The Editor's Corner
**Steve Platnick**
EOS Senior Project Scientist

The Biden Administration has taken an important step in pursuit of its climate science objectives for NASA, creating the new position of senior climate advisor. **Gavin Schmidt** [NASA's Goddard Institute for Space Studies (GISS)] has been appointed to serve in the role in an acting capacity until a permanent appointment is made. Schmidt is eminently qualified for the position having served as Director of GISS since 2014 with a research career focused on climate modeling, paleoclimate, and climate change detection and attribution. In his role as climate advisor, Schmidt will "advocate for NASA climate investments in the context of broader government agendas and work closely with the White House Office of Science and Technology Policy and the Office of Management and Budget."[1] My congratulations to Schmidt for this well-deserved inaugural appointment.

This issue's feature article focuses on NASA's DEVELOP National Program, which is part of the Earth Science Division's Applied Sciences Program Capacity Building program. DEVELOP strives to bridge the gap between science and society by demonstrating the use of NASA Earth Science data in environmental decision making. The program facilitates 10-week experiential learning opportunities, where participants work directly with partner organizations to build skills and knowledge around geospatial tools and Earth observation data. Traditionally DEVELOP conducts three project terms per year (Spring, Summer, Fall), with participant teams working from one of the program's 11 host locations across the country (see Figure 1 on page 4 of this issue) on feasibility projects addressing environmental and public policy issues. However, COVID-19 forced an abrupt closure to the host sites in March 2020 and necessitated an *ad hoc* virtual learning environment to enable students to finish out the Spring 2020 term.

The Summer 2020 DEVELOP term (which began in June 2020) was conducted exclusively online, with 65 participants. From learning and transitioning to new virtual tools and participating in remote technical training, to collaborating and networking with partner organizations remotely, young professionals worked on applied science projects that addressed a variety of environmental issues. The term culminated with the opportunity for participants to present their work at the virtual Applied Sciences Week event to an audience of over 500 attendees.

[1] To learn more about Schmidt's specific responsibilities as senior climate advisor, visit *go.nasa.gov/2YEfYo6*.
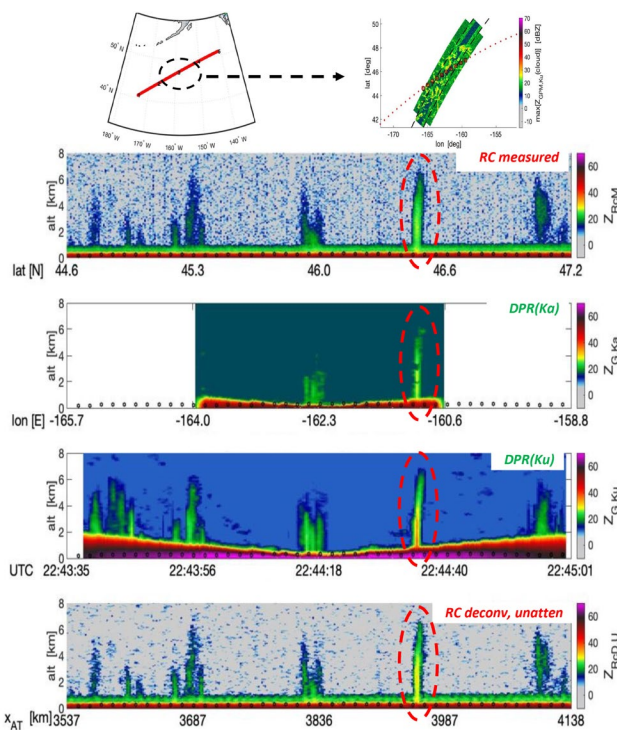
Shown here is an example of collocated RainCube and GPM radar observations of precipitation obtained on December 12, 2018, near the Aleutian Islands in the North Pacific Ocean. The RainCube ground track [*top row, left*] and GPM Dual Polarization Radar (DPR) swath [*top row, right*] are shown in the first row, along with RainCube Ka band observations [*second row*], DPR Ka-band section along the RainCube path [*third row*], DPR Ku-band section along the RainCube path [*fourth row*], and RainCube measurements sharpened as described in the article referenced in the Image credit [*bottom row*]. **Image credit:** From an article by Ousmane Sy et al. that has been accepted to appear in *IEEE Transactions on Geoscience and Remote Sensing 2021*.

editor's corner

In This Issue

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

Turn to page 4 of this issue to learn more about the DEVELOP Summer 2020 virtual learning experience. DEVELOP has since conducted two more online terms, with the most recent (Spring 2021) concluding on April 3, 2021.

The GPM Core Observatory celebrated the seventh anniversary of its launch on February 27, 2021. The spacecraft and its two instruments—the GPM Microwave Imager (GMI) and Dual Frequency Precipitation Radar (DPR)—continue to perform well. The data that GMI and DPR return are used to unify precipitation measurements made by an international network of partner satellites to quantify when, where, and how much it rains or snows around the world.

As with any mission, the GPM algorithms have been refined throughout the course of the mission to improve the accuracy of the data collected. The GPM science team is currently working to deliver Version 07 (V07) of the GPM algorithms to the Precipitation Processing System (PPS) at GSFC. This work includes improved intercalibration of constellation microwave sensors, better approaches for retrieving precipitation over orography and at higher latitudes, and improved techniques for merging individual sensor precipitation measurements into the near-global Integrated Multisatellite Retrievals for GPM (IMERG) multi-satellite product.

The V07 release will include the first public release of dual-frequency observations across the larger K_u-band radar swath. Previously, such retrievals were possible only over the much narrower Ka-band radar swath. In May 2018, this radar was reconfigured to allow it to scan over the full Ku-band swath. Level-1 sensor products and Level-2 orbital retrieval products are expected to be reprocessed—for both GPM and TRMM—by Fall 2021, followed by the IMERG and latent heating products.

GPM data are used for a wide variety of applications. For example, the GPM Applications Team, in collaboration with the Aerosols, Clouds, Convection and Precipitation (ACCP)[2] Study Applications Impact Team organized an online workshop held in November 2020 to address how NASA data might enable support of operations within the transportation and logistical sectors. This event consisted of science presentations, panel discussions, and breakout rooms spread over three half-day sessions, as well as a virtual training session. Please turn to page 12 to learn more about this meeting.

While the 2017 Decadal Survey envisioned the continued need for substantially sized satellites (e.g., Designated Observable mission concepts such as ACCP), NASA continues to make significant investment and progress in demonstrating the technical and scientific capability of CubeSats.[3]

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[2] A NASA ACCP study team was tasked with exploring ACCP observing system architectures to address both science and enabled applications.

[3] The history of NASA CubeSats is in "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*].

JPL's RainCube[4] mission, which completed its 2.5-year extended mission on December 24, 2020. RainCube (a 6U CubeSat) launched to the International Space Station in May 2018 (as part of the CSLI ELaNa 23 mission) and deployed into Low Earth Orbit. The goal of the initial three-month technology demonstration mission and the extended mission was to enable Ka-band precipitation profiling radars on a low-cost, quick-turnaround platform. The mission included two new technologies developed by JPL: a miniaturized Ka-band atmospheric radar (for comparison, DPR on GPM is a larger Ka- and Ku-band radar) and an ultra-compact deployable Ka-band antenna.

Throughout the mission, RainCube provided high quality images of precipitating structures ranging from hurricanes to winter storms. In many cases, these storms were observed coincidentally with TEMPEST-D, the sister CubeSat technology demonstration mission to enable multi-frequency millimeter wave radiometer technologies on a low-cost, short development schedule. Also, in some select cases, the storms were measured coincidently by RainCube and GPM, which served as excellent reference for validation and calibration of RainCube products—e.g., see front cover graphic.

RainCube also completed the first ever in-space demonstration of techniques essential to enable a new generation of cloud and precipitation radars, which has already helped shape the vision for the next major NASA mission concept targeting clouds and precipitation (ACCP, discussed above) and provides valuable insight for mission concepts under study by NASA, other agencies, and commercial ventures.[5] Congratulations to Principal Investigator (PI) **Eva Pera** [JPL] and the entire RainCube team.

In this issue, we also report on a virtual community forum held during the fall of 2020 that covered multiple aspects of crop-residue and biomass burning and their impacts on regional air quality in the Indian Sub-Continent. Organized by **Pawan Gupta** [MSFC], the forum featured a series of weekly meetings with different subject matter experts presenting on selected topics—see list on pages 18–19 of this issue. After each presentation there was an opportunity for questions and answers, as well as open discussions. Some of the sessions also provided training on how to use available Earth observations and tools to analyze fire, smoke, and air quality data. The participants in this forum represented a broad spectrum of the Earth science and air quality community, including researchers and students conducting research on air quality, fires, and climate; advocacy groups; media personnel; and international

organizations. Please turn to page 17 to learn more about the forum.

In other news, despite the pandemic, NASA Earth Science field campaigns continue. April 2, 2021 marked the end of the winter 2021 Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment (ACTIVATE) flight campaign—the third of six planned flight campaigns and the second successful campaign since COVID-19 disruptions. ACTIVATE, led by PI **Armin Sorooshian** [University of Arizona], is studying the class of aerosol particles that serve as nucleation sites for water vapor to condense and grow to droplet sizes in warm boundary layer clouds, as well as the cloud processes that remove these aerosols from the atmosphere. The role of aerosol cloud condensation nuclei on cloud radiation, water content, and lifecycle continues to be an observational and modeling challenge. Using two aircraft based out of NASA LaRC (HU-25 Falcon and King Air), ACTIVATE has been able to sample a variety of aerosol types and meteorological conditions that affect marine boundary layer clouds. Congratulations to the ACTIVATE team on completing their third campaign, once again under difficult COVID-19 circumstances. Learn more about ACTIVATE at *go.nasa.gov/3df4uQh*.

In other campaign news, NASA is conducting a multi-year SnowEx program to test and develop remote sensing technologies to monitor snow characteristics from space—snow water equivalent (SWE) in particular. Following campaigns in 2017 and 2020, the 2021 campaign is ongoing through late-April in the Western U.S. SnowEx 2021 instruments include airborne L-band interferometric synthetic aperture radar (InSAR), lidar, and hyperspectral imaging systems to measure the albedo of the snow surface, as well as coordinated *in situ* ground measurements that can be compared with the airborne data.

Like many other campaign activities, SnowEx 2021 had to adjust to the realities imposed by the pandemic. Typically, each SnowEx campaign includes a two- or three-week intensive data collection period focused on one site. Due to COVID, the 2021 campaign did not include the intensive collection effort, and instead relying on teams based at sites across the Western U.S. to collect snow data weekly from January through April. Only local teams within a two-hour drive of their home base collected ground observations. To learn more about SnowEx 2021, see the News story on page 24. ∎

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[4] JPL managed RainCube, while Tyvak Nano-Satellite Systems provided spacecraft and mission operations.
[5] To learn more about RainCube and the end of its mission, see *go.nasa.gov/3jx2sMS*.

feature article

NASA's DEVELOP Program Engages Summer Participants in Virtual Activities

Amanda Clayton, NASA's Langley Research Center/Science Systems and Applications, Inc., amanda.l.clayton@nasa.gov

The DEVELOP model uses a dual capacity-building approach that engages young professionals to work on feasibility projects under the guidance of science advisors and mentors at the program's 11 host locations.

Introduction

NASA's DEVELOP[1] National Program bridges the gap between science and society by demonstrating how NASA Earth Science data can be applied to environmental decision making. Part of the NASA Earth Science Division's Applied Sciences Program's (ASP's) Capacity Building program area,[2] DEVELOP facilitates 10-week experiential learning opportunities during which participants work directly with partner organizations to build skills and knowledge around geospatial tools and Earth-observation data.

The DEVELOP model uses a dual capacity-building approach that engages young professionals to work on feasibility projects under the guidance of science advisors and mentors at the program's 11 host locations—see **Figure 1**. This approach enables participants to rapidly build their technical knowledge of remote sensing and geographic information system (GIS) techniques to create methodologies and decision-support tools to enhance the partners' environmental decision-making capabilities. In addition to building their geospatial skillset, participants focus on technical writing and science communications and learn how to contribute effectively to an interdisciplinary team.

End-user organizations are central to the creation of a DEVELOP project, which begins with a needs assessment focused on the environmental concern at hand and the partners' decision-making process. At the end of the 10 weeks, teams participate in "partner handoff" and "closeout" presentations, where teams share the project methodologies and present the feasibility study results to a broad audience of decision makers, scientists, and project collaborators.

DEVELOP began at NASA's Langley Research Center in 1998 and is now a national program, supporting project activity at regional offices (Fort Collins, CO; Athens, GA; Asheville, NC; Pocatello, ID; Tempe, AZ; and Boston, MA) and other NASA centers [Ames Research Center, Goddard Space Flight Center (GSFC), Jet Propulsion Laboratory (JPL), and Marshall Space Flight Center]. DEVELOP conducts three project terms per year, and participant teams work from one of the program's 11 host locations across the country on feasibility projects addressing environmental and public policy issues around the globe.

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[1] Originally DEVELOP stood for Digital Earth Virtual Environment and Learning Outreach Program, but that acronym is no longer used.

[2] For more information, visit *appliedsciences.nasa.gov/what-we-do/capacity-building*.
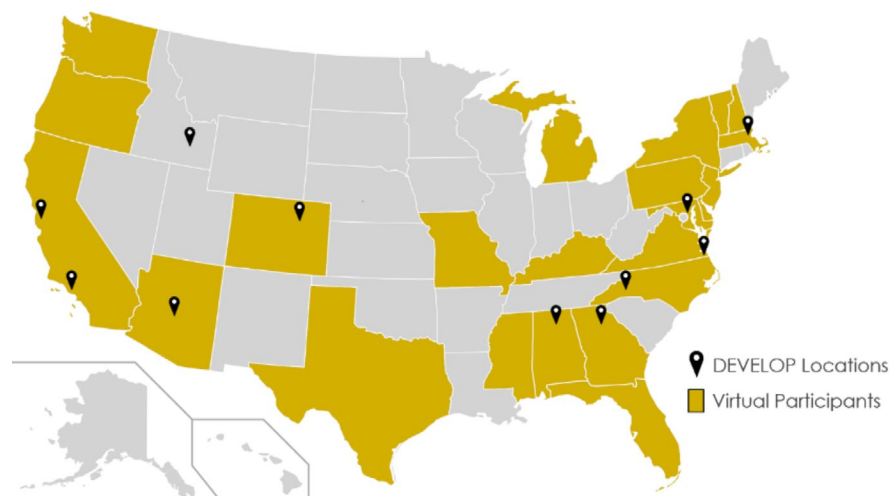
Figure 1. Map of 11 DEVELOP host locations and virtual participation for the Summer 2020 term. **Image credit**: NASA DEVELOP

Spring 2020: Transitioning to a Virtual Term

During DEVELOP's Spring 2020 term, rapidly evolving circumstances required an *ad hoc* rollout of a virtual approach to complete the ongoing projects. Participants were roughly seven weeks into the project term in mid-March when the program's host locations began closing because of the COVID-19 pandemic. In response to these new workplace realities, the DEVELOP Program pivoted from colocating students, emerging professionals, and science advisors at in-person locations to forming virtual teams from across the U.S.

