National Aeronautics and Space Administration
Goddard Earth Science Data Information and

README Document for the
GPM Data

Last Revised 03/12/2017

Prepared By:

Dr. Andrey Savtchenko

_____   _____
Name   Name
GES DISC   External Organization
GSFC Code 610.2

Goddard Space Flight Center
Greenbelt, Maryland

Revision History

Revision Date	Changes	Author
7/17/2023	Updated old links	Andrey Savtchenko
4/29/2021	Consolidated content; added new sources for documentation from the GPM Project; Fixed inconsistency between the Table of content and sections. Added how to properly cite datasets.	Andrey Savtchenko
3/13/2019	Revised and updated hyperlinks throughout the document	Andrey Savtchenko

Table of Contents

1 Introduction

This document provides basic information for using Global Precipitation Measurement (GPM) data products.

The GPM mission is an international network of satellites that provide the next-generation global observations of rain and snow. Building upon the success of the Tropical Rainfall Measuring Mission (TRMM), the GPM concept centers on the deployment of a "Core" satellite carrying an advanced radar / radiometer system to measure precipitation from space and serve as a reference standard to unify precipitation measurements from a constellation of research and operational satellites.

The GPM Core Observatory design is an extension of TRMM which focused primarily on heavy to moderate rain over tropical and subtropical oceans. It carries the first space-borne Ku/Ka-band Dual-frequency Precipitation Radar (DPR) and a multi-channel GPM Microwave Imager (GMI). The DPR instrument, which will provide three dimensional measurements of precipitation structure over 78 and 152 mile (125 and 245 km) swaths, consists of a Ka-band precipitation radar (KaPR) operating at 35.5 GHz and a Ku-band precipitation radar (KuPR) operating at 13.6 GHz. The GMI instrument is a conical-scanning multi-channel microwave radiometer covering a swath of 550 miles (885 km) with thirteen channels ranging in frequency from 10 GHz to 183 GHz.

1.1 Mission Instrument Description

The Global Precipitation Measurement (GPM) mission is an international network of satellites that provide the next-generation global observations of rain and snow. Building upon the success of the Tropical Rainfall Measuring Mission (TRMM), the GPM concept centers on the deployment of a "Core" satellite carrying an advanced radar / radiometer system to measure precipitation from space and serve as a reference standard to unify precipitation measurements from a constellation of research and operational satellites. Through improved measurements of precipitation globally, the GPM mission will help to advance our understanding of Earth's water and energy cycle, improve forecasting of extreme events that cause natural hazards and disasters, and extend current capabilities in using accurate and timely information of precipitation to directly benefit society. GPM, initiated by NASA and the Japan Aerospace Exploration Agency (JAXA) as a global successor to TRMM, comprises 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), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and others. The GPM Core Observatory launched on February 27, 2014 at 1:37pm EST from Tanegashima Space Center, Japan.

Illustration of the GPM satellite constellation.

Building upon TRMM's Legacy

The Tropical Rainfall Measuring Mission (TRMM), launched by NASA and JAXA in 1997, uses both active and passive microwave instruments to measure rainfall in the tropics. It also provides a foundation for merging rainfall information from other satellites. TRMM has shown the importance of taking observations from a non-Sun-synchronous orbit at different times of the day, between observations by polar orbiting sensors at fixed times of the day, to improve near real-time monitoring of hurricanes and accurate estimation of time-accumulation of rain volume. The GPM Core Observatory will continue this sampling from a non-Sun-synchronous orbit and extend coverage to higher latitudes to provide a global view of precipitation.

The GPM Core Observatory design is an extension of TRMM's highly successful rain-sensing package, which focused primarily on heavy to moderate rain over tropical and subtropical oceans. Since light rain and falling snow account for significant fractions of precipitation occurrences in middle and high latitudes, a key advancement of GPM over TRMM is the extended capability to measure light rain (< 0.5 mm hr-1), solid precipitation and the microphysical properties of precipitating particles. This capability drives the designs of both the active and passive microwave instruments on GPM. The Core Observatory will then act as a reference standard for the precipitation estimates acquired by the GPM constellation of sensors.

