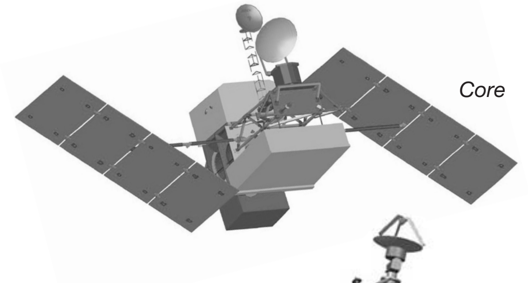
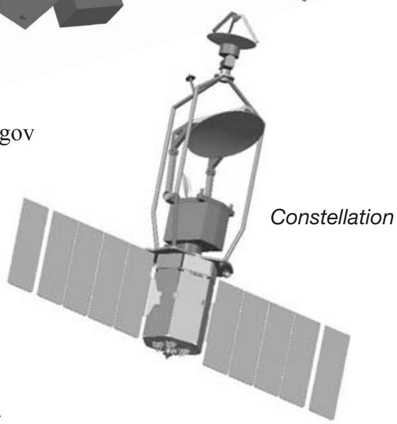
GPM

Global Precipitation Measurement Mission





GPM URL

gpm.gsfc.nasa.gov

Summary

GPM builds on the success of the Tropical Rainfall Measuring Mission (TRMM) and will provide more accurate, frequent (3-hourly), global, high spatial resolution, and microphysically detailed measurements of precipitation. An advanced core satellite with a first-of-its-kind dual frequency radar and passive microwave radiometer will provide key measurements of precipitation physics and serve as a calibrator for a set of constellation satellites. Each member of the constellation will carry some type of passive microwave radiometer and will provide global and temporal sampling and also reduce error uncertainty in precipitation measurements. GPM is also composed of a comprehensive precipitation processing system and an international ground validation effort. Scientifically, GPM will provide accurate assessment of the water cycle and improved prediction of weather, climate, and hydrometeorological processes.

Instruments

Core:

- Dual-frequency Precipitation Radar (DPR), JAXA
- GPM Microwave Imager (GMI), NASA

Constellation:

- GPM Microwave Imager (GMI), NASA

Note: In this context, Core and Constellation refer to *two specific spacecraft missions* that represent NASA's contribution to GPM. (See Mission Background section for further clarification.)

Key GPM Core Facts

Heritage: Tropical Rainfall Measuring Mission (TRMM)

Orbit:
- Type: Circular orbit
- Equatorial Crossing: Non-specified
- Altitude: 400 km
- Inclination: 65°
- Period: 92.56 min (nominal 400 km orbit)
- Repeat Cycle: Changes 24 hours of local time in 46-day precession cycle

Dimensions: TBD when spacecraft provider is selected (preliminary designs shown)

Mass: 3200 kg

Power: 1450 W

Design Life: 3 years required; 5-year goal

Average Data Rate: ~300 kbps

Data Storage: 12 hours of science and housekeeping data without loss

Data Relay Methods: Data are returned essentially continuously over a low-rate Tracking and Data Relay Satellite System (TDRSS)-Multi-access (MA) link enabling 'virtual broadcast' of data over the Internet as well as once per orbit via the single-access (SA) service of TDRSS.

Key GPM Constellation Facts

Orbit:
- Type: Circular orbit
- Equatorial Crossing: TBD
- Altitude: ~635 km
- Inclination: Sun-synchronous (TBD)
- Period: 97.42 min
- Repeat Cycle: TBD

Dimensions: TBD when spacecraft provider is selected (preliminary design shown)

Mass: ~500 kg

Power: ~400 W

Design Life: 3 years required; 5-year goal

Average Data Rate: ~50 kbps

Data Storage: 12 hours of science and housekeeping data without loss

Data Relay Methods: Data are returned essentially continuously over a low-rate Tracking and Data Relay Satellite System (TDRSS) Multi-access (MA) link enabling 'virtual broadcast' of data over the Internet.

