by Dalia Kirschbaum and Arthur Hou

AT THE CORE

GLOBAL PRECIPITATION MEASUREMENT (GPM) MISSION

Next-generation unified precipitation observations from space will refine global data using the latest satellite technology

Satellite remote sensing provides the means for obtaining the quantitative precipitation estimates needed for scientific research and societal applications across the globe, including areas where rain-gauge and radar networks are sparse or non-existent. However, for the direct measurement of precipitating particles, current technologies are such that a time-continuous global view of precipitation is still a challenge. The Tropical Rainfall Measuring Mission (TRMM: http://trmm.gsfc.nasa.gov), launched in 1997, uses both active and passive microwave instruments to improve rainfall estimates in the tropics and provides a foundation for merging rainfall information from other satellites. The Global Precipitation Measurement (GPM) Mission will extend rain and snowfall sensing capabilities over all latitudes using an advanced radar-radiometer measurement system to unify and refine precipitation retrievals from a constellation of research and operational satellites.

The GPM Mission was initiated by the National Aeronautic and Space Administration (NASA) and the Japan Aerospace and Exploration Agency (JAXA) as a follow-on to TRMM to provide precipitation observations every two to four hours anywhere on the globe. It comprises a space network of microwave sensors provided by a consortium of international space agencies, including the Centre National d'Études Spatiales (CNES), the Indian Space Research Organization (ISRO), the National Oceanic and Atmospheric Administration (NOAA), and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). NASA and JAXA will deploy a core observatory carrying the first space-borne dual-frequency precipitation radar (DPR) and a multichannel GPM microwave imager (GMI) to be launched in July 2013 from Tanegashima Island in Japan. The GPM core observatory will have a primary mission life of three years, with consumables for an operational minimum of five years. NASA will also deploy a second GMI to fly on a partner-provided low-inclination observatory (LIO) with a target launch date in late 2014.

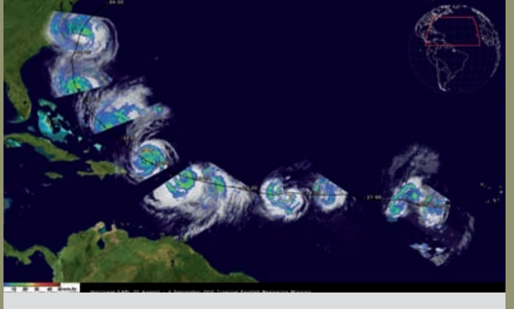
GPM Core Observatory

The GPM core observatory will function as a precipitation physics observatory and establish a transfer standard to unify and refine precipitation measurements from all constellation sensors. It will be deployed in a non-sun-synchronous orbit at a 65° inclination and a mean altitude of 407km. This will maximize latitudinal coverage while keeping a relatively short procession period to sample diurnal variability of precipitation for over 90% of the earth.

The inclined orbit will also enable the core observatory to collect coincident measurements with constellation sensors over a wide range of latitudes for inter-sensor calibration. The core observatory's rain-sensing package, which will extend the current capabilities of TRMM to measure light rain (<0.5mm/hr), falling snow, and the microphysical properties of precipitating particles, consists of several instruments.

The Dual-frequency Precipitation Radar (DPR) consists of a Ka-band precipitation radar at 35.5GHz and a Ku-band precipitation radar at 13.6GHz. They provide three-dimensional measurements of