GPM Core Observatory

The GPM Core Observatory will carry the first space-borne Ku/Ka-band Dual-frequency Precipitation Radar (DPR) and a multi-channel GPM Microwave Imager (GMI). The DPR instrument, which will provide three dimensional measurements of precipitation structure over 78 and 152 mile (125 and 245 km) swaths, consists of a Ka-band precipitation radar (KaPR) operating at 35.5 GHz and a Ku-band precipitation radar (KuPR) operating at 13.6 GHz. Relative to the TRMM precipitation radar, the DPR is more sensitive to light rain rates and snowfall. In addition, simultaneous measurements by the overlapping of Ka/Ku-bands of the DPR can provide new information on particle drop size distributions over moderate precipitation intensities. In addition, by providing new microphysical measurements from the DPR to complement cloud and aerosol observations, GPM is expected to provide further insights into how precipitation processes may be affected by human activities.

The GMI instrument is a conical-scanning multi-channel microwave radiometer covering a swath of 550 miles (885 km) with thirteen channels ranging in frequency from 10 GHz to 183 GHz. The GMI uses a set of frequencies that have been optimized over the past two decades to retrieve heavy, moderate and light precipitation using the polarization difference at each channel as an indicator of the optical thickness and water content.

GPM Science and Applications

GPM will provide global precipitation measurements with improved accuracy, coverage and dynamic range for studying precipitation characteristics. GPM is also expected to improve weather and precipitation forecasts through assimilation of instantaneous precipitation information. Relative to TRMM, the enhanced measurement and sampling capabilities of GPM will offer many advanced science contributions and societal benefits:

- Improved knowledge of the Earth's water cycle and its link to climate change
- New insights into storm structures and large-scale atmospheric processes
- New insights into precipitation microphysics
- Advanced understanding of climate sensitivity and feedback processes
- Extended capabilities in monitoring and predicting hurricanes and other extreme weather events
- Improved forecasting abilities for natural hazards, including floods, droughts and landslides.
- Enhanced numerical prediction skills
- Improved agricultural crop forecasting and monitoring of freshwater resources

1.1.1 GMI

The Global Precipitation Measurement (GPM) Microwave Imager (GMI) instrument is a multi-channel, conical- scanning, microwave radiometer serving an essential role in the near-global-coverage and frequent-revisit-time requirements of GPM.

The instrumentation enables the Core spacecraft to serve as both a precipitation standard and as a radiometric standard for the other GPM constellation members.

The GMI is characterized by thirteen microwave channels ranging in frequency from 10 GHz to 183 GHz. In addition to carrying channels similar to those on the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI), the GMI carries four high frequency, millimeter-wave, channels about 166 GHz and 183 GHz.

With a 1.2 m diameter antenna, the GMI will provide significantly improved spatial resolution over TMI.

Scan Geometry

The off-nadir-angle defining the cone swept out by the GMI is set at 48.5 degrees which represents an earth-incidence-angle of 52.8 degrees. To maintain similar geometry with the predecessor TMI instrument, the-earth-incidence angle of GMI was chosen identical to that of the TMI. Rotating at 32 rotations per minute, the GMI will gather microwave radiometric brightness measurements over a 140 degree sector centered about the spacecraft ground track vector. The remaining angular sector is used for performing calibration; i.e. observation of cold space as well as observation of a hot calibration target.
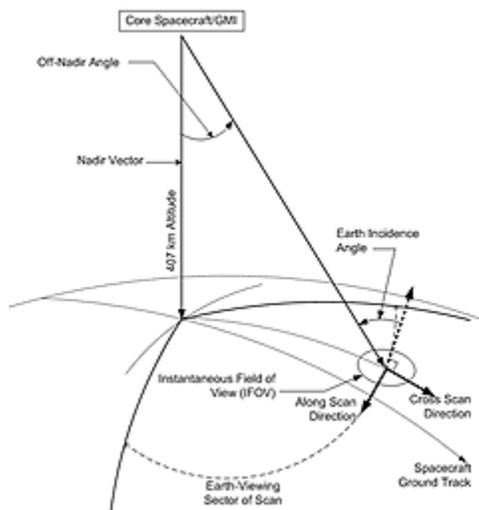
Diagram of the conical scanning geometry.

