASA's Pandora Project and the European Space Agency's Pandonia project. Learn more at *www.pandonia-global-network.org*.

SHADOZ Team Participates in New Ozonesonde Standards Report

During the Regional Meet-Ups, the GSFC team discussed the importance of SHADOZ data quality and consistency for the user community, as well as the GSFC team's participation in the ASOPOS experts panel. Current activities for ASOPOS include the publication of a new ASOPOS 2.0 report,[12] an update to the WMO/GAW Report #201—long considered an indispensable handbook for ozonesonde standard operating procedures (SOPs) and data processing. The ASOPOS 2.0 Report contains the measurement principles of the ozonesonde instrument, the uncertainty chain of the parameters affecting the measurement, new recommendations for ozonesonde preparation steps, and revised data-processing protocols.

Newly added sections give expanded guidelines on data quality indicators and the rationale for enhanced metadata—a topic **Debra Kollonige** emphasized in her Meet-Up presentations. With adoption of the new SOPs, in which the SHADOZ community has played a leading role, the global ozonesonde community has the potential to achieve the 5% uncertainty level in tropospheric and stratospheric ozone requested by the satellite and trends communities.

Other Recent SHADOZ Meetings and Activity

On May 26 the GSFC team gave presentations at the 2021 NOAA/GML Virtual Global Monitoring Annual Conference (eGMAC). **Anne Thompson** reported on SHADOZ upper-troposphere, lowermost-stratosphere ozone trends; **Ryan Stauffer** presented an update on global ozonesonde data quality; and **Debra Kollonige** shared an overview of the ASOPOS 2.0 report.

[12] **Anne Thompson** is a co-editor for the report; **Ryan Stauffer** and **Debra Kollonige** are chapter authors.

continued on page 24

in the news

How Scientists Are Using the International Space Station to Study Earth's Climate

Erin Winick Anthony, NASA's Johnson Space Center, International Space Station Program Research Office, erin.winick@gmail.com

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

On Earth, we often look toward the sky longing to know what resides in the rest of the universe. Meanwhile, 250 miles (402 km) above our planet, the International Space Station (ISS) is looking back.

Above us, multiple Earth-observing instruments are mounted on the exterior of several of the station's modules, including a limb full of cameras, boxes, and tools that hangs off the edge of the station's Japanese Experiment Module (JEM)—see **Figure**. Earth-observing CubeSats regularly deploy from the station's airlock. Astronauts take photos of the planet from the orbiting lab's windows. This outpost even conducts Earth science experiments. All of this work provides insight into the climate of our home and how we might prepare for coming changes.

"If you don't have a good understanding of how things might change, you are in a very poor position to be able to handle it when they do," says **William Stefanov** [NASA's Johnson Space Center—*Manager of the Exploration Science Office*].

Weather reflects the conditions of the atmosphere over a short period of time, and climate is how the atmosphere "behaves" over decades, hundreds of years, or even geological time spans, says Stefanov.

That means the factors influencing our climate must be tracked over long periods. Its more than 20 years in orbit makes the space station a great place to collect these long-term data. The combined information creates a unique dataset that helps us inform climate decisions and potentially develop solutions to environmental issues.

Eyes on Earth

The space station affords a unique planetary perspective with an orbital path passing over 90% of the Earth's population. Its approximately 52° orbital inclination allows astronauts and Earth-observing payloads to see the Sun rise and set 16 times each day as the station orbits the Earth.

"That orbit allows the space station to pass over different spots of Earth at different times of day or night

