GPM Core Observatory: Advancing Precipitation Instruments and Expanding Coverage

Heather Hanson, NASA's Goddard Space Flight Center/Global Science & Technology, heather.h.hanson@nasa.gov
Ellen Gray, NASA's Goddard Space Flight Center/Wyle, ellen.t.gray@nasa.gov

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Precipitation Measurement Science

To study the effects of precipitation and how it influences other phenomena, scientists study moisture and precipitation in the atmosphere. Water, in all its forms, is difficult to measure consistently around the globe. Rain, snow, and other precipitation types, such as hail and sleet, vary greatly over land and oceans. Obtaining reliable, ground-based measurements of precipitation, from rain gauges for example, often presents a challenge due to large data gaps between monitoring instruments on land, and even larger gaps over oceans.

Satellite observations, however, cover broad areas and provide more frequent measurements that offer insights into when, where, and how much it rains or snows worldwide. Earth-observing satellites carry numerous instruments designed to observe specific atmospheric constituents such as water droplets and ice particles. These observations are detailed enough to allow scientists to distinguish between rain, snow, and other precipitation types, as well as to observe the structure, intensity, and dynamics of storms. These data are also fed into the weather forecast models that meteorologists use to issue weather warnings.

Global Precipitation Measurement Mission

The Global Precipitation Measurement (GPM) mission is an international partnership co-led by NASA and the Japan Aerospace Exploration Agency (JAXA). The mission centers on deploying the GPM Core Observatory and consists of a network, or *constellation*, of additional satellites that together will provide next-generation global observations of precipitation from space—see **Figure 1**. The GPM Core Observatory will launch from the Tanegashima Space Center in Tanegashima, Japan, aboard a JAXA H-IIA rocket in early 2014. The spacecraft will carry an advanced radar/radiometer system and will serve as a reference standard to unify precipitation measurements from all satellites that fly as part of the constellation.

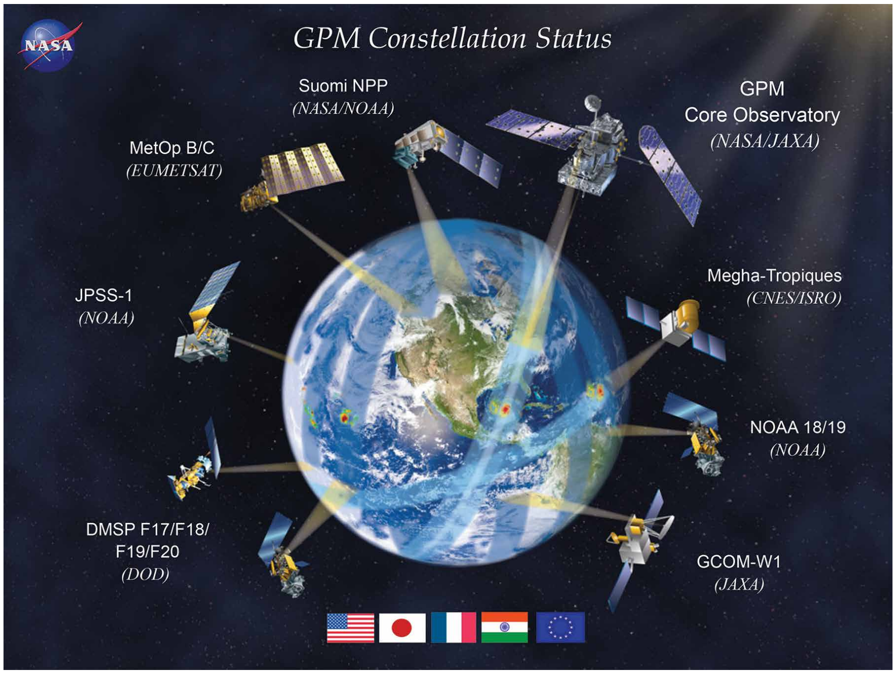

Figure 1. The GPM mission, initiated by NASA and JAXA, comprises a consortium of U.S. and international space agencies, including the French Centre National d'Études Spatiales (CNES); U.S. Department of Defense, Defense Meteorological Satellite Program (DMSP); European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT); Indian Space Research Organisation (ISRO); and the U.S. National Oceanic and Atmospheric Administration (NOAA). The satellites pictured here are expected to form the GPM satellite constellation. **Image credit:** NASA

