GPM Data Utilization Handbook

Version 5. 1

March, 2024

JAXA

Preface

Global environment change has become a worldwide concern in recent years. For such issues, aiming applications to the fields closely linked with our lives such as weather forecast and flood forecast as well as for climate research but with utilizing observation technology by satellite, Global Precipitation Measurement: GPM project has been in the works under international cooperation. The GPM project is follow-on and expansion of the Tropical Rainfall Measuring Mission (TRMM) satellite, and significantly enhances observation range and frequency by cooperation with a constellation of several other satellites developed by each international partner. The GPM core satellite has been cooperatively developed by the National Aeronautics and Space Administration (NASA) and Japan Aerospace Exploration Agency (JAXA), and carries a Dual-frequency Precipitation Radar (DPR), which has been jointly developed by JAXA and the National Institute of Information and Communications Technology (NICT) and GPM Microwave Imager (GMI), which has been developed by NASA.

The Global Precipitation Measurement (GPM) Core Satellite was launched by H-IIA Launch Vehicle No.23 at 3:37 a.m. on February 28, 2014 (Japan Standard Time, JST) from the Japan Aerospace Exploration Agency/Tanegashima Space Center, and has gone into a circular orbit of altitude 407 km, inclination angle 65° and period approx. 90 min. The data from GPM Core Satellite are received at the NASA ground station via Tracking and Data Relay Satellite System (TDRSS), and some of observation data are transmitted from NASA Goddard Space Flight Center (GSFC) to JAXA/Tsukuba Space Center. The data processing has been performed at both NASA and JAXA.

After the end of the initial functional verification phase, the GPM products of Level 1 to Level 3 have been opened for public access online at JAXA Earth Observation Satellite Data Distribution System “G-Portal” (https://gportal.jaxa.jp/gpr/) from September 2014. We are updating GPM products by improvement algorithms and continuously calibration and validation. In addition, we have reprocessed GPM and TRMM product which is long-term data set.

The GPM Core satellite is planning a controlled re-entry (the return of a spacecraft into Earth's atmosphere) after the mission ends, and it is necessary to secure fuel for this purpose. As it was suggested that the mission might end earlier than expected, NASA and JAXA performed two orbit boost maneuver operations in November 2023. After the operations, it flight at an altitude of approximately 442km, and based on the amount of fuel remaining, that satellite lifespan has been getting longer until around 2030.

The purpose of this handbook is to provide necessary information regarding the use of the GPM products. We wish the GPM products with this handbook utilize your studies on enhancement of climate change analysis, as well as the operational uses.

March, 2024
Japan Aerospace Exploration Agency
Satellite Applications and Operations Center
Earth Observation Research Center

Contents

Change History

revision	date	section	content, reason
Version 1.0	Sept. 2nd 2014	-	The first edition
Version 2.0	Mar. 1st 2016	p.i	Update of the GPM product version 4
		p.2-4,2-5	Update of the table of the list of the Constellation Satellites.
		p.2-8,2-9	Update of the table of DPR operation mode.
		p.4-1	Addition of the definition of GPM product level, GPM L2,3 data processing, spectral latent heating, the GPM Comb DPR/GMI L3 convective stratiform heating information and the component factor of data group.
		p. 4-2	Addition of the spectral latent heating product and update file size, scene definition and frequency.
		p.4-4~4-8	Revise product size and file size.
		p.4-9	Addition of the scene unit definitions of NRT GMI, NRT GPM and NRT DPR/GMI COMB products.
		p. 4-10~4-18	Addition of the GSMaP L3 (Hourly, Monthly), DPR L3 (Daily, Monthly) and GPM spectral latent heating L2/L3 standard (STD) Products and KuPR/KaPR/DPR Environment Auxiliary (ENV) Products information.
		p.4-19	Addition of the Algorithm key in table 4.1-17 and the explanations of L3 Algorithm and Grid.
		p. 4-27	Addition of the providing time of NRT products.
		p.4-31	Addition of the external calibration information in the table 4.9-1 and table 4.9-2.
		p.5-7	Addition of GPM/DPR and GMI in the EO satellite list.
		P6-5~6-12	Revise data analysis tools and format conversion tools, addition of sample program
Version 2.1	May. 26th 2017	All	Correction of the sentences.
		P.2-4	Addition of the operation termination of the Defense Meteorological Satellite Program (DMSP) F19.
		P.4-7	Removal of DMSP F19 SSMIS Level 1CR.
		P.4-9~4-10	Addition of the image of scene definition.
		P.4-6	Addition of the GSMaP products (netCDF format).
		P.4-19	Addition of the file naming convention of GSMaP standard products (netCDF format).
		P.4-32	Update of the GSMaP algorithm flow.
		P.4-41~4-45	Reflect the product evaluation of GPM product version 5.
		APPENDIX 2-2	Updated the e-mail address of contact point.
		P.4-7	Removal of DMSP F19 SSMIS Level 1CR.

revision	date	section	content, reason
Version 3.0	Oct. 3rd 2017	P.1-1	Update the sections description.
		P.2-12~P.2-13	Addition of "2.3. Overview of the TRMM Spacecraft"
		P.2-14~P.2-19	Addition of "2.4. Outline of TRMM Mission Critical Devices"
		P.2-20~P.2-21	Addition of "2.5. Outline of ground system"
		-	Removal of "OUTLINE OF GPM GROUND SYSTEM".
		P.3-1~P.3-6	Addition of "3.1.1. Scene Definitions"
		P.3-6	Addition of "3.1.2 Definition of GPM Processing Levels"
		P.3-8~P.3-9	Addition of "the processing flow of TRMM" into figure 3.1-5
		P.3-10~P.3-15	Update of product name of table 3.1-3 and 3.1-4
		P.3-16~P.3-17	Addition of "List of Standard TRMM Products" into table 3.1-5
		P.3-18~P.3-29	Update of "3.1.5. File Naming Conventions"
		P.3-29~P.3-31	Addition of "3.1.6 Definition of GPM Processing Levels"
		P.3-32	Addition of "3.1.7. Conceptual Explanation of Product/Algorithm Versions"
		P.3-33~P.3-38	Update of "3.2 Processing Description"
		P.3-39~P.3-40	Addition of "3.2.3. PR Product Processing"
		Appendix 4-1	Addition of "TRMM PRODUCT LIST AND CAVEAT"
Version 3.1	July 2nd 2018	P.4-1~P.4-10	Update of "4.1. Service Descriptions" by renewal of G-Portal (earth observation data providing system)
		P.4-10	Removal of 4.2. Usage of the Data Distribution Service
Version 4.0	Dec 6th 2021	P.2-2, Table 2.2-1, P2-7, P.3-2, P3-3, P3-38	Addition of information for KaPR scan pattern changes.
		P.2-4, 2-5	Deletion F20 of SSMIS and update of information for ATMS/JPSS.
		P.3-1	Correction of scene definition of L1/L2 products.
		Table 3.1-3	Addition of sampling resolution/ grid size and partially correction.
		P.3-4	Correction of information of L3 products.
		Table 3.1-12	Update of file naming conventions of L3 Standard Products for V07.
		Table 3.1-15	Addition of information of NOAA-20 and METOP-C.
		All	Update of URL information.
		Appendix 4-1, Appendix 5-1, Appendix 3-1	Deletion Appendix 4-1 and Appendix 5-1 and update of Appendix 3-1

revision	date	section	content, reason
Version 4.1	Jan. 24th 2022	All, P.2-2, Table 2.1-2, Table 2.2-1, Table 3.2-1	Update of information for DPR specification.
Version 4.2	July 7th 2023	P.2-5, P3-31, Table 2.1-3, Table3.1-15	Addition of information of NOAA-21.
Version 5.0	Mar 5th 2024	Preface, P.2-5, P.2-6, P.2-10, P.2-12, P.3-2, P.3-33, P.4-11, P.5-1, P.5-3, P.5-5, P.5-6, P.5-8, P.5-9, P.5-11, Table 2.1-2, Table 2.2-1, Table 2.2-2, Table 2.2-3, Table 3.1-3, Table 3.1-4, Table 3.2-1, Appendix 2-1	Corrections due to GPM Core satellite performed two orbit boost maneuvers that raised its altitude
		Table 2.1-3	Constellation satellite information update
		Table 2.2-3	Typo correction
Version 5.1	Mar 18th 2024	Preface, P.2-1, P.2-10	Satellite altitude information update

Chapter 1 INTRODUCTION

The Global Precipitation Measurement (GPM) Core Satellite was launched by H-IIA Launch Vehicle No.23 at 3:07 a.m. JST Friday, Feb. 28 from the Tanegashima Space Center.

This satellite has been developed as a joint project between JAXA and NASA and the Dual-frequency Precipitation Radar (DPR) carried on the satellite is the observation device developed by JAXA with the National Institute of Information and Communication Technology (NICT).

GPM performs the observation of rain intensity and the distribution of Approx. 90 percent region of whole globe. And the data from GPM Core Satellite and the constellation satellite of GPM plan is expected that it will play an integral role in elucidating global climate change and monitoring environmental change.

1.1. Purpose

We introduce not only various information related to standard products and near-real-time products, but also information related to GPM Core Satellite itself, as well as other related information about the sensors on the Satellite and the ground systems.

1.2. Scope

This document consists of five sections and appendices:

Section 1 : Describes the purpose and scope of the document and the overview of GPM mission;

Section 2 : Introduces the outline of GPM system, describes the details of specification of DPR sensor and GMI sensor and also ground system related to GPM;

Section 3 : Describes the outline of data processing algorithm and data format of standard products and near-real-time products provided by JAXA;

Section 4 : Describes the outline of data services related to standard products and near-real-time products provided by JAXA Earth Observation Satellite Data Distribution System(G-Portal);

Section 5 : Describes the outline of software tools to visualize or analyze GPM data.

1.3. Overview of GPM Project

The Global Precipitation Measurement Project (GPM) is follow-on and expansion of the tropical rain observation satellite (TRMM) satellite, and an international cooperative mission to measure global precipitation more accurately and frequently for elucidating changes in climate and water circulation using one GPM core satellite with the Dual-frequency Precipitation Radar (DPR) and the GPM Microwave Imager (GMI) onboard and constellation of several other satellites with a microwave imager onboard. Figure 1.3-1 provides an overview of GPM project.

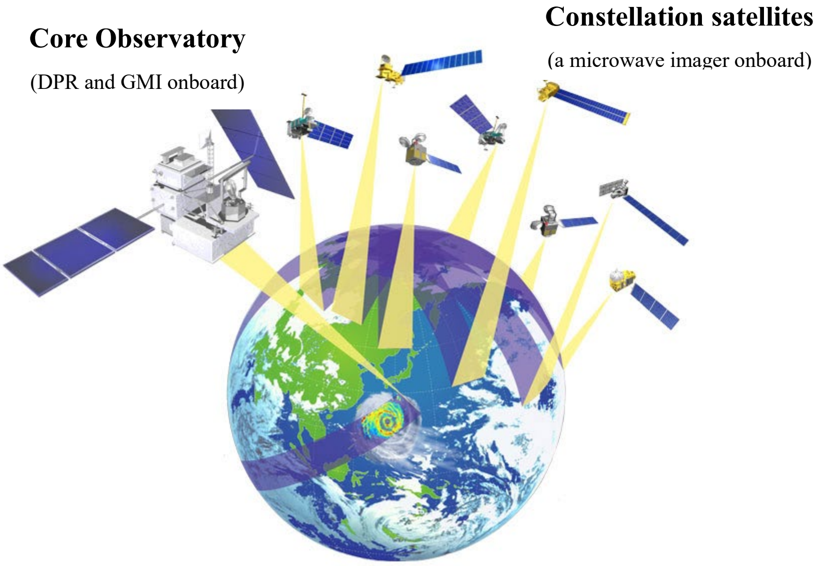


Figure 1.3-1 Overview of GPM Project

Similar to a mission for water cycle variation observation under JAXA's Earth Environmental program, mission objectives of GPM are to continue and expand knowledge and outcomes obtained by the TRMM satellite, and to achieve the following targets:

(1) Highly accurate and frequent global precipitation observation for climate and water cycle change

(2) Data utilization method development through distribution of near real time global precipitation maps

(3) Development and demonstration of the improved precipitation retrieval method of the multi microwave radiometers (including both imager and sounder) using DPR data

(4) Application demonstration for operational use, such as flood prediction, numerical weather forecast, prevention of damage from a storm and flood; and

(5) Demonstration of DPR technology, which will succeed and expand TRMM/PR technology, to achieve highly accurate precipitation observation.

The applications for which future growth is expected through GPM mission shows below.

(1) Utilization in Weather Forecasts

Satellite data is used commonly in weather forecasts. The Japan Meteorological Agency (JMA) has been using satellite microwave brightness temperature data in its numerical weather prediction since 2003, and has been introducing data from the Global Change Observation Mission - Water (GCOM-

W) satellite since August 2013. This data contributes to improve the accuracy of weather forecasts, and also achieves more accurate typhoon analyses. For example, errors with numerical weather prediction have decreased by about 25% during the period from 2004 to 2012 through the introduction of satellite data and improvements in model schemes. For typhoon analysis, estimates of the position of the typhoon's eye that is difficult to determine from geostationary satellites are improved by the passive microwave imagers, as well as from improvements in the storm track forecasts. As for GPM era, JMA is preparing for operational use of it in its system, and meteorological agencies in the other countries plan to use it too.

Improvements in the accuracy of weather forecasts also directly contribute to weather information services and society. Weather information is used in routine work for the service and retail industries, traffics, agriculture, forestry and fisheries industries, and the infrastructure-related fields. Furthermore, improvements in the storm track forecast accuracy of tropical cyclones will largely contribute to protecting the human lives and property. It was estimated that the data from the Tropical Rainfall Measuring Mission (TRMM) satellite contributes to protecting lives of 100–500 people per year in the world (Adler, 2005). Recently, the Japan Weather Association has started to release regional satellite images through cell-phone website using JAXA Global Rainfall Watch (GSMaP) and the GCOM-W data.