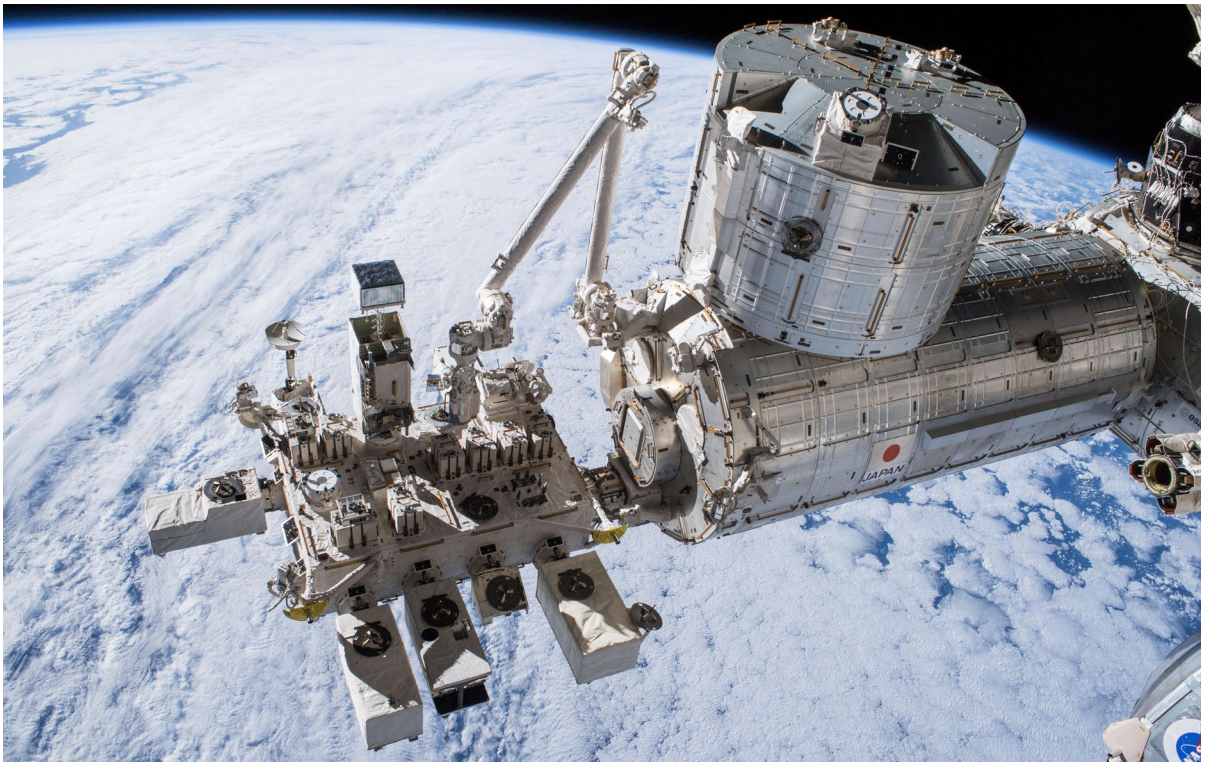

Figure. The suite of Earth-observing payloads attached to the Japanese Experiment Module is shown as the International Space Station orbits over the southern Pacific Ocean east of New Zealand. **Credit:** NASA

[called *diurnal variability*] and collect data. It is a fundamentally different dataset than most other remote sensing instruments collect on free-flying satellites," says Stefanov.

Mounted on the outside of the orbiting laboratory, international payloads include NASA's Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), Global Ecosystem Dynamics Investigation (GEDI) mission, Orbiting Carbon Observatory 3 (OCO-3), Total and Spectral Solar Irradiance Sensor (TSIS, also known as TSIS-1), and Hyperspectral Imager Suite (HISUI),[1] as well as the Deutsches Zentrum für Luft- und Raumfahrt (DLR)[2] Earth Sensing Imaging Spectrometer [DESIS]. Individually, all of these missions collect climate-related data from the unique vantage point of the ISS. In combination, they provide a unique set of measurements that could push the leading edge of environmental research.

For example, "The OCO-3 team wants to understand plants and their role in the carbon cycle," says **Annmarie Eldering** [NASA/Jet Propulsion Laboratory—*OCO-3 Project Scientist*]. "It turns out our space station neighbor ECOSTRESS is looking at how plants respond to stress. And then there is GEDI, which is looking at how much plant material is on the ground. Scientists who are thinking about plants and their role in the carbon cycle are super excited. We have heard lots of discussion about how we can use all the data together to better understand plants."

The OCO-3 sensor uses sunlight reflections through the atmosphere to measure variations in atmospheric carbon dioxide, observing changes of less than a single part per million.

"Most gases like ozone, carbon monoxide, or water vapor double or triple in atmospheric concentration when [the atmosphere is] polluted, so it is pretty easy to detect. But for carbon dioxide (CO_2), it is uniquely difficult to see the changes," says Eldering.

Measuring those small changes could be key to answering long-standing questions about atmospheric CO_2.

"Fortunately for us, the plants and ocean absorb about half of human-generated carbon dioxide emissions every year. But there are still mysteries around how they do that, why the amount is different each year, and how absorption is going to happen in the future," Eldering said. "Our data are meant to help answer those kinds of questions."

Carbon storage and removal also have been investigated both inside and outside the space station. Photobioreactor[3] examined whether microalgae could help close the carbon loop in life support systems. A Kuwait experiment called *E. coli* C[5] studied the effect of microgravity on E. coli bacteria that were modified to consume CO_2 as a food source[4]. Images taken by former space station payload Hyperspectral Imager for the Coastal Ocean (HICO) helped develop an algorithm to detect harmful algal blooms. Algae play a major role in the global carbon cycle, and blooms are responsible for much of the ocean's carbon absorption.

With other devices such as the Stratospheric Aerosol and Gas Experiment III-ISS (SAGE III-ISS) tracking ozone, Lightning Imaging Sensor (ISS-LIS) and Atmosphere-Space Interactions Monitor (ASIM) monitoring lightning, and TSIS tracking the total energy flowing to Earth from the Sun, station experiments advance numerous climate records and models.