The 140 degree GMI swath represents a swath of 904 km (562 miles) on the Earth's surface. For comparison, the DPR instrument is characterized by cross-track swath widths of 245 km (152 miles) and 120 km (75 miles), for the Ku and Ka-band radars respectively. Only the central portions of the GMI swath will overlap the radar swaths (and with approximately 67 second duration between measurements due to the geometry and spacecraft motion). These measurements within the overlapped swaths are important for improving precipitation retrievals, and in particular, the radiometer-based retrievals.

1.1.2 DPR

One of the prime instruments for the GPM Core Observatory is called the Dual-frequency Precipitation Radar (DPR). The DPR consists of a Ku-band precipitation radar (KuPR) and a Ka-band precipitation radar (KaPR). The KuPR (13.6 GHz) is an updated version of the highly successful unit flown on the TRMM mission (shown below). The KuPR and the KaPR will be co-aligned on the GPM spacecraft bus such that that the 5 km (3.1 mile) footprint location on the earth will be the same.

Data collected from the KuPR and KaPR units will provide 3-dimensional observations of rain and will also provide an accurate estimation of rainfall rate to the scientific community. The DPR instrument will be allocated 190 Kbps bandwidth over the 1553B spacecraft data bus.

DPR Instrument Details

The DPR is a spaceborne precipitation radar capable of making accurate rainfall measurements. The DPR is expected to be more sensitive than its TRMM predecessor especially in the measurement of light rainfall and snowfall in high latitude regions. Rain/snow determination is expected to be accomplished by using the differential attenuation between the Ku-band and the Ka-band frequencies. The variable pulse repetition frequency (VPRF) technique is also expected to increase the number of samples at each IFOV to realize a 0.2 mm/h sensitivity.

The KuPR and KaPR, together with GMI, are the primary instruments on the GPM spacecraft. These Earth-pointing KuPR and KaPR instruments will provide rain sensing over both land and ocean, both day and night.

Top-level general design specifications are as follows:

Item	KuPR	KaPR
Swath Width	245 kilometers (km)	120 kilometers (km)
Range Resolution	250 meters (m)	250/500 meters (m)
Spatial Resolution	5 km (Nadir)	5 km (Nadir)
Beam Width	0.71 degrees	0.71 degrees
Transmitter	128 Solid State Amplifiers	128 Solid State Amplifiers

Peak Transmit Power	1013 Watts (W)	146 Watts (W)
Pulse Repetition Freq. (In nominal operations mode)	4100 to 4400 Hertz	4100 to 4400 Hertz
Pulse Width	two 1.667 microseconds (μs) pulses	two 1.667 microseconds (μs) pulses in matched beams two 3.234 microseconds (μs) pulses in interlaced scans
Beam Number	49	49 (25 in matched beams and 24 in interlaced scans)

2 Data Organization

The logical format of a data product consists of the names, types, dimensions, and organization of the data. The physical format is the implementation of the logical format with an underlying format such as Hierarchical Data Format (HDF).

GPM data products contain metadata and data. Metadata are small text strings containing label information such as the name, date, and time of the data products. Metadata are often organized into metadata groups.

Data are arrays or scalars. Data are often organized into swath structures or grid structures. Some products have groups outside or inside swath structures or grid structures.

The processing level is one of the main scopes to distinguish various GPM public data. At Level 1 and 2, the data are in "swath" format, closely resembling the instrument scanning pattern. Level 1 are usually at best calibrated radiances or radar reflectivity, while Level 2 contain results of some science retrieval – precipitation, for example. GPM Level 1 and 2 are organized in orbital granules, i.e. every data file contains about 100 minutes of a sensor observation record. At Level 3, science retrievals from Level 2 are grided to some regular global grid, at Daily and Monthly aggregations.

2.1 Swath Structure

The swath structure stores satellite data which are organized by scans. Swath structures are implemented in Levels 1A, 1B, 1C, 2A, and 2B. The swath structure is contained in a group. In this swath group is the metadata group SwathHeader, data group ScanTime, data arrays Latitude and Longitude and other data arrays. In some products there are additional data groups under the swath group. The contents of the metadata group

SwathHeader are explained in Metadata for GPM Products.