(2) Utilization in Flood Predictions and River Managements

During 10-year from 1988 to 1997, two thirds of natural catastrophes worldwide were caused by floods and storms (World Water Council, 2000). The GSMaP product, which was developed in Japan For the GPM mission, provides an hourly global rainfall map four hour after observation. The flood alert system and tool, which use the GSMaP as inputs, are developed on a trial basis by the International Centre for Water Hazard and Risk Managements (ICHARM), a UNESCO Category II Centre and hosted by the Public Works Research Institute (PWRI), and the Infrastructure Development Institute (IDI-JAPAN), the secretariat of International Flood Network (IFNet). The GSMaP is expected to be used in operation in the GPM era. Since the satellite data is especially effective in the regions that are lacking in ground observations, efforts toward utilizing satellite data in flood predictions and river managements are underway in many Asian countries through funding from UNESCO, the Asian Development Bank, etc.

(3) Utilization in Global Change and Climate Variation Studies

Future projections of precipitation were reported by the Intergovernmental Panel on Climate Change (IPCC) Working Group I in September 2013 as a contribution to the Fifth Assessment Report that “Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases.” The latest simulations by climate models indicate that changes in the global water cycle in response to global warming, such as an increase in the contrast of precipitation between wet and dry regions and between wet and dry seasons.

Current global climate models, however, still have uncertainty in projections in precipitation changes in response to global warming. Information from the GPM mission, especially highly accurate three-dimensional information of precipitation particles and systems derived from the Dual-frequency

Precipitation Radar (DPR) will contribute in the validation of climate models and improvements in the precipitation processes. Another important role of satellite observation is to monitor long term changes in precipitation distribution, by combining various satellite and ground observation. To detect global-scale changes, global observations by satellites are essential.

Studies of precipitation system climatology have made substantial progress since the launch of the TRMM satellite and the Precipitation Radar (PR). Diurnal cycles of rainfall over the tropical regions were revealed by PR observations, as were the typical rainfall system of each region and statistics on extreme rainfall events. Observations that lead to a significant increase in the frequency of recent extreme rainfall events may be obtained by long term records, which will be carried on for more than 20 years through the TRMM to the GPM.

(4) Utilization in Water Cycle Studies

To assess the global water cycle quantitatively, observations of precipitation that is observable flux quantity is essential. Precipitation observations in the mid-latitude whose rainy areas are brought by extra tropical cyclones follow that in the tropics and subtropics, and are critical as a new challenge in the GPM mission.

It is expected that improvements in temporal and spatial resolution in GPM precipitation observations will contribute to the refinement of hydrological models. GPM data will quantify the water cycle and its variations, and be a big step to identify natural and anthropogenic variations in the water cycle. Studies to simulate rive runoff and use satellite global rainfall map as inputs to land models are underway and at the evaluation stage for operational use in flood monitoring and water resource management.

Chapter 2 GPM/TRMM SATELLITE SYSTEM

This chapter provides not only the overview of the GPM and TRMM spacecraft subsystems but the specification of its onboard instruments such as DPR sensor and GMI sensor. In addition, this chapter describes the outline of the ground systems related to GPM and TRMM operation.

2.1. Overview of the GPM Spacecraft

2.1.1. GPM Project

The Global Precipitation Measurement Project (GPM) is an international cooperative mission to measure global precipitation more accurately and frequently using one GPM core satellite with the Dual-frequency Precipitation Radar (DPR) and the GPM Microwave Imager (GMI) onboard and other sub-satellites with either a microwave imager (imager/sounder) onboard. By cooperation with multiple number of constellation satellites will enable global measurement of precipitation about every three hours. Figure 2.1-1 shows constellation satellites consists GPM Project.

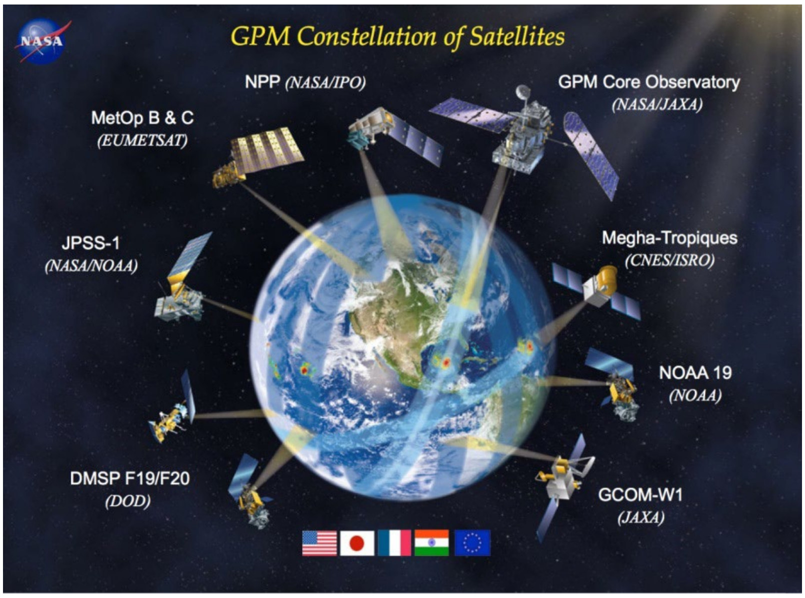


Figure 2.1-1 GPM Constellation of Satellites

The GPM core satellite has been cooperatively developed by JAXA and NASA, and the DPR has been jointly developed by JAXA in cooperation with NICT. And JAXA performs both developing mission instruments as well as launch services with the H-IIA Rocket Vehicle at Tanegashima Space Center and data processing/providing.

The constellation of satellites is feasible by international cooperation for the existing or future microwave imager (imager/sounder) onboard project of which NASA, National Oceanic and Atmospheric Administration (NOAA), European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), Centre National D'Etudes Spatiales (CNES), and Indian Space Research

Organization (ISRO), and so on. Here is the responsibility sharing between GPM Core Satellite and constellation satellites of each international partner (space agency) below.

Table 2.1-1 Responsibility Sharing between GPM Core Observatory and Constellation Satellites

			NASA	JAXA	Note
GPM Core Satellite	Satellite bus		X		
	Instruments				
		DPR		X	Developed with NICT
		GMI	X		
	Launch			X	H-IIA Launch Vehicle
	Tracking and Control		X		
	Data processing		X	X	
	Data distribution		X	X	
Constellation satellites			NASA (USA), NOAA (USA), CNES (France)/ISRO (India), EUMETSAT (EU), JAXA, etc.		

2.1.2. Outline of GPM Core Satellite

GPM Core Satellite carries Dual-frequency Precipitation Radar (DPR) and a microwave radiometer. Main purposes of the GPM are “Comprehension of horizontal and vertical structure of precipitation systems”, “Acquisition of precipitation particles information” and “Improvement of accuracy of precipitation by constellation satellites”.

GPM Core Satellite can observe the range from the south latitude about 65 degrees to the north latitude about 65 degrees, and flies Non-Sun-synchronous Circular Orbit at about the 407 km altitude. To keep the altitude, the Core Satellite does the orbit maintenance maneuver. The interval is about 7-10 days. In addition, asGPM Core satellite performed two orbit boost maneuvers on

Nov. 2023 that raised its altitude, the satellite altitude rose to approximately 442 km.

Overview of GPM Core Satellite is shown in Figure 2.1-2, Main Characteristics of GPM Core Satellite are shown in Table 2.1-2 and the concept of precipitation observation by the GPM Core Satellite (at about 407 km altitude) is shown in Figure 2.1-3.

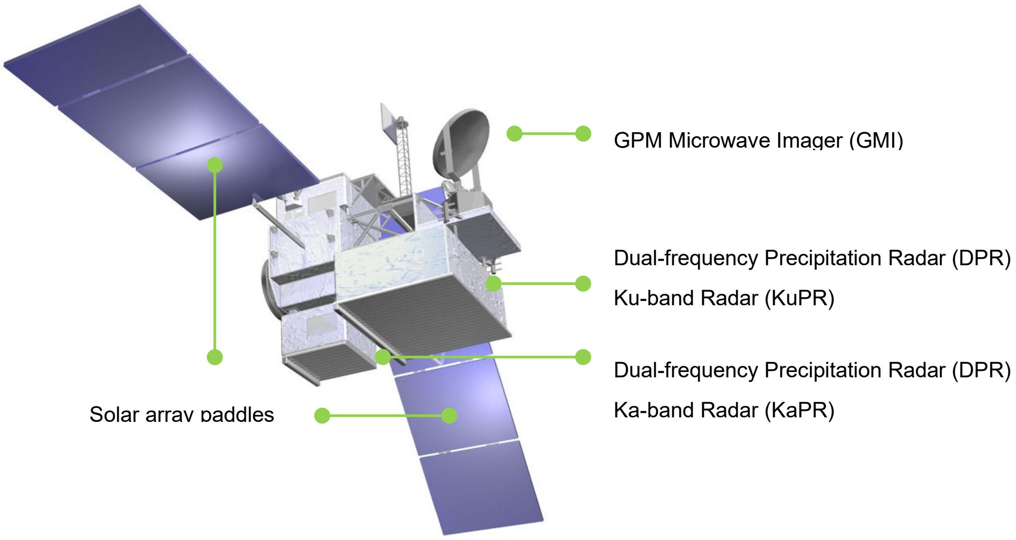


Figure 2.1-2 Overview Design of GPM Core Satellite

Table 2.1-2 Main Characteristics of GPM Core Satellite

Main Characteristics	GPM Core Observatory
Launcher	H-IIA Launch Vehicle No.23 (from Tanegashima Space Center)
Launch date	February 27, 2014 (UTC)
Orbit	Non-Sun-synchronous Circular Orbit
Altitude	397–419 km (before Nov. 2023) 432–454 km (after Nov. 2023)
Inclination	Approx. 65 degrees
Semi-major axis	Approx. 6776 km (before Nov. 2023) Approx. 6811 km (after Nov. 2023)
A/C Altitude Control Box	±1 km
Orbit Eccentricity	0.00010
Transmission path	Via NASA/Tracking and Data Relay Satellite (TDRSS)
Design life	3 years and 2 months after the launch
Instruments	Dual-frequency Precipitation Radar (DPR) ・Ku Band Rader (KuPR) ・Ka Band Rader (KaPR) GPM Microwave Imager (GMI)
Weight	Approx. 3850 kg
Dimensions	13.0 m × 6.5 m × 5.0 m

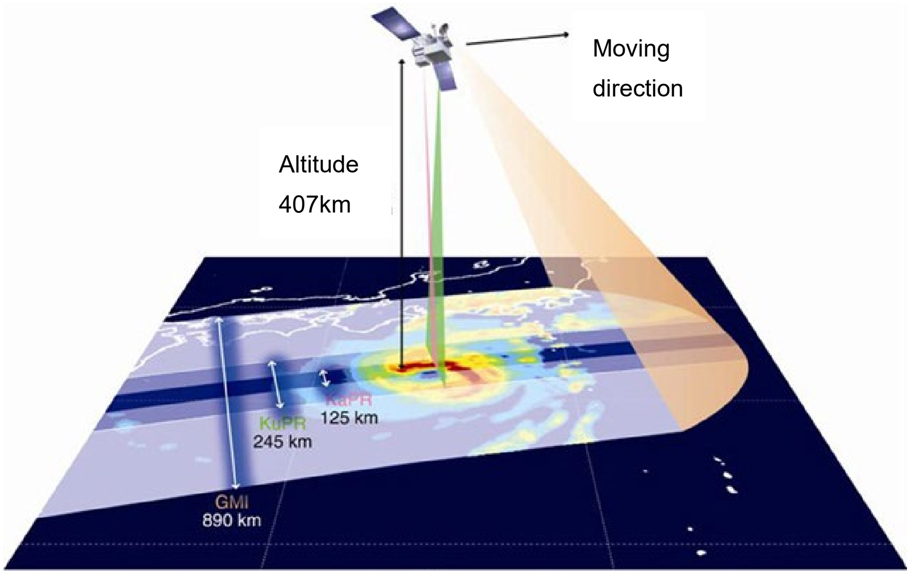


Figure 2.1-3 Concept of Precipitation Observation by the GPM Core Observatory

The main role of Core Satellite is to work as a calibrator for all observation data by simultaneous measurements of DPR and GMI instruments and to improve precipitation observation accuracy of microwave radiometer including constellation satellites.

2.1.3. Outline of GPM Constellation Satellites

Only one satellite for the low-earth-orbit satellite like TRMM lowers the frequency of the observation. In the GPM mission, it cooperates with other satellites to overcome this weak point, and to achieve the frequent observation. The existing satellites carrying microwave radiometer or the microwave sounder around year 2014 configure GPM constellation satellites. The list of constellation satellites is shown in Table 2.1-3.