"Climate change presents what is perhaps humankind's greatest environmental challenge," says **Peter Pilewskie** [University of Colorado—*Former TSIS Principal Investigator*]. "Monitoring the energy that flows into, within, and out of the system underpins our ability to understand how the climate system works, recognize that it is changing, and identify those mechanisms responsible for climate change."

The ISS offers a standardized, capable platform to house Earth-observation experiments such as TSIS. With the ISS the size of a football field and equipped with numerous attachment points, plenty of data capacity, and a large power supply (slated to become even larger with the upcoming installation of the Roll-Out Solar Array (iROSA) solar panels), the ISS can host a wide variety of instruments simultaneously.

The availability of these resources made the ISS a great last-minute option for the TSIS team to quickly get their payload into orbit. After some delays, the team was facing potential failure of previous tracking instruments before TSIS could launch.

"It started to get pretty dire, because accuracy of the climate record is maintained at its highest possible level when the data record is continuous," says Pilewskie. "Because of [the] space station, we were able to continue this record."

After researchers learn the basics of creating a payload for the space station, they can apply that knowledge to future station projects. Pilewskie is already working on his next experiment, Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder, scheduled to launch in the next few years.

[1] HISUI was developed by the Japanese Ministry of Economy, Trade, and Industry, or METI.
[2] DLR is the German Space Agency.

[3] To learn more about Photobioreactor, visit *go.nasa.gov/2QviMUo*.
[4] To learn more about this experiment, visit *go.nasa.gov/2RoPNC0*.

"The value that we gained from operating an instrument on station that needed to point very precisely cannot be understated," says Pilewskie. "We have to do the same thing with CLARREO Pathfinder, so we are using some of the same motors that we use to drive the TSIS instruments."

CLARREO plans to study Earth's climate by taking measurements of sunlight reflected by Earth and the Moon with five to ten times lower uncertainty than measurements from existing sensors.

The Human Element

It is not only sensors monitoring our planet from above. People do as well.

The windows of the space station provide an opportunity for astronaut photography and manual collection of climate data. Astronauts have taken more than 4 million images of Earth from space (over 3.5 million from the space station), contributing to one of the longest running records of how Earth has changed over time. Crew Earth Observations[5] currently support a number of urban night lighting studies, glacier and volcano monitoring, and studies of atmospheric processes affected by powerful volcanic eruptions. The images also are used in ecological investigations, including a collaborative project called the Avian Migration Aerial Surface Space (AMASS) project, which tracked bird migration routes and the effects of changes occurring along those routes.[6]

These images also support disaster relief efforts for events such as hurricanes and wildfires. After receiving notification a natural disaster has occurred, scientists on the ground determine whether the crew will be able to see that area while orbiting overhead. If so, the crew captures and sends imagery back to Earth. The pictures are then georeferenced for use by hazard teams on the ground. Astronaut imagery has been useful for wildfire events, for example, showing responders where the smoke plume is going.

Deploying Beyond Station

The ISS extends its climate science impact by deploying CubeSats into low-Earth orbit. These shoe box-sized devices, which contain technology demonstrations or test new types of climate science, launch to the station along with thousands of pounds of other research investigations and cargo supplies. Astronauts unload and prep them on the station and then deploy them out of the station airlock.

"A lot of our smaller satellites, e.g., CubeSats, are getting rides because of the space station. That has been a great resource for small programs, especially universities or NASA centers trying to get some small projects going. CubeSats might be their first stepping stone to larger things," says **Tom Woods** [University of Colorado Boulder, Laboratory for Atmospheric and Space Physics—*TSIS* and *NanoRacks–MinXSS Principal Investigator*]. "Space station offers a lot of opportunities to get these smaller things into space."

More than 250 CubeSats have been released from station, including many climate centric payloads.[7] For example:

- The student-designed NanoRacks–MinXSS[8] CubeSat targeted a better understanding of solar X-ray energy and how it affects the layers of Earth's upper atmosphere.
- The DIWATA-1[9] satellite provides remote sensing information to the Philippines by observing meteorological disasters such as typhoons and localized heavy rains.
- The HARP[10] CubeSat helps us better understand how clouds and aerosols impact weather, climate, and air quality.

As Earth's climate changes, the ISS will be watching from above, helping provide unique insights needed to keep our planet safe. ■

[5] To learn more, visit *go.nasa.gov/2KLFAaq*.
[6] To learn more, visit *go.nasa.gov/3b6UXcQ*.

[7] To learn more about how CubeSats are being used for NASA Earth Science, see "CubeSats and Their Roles in NASA's Earth Science Investigations" in the November–December 2020 issue of *The Earth Observer* [**Volume 32**, **Issue 6**, pp. 5–17—*go.nasa.gov/3tmwAig*].
[8] The University of Colorado Laboratory for Atmospheric Space Physics (LASP) developed the NanoRacks–Miniature X-ray Solar Spectrometer CubeSat (NanoRacks–MinXSS).
[9] The JEM Small Satellite Orbital Deployer for Microsatellite (J-SSOD–M1) mission deploys the 50 kg (~110 lb) CubeSat DIWATA-1, the first satellite from the Philippines, from the Japanese Kibo module.
[10] The HyperAngular Rainbow Polarimeter (HARP) CubeSat demonstrates a technology for measuring the properties and size of aerosols, cloud droplets, and cloud ice particles and their interactions.