2.2 Grid Structure

The grid structure stores earth located grids. Each grid is an array of grid boxes, rather than grid points. Grid structures are implemented in Level 3A and 3B products. The grid structure is contained in a grid group. In this group is the metadata group GridHeader and data arrays. In some products there are additional data groups under the grid group. The contents of the metadata group GridHeader are explained in Metadata for GPM Products.

2.3 Physical Format

The logical format of GPM data products is written in an underlying format such as HDF. The logical array or scalar is implemented in HDF as a Scientific Data Set. Each SDS contains the data array and additional information as attributes: names of dimensions, units, scale, offset, and scale description. Each metadata group is implemented in HDF as an attribute. Elements within a group are implemented as
ElementName=ElementValue;

If the element has a list of values, the values are separated with a comma:
ElementName=Value1,Value2,...,ValueN;

2.4 Formatting Conventions

2.4.1 HDF5 and netCDF-4

For novice users, it is important to understand that HDF5 and netCDF-4 formats are **interchangeable**.

Users do not have to spend time to convert HDF5 into netCDF-4, unless it is critical for their particular application (like GIS).

2.4.2 File Contents

The best and the most current document for GPM data file contents can be found by searching for a title that contains "file spec" at:

https://gpm.nasa.gov/resources/documents

3 Data Contents and Products

3.1 Data Products and Descriptions

One good way to have a glimpse at all publicly available GPM products is to go through the File Spec provided by the GPM Project:

https://gpm.nasa.gov/resources/documents?field_document_category_target_id=All&title=file+spec

A better way to see through all currently public GPM products at the Goddard DAAC is:

https://disc.gsfc.nasa.gov/datasets?page=1&project=GPM

and further filter the result by facets like processing level, source (sensor), and "temporal resolution" which is actually the data granularity.

The most popular GPM product, IMERG, in all temporal resolutions, half-hourly, daily, and monthly, can be quickly seen by:

https://disc.gsfc.nasa.gov/datasets?keywords=imerg&page=1

4 Options for Reading the Data

There are many tools and visualization packages (free and commercial) for viewing and dumping the contents of HDF5 files. Libraries are available in several programming languages for writing software to read HDF5 files.

One excellent source for code snippets in Python, NCL, MATLAB, and IDL can be found at:

https://hdfeos.org/zoo/index_openGESDISC_Examples.php

HDF5 tools and software can be researched at the HDF Group's web page at
http://www.hdfgroup.org/products/hdf5_tools/.

4.1 Command Line Utilities

4.1.1 h5dump (free)

The h5dump tool, developed by the HDFGroup, enables users to examine the contents of an HDF5 file and dump those contents, in human readable form, to an ASCII file, or alternatively to an XML file or binary output. It can display the contents of the entire HDF5 file or selected objects, which can be groups, datasets, a subset of a dataset, links, attributes, or datatypes. The h5dump tool is included as part of the HDF5 library, or separately as a stand-alone binary tool at:
http://www.hdfgroup.org/HDF5/release/obtain5.html

4.1.2 ncdump (free)

The ncdump tool, developed by Unidata, will print the contents of a netCDF or compatible file to standard out as CDL text (ASCII) format. The tool may also be used as a simple browser, to display the dimension names and lengths; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables. To view HDF5 data files, version 4.1 or higher is required. The ncdump tool is included with the netCDF library. **NOTE: you must include HDF5 support during build.**
http://www.unidata.ucar.edu/downloads/netcdf/

4.1.3 H5_PARSE (IDL/commercial)

The H5_PARSE function recursively descends through an HDF5 file or group and creates an IDL structure containing object information and data values. You must purchase an IDL package, version 8 or higher, to read the MZM HDF5 data files.
https://www.harrisgeospatial.com/docs/home.html

4.1.4 PPS Science Algorithm Input/Output Toolkit

The Toolkit provides: 1) a set of commonly used routines and constants for algorithm developers and researchers and 2) seamless integration of Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Measurement (GPM) algorithms into the PPS environment.

ftp://pps.gsfc.nasa.gov/pub/PPStoolkit/GPM/

4.2 Tools/Programming

Any application that supports the HDF5/netCDF-4 file format can be used to read the GPM data. If you are new to HDF5, the following tools might be useful starting points.