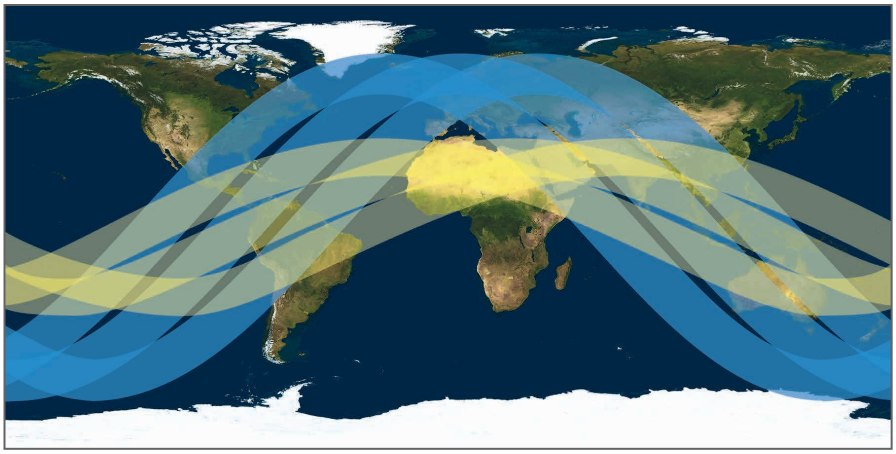

Figure 2. This graphic compares the area covered by three TRMM orbits (yellow) versus three orbits of the GPM Core Observatory (blue). **Image credit:** NASA

The GPM mission concept builds on the success of the Tropical Rainfall Measuring Mission (TRMM), a joint NASA and JAXA satellite launched in 1997 that measures precipitation over tropical and subtropical regions, from approximately 35° N latitude (e.g., the Mediterranean Sea) to 35° S latitude (e.g., the southern tip of South Africa)—see *Successes from TRMM* on page 8.

Measurements from the GPM Core Observatory, however, will provide even greater coverage—between approximately 65° N latitude (e.g., the Arctic Circle) and 65° S latitude (e.g., the Antarctic Circle)—see **Figure 2.** These measurements, combined with those from other satellites in the constellation, will provide global precipitation observations approximately every three hours. This integrated approach and unified dataset will help advance scientists' understanding of Earth's water and energy cycles.

The GPM constellation will provide measurements on the:

- intensity and variability of precipitation;
- three-dimensional structure of cloud and storm systems;
- microphysics of ice and liquid particles within clouds; and
- amount of water falling to Earth's surface.

Observations from the GPM constellation, combined with land-surface data, will improve:

- weather forecast models;
- climate models;
- integrated hydrologic models of watersheds; and
- forecasts of hurricanes, landslides, floods, and droughts.

Above all, global observations from GPM mission satellites will continue and expand the data records that began with previous precipitation missions, such as TRMM, and improve precipitation estimates around the globe. The mission will help scientists understand how local, regional, and global precipitation patterns change over time.