Dust Storms and Valley Fever in the American West

Lia Poteet, NASA Headquarters, lia.n.poteet@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*.

Valley fever is a dangerous threat to human health—and cases are on the rise in the arid southwestern U.S., as wind from increasing dust storms can transport the fungal spores that cause the disease. Valley Fever is caused by the *Coccidioides* fungus, which grows in dirt and fields and can cause fever, rash, and coughing. Using NASA research and satellite data, the World Meteorological Organization is refining its Sand and Dust Storm Warning Advisory and Assessment System to help forecast where dust risk is greatest.

Daniel Tong [George Mason University], one of the first scientists to discover the link between dust storms and Valley fever, leads a NASA-funded team that is—for the first time—tracking the airborne spread of Valley fever across the U.S.

According to the U.S. Centers for Disease Control (CDC) there are about 15,000 cases of Valley Fever in the U.S. each year, and approximately 200 deaths. Funded by NASA's Earth Science Division, Tong's team is helping track disease risk for epidemiologists, health care providers, and public health decision makers.

"Our paper was the first one to reveal the positive relationship between dust storms and Valley fever," said Tong. "So now we're asking the question: How can we detect that dust in the air?"

Tong and his team are combining NASA satellite data and high-end computer modeling with homemade dust catchers made of pans for baking cakes and marbles. Previously, on-site dust sampling was only available through expensive monitors, such as the ones used by the CDC. When they needed more sensors to cover exposure across a wide area, the team realized they could develop their own methods to capture the airborne dirt for a fraction of the cost.

One such method involves filling a store-bought baking pan—the kind used to bake a homemade birthday cake—with marbles. As wind passes over the uneven surface of the marbles, the interrupted flow causes the air to release the dust and spores it is carrying. As the sediment falls through the layers of marbles to the bottom of the pan, it is protected from being picked up by wind again and stored safely until the scientists come to collect several weeks' worth of samples at a time—see **Figure 1**.

The dust samples are sent to George Mason University (GMU), with research support from GMU's Institute for a Sustainable Earth. It is one of the few institutes in the country that can conduct DNA sequencing to identify the *Coccidioides* fungus in dust.

Figure 1. A cake pan filled with marbles is one of the sampling tools designed and built by Tong's team. This is installed at a U.S. Department of Agriculture (USDA) facility. **Credit:** NASA/Daniel Tong

While the team gathers data on the ground, NASA satellites are hard at work getting the view from above. Tong's team uses data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments onboard Terra and Aqua. These data show likely habitats for this fungus because they monitor vegetation and soil moisture, revealing where conditions are ripe for fungal growth and spread of arid dust.

Currently the team is using that information on local plant growth as a measure to identify likely dust source areas. They're working to shed more light onto the physical and biological processes that impact the fungus's spread, which Tong says is important information for scientists and health officials to have. But tracking dust storms' movement through air is easier with the help of NASA's Earth-observing instruments—e.g., MODIS—which can also detect the light reflected from the tiny particles as they're swept across the country. These true color dust observations from MODIS even helped to "train" models developed by