GPM APPLICATIONS: INSIGHTS INTO TROPICAL STORM STRUCTURE

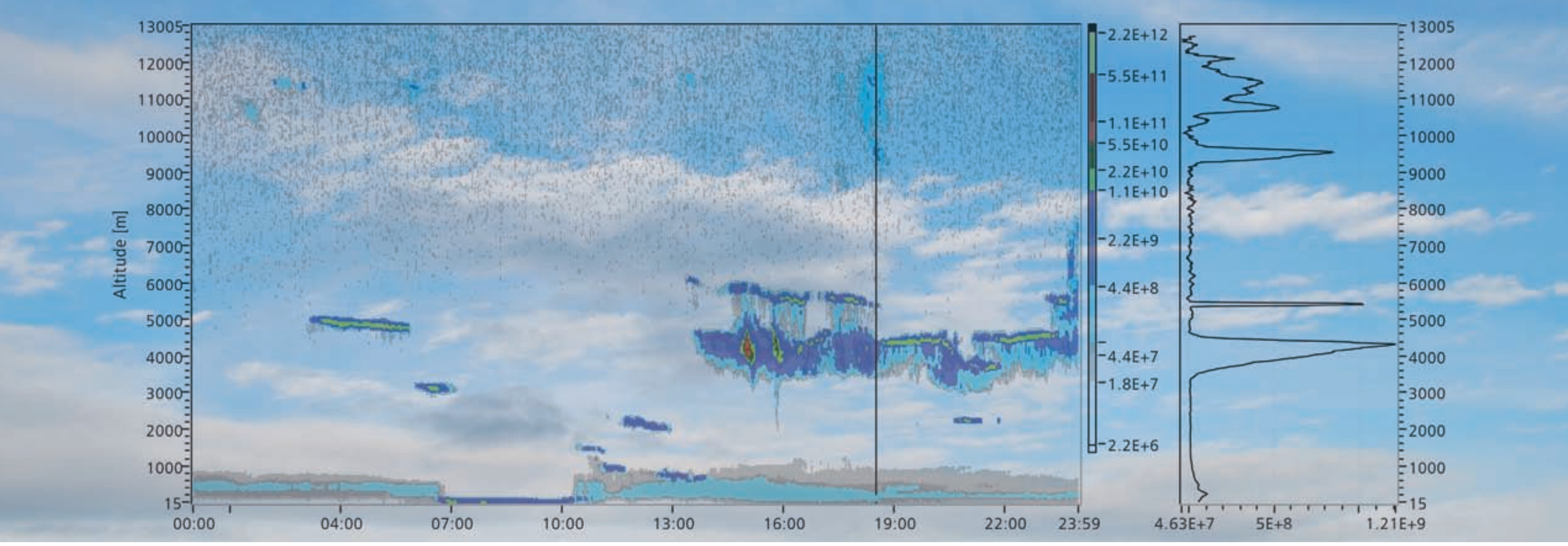


Monitoring cyclone transition. Picture courtesy: Harold Pierce, SSAI/NASA GSFC

The GPM mission will have the capability to monitor tropical cyclone transition into mid-latitude systems. The DPR and GMI instruments on board the GPM core observatory will provide three-dimensional precipitation structure information, which is vital for understanding how these tropical systems develop and how they may intensify or weaken as they change from tropical cyclones into mid-latitude frontal systems.

This composite image illustrates the current capability of TRMM's PR and TMI instruments to monitor the development and progression of Hurricane Earl as it moved through the Caribbean and up the eastern coast of the USA from August 25 to September 4, 2010. The storm path (black line) depicts the hurricane eye, with markers showing the location of the eye at the beginning of each day. The GPM core observatory will extend the latitudinal capability to evaluate the three-dimensional structure of storms as they change into mid- and high-latitude systems.

The Global Precipitation Measurement (GPM) mission is one of the next generation of satellite-based Earth science missions that will study global precipitation (rain, snow, ice)



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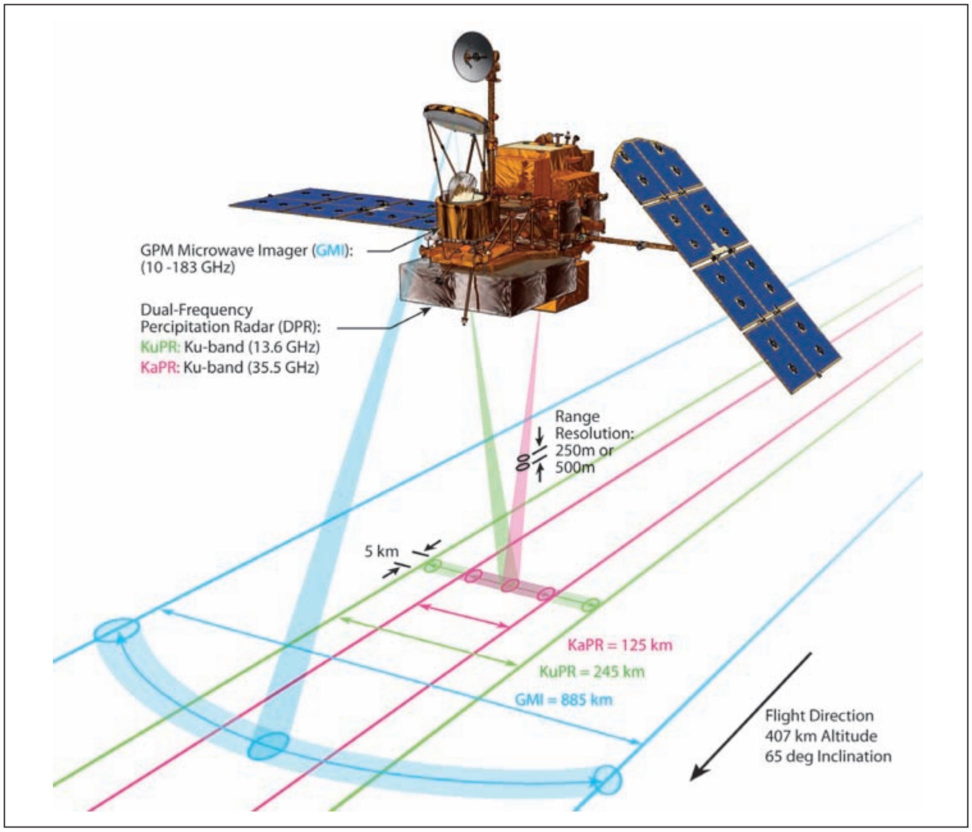