To continue providing opportunities for the program's participants, based on the experience from the rapid transition during the spring term and a few weeks of planning, DEVELOP made the decision to host its first fully virtual Summer 2020 term June 1–August 7.

DEVELOP had to overcome a number of obstacles as it transitioned from the 10-week participant experience at a host location to the virtual environment. Participants and facilitators had to learn about and adopt new virtual tools, as well as determine how to best facilitate collaboration across virtual project teams and with partner organizations, remotely—see **Photo** below. Managed through a contract with Science Systems and Applications, Inc. (SSAI), DEVELOP implemented the use of collaborative software tools, which were critical for communication within project teams, across DEVELOP locations, and even program wide—see *Software Carpentry Workshop* below. To support conducting projects remotely, participants were given access to *virtual machines*—which emulate a computer system for remote users—that provided the technical software and data-processing capabilities needed to effectively complete project work.
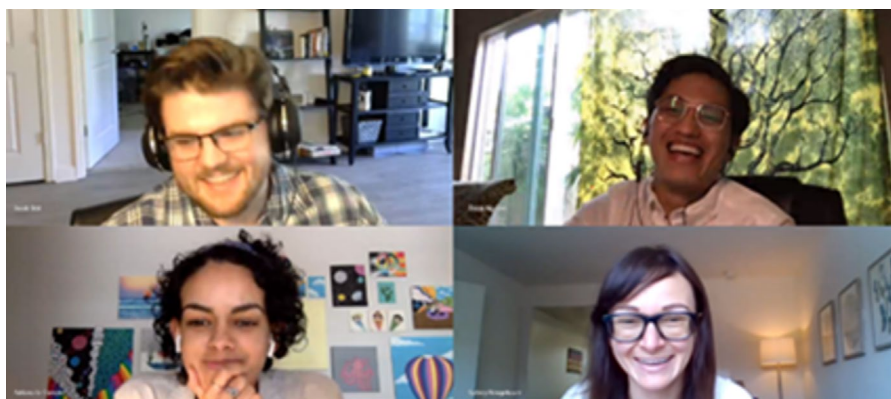
DEVELOP had to overcome a number of obstacles as it transitioned … to the virtual environment. Participants and facilitators had to learn about and adopt new virtual tools, as well as determine how to best facilitate collaboration across virtual project teams and with partner organizations, remotely.

Photo. DEVELOP participants utilized video-conferencing tools to collaborate on projects across time zones. Shown here are [*clockwise from top left*]: **Jake Stid** [SSAI/Michigan State University], **Derek Nguyen** [SSAI/University of California, Santa Barbara], **Sydney Neugebauer** [SSAI/Boston University], and **Adriana Le Compte** [SSAI/Iowa State University]. **Photo credit**: NASA DEVELOP

Software Carpentry Workshop

In early June, DEVELOP hosted a virtual Software Carpentry (*software-carpentry.org*) workshop to introduce participants to coding best practices and to facilitate the use of programming in their feasibility projects and potentially for their future careers in Earth science. A total of 54 of the 65 DEVELOP summer-term participants joined multiple training sessions to build introductory programming skills for scientific analysis. These workshops—delivered entirely online—increased DEVELOP's technical training capability at the program level and have brought significant added value to the virtual experience—particularly for DEVELOP locations that did not previously have access to formal technical instruction. The program supports an internal network of certified Software Carpentry instructors, made up of personnel from DEVELOP and other Capacity Building Program elements, as well as several DEVELOP alumni volunteers, who led the training.

"I wanted to participate in DEVELOP to gain skills and experience in the field of geoinformatics, but now consider myself extremely fortunate to be part of the DEVELOP Program. I learned that such programs signify a greater societal benefit."

—Kelzang Jigme
[SSAI—*DEVELOP Southern Bhutan Ecological Forecasting Team Member*]

DEVELOP 2020 Summer Term Projects

A total of 65 participants, including students, recent graduates, and early-career professionals, worked remotely on 15 projects that highlighted how NASA's Earth-observation capabilities can aid decision makers on issues ranging from understanding how impervious surface area and tree-canopy cover impact the urban heat island effect in cities, to analyzing wildfire impacts on air quality and forest regeneration. All of the summer participants were associated with one of DEVELOP's existing host locations and joined the program working remotely from 23 states across the nation—as shown in Figure 1.

Each project is assigned to an ASP program area. The list is available at *go.nasa. gov/3clVw3F*. Several of these projects are discussed in greater detail in the remainder of this report, including: Southern Bhutan Ecological Forecasting, Bhutan Water Resources, South Carolina Water Resources, Satellite Beach Energy, and Ellicott City Disasters III. DEVELOP has a project archive dating back to 2014, accessible at *develop.larc.nasa.gov/project-archive.php*. The complete list of Summer 2020 projects can also be found there.

Bhutan STEM Engagement Projects

Nine Bhutanese scholars participated in DEVELOP's virtual Summer 2020 term as part of a multiyear interagency agreement with the U.S. Department of State. The goal of this collaboration is to strengthen the foundations of science, technology, engineering, and math in Bhutan through the expanded use of Earth-observation information. The program provided technical training to scholars in the U.S. by conducting rapid feasibility studies for mutual learning on how to apply NASA and other Earth-science data to environmental decision making in Bhutan.

The nine scholars worked on two feasibility projects in collaboration with the Bhutan Foundation's U.S.-based office, along with civil-society organizations in Bhutan. The Southern Bhutan Ecological Forecasting team generated land-cover classifications and modeled Asian elephant habitat suitability to inform conservation efforts, while the Bhutan Water Resources team analyzed trends in precipitation and temperature to assess local climate vulnerability across the country. Both project teams included members with interdisciplinary backgrounds, ranging from psychology and civil engineering to global supply chain management and international business. The participants used their diverse skills and knowledge of local environmental issues that impact Bhutan to work collaboratively on the DEVELOP projects and build a technical foundation in Earth science, remote sensing, and GIS for their future careers.

The summer term concluded on August 7, 2020, with a presentation to **Ambassador Doma Tshering** [Permanent Representative of Bhutan to the United Nations in New York] and to representatives from NASA, the U.S. State Department's Bureau of South and Central Asian Affairs, the Bhutan Foundation, and SSAI (the DEVELOP contract manager). The Bhutanese scholars shared personal reflections on their capacity-building experience and participation in the DEVELOP Program. They also had their work highlighted by **NASA Administrator Jim Bridenstine**—see **Figure 2**. DEVELOP is continuing to support science and technology efforts in Bhutan with 10 additional scholars participating in the Spring 2021 project term and will have more Bhutan projects participating during the Summer 2021 term.

Applied Sciences Week 2020

Each summer DEVELOP participants from around the country typically travel to Washington, DC, to present their project results at the Annual Earth Science Applications Showcase at NASA Headquarters (HQ).[3] This event features the ASP's

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[3] To read a summary of the 2018 Earth Science Applications Showcase, see "NASA's DEVELOP Program Recognizes 20 Years of Science Serving Society" in the September–October 2018 issue of *The Earth Observer* [**Volume 30**, **Issue 5**, pp. 11–17—*go.nasa.gov/2NRpYsl*]. The summary of the 2018 showcase begins on page 13.

many contributions to society through the application of Earth observations and includes highlight presentations, flash talks, and speaker panels. Due to the inability to convene in person, this year's event transformed into an Applied Sciences Week, held virtually August 3–6, 2020. While the DEVELOP Program and its early-career professionals continued to be a main focus of the event, the expansion from a single-day to a week-long event allowed the organizing team to engage additional parts of ASP through a variety of programmatic and partnership highlights, as briefly described here.

Jim Bridenstine ✔
@JimBridenstine

Congratulations @NASA_Develop #Bhutan scholars on their @NASAEarth Applied Sciences projects! Using freely available NASA data their mapping projects will help wildlife & the environment. We are pleased to partner with these scholars of Bhutan! go.nasa.gov/3ifOQUb @State_SCA

Elephant Occurrence
LOW ▬▬▬▬▬▬▬▬ HIGH
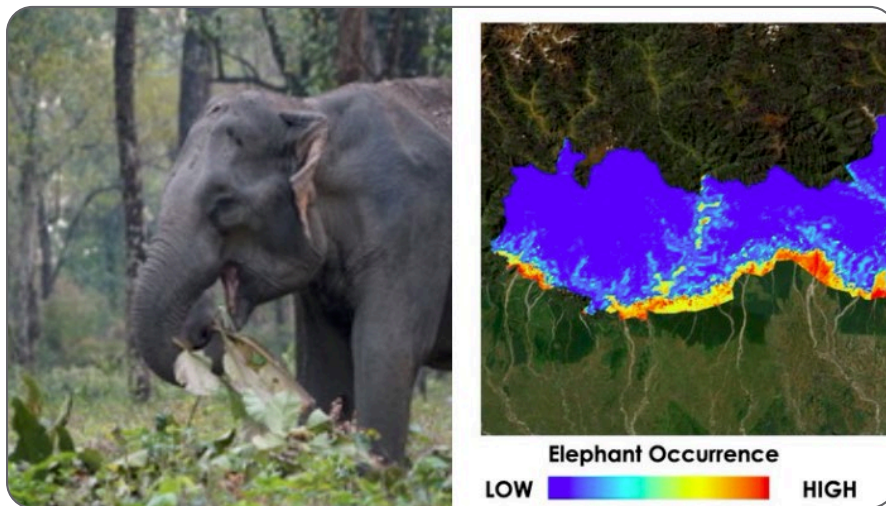
Figure 2. NASA Administrator Jim Bridenstine highlighted the Summer 2020 Bhutanese scholars and their work on the Southern Bhutan Ecological Forecasting and Bhutan Water Resources projects on social media. **Image credit**: NASA

Opening Remarks from Earth Science Division Director

Karen St. Germain [NASA HQ—*Director of the Earth Science Division*] opened the week's first plenary session, using her remarks to recognize the many applications of NASA Earth Science data and the meaningful achievements and impacts of related projects across the globe.

ASP Update

Following St. Germain's remarks, **Lawrence Friedl** [NASA HQ—*ASP Director*] and **Emily Sylak-Glassman** [NASA HQ—*ASP Manager*] presented an overview and highlights of the ASP, which set the stage for five brief presentation sessions. Each session focused on a different ASP thematic application area, as summarized here.

- *Health & Air Quality.* **John Haynes** [NASA HQ—*Health & Air Quality Program Manager*] provided an overview of recent Health & Air Quality applications, highlighting a tool used to forecast poor air quality events in the Caribbean and two projects that used satellite data to predict vector-borne disease risk. **Jonathan O'Brien** [SSAI—*Applied Remote Sensing Training Program (ARSET) Technical Writer/Editor*] and **Selwin Hudson-Odoi** [University of Maryland, Baltimore County—*ARSET Training Coordinator*] presented a profile of ARSET training attendee, **Sarah Strachan** [Idaho Department of Environmental Quality], who used the information she learned about NASA data and resources to develop the Idaho Wildfire Smoke Portal (*storymaps.arcgis.com/stories/f681a2398cf24f26ae0542abe0ff6b60*).

The Summer DEVELOP teams had the unique opportunity to collaborate with approximately 20 different decision-making organizations across multiple sectors.

- ***Ecological Forecasting.*** **Woody Turner** [NASA HQ—*Ecological Forecasting Program Manager*] spoke about the various ways that the Ecological Forecasting program area is using satellite information to predict changes to life on Earth for conservation and resource management. He included a description of NASA's partnership with Conservation International. **Andrea Nicolau** [University of Alabama in Huntsville—*SERVIR-Mekong Regional Science Associate*] highlighted SERVIR[4] activities as part of its Land Cover and Land Use Change service area throughout Asia, Africa, and the Americas.

- ***Disasters.*** **David Green** [NASA HQ—*Disasters Program Manager*] presented examples of how NASA promotes the use of Earth observations to inform disaster risk reduction and resilience and highlighted the data and tools hosted at the NASA Disasters Mapping Portal (*maps.disasters.nasa.gov*), which is an ArcGIS-based online interface for analyzing and downloading data on natural disasters. **Erika Munshi** [SSAI—*Ellicott City Disasters III Project Lead*] presented her team's efforts to build a real-time predictive flood model to improve early warning systems—see page 9 for more details.

- ***Water Resources.*** **Sarah Brennan** [Booz Allen Hamilton Inc. (BAH)—*Water Resources & Food Security Associate*] highlighted how the Water Resources program area is working to identify gaps and opportunities in the current understanding of freshwater resources, and how it works with partners to make a sustainable impact on water-management strategies. **Indrani Grazcyk** [JPL—*Western Water Applications Office Program Manager*] described the portfolio of applied research projects being pursued by the Western Water Applications Office, whose goal is to transition water applications to western water managers for operations and long-term impact.

- ***Agriculture & Food Security.*** **Sarah Brennan** [BAH—*Water Resources & Food Security Associate*] and **Alyssa Whitcraft** [University of Maryland, College Park—*NASA Harvest Associate Director* and *Program Manager*] spoke about the NASA Harvest consortium as an example of the extensive partnerships supported by NASA to enable and advance the awareness, use, and adoption of satellite data to benefit food security and agriculture worldwide. Domestically, the program area and consortium partners with the U.S. Department of Agriculture to support improved agriculture methods and provide scientific and technical information to end users.

DEVELOP Summer Project Highlights

The Summer DEVELOP teams had the unique opportunity to collaborate with approximately 20 different decision-making organizations across multiple sectors. Representatives of three of these decision-making organizations participated in a panel, which **Nancy Searby** [NASA HQ—*Capacity Building Program Manager*] moderated. **Chris Chiesa** [Pacific Disaster Center], **Mitch Roffer** [Fishing Oceanography, Inc.], and **Rish Vaidyanathan** [U.S. Centers for Disease Control and Prevention] each described how their engagement with the ASP and the ability to leverage satellite data and tools has benefitted their respective organizations by providing enhanced decision-making capabilities.

In addition to the decision makers, the showcase also highlighted two of DEVELOP's summer project partners, which are summarized below. Both of these end users highlighted the communication and collaboration that occurred with the project teams throughout the term and how DEVELOP helped them build capacity by providing

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[4] SERVIR is not an acronym; it's the Spanish word for "to serve." It is a joint development initiative between NASA's Applied Science Program and the U.S. Agency for International Development (USAID) that provides local decision makers with the tools, training, and services they need to act on climate-sensitive issues like disasters, agricultural security, water management, and land use. Learn more about SERVIR at *go.nasa.gov/2RTZuUu*.

feature article

data and methodologies that contribute to the local knowledge base of these complex environmental issues.

