The Global Precipitation Measurement (GPM) Mission: Overview and U.S. Status

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5th IPWG Workshop
11-15 October 2010
GPM Mission Concept

An international satellite mission to unify and advance precipitation measurements from space

Low Inclination Observatory (40°)
GMI (10-183 GHz)
(NASA & Partner, 2014)

- Enhanced capability for near-realtime monitoring of hurricanes & midlatitude storms
- Improved accuracy in rain accumulation

Partner Satellites:
GCOM-W1
DMSP F-18, F-19/20
Megha-Tropiques
MetOp, NOAA-19
NPP, JPSS (over land)

GPM Core Observatory (65°)
DPR (Ku-Ka band)
GMI (10-183 GHz)
(NASA-JAXA, LRD 2013)

- Precipitation physics observatory
- Transfer standard for inter-satellite calibration of constellation sensors

Key Contribution
Refine constellation sensor retrievals within a consistent framework to provide next-generation global precipitation data products

Coverage & Sampling
- 1-2 hr revisit time over land
- < 3 hr mean revisit time over 90% of globe
A science mission with integrated application goals

GPM Science Goals

- New reference standards for precipitation measurements from space
  - using combined information from active and passive microwave sensors
- Better understanding of water cycle variability, and freshwater availability
  - through better description of space-time distribution of precipitation processes
- Improved numerical weather prediction skills
  - through better instantaneous precipitation information and associated error characterization
- Improved hydrological prediction capabilities for floods, landslides, and freshwater resources
  - through downscaling and innovative hydrological modeling
- Improved climate modeling and prediction capabilities
  - through better estimates of latent heating, precipitation microphysics, & surface water fluxes

Key to better global precipitation data products:

- Accuracy of instantaneous precipitation estimate
- Spatial coverage & temporal sampling (for improved estimation of precipitation accumulation)
- Spatial resolution (for local-scale applications)
- Data latency (for near real-time operational use)
Core Observatory Measurement Capabilities

**Dual-Frequency (Ku-Ka band) Precipitation Radar (DPR):**

- Increased sensitivity (~12 dBZ) for light rain and snow detection relative to TRMM
- Better measurement accuracy with differential attenuation correction
- Detailed microphysical information (DSD mean mass diameter & particle no. density) & identification of liquid, ice, and mixed-phase regions

**Multi-Channel (10-183 GHz) GPM Microwave Imager (GMI):**

- Higher spatial resolution (IFOV: 6-26 km)
- Improved light rain & snow detection
- Improved signals of solid precipitation over land (especially over snow-covered surfaces)
- 4-point calibration to serve as a radiometric reference for constellation radiometers

**Combined Radar-Radiometer Retrieval**

- DPR & GMI together provide greater constraints on precipitation retrieval for improved accuracy
- DPR/GMI-constrained cloud database for constellation radiometer retrievals
GPM Strategy to Global Precipitation Estimation

- Radar for vertical structural details
- Radiometers for horizontal coverage
- A radar-radiometer system for a common transfer standard

DPR Retrievals:

- A characteristic size parameter ($D_0$) of the PSD estimated from the difference (in dB) between Ku- and Ka-band radar reflectivity factors
- Ambiguities include unknown shape parameter ($\mu$) of the gamma PSD distribution and the snow mass density ($\rho$)
- Characteristic number concentration of PSD is given by $D_0$ and the radar equation
- Step-by-step estimation of attenuation correction based on PSD estimates
- Precipitation rate and the equivalent water content are derived from the PSD for an assumed velocity distribution

Meneghini et al., NASA/GSFC
Combined DPR+GMI retrievals

• Using GMI radiance measurements as additional constraints on the DPR profiling algorithm:

  Assumptions regarding the particle size distribution, ice microphysics, cloud water and water vapor vertical distribution are refined using a variational procedure that minimizes departures between simulated and observed brightness temperatures - according to the sensitivity of simulated brightness temperatures to assumptions in DPR retrievals.

• Retrievials are consistent with both DPR reflectivities and GMI radiances within a maximum-likelihood estimation framework.

• Construction of an a-priori database that relates hydrometeors to brightness temperatures over the range of observed $T_b$ values for precipitation retrievals from constellation radiometers.