Points of Contact

- *GPM Project Scientist:* Arthur Hou, NASA Goddard Space Flight Center
- *GPM Deputy Project Scientist:* Marshall Shepherd, NASA Goddard Space Flight Center
- *GPM Deputy Project Scientist for Data Systems:* Erich Stocker, NASA Goddard Space Flight Center

Other Key Personnel

- *GPM Program Scientist:* Ramesh Kakar, NASA Headquarters
- *GPM Program Executive:* Steven Neeck, NASA Headquarters
- *GPM Formulation Manager:* John Durning, NASA Goddard Space Flight Center

Mission Type

Next-generation Systematic Measurement

Launch

- *Date and Location:*

  Core: Date TBD from Tanegashima Space Complex in Tanegashima, Japan

  Constellation: Date TBD, from Vandenberg Air Force Base, California

- *Vehicle:*

  Core: JAXA H-II A launch vehicle

  Constellation: Taurus Class launch vehicle

Relevant Science Focus Areas

(see NASA's Earth Science Program section)

- Climate Variability and Change
- Water and Energy Cycles
- Weather

Related Applications

(see Applied Sciences Program section)

- Agricultural Efficiency
- Aviation
- Disaster Management
- Energy Management
- Public Health
- Water Management

GPM Instruments

GMI

GPM Microwave Imager

A conical-scan, passive microwave radiometer that will be used for rainfall measurements; two identical GMI instruments will be produced, one for Core and one for Constellation.

DPR

Dual-frequency Precipitation Radar

Consists of two essentially independent Precipitation Radars each operating at a different microwave frequency, enabling more detailed measurements of cloud structure and precipitation characteristics than with previous precipitation radar systems.

GPM Science Goals

- *Climate Prediction*—Improve climate prediction through progress in quantifying space-time variability of precipitation along with improvements in achieving water budget closure, plus focused research on relationships between precipitation and climate variations.

- *Weather Prediction*—Improve the accuracy of global and regional numerical weather prediction models through accurate and precise measurements of instantaneous rain rates, made frequently and with global distribution, plus focused research on more advanced techniques in satellite rainfall data assimilation.

- *Flood/Fresh Water Resource Prediction*—Improve flood and fresh water resource prediction through frequent sampling and complete Earth coverage of high-resolution precipitation measurements, plus focused research on more innovative designs in hydro-meteorological modeling.

GPM Mission Background

Water cycling and the future availability of fresh water resources are immense societal concerns that impact every nation on Earth. Furthermore, precipitation is a fundamental component in virtually every environmental issue. Comprehensive information on precipitation is valuable for a wide range of research areas and related applications with practical benefits for society. Unfortunately, precipitation is a difficult meteorological field to measure because precipitation systems tend to exhibit a somewhat random nature and also evolve and dissipate very rapidly. It is not at all uncommon to see a wide range of rain amounts over a very small area; and in any given area, the amount of rain can vary quite a bit over a very short amount of time. These factors make quality precipitation measurements difficult or even impossible to obtain. It's also difficult to obtain reliable ground-based precipitation measurements over regional and global scales because most of the world is covered by water and many countries are not equipped with precision rain measuring sensors (i.e., rain gauges and/or radars). It might be possible to study precipitation over a small area using ground-based data, but rarely beyond that. The only practical way to obtain useful regional and global scale precipitation measurements is from the vantage point of a space-based remote sensing instrument.

Participants from a large number of nations have initiated an effort to develop a next generation, space-based measuring system that can fulfill the requirements for frequent, global, and accurate precipitation measurements that are continuously acquired. The effort, known as the Global Precipitation Measurement (GPM) Mission, involves various space agencies, weather and hydro-meteorological forecast services, research institutions, and individual scientists from around the world. They are working together to develop a flagship satellite mission for a variety of water-research and applications programs. These include support of international research programs involved with the global water and energy cycle, such as the World Climate Research Program (WCRP) Global Energy and Water Cycle Experiment (GEWEX), and Global Earth Observation System of Systems (GEOSS), as well as support of basic research, applications-oriented research, and operational environmental forecasting throughout individual nations and consortia of nations.

GPM Space Hardware

The GPM Mission will have the capability to provide physically based retrievals on a global basis, with ~3-hour sampling assured at any given Earth coordinate ~90% of the time. Such frequent diurnal sampling is made possible by a mixed non-sun-synchronous/sun-synchronous satellite orbit architecture.