- HDFView (http://www.hdfgroup.org/hdf-java-html/hdfview/index.html)
- Panoply **(**http://www.giss.nasa.gov/tools/panoply/)
- https://disc.gsfc.nasa.gov/information/howto?title=How to View Remote Data in OPeNDAP with Panoply

For more advanced users or programmers:
- IDL (https://www.harrisgeospatial.com/docs/home.html)
- Matlab (http://www.mathworks.com/products/matlab/)
- GrADS (http://cola.gmu.edu/grads/)
- Java (http://www.hdfgroup.org/)
- HDF5 (http://www.hdfgroup.org/HDF5/)

Advanced users who will program in C or Fortran should register and acquire the newest HDF5 libraries from:

https://www.hdfgroup.org/downloads/hdf5/

4.2.1 HDFView (free)

HDFView, developed by the HDFGroup, is a Java-based graphic utility designed for viewing and editing the contents of HDF4 and HDF5 files. It allows users to browse through any HDF file, starting with a tree view of all top-level objects in an HDF file's hierarchy. HDFView allows a user to descend through the hierarchy and navigate among the file's data objects. Editing features allow a user to create, delete, and modify the value of HDF objects and attributes. For more info see:
http://www.hdfgroup.org/hdf-java-html/hdfview/

4.2.2 Panoply (free)

Panoply, developed at the Goddard Institute for Space Studies (GISS), is a cross-platform application which plots geo-gridded arrays from netCDF, HDF and GRIB files. The tool allows one to slice and plot latitude-longitude, latitude-vertical, longitude-vertical, or time-latitude arrays from larger multidimensional variables, combine two arrays in one plot by differencing, summing or averaging, and change map projections. One may also access files remotely into the Panoply application.
http://www.giss.nasa.gov/tools/panoply/

4.2.3 Unidata's Integrated Data Viewer (free)

The Integrated Data Viewer (IDV) from Unidata is a Java™-based software framework for analyzing and visualizing geoscience data. This IDV release includes a software library and a reference application made from that software. It uses
the VisAD (http://www.ssec.wisc.edu/~billh/visad.html) and netCDF-
Java (https://www.unidata.ucar.edu/software/netcdf-java) libraries and other Java-based utility packages.
For more details and download instructions please visit:

https://www.unidata.ucar.edu/software/idv/docs/userguide/index.html

4.2.4 Orbit Viewer THOR (free)

Orbit Viewer THOR is a tool for displaying TRMM and GPM satellite data files. THOR stands for Tool for High-resolution Observation Review. This viewer enables you to display TRMM and GPM observations at the full instrument resolution.

http://pps.gsfc.nasa.gov/thorrelease.html

4.2.5 H5_BROWSER (IDL/commercial)

The H5_BROWSER function presents a graphical user interface for viewing and reading HDF5 files. The browser provides a tree view of the HDF5 file or files, a data preview window, and an information window for the selected objects. The browser may be created as either a selection dialog with Open/Cancel buttons, or as a standalone browser that can import data to the IDL main program. You must purchase an IDL package, version 8 or higher to view the MZM HDF5 data files. https://www.harrisgeospatial.com/docs/home.html

4.3 Programming Languages

Advanced users may wish to write their own software to read GPM HDF5 data files. The following is a list of available programming languages that support HDF5:
Free:
- C/C++ (http://www.hdfgroup.org/HDF5/release/obtain5.html)
- Fortran (http://www.hdfgroup.org/HDF5/release/obtain5.html)
- Java (http://www.hdfgroup.org/)
- GrADS (http://cola.gmu.edu/grads)
Commercial:

- IDL (https://www.harrisgeospatial.com/docs/home.html)
- MATLAB (http://www.mathworks.com/products/matlab/)

5 Data Services

5.1 Goddard DAAC User Interface

Goddard DAAC provides advanced search and subset services through its new User Interface. Searches are using keywords against content-based database, with major content items being Data Collections, Documentation, FAQs, Glossary, How-To, and News. For example, this search will return all GPM-related Data Collections, or more precisely links to the Datasets Landing Pages:
https://disc.gsfc.nasa.gov/datasets?keywords=GPM

Search results can be further refined using "facets" constraining the processing level, partner satellites, spatial resolution, etc.
Note that the old data interface, "Mirador", has been phased out.

