NASA’s Global Precipitation Measurement (GPM) Mission: Observing Rain and Snow for Science and Society

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gpm.nasa.gov

EUMETRAIN
25 November 2015
Science Objectives:
- New reference standards for precipitation measurements from space
- Improved knowledge of water cycle variability and freshwater availability
- Improved numerical weather prediction skills
- Improved climate prediction capabilities
- Improved predictions for floods, landslides, and freshwater resources

Societal Benefits:
- Floods and Landslides
- Freshwater Availability/Agriculture/Famine
- Extreme Events
- World Health

Applications & Users:
Partnership with the Japanese
- JAXA built the Dual-frequency Precipitation Radar (DPR)
- NASA provided the GPM Microwave Imager (GMI); Ball Aerospace built it under contract
- Integration to the spacecraft bus occurred at NASA Goddard Space Flight Center in 2013
- Launched from Tanegashima Island, Japan on Feb 28, 2014
- Followed successful partnership for the Tropical Rainfall Measuring Mission (TRMM)

Mission Operation
- Fully staffed
- Feathering the Solar Arrays to save fuel; orbit adjust once every two weeks
  - Fuel expectancy 15+ years

Precipitation Processing System (PPS)
- Fully operational and processing precipitation data
  - Rain rates from 0.2-110 mm/hr and detecting/estimating falling snow

Launched 3:37 a.m. JST on Feb. 28, 2014 from Tanegashima Island, Japan
The **GPM Core Observatory** carries **two advanced instruments** that allow us to view precipitation (rain, snow, ice) in new ways and serve as a **connector** between the GPM Core and measurements taken on other partner satellites.

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

13 channels provide an integrated picture of the energy emitted by precipitation, including light rain to heavy rain to falling snow. Like an X-Ray.

**Dual-frequency Precipitation Radar (DPR): Ku-Ka bands**

Two different radar frequencies that measure precipitation in 3-D throughout the atmospheric column. Like a CT Scan.

**Built by JAXA**

Non-Sun-Synchronous orbit at 65° inclination (Arctic to the Antarctic Circle) at 407 km.
Core Observatory Geometry and Instruments

0.2-110mm/hr & snow

- Orbit: 407 km; 65 deg inclin.; 3-year life, 15+ year fuel

GPM Microwave Imager (GMI)
- Passive microwave radiometer with hot and cold calibration, includes novel calibration engineering
- Provides measurements of precipitation (rain and snow) intensity and distribution over wide swath (880 km)
- High spatial resolution (down to ~5km footprints)
- 166 Kg, 162 W, 34.9 Kbs Science, 1.2 m diameter reflector

Dual-frequency (Ku-Ka band) Precipitation Radar (DPR)
- KuPR similar to TRMM, KaPR added for GPM
- Provides three-dimensional measurements of precipitation structure, precipitation particle size distribution (PSD) and precipitation intensity and distribution
- High spatial resolution (5km horizontal; 250m vertical)

<table>
<thead>
<tr>
<th>DPR</th>
<th>KuPR</th>
<th>KaPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>13.597, 13.603 GHz</td>
<td>35.547, 35.553 GHz</td>
</tr>
<tr>
<td>Min. detectable rainfall rate</td>
<td>0.5 mm/hr</td>
<td>0.2 mm/hr</td>
</tr>
<tr>
<td>Data Rate</td>
<td>&lt; 109 kbps</td>
<td>&lt; 81 kbps</td>
</tr>
<tr>
<td>Mass</td>
<td>&lt; 472 kg</td>
<td>&lt; 336 kg</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>&lt; 446 W</td>
<td>&lt; 344 W</td>
</tr>
<tr>
<td>Size</td>
<td>$2.5 \times 2.4 \times 0.6$ m</td>
<td>$1.2 \times 1.4 \times 0.7$ m</td>
</tr>
</tbody>
</table>

GMI Frequencies
- 10.65 GHz V/H
- 18.7 GHz V/H
- 23.8 GHz V
- 36.5 GHz V/H
- 89 GHz V/H
- 166 GHz V/H
- 183 GHz Va/Vb ($\pm 3 \& \pm 7$)
Different types of precipitation emit energy at different frequencies (GHz). The GMI passively absorbs this energy (and other competing signals) and can decipher what is happening in the cloud (sort of like an x-ray).