The design and development of GPM is an outgrowth of valuable knowledge that has been obtained by TRMM, and published by various U.S., Japanese, and European Union (EU) research teams, and by individual scientists. TRMM was a single satellite, which is less than ideal for making a global measurement of a highly variable meteorological parameter like precipitation. GPM will instead consist of a constellation of satellites, some dedicated solely to GPM and others conveniently available through other experimental and operational missions supported by various space agencies around the world.

GPM Core Satellite—NASA and the Japan Aerospace Exploration Agency (JAXA) are working together to build and launch the GPM Core Satellite (referred to as 'Core' in this section). As was the case with TRMM, the plan is that JAXA will provide the radar and the launch while NASA will provide the radiometer, the satellite bus, and the ground segment. Core is the central rain-measuring observatory of GPM and will fly both a Dual-frequency Precipitation Radar (DPR) and a high-resolution, multi-channel passive microwave (PMW) rain radiometer known as the GPM Microwave Imager (GMI). Core will also serve as the calibration reference system and the fundamental microphysics probe to enable an integrated measuring system with the constellation-support satellites.

Dedicated NASA GPM Constellation Satellite—In addition to Core, NASA will also provide a dedicated member of the constellation (referred to as 'Constellation' in this section.) This is conceived as a relatively small spacecraft that will carry a single radiometer on board. The radiometer will be identical to the GMI on Core.

Other GPM Constellation Members—Besides Constellation, up to seven other missions may be part of the GPM constellation. Other missions are classified as 'satellites of opportunity'. One specific example of a potential satellite of opportunity is the proposed French/Indian mission known as Megha-Tropiques. Each satellite of opportunity has its own unique scientific mission and could also contribute rainfall measurements for GPM. Each satellite in the constellation will carry one or more precipitation sensing instruments. At a minimum, to be a support satellite for the GPM constellation, a mission has to carry some type of passive microwave radiometer measuring several rain frequencies. Estimates are that by the time GPM is fully operational, ten agencies from seven countries and the EU could be participating in the constellation, representing an unprecedented level of international cooperation on a satellite mission.

Proposed ESA EGPM Satellite—The European Space Agency (ESA) and a consortium of European and Canadian scientists have proposed to contribute a European GPM (EGPM) satellite that would add measurement capabilities that complement Core. This observatory would be fitted with an advanced rain radiometer using a mix of window and molecular O_2 sounding frequencies, and an additional high-sensitivity radar. The instruments on EGPM would measure light and warm rainfall, moderate to heavy drizzle, and light to moderate snowfall. All of these types of precipitation make important contributions to Earth's water cycle at mid- to high-latitudes but will be largely undetectable by Core. As of this writing, ESA has not formally selected this mission as part of its program.

GPM Data Processing System

The data information system for GPM is called the GPM Precipitation Processing System (PPS). It builds on the existing mission-specific TRMM Science Data and Information System (TSDIS), but is now a generic framework that can easily be adapted for use on any precipitation mission by adding, deleting, and/or modifying processing threads and equipment suitable to individual mission requirements.

The main responsibilities of the PPS are: 1) to acquire Level 0 and 1 sensor data; 2) to produce and maintain consistent Level 1 calibrated/Earth located radiometer brightness temperatures and radar reflectivities; 3) to process Level 1 data into consistent Level 2 and 3 standard precipitation products; 4) to disseminate precipitation products through both 'push' and 'pull' data transfer mechanisms; and 5) to assure archival of all data products acquired or produced by the PPS—either within the PPS or through suitable arrangements with other data archive services. (Data products are described in greater detail in the GPM Data Products section.)

The PPS will reside at the NASA Goddard Space Flight Center. Additional data processing systems are envisioned at JAXA's Earth Observation Research and application Center (EORC) and ESA's European Space Research Institute (ESRIN) in Tokyo, Japan and Frascatti, Italy, respectively. Each of these will make important contributions to the overall GPM mission.

