Over Thirty Years Reporting on NASA's Earth Science Program

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The Editor's Corner

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EOS Senior Project Scientist

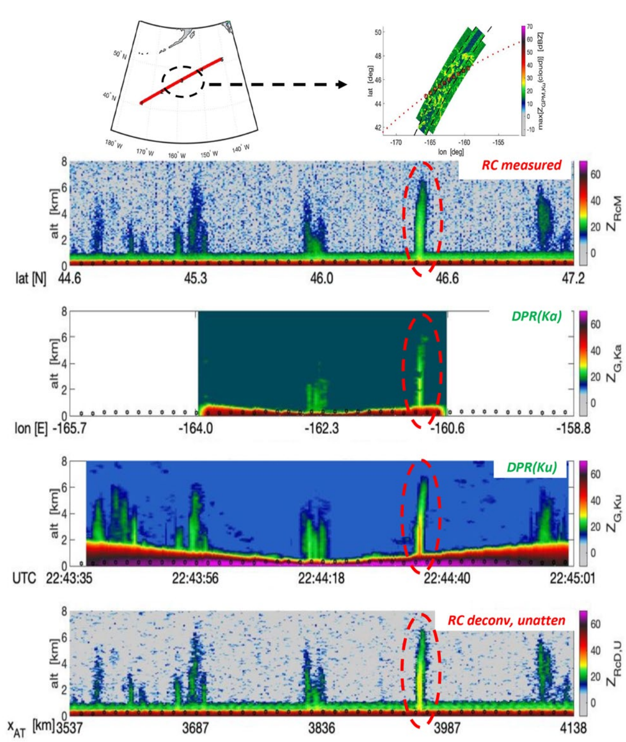
The Biden Administration has taken an important step in pursuit of its climate science objectives for NASA, creating the new position of senior climate advisor. **Gavin Schmidt** [NASA's Goddard Institute for Space Studies (GISS)] has been appointed to serve in the role in an acting capacity until a 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*.

continued on page 2



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*.

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]

[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. ■

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

[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*.

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

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.

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.

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.

[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*.

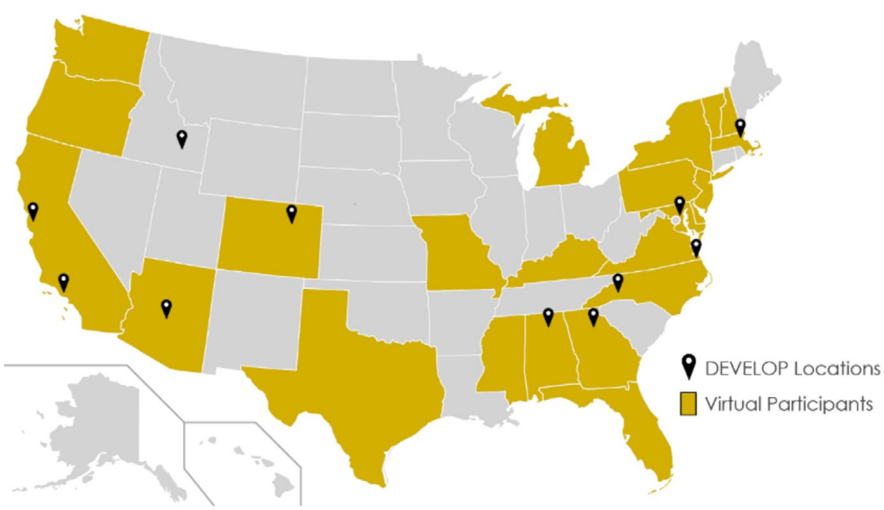


Figure 1. Map of 11 DEVELOP host locations and virtual participation for the Summer 2020 term. **Image credit**: NASA DEVELOP

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.

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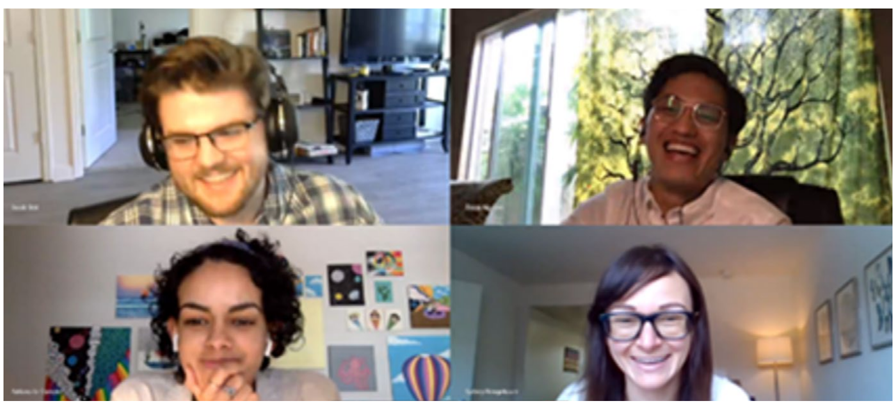

Photo. DEVELOP participants utilized video-conferencing tools to collaborate on projects across time zones. Shown here are [*clockwise from top left*]: **Jake Stid** [SSAI/Michigan State University], **Derek Nguyen** [SSAI/University of California, Santa Barbara], **Sydney Neugebauer** [SSAI/Boston University],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

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.