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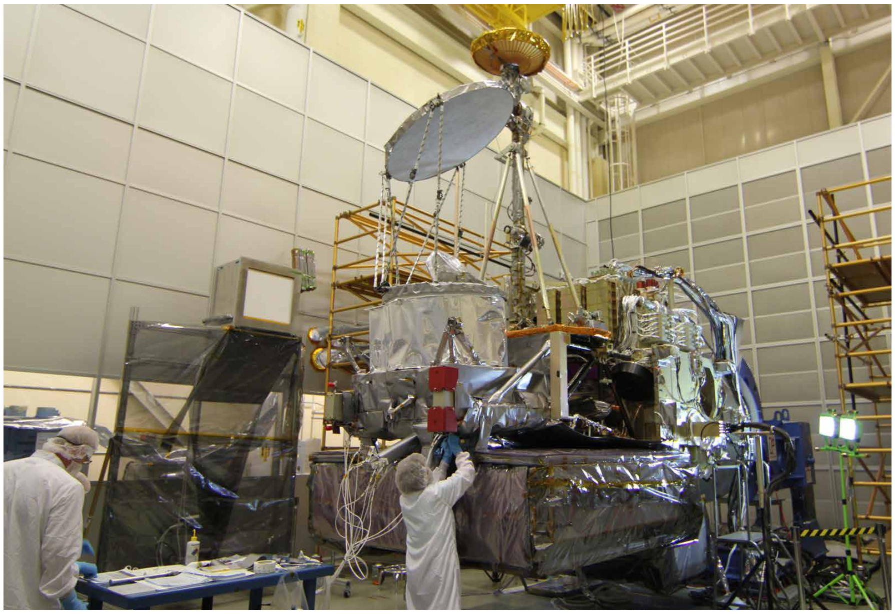
GPM Core Observatory

The GPM Core Observatory improves upon the capabilities of its predecessor, the TRMM satellite, with advanced precipitation instruments and expanded coverage of Earth's surface. The GPM Core will carry two instruments: the *GPM Microwave Imager* (GMI) and *Dual-frequency Precipitation Radar* (DPR). These instruments will collect improved observations that will allow scientists to better "see" inside clouds. The GMI has the capability to measure the amount, size, intensity, and type of precipitation, from heavy-to-moderate rain to light rain and snowfall. The DPR will return three-dimensional profiles and intensities of liquid and solid precipitation. These data will reveal the internal structure of storms within and below clouds.



The GPM mission concept centers on the GPM Core Observatory, pictured here. The drum-shaped instrument and disc [*center*] is the GMI. The large blocky foil-covered instrument [*bottom of the spacecraft*] is the DPR. The antenna [*top*] is the high gain antenna for communications. The observatory was built and tested at NASA's Goddard Space Flight Center. **Image credit:** NASA

The GPM Core Observatory—characteristics listed in **Table 1**—will be able to observe storms forming in the tropical oceans and track these storms as they move poleward into middle and high latitudes. With the advanced observations from the GMI and DPR, scientists will be able to study the internal structure of these storms throughout their life cycles, and view how they change over the long term. This capability will help scientists understand why some storms change in intensity as they move from the tropics to the mid-latitudes.

Together, the GMI and DPR will provide a database of measurements against which other partner satellites' microwave observations can be meaningfully compared and combined to generate uniform global precipitation datasets. Measurements from the GMI will also serve as a reference standard for cross-calibration of other satellites in the GPM constellation. For example, when overlapping measurements of the same Earth scene are made, measurements from GMI will be used to calibrate precipitation estimates from GPM constellation sensors within a consistent framework.

Table 1.

GPM Core Observatory Characteristics	
Altitude: 407 km (253 mi)	**Orbit duration:** 93 min
Inclination: 65°	**Orbits per day:** about 16
Speed: 7 km/sec (~4 mi/sec)	**Design life:** 3 yrs
Orbit: circular, non-sun-synchronous	**Fuel life:** 5 yrs

The GMI—built by Ball Aerospace & Technology Corp. under contract to NASA's Goddard Space Flight Center (GSFC)—is a multichannel microwave radiometer designed to sense the total precipitation within all cloud layers, including light rain and snowfall.

GPM Microwave Imager

The GMI—built by Ball Aerospace & Technology Corp. under contract to NASA's Goddard Space Flight Center (GSFC)—is a multichannel microwave radiometer designed to sense the total precipitation within all cloud layers, including light rain and snowfall. It does this by measuring the intensity of microwave energy that is constantly emitted by all parts of the Earth system—including rain and snow, which has a unique signature.

