

SUCCESSSES WITH THE GLOBAL PRECIPITATION MEASUREMENT (GPM) MISSION

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ABSTRACT

Water is essential to our planet Earth. Knowing when, where and how precipitation falls is crucial for understanding the linkages between the Earth's water and energy cycles and is extraordinarily important for sustaining life on our planet during climate change. The Global Precipitation Measurement (GPM) Core Observatory spacecraft launched February 27, 2014, is the anchor to the GPM international satellite mission to unify and advance precipitation measurements from a constellation of research and operational sensors to provide "next-generation" precipitation products [1-2]. GPM is currently a partnership between NASA and the Japan Aerospace Exploration Agency (JAXA). Status and successes in terms of spacecraft, instruments, retrieval products, validation, and impacts for science and society will be presented.

Index Terms— Precipitation, microwave, satellite

1. INTRODUCTION

The GPM Core Observatory was launched 27 February 2014 from Tanagashima Island, Japan and placed in a non-sun-synchronous orbit. This orbit allows for highly sophisticated observations of precipitation in the mid-latitudes where a majority of the population lives. GPM's requirements are to measure rain rates from 0.2 to 110 mm/hr and to detect and estimate falling snow. GPM expands the Tropical Rainfall Measuring Mission (TRMM)'s reach in terms of Earth coverage, inter-calibration of constellation member datasets, coordinated formal-partnership merged precipitation data sets, reduced latency for delivering data products, sophisticated satellite instrumentation, simplified data access, expanded global ground validation efforts and integrated user applications.

The cornerstone, or anchor, of the GPM mission is the GPM Core Observatory in a unique 65° non-Sun-synchronous orbit at an altitude of 407 km serving as a physics observatory and a calibration reference to improve precipitation measurements by a constellation of 8 or more dedicated and operational, U.S. and international passive microwave sensors. GPM's constellation concept [Fig. 1] sets

the GPM Core Observatory spacecraft's orbit to allow for coincident measurements with partner precipitation satellite sensors (as listed in [2]). These coincident measurements help to remove biases in the passive microwave brightness temperatures (and hence the resultant precipitation retrievals) among the various sensors using GMI as the calibrator. GPM has several retrieval product levels ranging from raw instrument data to swath precipitation estimates to gridded and accumulated products and finally to multi-satellite merged products. The latter merged product, called IMERG, is available with a 5-hour latency with temporal resolution of 30 minutes and spatial resolution of 0.1° x 0.1° (~10km x 10km) grid box. Some products have a 1-hour latency for societal applications such as floods, landslides, hurricanes, blizzards, and typhoons and all have late-latency high-quality science products.

The Global Precipitation Measurement (GPM) mission has several scientific objectives including (1) advancing precipitation measurements from space, (2) improving knowledge of precipitation systems, water cycle variability and freshwater availability, (3) improving climate modeling and prediction, (4) improving weather forecasting and 4D reanalysis, and (5) improving hydrological modeling and prediction [1]-[2].

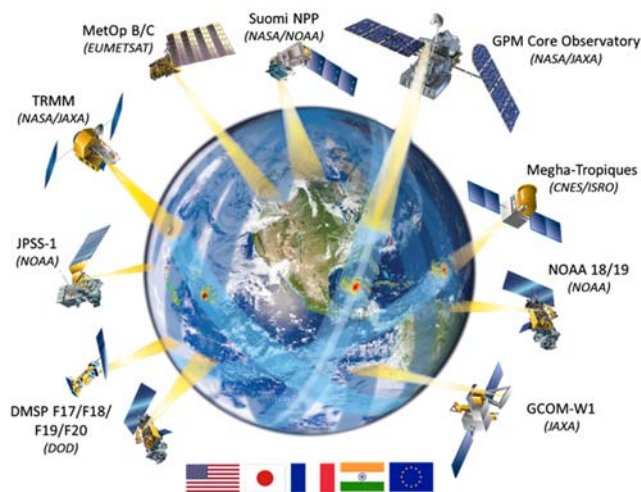


Figure 1: The GPM constellation configuration (see [2]).

2. INSTRUMENT STATUS AND SUCCESSES

The GPM Core Observatory is an advanced version of TRMM [3] with additional sensing channels on both the Japanese provided Dual-frequency Precipitation Radar (DPR) and on the NASA provided GPM Microwave Imager (GMI). GMI's engineering design included several features to eliminate or reduce typical calibration issues found on most passive radiometers prior to GMI. GMI has already been identified as the best calibrated passive conically scanning radiometer in space in 2015 [4].