Tanner Arrington [South Carolina Department of Natural Resources] and **Lexi Miller** [City of Satellite Beach, FL—*Project Manager*] participated in the user panel and represented the type of state and local government end users with whom DEVELOP commonly engages. Decision makers in South Carolina became interested when DEVELOP approached them with the opportunity to pilot a project that used the unvegetated-to-vegetated marsh ratio (UVVR)[5] to assess salt-marsh health vulnerability along the South Carolina coast. Salt marshes are ecological and cultural resources that provide critical ecosystem services; the increasing availability and accessibility of remote sensing data can supplement traditional, field-based monitoring practices for assessing marsh health.

Sustainability Board members from Satellite Beach, FL, were connected to the program by a local resident who had read about a prior DEVELOP project that used Earth observations datasets to calculate rooftop solar energy potential in Ohio. Satellite Beach was interested in seeing if these methods could be applied in their community. The city is working toward a large sustainability goal to meet its energy demand with renewable sources by 2050. The DEVELOP team provided visualizations that can be used by partners to engage the local community in conversations on the city's ongoing resiliency and vulnerability assessments.

Erika Munshi [SSAI—*DEVELOP Project Lead*] and **John Bolten** [GSFC—*DEVELOP Lead Science Advisor*] presented DEVELOP's Ellicott City Disasters project as an example of work done by the ASP's Disasters Program area. This project began in summer 2019 and was conducted over three 10-week project terms by both in-person and virtual-participant teams. These teams examined how the use of real-time data sources from NASA's Earth observations, modeled weather products from the National Oceanic and Atmospheric Administration (NOAA), and *in situ* rain-gauge data could be incorporated into a machine-learning approach to construct a real-time flood forecasting tool. To learn more, see *DEVELOPing Tools to Predict Rising Flood Waters in a Historic Maryland Town* on page 10.

The plenary sessions held over the next three days featured more applications highlights, which showcased the work of DEVELOP's 15 summer projects and 12 principal-investigator-led Research Opportunities in Space and Earth Sciences (ROSES) projects.

Other Applications Week Highlights

As implied by its name, Applied Science Week has a broader focus than just the DEVELOP program. Participants heard updates on other ASP activities. The SERVIR Program highlighted its work in developing countries and hubs in West Africa, Eastern and Southern Africa, Hindu Kush–Himalayan region, Lower Mekong region, and Amazonia (South America). The week also showcased the ongoing programmatic and partnership highlights, including the work of NASA's VALUABLES Consortium,[6] efforts toward supporting the United Nations' Sustainable Development Goals, engagement with the Sistema de la Integración Centroamericana (SICA),[7] and activities focused on the Earth Science Division's Global Partnerships Program.

To capture the dynamic of an in-person event, concurrent breakout rooms were organized thematically around the ASP applications theme areas, allowing presenters and attendees to interact and foster engagement around work presented each day.

"DEVELOP was constantly in contact with us and we worked together to come up with the most beneficial product for our state"

—**Tanner Arrington** [South Carolina Department of Natural Resources—*DEVELOP End User*]

[5] UVVR has been proven to be a good surrogate for more-extensive field studies used to assess salt-marsh vulnerability.

[6] VALUABLES is a collaboration between NASA and Resources for the Future (an independent, nonprofit research institution in Washington, DC) to measure how satellite information benefits people and the environment when it is used to help make decisions.

[7] SICA is Spanish for the Central American Integration System, which has been the economic and political organization of Central American states since February 1, 1993. To learn more, see *www.sica.int/sica/propositos*.

feature article

DEVELOPing Tools to Predict Rising Flood Waters in a Historic Maryland Town

The town of Ellicott City, MD, has experienced several extreme flooding events in recent years that have resulted in significant damage and many negative impacts to businesses, local residents, and public infrastructure. Accurate, timely, and detailed data reports are necessary to mitigate the effects of severe flooding in the region and to inform early warning systems. The team doing this project is based at NASA's Goddard Space Flight Center (GSFC), which is only a short distance from Ellicott City. This proximity allowed the team the unique opportunity to meet in person and collaborate with local project partners from Howard County's Office of Emergency Management in Ellicott City.

Flooding in Ellicott City, MD. **Photo credit:** Libby Soloman

The diagram below illustrates the process the team uses to make a flood forecast. Team members created the Sequentially Trained Real-time Estimated Model (STREAM), which uses a deep-learning architecture to learn from historical data records combined with freely available and real-time rain-accumulation and river water-level data to predict stage height up to eight hours in advance. Data from Geostationary Operational Environmental Satellite (GOES)-16 and other NOAA real-time weather products are input into the model to produce flood forecasts. The team explored how the partners could incorporate the predictive model output into their existing OneRain Data Portal (*onerain.com*) to enhance their ability to better predict the timing and magnitude of flood events and to better prepare local residents to respond to potential flood impacts. Although the DEVELOP project concluded in virtual space, it included participation of local decision makers who provided the team with the unique opportunity to experience firsthand how utilizing satellite data can have real impacts on local communities. Building on the foundation of the DEVELOP team's feasibility study, ASP researchers at GSFC continue to work with end users in Ellicott City to refine the forecast model and provide decision-support tools to inform flood early-warning systems.
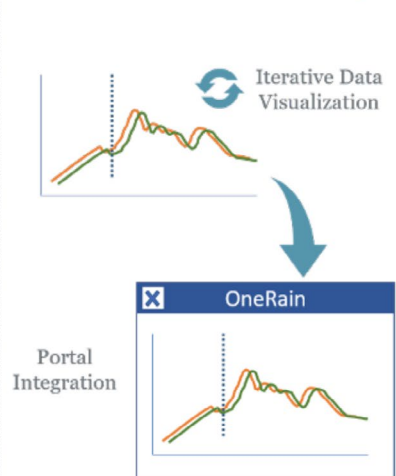

Diagram of the methodology used by the Ellicott City Disasters DEVELOP team to predict flood stage height. There are three primary stages: the acquisition of *in situ* stream-gauge and Earth observation data [*left*], machine-learning model development and training [*center*], and model output visualizations [*right*]. **Image credit**: NASA DEVELOP

DEVELOP Fellow, **Sydney Neugebauer** [SSAI], emceed the inaugural Applied Sciences Week 2020 event, which drew over 550 unique attendees.

To view the video and presentations from Applied Sciences Week 2020, visit *applied-sciences.nasa.gov/nasa-earth-applied-sciences-week-2020*.

Conclusions

When COVID-19 forced the hosts of its in-person training locations to shut down in March 2020, NASA's DEVELOP Program quickly adapted to engage participants from across the country in a robust virtual opportunity that paralleled the in-person experience provided at the program's regional and NASA field center locations. Overall, the virtual environment has not negatively impacted interactions with project partners or the teams' abilities to provide meaningful Earth science data and tools to inform local environmental decision making. Guided by the success of the virtual Summer 2020 project term, having received valuable feedback from program participants, and having monitored national conditions, DEVELOP hosted 49 participants for its second virtual term, held from September 14–November 20, 2020.

While the program will continue to provide virtual opportunities until conditions allow a transition back to hosting project activities at DEVELOP's in-person locations, participants have continued to learn new ways to collaborate, receive technical training, and gain exposure to emerging remote sensing and GIS technology and methodologies. Although challenging, the virtual environment provided DEVELOP participants the opportunity to explore new and innovative ways for the program to expand its reach and engage a broader group of future scientific leaders and Earth observation users from across the country in meaningful, real-world projects.

For more information about the DEVELOP Program, visit *develop.larc.nasa.gov*.

"I was apprehensive about this term due to its online status, and I nearly declined because of it. I can honestly say that I got everything I could've ever wanted from this term and possibly more, and I couldn't be happier that I made the decision to join. I know it was an immense task to move this online, and I thank everyone who had a hand in the process. I would love participating again, either online or in person."

— **DEVELOP Summer Program Participant** (*Anonymous*)

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

ACCP	Aerosol, Clouds, Convection, and Precipitation
COVID-19	2019 Novel Corona Virus Disease
CSLI	CubeSat Launch Initiative
ELaNa	Educational Launch of Nanosatellites
GISS	NASA's Goddard Institute for Space Studies
GPM	Global Precipitation Measurement
GSFC	NASA's Goddard Space Flight Center
JPL	NASA/Jet Propulsion Laboratory
MSFC	NASA's Marshall Space Flight Center
ROSES	Research Opportunities in Space and Earth Sciences
TEMPEST-D	Temporal Experiment for Storms and Tropical Systems—Demonstration
TRMM	Tropical Rainfall Measuring Mission
USDA	U.S. Department of Agriculture

feature article

meeting summaries

The 2020 NASA GPM–ACCP Transportation and Logistics Workshop: Lessons Learned from the Transportation Community of Practice

Andrea Portier, NASA's Goddard Space Flight Center/Science Systems and Applications, Inc., andrea.m.portier@nasa.gov
Dalia Kirschbaum, NASA's Goddard Space Flight Center, dalia.b.kirschbaum@nasa.gov

Introduction

Hazardous weather such as extreme precipitation, fog, and severe storm systems are known to cause problems for the transportation and logistical sectors, e.g., poor visibility, turbulence and airplane icing issues, and flash-flood events. Consequently, these conditions may influence disruptions in transportation operations and impact safety, leading to injury and severe economic damage. Given these issues, identifying data needs and priorities to improve weather monitoring and forecasting for these sectors is of vital importance and could have significant societal benefit.

To address how NASA data can enable support of operations within the transportation and logistical sectors, the NASA Global Precipitation Measurement (GPM)[1] Mission Applications Team, in collaboration with the Aerosols, Clouds, Convection and Precipitation (ACCP)[2] Study Applications Impact Team (AIT), organized the virtual *2020 NASA GPM-ACCP Transportation and Logistics Workshop*. The virtual workshop was held November 2, 4, and 5, 2020, with three half-day meetings and one virtual training session. The workshop consisted of a mixture of scientific sessions, panels, and breakouts that brought together ~70 representatives from NASA, federal and state operational agencies, private companies, and boundary organizations to discuss how NASA precipitation and cloud products could be better leveraged to inform decision making for current and future operations of

aviation, maritime, and road and highway transportation systems, for both current and future NASA mission planning.

The workshop's objectives included:

- providing opportunities for discussions on how current NASA data products are being used for transportation and logistical activities for aviation, maritime, and highway systems;

- providing opportunities to expand community engagement on satellite applications and needs, with a focus on transportation and logistics sectors;

- reaching into communities that are expanding their capabilities for using satellite data directly from NASA as input into their systems;

- articulating the challenges, barriers, and other limitations 'from end users' perspectives' related to data use in the transportation and logistics areas; and

- discussing current and future satellite needs and gaps and how products from the ACCP study can be used by these communities.

The full meeting agenda, presentations, and recordings can be accessed at *go.nasa.gov/3cCz328*.

Workshop Overview

The goal of the first day of the meeting was to create awareness and show examples of how NASA data can inform decision making. This was accomplished via a series of overview presentations from NASA scientists about various aspects of the GPM mission, NASA's Applied Sciences Program, and the 2017 Earth Science Decadal Survey, including the ACCP study.

Dalia Kirschbaum [NASA's Goddard Space Flight Center (GSFC)—*Chief of the Hydrological Sciences Laboratory* and *GPM Mission Deputy Project Scientist for Applications*] set the stage for the meeting and welcomed participants. Following the opening remarks, **Gail Skofronick-Jackson** [NASA Headquarters (HQ)] provided an overview of the GPM mission and applications for using GPM data and **George Huffman** [GSFC] provided an update on GPM data products. **John Haynes** [NASA HQ] then provided an overview of the NASA Applied Sciences Program. After that, **Scott Braun** [GSFC] provided an introduction to the Decadal Survey and study observables and the ACCP

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[1] GPM is co-led by NASA and the Japan Aerospace Exploration Agency (JAXA) and includes more than 20 additional international partners. To learn more about GPM, see "GPM Core Observatory: Advancing Precipitation Measurements and Expanding Coverage" in the November– December 2013 issue of *The Earth Observer* [**Volume 25, Issue 6**, pp. 4-11, *go.nasa.gov/2QaMugC*] and "The Global Precipitation Measurement (GPM) mission's scientific achievements and societal contributions: reviewing four years of advanced rain and snow observations," at *doi.org/10.1002/qj.3313*.

[2] The National Research Council released its second Earth Science Decadal Survey in 2017. The survey identified Aerosols (A) and Clouds, Convection, and Precipitation (CCP) as two (of a total of five) Designated Observables (DOs) to be addressed and implemented as a cost-capped medium- or large-scale mission by NASA. Subsequently, these two DOs have been combined and are referred to as ACCP. The NASA ACCP study is currently being conducted to explore observing system architectures to address the DOs and how they would satisfy both science goals and enabled applications. For more information, see *go.nasa.gov/2wXJn2n* and *vac.gsfc.nasa.gov/accp*.

Study Overview, and **Emily Berndt** [NASA's Marshall Space Flight Center (MSFC)] discussed potential ACCP applications.

The subsequent days consisted of three panel sessions, highlighting different applications of precipitation and cloud data for operations, and three breakout sessions, which focused on discussions related to end-user needs, and strengths and challenges using satellite precipitation and cloud data from the NASA Program of Record.[3]

Transportation Community of Practice

This article focuses on the Transportation Community of Practice (CoP)[4] and identifying lessons learned from panel presentations and breakout discussions from the workshop covering the aviation, roads and highway, maritime, and logistics sectors. The GPM and ACCP Applications teams invited organizations from these four main sectors to represent end-user needs for the transportation community. The remainder of this report is divided into several focus areas that fall under the Transportation CoP—listed in **Table 1**, below. Each summary highlights participants' data needs in the particular focus area, challenges, and gaps with respect to applying precipitation and cloud data within the specific applications community.

Aviation

Workshop participants from the aviation community included nine individuals from the Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), United Airlines, United Parcel Service (UPS) Airlines, General Electric Company (GE) Aviation, and members of Airlines for America. These participants are well versed in using surface, radar, and satellite observations at lower levels of processing to conduct analyses and forecasts, and to disseminate weather information to inform decision making and meet user needs. **Patrick Gatlin** [MSFC] chaired this session, with members of the AIT, including **Emily Berndt, Amber Soja** [NASA's Langley

Research Center (LaRC)], and **Anita LeRoy** [MSFC] serving as rapporteurs.

Aviation weather services are provided primarily by the federal and private sectors, including the FAA, NOAA [particularly the National Weather Service NWS)], and operational airline companies. Accurate and timely reports of weather conditions are provided through web portals and are needed to feed information to end users such as air traffic control centers, airport towers, flight dispatch, and pilots in the form of high-resolution gridded precipitation and lightning products for aviation safety and efficiency. An understanding of aviation impact variables such as ceiling, visibility, turbulence, and icing, along with the ability to produce short-term forecasts at local and regional scales, are particularly important for flight operations. The incorporation of Earth-observing satellite data into aviation weather services is well underway. Examples include using: Geostationary Operational Environmental Satellite–16 (GOES-16) imagery to detect icing threat areas, convective storms, and fog; GOES-16 Geostationary Lightning Mapper (GLM) data to characterize convection and icing probability; and infrared (IR) data from Meteosat-9 processed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) to identify deep tropical convection.