Specifically, GMI uses 13 channels to measure the intensity of microwave radiation emitted from Earth's surface and atmosphere. The lower-frequency channels (10 to 89 GHz, similar to those of the microwave imager onboard the TRMM satellite) detect heavy-to-moderate rainfall. GMI's advancements include four additional high-frequency channels (166 to 183 GHz) that will measure moderate-to-light precipitation—see **Table 2.**

Each object, such as rain, snow, and Earth's surfaces, emits or scatters energy differently, based on the object's temperature and physical properties. Scientists use their knowledge and the contrast between the signals received by the different channels to distinguish between rain and snow and to calculate precipitation rates and quantify precipitation intensity.

Table 2. This table compares the TRMM Microwave Imager with the GPM Microwave Imager.

Instrument	Channels	Frequency Range	Swath Width
TMI (on TRMM)	9	10-85.5 GHz	758.5 km (471 mi)
GMI (on GPM)	13	10-183 GHz	885 km (550 mi)

Dual-frequency Precipitation Radar

Ground-based weather radars emerged during World War II and have since been used to measure precipitation, mostly over land. The first spaceborne precipitation radar, however, did not launch until November 1997 onboard the TRMM satellite. TRMM's Precipitation Radar (PR) instrument provides three-dimensional maps of tropical and subtropical rainfall over land and oceans, which have revolutionized scientists' understanding of storms.

The GPM Core Observatory will carry the next-generation spaceborne precipitation radar—the DPR. The DPR will make detailed three-dimensional measurements of precipitation structures and rates and, with the Core's expanded coverage, will do so across much more of Earth's surface than previous sensors. NEC Toshiba Space Systems, Ltd. built the DPR, which was designed by JAXA and the National Institute of Information and Communications Technology in Japan.

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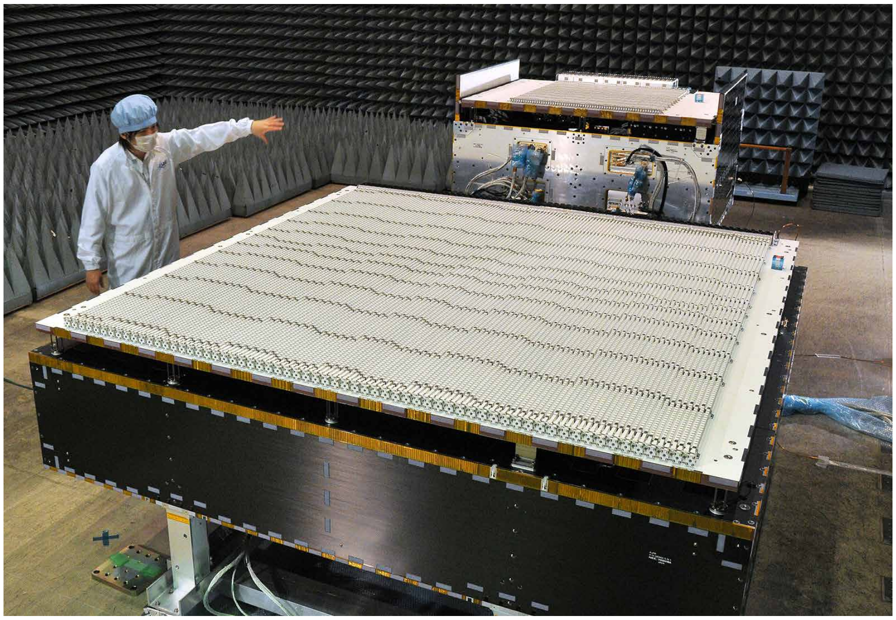
One of the major advancements of the DPR is the addition of a second radar frequency. In addition to the DPR's K_u-band radar that will measure moderate-to-heavy rain at 13.6 GHz (similar to the PR), its K_a-band radar will measure frozen



In this photo, a JAXA technician stands next to the DPR. The K_u-band radar [*foreground*] measures 2.4 x 2.4 x 0.6 m (~7.9 x 7.9 x 2 ft), while the K_a-band radar [*background*] measures 1.44 x 1.44 x 0.7 m (~4.7 x 4.7 x 2.3 ft).