Table 2.1-3 List of Constellation Satellites

Sensor	Satellite	Period	Organization
TRMM Microwave Imager (TMI)	Tropical Rainfall Measuring Mission (TRMM)	1997–2015	NASA
Special Sensor Microwave Imager (SSMI)	Defense Meteorological Satellite Program (DMSP) series	F-15：1999– in operation	DoD
Special Sensor Microwave Imager/Sounder (SSMIS)	Defense Meteorological Satellite Program (DMSP) series	F-16：2003– in operation F-17：2006– in operation F-18：2009– in operation F-19：2014–2016	DoD

Sensor	Satellite	Period	Organization
Advanced Microwave Scanning Radiometer2 (AMSR2)	Global Change Observation Mission – Water (GCOM-W)	2012– in operation	JAXA
Microwave Analysis and Detection of Rain and Atmospheric Systems (MADRAS)	Megha-Tropiques	2011–2013	CNES/ISRO
Sondeur Atmospherique du Profil d'Humidite Intertropicale par Radiometrie (SAPHIR)		2011– in operation	
Microwave Humidity Sounder (MHS)	National Oceanic and Atmospheric Administration (NOAA) series	NOAA-18 ：2005–2018 NOAA-19 ：2009– in operation	NOAA
Advanced Microwave Sounding Unit-A (AMSU-A)		NOAA-18 ：2005–2018 NOAA-19 ：2009– in operation	
MHS	MetOp series	Metop-A ：2006–2021 Metop-B ：2012– in operation Metop-C ：2018– not determined	EUMETSAT
AMSU-A		Metop-A ：2006–2021 Metop-B ：2012– in operation Metop-C ：2018– in operation	
Advanced Technology Microwave Sounder (ATMS)	NOAA-NASA Joint Polar Satellite System (JPSS)	Suomi NPP ：2011– in operation NOAA-20 ：2017– in operation NOAA-21 ：2023– in operation	NASA/NOAA

2.2. Outline of GPM Mission Critical Devices

2.2.1. The Dual-frequency Precipitation Radar (DPR)

The DPR has two different frequencies to measure the three-dimensional structure of precipitation, and is capable of observing snowfall from space for the first time, in addition to observing both strong and weak rainfall. The DPR's observations will provide global precipitation dataset including weak rainfall by extra tropical cyclones in mid-to-high latitudes, in addition to carrying on the archive of long-term rainfall dataset in the tropics and the subtropics by PR. Furthermore, through its high-resolution and highly accurate observations, DPR will play a role of the reference standard for the microwave radiometers carrying on the Constellation Satellites who join the GPM mission, through the GPM Microwave Imager on board the same platform. The swaths of DPR instrument are about 125 and 245 km (78 and 152 mile) for a Ka-band precipitation radar (KaPR) (about 245 km after May 21, 2018) and a Ku-band precipitation radar (KuPR) respectively. In addition, simultaneous measurements are done at the overlapping of Ka/Ku-bands of the DPR. The GMI instrument is a conical-scanning multi-channel microwave radiometer covering a swath of 904 km (565 miles).

The appearance diagram of DPR is shown in Figure 2.2-1 and the main characteristics of DPR are shown in Table 2.2-1.

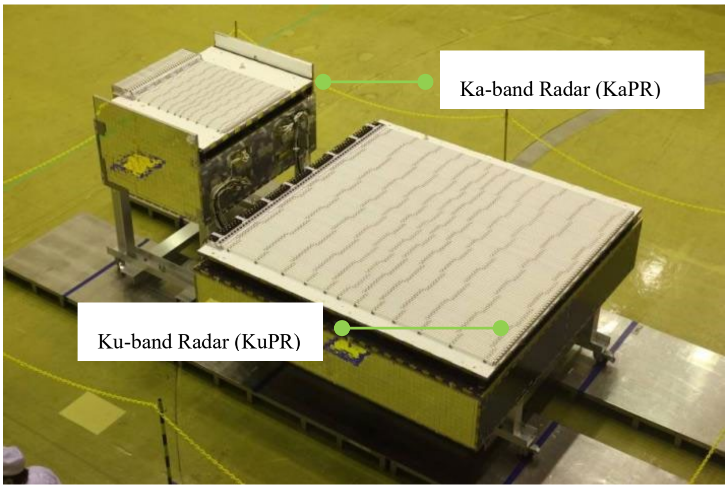


Figure 2.2-1 Appearance of DPR

Table 2.2-1 Main Characteristics of DPR (Specification)

Main Characteristics	KuPR	KaPR
Radar Type	Active Phased Array Radar	
Antenna	Slotted Waveguide Antenna	
Frequency	Ku-band 13.597, 13.603 GHz	Ka-band 35.547, 35.553 GHz
Peak Transmit Power	> 1000 W	> 140 W
Range Resolution Pulse Width	≤ 250 m 1.67 microseconds	≤ 250 m / ≤ 500 m 1.67 microseconds /

Main Characteristics	KuPR	KaPR	
		3.34 microseconds	
Horizontal Resolution	5.04 +/- 0.14 km (at nadir) 【5.48km ± 0.16 km (at nadir) (after Nov. 8th 2023)】		
Beam Width	0.71 degrees +/- 0.02 degrees (at nadir)		
Band Width	14 MHz		
Beam Number	49	49 Before May 21, 2018: 25 in matched beams 24 in interlaced scans After May 21, 2018: 25 in matched beams 24 in matched beams with high sensitivity	
Transmitter	128 Solid State Amplifiers		
Peak Transmit Power	1012.0 W	146.5 W	
Pulse Repetition Frequency (PRF)	variable		
Swath Width	≥ Approx. 245 km	≥ Approx. 125 km	
	≥ Approx. 245 km after May 21, 2018 【Approx. 278 km (after Nov. 8th 2023)】		
Scan Interval	0.7 sec		
Observable Range	Up to 19 km		
Minimum Detectable Rain Rate	Specification:0.5 mm/hr Theoretical value:0.30 mm/hr 【0.33 mm/hr (after Nov. 8th 2023)】	**High sensibility beam** Specification: 0.2 mm/hr Theoretical value:0.16 mm/hr 【0.19 mm/hr (after Nov. 8th 2023)】	**Matched beam** Specification:0.2 mm/hr Theoretical value:0.38 mm/hr 【0.42 mm/hr (after Nov. 8th 2023)】
Receiver power accuracy	+/- 1dB		
Beam-matching Error	< 1000 m 【< 1090 m (after Nov. 8th 2023)】		
Design life	3 years and 2 months after the launch		
Data Rate	< 109 kbps	< 81 kbps	
Mass	< 415 kg	< 336 kg	
Power Consumption	< 446 W orbit average	< 344 W orbit average	
Dimensions	Approx. 2.6 m × 2.4 m × 0.7 m	Approx. 1.3 m × 1.5 m × 0.8 m	

(1) Observation Overview

The DPR is composed of two radars; a Ku-band Precipitation Radar (KuPR) and a Ka-band Precipitation Radar (KaPR). The KaPR instrument aims at sensitive observations, and can detect weak rainfall and snowfall that cannot be measured by the KuPR. Since the KuPR instrument can detect heavier rainfall, simultaneous observations by the KaPR and KuPR will enable accurate measurements of precipitation from heavy rainfall in the tropics to weak snowfall in high-latitudes.

In general, strength of precipitation echoes is affected by attenuation due to precipitation on those frequencies, but the amount of attenuation depends on the frequency and the size of raindrops. The KuPR and KaPR, therefore, match their radar beam positions and transmission pulse timings of each other to estimate a size of a raindrop (Raindrop Size Distribution, DSD) by calculating the difference in precipitation attenuations. The Observation Image Diagram of DPR is shown in Figure 2.2-2.

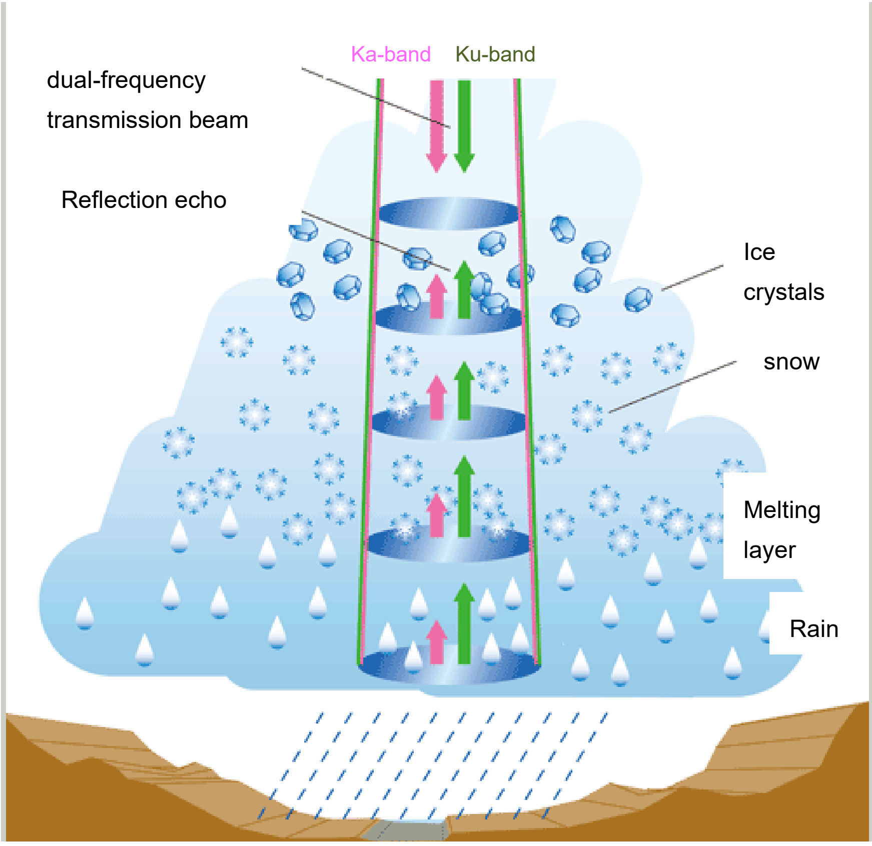


Figure 2.2-2 Observation Image Diagram of DPR

(2) Operational Mode

The usual DPR operation mode is "Observation mode". However, other operation modes exist in DPR, and it is necessary to note the handling of data enough for those operation modes.

The DPR Operation Modes are shown in Table 2.2-2.

Table 2.2-2 DPR Operation Modes

Operational Mode	Description	Frequency (*)	Note for data utilization
Observation Mode	During this mode, the KuPR and KaPR instruments perform normal rain echo measurements with a ±17.04 degrees scanning capability (49 beams) for	usual	DPR L1 product with modes except "Observation Mode" is not able to use for

Operational Mode	Description	Frequency (*)	Note for data utilization
	KuPR and with a ±8.52 degrees（± 17.04 degrees after May 21th, 2018）scanning capability (49 beams) for KaPR.		physical quantities calculation like rain rate. It is necessary to check “operational mode” and to process “Observation Mode” data only. The missing value is stored in the DPR L2 product which mode is not "Observation Mode".
External Calibration Mode	During this mode, DPR calibration and beam matching measurements between KuPR and KaPR are performed by Active radio calibrator (ARC) on the ground.	8 times / year (7 minutes / time)	
Internal Calibration Mode	During this mode, DPR receiver calibration is performed by using a loopback RF signal of FCIF.	once / week (2 minutes or 35 minutes / time)	
SSPA Analysis Mode	The receiving beam is fixed to the scan angle bin specified by commands, and a pulse is transmitted with one SSPA element one by one. The reflection echo from the sea surface is observed and it is confirmed that each element of SSPA has amplified the signal correctly.	4 times / year (5 minutes / time)	
LNA Analysis Mode	The transmission beam is fixed to the scan angle bin specified by commands, and a regulated pulse is transmitted. The reflection echo from the sea surface is received one by one in LNA. It is confirmed that each element of LNA has amplified the signal correctly.	4 times / year (5 minutes / times or 92 minutes / times)	
Health-Check Mode	Health-Check of internal function of SCDP is performed.	when DPR operational mode transition occurs	
Stand-by Mode	This mode is used for re-loading phase code and VPRF data, changing timing offset between KuPR and KaPR, and dumping current parameters.	when DPR operational mode transition occurs	
Safety Mode	This shall be the mode which the DPR is only provided DPR survival heater power from the Spacecraft. The DPR is not provided DPR instrument power for observation from the Spacecraft in this mode.	when anomaly of Spacecraft or DPR	

(*) The frequency shown here is the one for the nominal operation period.

2.2.2. The GPM Microwave Imager (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 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.

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 degrees 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. The 140 degrees GMI swath represents a swath of 904 km (562 miles) on the Earth's surface.

Only the central portions of the GMI swath will overlap the DPR 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.

The appearance diagram of GMI is shown in Figure 2.2-3 and the main characteristics of GMI are shown in Table 2.2-3.

In November 2023, the satellite performed two orbit boost maneuvers that raised its altitude to approximately 442km. As a result, the off-nadir angle of GMI was 49.5°, which corresponds to an incidence angle of 53.2°. The observation scanning angle remained at 140° (±70°), so the scanning width was expanded to approximately 1015 km.

Figure 2.2-4 shows an outline of GMI observation before and after raised the satellite altitude.