GPM Validation Program

GPM is attempting to make the most comprehensive and accurate measurements of global precipitation is ever obtained. As noted previously, precipitation is an extremely rapidly varying meteorological variable in both space and time. Therefore, an extensive network of ground validation (GV) sites is needed. No single nation can practically set up and maintain, or for that matter pay for, such a network. Just as with the space hardware, an international collaboration is needed for these validation activities. The main functions of the GPM GV program will be: 1) to acquire ground-based sensor data relevant to the validation of and/or comparison with satellite sensor measurements and standard precipitation product retrievals; and 2) to produce, archive, and publicly make available on the Internet standard GV products. The program has three main objectives:

- Determine the measurement uncertainty for GPM measurements to allow users of GPM data to interpret results with proper caution and restraint;

- Improve the retrieval algorithms used by GPM and future space-based precipitation measurement missions; and

- Improve the ground-based GV measurements themselves, which have historically been beset with difficulties.

The GPM GV program will consist of a worldwide network of GV measuring sites—referred to as 'GPM GV Sites'—and their associated scientific and technical support organizations. The sites will be distributed all across the globe and each will represent their own self-interests and concerns, but will all operate under a straightforward strategy. They all agree to serve the greater GPM community by engaging in various means to communicate their scientific findings. Beyond that, however, the individual GPM GV sites have a great deal of flexibility as to how they run their operation, what types of instrumentation they use, and so forth.

To assure a degree of consistency across the eventual site network, a subset of the GPM GV sites will be designated 'GV Supersites', which will operate in a semi-continuous, near-realtime mode under a well-defined GV data reporting protocol supported by the GSFC PPS. GV Supersites will, in addition to their normal activities, provide near-realtime error characteristics concerning instantaneous rain rate retrievals from the core-level satellites (i.e., Core and EGPM), consisting of bias, bias uncertainty, and spatial error covariance information. They will also support ongoing standard algorithm improvement by reporting significant errors in instantaneous retrievals from the core-level satellites to scientific groups authoring and maintaining the standard rain rate algorithms, including with the reports, essential core (and core type) satellite and GV data needed to effectively interpret algorithm breakdowns.

GPM Principal Scientific Themes

As a means to achieve the scientific objectives of the GPM Mission, various scientific strategies have evolved within the different NASA, JAXA, and ESA Science Teams that will accomplish the majority of the initial research. NASA has chosen to divide the research process into different themes, emphasizing the fundamental barrier problems. Thus, for NASA's GPM Scientific Implementation Plan (GPM SIP) there are nine principal research themes which help organize the research and guide the evolution of the research working groups. These nine themes and main topic areas for research are as follows:

1. Global Water and Energy Cycle Processes and Modeling: Role of Precipitation

2. Climate System Variability and Climate Diagnostics: Role of Precipitation

3. Climate Model Simulations and Reanalysis, NWP Techniques, and Data Assimilation: Role of Precipitation

4. Land Surface Hydrology and Hydrometeorological Modeling: Role of Precipitation

5. Ocean Surface and Marine Boundary Layer Processes: Role of Precipitation

6. Coupled Cloud-Radiation Modeling: Physical Interpretation of Precipitation Processes

7. Precipitation Retrieval:
    a. Reference Radar-Radiometer Core Algorithm/Radar Simulator Studies
    b. Parametric Radiometer Constellation Algorithm/Radiometer Simulator Studies
    c. Cross-Satellite Calibration Transfer and Bias Removal

8. Calibration and Validation of Satellite Precipitation Measurements

9. Applications, Public Service and Educational Outreach

GPM Partners

GPM represents the largest international cooperative effort on a satellite mission to date. NASA and JAXA will lead the mission and coordinate overall development, operations, and research activities. Other partners participate in their selected areas, which includes hardware (spacecraft, instrument, launch vehicle, and launch operations), ground systems development (flight operations system, science data processing, and archive and distribution system), system operations (flight operations, launch operations. and science system operations), data validation, and research activities.

Besides overall management and leadership, NASA is contributing two spacecraft (Core and Constellation), two identical passive microwave radiometers, launch services for Constellation, the ground system, and PPS. NASA will also contribute to and participate in algorithm development and data validation activities. JAXA plans to contribute DPR, the launch vehicle, and launch operation services, and participate in algorithm development and data validation activities.