• Pre-launch algorithm advances focus on retrievals of solid precipitation and physical retrievals over land:

  - Modeling of nonlinear, under-constrained relationships between physical characteristics of precipitation particles and microwave observations
  - Characterization of land surface variability/emissivity
Role of GPM Ground Validation

Pre-launch algorithm development & post-launch product evaluation

- Refine algorithm assumptions & parameters
- Characterize uncertainties in satellite retrievals & GV measurements

“Truth” is estimated through the convergence of satellite and ground-based estimates

Three complementary approaches:

• **Direct statistical validation (surface):**
  - Leveraging off operational networks to identify and resolve first-order discrepancies between satellite and ground-based precipitation estimates

• **Physical process validation (vertical column):**
  - Cloud system and microphysical studies geared toward testing and refinement of physically-based retrieval algorithms

• **Integrated hydrologic validation/applications (4-dimensional):**
  - Identify space-time scales at which satellite precipitation data are useful to water budget studies and hydrological applications; characterization of model and observation errors
International Collaborations on GPM GV

- Joint field campaigns
- National networks and other ground assets (radar, gauges, etc.)
- Hydrological validation sites (streamflow gauges, etc.)

15 Active International Projects

GPM Joint Field Campaigns:

- Joint campaign with Brazil on warm rain retrieval over land in Alcântara, 3-24 March 2010
- Light Precipitation Validation Experiment (LPVEx): CloudSat-GPM light rain in shallow melting layer situations in Helsinki, Finland, 15 Sept - 20 Oct 2010
- Mid-Latitude Continental Convective Clouds Experiment (MC3E): NASA-DOE field campaign in central Oklahoma, Apr-May 2011
- High-Latitude Cold-Season Snowfall Experiment: Joint campaign with Environment Canada on snowfall retrieval in Ontario, Canada, Jan-Feb 2012
- Hydrological validation with NOAA HMT in 2013 (under development)
“Golden Day”

21 September 2010
9:20 GMT

10:05 GMT

Aircraft spiral from 1 Kft to 12 kft
Freezing Level: 1.9 km
GPM Sampling and Coverage

Baseline Constellation Schedule

Current Capability:
≤ 3h over 45% of globe

GPM (2015): ≤ 3h over 90% of globe

1-2 hr revisit time over land with inclusion of sounders

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Near real-time observations from the GPM Core and LIO between overpasses by polar orbiters at fixed times of the day for:

- Near real-time monitoring of hurricanes & midlatitude storms
- Improved accuracy of rain volume estimation
- Resolving diurnal variability in rainfall climatology
- Coincident observations with constellation radiometers for intercalibration over wide ranges of latitudes and climate regimes
Inter-Satellite Calibration of Microwave Radiometers

• **Objective:** Quantify and reconcile differences between similar (but not identical) microwave radiometers to remove relative biases in measurements

• **X-Cal (Imagers):** Convert observations of one satellite to virtual observations of another using a non-Sun-synchronous satellite as transfer standard (e.g. TMI or GMI)
  - Develop corrections for recurring instrument errors and implementation strategy for routine intercalibration of constellation radiometers
  - Bias correction a function of orbital phase and solar beta angle
  - Agreement between different methods \(\sim 0.3\) K

• **X-Cal (Sounders):**
  - Double differencing using forecast residual as primary transfer standard to provide a basis for calibration consistency
  - Collaboration with NWP centers

GPM International X-Cal Working Group (NASA, JAXA, NOAA, CNRS, EUMETSAT, CMA, CONAE, GIST, & universities) in coordination with WMO/CGMS GSICS

Hou, 5th IPWG Workshop, 11-15 Oct 2010  

 Courtesy of Wilheit (Texas A&M) & Jones (UCF)  

 Courtesy of Hanna, Weng, & Yan (NOAA)
Next-Generation Global Precipitation Products

• Intercalibrated constellation radiometric data reconciling differences in center frequency, viewing geometry, resolution, etc.
  - Converting observations of one satellite to virtual observations of another using non-Sun-synchronous satellite as a transfer standard
  - GMI employs an encased hot load design (to minimize solar intrusion) and noise diodes for nonlinearity removal to attain greater accuracy & stability

• Unified precipitation retrievals using a common cloud database constrained by DPR+GMI measurements from the Core Observatory

Optimally matching observed $T_b$ with simulated $T_b$ from an a priori cloud database

Prototype GPM Radiometer Retrieval

Simulated $T_b$    Observed $T_b$

TRMM uses a model-generated cloud database
GPM uses a DPR/GMI-constrained database

Comparison of TRMM PR surface rain with TMI rain retrieval using an cloud database consistent with PR reflectivity and GMI multichannel radiances

Hou, 5th IPWG Workshop, 11-15 Oct 2010
Sensor and Product Resolution

- DPR will provide precipitation structure information at 5 km horizontal resolution.
- GMI on Core Observatory at 407 km will offer the highest resolution radiometric imaging data.