Figure 2.2-3 Appearance of GMI

Table 2.2-3 Main Characteristics of GMI

Main Characteristics	GMI
Frequency	10.65 GHz (V/H), 18.7 GHz (V/H), 23.8 GHz (V), 36.5 GHz (V/H), 89.0 GHz(V/H), 165.5 GHz (V/H), 183.31 ± 3 GHz (V), 183.31 ± 8 GHz (V)
Horizontal Resolution	6 to 26 km 【6 to 28 km (after Nov. 8th 2023)】
Swath Width	904 km 【1015 km (after Nov. 8th 2023)】
Scan Interval	1.875 sec
Design life	3 years and 2 months
Data Rate	< 25 kbps
Weight	< 153 kg
Power Consumption	< 141 W
Dimensions (diameter of antenna)	1.2 m
Off-Nadir Angle	48.5 degree (Incidence Angle:52.8 degree) 【49.5 degree (Incidence Angle:53.2 degree) (after Nov. 8th 2023)】

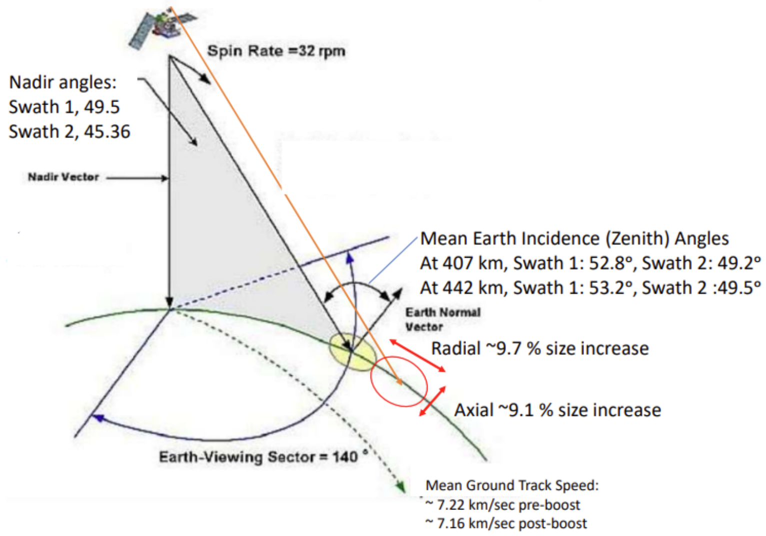


Figure 2.2-4 Outline of GMI observation before and after raised the satellite altitude

2.3. Overview of the TRMM Spacecraft

2.3.1. Outline of TRMM Satellite

TRMM mainly observes rain structure, rate and distribution in tropical and subtropical regions, the data plays an important role for understanding mechanisms of global climate change and monitoring environmental variation.

The TRMM observatory includes five science instruments, namely the Precipitation Radar (PR), the TRMM Microwave Imager (TMI), the Visible and Infrared Scanner (VIRS), the Clouds and the Earth's Radiant Energy System (CERES), and the Lightning Imaging Sensor (LIS).

TRMM has three instruments (PR, TMI, and VlRS) in its rainfall measurement package, to obtain tropical and subtropical rainfall measurements, rain profiles, and brightness temperature. TRMM has the only passive microwave instrument (TMI) in an inclined orbit and the only rain radar (PR) in space. The three rain instruments are providing the most complete rain data set (to date) in order to generate climate models and perform severe storm studies. The two additional instruments flown on-board TRMM are the CERES and LIS. CERES and LIS are flown on board TRMM as instruments of opportunity for the Earth Observation System Program. The CERES instrument measures the Earth's radiation budget, and the LIS instrument investigates the global distribution of lightning.

Overview of TRMM Satellite is shown in Figure 2.3-1, Main Characteristics of TRMM Satellite are shown in Table 2.3-1 and the TRMM operation history is shown in Table 2.3-2.

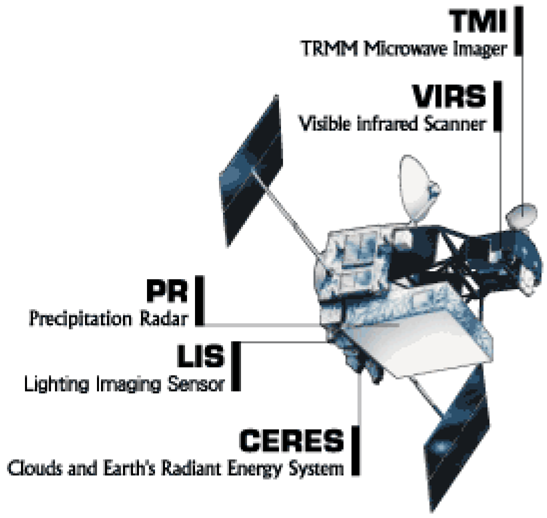


Figure 2.3-1 Overview of TRMM Satellite

Table 2.3-1 Main Characteristics of TRMM Satellite

Characteristics	TRMM Satellite
Launcher	H-II Launch Vehicle No.6
Launch date (JST)	November 28, 1997
Orbit	Non-Sun-synchronous Circular Orbit
Altitude	Approx. 350 km (Approx. 402.5 km*)
Inclination	Approx. 35 degrees

Characteristics	TRMM Satellite
Data transmission	Via TDRS 32Kbps (Real Time), 2Mbps (Play Back)
Design life	3 years and 2 months
Mission instrument	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible and Infrared Scanner (VIRS) Clouds and the Earth's Radiant Energy System (CERES) Lightning Imaging Sensor (LIS)
Weight	Approx. 3524 kg
Shape	At lift-off: 5.1 m (length), 3.7 m (diameter) In orbit: 5.1 m (length), 14.6 m (in paddle direction)

*: Post orbit boost (August 25, 2001)

Table 2.3-2 TRMM operation history

Date	Event
1997/11	Launch by the H-II Launch Vehicle No.6 from Tanegashima Space Center (28th)
1998/06	Publication for TRMM products L1 version 4
1998/09	Publication for TRMM products L2-3 version 4
1998/11	Instruments powered off due to Leonid Storm (18th–19th)
1999/01	Instruments powered off in Sun Acquisition mode (3rd–6th)
1999/11	Publication for TRMM products version 5
1999/11	Instruments powered off due to Leonid Storm (17th–18th)
2000/09	Instrument powered off in Low Power mode (17th–22nd)
2000/11	Instruments powered off due to Leonid Storm (18th)
2001/05	Suspension of CERES operation.
2001/08	TRMM boost (350 km–402.5 km). (7th–24th)
2001/11	Instruments powered off due to Leonid Storm (18th–19th)
2002/06	Publication for TRMM products version 6
2002/11	Instruments powered off due to Leonid Storm (18th–19th)
2009/05	Instruments powered off due to PR anomaly (29th–June 18th)
2011/07	Publication for TRMM products version 7
2014/10	TRMM boost (402.5 km–350 km). (7th–Feb 12th 2015)
2015/06	TRMM satellite re-entered the atmosphere (16th)

2.4. Outline of TRMM Mission Critical Devices

2.4.1. Precipitation Radar (PR)

When properly combined with TMI measurements, the PR data is instrumental in obtaining the height profile of the precipitation content, from which the profile of latent heat release from the Earth can be estimated. The rain rate is estimated from the radar reflectivity factor when the rain rate is small by applying conventional algorithms used for ground-based radar. For large rain rates, a rain attenuation correction is made using the total-path attenuation of land or sea surface echoes.

The appearance diagram of PR is shown in Figure 2.4-1 and the main characteristics of PR are shown in Table 2.4-1.

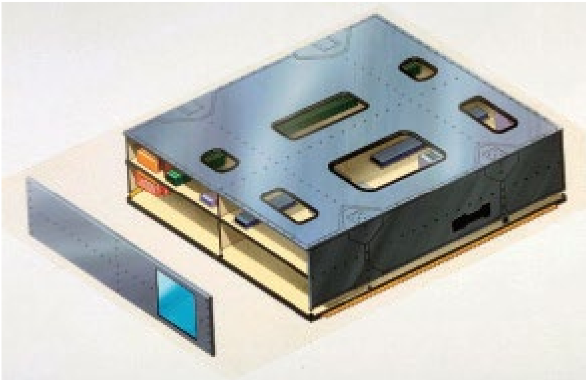


Figure 2.4-1 Appearance of PR

Table 2.4-1 Main Characteristics of PR

Main Characteristics	PR
Radar Type	Active Phased Array Radar
Frequency	13.796 GHz & 13.802 GHz (Two-channel frequency agility)
Range Resolution	250 m
Pulse Width	1.6 μs
Horizontal Resolution	4.34 km ± 0.12 km (at nadir)*
Beam Width	0.71 deg. × 0.71 deg.
Swath Width	~215 km*
Observable Range	From surface to height ≥ 15 km*
Sensitivity	S/N per pulse ≥ 0 dB for 0.5 mm/h rain at rain top*
Data Rate	93.5 kbps
Weight	465 kg
Power	213 W

*: Post orbit boost (August 25, 2001)

(1) Operational Mode

The usual PR operation mode is "Observation". However, other operation modes exist in PR, and it is necessary to note the handling of data enough for those operation modes.

The PR Operation Modes are shown in Table 2.4-2.

Table 2.4-2 PR Operational Modes

PR MODE	MODE DESCRIPTION
Observation	This will be the normal operating mode of the instrument. During this mode, the PR instrument performs normal rain echo measurements with a ± 17˚ scanning range.
External Calibration	This mode will provide an on-orbit calibration of the PR instrument by the Active Radar Calibrator (ARC) on the ground. Limited scan or Fixed beam submodes may be used in either the spacecraft nominal configuration or the 90˚ yaw configuration. Limited scan - scanning for 7 beam directions centered at a selected angle bin. Fixed beam - Beam is fixed to a selected angle bin. No scanning is performed.
Internal Calibration	This mode will provide an on-orbit calibration about the input-output characteristics of LOGAMP with internal loop signal. During this mode, no RF signal is radiated from the antenna and science observation will not occur.
Health Check	This mode is for checking RAMs and ROMs used in the System Control Data Processing (SCDP) component. By electrical power turn-on, PR moves from Safety Mode to this mode.
LNA Analysis	This mode is used to check whether each LNA is alive or not. During this mode, no science observation will occur.
Stand-By	This mode is for checking the phase code stored in the SCDP. Also, this mode shall be selected to temporarily stop the RF radiation. During this mode, the PR instrument is ON but is not initiating any RF transmissions.
Safety	This mode will be used when the TRMM observatory is in any of the following modes of operation: - Launch Mode - Initial Orbit Acquisition Mode - Safe-Hold/Low Power Mode When Safe-hold/Low Power signal is received, the PR instrument will be internally commanded to this mode, prior to the autonomous removal of the NEB power supply. During this mode, the PR instrument is OFF with the exception of the survival heaters.

2.4.2. TRMM Microwave Imager (TMI)

The TRMM Microwave Imager (TMI) is a Multi-channel dual-polarized passive microwave radiometer. TMI utilizes nine channels with operating frequencies of l0.65 GHz, 19.35 GHz, 21.3 GHz, 37 GHz, and 85.5 GHz. The TMI instrument provides data related to the rainfall rates over the oceans, but less reliable data over land, where non-homogeneous surface emissions make interpretation difficult. The TMI instrument is similar to the SSM/I instrument currently in orbit on the Defense Meteorological Satellite Program spacecraft. The TMI data combined with the data from the PR and VIRS also utilized for deriving precipitation profiles.

The TMI instrument has a single operational mode and no commendable redundancy. Accordingly, command procedures are minimal and focus on power and heater control. TMI essentially has two modes, OFF and ON. Two external calibrators on the stationary shaft are used to perform calibrations during each instrument rotation (scan). The instrument spins at a rate of 31.6 RPM. Each scan begins with 130˚ of scene data, followed by a cold reference measurement and then a hot load reference measurement. These reference measurements, along with the known temperatures of the calibration loads, serve to calibrate the scan.

The appearance diagram of TMI is shown in Figure 2.4-2 and the main characteristics of TMI are shown in Table 2.4-3.

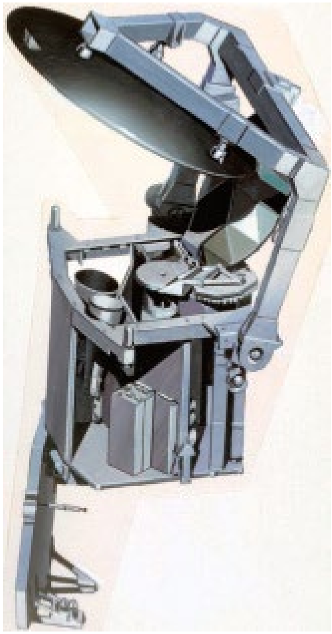


Figure 2.4-2 Appearance of TMI

Table 2.4-3 Main Characteristics of TMI

Main Characteristics	TMI
Observation Frequency	10.65, 19.35, 21.3, 37 and 85.5 GHz
Horizontal Resolution	6 - 50 km*
Swath Width	~ 760 km*
Data Rate	8.8 kbps
Weight	50 kg
Power	39 W

*: Post orbit boost (August 25, 2001)

2.4.3. Visible and Infrared Scanner（VIRS）

The VIRS instrument is a cross-track scanning radiometer, which measures scene radiance in five spectral bands, operating in the visible through infrared spectral regions. VIRS is similar to instruments flown on other NASA and NOAA meteorological satellites. Comparison of the microwave data with VIRS visible and infrared data is expected to provide the means whereby precipitation can be estimated more accurately than by visible and infrared data alone. The VIRS instrument serves as a background imager and provides the cloud context within which the passive microwave and radar observations are made. Data from the VIRS instrument is used in rain estimation algorithms based primarily on the passive and active microwave sensors.

The appearance diagram of VIRS is shown in Figure 2.4-3 and the main characteristics of VIRS are shown in Table 2.4-4.