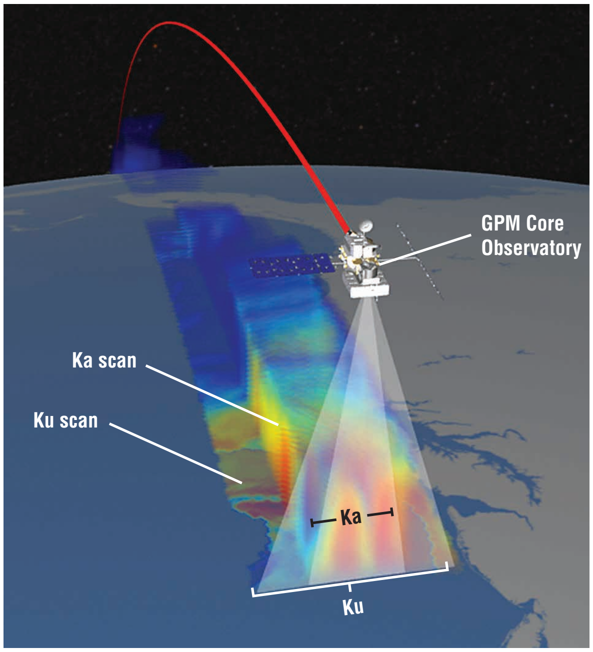
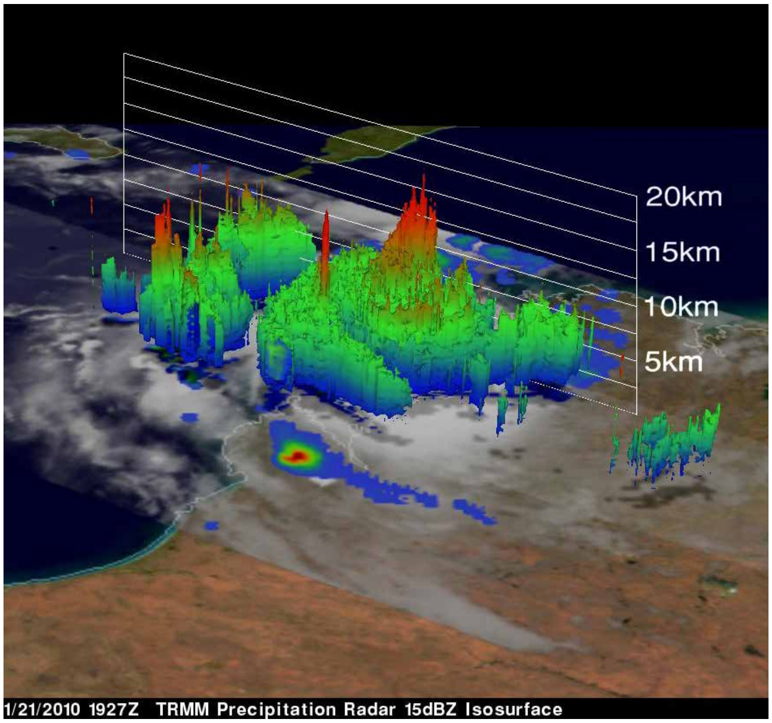


Figure 3. This illustration shows the scanning capabilities of the DPR onboard the GPM Core Observatory, which will provide data to show the three-dimensional structure of storms. Red, orange and yellow shades indicate heavy-to-moderate rainfall, while darker shades indicate light rainfall. The K_a-band radar swath is nested within the wider K_u-band radar swath. **Image credit:** NASA

precipitation and light rain at 35.5 GHz. Simultaneous measurements from the overlapping swaths of K_a/K_u-band data—see **Figure 3**—will provide new information on particle *drop size distributions*—i.e., how many raindrops of different sizes are in the cloud layers and how they are distributed throughout the storm system.