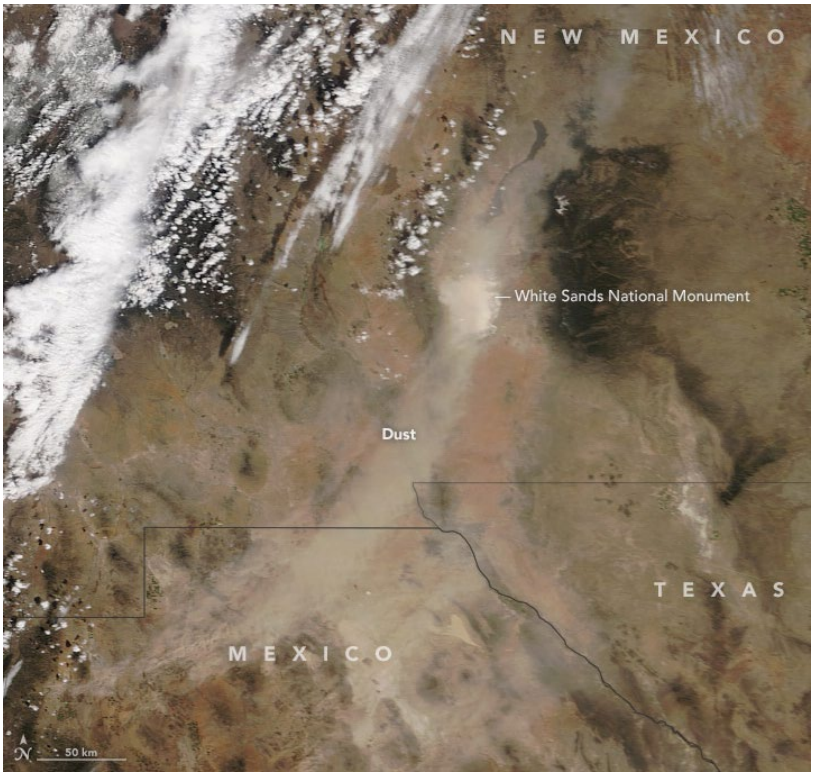

Figure 2. The MODIS instrument on NASA's Terra satellite captured this image of thick plumes of dust stretching from northern Mexico into Texas and New Mexico on March 31, 2017. The Sand and Dust Storm Warning Advisory and Assessment System from the World Meteorological Organization now has a Pan-American node that is incorporating NASA Earth observations like these. **Credit:** NASA Land, Atmosphere Near-real-time Capability for EOS (LANCE)/Jeff Schmaltz

the team to assess how the frequency of dust storms is changing—see **Figure 2**.

"We have a satellite-trained algorithm developed with support from NASA to look at the long-term data from dust storms," Tong said. "We were surprised to see dust storms in the American southwest increasing 10 times faster than the global level over the last few decades, causing increasing risk to local communities."

Through the 1930s, dust storms in the Western U.S. infamously destroyed farms and forced families to abandon homes. "Climate change is bringing that threat back," warned Tong. "Global climate models predict the west and southwest will become drier and drier, meaning we could have dust bowls—plural."

Tong says that with more dust storms there will be more instances of Valley fever. For reasons that are not well understood, some people are more susceptible to the effects of Valley fever than others. Only 40% of people infected have symptoms, and 8% of those go to the hospital. "There's no vaccine—the fungus lives with you for the rest of your life," said Tong. "Those infected are paying about $50,000 per hospital visit (in the U.S.), and a quarter of those people have to go 10 times or more."

Tong's team collaborates with the CDC as well as state and local public health officials in New Mexico, California, and Arizona. As the threat of Valley fever rises, local health officials hope Tong's research will continue to uncover ways to track its dangerous spread.

"Now that we're beginning to understand the risk to public health, the scientific community is really coming together," said Tong. "They're very curious, going out of their own way to help. I feel very lucky to have this support."

The team is working with local agencies to place the sensors in areas with frequent dust storms to see where Valley fever might be affecting the most people. Local health agencies like the Pinal County Public Health Department in Arizona and community physicians are already incorporating these data to inform health and safety measures like increased testing and public education.

Next, the National Weather Service (NWS) and the Pan American Health Organization (PAHO) are working to incorporate this research to improve dust forecasting for everything from air quality to visibility for transportation. "We aim to bring longevity to this project," Tong said, "so people can continue using this research to protect public health in the future.

For communities in the southwest, that means informing public health decisions in the face of increasing dust storms in the future. ■

In a First, Scientists Map Particle-Laden Rivers in the Sky

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

Windy regions high in the atmosphere can transport pollutants like dust or soot thousands of miles around the world and disrupt everyday life for thousands of people.

Last summer, "Godzilla" came for the Caribbean and the U.S. Gulf Coast. This particular monster wasn't of the sci-fi variety, but, rather, a massive dust storm kicked up by winds from the Sahara Desert and carried across the Atlantic Ocean toward the continental U.S. The dust storm was an extreme example of a phenomenon that happens regularly: the global transport of dust, soot, and other airborne particles, collectively known as *aerosols*, by jets of winds in the atmosphere. The result is the formation of what are called *aerosol atmospheric rivers*—see **Figure**.

Gaining a better understanding of how these particles are transported around the globe is important because certain aerosols can nourish rainforest soil, help or hinder cloud formation, reduce visibility, or affect air quality—which can impact human health. But studies of aerosol transport have tended to focus on single events in a particular part of the world. There wasn't really a way of looking at them in a holistic, global way.

In a first, a recent study published in the journal *Geophysical Research Letters*[1] does just that. Five types of aerosols are of particular interest to researchers: dust, two kinds of carbon particles (soot and organic carbon), sulfate (emitted during events like volcanic eruptions or the burning of fossil fuels), and sea salt. The study authors identified where aerosol atmospheric rivers tend to occur and how often extreme events, similar to the Godzilla dust storm, happen each year. To do this, they took a computer program they previously developed to detect atmospheric rivers around the world that move water vapor and produce precipitation, and they modified it to detect aerosol atmospheric rivers instead.

The shift from using atmospheric rivers to study the movement of water vapor to using them to study aerosol transport was something of a revelation because researchers only started to use the global detection framework of atmospheric rivers to look at the movement of extreme amounts of water vapor about six years ago. The concept of atmospheric rivers is only about 20 years old.