The DPR has a Ku (13 GHz) and Ka-band (35 GHz) channel while GMI has 13 channels between 10 and 183 GHz. The Ka on DPR and the 166V, 166H, 183±3, and 183±7 GHz channels on the GMI were added to TRMM's 9 channels from 10-89 GHz design to observe the smaller precipitation particles associated with light rain and falling snow found in the mid-latitudes. The DPR infers the sizes of precipitation particles layer by layer in the cloud and offer insights into precipitation structural characteristics.

The prime mission lifetime (instrument design life) is 3 years (to May 2017) but fuel is projected to last well beyond that, with the GPM Core Observatory lasting potentially 20+ years if the instruments do not fail.

3. RETRIEVAL STATUS AND SUCCESSES

Relative to current global rainfall products, GPM data products are characterized by: (1) more accurate instantaneous precipitation measurements (especially for light rain and cold-season solid precipitation), (2) more frequent sampling by an expanded constellation of domestic and international microwave radiometers including operational humidity sounders, (3) inter-calibrated microwave brightness temperatures from constellation radiometers within a unified framework, and (4) physical-based precipitation retrievals from constellation radiometers using a common a priori cloud/hydrometeor database derived from GPM Core sensor measurements.

The Precipitation Processing System (PPS) processes, analyzes, distributes, and archives data from GPM, partner satellites and TRMM [5]. PPS is responsible for converting scientist provided algorithms into suitable code for producing the precipitation products and meeting data latency requirements. In the spring of 2016, PPS will start releasing reprocessed precipitation estimates from improved algorithms. These improved algorithms will improve the light rain, falling snow, merged products as well as the 3D precipitation particle size distributions available from the DPR instrument. PPS also works closely with the Japanese data processing center.

Successes with retrieval products include proof that GPM was able to detect and estimate falling snow with an overpass less than 3 weeks after launch (Fig. 2) and the multi-satellite product (Fig. 3).

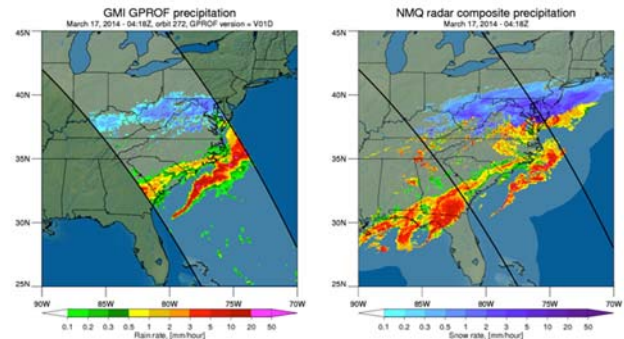


Figure 2: This snow event occurred March 17, 2014 and deposited more than 7" of snow in the Washington, DC metro area. *Left:* GMI retrievals of liquid rain and falling snow. *Right:* Ground measurements from NOAA's National Mosaic & Multi-Sensor QPE (CONUS 3D radar mosaic at 1km resolution).

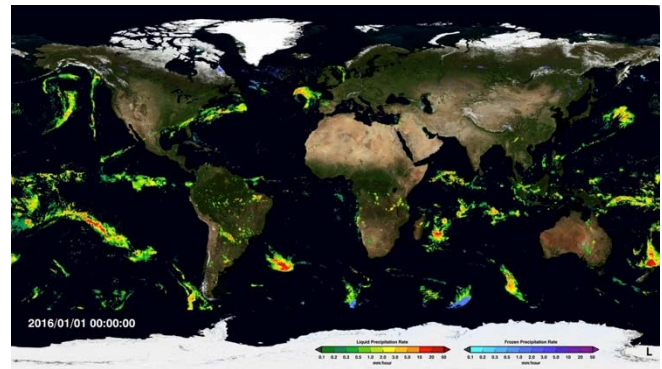


Figure 3: The multi-satellite merged product called IMERG on 01/01/2016 at 00UTC.

4. VALIDATION EFFORTS

GPM validation activities [6] consider not only direct validation of the satellite products, but also validation of the relationships between physical and radiatively observed properties as well as via integrated applications that embrace cloud resolving models and coupled land surface/cloud resolving models used in hydrologic applications.