Diagram of the GPM core observatory, highlighting the location of the GMI and DPR as well as ground resolution and swath of the sensors. (Image credits: Harold Pierce, SSAI/NASA GSFC)

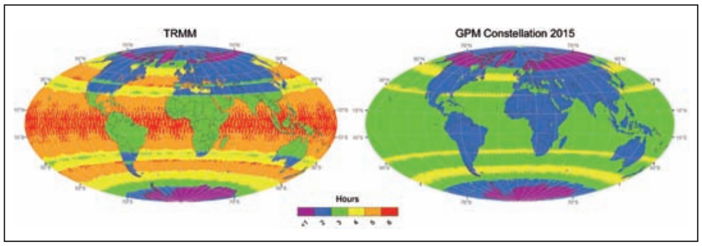
precipitation structures at 5km footprints over a cross-track swath width of 125km and 245km respectively. The DPR has increased sensitivity to the detection of light rain and snowfall relative to the TRMM radar, and, as a dual-frequency instrument, is capable of providing quantitative information about the microphysical properties of precipitation particles that are needed to improve retrieval accuracy. The DPR is currently under development at JAXA and the National Institute of Information and Communications Technology (NICT).

The GPM Microwave Imager (GMI) is a conical-scanning microwave radiometer with 13 channels ranging in frequency from 10-183GHz. The GMI combines both imaging and sounding channels to measure a spectrum of heavy, moderate, and light precipitation rates. The GMI has an off-nadir-viewing angle of 48.5°, which corresponds to an earth-incidence angle of 53° for the core. The GMI will rotate over a 140° sector centered on the satellite ground track, providing a cross-track swath of 885km with the central portion overlapping the DPR Ka-Ku swath. Within the region where the DPR and GMI swaths overlap, GPM precipitation retrievals will be of the highest quality as they will benefit from both radar and radiometer measurements. The GMI is being developed by the Ball Aerospace & Technologies Corp under a contract with NASA.

Low-Inclination Observatory (LIO): a second GMI will be launched in late 2014 to complement the non-sun-synchronous orbit of the GPM core observatory and offer improved temporal sampling and near real-time monitoring of rainfall accumulation and intensity during extreme meteorological events. The radiometer is expected to be flown on a partner-provided spacecraft at a 40° inclination and altitude of 635km.

Mission goals

GPM is designed to advance scientific understanding of the earth's water and energy cycles but it will also provide near real-time data for a wide array of societal applications. As a science mission with integrated application goals, the GPM mission has five scientific objectives: advance precipitation measurements from space using combined information from active and passive microwave sensors; improve understanding of the water cycle and fresh water availability through better measurements of precipitation variability in space and time; enhance climate modeling and prediction capabilities through improved measurements of latent heating, microphysics, and surface water fluxes; advance numerical weather prediction skill by providing better instantaneous measurements of precipitation rain rates and improved error characterization; and improve hydrometeorological modeling and prediction through more accurate estimates of precipitation accumulation and distribution at a high spatio-temporal resolution.