5.2 OPeNDAP

OPeNDAP stands for "Open-source Project for a Network Data Access Protocol". OPeNDAP is a framework that simplifies all aspects of scientific data networking. It provides simple means for parameter and spatial subset. The spatial subset is actually a subset by array index - array being the grid data. In the most simplistic case, OPeNDAP can be used to convert data from HDF-EOS5 to ASCII. The data directory hierarchy, as served by OPeNDAP, can be viewed in any browser.

6 More Information

6.1 GPM Documents

The most important documents (per dataset) can be found under the "Documentation" tab in the Goddard DAAC Dataset Landing Pages. All GPM dataset landing pages can be found by:

https://disc.gsfc.nasa.gov/datasets?page=1&project=GPM

and filtering by additional facets, like processing level, temporal resolution, etc..

GPM Project has recently introduced interactive interface to search for documentation. It finds documents by keywords, like "file naming", of "file spec", or "ATBD":

https://gpm.nasa.gov/resources/documents

An alternative way to browse through documentation is provided also by the Precipitation Processing System. Regardless of its title, this location refers to also finalized documentation:

https://pps.gsfc.nasa.gov/GPMprelimdocs.html

The available Algorithm Theoretical Basis Documents (**ATBD**) are currently consolidated at this location:

https://arthurhou.pps.eosdis.nasa.gov/atbd.html

Another way to see and access all available GPM and TRMM documents is to visit the Precipitation Processing System documentation page:

https://arthurhou.pps.eosdis.nasa.gov/GPMprelimdocs.html

6.2 Frequently Asked Questions

Goddard DAAC provides key-word searchable frequently asked questions (FAQ). For instance, entering "GIS" in the search box will return all FAQ that are relevant to Geographical Information Systems applications:

https://disc.gsfc.nasa.gov/information/faqs

6.3 How-to Recipes

The Goddard DAAC website offers searchable content on various how-to recipes and code snippets. In many cases, other mission's recipes are also applicable for GPM data. Hence, users don't have to necessarily search by "GPM", rather they can find useful pointers in how-to's by such keywords as "python" or "GIS" or "NCO".

https://disc.gsfc.nasa.gov/information/howto?page=1

6.4 Point of Contact

Name: GES DISC Help Desk

URL: http://disc.gsfc.nasa.gov/

E-mail: gsfc-dl-help-disc at mail.nasa.gov

Phone: 301-614-5224 Fax: 301-614-5228

Address: Goddard Earth Sciences Data and Information Services Center

Attn: Help Desk Code 610.2 NASA Goddard Space Flight Center Greenbelt, MD 20771, USA

7 Data citation

The correct data citation is of critical importance in giving proper credits to the Principal Investigators who produced the science algorithms, and who need to report on their products and justify their funding. The proper data citation is given under the "Data Citation" tab to every product page at the Goddard DAAC:

For instance, as shown in the snapshot, the research-quality half-hour IMERGHH of version 06 should be cited as:
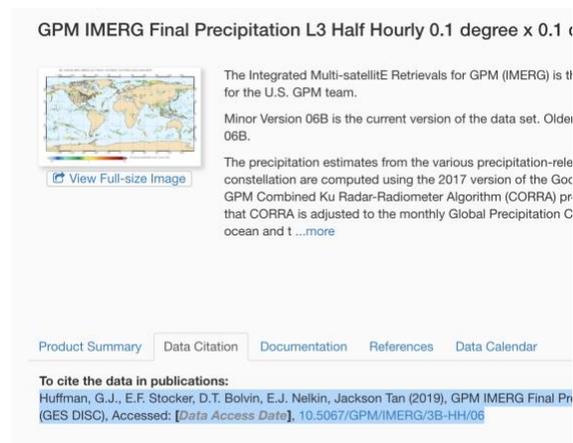
Huffman, G.J., E.F. Stocker, D.T. Bolvin, E.J. Nelkin, Jackson Tan (2019), GPM IMERG Final Precipitation L3 Half Hourly 0.1 degree x 0.1 degree V06, Greenbelt, MD, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: [Data Access Date], 10.5067/GPM/IMERG/3B-HH/06