Earth Observing Satellite Challenges and Needs

Aviation-focused participants expressed specific challenges and needs for using Earth observing satellite data for operations. Ingestion of small ice crystals into jet engines and aircraft ice accumulation (e.g., wing icing) are well-known aviation hazards. To detect these threats, accurate detection and distinction between freezing rain and freezing drizzle as well as monitoring of high ice water content (HIWC) at near-surface and cruise altitudes are needed. However, end users have reported that precipitation types and HIWC are not easily detectable by traditional ground-based radar or geostationary satellites used by most operational systems. Measurements of fog layer depth and extent are particularly needed at all hours and at a higher resolution (e.g., airport level) to improve visibility forecasts.

In terms of monitoring convection that can cause severe storm systems and hazards such as turbulence, participants expressed their challenges in obtaining vertical

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[3] A NASA Program of Record is defined as NASA activities that will continue as planned through the next decade in the absence of recommendations from the Decadal Survey.
[4] "Community of Practice" in this context refers to organizations and individuals that seek to use—or are familiar with— using Earth observing satellite data to improve decision making within the transportation and logistical sectors.

Table 1. Workshop focus areas and organizational affiliations of panelists at the NASA 2020 Transportation Workshop.

Area	Organizational Affiliations of Panelists
Aviation	Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), United Airlines
Roads and Highways	Oregon Department of Transportation, Louisiana Office of Technology Services
Maritime	Fathom Science, NASA's Langley Research Center (LaRC)
Logistics	World Resources Institute, United Parcel Service (UPS) Airlines

profile information in data-sparse regions as well as having hourly information on cloud bases and more accurate total and frequent lightning measurements.

Participants also expressed a need for more data coverage at higher latitudes and higher resolutions, to capture changes at local airports. Lastly, they conveyed their frustrations about the slow pace of implementing research results into operations in the aviation community. They described that implementing new products and technology can take a long time—approximately 7 to 8 years—which can influence operations and needs to be considered with new Earth-observation technological developments.

Moving Forward

Participants expressed specific needs and described future opportunities to support and enhance applications relating to the current NASA Program of Record and opportunities presented by the ACCP study. These include improvements: in three-dimensional measurements of storms; in modeling and understanding of convective storms—to avoid turbulence; in modeling of fog ceilings and low clouds—to improve visibility and decrease incidences of delays; and in the precision of forecasts issued 12 to 14 hours before flights. Measurements from ACCP will help address these concerns by leveraging results from the current Program of Record, such as precipitation retrievals from GPM's Dual Frequency Precipitation Radar[5] instrument and ACCP's future ability to measure vertical air motion and rapidly retrieve atmospheric parameters to improve monitoring of severe storm events.

These aviation-sector participants noted that they will continue to ingest satellite data into their systems and processes for validation and verification, and they are looking forward to new and innovative measurements to advance their operational predictions and forecasts.

Roads and Highways

Anita LeRoy facilitated the Roads and Highway panel and breakout discussion, with **Svetla Hristova-Veleva** [NASA/Jet Propulsion Laboratory (JPL)], **Emily Berndt**, and **Dalia Kirschbaum** serving as rapporteurs. Representatives from the Oregon and Louisiana State Departments of Transportation (DOT) attended, along with others from private and academic institutions. The discussion focused on ground transportation operations and relevant data needs within the U.S.

Ground transportation hazards can vary significantly by state and region. Precipitation extremes in the northwest

can result in landslides; hurricanes and heavy rainfall in the southeast can lead to flooding; and heavy snowfall can lead to icing on roads, poor visibility, and delays in the northeast. Wherever severe weather may hit, information about roads and highway hazards is disseminated by state transportation agencies' 511 service and road signage. Near-real-time (NRT) data at watershed and smaller scales are needed for early warning systems to improve safety, and historical data are important for operational planning of road and bridge designs. Surface precipitation estimates, Doppler radar, and forecast precipitation data from NOAA's NWS are routinely used by state DOT personnel to communicate hazards to the public. Gridded satellite products are used by some DOT agencies—but not as often as they could be. Lower levels of satellite data—e.g., nongridded precipitation and cloud products—are used even less for operations. One example where satellite data are being applied to ground transportation studies is GOES-16 imagery, which is used to assess precipitation intensity and accumulation across the East Coast of the U.S.

Earth Observing Satellite Challenges and Needs

While ground data are primarily used for operations by state agencies, workshop participants emphasized opportunities for ingesting more satellite information if they could be delivered through fast (i.e., in real time) and efficient geospatial web services. Knowledge of the existence and location of satellite mission data, data access protocols and formats, and ingestion of satellite data into operational systems are known technical hurdles for these communities. State agencies have expressed the need for real-time and historical data with higher spatial and temporal resolution, which would be valuable for capturing parameters such as rainfall intensity, volume, and duration during a storm event.

Moving Forward

Exploring the current NASA Program of Record and precipitation estimates made possible from future missions (such as articulated in the ACCP Study; see *vac.gsfc.nasa.gov/accp*) is of interest for current and future applications for ground transportation sectors. Specifically, end users have expressed a desire to learn more about gridded precipitation products and the NASA Landslide Hazard Assessment model for Situational Awareness (LHASA; see *landslides.nasa.gov*), both of which can provide useful information to advance transportation applications. They have shown interest in participating in the NASA Applied Remote Sensing Training (ARSET) courses as well as in reviewing previous GPM application and data webinars. Overall, offering more opportunities for remote sensing training and promoting greater awareness of satellite products are high priorities for these agencies, both of which should lead to increased use of satellite data for internal operations.

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[5] One of the prime instruments onboard the GPM Core Observatory is the Dual-frequency Precipitation Radar (DPR). Data collected from the DPR provide three-dimensional observations of rain and also provide accurate estimation of rainfall rate to the scientific community. For more information on the GPM's DPR, see *go.nasa.gov/2O5U0c4*.

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Maritime

Two representatives from Fathom Science—a science and technology company providing high-resolution maritime environment analytics—participated as panelists at the workshop. Lessons learned from Fathom Science (discussed below) were used to establish a summary of satellite challenges, data gaps and needs within the maritime sector. **Anita LeRoy** chaired the session and moderated the panel discussion.

Federal agencies, private companies, and international organizations heavily utilize satellite data for maritime services and operations. This sector caters to a wide range of users including fisheries, military organizations, shipping companies, energy services, port authorities, and disaster response organizations. Near-real-time and historical data from Level-2 satellite products (e.g., geophysical variables such as precipitation rate that are not spatially gridded) and Level-3 satellite products (e.g., geophysical variables mapped to a spatial grid) are often used to deliver downstream products through technology platforms or web portals, providing high-resolution meteorological and physical oceanographic information and value-added products on demand. As one example, Fathom Science presented a case study demonstrating how NASA GPM precipitation data were used in their system to model the arrival of Hurricane Florence and to forecast compound flooding in North Carolina in September 2018. This forecast was then disseminated through Fathom's web portal—see **Figure**. Satellite observations of precipitation, clouds, water vapor, sea-surface height, and sea-surface temperature are often used as input to constrain and validate models within their systems.

Earth Observing Satellite Needs and Moving Forward

Maritime service providers have expressed specific meteorological needs that are important for operations. These include: more-frequent and higher-resolution vertical profiles of temperature, moisture, and wind; the need for both local and global coverage; and spatio-temporal continuity of data. Workshop participants expressed interest in instruments that would enhance monitoring of hazardous storms over lakes. These participants also emphasized that incorporating new data within their systems needs to be strategic and planned, as ingesting new data into systems and models takes time; costs need to be considered; and training on data utilization is important.

Logistics

While the date and timing of the virtual workshop prohibited most *logistical companies*—e.g., brand name companies like Walmart, FedEx, and UPS—from directly participating, several of these companies did provide information on operations and data needs prior to the event. A representative from the World Resources Institute (WRI) participated as a panelist during the workshop. The information summarized here consists of lessons learned from WRI and logistical organizations prior to the workshop event. **Aaron Naeger** [MSFC] led the session and moderated the panel discussion.

Major logistical companies rely on weather information to strategically allocate resources for business continuity and to monitor supply chain disruptions from their partners. Many of these private and public companies
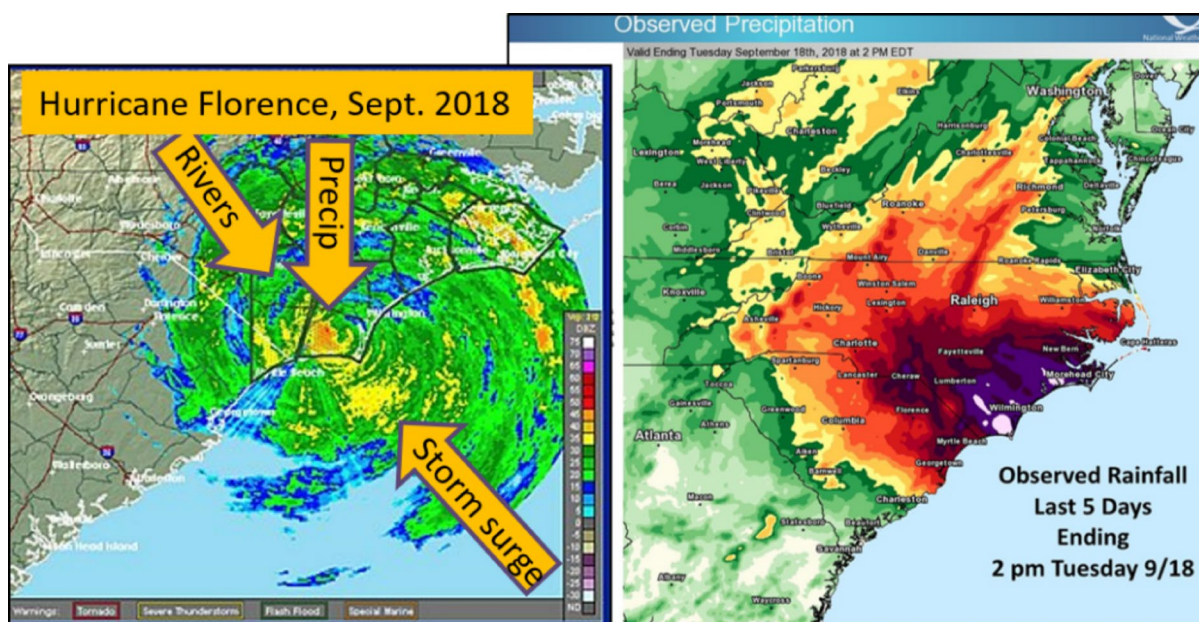
Figure. Fathom Science incorporated NASA data into their system to model the arrival of Hurricane Florence and forecast compound flooding in NC in September 2018. The left image shows the area most at risk for compound flooding. The image on the right shows observed precipitation using GPM data. **Image credit:** Fathom Science

Table 2. High-level summary of level of experience, challenges, and needs using satellite-based Earth observation data by sector.

Focus Area	Experience	Challenges	Needs
Aviation	Expert	Frozen precipitation detection, spatial resolution around airports, cloud-base information, frequency of fog observations	Three-dimensional measurements of storms, higher resolution of fog-layer depth, improved short-term forecasts (12–14 hours)
Roads and Highway	Novice to intermediate	Time and knowledge of ingesting satellite data	Rainfall intensity, volume and duration, NRT and historical data, remote sensing training opportunities
Maritime	Intermediate	Research to operation with new data takes time	Vertical profiles of temperature, moisture and wind, local and global coverage, continuity of data
Logistics	Novice (ground-based)	Rely on third-party services, knowledge of available Earth observing satellite data	Continued use by third parties, remote sensing training at a future date

*For higher level summary notes from transportation end users view the workshop webpage provided in the Introduction.

and organizations need data products within 24–48 hours of an event to alert their transportation service providers of the probability of heavy rain, snowfall, and fog. Three- to seven-day weather forecasts are also valuable for identifying large storm systems such as hurricanes. For these groups, most data come from third-party platforms and vendors, such as StormGeo or AccuWeather, to monitor multiple locations. These third-party entities enable easy and direct access to specific thresholds (e.g., snow amounts) that may influence transport routes and delivery of goods. Currently, logistical companies and carriers' operational needs are low for satellite data accessed directly from NASA or other federal partners. However, some logistical organizations have expressed desire to understand the full range of data that is available to enhance operational decision making.

Transportation CoP Summary

Overall, the discussions were excellent opportunities to encourage communication between applied users from transportation communities and NASA scientists. The meeting also provided opportunities to discuss future NASA mission planning, including measurements anticipated from the ACCP Study and how to get key feedback from the community as to the most significant gap areas and opportunities for enhancing applications within their operations. **Table 2** gives a high-level summary of the level of experience, challenges, and needs, using Earth observing satellite data for each focus area. Participants expressed interest in continuing

this dialogue to increase support for potential applications. These workshop results will help to improve current data products and services developed by the GPM team and guide how the applications communities will use the observations made from future NASA missions.

Conclusion

The meeting provided opportunities to understand current satellite data needs and challenges faced by air and ground transportation sectors and to facilitate increased awareness of the availability of satellite data to support future applications. The meeting also helped showcase applications of current satellite data used for operations. While members of these sectors are at different levels of experience with remote sensing data, all participants acknowledged how satellite data could enhance applications within their operations. Participants also expressed interest in becoming more aware of how NASA products could be used directly within their systems. However, participants also emphasized the concern that the transfer of current and future NASA data into operations is often a long process that can require significant investment on their part. This includes gaining knowledge and training on use of the data, costs, and time for model ingestion and validation, all of which must be considered for successful implementation of such data for applications. ■

Earth Observations of Crop Burning and Air Pollution Over India: A Community Response Forum

Pawan Gupta, NASA's Marshall Space Flight Center/Universities Space Research Association, pawan.gupta@nasa.gov
Alan B. Ward, NASA's Goddard Space Flight Center/Global Science and Technology, Inc., alan.b.ward@nasa.gov

meeting summaries

Introduction

This article reports on a *community response forum*—a series of virtual meetings held during the fall of 2020 that covered multiple aspects of crop-residue and biomass burning and their impacts on regional air quality in the Indian Sub-Continent (ISC). The forum hosted a panel of experts who shared subject matter knowledge with participants via presentations on selected topics. The panel was followed by question-and-answer time and open discussion. Some of the sessions also provided training on how to use available Earth observations and tools to analyze fire, smoke, and air-quality data.