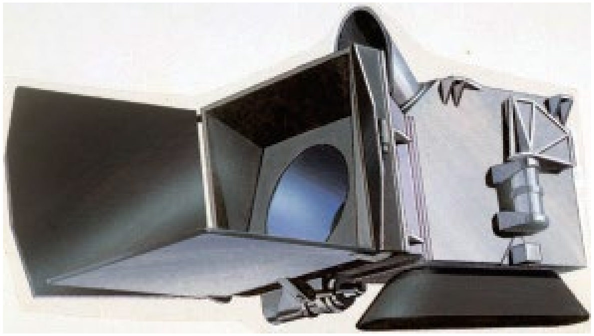


Figure 2.4-3 Appearance of VIRS

Table 2.4-4 Main Characteristics of VIRS

Main Characteristics	VIRS
Observation Band	0.63, 1.61, 3.75, 10.80 & 12.00 µm
Swath Width	Scan angle ± 45 degrees, 720 km* at ground
Data Rate	50 kbps (Daytime)
Weight	49 kg
Power	53 W

*: Post orbit boost (August 25, 2001)

2.4.4. Clouds and the Earth's Radiant Energy System（CERES）

The CERES experiment will help reduce one of the major uncertainties in predicting long-term changes in the Earth's climate. Radiant fluxes at the top of the Earth's atmosphere (TOA) were measured by the Earth Radiation Budget Experiment (ERBE), not merely as an undifferentiated field, but with reasonable separation between fluxes originating from clear and cloudy atmospheres. It was also discovered from ERBE that clouds have a greater effect on the TOA fluxes than was previously believed, but details of the process are not yet fully understood. The CERES experiment will attempt to provide a better understanding of how different cloud processes, such as convective activity and boundary-layer meteorology, affect the TOA fluxes. This understanding will help determine the radiative flux divergence, which enters directly into physically based, extended-range weather and climate forecasting. CERES will also provide information to determine the surface radiation budget, which is important in atmospheric energetics, studies of biological productivity, and air-sea energy transfer.

Since September 1998, however, CERES operated intermittently to acquire science data for only campaign purpose, because an anomaly occurred on the power source of data collection system (DAA) of CERES in August 1998. Moreover, CERES operation was completely terminated since May 29 2001.

The appearance diagram of CERES is shown in Figure 2.4-4 and the main characteristics of CERES are shown in Table 2.4-5.

Figure 2.4-4 Appearance of CERES

Table 2.4-5 Main Characteristics of CERES

Main Characteristics	CERES
Observation Band	0.3 – 5 µm (short Wave Channel) 8 – 12 µm (Long Wave Channel) 0.3 ~> 50 µm (Total Wave Channel)
Horizontal Resolution	10 km (nadir)
Swath Width	Scan Angle: ± 82 deg.
Data Rate	8.5 kbps
Weight	45.5 kg
Power	47 W

2.4.5. Lightning Imaging Sensor（LIS）

The LIS is an optical staring telescope and filter imaging system that acquires and investigates the distribution and variability of both intracloud and cloud-to-ground lightning over the Earth. The LIS data also is used with PR, TMI and VIRS data to investigate the correlation of the global incidence of lightning with rainfall and other storm properties. The data from the LIS instrument can be correlated to the global rates, amounts, and distribution of precipitation, and to the release and transport of latent heat. LIS is a single string instrument with multiple single points of failure. The LIS instrument was powered ON during the initial instrument activation, and remains powered in that configuration for the duration of the mission (barring any unforeseen anomalous conditions).

The appearance diagram of LIS is shown in Figure 2.4-5 and the main characteristics of LIS are shown in Table 2.4-6.

Figure 2.4-5 Appearance of LIS

Table 2.4-6 Appearance of LIS

Main Characteristics	LIS
Observation Band	0.777655 μm
Horizontal Resolution	4 km (nadir)*
Swath Width	~ 600 km*
Data Rate	Ave. 6 kbps
Weight	18 kg
Power	42 W

*: Post orbit boost (August 25, 2001)

2.5. Outline of ground system

2.5.1. GPM Ground System and data flow

GPM Ground System and its major facilities are shown in Figure 2.5-1.

Mission Operation Center (MOC) that exists in Goddard Space Flight Center (GSFC) of NASA provides all facilities necessary to support spacecraft operations. It includes a command unlinking and a telemetry archival via Tracking and Data Relay Satellite (TDRSS). TDRSS consists of some constellation satellites and can downlink approximately at all the time. Return/forward service data rates are variable depending on the selection of Single Service Access (SSA) or Multi-Access (MA) service utilization. For GPM operation, either MA (a phased array antenna) or SSA (a high-gain antenna) service is applied to receive all telemetry data which are packed into 5-minute duration file by the GPM core spacecraft. GMI science telemetry data, GMI HK telemetry data and spacecraft HK telemetry data can be downlinked approximately at all the time via MA. On the other hand, DPR telemetry data can be downlinked 2-3 times per one orbit via SSA because DPR data file size is larger than GMI data file size. And for short or intermittent telemetry data outages resulting in the loss of file fragments, CCSDS File Delivery Protocol (CFDP) is used to automatically recover the telemetry data. The received telemetry data is sent to the Precipitation Processing System (PPS) of NASA immediately via MOC. After that, they are transmitted from PPS to JAXA GPM ground system in Tsukuba Space Center (TKSC). An international dedicated line is used for this transmission to increase reliability.

Some microwave radiometer/sounder observation data (L1) are ingested by NASA and JAXA ground system from Constellation Satellite Data Distribution Organizations. And environment auxiliary data and IR data are collected from the Japan Meteorological Agency (JMA) and National Oceanic and Atmospheric Administration (NOAA) etc. GPM products are generated using them and provided to users.

JAXA GPM ground system consists of GPM/DPR mission operation system (GPM/MOS), Earth Observation Satellite Data Distribution System (G-Portal) and JAXA Earth Observation Research Center (EORC). In addition, GPM/MOS consists of the GPM/DPR Data Processing System (DPS) and the Earth Observation Satellite Mission External Interface Gateway (E-XING). DPS receives DPR science/HK telemetry data from NASA/PPS and GMI products and some microwave radiometer/sounder observation data by constellation satellites and ancillary data via E-XING. DPS conducts near-real-time (NRT) products processing immediately and conducts high-level processing of GPM standard products. These products are stored to E-XING and provide to G-Portal. The registered user (researcher etc.) can search and obtain the GPM product from G-Portal. These data transmission, reception, processing, archive, and distribution is automatically operated.

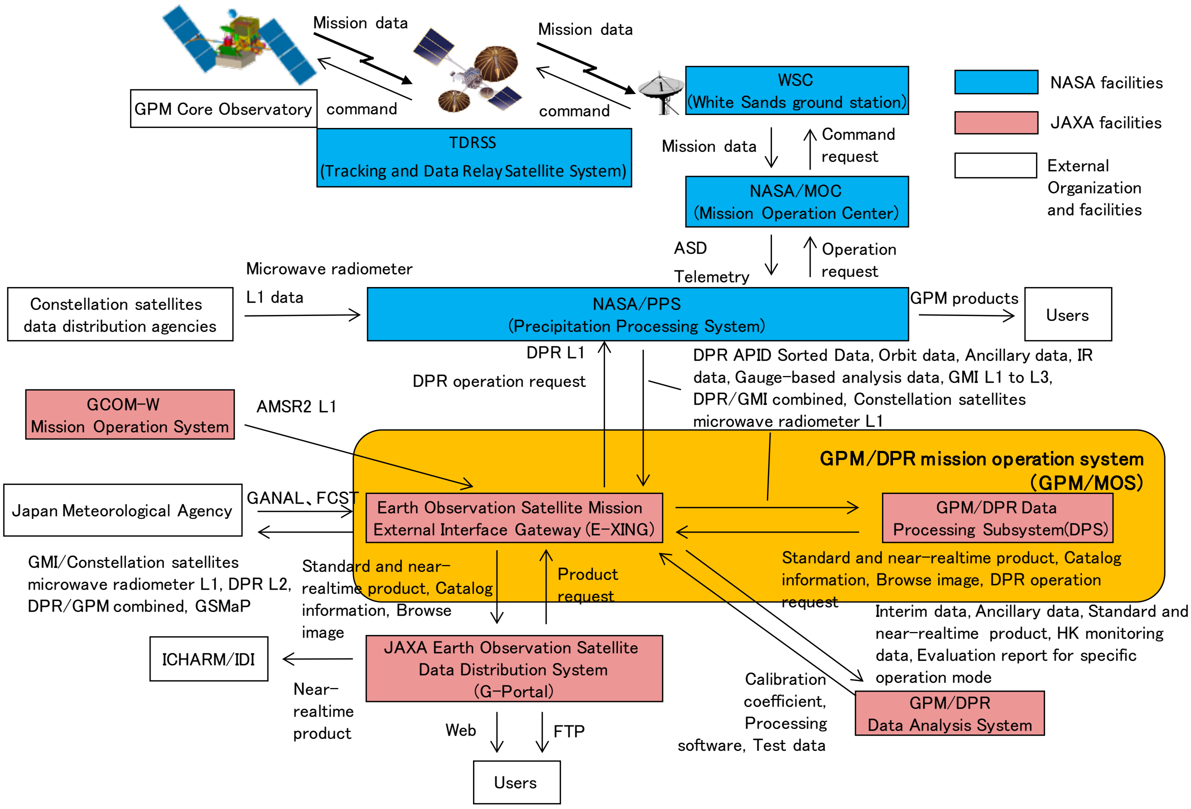


Figure 2.5-1 GPM Ground System

Chapter 3 GPM PRODUCT

This chapter describes outlines of data processing algorithm and data format of standard products and near-real-time products provided by JAXA.

3.1. Outline of the Products

3.1.1. Scene Definitions

(1) Scene of Level 1 and Level 2 Products

A scene of Level 1 and Level 2 DPR products is defined as data for an orbit with the southernmost point of the Earth as the start point without overlap. Figure 3.1-1 shows an image of the scene definition of KuPR and KaPR.

A near-real-time (NRT) GMI product's file is generated by the receiving data of 5 minutes from the satellite. A near-real-time DPR and DPR/GMI COMB product's files are generated by the receiving data of 30 minutes from the satellite.

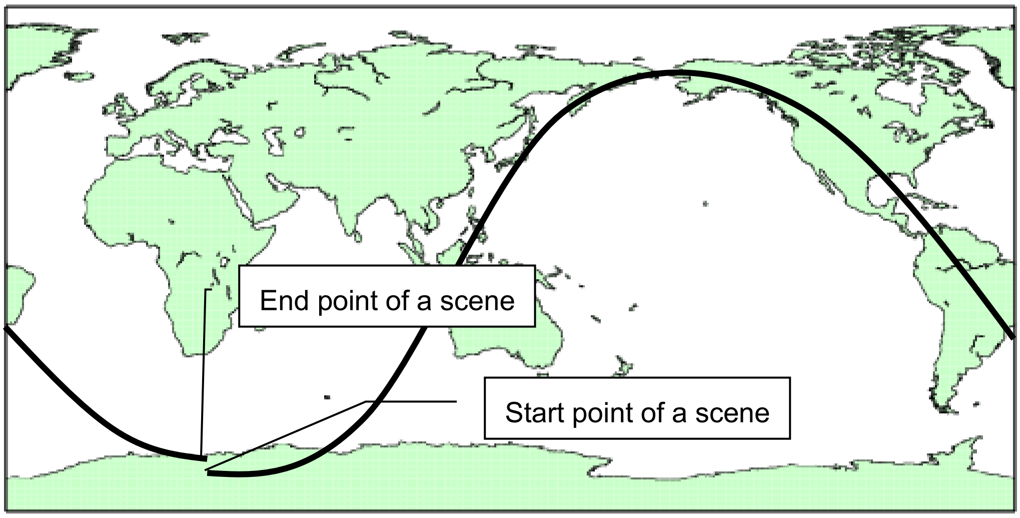


Figure 3.1-1 Image of Scene Definition

The number of angle bin within one scan is 52 (0 to 51); 49 of them (1 to 49) are actually used for observation by transmitting radio wave.

Figure 3.1-2 shown below is an outline of normal observation before KaPR scan pattern change. The swath of KuPR is about 245 km wide and that of KaPR is about 125 km wide.

In Ku/Ka/DPR L2 products, the names of scan are used as noted below;

“FS” = Full scan, corresponding to the blue footprint (49 angle bin) in Figure 3.1-2.

“MS” = Matched beam scan, corresponding to the yellow footprint (25 angle bin) in Figure 3.1-2.

“HS” = High sensibility beam scan, corresponding to the red footprint (24 angle bin) in Figure 3.1-2.

On May 21, 2018, JAXA and NASA changed the scanning pattern of the KaPR. Figure 3.1-3 shown below is an outline of normal observation after KaPR scan pattern change. KaPR High-Sensitivity (KaHS) beams shown as red circles in Figure 3.1-2 scan in the inner swath before May 21 2018, but now they scan in the outer swath and match with KuPR’s beams.

Furthermore, because GPM Core satellite performed two orbit boost maneuvers that raised its altitude on November 2023, the observation width of both KuPR and KaPR have become approximately 278 km.