<table>
<thead>
<tr>
<th>Water vapor:</th>
</tr>
</thead>
<tbody>
<tr>
<td>absorption/Emission</td>
</tr>
</tbody>
</table>

- Ice: scattering
- Rain: scattering, emission/absorption
- Surface: scattering, emission/absorption

GMI Testing at Ball Aerospace (Colorado, USA)
Dual-frequency Precipitation Radar

- The DPR sends out two different frequencies at 35 GHz and 13.6 GHz and can determine the size and distribution of rain, snow, and ice from the strength of the returning signal.
- By using two frequencies it enables us to better understand particle distribution and microphysics, which is very important for improving estimates of rain rate on the surface.
- Takes 3D data like a CT scan.
The Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR) can sense and retrieve the three-dimensional structure of precipitation within clouds?

Yes/True?

No/False?
How GPM works:

Movie: svs.gsfc.nasa.gov (search on 4016)
GPM Constellation Concept

- **GPM Core Observatory**
  - NASA/JAXA
  - Launched Feb 2014
  - DPR (Ku & Ka band)
  - GMI (10-183 GHz)
  - 65° Incl & 407 km Alt.
  - 5 km best resolution
  - Rain 0.2–110 mm/hr & snow
  - Megha-Tropiques
    - CNES/ISRO

- **GPM Constellation Concept**
  - MetOp B/C
    - EUMETSAT
  - Suomi NPP
    - NASA/NOAA
  - TRMM
    - NASA/JAXA
  - JPSS-1
    - NOAA
  - DMSP F17/F18/F19/F20
    - DOD
  - NOAA 18/19
    - NOAA
  - GCOM-W1
    - JAXA

**Next-Generation Unified Global Precipitation Products Using GPM Core Observatory as Reference**
The Global Precipitation Measurement (GPM) Core Observatory spacecraft is used to intercalibrate partner constellation precipitation data to produce next-generation unified precipitation estimates globally?

Yes/True?

No/False?
TRMM ACCOMPLISHMENTS

- **Space standard** for measuring precipitation
- **Improved** **climatologies** of rainfall, latent heating and diurnal signals
- **Improved** **climate and weather models**
- **Hurricane/typhoon** **structure/evolution**
- **Multi-satellite** (~3-hr) rainfall analyses using TRMM+other satellites
- **Flood and agricultural** applications
- **Operational use** of data by weather agencies.

~1 year overlap with GPM

# TRMM Citations = 25,274+
GPM Enhancements Compared to TRMM

- Increased Earth Coverage
- Advanced Instruments
  - Dual Frequency Precipitation Radar
  - Passive Radiometer (10-183 GHz)
- Finer spatial resolution
- Detects falling snow
- Well designed radiometer (unifies partner estimates)
<table>
<thead>
<tr>
<th>Name</th>
<th>Features</th>
<th>Latency</th>
<th>Resolution</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GMI</strong></td>
<td>Level 1: Calibrated TB; Level 2: precip rates; Level 3: accumulations</td>
<td>Near real time 1 hour</td>
<td>~15 km</td>
<td>Constellation precipitation rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~5 km resolution</td>
<td></td>
<td>Name: GPROF</td>
</tr>
<tr>
<td><strong>DPR</strong></td>
<td>Level 1: Calibrated powers; Level 2: Z &amp; precip rates; Level 3: accumulations</td>
<td>Near real time 3 hours</td>
<td>~5 km</td>
<td>Ku, Ka, and Ku+Ka products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~3 hours</td>
<td></td>
<td>Name: DPR</td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td>Level 2: Combined DPR &amp; GMI; Level 3: accumulations</td>
<td>Near real time 3 hours</td>
<td>~15 km</td>
<td>Greater constraints on estimates; database for GPROF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~3 hours</td>
<td></td>
<td>Name: CMB</td>
</tr>
<tr>
<td><strong>Multi-Satellite</strong></td>
<td>Level 2: precip rates; Level 3: accumulations</td>
<td>Near real time 4-6 hrs</td>
<td>~10 km res., every 30 minutes</td>
<td>Uses IR to fill between microwave for 30 min data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~10 km resolution</td>
<td></td>
<td>Name: IMERG</td>
</tr>
</tbody>
</table>
• Data Usage Statistics:
  – Average monthly downloads on the order of 64TB in >6 million files/month
  – Daily downloads from *users and agencies all over the world*: EUMETSAT, ECMWF, UK Met Office, United Nations, Brazil, Netherlands, Argentina, Taiwan, Mexico, Australia, Japan, UK, Korea, European Union, China, India, South Africa, Spain

• Data *product reprocessing in early 2016* for updated algorithms

• *Meeting Data Latency Requirements of 1-3 hours* for GPM Core Products > 97% of the time