The forum participants represented a broad spectrum of the Earth science and air quality community, including: researchers and students conducting research on air quality, fires, and climate; advocacy groups; media personnel; and international organizations. Some of the institutions represented during the forum include the Public Health Foundation of India (PFI), Indian Institutes of Technology (IIT), Indian Agriculture Research Institute (IARI), Indian Institute of Tropical Meteorology (IITM), Indian Space Research Organization (ISRO), Indian Center for Advanced Spatial and Environmental Research (CASER), Japanese Research Institute for Humanity and Nature (RIHN), Tokyo Institute of Technology (Tokyo Tech), NASA's Goddard Space Flight Center (GSFC), NASA's Marshall Space Flight Center (MSFC), National Oceanic and Atmospheric Administration (NOAA), World Bank, World Health Organization (WHO), University of Alabama in Huntsville (UAH), and RTI International (RTI).[1]

After a brief introduction of the science to provide context for the meeting, the remainder of this report summarizes the forum.

Forum Context: Fire, Smoke, and Air Quality Issues in India

Poor air quality, in the form of elevated particulate matter, is a critical and pressing problem in the newly industrializing and developing countries of the ISC, severely threatening human health, ecosystem processes, agricultural productivity, biodiversity, regional climate, and overall quality of life. The ISC is home to 25% of the world's population and experiences annual mean levels of particulate pollution that exceed WHO standards by seven-to-ten fold.[2] Individual pollution events,

e.g., smoke from fires and dust storms, can be especially deadly. The burning of agricultural waste in open fields for crop rotation is common in several parts of India and most prominently in the northwestern part of the Indo-Gangetic Plains (IGP). India is an agrarian country and generates a large quantity of agricultural waste every year, particularly during the harvest season. Sources of this waste include cereal straws, woody stalks, and sugar-cane leaves and tops. Portions of these residues are used as animal feed, thatching for rural homes, residential cooking fuel, and industrial fuel. However, much of the crop residue is burned in the field because farmers need to prepare the field for the next crop, and residue burning is a quick and affordable method for them to manage the large quantities of unusable biomass. Large uncertainties exist in the estimates of emissions from crop-residue burning. Millions of tons of waste burned after harvest season emit a tremendous amount of smoke particles and gaseous pollutants into the atmosphere.

Forum Summary

In an effort to facilitate and encourage discussion of these important topics among the community of practice, **Pawan Gupta** [MSFC/USRA] took the lead in organizing a community response forum that took place during the fall of 2020,[3] which corresponds to Northern India's 2020 post-monsoon crop-residue burning season—see **Figure 1** on page 18. Forum meetings were held online on a weekly basis from September 24 to November 19. The **Table** on pages 18–19 gives a complete list of speakers and topics at each weekly meeting, as well as links to view presentations, when available.

Meeting Logistics

The forum was free and open to anyone interested in the topic. Participants registered the first time they participated. While a total of 350 participants registered for the forum, only a small group of about 40-50 on average took part during each individual meeting. The meetings took place using online meeting software called *Ring Central*, which USRA provided. Reminders and agendas for each weekly meeting were widely publicized via email and social media to all registered participants. There were also a blog and website (*www.firesandaq2020.info*) maintained throughout the season, which provided agendas, presentations, and daily analysis reports of fires and aerosols from satellite observations.

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[1] RTI originally stood for Research Triangle Institute; however, the acronym is no longer used.
[2] The WHO guideline stipulates that $PM_{2.5}$ not exceed 10 µg/m³ in its annual mean.

meeting summaries
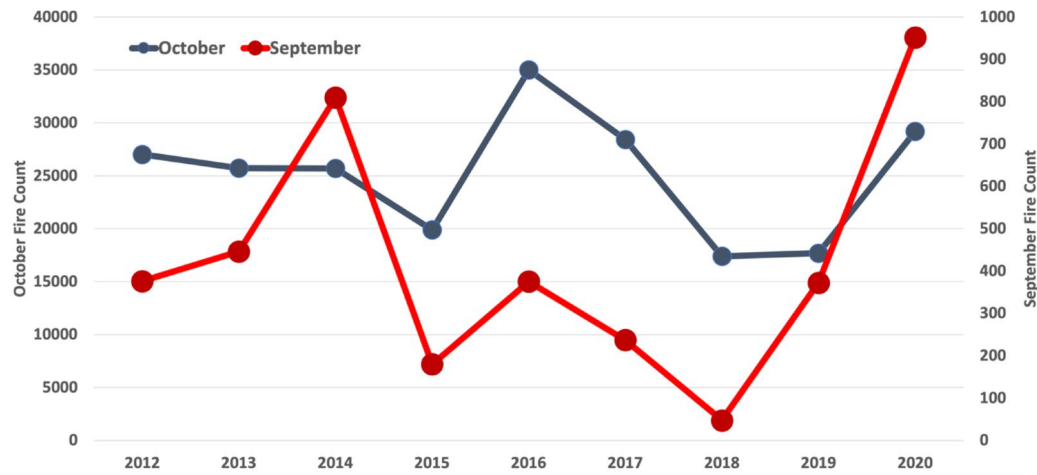
Figure 1. *Early Burning in Punjab in 2020*. The graph shows fire activity in the Indian state of Punjab using Visible Infrared Imaging Radiometer Suite (VIIRS) data from the Suomi National Polar-orbiting Partnership (NPP) satellite for September [*right y-axis*] and October [*left y-axis*]. The plot shows total fire counts for September and October of each year, starting in 2012. Typically, the crop fire season in Punjab starts in late September, but in 2020 it started 7-10 days earlier and recorded the highest September fires totaling double the mean compared to the previous eight years. The early fires were mainly due to early harvest in a certain rice paddy crop, which was directly seeded in the field. Similarly, October was also a very active season and recorded a year with the second-highest fire counts, exceeded only in 2016. **Image credit**: Pawan Gupta

Table. List of speakers and topics for each weekly meeting held during the Forum. Visit URLs to view full presentations.

| Speaker [Affiliation]	Topic	URL
September 24, 2020		
Pawan Gupta [MSFC/ USRA]	Introduction to the Forum and Logistics	*drive.google.com/file/d/16FiYpfCUL5ias9up66 55ufAulVJ1Wjow/view*
Vinay Sehgal [IARI]	Paddy-Residue Burning in North India During 2019-20	*drive.google.com/file/d/1lCjmKCObv2kneo2hgj lUPAfj3GwmUUKF/view*
Jyothi S. Menon [PFI]	Air Quality and Health Impacts of Crop-Residue Burning	*drive.google.com/file/d/1g97e--3XIqPS1A6P- fiZkPI7_xWBqxIxH/view*
October 1, 2020		
Pawan Gupta	Latest Satellite Observations of Fires and Air Quality in India	*drive.google.com/file/d/1nSKoJQJ5papLDN- gmhUh_zs7h5aKATSq/view*
October 8, 2020		
Sundar A. Christopher [UAH]	Introduction to Aerosol Optical Depth and Applications	*drive.google.com/file/d/1weeOC6iW_3gwi7FM cNEYEgLRrwc_3Cny/view*
Hongqing Liu [NOAA]	NOAA Enterprise VIIRS Aerosol Optical Depth Algorithm and Product	*drive.google.com/file/d/1tMpS2zoDTgUP0ZB4 V0JYU6SXXSfcy1xr/view*
Pawan Gupta	Fire and Air-Quality Updates	*drive.google.com/file/d/1dqNFoA5i6WNgmXM Qd6BiT0VPpHR1lx_g/view*
October 15, 2020		
Krishna Vadrevu [MSFC]	Utility of Very-High-Resolution Planet Data for Burnt-Area Mapping in Forest and Agricultural Landscapes of India	Not Available
Pubu Ciren [NOAA]	NOAA Enterprise VIIRS Aerosol-Detection Algorithm and Product	*drive.google.com/file/d/19cVBp9akRsbY4v1OIl y2s7MZB6JnwsxD/view*
Jeffery K Smith [WHO]	Health and COVID-19	*drive.google.com/file/d/1wjUVVaA_5woJrTT5 QJ8rVfXbbKYFpDha/view*

Speaker [Affiliation]	Topic	URL
October 22, 2020		
Sagnik Dey [IIT Delhi]	High-Resolution, Satellite-Derived $PM_{2.5}$ Datasets Over India: Method, Validation, Access, and Applications	*drive.google.com/file/ d/1aIh7hvZv6cjEUAPy5my4fB_fpwdulLjC/ view*
Falguni Patadia [MSFC/ USRA]	Satellite Observations of Fires— Updates	*drive.google.com/file/d/1PHJa6AwvR90gdnU0f pqtncDW2TYmh37i/view*
October 29, 2020		
Wilfrid Schroeder [NOAA]	The NOAA/NASA VIIRS Active-Fire Science Dataset	*drive.google.com/file/ d/1wx1Wm5pZBQhXypfS7Ge6m8-xjkTLGsfg/ view*
Pawan Gupta	How Many Fires?	*drive.google.com/file/d/1QdrgnLjzQhieQ1V8h3 C23d1B8ZuDR13i/view*
November 5, 2020		
Sachin Ghude [IITM]	High-Resolution Operational Air-Quality Early-Warning System for Delhi	*drive.google.com/file/d/1ocrUDEvs441jOe55N deVpc1YwRndXXqe/view?usp=sharing*
Pawan Gupta	Fire-Season Updates	*drive.google.com/file/d/1nD2l_v8o84YD9Vk- FYDeiMqj63DTqKHI5/view?usp=sharing*
Narendran Kodandapani [CASER]	Emerging Trends in Wildfire Activity in the Western Ghats, India	*drive.google.com/file/d/1q4ksgx0hGyJYHdKAtsJ 5A1Ms3jYS3SeP/view?usp=sharing*
November 12, 2020		
Sachiko Hayashida [RIHN]	Project Aakash: An Interdisciplinary Study Toward Clean Air, Public Health, and Sustainable Agriculture: The Case of Crop-Residue Burning in North India	Not Available
Prakash Doraiswamy [RTI]	A Citizen Science Air Quality Network Deployment in the U.S. and India	*drive.google.com/file/d/1zjKPGmXmunMLAXp 0YqNzW3NKza5zkiLX/view?usp=sharing*
Pawan Gupta	Fire Season Updates	Not Available
November 19, 2020		
Vinay Sehgal	Summary of the 2020 Fire Season in Four States in Northern India	*drive.google.com/file/d/1Ku_ DqkGyuZYQ1C8yDHeRiQgkdslW_Mt9/ view?usp=sharing*
Pawan Gupta	Summary of Air Quality and Fires across India	*drive.google.com/file/d/1Wc0hsfzi2pZAYJ- V0PqMckXdzFJkzhAz/view?usp=sharing*

*Note that these titles match those given in the meeting agenda, which, in some cases, differ from what appears in the presentation online.

Meeting Format

Each weekly forum meeting began with an update on crop fire activity in Northern India and its impact on regional air quality. This included generating and discussing daily analyses of satellite measurements and model forecasts of fires, aerosols, and air quality. Owing to its high spatial resolution, the primary source of the data used in the analyses (from September 6 to November 30) was the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (NPP) satellite—see **Figures 2** and **3** on pages 20 and 22, respectively. NOAA provided the near-real-time (NRT) VIIRS aerosol data used in the analyses. The three-hour air quality forecasts for the next 72 hours in advance were made using NASA's Global Modeling and Assimilation Office's Goddard Earth Observing System—Forward Processing (GEOS-FP) forecast model integrated with a machine learning algorithm to bias correct for the local

meeting summaries
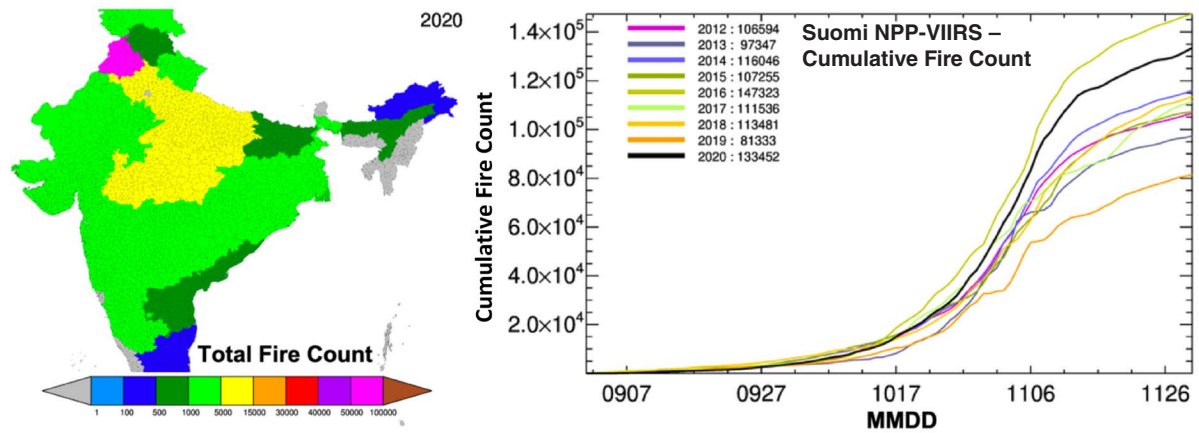
Figure 2. *Long-Term Fire Records over India.* The map shows total fire counts for each state in India as detected by VIIRS on Suomi NPP between September 6 and November 30, 2020 [*left*]. The graph [*right*] shows cumulative fire-count for the past nine years for the entire country. The small numbers next to each year are the total fire count for that year for the whole country. In nine years of VIIRS data records, the year 2016 (~147,000) was the most-active fire season, followed by 2020 (~133,000), whereas 2019 (~81,000) was the least-busy fire season. The state of Punjab observed the highest number of fires (~75,000), followed by Madhya Pradesh (~14,000), Haryana (~5000), and Uttar Pradesh (~5000). **Image credit**: Pawan Gupta

conditions. These forecasts were generated via a partnership with NASA's SERVIR[4] program.

After the opening analysis, each week included one or more presentations, which are listed in the Table on pages 18–19. About 70% of the weekly meeting time was allocated for presentations, whereas about 30% was utilized for Q&A and discussion. The next section gives some highlights from the weekly discussions.

Highlights from Forum Discussion

Most of the discussion at each individual meeting focused on topics and techniques introduced by specific speaker(s) each day and will not be repeated here. However, some recurring discussion topics were raised more than once during the individual meetings, and some selected examples of those are provided here.

One recurring discussion topic was the confusion encountered by some members of the end-user community who had little background in satellite remote sensing and in how to use and interpret fire-detection data correctly. This confusion is understandable: satellite-based fire detections are performed using multiple sensors—MODIS,[5] VIIRS, AHI,[6] and from the Indian National Satellite System (INSAT)-3D mission—each with varying instrument characteristics, e.g., spatial resolution, time of observations (i.e., diurnal variation,

day versus night), and weather conditions of observation (i.e., cloudy versus clear skies). The day-to-day variation in viewing geometry from polar-orbiting satellites results in inconsistent fire detection over a given region. The current fire-anomaly data provide the latitude and longitude of the center of the satellite *pixel* (the smallest area in a satellite image for which observations are available) and *fire radiative power* associated with the detected fire. The number of fire incidents in a given region is calculated differently by each sensor and, thus, the data vary from sensor to sensor and from day to day within each sensor.