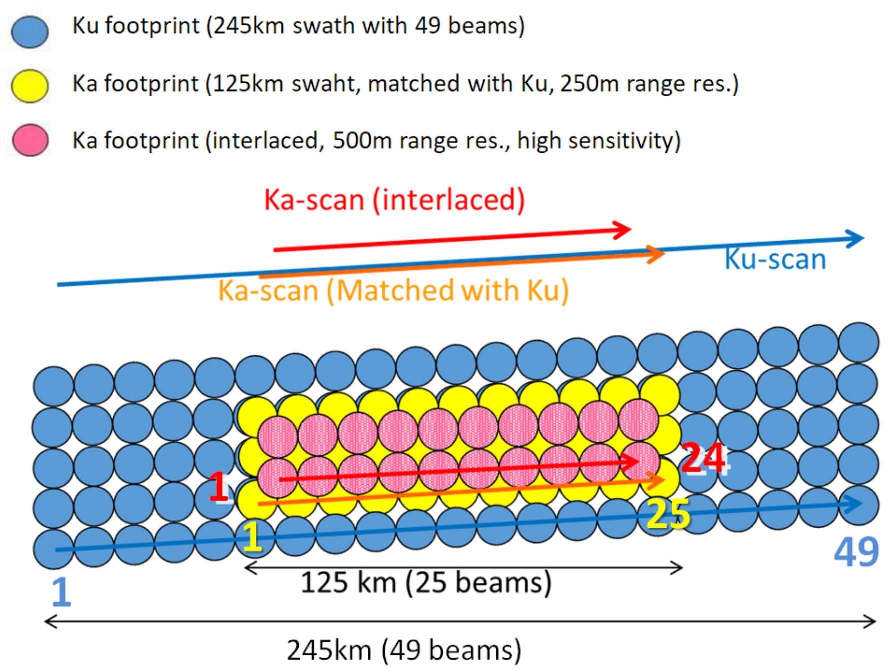


Figure 3.1-2 The Outline of KuPR and KaPR Under Normal Observation

(Before KaPR scan pattern change)

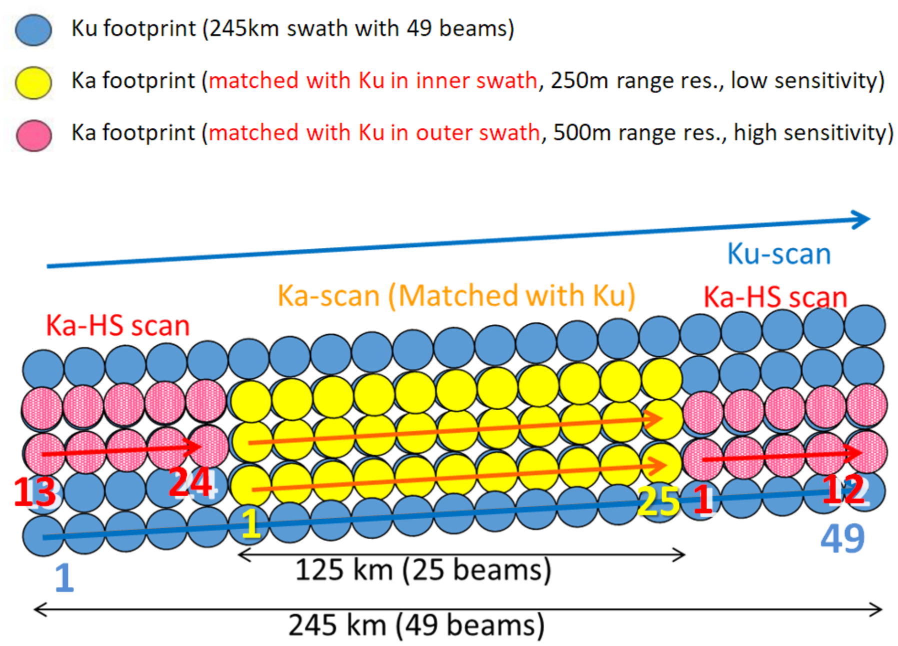


Figure 3.1-3 The Outline of KuPR and KaPR Under Normal Observation

(After KaPR scan pattern change)

(2) Scene of Level 3 Products

The following table shows a scene definition for GPM Level 3 products. The data format of the products shown in Table 3.1-1 is gridded by using the scene coverage, respectively. However, the grid size and the scene coverage (the range of latitude) are different, respectively.

Table 3.1-1 Scene Definitions for Level 3 Products

Product	Temporal Resolution and Grid Size	Scene Coverage
GPM DPR L3 Precipitation	**Standard Product** - Daily (Text format) Resolution: 0.1° × 0.1° - Daily (HDF format) Resolution: 0.25° × 0.25° - Daily (GeoTIFF format) Resolution: 0.25° × 0.25° - Monthly (HDF format) Resolution: 0.25° × 0.25°, 5° × 5° - Monthly (GeoTIFF format) Resolution: 0.25° × 0.25°	(1) Resolution=0.1, 0.25°: Products covering: 67°S to 67°N, 180°W to 180°E (2) Resolution=5°: Products covering: 70°S to 70°N, 180°W to 180°E
GPM DPR L3 Spectral Latent Heating (SLH)	**Standard Product** - Gridded Orbital Resolution: 0.5° × 0.5° - Monthly Resolution: 0.5° × 0.5°	Products covering: 67°S to 67°N, 180°W to 180°E
GPM GMI L3 Precipitation	**Standard Product** - Monthly Resolution: 0.25° × 0.25°	Products covering: 90°S to 90°N, 180°W to 180°E
GPM DPR/GMI Comb L3 Precipitation	**Standard Product** - Monthly Resolution: 0.25° × 0.25° & 5° × 5°	(1) Resolution=0.25°: Products covering: 67°S to 67°N, 180°W to 180°E (2) Resolution=5°: Products covering: 70°S to 70°N, 180°W to 180°E
GPM DPR/GMI Comb L3 Convective Stratiform Heating (CSH)	**Standard Product** - Gridded Orbital Resolution: 0.25° × 0.25° - Monthly Resolution: 0.25° × 0.25°	Products covering: 67°S to 67°N, 180°W to 180°E
GSMaP Precipitation	**Standard Product** - Hourly (Text format) Resolution: 0.1° × 0.1° - Hourly (HDF format) Resolution: 0.1° × 0.1° - Hourly (GeoTIFF format)	Products covering 90°S to 90°N, 180°W to 180°E

Product	Temporal Resolution and Grid Size	Scene Coverage
	Resolution: 0.1° × 0.1° - Monthly (HDF format) Resolution: 0.1°× 0.1° - Monthly (GeoTIFF format) Resolution: 0.1°× 0.1° - Hourly (netCDF format) Resolution: 0.1° × 0.1° - Monthly (netCDF format) Resolution: 0.1°× 0.1°	
	Near-Real-Time Product - Hourly (Text format) Resolution: 0.1° × 0.1° - Hourly (HDF format) Resolution: 0.1° × 0.1°	Products covering 90°S to 90°N, 180°W to 180°E
TRMM PR L3 Precipitation	**Standard Product** - Daily (Text format) Resolution: 0.1° × 0.1° - Daily (HDF format) Resolution: 0.25° × 0.25° - Monthly (HDF format) Resolution: 0.25° × 0.25°, 5° × 5°	(1) Resolution=0.1, 0.25°: Products covering: 67°S to 67°N, 180°W to 180°E (2) Resolution=5°: Products covering: 70°S to 70°N, 180°W to 180°E
TRMM PR L3 Spectral Latent Heating (SLHT)	**Standard Product** - Gridded Orbital Resolution: 0.5° × 0.5° - Monthly Resolution: 0.5° × 0.5°	Products covering: 67°S to 67°N, 180°W to 180°E
TRMM TMI L3 Precipitation	**Standard Product** - Monthly Resolution: 0.25° × 0.25°	Products covering: 90°S to 90°N, 180°W to 180°E
TRMM PR/TMI Comb L3 Precipitation	**Standard Product** - Monthly Resolution: 0.25° × 0.25° & 5° × 5°	(1) Resolution=0.25°: Products covering: 67°S to 67°N, 180°W to 180°E (2) Resolution=5°: Products covering: 70°S to 70°N, 180°W to 180°E
TRMM PR/TMI Comb L3 Convective Stratiform Heating (CSHT)	**Standard Product** - Gridded Orbital Resolution: 0.25° × 0.25° - Monthly Resolution: 0.25° × 0.25°	Products covering: 67°S to 67°N, 180°W to 180°E

3.1.2. Definition of GPM Processing Levels

The definitions of the processing levels are shown in Table 3.1-2.

Table 3.1-2 Definitions of Processing Levels of GPM Product

Processing level	Descriptions
Level 0	The processing input APID Sorted Data (data originated in satellite, packet-synchronized in accordance with CCSDS standard and divided by APIDs). From the primary and secondary headers of the packets, they check the time range, the continuousness (data missing) and so on. Level 0 data, which they output, are not provided to users.
Level 1A	The processing input Level 0 data and output Level 1A data. Level 1A data store sensor output engineering values, satellite attitude/position, sensor status, transform coefficients and so on in the time range, or scene, of respective files. L1A data are archived as master data, but not provided to users.
Level 1B, Level 1C	The processing input Level 1A data, conduct geometric corrections, and convert into received powers, brightness temperatures and so on.
Level 2	The processing input Level 1 products and derive physical quantities regarding precipitation, e.g. earth surface scattering cross-sections, precipitation types, bright band height, attenuation-compensated radar reflectivity factor, precipitation intensity, latent heating and so on.
Level 3	The processing input Level 1 or 2 products and conduct spatial and/or temporal statistical processing. The output products cover whole globe. The time coverage of the products is one month, one day or one hour (this goes for global precipitation mapping, latent heating, convective stratiform heating).

3.1.3. Processing Diagram

Figure 3.1-4a, Figure 3.1-4b, Figure 3.1-5a and Figure 3.1-5b show the processing flow of GPM products.

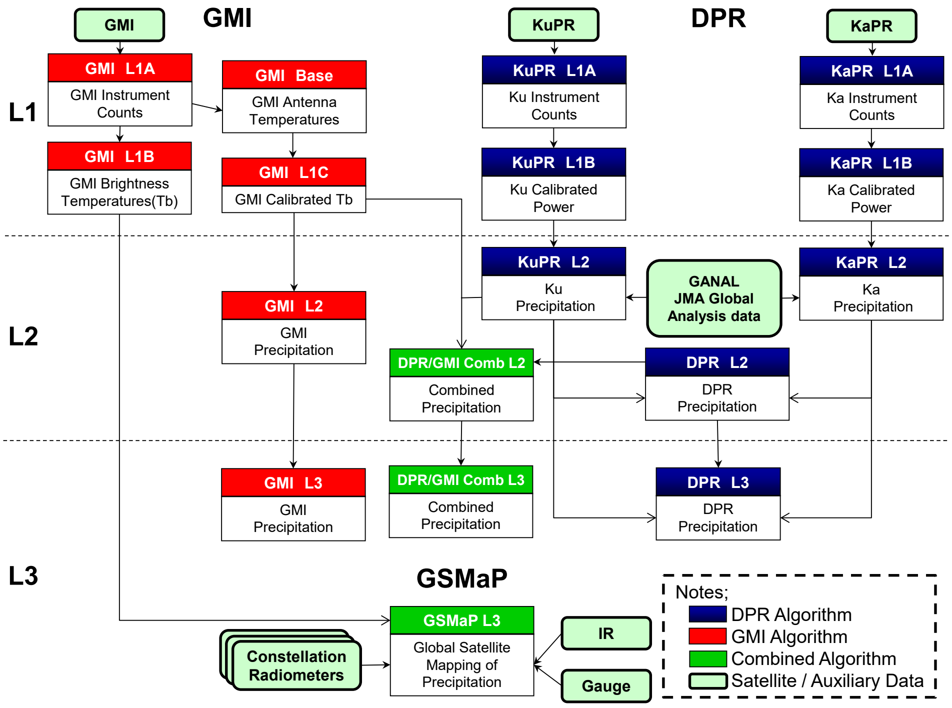


Figure 3.1-4a Processing Diagram of GPM Products (Precipitation Products)

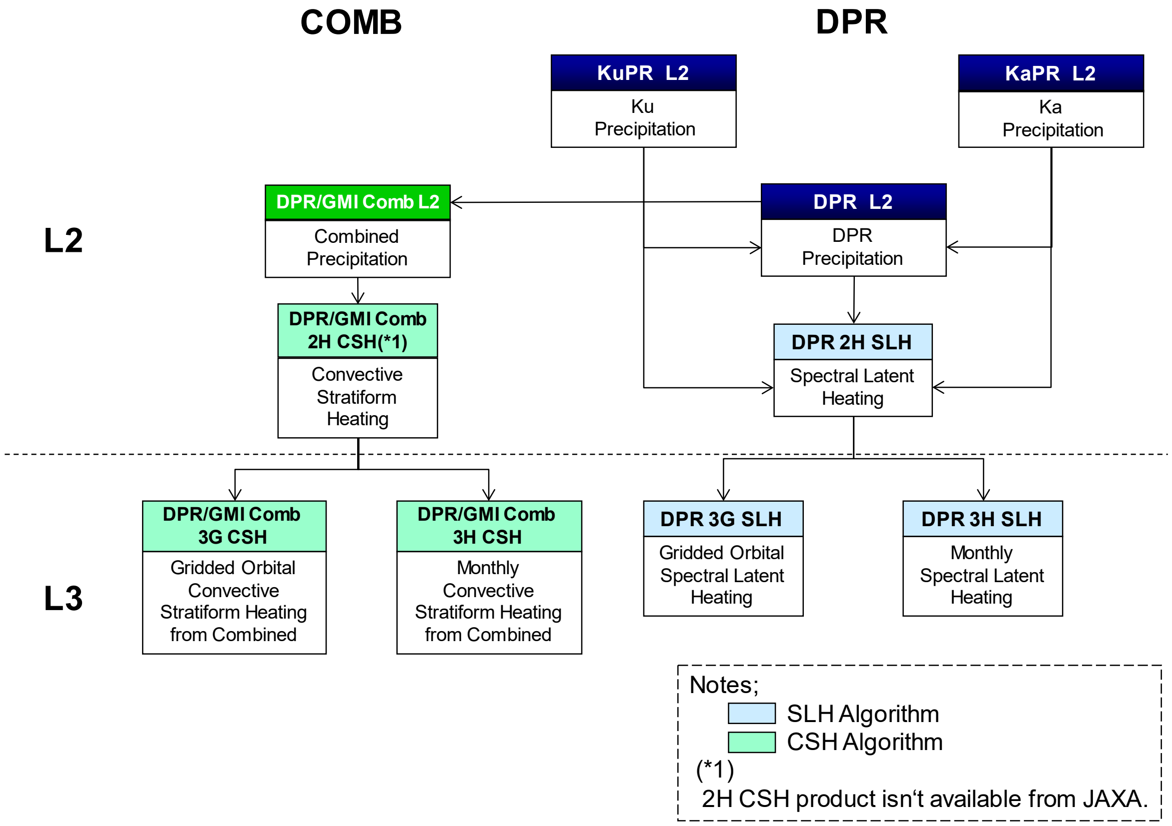


Figure 3.1-4b Processing Diagram of GPM Products (Latent Heating and Convective Stratiform Heating Products)