> "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*]

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

[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.

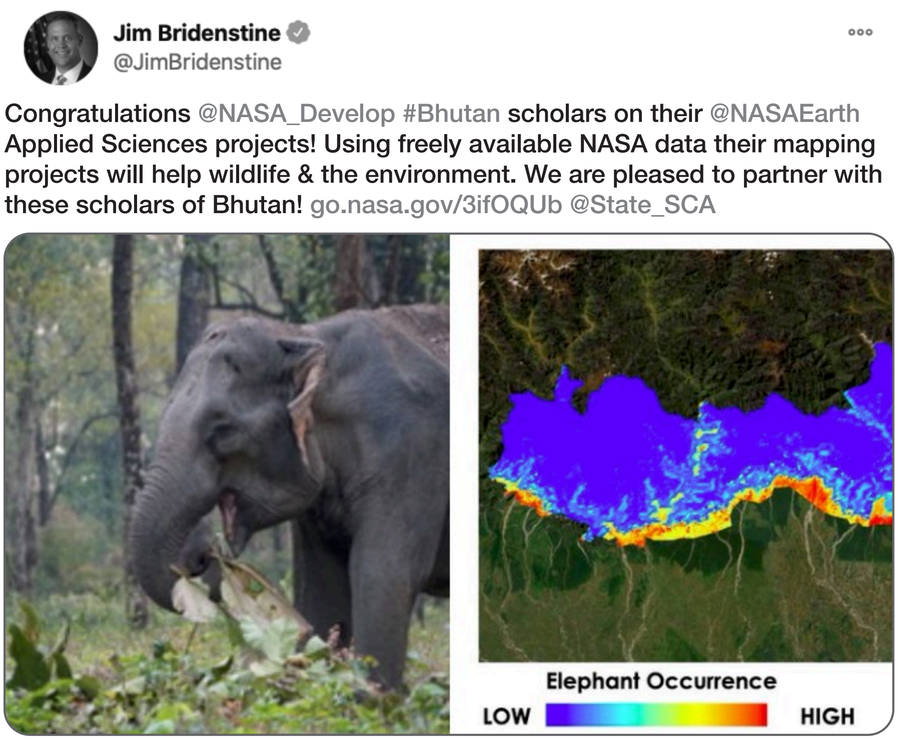

Figure 2. **NASA Administrator Jim Bridenstine** highlighted the Summer 2020 Bhutanese scholars and their work on the Southern Bhutan Ecological Forecasting and Bhutan Water Resources projects on social media. **Image credit**: NASA

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*).

- ***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.

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

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

[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*.

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.

“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*]

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.

[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*.

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.

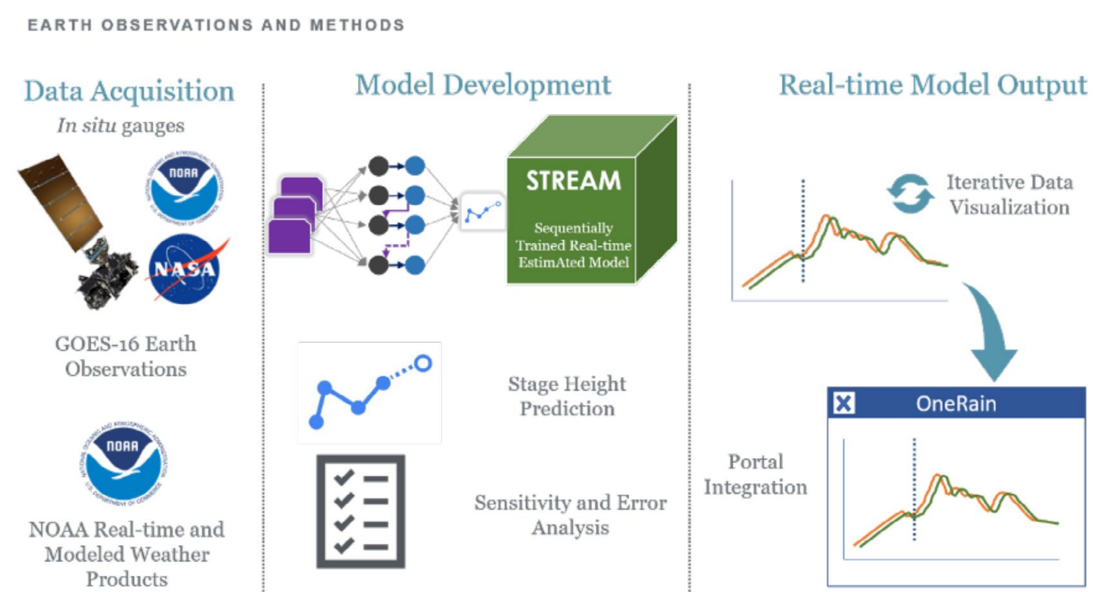

Diagram of the methodology used by the Ellicott City Disasters DEVELOP team to predict flood stage height. There are three primary stages: the acquisition of *in situ* stream-gauge and Earth observation data [*left*], machine-learning model development and training [*center*], and model output visualizations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

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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

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

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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

[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

[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.

[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*.