Complicating the picture even further is that *some* of the observer variability is *real* (i.e., not a byproduct of the varying instrument properties) and reflects actual change in fire activity from day to day, while some arises due to changes in viewing geometry (and hence pixel size) of the sensor. The variability in pixel size can create a huge problem while analyzing fire activity on a daily scale.

There were some solutions proposed and discussed during the forum; for example, instead of looking at variability in *fire count*, perhaps measuring the total area of pixels detected as fire—which is not the same as the *burnt area*—may provide a better estimate of day-to-day variability because it would be affected less by viewing geometry. The total area can be calculated using scene- and track-position pixel size that is provided along with NRT data. Another proposed idea to tackle challenges of comparing measurements between sensors is to examine the running average of the fire count over four successive days, to account for the change in geometry on both sides of the swath.

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[4] SERVIR is not a acronym. It's a Spanish word that means "to serve." For more details see footnote 4 on page 8.
[5] MODIS stands for Moderate Resolution Imaging Spectroradiometer, which flies on NASA's Terra and Aqua platforms.
[6] AHI stands for Advanced Himawari Imager, which flies on the Japanese Meteorological Agency's Himawari-8 geostationary platform.

Beyond reconciling variations between different instruments, there are also issues with the same instrument on different platforms. The most relevant example for the context of this forum is that there are significant differences in fire counts measured using data from VIIRS on Suomi NPP and VIIRS on NOAA-20—which make measurements within 50 minutes of each other. There can be two possible geophysical reasons for the difference in fire count: change in fire activity within 50 minutes on the ground, and/or change in observational conditions (e.g., clouds, viewing geometry) within 50 minutes. While further investigation is needed to resolve these issues, initial analysis has shown that the difference in viewing geometry between NOAA-20 and Suomi NPP on a given day can produce significant fire count differences in a given region.

Another idea to capture more accurate fire activity on a daily scale (while counting fire detections from multiple sensors) is *gridding*. Gridding will allow merging data from multiple sensors observed on a certain day and create high-spatial-resolution datasets.

Another item noted during the forum discussions—but anecdotal at best—is that farmers are learning to follow (even "outsmart") satellite overpasses. Some farmers have become aware of satellite overpass times and may be timing their burning so that it takes place after the satellite passes over their region—thus avoiding detection. Another technique farmers sometimes use to avoid detection is watering their fields as they burn them.

There was discussion about the distinction between the requirements for fire information at the pixel level versus the requirements to distinguish geographic and political boundaries. The individual pixel-level data available from NASA's Fire Information for Resource Management System (FIRMS)[7] are sufficient to locate fires, but not for government and policymakers who also need to know fire data for individual administrative boundaries such as taluka, districts, and states.[8] To meet the requirements for both customers, geographic information system (GIS) techniques are used to flag each detected fire pixel with the appropriate place name. After that, the total fire counts were calculated for

each administrative boundary by counting the number of fires for each day. These data are processed for the current year and made available for India as daily files.

Another concern that came up often during forum discussions was identifying fire type using remote sensing data. It was suggested that high-resolution land-use information be integrated with fire data to filter fire types and improve accuracies in monitoring crop fire counts. Such information is already packaged in operational data, but the consensus was that it will be beneficial if this information can also be combined in NRT data.

The contribution of smoke from fires to local and regional air quality is another important issue that came up many times during the forum. This is one area where understanding is still limited, and current estimates have large uncertainties. Some investigators have incorporated MODIS-based fire emissions into community-scale air-quality models and can provide an estimate of the impact of fires on local air quality. However, the lack of updated emission inventories from anthropogenic sources makes it challenging to precisely identify how much each source contributes to the pollution. More robust measurements and modeling studies are required in the region to understand the amount and extent of the contribution from crop fires to total particulate matter with diameters of 2.5 μm or smaller ($PM_{2.5}$).[9]

A final topic of frequent conversation was how far smoke from crop fires in Punjab gets transported. To address this, some forum participants shared how they conducted a daily analysis of the NOAA smoke-detection product from both Suomi NPP and NOAA-20, and generated maps showing smoke transport in the region. Although some uncertainties in the detection as yet preclude a quantitative analysis, the maps provide an excellent qualitative visual to see the extent of smoke transport over the ISC—see **Figure 3** on page 22. There were many days during the fire season when winds were conducive for transporting smoke all the way to India's southern border. The plan is to continue evaluating smoke detection and to develop a more robust way to quantify the impact on air quality in different parts of the country.

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[7] FIRMS distributes three-hourly data for MODIS and VIIRS. Learn more at *earthdata.nasa.gov/earth-observation-data/near-real-time/firms*.

[8] In India, the smallest unit of community organization is called a *village*, a group of villages forms a *taluk*, several taluka form a *zilla* (or district), and several districts form a *rajya* (or state). What would be classified as a *county* in the U.S. would be equivalent to either a taluk or zilla, depending on its size.

[9] $PM_{2.5}$ is a criterion pollutant for air pollution measured by the U.S. Environmental Protection Agency.

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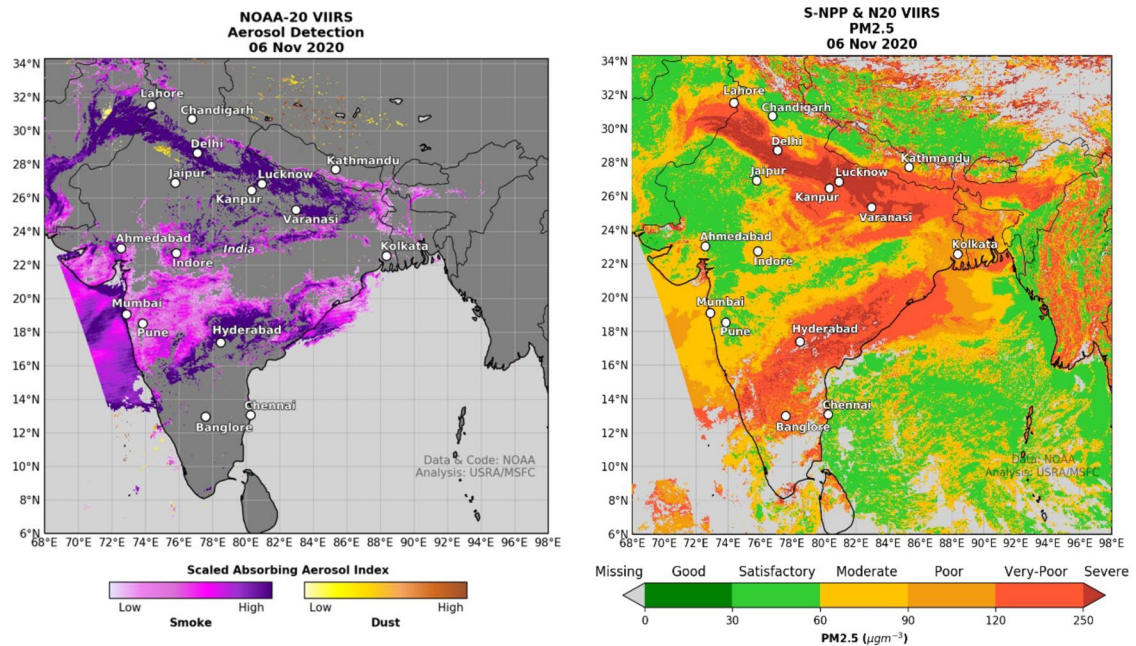
Figure 3. *Tracking Smoke Transport from Satellite*. The two maps here show an absorbing aerosol index derived using VIIRS data from NOAA-20 [*left*] and estimated PM$_{2.5}$ from Suomi NPP and NOAA 20 VIIRS data. [*right*] on November 6, 2020. On this date, more than 5000 crop-fire incidents were detected in the state of Punjab alone. The aerosol detection product [*left*] from NOAA provides the *qualitative* presence of smoke/dust. **Image credit**: Jashwanth Reddy Tupili [UAH]

Conclusion

The USRA/NASA team organized a first-of-its-kind community response forum to address post-monsoon crop stubble burning and its impact on local and regional air quality over India. The community met virtually in nine sessions over a period of two months, providing a forum to share research, NRT data, and impact stories. The forum was attended by scientists, students, advocacy groups, researchers, and media personnel representing various domestic and international agencies. The feedback received from the community on the forum suggested that the online discussion helped create situational awareness during the 2020 burning season. The forum also provided an opportunity to share research applications and related activities that have advanced knowledge of biomass burning and air quality over India. Participants highly appreciated the daily satellite analyses of fires and air quality for the region generated by the NASA/USRA team and made available through an online portal (*www.firesandaq2020.info*). Interactive discussions of the analysis occurred during these forum meetings. Similar efforts in the future will help build awareness and enhance the application of Earth observations in management of crop fires and resulting air quality in that region.

NASA Study Finds Reduced African Grassland Fires Contribute to Short-Lived Air Quality Improvements

Sofie Bates, NASA's Goddard Space Flight Center, sofie.bates@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*.

NASA researchers have found a small but unexpected decrease in air pollution over some parts of Africa despite growing use of fossil fuels in many countries due to development and economic growth. However, they note the findings were evident only during the dry season over areas where a reduction in grassland fires occurred—which likely will not be enough to offset growing human-caused air pollution in the long term.

Researchers from NASA's Goddard Institute for Space Studies (GISS) analyzed satellite observations of the air pollutant nitrogen dioxide (NO_2), a gas that causes respiratory illnesses in humans and can increase the formation close to Earth's surface of other pollutants like particulate matter and ozone, which are also harmful to human health. They found that over the northern grassland region of sub-Saharan Africa—for the period from 2005 to 2017—during the dry season, (November through February) NO_2 dropped by 4.5%, about a 0.35% annual decline on average—see **Figure**.
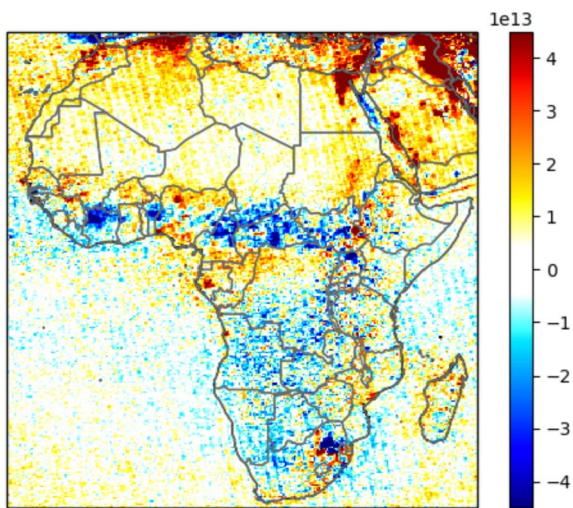
Figure. Trend in atmospheric NO_2 concentrations over Africa from 2005 to 2017. Notice that air quality improved (represented by decreasing NO_2 levels shown as negative values) in the northern savanna of Africa, where biomass burning declined significantly. **Image credit:** Jonathan Hickman/GISS

Though the decrease was small, it was unexpected, as higher fossil fuel consumption was expected to result in increased pollution levels.

The scientists attribute this small but unexpected air quality improvement to the fact that a decrease in burning grasslands from wildfires and controlled burns offset the increased burning of fossil fuels during the four months of the dry season. The total area of savanna burned in sub-Saharan Africa is getting smaller each year, as woodlands and grasslands are converted to agricultural land and more densely populated towns and villages.

Researcher **Jonathan Hickman** [GISS] cautions that this positive trend may continue only to a point. Eventually, there may be a net worsening of air quality as the pollution resulting from the amount of fossil fuels burned surpasses what the decline in natural wildfires during the dry season can offset.

In addition, the study found that air quality only improved during the dry season, when the decline in wildfires was more apparent; pollution increased somewhat during the rainy season, but not enough to cancel out the decreases during the dry season.

Results from Hickman and his research team at GISS were published February 8, 2021, in the journal *Proceedings of the National Academy of Sciences*.[1]

The GISS team analyzed measurements of NO_2 from the Dutch–Finnish Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite. In addition to monitoring stratospheric ozone, OMI also measures harmful air pollutants like NO_2, sulfur dioxide (SO_2), and formaldehyde (HCHO) in the atmosphere. NO_2 is primarily released as a byproduct of burning fossil fuels for electricity or in automobiles, from burning of vegetation like grasslands or crops, and by soil microbes. ■

[1] To read the study, visit *www.pnas.org/content/118/7/ e2002579118.short*.

in the news

NASA Snow Campaign Digs Deep in 2021

Jessica Merzdorf, 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*.

Whether the first snowflakes of winter fill you with glee or make you groan, winter snowfall is a crucial water source for drinking, agriculture, and hydropower for more than one billion people worldwide.

To plan water management and disaster preparedness during the rest of the year, hydrologists and resource managers need to know how much water each winter's snowpack holds. Currently, ground or airborne observations of that measurement—called *snow-water equivalent* (SWE), pronounced "swee"—are collected at only a very limited number of locations around the world. However, NASA hopes in the future to launch a global satellite mission to track this precious resource from space.

To design a mission that can measure all the snow characteristics that make up SWE, scientists need to determine what instrument combination to use—since no one instrument can do it alone. Enter NASA's SnowEx[1] field campaign, which measures snow properties like depth, density, grain size, and temperature using a variety of instruments, on the ground and in the air. A potential future NASA global snow mission will combine multiple remote sensing instruments, field observations, and models—and SnowEx is discovering the best combination for the job.

Meeting the Measurement Challenges

Measuring snow might seem straightforward, but each environment brings unique challenges for remote sensing instruments. For example, snowfall in forests gets caught in branches or falls underneath the tree canopy, making it more difficult to measure remotely than snow that falls on an open landscape.

To dig into those differences, SnowEx measures snow from the ground and by air. The ground and air teams take similar measurements to compare their results, gauging how similar instruments perform under different conditions.

"Airborne observations allow us to collect high-resolution data over a large area, allowing simulation of remote sensing observations we might get from a satellite, at a range of resolutions and spatial extents,"

Figure. In a video posted on YouTube at *youtu.be/Ay0tl7qusUw*, **Carrie Vuyovich** [NASA's Goddard Space Flight Center—*SnowEx 2021 Project Scientist* and *Lead Snow Scientist for NASA's Terrestrial Hydrology Program*] explains how NASA's SnowEx ground and airborne campaign is a multiyear effort using a variety of techniques to study snow characteristics. **Credit:** NASA's Goddard Space Flight Center/Scientific Visualization Studio/Boise State University

said **Carrie Vuyovich** [NASA's Goddard Space Flight Center—*SnowEx 2021 Project Scientist* and *Lead Snow Scientist for NASA's Terrestrial Hydrology Program*]. "Ground observations do not have the same spatial coverage but allow us to validate the sensing technique in multiple, diverse locations, and the small footprint simplifies interpretation."

