meeting summaries

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.*

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

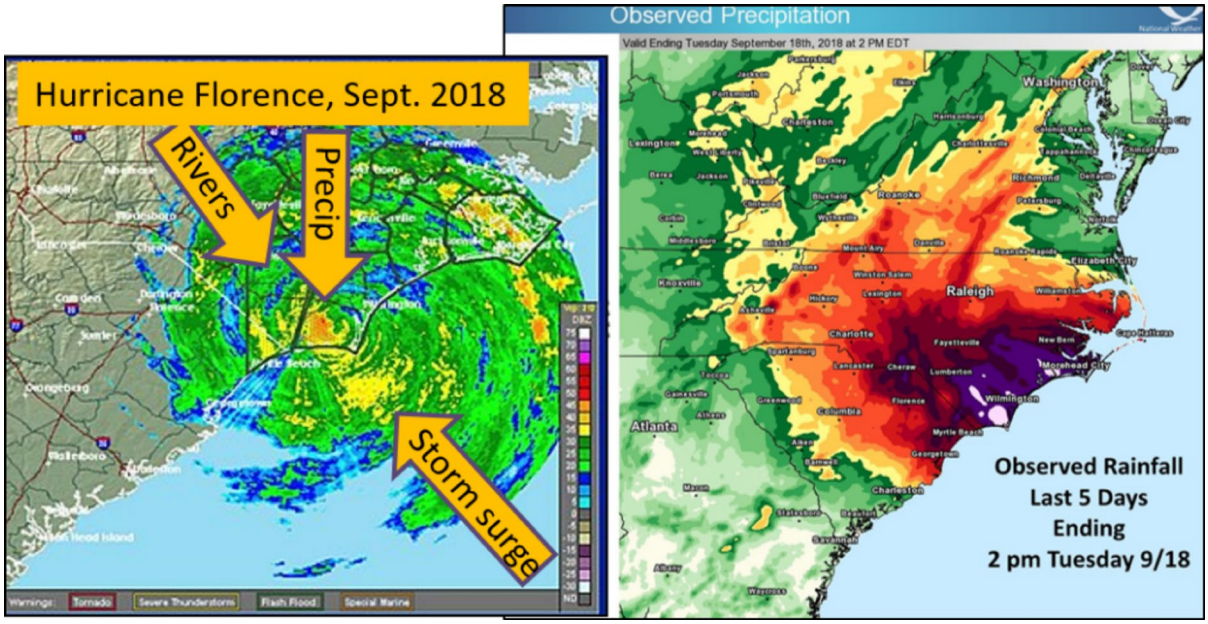

Figure. Fathom Science incorporated NASA data into their system to model the arrival of Hurricane Florence and forecast compound flooding in NC in September 2018. The left image shows the area most at risk for compound flooding. The image on the right shows observed precipitation using GPM data. **Image 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. ■