- Dynamically or statistically downscaled precipitation products at 1-2 km resolution

Assimilation of rain-affected radiances from TMI and AMSR-E into the NASA/CSU WRF Ensemble Data Assimilation System (EDAS)

Rain accumulation for 15-22 September 2009 over the Southeast U.S. flood region
# GPM Data Products

<table>
<thead>
<tr>
<th>Product Level</th>
<th>Description</th>
<th>Coverage</th>
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</thead>
<tbody>
<tr>
<td>Level 1B GMI, GMI-2</td>
<td>Geolocated Brightness Temperature and intercalibrated brightness temperature</td>
<td>Swath, instrument field of view (IFOV)</td>
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<tr>
<td>Level 1C GMI, GMI-2</td>
<td></td>
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<tr>
<td>Latency ~ 1 hour</td>
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<tr>
<td>Level 1B DPR</td>
<td>Geolocated, calibrated radar powers</td>
<td>Swath, IFOV (produced at JAXA)</td>
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<tr>
<td>Level 1C, partner radiometers</td>
<td>Intercalibrated brightness temperatures</td>
<td>Swath, IFOV</td>
</tr>
<tr>
<td>Level 2 GMI, GMI2</td>
<td>Radar enhanced (RE) precipitation retrievals</td>
<td>Swath, IFOV</td>
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<tr>
<td>Latency ~1 hour</td>
<td></td>
<td></td>
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<tr>
<td>Level 2 partner radiometers</td>
<td>RE precipitation retrievals from 1C</td>
<td>Swath, IFOV</td>
</tr>
<tr>
<td>Level 2 DPR</td>
<td>Reflectivities, Sigma Zero, Characterization, DSD, Precipitation with vertical structure</td>
<td>Swath, IFOV (Ku, Ka, combined Ku/Ka)</td>
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<tr>
<td>Latency ~3 hours</td>
<td></td>
<td></td>
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<tr>
<td>Level 2 combined GMI/DPR</td>
<td>Precipitation</td>
<td>Swath, IFOV (initially at DPR Ku swath and then at GMI swath)</td>
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<tr>
<td>Latency ~3 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3 Latent Heating (GMI, DPR, Combined)</td>
<td>Latent Heating and associated related parameters</td>
<td>0.1 x 0.1 monthly grid</td>
</tr>
<tr>
<td>Level 3 Instrument Accumulations</td>
<td>GMI, partner radiometers, combined and DPR</td>
<td>0.1 x 0.1 monthly grid</td>
</tr>
<tr>
<td>Level 3 Merged Product</td>
<td>Merger of GMI, partner radiometer, and IR</td>
<td>0.1 x 0.1 hourly grid</td>
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<tr>
<td>Level 4 Products</td>
<td>Model assimilated data</td>
<td>Fine temporal and spatial scale TBD</td>
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Mission Status

• GPM is in Phase C implementation at NASA
  - GMI # 1 & 2 fabrication & assembly underway
  - Core Spacecraft manufacturing in progress: Integration & Test in Dec 2010

• Core Observatory Launch Readiness Date: 21 July 2013

• NASA in partnership discussion to launch the GPM LIO in late 2014

• NASA Precipitation Processing System currently producing
  - Prototype inter-calibrated Level-1 products for TMI, SSMI, AMSR-E, SSMIS, & WindSat
  - Level-3 merged global precipitation products using TMI, SSMI, AMSR-E, AMSU, & MetOp in near real-time for research & applications

• International and domestic partnership agreements under development
  - CNES, ISRO, AEB/INPE, EUMETSAT, NOAA, JPSS, DWSS

• NASA is conducting a series of joint field campaigns with domestic and international partners to refine algorithm assumptions and parameters.

• GPM is the cornerstone for the CEOS Precipitation Constellation (PC) under development in support of GEOSS and GEO
  - 9th GPM International Planning Workshop and 4th CEOS PC Workshop will be hosted by INPE/AEB in Fortaleza, Brazil, in April 2011