This year, the SnowEx team will deploy airborne lidar, radar, and imaging systems to measure snow depth, changes in SWE, and the albedo of the snow surface, while collecting similar and complementary data over the same locations on the ground to compare and validate results—see **Figure**. The albedo is the fraction of energy from the Sun reflected from a surface, a critical snow property for modeling melt.

There are three primary goals for the SnowEx 2021 campaign. The first goal is to repeat the L-band Interferometric Synthetic Aperture Radar (InSAR)[2] airborne measurement time series that was cut short by COVID-19 in spring 2020. This year, NASA/Jet Propulsion Laboratory's Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument will fly on a Gulf Stream 3 (G-3) aircraft weekly over each of six sites in Idaho, Utah, Colorado, and Montana, from mid-January through late March.

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[1] UPDATE: This News story was writeen before the 2021 SnowEx flights began. As of the publication of this newsletter they are ongoing, expected to continue through late April. Learn more in the Editorial of this issue.

[2] InSAR is a radar technique that estimates snow depth similarly to lidar, tracking changes in how long it takes for radar pulses to travel from the aircraft to the bottom of the snowpack and back.

In 2022, NASA and the Indian Space Research Organisation (ISRO) will launch the NASA–ISRO Synthetic Aperture Radar (NISAR) mission, a space-based InSAR mission to study Earth's surface, including land, water, and ice. SnowEx's InSAR explorations will inform future snow research with NISAR and other radar missions. The team will use lidar to validate the InSAR measurements on the ground.

Secondly, the team will use a *spectrometer*—an instrument that measures the intensity of visible and infrared radiation as a function of wavelength—to study albedo. Measuring albedo with spectrometers is a component of NASA's Surface Biology and Geology (SBG) study, which is developing research initiatives to better understand Earth's land and water ecosystems as part of the National Academies of Sciences, Engineering, and Medicine's decadal survey.[3] This is the first year SnowEx is directly targeting high-quality albedo observations, which will be focused in forested, steep terrain during the melt period. The team will fly NASA's Airborne Visible/InfraRed Imaging Spectrometer-Next Generation (AVIRIS-NG) over two sites in Colorado during March and April to collect these observations.

A third goal for 2021 is to investigate snow properties in prairie landscapes. Snow is difficult to measure on prairies using the same approaches as over mountains because of their shallower depths.

"Prairie landscapes are identified as a gap in our remote sensing capabilities," said Vuyovich. "The *substrate*—the ground underneath—affects the signals and the ability to measure shallow snow. In addition, the spatial distribution of the snow in that environment is different from other environments and can be difficult to measure and validate. Wind plays a significant role in redistributing snow across the landscape, which includes fields, crops, stubble, and ditches, leaving deep drifts and bare patches."

On the ground, teams dig *snow pits*—car-sized holes in the snow that reach down to the ground—and measure snow depth, water content, temperature, reflectance, and grain size in the pit walls. Other team members on skis or snowshoes take handheld probe measurements of snow depth and albedo with field spectrometers. Using a snow micropenetrometer, measurements of the force on the probe tip provide detailed profiles of snow hardness and microstructure. The ground team also uses radar to rapidly measure how snow properties vary across the area of a typical satellite sensor pixel. The radar systems are mounted on snowmobiles or towed while skiing.

"This year we have some new instruments, like helicopter- and UAV-based lidar surveys, which allow us to adapt to weather and line up these calibration and

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[3] For more information, visit *go.nasa.gov/2wXJn2n*.

validation surveys with the airborne radar. The low-cost flight platforms allow more frequent surveys over a given area than from a fixed-wing aircraft, which is important for this time series experiment," said **Hans Peter "HP" Marshall** [Boise State University—*SnowEx 2021's Co-Project Scientist*]. Airborne lidar works by bouncing laser pulses off the surface and measuring the time it takes for the pulse to return. By tracking differences in timing across the landscape, lidar creates a three-dimensional picture of the height and structure of the surface below. Scientists can calculate snow depth by comparing lidar measurements of the same area when there is snow with surveys from when there is no snow.

In addition to collecting observational data, SnowEx's modeling research helps the team see how snow changes across different terrains and time.[4]

"Modeling fills in the gaps in the remote sensing and ground observations," said Marshall. "In hard-to-measure areas like forests, models can use remote sensing observations in open areas to define precipitation patterns, allowing predictions of snow properties in the forest. Some of the remote sensing approaches that measure depth, such as lidar, also require models to estimate snow density, to allow conversion of depth to SWE. Between remote sensing acquisitions, models continue to simulate snow conditions. The models can be constantly updated when and where the remote sensing and ground observations of snow properties are available. All three approaches work together to provide the best estimates of snow conditions."

"People use models for different reasons," Vuyovich said. "Water managers could use models to help make decisions. NASA's Terrestrial Hydrology Program and SnowEx efforts will help design what we need from a satellite: what coverage, temporal frequency, accuracy, and resolution are needed. Models can also help us fill in the gaps we may get between space-based observations."

Navigating a Challenging Landscape

In the sequential component of each campaign, SnowEx teams at sites across the western U.S. collect snow data weekly from December through May.[5] Normally, this effort is punctuated by an intensive two- or three-week period of intensive data collection in one area, larger than the other site areas. In order to protect the teams during the ongoing COVID-19 pandemic, however, this year's campaign will only include the time

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[4] To learn more about NASA's snow research, visit *snow.nasa.gov*. Also see "Summary of NASA's Terrestrial Hydrology Program 2020 Snow Virtual Meeting" in the November–December 2020 issue of *The Earth Observe*r [**Volume 32, Issue 6**, pp. 31–38—*go.nasa.gov/31W16TV*].
[5] To follow SnowEx 2021 in the field, watch *go.nasa.gov/2PoD6WG*.

in the news

series. At each site, only local teams within a two-hour drive of their home base will collect ground observations over a limited area, to avoid the need for overnight stays or gathering in large groups.

"This is a pandemic world, and we're doing a lot virtually," Marshall said. "I'm excited that we're able to navigate this, that we have dedicated local field crews who can do this safely, and that we can still get on the snow. Our committed local field teams include students and researchers from many different government labs and universities, who deploy to their respective fields each week, on the same day as the overflights."

Most years, NASA and SnowEx partner with local schools and organizations to support citizen science efforts and educational opportunities, but this year

those activities will happen virtually through blogs, videos, and remote data collection. SnowEx's primary outreach partner is the Winter Wildlands Alliance SnowSchool, a nationwide program with 70 sites that reaches 35,000 K–12 students. This year, they have developed virtual snow science activities to allow K–12 students to continue to learn about snow during the pandemic (*winterwildlands.org/homeschool-snowschool*), as well as follow-on activities for schools that have been to Snow School in the past.
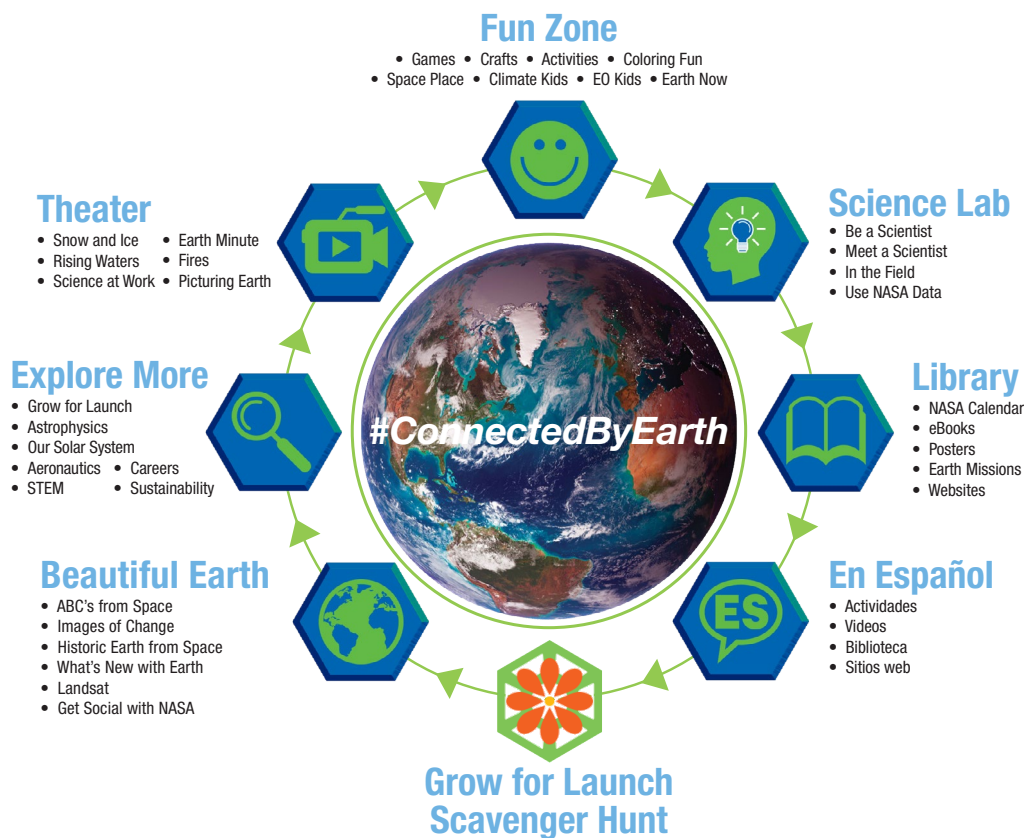
"We're excited this is happening," said Vuyovich. "With all of these challenges, we're excited that people are going to get out in the field and that we can continue to push forward. I may not see much snow here in DC, so I'll be living vicariously through these photos and blogs." ■

announcement

NASA's 2021 Virtual Earth Day Event

A variety of Earth Day activities, including on-demand theater content, games, videos, and great downloadable posters and books, are available through the month of May for NASA's Earth Day Virtual Event. Register at *go.nasa.gov/JoinEarthDay2021*.

From April 21 through May 31, 2021, anyone can join the free, online event.

Fun Zone
• Games • Crafts • Activities • Coloring Fun
• Space Place • Climate Kids • EO Kids • Earth Now

Theater
• Snow and Ice   • Earth Minute
• Rising Waters   • Fires
• Science at Work   • Picturing Earth

Science Lab
• Be a Scientist
• Meet a Scientist
• In the Field
• Use NASA Data

Explore More
• Grow for Launch
• Astrophysics
• Our Solar System
• Aeronautics   • Careers
• STEM   • Sustainability

Library
• NASA Calendar
• eBooks
• Posters
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• Websites

#ConnectedByEarth

Beautiful Earth
• ABC's from Space
• Images of Change
• Historic Earth from Space
• What's New with Earth
• Landsat
• Get Social with NASA

En Español
• Actividades
• Videos
• Biblioteca
• Sitios web

Grow for Launch
Scavenger Hunt

NASA Data Powers New USDA Soil Moisture Portal

Teresa White, U.S. Department of Agriculture's National Agricultural Statistics Service, teresa.white@usda.gov
Jane Lee, NASA/Jet Propulsion Laboratory, jane.lee@jpl.nasa.gov
Jessica Merzdorf, 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*.

Farmers, researchers, meteorologists, and others now have access to high-resolution NASA data on soil moisture, thanks to a new tool developed by the U.S. Department of Agriculture (USDA)'s National Agricultural Statistics Service (NASS) in collaboration with NASA and George Mason University.

The tool, Crop Condition and Soil Moisture Analytics (Crop-CASMA), provides access to high-resolution data from NASA's Soil Moisture Active Passive (SMAP) mission and the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument in a user-friendly format—see **Figure**. Soil moisture data are critical for professionals in the agriculture and natural resources sectors who use soil moisture in tandem with other data to plan crop planting, forecast yields, track droughts or floods, and improve weather forecasts. Crop-CASMA is available for free online at *cloud.csiss. gmu.edu/Crop-CASMA*.

The tool provides more thorough spatial coverage and consistency than other soil moisture measurement methods, said **Rajat Bindlish** [NASA's Goddard Space Flight Center (GSFC)].

"Soil moisture is a very important piece of information for agricultural yield and productivity," said Bindlish. "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."

Some of Crop-CASMA's primary users will be USDA NASS researchers and statisticians, who release weekly Crop Progress Reports that currently classify states into moisture categories (very short, short, adequate, surplus) to aid farmers and farm managers. The reports also track crops' health and growing progress.

USDA researchers and statisticians will incorporate the tool into applications from spotting flooded fields to identifying conditions that might prevent planting, said **Rick Mueller** [USDA].

"There are also challenges deriving early season crop acreage estimates using remote sensing methods," Mueller said. "Crop-CASMA can help identify areas that could not be planted because of wet, saturated, frozen, excessively dry, or inaccessible fields resulting in improved planted statistical acreage estimates."

In addition to supporting agricultural operations, it will enable research into sustainability and the impact of extreme weather events, Mueller said. "These satellite-derived vegetation condition indices and soil moisture condition maps show first-hand the ever-changing landscape of U.S. agriculture."
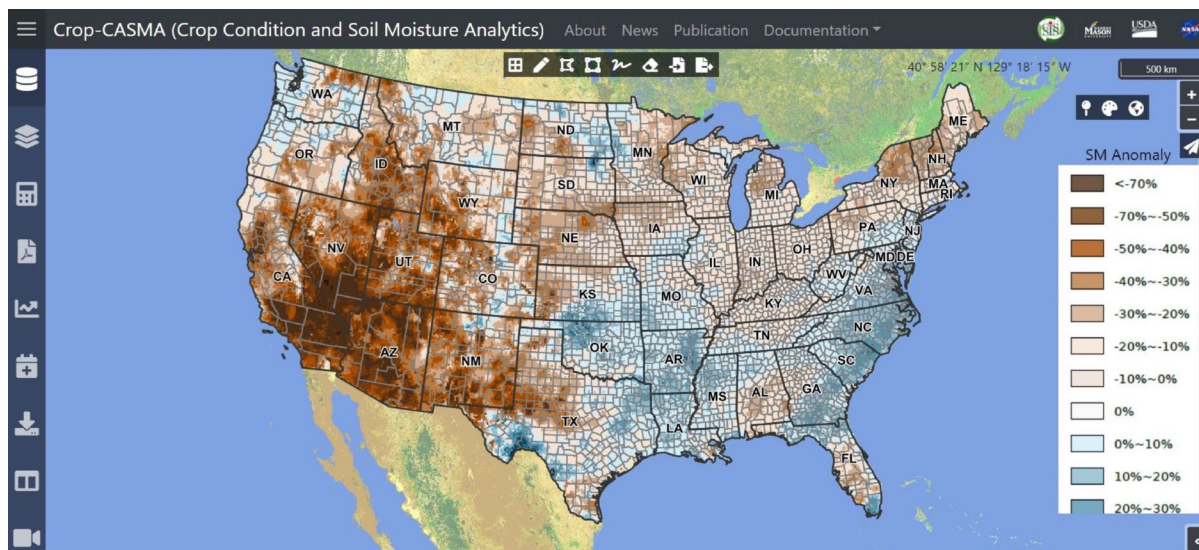
Figure. A screenshot of the Crop-CASMA web-based geospatial application tool. This application is designed for users to utilize the remotely sensed geospatial soil moisture and vegetation index data derived from SMAP and MODIS data to assess conterminous U.S. crop vegetation conditions and soil moisture condition. **Image credit:** NASA

in the news

The tool is formatted to be accessible to private users, including farmers, researchers, and students, said **Zhengwei Yang** [USDA—*Crop-CASMA Project Leader*], a USDA geographer and co-investigator of the High-Resolution Soil Moisture Development Project.