<table>
<thead>
<tr>
<th>Month</th>
<th>1c (GMI Brightness)</th>
<th>GPROF (GMI Precipitation)</th>
<th>Combined (DPR/GMI Precipitation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2015</td>
<td>99.000%</td>
<td>98.875%</td>
<td>97.750%</td>
</tr>
<tr>
<td>June 2015</td>
<td>99.958%</td>
<td>99.889%</td>
<td>98.833%</td>
</tr>
<tr>
<td>July 2015</td>
<td>99.380%</td>
<td>99.194%</td>
<td>98.405%</td>
</tr>
<tr>
<td>August 2015</td>
<td>100.000%</td>
<td>100.000%</td>
<td>97.596%</td>
</tr>
<tr>
<td>September 2015</td>
<td>99.609%</td>
<td>99.566%</td>
<td>97.743%</td>
</tr>
<tr>
<td>October 2015</td>
<td>99.702%</td>
<td>99.616%</td>
<td>98.884%</td>
</tr>
</tbody>
</table>
Data Access (http://pps.gsfc.nasa.gov)

How to Access TRMM & GPM Precipitation Data

Precipitation data from the GPM and TRMM missions is made available free to the public in a variety of formats from several sources at NASA Goddard Space Flight Center. This section outlines the different types of data available, the levels of processing, the sources to download the data, and some helpful tips for utilizing precipitation data in your research.

- **GPM Data Downloads**
- **TRMM Data Downloads**
- **Explanation of GPM & TRMM Data Sources**
- **Data Processing "Recipes"**
- **TRMM Data in Google Earth**
- **Frequently Asked Questions (FAQ)**

TRMM & GPM Data Policy

TRMM and GPM data are freely available at all levels for which the particular sensor or sensor combination has been processed by GPM. For the GPM Core Observatory this is for Levels 0 through 3 products (as applicable). For the partner satellites in the GPM constellation this is Levels 1c through 3 (as applicable).

Users are encouraged to access data from the primary TRMM and GPM archives (i.e. nasa.gov domains at Goddard Space Flight Center). When data from secondary archives are used, it is incumbent on the user to verify that the data values accessed are accurate, up-to-date, current-version copies of the original data. Data format questions should be directed to the relevant archive site, while science questions should be sent to the dataset developers.
Data Access (http://pps.gsfc.nasa.gov)

PRECIPITATION MEASUREMENT MISSIONS

GPM Data Downloads

NOTE: The GPM Core Observatory launched on February 27th 2014 and the pipeline for generating data products is still being developed, therefore not all planned GPM data products are currently available. Click here for a projected schedule of when these products will be released. Please check back at http://gpm.nasa.gov and http://twitter.com/NASA_Rain for the latest news.

Level 3 Level 2 Level 1

Geophysical parameters that have been spatially and/or temporally resampled from Level 1 or Level 2 data.

IMERG: Rainfall estimates combining data from all passive-microwave instruments in the GPM Constellation

(Pending Release) This algorithm is intended to intercalibrate, merge, and interpolate "all" satellite microwave precipitation estimates, together with microwave-calibrated infrared (IR) satellite estimates, precipitation gauge analyses, and potentially other precipitation estimators at fine time and space scales for the TRMM and GPM eras over the entire globe. The system is run several times for each observation time, first giving a quick estimate and successively providing better estimates as more data arrive. The final step uses monthly gauge data to create research-level products. Full Documentation

Learn about the upcoming transition from TMPA (3B42v2) to IMERG

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Regions - Dates</th>
<th>Latency</th>
<th>Format</th>
<th>Source</th>
<th>DL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1° - 30 minute</td>
<td>Gridded, 90°N-90°S, March 2014 to present</td>
<td>4 hours (RT)</td>
<td>HDF5</td>
<td>RT: FTP (PPS)*</td>
<td></td>
</tr>
<tr>
<td>0.1° - 30 minute</td>
<td>Gridded, 90°N-90°S, March 2014 to present</td>
<td>12 hours (RT)</td>
<td>HDF5</td>
<td>Mirador</td>
<td></td>
</tr>
<tr>
<td>0.1° - 30 minute</td>
<td>Gridded, 90°N-90°S, March 2014 to present</td>
<td>4 months (Prod)</td>
<td>HDF5</td>
<td>Prod: FTP (PPS)*</td>
<td></td>
</tr>
<tr>
<td>0.1° - 30 minute</td>
<td>Gridded, 90°N-90°S, March 2014 to present</td>
<td>12 hours (RT)</td>
<td>HDF5</td>
<td>Prod: STORM</td>
<td></td>
</tr>
</tbody>
</table>
Select a Data Type and a date range