Improved observations of precipitation size, shape, and distribution will offer scientists insight into the microphysical processes of precipitation and help to distinguish between regions of rain and snow. They will also provide bulk precipitation properties such as precipitation intensity, water fluxes, and water content. Information on the distribution and size of precipitation particles, together with microwave radiometer measurements made by the GMI, will improve the accuracy of rain and snowfall estimates.

Successes from TRMM



This three-dimensional image, made with data from TRMM's Precipitation Radar, shows Tropical Cyclone Magna off the coast of Australia on January 21, 2010. Red shades indicate taller, more intense thunderstorms near Magda's eyewall. **Image credit:** NASA

The TRMM satellite was primarily designed to measure heavy-to-moderate rainfall over tropical and subtropical regions. Measurements from TRMM have advanced our understanding of mean annual tropical rainfall—particularly over oceans—and have returned many innovative analyses, including the first three-dimensional images from space of storm intensity and structure. TRMM has also provided frequent and detailed observations of precipitation for more than 15 years.

How the Instruments Work

GPM Microwave Imager

The GMI is a *conical-scanning radiometer*, which consists of two main assemblies: the detectors that measure microwave energy, and the scanning antenna that collects the microwaves from the scene and reflects them to the detectors. The scanning antenna spins at 32 rpm to collect microwave data along the circular track it traces on the ground. When the antenna faces the arc away from the satellite, it collects data from the scene along the satellite's ground path. When the antenna faces towards the spacecraft, the instrument does calibration checks to ensure that its measurements are accurate. The GMI's 1.2-m (~4-ft) diameter antenna will provide significantly improved spatial resolution over that from the TRMM Microwave Imager.

Dual-frequency Precipitation Radar

The DPR employs two cross-track scanning precipitation radars—a K_u- and K_a-band radar. Both radars will have a spatial resolution of 5 km (~3 mi) and emit 4100 to 4400 pulses per second, with 250-m (~820-ft) pulse lengths. In the time that it takes the K_u-band radar to measure its wider swath with 250-m (~820-ft) pulse lengths, the K_a-band radar will measure its swath with both 250- and 500-m (~1640-ft) pulse lengths. This will allow the K_a-band radar to collect measurements that require high sensitivity—crucial for observing smaller water droplets and ice particles. Each radar will return its own data that scientists can analyze separately or together. For example, by using differences in how the K_u- and K_a-band radar return pulses change intensity when they encounter different precipitation types, scientists expect to be able to distinguish rain from snow.

Spacecraft Design

The spacecraft consists of the structural/mechanical subsystem, solar array drive and deployment subsystem, power subsystem, attitude and thermal control subsystems, propulsion and guidance subsystems, navigation and control subsystems, high-gain antenna and radio-frequency communications subsystems, and the command and data-handling subsystem.

The GPM Core Observatory, developed and tested at GSFC, will supply power, orbit and attitude control, communications, and data storage for GMI and DPR. The spacecraft consists of the structural/mechanical subsystem, solar array drive and deployment subsystem, power subsystem, attitude and thermal control subsystems, propulsion and guidance subsystems, navigation and control subsystems, high-gain antenna and radio-frequency communications subsystems, and the command and data-handling subsystem.

Two deployable solar arrays will charge the spacecraft's battery and power the observatory's components through the power supply electronics. A solid-state data recorder will provide data storage aboard the spacecraft, and the S-band high-gain antenna will transmit GMI and DPR data, either in real time or played back from the data recorder.

As the GPM Core Observatory orbits 407 km (~253 mi) above Earth's surface, the GMI and DPR instruments will constantly scan coordinated areas of the surface below—see **Figure 4.** The GMI will scan an 885-km (~550-mi) wide swath, while the DPR's K_u- and K_a-band radars will take overlapping scans in the center of the GMI swath. Specifically, the K_a-band radar will scan across a region of 120 km (~75 mi), nested within the wider scan of the K_u-band radar of 245 km (~152 mi). Measurements within the overlapped swaths are important for improving precipitation retrievals of data and, in particular, the radiometer-based retrievals.