Two field campaigns have occurred since GPM's launch in Feb 2014 for focused physical validation and integrated validation. Meanwhile, direct validation efforts compare GPM satellite data to similar measurements from the national network (Fig. 4) of operational weather radars [6]. The goal of this Validation Network (VN) is to identify and resolve significant discrepancies between the US national network of ground radar observations and satellite observations. In addition, NOAA's Multiple Radar Multiple Sensor (MRMS) system [7] combines data streams from multiple radars, satellites, surface observations, upper air observations, lightning reports, rain gauges and numerical weather prediction models to produce a suite of products every two minutes at a resolution of 1km and with 31 vertical levels.

GPM-GV VN Sites

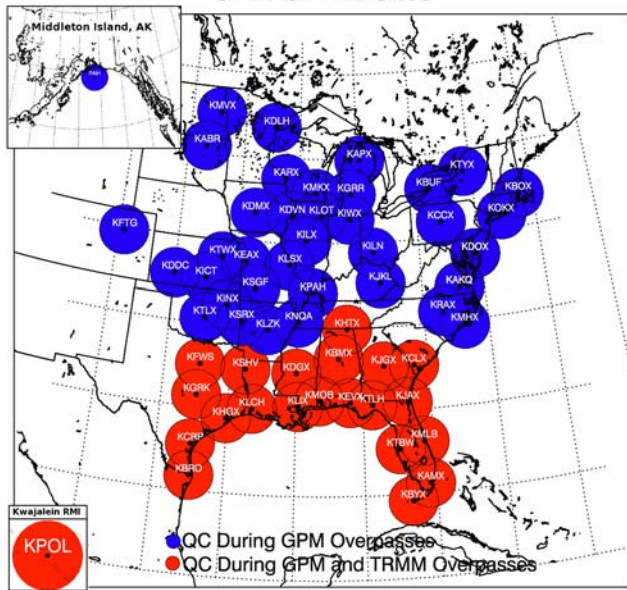


Figure 4: Location of radars in the Validation Network. Red circles indicate the original set used with TRMM, and blue circles indicate new radars added for analysis with GPM.

Re-evaluation of the reprocessed (new) GPM algorithms is underway in 2016. In addition, validation will play an essential role in proving that GPM meets its Level 1 Mission requirements. Basically, these requirements are that the instantaneous rain rate estimate has a bias and random error of $< 25\%$ at rain rates of 10 mm/hr and $< 50\%$ at rain rates of 1 mm/hr over a 0.5° (50×50 km) grid scale.

5. SOCIETAL APPLICATIONS

The precipitation data provided by GPM is vital to understanding how weather and climate impact both our environment and Earth's water and energy cycles. Through improved measurements of rain and snow, precipitation data from TRMM and GPM can reveal new information on hurricane eyewalls and intensity, measure hazard-triggering rainfall events, provide inputs into climate and land surface models, and offer new insights into agricultural productivity and world health. GPM's remotely sensed precipitation data enable a diverse range of applications across agencies, research institutions and the global community, including: Tropical Cyclones, Extreme Weather, Floods, Landslides, Land Surface Models, Climate Prediction, Soil Moisture, Agriculture, Freshwater Availability, and World Health. GPM's data is used in, for example, on-line databases of flood, landslide, and fire susceptibility maps.

6. PARTNERS AND SCIENCE TEAMS

The strongest partnership of GPM is between NASA and the Japanese Aerospace and Exploration Agency (JAXA) that built DPR and launched the GPM Core Observatory. Because

of the international nature of GPM, country, agency, and university partnerships are formed independently with both NASA and JAXA for sharing spacecraft data, ground validation measurements and scientific expertise. For NASA, these international partnerships are at no cost to the US Government and are formalized through the selection of an unsolicited proposal submitted to NASA Headquarters. As Jan 2016, there are currently 25 formalized international partners with NASA. In addition, both NASA and JAXA have Science Teams with funded Principal Investigators and their teams. The NASA science team currently consists of 60 United States Principal Investigators investigating TRMM and GPM Science, algorithms, validation, climate and applications.

7. CONCLUSIONS

The GPM mission is well on its way to providing essential data on precipitation (rain and snow) from micro to local to global scales via providing precipitation particle size distributions internal to the cloud, 5-15 km estimates of regional precipitation and merged global precipitation. Once TRMM data is recalibrated to the high quality standards of GPM (and as GPM continues to operate), TRMM and GPM together, with partner data) can provide a 25-30+ year record of global precipitation. Scientists and hazard decision makers all over the world value GPM's data.

8. REFERENCES

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