- Optionally...
  - Specify a geographic region
  - Specify variables of interest within the file
  - Order a custom subset of these variables and region

- Download the HDF5 file via FTP
- Explore the HDF5 file online using THORonline

Search Result Table

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Download / View</th>
<th>Start Time</th>
</tr>
</thead>
<tbody>
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<td>2AGPROF</td>
<td>THOR</td>
<td>2015-10-31</td>
</tr>
<tr>
<td>2AGPROF</td>
<td>THOR</td>
<td>2015-11-01</td>
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<tr>
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<td>2AGPROF</td>
<td>THOR</td>
<td>2015-11-01</td>
</tr>
</tbody>
</table>
GPM browse data are being made available through NASA Worldview Global Imagery Browse Services (GIBS)

- Zoomable, browseable interface of daily ascending and descending composites
- Can overlay multiple fields with variable transparency
- Current data fields include:
  - 3-channel composite Tb
  - GPROF rain and snow
- Overlay ground tracks and overpass times
- URL: https://earthdata.nasa.gov/labs/worldview/
- GPM example: http://go.nasa.gov/1Xb4qyU
- Feedback to Joe Munchak (s.j.munchak@nasa.gov)
The GPM data (formatted in imagery and as raw data) are available at near real-time for application users and later for higher-quality scientific investigations?

Yes/True?

No/False?
March 17, 2014 Snow Storm

Note melting layer (red to purple dividing line) and cloud top heights

Washington, DC Snow event, 18 cm March 17, 2014

Movie: sv.sgsfc.nasa.gov (search on 4173)
IMERG Rain (Nov 11-18, 2015)

30 minute by 0.1 deg by 0.1 deg; available ~ 4-6 hours after obs.

Movie: svs.gsfc.nasa.gov (search on 4285)
One day after flooding the Solomon Islands, the precursor to Tropical Cyclone Ita is seen by GPM

4 April 2014 0853 UTC 12°S 158°E

Precipitation Signal Strength
Ku weak red mid strong
Ka very weak yellow 100 km

GPM data courtesy of NASA / JAXA
The most **extensive** precipitation systems are found over mid and high latitude ocean.

The **strongest** storms such as hailstorms and lightning storms are dominant over land.
In early September 2015, Japan experienced extreme rainfall that resulted in flooding, landslides and many injuries. A nearly stationary front that was already moving over Japan caused much of the rain but tropical storm Etau also interacted with the front and magnified the scale of the deluge. The images show rainfall accumulations from Sept. 2-9 from the Integrated Multi-satellite Retrievals for GPM (IMERG) data (left). The inset image shows GPM’s DPR and GMI rainfall measurements of Etau when the satellite passed over the center of the tropical storm on September 7, 2015 at 1416 UTC.
The United States has seen a tale of two extremes in 2015, with drenching rains in the eastern half of the country and persistent drought in the west. A new visualization of rainfall data collected from space shows the stark contrast between east and west for the first half of 2015.
Flooding in Southern Europe (November 6, 2014)

Heavy rains struck southern France (peaking Tuesday-Wednesday) and then parts of northern Italy. Calculations based on TRMM/GPM rainfall are extended in time using GEOS-5 rain forecasts with a second peak forecast for Venice for Saturday.

St Marks Square, Venice

Global Flood Monitoring System (GFMS) Adler/Wu U. of Maryland
NASA's Integrated Multi-satellite Retrievals for GPM (IMERG) data were used to estimate the historic amount of rain that fell during Sept 29-Oct 5, 2015 in the US Carolinas. A "fire hose" of moisture was pumped into this region from hurricane Joaquin resulting in widespread flooding. Over two feet of rain were reported in South Carolina. This analysis indicated that major hurricane Joaquin also dropped over 700 mm (27.5 inches) in the Bahamas.

Visualization and caption credit: Hal Pierce/GSFC
NASA's Integrated Multi-satellite Retrievals for GPM (IMERG) data were used to estimate the historic amount of rain that fell during Sept 29-Oct 5, 2015 in the US Carolinas. A "fire hose" of moisture has been pumped into this region from hurricane Joaquin resulting in widespread flooding. Over two feet of rain have been reported in South Carolina. This analysis indicated that major hurricane Joaquin also dropped over 700 mm (27.5 inches) in the Bahamas.