"It took scientists time to recognize and leverage atmospheric rivers as a concept," said **Duane Waliser** [NASA/Jet Propulsion Laboratory], one of the study's co-authors. And it wasn't until Waliser was speaking to his colleague, **Arlindo da Silva** [NASA's Goddard Space Flight Center], about the atmospheric river concept that a light went on for both of the researchers. "'We should take our algorithm and apply it to your aerosol dataset,'" Waliser said.

[1] To read the study, visit *agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL091827*.

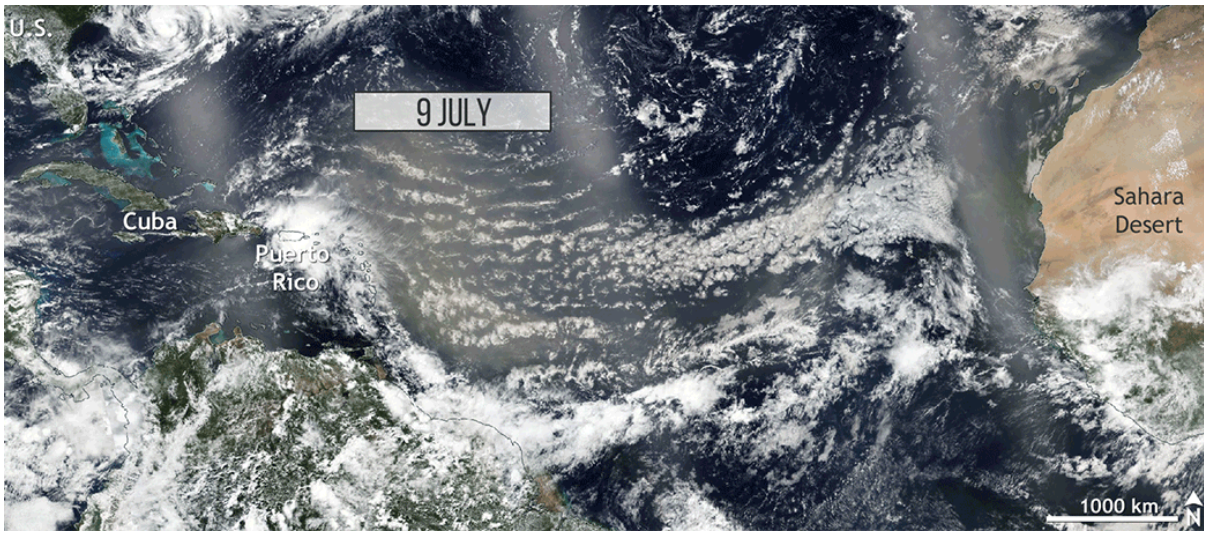

Figure. This image, created using data from the Suomi National Polar-orbiting Partnership satellite, shows an atmospheric river carrying dust particles across the North Atlantic Ocean from Africa to the Caribbean on July 9, 2018. **Credit:** NASA Worldview

Location, Location, Location

After modifying the atmospheric river algorithm for aerosol atmospheric rivers, the study's authors applied it to a state-of-the-art reconstruction of Earth's atmosphere called the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) from NASA's Global Modeling and Assimilation Office. It incorporates datasets from satellites, airborne instruments, and sensors on the ground from 1980 to the present to produce a representation of the structure of Earth's atmosphere every six hours.

MERRA-2 enabled the researchers to look back in time to analyze the location and frequency of aerosol atmospheric rivers around the world from 1997 to 2014. The study authors found that regions including the Sahara, Patagonia, Asian deserts, and Namibia are big sources of dust aerosol atmospheric rivers, while areas like the eastern U.S., the southern Amazon and Africa, and northern India tend to produce ones dominated by soot resulting from wildfires and the burning of fossil fuels.

The analysis also showed these atmospheric rivers tend to move large amounts of aerosols in a limited number of extreme events instead of in a steady stream throughout the year.

"We were astonished to find that a few major events a year can transport between 40% to 100% of the aerosols moved by the atmosphere," said **Sudip Chakraborty** [JPL], a study co-author.

Now that scientists have a way of looking at aerosol atmospheric rivers globally, the framework gives them a way to study how these particle-laden rivers in the sky affect Earth's climate. This includes how aerosols interact with clouds to potentially supercharge storms, how they trap or reflect heat in the atmosphere, and whether phenomena like El Niño and La Niña affect atmospheric aerosol river pathways and frequency.

The new approach also gives researchers insight into how aerosol atmospheric rivers could affect communities around the world, through their impacts on air quality and visibility and their ability to move plant pathogens that can affect crops. "When you realize a lot of the transport is happening in just a few big events, then you know to focus on those big events," said da Silva. ■

NASA's SHADOZ Team Makes Advances in 2021 Despite the Pandemic

continued from page 17

In addition, in advance of the submission deadline for the upcoming QOS, the GSFC team worked with SHADOZ station PIs in preparing abstracts that highlight their respective stations' ozonesonde measurements.