The Goddard Earth Sciences Distributed Active Archive Center (GDAAC) receives data from all members of the federation and creates data products. Besides the GDAAC, the Global Hydrology Climate Center (Huntsville, Alabama), the JAXA data processing center (Japan), and other partner data centers are involved. These other centers generate products and send them to the GDAAC.

GPM Instruments

The objectives of GPM require that two types of measurements be made: near-global measurements of rainfall and three-dimensional measurements of cloud structure and precipitation (including drop size distributions). These measurements can best be obtained using two different types of instruments: a PMW radiometer, the GMI, and an active radar, the DPR.

GMI

GPM Microwave Imager—NASA

Microwave radiometers are versatile instruments, and when properly configured, they can be used to infer a wide variety of phenomena, such as atmospheric moisture and temperature profiles, soil moisture, and sea surface temperature. Their versatility has made them instruments of choice for a variety of measurement programs, including environmental remote sensing and weather forecasting. Plans are in place to use microwave radiometers on several satellite missions that will be in orbit during the GPM era. GPM has initiated the planning and coordination needed so that the measurements made by these instruments will be available to assist GPM in meeting its objectives for frequent, global measurements of rainfall.

GMI is a conical-scan, passive microwave radiometer that will be used for rainfall measurement. NASA will procure two nearly identical GMI instruments from industry, one instrument to be placed on Core, and the other on Constellation. Although the vendor for GMI has not been selected at this time, the instrument's design will most likely incorporate substantial heritage from a previous design (see Key GMI Facts). This heritage will benefit GPM by reducing the technical risk, time required for design and fabrication, and procurement cost. GMI will be designed to make simultaneous measurements in several microwave frequencies (e.g., 10.7, 19.3, 21, 37, 89 GHz), giving the instrument the capability to measure a variety of rainfall rates and related environmental parameters. Additional, higher frequency measurement channels (150–165 and 183 GHz) are under consideration in order to provide increased sensitivity for the measurement of light rains frequently found at Earth's higher latitudes; a decision concerning the inclusion of these additional measurement channels will be made as part of the procurement process.

The notional design for GMI includes an offset parabolic reflector of approximately 1.0 m diameter that rotates about the instrument's vertical axis. The antenna will point at an off-nadir angle of ~49º, providing a ground measurement swath of ~850 km from side-to-side centered along the ground-track of the core spacecraft. The speed of rotation has not been firmly established, but most heritage systems have used a rotational rate of about 32 rpm. During each 2-s revolution, measurements will be made over ~130º scan sector centered on the spacecraft velocity vector. The remaining 230º of the antenna rotation will be used to perform a hot and a cold calibration and other housekeeping functions. The instrument will thus be calibrated once per scan at both ends of its measurement range, or about every two seconds. The rotating mass of the instrument generates momentum that must be compensated either by the instrument or by the spacecraft. Momentum compensation can be incorporated into the instrument, accomplished by a separate wheel placed on the spacecraft, or assumed by the spacecraft attitude control system; a decision concerning which approach will be used has not been identified at this time. The GMI is expected to

Key GMI Facts

Heritage: TRMM Microwave Imager (TMI), Special Sensor Microwave Imager (SSM/I), Special Sensor Microwave Imager/Sounder (SSMIS), Conical Scanning Microwave Imager/Sounder (CMIS)

Instruments: Two identical instruments, one for Core spacecraft and one for NASA Constellation spacecraft.

Instrument Type: Passive Microwave Radiometer

Scan Type: Conical scan at off-nadir angle of ~49º

Swath: 850 km from side to side centered along the spacecraft ground track.

Spectral Range: 10.65–89.0 GHz (possibly up to 183 GHz)

Channels: 10.65 GHz, H & V Pol; 18.7 GHz, H & V Pol; 21.3 GHz, V Pol; 37.0 GHz H & V Pol; 89.0 GHz, H & V Pol. Additional higher frequency channels at 150–165 and 183 GHz are also under consideration.