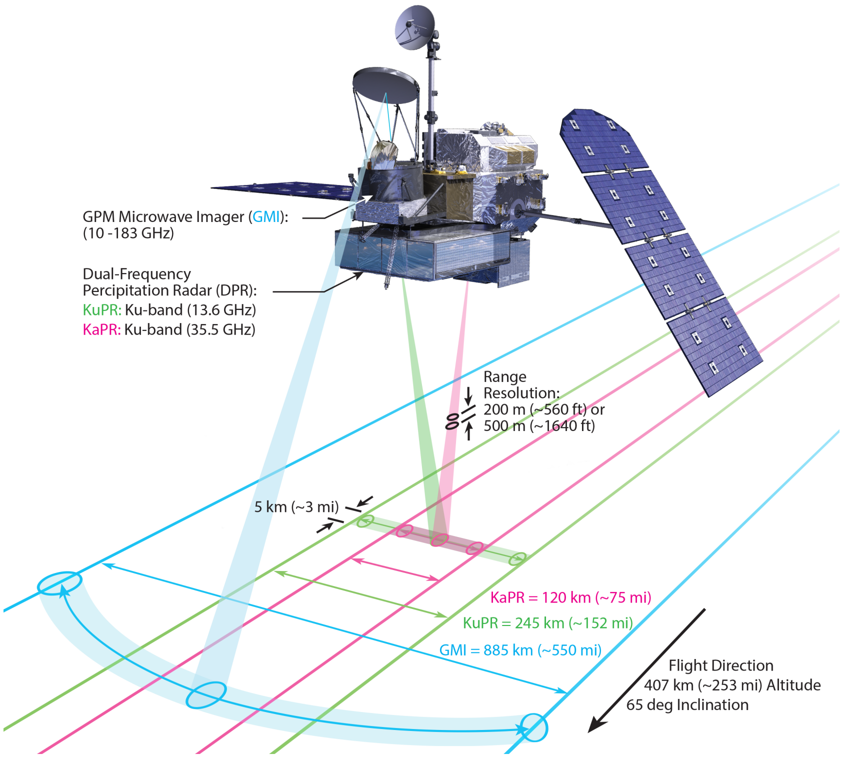


Figure 4. This image shows the GMI and DPR instruments aboard the GPM Core Observatory and their respective swaths. **Image credit:** NASA

Ground System and Data

The GPM mission ground system includes all the assets needed to command and operate the GPM Core Observatory in orbit, and to manage and distribute data received from the Core and other satellites in the constellation.

To communicate with the GPM Core Observatory, the Mission Operations Center (MOC) at GSFC sends software commands through the ground station in White Sands, NM, to NASA's geosynchronous Tracking and Data Relay Satellite System (TDRSS). This system of three active satellites is used by NASA to communicate with satellite platforms—in this case, the GPM Core Observatory. In return, the GPM Core Observatory transmits spacecraft and instrument telemetry, which report on the satellite's location and functioning, and science data from the instruments to TDRSS. Once data are transmitted to TDRSS, it sends the information to the White Sands ground station. From White Sands the data go to the MOC, which passes the science data to the Precipitation Processing System (PPS) at GSFC—see **Figure 5.**

Data from the GPM Core Observatory's GMI instrument are returned continuously through the TDRSS Multiple Access link, while data from the DPR are returned once an orbit—approximately every 90 minutes—through the TDRSS Scheduled Access link. The partner agencies that control the other satellites in the GPM constellation send their respective satellite data to the PPS via their own data facilities.