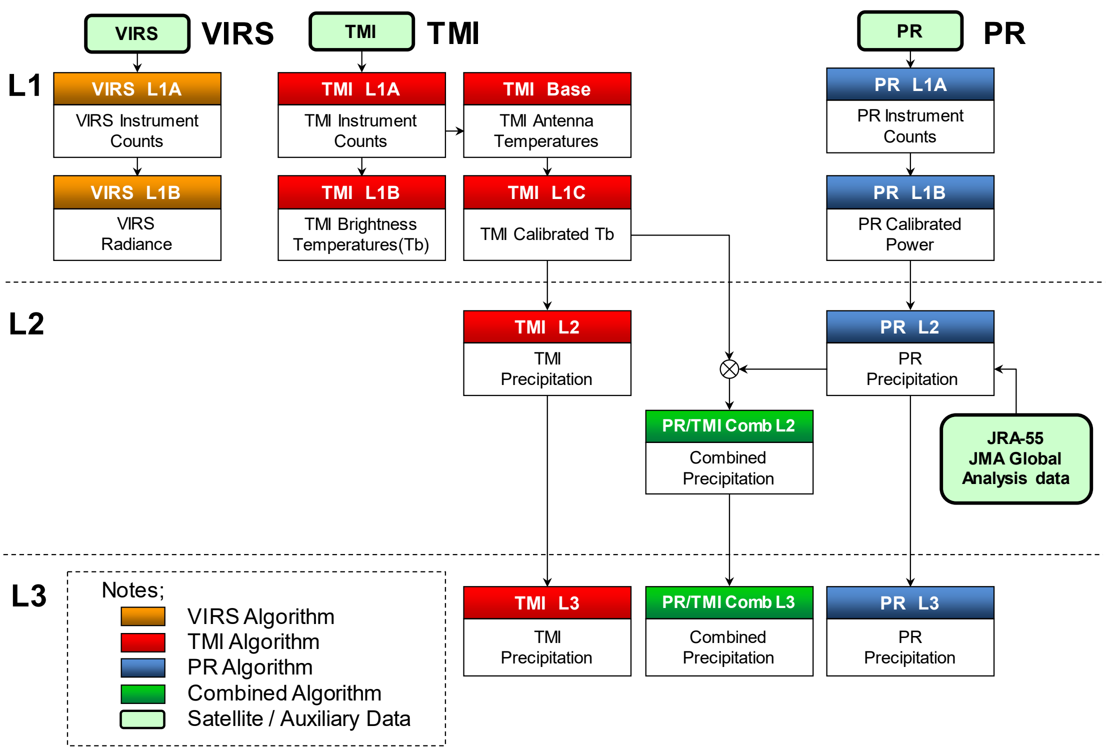


Figure 3.1-5a Processing Diagram of TRMM Products (Precipitation Products)

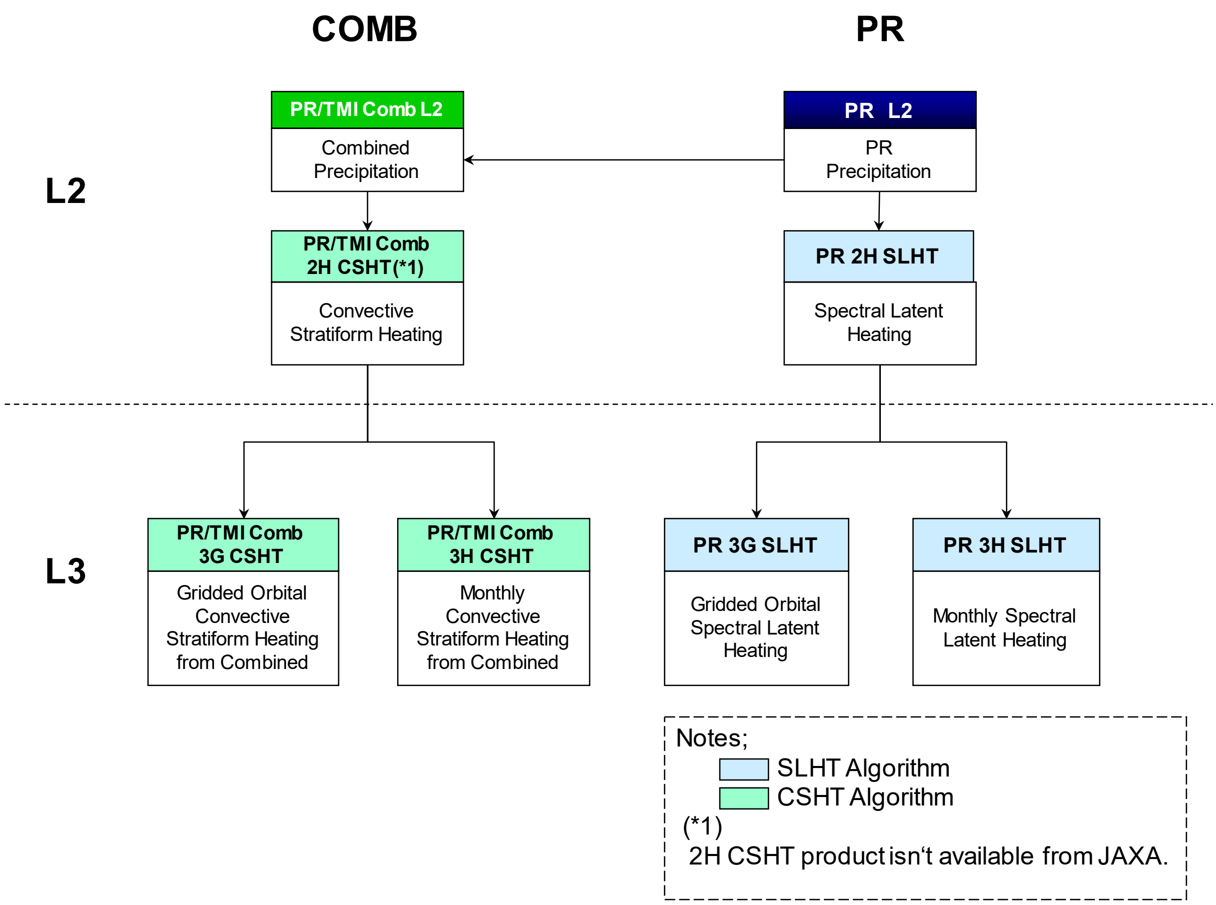


Figure 3.1-5b Processing Diagram of TRMM Products (Precipitation Products)

3.1.4. Products

Table 3.1-3, Table 3.1-4 and Table 3.1-5 respectively show JAXA GPM standard , GPM near-real-time and TRMM standard products.

Standard products are provided with accuracy assurance by JAXA or NASA. Near-real-time products are intended to be used by meteorological organizations etc. for weather forecast etc. Between near-real-time products and standard products, there are some differences on the input auxiliary data or the file coverage in order to shorten latency for near-real-time products.

Table 3.1-3 List of Standard Products

Group	Product	File size (*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
DPR product	KuPR L1B Received Power	Approx. 122.4 MB	One orbit	Approx. 5 km (*3) (horizontal) 125 m (vertical)	Approx. 16 files/ day
	KaPR L1B Received Power	Approx. 107.3 MB	One orbit	Approx. 5 km (*3) (horizontal) 125/250 m (vertical)	Approx. 16 files/ day
	KuPR L2 Precipitation	Approx. 209.6 MB	One orbit	Approx. 5 km (*3) (horizontal) 125 m (vertical)	Approx. 16 files/ day
	KaPR L2 Precipitation	Approx. 187.4 MB	One orbit	Approx. 5 km (*3) (horizontal) 125/250 m (vertical)	Approx. 16 files/ day
	DPR L2 Precipitation	Approx. 397.4 MB	One orbit	Approx. 5 km (*3) (horizontal) 125 m (vertical)	Approx. 16 files/ day
	DPR L2 Spectral Latent Heating	Approx. 5 MB	One orbit	Approx. 5 km (*3) (horizontal) 250 m (vertical)	Approx. 16 files/ day
	DPR L3 Precipitation (Daily TEXT)	Approx. 1.5 MB	Global	0.1° grid 67°N–67°S	one file/ day
	DPR L3 Precipitation (Daily HDF)	Approx. 3.2 MB	Global	0.25° grid 67°N–67°S, 5° grid 70°N–70°S	one file/ day

Group	Product	File size (*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
	DPR L3 Precipitation (Daily Ascending GeoTIFF)	Approx. 70 KB	Global	0.25° grid 67°N–67°S	one file/ day
	DPR L3 Precipitation (Daily Descending GeoTIFF)	Approx. 70 KB	Global	0.25° grid 67°N–67°S	one file/ day
	DPR L3 Precipitation (Monthly HDF)	Approx. 968.8 MB	Global	0.25° grid 67°N–67°S, 5° grid 70°N–70°S	one file / month
	DPR L3 Precipitation (Monthly GeoTIFF)	Approx. 2 MB	Global	0.25° grid 67°N–67°S	one file / month
	DPR L3 Gridded Orbital Spectral Latent Heating	Approx. 770 MB	One orbit	0.5° grid 67°N–67°S	Approx. 16 files/ day
	DPR L3 Monthly Spectral Latent Heating	Approx. 100 MB	Global	0.5° grid 67°N–67°S	one file / month
GMI product	GMI L1B Brightness Temperature	Approx. 58.3 MB	One orbit	Approx. 6–26km (*3) (horizontal)	Approx. 16 files/ day
	GMI L1C Inter-Calibrated Brightness Temperature	Approx. 27.7 MB	One orbit	Approx. 6–26km (*3) (horizontal)	Approx. 16 files/ day
	GMI L2 Precipitation	Approx. 16.8 MB	One orbit	Approx. 6–26 km (*3) (horizontal)	Approx. 16 files/ day
	GMI L3 Precipitation	Approx. 16.4 MB	Global	0.25° grid 90°N-90°S	one file/ month

Group	Product	File size (*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
DPR/GMI combined product	COMB L2 Precipitation	Approx. 121.3 MB	Global	Approx. 5 km (*3) (horizontal)	Approx. 16 files/ day
	COMB L3 Precipitation	Approx. 596.2 MB	Global	0.25° grid 67°N–67°S 5° grid 70°N–70°S	one file/ month
	COMB L3 Gridded Orbital Spectral Latent Heating *3	Approx. 5MB	Global	0.25° grid 67°N–67°S	Approx. 16 files/ day
	COMB L3 Monthly Spectral Latent Heating*3	Approx. 40MB	Global	0.25° grid 67°N–67°S	one file/ month
GSMaP product	GSMaP Precipitation (Hourly HDF)	Approx. 4.7 MB	Global	0.1° grid 90°N–90°S	24 files/ day
	GSMaP Precipitation (Hourly TEXT)	Approx. 12.5 MB	Global	0.1° grid 90°N–90°S	24 files/ day
	GSMaP Precipitation (Hourly GeoTIFF)	Approx. 1.5MB	Global	0.1° grid 90°N-90°S	24 files/ day
	GSMaP Precipitation (Hourly NetCDF)	Approx. 4.5MB	Global	0.1° grid 90°N–90°S	24 files/ day
	GSMaP Precipitation (Monthly HDF)	Approx. 41.6 MB	Global	0.1° grid 90°N–90°S	one file/ month
	GSMaP Precipitation (Monthly GeoTIFF)	Approx. 15 MB	Global	0.1° grid 90°N–90°S	one file/ month

Group	Product	File size (*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
	GSMaP Precipitation (Monthly NetCDF)	Approx. 41.6MB	Global	0.1° grid 90°N–90°S	one file/ month
Constellation satellite L1C product	DMSP F16 SSMIS L1C Inter-Calibrated Brightness Temperature	Approx. 22.9 MB	One orbit	Approx. 13–69km (horizontal)	14 files/ day
	DMSP F17 SSMIS L1C Inter-Calibrated Brightness Temperature	Approx. 22.7 MB	One orbit	Approx. 13–69km (horizontal)	14 files/ day
	DMSP F18 SSMIS L1C Inter-Calibrated Brightness Temperature	Approx. 21.7 MB	One orbit	Approx. 13–69km (horizontal)	14 files/ day
	DMSP F19 SSMIS L1C Inter-Calibrated Brightness Temperature	Approx. 23.1 MB	One orbit	Approx. 13–69km (horizontal)	14 files/day
	METOP-A MHS L1C Inter-Calibrated Brightness Temperature	Approx. 3.9 MB	One orbit	Approx. 30–50km (horizontal)	14files/ day
	METOP-B MHS L1C Inter-Calibrated Brightness Temperature	Approx. 3.9 MB	One orbit	Approx. 30–50km (horizontal)	14 files/ day
	NOAA-18 MHS L1C Inter-Calibrated Brightness Temperature	Approx. 3.9 MB	One orbit	Approx. 30–50km (horizontal)	14 files/ day
	NOAA-19 MHS L1C Inter-Calibrated Brightness Temperature	Approx. 3.9 MB	One orbit	Approx. 30–50km (horizontal)	14 files/ day
	NPP ATMS L1C Inter-Calibrated Brightness Temperature	Approx. 11.9 MB	One orbit	Approx. 1.1–5.2° (horizontal)	14 files/ day
	Megha Tropiques SAPHIR L1C Inter-Calibrated Brightness Temperature	Approx. 9.7 MB	One orbit	Approx. 10 km (horizontal)	14 files/ day

Group	Product	File size (*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
	GCOM-W AMSR2 L1C Inter-Calibrated Brightness Temperature	Approx. 83.3 MB	One orbit	Approx. 5–50km (horizontal)	15 files/ day
	TRMM TMI L1C Inter-Calibrated Brightness Temperature	Approx. 13.7 MB	One orbit	Approx. 2.5 km (horizontal)	16 files/ day
ENV product	KuPR Environment Auxiliary	Approx. 644 MB	One orbit	Approx. 5 km (*3) (horizontal)	Approx. 16 files/ day
	KaPR Environment Auxiliary	Approx. 484 MB	One orbit	Approx. 5 km (*3) (horizontal)	Approx. 16 files/day
	DPR Environment Auxiliary	Approx. 805 MB	One orbit	Approx. 5 km (*3) (horizontal)	Approx. 16 files/day

(*1) The product of this HDF form indicates actual file size (internal compression).