Dimensions: Electronics enclosure: 0.5 m × 0.5 m × 0.5 m; antenna size: ~1.0 m diameter

Mass: 100 kg

Power: 90 W

Data Rate: 14 kbps

Calibration: Hot and cold calibration once per scan at both ends of the GMI measurement range, about every two seconds

Contributor: TBD; NASA will conduct competitive procurement from industry

Key DPR Facts

Heritage: Precipitation Radar (PR) on TRMM

Instrument Type: Active Radar

Swath: 245 km (comprised of 49 footprints, each 5 km in width)

Mass: 660 kg

Power: 570 W

have mass of about 70 kg. The electronics enclosure should be on the order of 0.5 m × 0.5 m × 0.5 m, supporting the ~1.0 m diameter reflector.

DPR

Dual-frequency Precipitation Radar—JAXA

Detailed measurements of cloud structure and precipitation characteristics will be made with the DPR. JAXA is providing this instrument for GPM. The DPR is comprised of two essentially independent radars operating in the microwave region of the electromagnetic spectrum. One radar operates in the Ku-Band (13.6 GHz) and is referred to as the Precipitation Radar (PR)-U. The other radar operates in the Ka-Band (35.55 GHz) and is referred to as the PR-A. By measuring the reflectivities of rain at two different radar frequencies, it is possible to infer information regarding rainrate, cloud type and its three-dimensional structure, and drop-size distribution.

The design approach for both radars is based upon the TRMM PR design, updated as necessary to incorporate new technologies, and modified for operation at the specified frequencies. Like the PR, each of the DPRs uses a 128-element active phased array. The two radars are designed to provide temporally matching ground footprints with the same spatial size and scan pattern. Careful physical alignment of the radar antennas will be required on the spacecraft to ensure that co-alignment of the beams is achieved on-orbit. The DPR will have a 245 km wide ground swath, comprised of 49 footprints, each 5 km in width. The DPR's mass is estimated to be 660 kg. The antenna for PR-U will be 2.4 m × 2.4 m × 0.5 m in size, and that for PR-A will be 1.0 m × 1.0 m × 0.5 m.

GPM References

Adams, W. J., P. Hwang, D. Everett, G. M. Flaming, S. Bidwell, E. Stocker, J. Durning, C. Woodall, and T. Rykowski, 2002: Global Precipitation Measurement—Report 8: White Paper, W. J. Adams and E. A. Smith, eds., NASA STI Program Office, 31 pp. NASA/TM—2002-211609

Smith, E., and 31 others, 2005: International Global Precipitation Measurement (GPM) Program and Mission: An Overview, Measuring Precipitation from Space: EURAINSAT and the Future, Kluwer Publishers, in press.

Key DPR Facts *(cont.)*

Data Rate: 190 kbps

Consists of two distinct radar systems:

Precipitation Radar-A (PR-A)
- Frequency: 35.55 GHz
- Sensitivity: 11 dBZ
- Peak Power: 180 W
- Antenna Size: 1.0 m × 1.0 m × 0.5 m

Precipitation Radar-U (PR-U)
- Frequency: 13.6 GHz
- Sensitivity: 17 dBZ
- Peak Power: 1000 W
- Antenna Size: 2.4 m × 2.4 m × 0.5 m

Contributor: JAXA

GPM Data Products

All routine swath and gridded products will be archived and distributed by the Goddard Earth Sciences Distributed Active Archive Center (GDAAC). Products are generated through three levels. Level 1 consists of the calibrated, geo-located, instrument values at the instrument field of view. Level 2 maintains the instrument footprint orientation but converts instrument values to physical parameters, the key parameter for GPM being precipitation rate. Level 3 products aggregate the Level 2 physical parameters into different time-space grid orientations. This level provides the key climate quality research products produced by GPM.

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
GMI and DPR			
Calibrated Geo-located Instrument Values[2]	1	Instrument Field-of-View or Footprint	Raw instrument data
Physical Parameters[2]	2	Instrument Field-of-View or Footprint	The key parameter for the mission is precipitation rate
Climate Research Quality Product[2]	3	Global	Accuracy is stressed over timeliness
Global Precipitation Map[1]	3	Global	Global precipitation map available to all via the internet in near real time
Global Precipitation Product[1]	3	Global	Product to be used in weather modeling and forecast improvement; available every three hours.

[1] All data are made available to designated users 20 minutes after the collection of the last data bit in the product.

[2] All data are made available to designed users within 48 hours of having received all necessary data input.

GPM Data Products