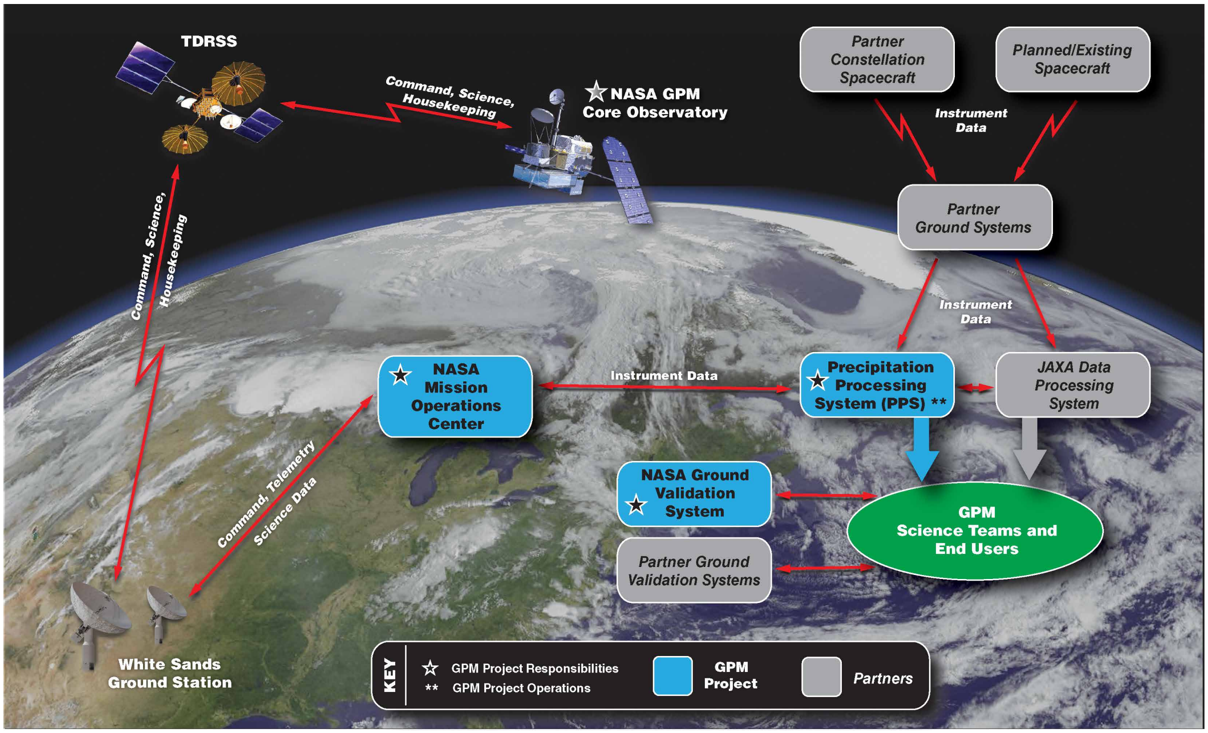


Figure 5. This graphic shows how data travel from the GPM Core Observatory and the constellation satellites to the Precipitation Processing System at GSFC. **Image credit:** NASA

The PPS processes all the data returned by GPM constellation satellites, with the exception of data from the DPR. DPR data are sent to JAXA's Mission Operations Systems for initial processing and returned to the PPS as a basic radar product for further processing and integration into global precipitation data products. GPM precipitation datasets will be freely available for download from the PPS website at *pps.gsfc.nasa.gov*.

GPM Mission Applications: A Global Understanding for a Better Future

Water is fundamental to life on Earth. Knowing where and how much precipitation falls globally is vital to understanding how weather and climate impact our environment, including the effects on agriculture, fresh water availability, and natural disasters. The use of advanced spaceborne instruments to measure global precipitation every three hours can reveal new information for a diverse range of applications across agencies, research institutions, and the global community.

Among the applications of GPM mission data are improvements to our understanding and forecasting of tropical cyclones, extreme weather, floods, landslides, land surface models, the spread of water borne diseases, agriculture, freshwater availability, and climate change. Data from the GPM Core Observatory, combined with data from other satellites within the constellation, will lead to advances in precipitation measurement science that will benefit society for years to come. ■