Conclusion

A goal for the NASA GSFC SHADOZ team in 2021 was to improve communication with its stations and foster a sense of community within the regional stations for collaborative research in the future. During the first half of 2021, the GSFC team organized and hosted three Regional Station Virtual Meet-Ups with the Southeast Asia, Equatorial Americas, and NOAA Pacific stations. With the restart of two formerly inactive SHADOZ stations in 2021, the success of the GSFC team's efforts exemplifies their dedication to continuing long-standing relations with their international partners to deliver quality, long-term data records to the user community.

These achievements will continue in the future under a new generation of leadership as **Anne Thompson** transitioned in June to emeritus status at GSFC after a 26-year career as a NASA employee. **Ryan Stauffer**, who started working with ozonesondes in 2010 when then-Professor Thompson was his doctoral advisor at Penn State University, will assume the PI role. Stauffer has worked at GSFC since 2016, part of the time as a Universities Space Research Association NASA Postdoctoral Program Fellow and partly as an employee of the University of Maryland's Earth System Science Interdisciplinary Center (ESSIC). **Debra Kollonige**, who also began working with Thompson at Penn State in 2012, came to GSFC in 2013 also to work with ESSIC. She will continue as SHADOZ Archiver and Webmaster, a position she has held since 2019 through a contract with Science Systems and Applications, Inc. (SSAI).

Stay tuned for more updates from the GSFC team as they continue their commitment to data quality assurance efforts for SHADOZ and the global ozonesonde network. As field work resumes after the COVID-19 pandemic interruption, SHADOZ stations look forward to more interaction with international partners, who are eager to collaborate with researchers in NASA-sponsored aircraft and ground-based campaigns. ■

NASA Earth Science in the News

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

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

NASA Developed a New Method of Predicting Volcanic Eruptions Using Satellites, April 14, *slashgear.com*. It's notoriously difficult to predict volcanic eruptions. There are often signs that a volcano is likely to erupt in the future, including an increase in seismic activity, changes in gas emissions, and sudden ground deformation, but accurately predicting eruptions is hard. NASA scientists at the Jet Propulsion Laboratory and researchers from the University of Alaska, Fairbanks, have developed a new method using satellite data that brings the possibility of predicting volcanic eruptions months or even years before they happen. The new methodology uses a subtle but significant increase in heat emissions over large areas of the volcano in the years leading to eruption. Researchers say it allows them to see the volcano has reawakened, often well before any other signs of volcanoes becoming active. During the study, the team analyzed over 16 years of radiant heat data from the Moderate Resolution Imaging Spectroradiometers (MODIS) instruments aboard the NASA Terra and Aqua satellites. The data covered several types of volcanoes that have erupted in the past two decades. NASA found that despite differences in the volcanoes, the results were uniform. In all instances, in the years leading up to the eruption, the radiant surface temperature over much of the volcano increased by about 1 °C (1.8 °F) from its normal state. The temperature decreased after each eruption. NASA stresses that it's not talking about hotspots. Rather, the warming of large areas of the volcano is believed to be related to fundamental processes happening in the volcano's depths. Scientists believe the heat increase could result from the interaction between magma reservoirs and hydrothermal systems. The scientists on the project are clear that other processes may also be at play because knowledge about volcanoes is limited. Researchers plan to test the new method on more volcanoes and continue to fine tune the system's precision.

Climate Change Expected to Decrease Saharan Dust Outbreaks to a 20,000-Year Low, April 22, *weather.com*. Saharan dust outbreaks over the Atlantic are predicted to decrease because of ocean warming from climate change over the next century. Bouts of dusty air of varying concentrations track thousands of miles from Africa to as far west as the Caribbean Sea, Florida and the Gulf of Mexico each year. These dust plumes are expected to decrease to a 20,000-year low over the next century, according to new research from NASA.[1] Known as the Saharan Air Layer (SAL), these dry dust plumes commonly form from late spring through early fall and move into the tropical Atlantic Ocean every three to five days. The trade winds responsible for sending this dust westward through the Atlantic could decrease in the future climate, which means less dust would be picked up from Africa. "Sea surface temperatures directly impact wind speeds, so when the northern Atlantic warms relative to the south Atlantic, the trade winds that blow the dust from east to west become weaker. As a result, the slower winds pick up and transport less dust from the Sahara," NASA said. Another factor that could curtail the transport of dust is the weakened trade winds opening the door for a band of rain or thunderstorms in the tropics to migrate farther into parts of the Sahara. That could make the dust somewhat wetter and cause it to be less susceptible to being lofted into the air. Upwards of 60 million tons of African dust are sent into the atmosphere annually in the current climate, according to NASA. There is expected to be a 30% decrease in the amount of dust picked up from Africa in the next 20 to 50 years, based on model data the NASA research team used from the Coupled Model Intercomparison Project 5 (CMIP5). Dust activity is predicted to continue declining beyond that time. Saharan dust has both positive and negative impacts in areas where it is deposited. Nutrients in the dust can help feed marine life in the ocean and plant life on land.