Soil Moisture Active/Passive (SMAP) satellite map

Visualization and caption credit: Hal Pierce/GSFC
The GPM Core Observatory satellite flew above the intensifying tropical cyclone on October 22, 2015 at 0401 UTC. Patricia was still a tropical storm with winds estimated at 55 kts (63 mph). Rainfall derived GMI and DPR showed that an eye was forming with intense rainfall just to the southeast of the forming eye. GPM's DPR measured rain falling at the extreme rate of almost 110 mm (4.3 inches) per hour within an intense feeder band west of Patricia's center.
Hurricane Patricia (10/20-24/2015), the most powerful hurricane on record in the Western Hemisphere, quickly lost power as it moved over Mexico. Then an upper-level low pressure system and the remnants of Hurricane Patricia combined to cause very heavy rain in Texas.

Data from NASA's Integrated Multi-satellite Retrievals for GPM (IMERG) were used to estimate the accumulation of rain from October 20-24, 2015.

Credit: Hal Pierce, SSAI/NASA GSFC
Total Views of GMI data on NRL page (June 2014-Feb.2015): 1,011,234 from 424K unique IP addresses

Images from Tropical Storm Arthur (7/1/14)

www.nrlmry.navy.mil/TC.html
The GPM satellite was successfully launched on February 27th, 2014. GMAO is currently developing the all-sky radiance data assimilation system to utilize GPM Microwave Imager (GMI) radiance data in GEOS-5 to improve global cloud and precipitation analyses. This will contribute to improve near-real time weather forecasts including severe storms like hurricanes.

Figure Credit: Min-Jeong Kim, Jianjun Jin, Will McCarty, Ricardo Todling, and Ron Gelaro
The Global Precipitation Measurement (GPM) data is already proving useful for science and society?

Yes/True?

No/False?
Ground Validation Activities

1. **Direct validation** (Satellite retrievals compared to ground observations)
   - Precipitation GV Research Facility at NASA Wallops
   - Operational Validation Network (VN) providing ground radar and coincident satellite overpass data over CONUS and some international partners.
   - Automated NMQ rain rate data stream over CONUS.

2. **Physical validation** (Understanding remote sensing principles)
3. **Integrated hydrological validation** (Linking to societal benefits)
A Global View of Precipitation with a Global Team

A Global Effort

CONUS/NOAA NMO/Q2 (Gauge/Radar)
Canada (Radars/Gauge)
(GCPEX; 2012 Snow, 2012- )
U. Iowa/Flood Center
(IFloodS; 2013)
OLYMPEX (TBC); 2015/16
DOE ARM SGP
MC3E; 2011
ARS Walnut Gulch
(Gauges)
IPHEX; 2014

WFF: Radar, disdrometers, gauges
EU gauges, radars, disdrometers
Finland: UH/FMI Helsinki,
Sodankylä radars, gauges
(LPVEX 2010; Snow 2012- )

HyMEX (2012- )
S. Korea (KMA)
Gauges, Radars
Japan (JAXA):
Radars, gauges, disdrometers
Kwajalein
Radar, gauges, disdrometers
Australia
Operational Radars/Gauges
Darwin, Australia, Gauges, Radar

Argentina
Operational Radars/Gauges
Megha-Tropiques GV
(Paris: Radar, gauge, disdrometer)
Israel
Operational Gauge/Radar network
Ethiopia
Blue Nile Gauges

International Ground Validation
EUMETRAIN November 2015
Post Launch Direct GV: What are we seeing? Product Consistency?

MRMS (Q3) and GPM: 03/14 to 06/2015: 0.5° grid; Liquid only; > 0.2 mm/hr; RQI > 0.9

- Considering liquid only and constraining GV (MRMS/Q3)
  - GPROF low relative to DPR, CMB and MRMS Products. CMB, DPR, MRMS similar - CMB a bit higher in mean; **How will things change with V4 of DPR/V2 of GPROF?**
- **Level 1 Requirements:** Mean relative error generally falls within requirements; RMSE......
Workshop: 9-10 June 2015
(~150 participants)

Social Media (Oct. 2015 Stats)

Twitter: NASA_Rain
Total Twitter Followers: > 14.7K

Facebook: NASA.Rain
Total Facebook Followers: > 23.7K

gpm.nasa.gov Pageviews: 43291
gpm.nasa.gov/education Pageviews: 49297
Movie webpage: svs.gsfc.nasa.gov

http://gpm.nasa.gov/education
The GPM Science team has 60 NASA funded PI teams

GPM has 25 no-cost International PI teams


2015 Science Team Meeting in Baltimore, MD

- Nearly 200 attendees (from 14 countries)
For more information on the TRMM and GPM Missions:

http://gpm.nasa.gov; Movies at: http://svs.gsfc.nasa.gov/

Twitter: NASA_Rain  Facebook: NASA.Rain

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