Comparison of mean revisit times (in hours) of the current capabilities and GPM constellation in 2015

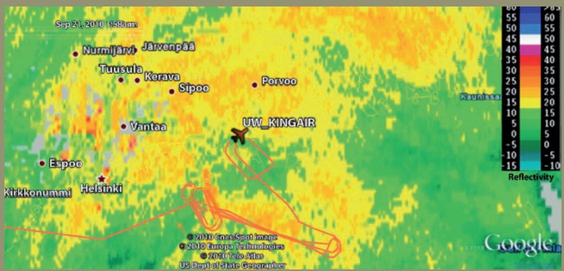
Radiometer intercalibration, remote-sensing algorithms, ground validation

As a prerequisite for deriving uniform precipitation estimates from a heterogeneous constellation of microwave sensors, relative biases among the sensor measurements must first be removed. The GPM mission is spearheading an international effort to develop a community consensus on methods for radiometric intercalibration by converting observations of one satellite to virtual observations of another using a non-sun-synchronous satellite such as the GPM

GROUND VALIDATION ACTIVITIES: HELSINKI FIELD EXPERIMENT

Ground validation activities prior to the GPM core observatory launch are integral to better understanding precipitation microphysics and improving retrieval algorithms. The Light Precipitation Validation Experiment (LPVEx) is a joint field campaign between CloudSat (http://cloudsat.atmos.colostate.edu) and GPM which seeks to detect light rainfall and rainfall intensity in high latitudes affected by shallow freezing levels over a six-week period starting on September 15, 2010 in the Gulf of Finland.

The experiment consists of a series of aircraft flights within an extensive network of ground-based observations. The King Air is deployed with a full suite of optical imaging probes for making measurements of liquid and ice water contents, and cloud and precipitation particle sizes and shapes, and it also carries a dual-polarimetric cloud radar. The ground-based observational component of LPVEx makes use of a triplet of ground-based dual-polarimetric radars, surface weather and sounding stations, several micro-rain radars, and surface rainfall and drop size distribution (DSD) measurements from a number of rain gauges and disdrometers. The collection of in-situ microphysical property measurements, remote sensing observations, and cloud-resolving model simulations will be used to develop and evaluate precipitation algorithms for current and future satellite platforms. The main goal of the campaign is to better understand light rainfall processes at high latitudes in order to enhance the microphysical cloud database for light rain retrieval.



core observatory as a transfer standard. Converting microwave sensor measurements into precipitation estimates requires a complex algorithm estimation framework. Dual-frequency radar algorithms are at the heart of algorithm development, serving as the foundation for combined radar-radiometer algorithms for the core observatory. The combined DPR-GMI algorithms will enable the construction of an *a priori* hydrometeor cloud database, which can then be used to retrieve precipitation information from all constellation radiometers within a unified framework.

Ground validation (GV) activities play a central role in refining retrieval algorithms during the pre-launch phase and evaluating precipitation products in the post-launch years. GPM GV pursues three complementary approaches: first, direct statistical validation of GPM precipitation estimates using ground-based networks to identify significant issues; second, physical validation of retrieval algorithms to evaluate and refine algorithm parameters and physical assumptions; and last, integrated hydrologic validation of GPM products to assess product utility in hydrometeorology and water budget studies. The GPM Mission has established an extensive international GV program in partnership with more than a dozen nations to perform statistical validation over various climatic and geographic regions and to carry out a series of pre-launch and post-launch field measurement campaigns.

> "Ground validation (GV) activities play a central role in refining retrieval algorithms during the pre-launch phase"

Deliverables

Radiometric intercalibration combined with physically based precipitation retrieval using a common cloud database will enable the GPM Mission to deliver next-generation intercalibrated global precipitation data products using measurements from a constellation of sensors. NASA and JAXA data processing systems will provide the following suite of data products: microwave radiances and precipitation rates over the GMI swaths within one hour of observation time; radar reflectivity and three-dimensional precipitation rates over the DPR swaths within three hours of observation time; precipitation rates from combined DPR and GMI retrievals within three hours of observation time; intercalibrated radiances from a constellation of radiometers and uniform constellation-based global precipitation products combining microwave and infrared measurements at 0.1 x 0.1° resolution, updated hourly according to data availability.

GPM is an international satellite mission to unify and advance precipitation measurements from space for scientific research and societal applications. The mission serves as a prototype for developing a multinational satellite constellation for monitoring established by the Committee on Earth Observation Satellites (CEOS) under the umbrella of the Global Earth Observing System of Systems (GEOSS), which provides comprehensive, long-term, and coordinated observations of the earth. Additional information about the GPM Mission, instrumentation, and data products can be found at http://pmm.gsfc.nasa.gov. ∎

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