On a Changing Planet, NASA Goes Green, April 22, *climatechange.ie*. NASA is responsible for collecting much of the data that people use to explain humanity's environmental impact on Earth, from documenting climate change and its impacts on ice, sea level, and weather patterns, to monitoring the health of forests and the movement of fresh water. But NASA doesn't just report the data. It also acts on it. NASA facilities across the U.S. are each working toward becoming more sustainable workplaces.

[1] To learn more, visit *go.nasa.gov/3fwfo46*.

Across 47 million ft^2 (4.3 million m^2) and 5,000 buildings, NASA works to fulfill its mission of revealing the unknown while lessening the agency's demand on the planet's resources. "NASA is a scientific leader, globally and nationally," said **Denise Thaller** [NASA Headquarters—*Director of NASA's Environmental Management Division*]. "We embody that focus on the stewardship of the Earth, so we need to lead by example. We need to evaluate everything we do and make sure we're reducing our impacts on the Earth while we study the Earth."

In March 2021, sandhill cranes visit the Vehicle Assembly Building at NASA's Kennedy Space Center in Florida. Kennedy shares space with the Merritt Island National Wildlife Refuge, which is home to thousands of species. **Image credit:** NASA/Ben Smegelsky

***On Earth Day, NASA Reminds Us How We're All Connected**, April 22, *space.com*. This Earth Day (April 22), NASA scientists, astronauts and even Grammy-nominated pop sensation Shawn Mendes teamed up to remind us how planet Earth connects us all. Earth Day can serve as a powerful reminder of just how incredible and precious this "beautiful rock we call home" really is, NASA Astronaut **Mark Vande Hei** said on a call with other members of the crew onboard the International Space Station and Mendes. The musician shared questions about Earth and space submitted by kids around the world for the astronauts—who included NASA's **Shannon Walker**, **Mike Hopkins**, **Victor Glover**, and **Vande Hei** and Japanese astronaut **Soichi Noguchi**—to answer. "Seeing Earth from here is quite spectacular," Glover said to Mendes, "and it also makes me realize how important it is that we do all that we can to take care of it." Glover and the rest of the crew went on to answer kids' Earth Day questions, which ranged from "How can students contribute to environmental protection?" to "Are there unicorns in space?" Though NASA might be most known for things like the Apollo moon landings, the space shuttle missions, and discoveries in fields like astrophysics, the space agency is also a major player when it comes to Earth sciences and climate change. This is no big surprise as Earth is, after all, a planet in space. And, as **Karen St. Germain** [NASA Headquarters—*Director of the Earth Science Division*] told *space.com* in an interview on Earth Day, space actually helps scientists to understand Earth much better. "When we want to understand what's happening around us, we naturally go up," St. Germain said. "We'll go to the top floor of a building and look, we'll climb a hill and look. [And] well, space is the ultimate high ground. It's a great vantage point for looking back at our Earth, our home planet, and really understanding how it works."

Entire Lehigh Valley Now Classified as Abnormally Dry, but a New Tool from NASA Could Help Area Farmers, May 11, *mcall.com* (*The Morning Call* newspaper for Allentown, PA and Lehigh Valley). The entirety of the Lehigh Valley is now subject to "abnormally dry" conditions, a situation that has been unfolding since March, the U.S. Drought Monitor shows. The latest data show 54% of Pennsylvania falls under the Drought Monitor's abnormally dry categorization, a 14% increase week-to-week, and a 22% increase from the start of the calendar year. Farmers, researchers and many others now have access to high-resolution NASA data on soil moisture, thanks to a tool developed by the U.S. Department of Agriculture's (USDA's) National Agricultural Statistics Service in collaboration with NASA and George Mason University.[2] The data are deemed critical for professionals in the agriculture and natural resources sectors who use soil moisture to plan crop planting, forecast yields, and track droughts or floods. "Soil moisture is a very important piece of information for agricultural yield and productivity," said **Rajat Bindlish** [NASA's Goddard Space Flight Center]. "This will provide a means of using NASA remote sensing data to guide predictions of moisture conditions and water availability. Information on the field conditions is important for agricultural operations."

*See story in this issue to learn more about this topic. ■

[2] To learn more, visit *go.nasa.gov/3yna7Eu*.

Earth Science Meeting and Workshop Calendar

NASA Community

NASA Community events will be updated in our next issue.

Global Science Community

August 1–6, 2021
AOGS 18th Annual Meeting, *virtual*
and online everywhere.
www.asiaoceania.org/aogs2021/public.asp?page=home.html

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

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

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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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