"We created an easy-to-use interface that requires little technical background to use," said Yang. "There's a tool to select an area and create a map you can save as a PDF, and you can also download data from the web to input into your model."

The SMAP data that are the foundation for Crop-CASMA are from the topsoil and rootzone levels, or from the surface to roughly 1 m (3 ft) underground. Raw SMAP data have a 36-km (roughly 22-mi) spatial resolution, meaning each data "footprint" is about the size of a county. The team also developed a data analysis method to estimate a higher-resolution soil moisture product using SMAP and land surface data, giving users information at 1-km (0.62-mi) resolution.

Having the data in finer resolution allows users to more accurately pinpoint areas of high or low moisture, said Yang.

"Our current reports are at the state level," Yang said. "One state may be categorized on average as *wet*, but the whole state might not actually be wet. For instance, one area of a state might be wet, while another might be dry. These new data deliver localized moisture readings—this is what matters to the farmer."

Crop-CASMA was developed in cooperation with the Center for Spatial Information Science and Systems (CSISS) at George Mason University, NASA's Goddard Space Flight Center, and NASA's Jet Propulsion Laboratory (JPL). JPL manages the SMAP mission for NASA, and Goddard produces the SMAP 9-km (5.6-mi) rootzone and 1-km surface soil moisture products. Hosted and maintained by the CSISS, the online tool is operated by NASS's Research and Development Division.

This work was also supported by NASA's Western Water Applications Office (WWAO) and the NASA Terrestrial Hydrology Program. WWAO's mission is to improve how water is managed in the arid western U.S., and the tool is part of a portfolio of water projects that use the power of remote sensing to deliver new solutions to water managers on issues including drought, agriculture, snowpack and water supplies.

"We know from our water partners in the western U.S. that there is a critical need for soil moisture data," explained **Indrani Graczyk** [WWAO]. "This project was a great opportunity to partner with the USDA to get NASA data directly into the hands of farmers, and we were happy to support it."

This collaboration is part of a larger, recently signed agreement between USDA and NASA to jointly strengthen agricultural and Earth science research.

"Having the SMAP soil moisture data going directly to the users at NASS realizes one of the key goals of the mission," said **Simon Yueh** [JPL—*SMAP Project Scientist*]. "A strong collaboration between NASA and USDA has made this possible." ■

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kudos

MOPITT Canadian Principal Investigator Receives Two Awards

James Drummond [Dalhousie University] was awarded the John H. Chapman Award of Excellence in March in part for his work as the Canadian Principal Investigator for the Measurement of Pollution in the Troposphere (MOPITT) instrument that flies on NASA's Terra mission. The Chapman Award is presented by the Canadian Space Agency in recognition of remarkable contributions to the advancement of the Canadian Space Program. The award follows Drummond's receipt of the Canadian Aeronautics and Space Institute's Alouette Award in January that recognizes outstanding contributions to advancement in Canadian space technology, application, science, or engineering. Drummond has been PI of MOPITT from its conception, to launch in 1999, and has overseen its continued operation over the past 22 years. *The Earth Observer* would like to congratulate Drummond on these prestigious achievements.
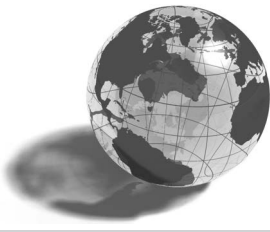
NASA Earth Science in the News

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*.

*Africa's Air Quality Has Improved Due to Reduced Fire, According to Research, March 15, *africanews. space*. Six researchers from the U.S., France, and Côte d'Ivoire have published a report showing a small but unexpected decrease in air pollution over some parts of Africa in recent years resulting in improved air quality. The study, titled "Reductions in NO_2 burden over north equatorial Africa from decline in biomass burning despite growing fossil fuel use, 2005 to 2017," was published in the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS).[1] The study found that nitrogen dioxide (NO_2) concentrations over the northern grassland region of sub-Saharan Africa dropped by 4.5% during the dry season (November through February). NO_2 is released as a byproduct of burning fossil fuels for electricity or transportation, from burning vegetation like grasslands or crops, and by the activity of soil microbes. The gas can cause or aggravate respiratory illnesses in humans and increase airborne particulates and ozone formation close to the Earth's surface. According to the research, air pollution reduction is most evident during the dry season in areas where grassland fires traditionally occur. While the researchers caution that the small seasonal decrease may not be enough to offset increasing human-caused air pollution in the long term, the results from this study do show an interesting shift in the air quality of this region. "The traditional paradigm is that as middle and low-income countries grow, you often see more emissions, and to see a different kind of trajectory is very interesting", said lead author **Jonathan Hickman** [NASA's Goddard Institute for Space Studies]. "It's nice to see a decline occurring when you'd expect to see pollution increasing." The researchers used data from the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite to track changes in NO_2 concentrations over Africa during November through February between 2005 to 2017. The scientists attributed the change to a decrease in wildfires and controlled burns in grasslands during the dry season.

Humans Drive Most of the Ups and Downs in Freshwater Storage at Earth's Surface, March 4, *spacedaily.com*. Water levels in the world's ponds, lakes, and human-managed reservoirs rise and fall from season to season. But until now, it has been difficult to parse out exactly how much of that variation is caused by humans and how much can be attributed to natural cycles. Analysis of new satellite data published March 3 in *Nature* shows fully 57% of the seasonal variability in Earth's surface water storage now occurs in dammed reservoirs and other water bodies managed by people. "Humans have a dominant effect on Earth's water cycle," said lead author **Sarah Cooley** [Stanford University, School of Earth, Energy and Environmental Sciences (Stanford Earth)]. The scientists used 22 months of data from the Advanced Topographic Laser Altimeter System (ATLAS) on NASA's Ice, Cloud, and land Elevation Satellite–2 (ICESat–2). ICESat–2 launched in October 2018 and has collected highly accurate measurements for 227,386 water bodies worldwide—including some smaller than a soccer field. "Previous satellites have not been able to come anywhere close to that," said Cooley, who performed most of the analysis on a laptop, stationed on her parents' couch, after coronavirus restrictions canceled her scheduled field season in Greenland. "I needed to find a project I could work on remotely," she said. Cooley and colleagues found that water levels in Earth's lakes and ponds change about 8.6 in (21.9 cm) between the wet and dry seasons. Meanwhile, human-managed reservoirs fluctuate by nearly four times that amount, rising and falling by an average of 2.8 ft (0.8 m) from season to season. The western U.S., southern Africa, and the Middle East rank among regions with the highest reservoir variability, averaging 6.5 to 12.4 ft (2.0 to 3.8 m). They also have some of the strongest human influence, with managed reservoirs accounting for 99% or more of the seasonal variations in surface water storage.

[1] To read the study, visit *www.pnas.org/content/118/7/e2002579118*.

NASA earth science in the news

New Data Help Quantify Role of Forests in Global Carbon Cycle, March 2, *kxan.com*. NASA scientists, in collaboration with other international researchers, have a new approach for assessing the important role forests play in our world's carbon cycle. This revised evaluation now uses ground, aerial, and satellite data to not only gauge the overall role forests play in absorbing carbon, but also the effect of various types of forests in the global carbon budget. Despite standardized guidelines issued by the Intergovernmental Panel on Climate Change (IPCC), data between countries still varies due to lack of resources. The new methodology differs from what's currently in place by using numerous sources of data to create a more consistent global framework. These additional data will help reduce the error where current metrics are not uniform and estimates are made. "All estimates come with an uncertainty around them, which is going to keep getting smaller and smaller as we get better datasets," said **Lola Fatoyinbo** [NASA's Goddard Space Flight Center]. The study integrates lidar data from three different NASA satellite missions [Ice, Cloud, and land Elevation Satellite (ICESat), ICESat-2, and Global Ecosystem Dynamics Investigation (GEDI)] as well as from NASA's Carbon Monitoring System Biomass Pilot.[2] These additional data will give scientists a more accurate picture of the state of the Earth's carbon cycle and are expected to help better inform policy-makers.

Atmospheric Rivers Increase Snow Mass in West Antarctica, March 2, *sciencedaily.com*. A new study published in the journal *Geophysical Research Letters* used NASA's ice-measuring laser satellite (i.e., ATLAS) to identify atmospheric river storms as a key driver of increased snowfall in West Antarctica during the 2019 austral winter.[3] These findings from scientists

at Scripps Institution of Oceanography (SIO) at the University of California San Diego and colleagues will help improve overall understanding of the processes driving change in Antarctica and lead to better predictions of sea-level rise. This is a NASA-funded study, with additional support from the Rhodium Group's Climate Impact Lab, which is a consortium of leading research institutions examining the risks of climate change. NASA's ICESat-2, launched into orbit in September 2018, is providing a detailed look at the height of ice and snow on the vast, frozen continent. "ICESat-2 is the first satellite to be able to measure snowfall over the Antarctic continent in such a precise way," said glaciologist **Helen Amanda Fricker** [SIO], co-author of the study. "In winter, weather conditions prohibit having a field team there making observations on the ground. ICESat-2 is filling in this lack of data over the vast ice sheets and giving us a greater understanding of snow mass gain and loss on a seasonal scale." Looking at ICESat-2 data, scientists found increases in height over the Antarctic Ice Sheet between April 2019 and June 2020 due to increased snowfall. Using a computational model of the atmosphere and snow, they found that 41% of height increases over West Antarctica during the 2019 winter occurred because intermittent extreme precipitation events delivered large quantities of snow during short periods of time. Of those events, 63% were identified as landfalling atmospheric rivers. These systems were distinguished from other storms by the much higher moisture levels measured in the lower portions of the atmosphere.

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

[2] The CMS Biomass Pilot utilized data from satellite and airborne sensors and in situ field measurements to improve quantitative estimates—with reduced uncertainties—of above ground terrestrial vegetation. To learn more visit *go.nasa.gov/3m2KUJO*.
[3] To read the study, visit *agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GL091076*.

▮ Earth Science Meeting and Workshop Calendar ▮

NASA Community

April 21–24, 2021
NASA's 2021 Virtual Earth Day Event
go.nasa.gov/JoinEarthDay2021

May 11–13, 2021
CERES–Libera online Science Team Meeting
go.nasa.gov/39RP2HO
Microsoft Teams link to attend the meeting will be
provided at URL above.

Global Science Community

April 19–30, 2021
EGU General Assembly, *virtual*
www.egu21.eu

May 30–June 2, 2021
Japan Geoscience Union Meeting, *virtual*
www.jpgu.org/meeting_e2021

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

NASA's Aura Mission Makes Appearance on "Jeopardy"

I'll Take "Up in the Air" for $800, Katie.

The answer: *This 4-letter word for a radiant
light around something is the name of the NASA
satellite mission studying the air we breathe since
2004.*
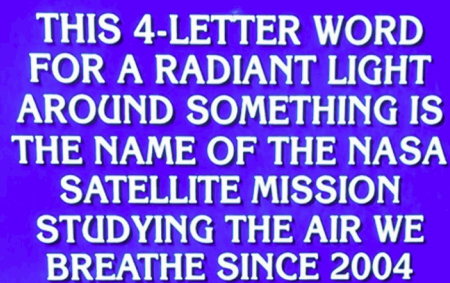
The question, of course, is: *What is Aura?*

This answer and question pair was featured
on the March 12, 2021, episode of the long-
running television game show *Jeopardy*. **Katie
Couric** was the guest host for this episode.

THIS 4-LETTER WORD
FOR A RADIANT LIGHT
AROUND SOMETHING IS
THE NAME OF THE NASA
SATELLITE MISSION
STUDYING THE AIR WE
BREATHE SINCE 2004

One of the contestants guessed: *What is HALO?* While HALO, or Hydrogen Albedo Lunar Orbiter, is also a
NASA satellite mission (a Planetary Science CubeSat), this was not the correct question in this case. The next
contestant gave the right question: *What is Aura?*

Congratulations to the Aura team on achieving this fun moment of outreach for the mission.

To learn more about the answers/questions featured on the March 12, 2021 episode of Jeopardy, see
jeopardyarchive.com/jeopardy-march-12-2021-answers.
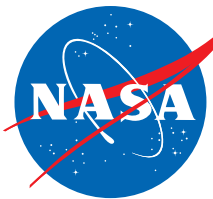
eospso.nasa.gov

The Earth Observer

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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.

To subscribe to *The Earth Observer*, or to change your mailing address, please call **Cindy Trapp** at (301) 614-5559, or send a message to *Cynthia.trapp-1@nasa.gov*. If you would like to stop receiving a hard copy and be notified via email when future issues of *The Earth Observer* are available for download as a PDF, please send an email with the subject **"Go Green"** to *cynthia.trapp-1@nasa.gov*. Your name and email address will then be added to an electronic distribution list and you will receive a bi-monthly email indicating that the next issue is available for download. If you change your mind, the email notification will provide an option for returning to the printed version. Finally, note that print copies of *The Earth Observer* are no longer sent to addresses at GSFC; they will be emailed to the addresses we have in our database. If you are located at GSFC and still wish to receive a print copy, you may provide a home (or alternative) address to Cindy Trapp, and we can add it to our database.

The Earth Observer Staff

Executive Editor:	Alan B. Ward (*alan.b.ward@nasa.gov*)
Associate Editor:	Heather H. Hanson (*heather.h.hanson@nasa.gov*)
Assistant/Technical Editor:	Mitchell K. Hobish (*mkh@sciential.com*)
Technical Editor:	Ernest Hilsenrath (*hilsenrath@umbc.edu*)
Assistant Editor:	Douglas Bennett (*douglas.bennett@nasa.gov*)
Design, Production:	Deborah McLean (*deborah.f.mclean@nasa.gov*)
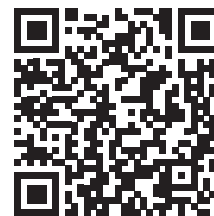
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