(*2) 3.1.1 shows the definitions of scene unit for products created in GPM mission operation system.

Data that will no longer be provided as of October 2020 are grayed out.

(*3) These values are before the rise of the satellite altitude. See the table 2.2-1 and 2.2-3 since the rise of the altitude in November 2023.

Table 3.1-4 List of Near-real-time Products

Group	Product	File size	Scene unit (*1)	Sampling resolution/ Grid size	Provision frequency	Provision latency from the observation (*2)
DPR product	KuPR L1B Received Power_nrt	Approx. 39.6 MB	30 minutes	Approx. 5 km (*3) (horizontal) 125 m (vertical)	48 files/ day	Approx. 60 minutes
	KaPR L1B Received Power_nrt	Approx. 35.0 MB	30 minutes	Approx. 5 km (*3) (horizontal) 125/250 m (vertical)	48 files/ day	Approx. 60 minutes
	KuPR L2 Precipitation_nrt	Approx. 67.7 MB	30 minutes	Approx. 5 km (*3) (horizontal) 125 m (vertical)	48 files/ day	Approx. 65 minutes
	KaPR L2 Precipitation_nrt	Approx. 60.7 MB	30 minutes	Approx. 5 km (*3) (horizontal) 125/250 m (vertical)	48 files/ day	Approx. 65 minutes
	DPR L2 Precipitation_nrt	Approx. 128.3 MB	30 minutes	Approx. 5 km (*3) (horizontal) 125 m (vertical)	48 files/ day	Approx. 70 minutes
GMI product	GMI L1B Brightness Temperature_nrt	Approx. 3.6 MB	5 minutes	Approx. 6–26 km (*3) (horizontal)	288 files/ day	Approx. 20 minutes
	GMI L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 1.6 MB	5 minutes	Approx. 6–26km (*3) (horizontal)	288 files/ day	Approx. 20 minutes
	GMI L2 Precipitation_nrt	Approx. 1.0 MB	5 minutes	Approx. 6–26km (*3) (horizontal)	288 files/ day	Approx. 25 minutes

Group	Product	File size	Scene unit (*1)	Sampling resolution/ Grid size	Provision frequency	Provision latency from the observation (*2)
DPR/GMI combined product	COMB L2 Precipitation_nrt	Approx. 38.4 MB	30 minutes	Approx. 5 km (*3) (horizontal)	48 files/ day	Approx. 85 minutes
GSMaP product	GSMaP Precipitation (Hourly HDF)_nrt	Approx. 2.5 MB	global	0.1° grid 90°N–90°S	24 files/ day	Approx. 255 minutes
	GSMaP Precipitation (Hourly TEXT)_nrt	Approx. 3.4 MB	global	0.1° grid 90°N–90°S	24 files/ day	Approx. 255 minutes
Constellation satellite L1C product	DMSP F16 SSMIS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 24.1 MB	One orbit	Approx. 13–69 km (horizontal)	14 files/ day	Approx. 130 minutes
	DMSP F17 SSMIS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 23.9 MB	One orbit	Approx. 13–69 km (horizontal)	14 files/ day	Approx. 150 minutes
	DMSP F18 SSMIS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 22.5 MB	One orbit	Approx. 13–69 km (horizontal)	14 files/ day	Approx. 130 minutes
	METOP-A MHS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 3.9 MB	One orbit	Approx. 30–50 km (horizontal)	14 files/ day	Approx. 155 minutes
	METOP-B MHS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 2.3 MB	One orbit	Approx. 30–50 km (horizontal)	14 files/ day	Approx. 105 minutes

Group	Product	File size	Scene unit (*1)	Sampling resolution/ Grid size	Provision frequency	Provision latency from the observation (*2)
	NOAA-18 MHS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 4.1 MB	One orbit	Approx. 30–50 km (horizontal)	14 files/ day	Approx. 300 minutes
	NOAA-19 MHS L1C Inter-Calibrated Brightness Temperature_nrt	Approx. 4.2 MB	One orbit	Approx. 30–50 km (horizontal)	14 files/ day	Approx. 160 minutes

(*1) 3.1.1 shows the definitions of scene unit for products created in GPM mission operation system.

(*2) The values are based on the actual operation from June 5th to 9th, 2014.

Data that will no longer be provided as of October 2020 are grayed out.

(*3) These values are before the rise of the satellite altitude. See the table 2.2-1 and 2.2-3 since the rise of the altitude in November 2023.

Table 3.1-5 List of Standard Products

Group	Product	File size(*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
PR product	PR L1B Received Power	Approx. 122.4 MB	One orbit	Approx. 4.3–5 km (horizontal) 250 m (vertical)	Approx. 16 files/ day
	PR L2 Precipitation	Approx. 209.6 MB	One orbit	Approx. 4.3–5 km (horizontal) 250 m (vertical)	Approx. 16 files/ day
	PR L2 Spectral Latent Heating	Approx. 5 MB	One orbit	Approx. 4.3–5 km (horizontal) 250 m (vertical)	Approx. 16 files/ day
	PR L3 Precipitation (Daily TEXT)	Approx. 1.5 MB	Global	0.1° grid 67°N–67°S	one file/ day
	PR L3 Precipitation (Daily HDF)	Approx. 3.2 MB	Global	0.25° grid 67°N–67°S	one file/ day
	PR L3 Precipitation (Monthly HDF)	Approx. 968.8 MB	Global	0.25° grid 67°N–67°S 5° grid 70°N–70°S	one file / month
	PR L3 Gridded Orbital Spectral Latent Heating	Approx. 770 MB	One orbit	0.5° grid 67°N–67°S	Approx. 16 files/ day
	PR L3 Monthly Spectral Latent Heating	Approx. 100 MB	Global	0.5° grid 67°N–67°S	one file / month

Group	Product	File size(*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
TMI product	TMI L1B Brightness Temperature	Approx. 58.3 MB	One orbit	Approx. 6–50 km (horizontal)	Approx. 16 files/ day
	TMI L1C Inter-Calibrated Brightness Temperature	Approx. 27.7 MB	One orbit	Approx. 6–50 km (horizontal)	Approx. 16 files/ day
	TMI L2 Precipitation	Approx. 16.8 MB	One orbit	Approx. 6–50 km (horizontal)	Approx. 16 files/ day
	TMI L3 Precipitation	Approx. 16.4 MB	Global	0.25° grid 90°N–90°S	one file/ month
PR/TMI combined product	COMB L2 Precipitation	Approx. 121.3 MB	One orbit	Approx. 5 km (horizontal)	Approx. 16 files/ day
	COMB L3 Precipitation	Approx. 596.2 MB	Global	0.25° grid 67°N–67°S 5° grid 70°N–70°S	one file/ month
	COMB L3 Gridded Orbital Spectral Latent Heating *3	Approx. 5 MB	One orbit	0.25° grid 67°N–67°S	Approx. 16 files/ day
	COMB L3 Monthly Spectral Latent Heating*3	Approx. 40 MB	Global	0.25° grid 67°N–67°S	one file/ month
VIRS product	VIRS L1B Radiance	Approx. 230 MB	One orbit	Approx. 2 km (horizontal)	Approx. 16 files/ day

Group	Product	File size(*1)	Scene unit (*2)	Sampling resolution/ Grid size	Provision frequency
ENV product	PR Environment Auxiliary	Approx. 644 MB	One orbit	Approx. 4.3–5 km (horizontal) 250 m (vertical)	Approx. 16 files/ day

(*1) The product of this HDF form indicates actual file size (internal compression).

(*2) 3.1.1 shows the definitions of scene unit for products created in GPM mission operation system.

(*3) Processed by PPS

3.1.5. File Naming Conventions

Granule IDs are employed as file names of products. Granule ID identifies the earth observation satellite data. Granule IDs of level 1 to 3 products consist of “scene ID” and “product ID”. “Scene ID” part includes mission ID, sensor ID, scene start/end time, and so on. “Product ID” part includes algorithm ID and so on. File naming conventions are described below.

(1) L1 and L2 Standard Products

All level 1 and level 2 standard products fall under this category. Table 3.1-6 shows the naming convention for L1 and L2 standard products.

Table 3.1-6 Naming Convention for L1 and L2 standard products

$$\underbrace{\text{GPMCOR}}_{(1)}\_\underbrace{\text{KUR}}_{(2)}\_\underbrace{\text{YYMMDDhhmm}}_{(3)}\_\underbrace{\text{hhmm}}_{(4)}\_\underbrace{\text{nnnnnn}}_{(5)}\_\underbrace{\text{1BS}}_{(6)}\_\underbrace{\text{xxx}}_{(7)}\_\underbrace{\text{vvv}}_{(8)}\text{.h5}$$

	Field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), xxx (COR: GPM core satellite, etc. See Table 3.1-15)
(2)	Sensor ID	3	sss (KUR: KuPR, KAR: KaPR, CMB: DPR/GMI combined, etc. See Table 3.1-15)
(3)	Scene Start	10	YYMMDDhhmm (UTC)
(4)	Scene End	4	hhmm (UTC)
(5)	Orbit Number	6	nnnnnn (000001–999999)
(6)	Process Level (Level+Type)	3	LL (1B: Level 1B, 1C: Level 1C, L2: Level 2) S (Standard, fixed)
(7)	Algorithm Key	3	Identify Algorithm name & Developer See Table 3.1-16
(8)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)

(2) L1 and L2 Near-real-time Products

All level 1 and level 2 near-real-time products fall under this category. Table 3.1-7 shows the naming convention for L1 and L2 near-real-time products.

Table 3.1-7 Naming Convention for L1 and L2 Near-real-time Products

$$\underbrace{\text{GPMCOR}}_{(1)}\_\underbrace{\text{KUR}}_{(2)}\_\underbrace{\text{YYMMDDhhmm}}_{(3)}\_\underbrace{\text{hhmm}}_{(4)}\_\underbrace{\text{1BR}}_{(5)}\_\underbrace{\text{xxx}}_{(6)}\_\underbrace{\text{vvv}}_{(7)}\text{.h5}$$

	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), xxx (COR: GPM core satellite, etc. See Table 3.1-15)
(2)	Sensor ID	3	sss (KUR: KuPR, KAR: KaPR, CMB: DPR/GMI combined, etc. See Table 3.1-15)
(3)	Scene Start (UTC)	10	YYMMDDhhmm (UTC)
(4)	Scene End (UTC)	4	hhmm (UTC)
(5)	Process Level	3	LL (1B: Level 1B, 1C: Level 1C, L2: Level 2) R (Near real time, fixed)
(6)	Algorithm Key	3	Identify Algorithm name & Developer See Table 3.1-16
(7)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)

(3) L3 (Hourly) Standard/Near-real-time Products

Global Satellite Mapping of Precipitation level 3 (NRT and STD) fall under this category. Table 3.1-8 shows the naming convention for L3 (Hourly) standard/near-real-time products.

Table 3.1-8 Naming Convention for L3 (Hourly) Standard/Near-real-time Products

GPMMRG_MAP_YYMMDDhhmm_H_L3R_xxx_vvv.h5

(1) (2) (3) (4) (5) (6) (7)

	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), MRG (GPM merge, fixed)
(2)	Sensor ID	3	MAP (Global Satellite Mapping of Precipitation, fixed)
(3)	Scene Start (UTC)	10	YYMMDDhhmm (UTC)
(4)	Process Unit	1	H (Hourly, fixed)
(5)	Process Level	3	L3 (Level 3, fixed) t (S: Standard, N: Near real time)
(6)	Algorithm Key	3	Identify Algorithm name & Developer See Table 3.1-16
(7)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)

(4) L3 (Daily) Standard Products

PR and DPR level 3 falls under this category. Table 3.1-9 shows the naming convention for L3 (Daily) standard products.

Table 3.1-9 Naming Convention for L3 (Daily) Standard Products

$\underbrace{\text{GPMCOR}}_{(1)}\text{\_}\underbrace{\text{DPR}}_{(2)}\text{\_}\underbrace{\text{YYMMDD}}_{(3)}\text{\_}\underbrace{\text{D}}_{(4)}\text{\_}\underbrace{\text{L3S}}_{(5)}\text{\_}\underbrace{\text{xxx}}_{(6)}\text{\_}\underbrace{\text{vvv}}_{(7)}\text{.h5}$

	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), COR (GPM core satellite, fixed)
(2)	Sensor ID	3	DPR (DPR: DPR, KUR: PR)
(3)	Scene Start (UTC)	6	YYMMDD (UTC)
(4)	Process Unit	1	D (Daily)
(5)	Process Level	3	L3 (L3: Level 3, fixed) S (Standard, fixed)
(6)	Algorithm Key	3	Identify Algorithm name & Developer See Table 3.1-16
(7)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)

(5) L3 (Monthly) Standard Products

DPR level 3, DPR/GMI combined level 3, Global Satellite Mapping of Precipitation level 3, GMI level 3, PR level 3, PR/TMI combined level 3 and TMI level 3 fall under this category. Table 3.1-10 shows the naming convention for L3 (Monthly) standard products.

Table 3.1-10 Naming Convention for L3 (Monthly) Standard Products

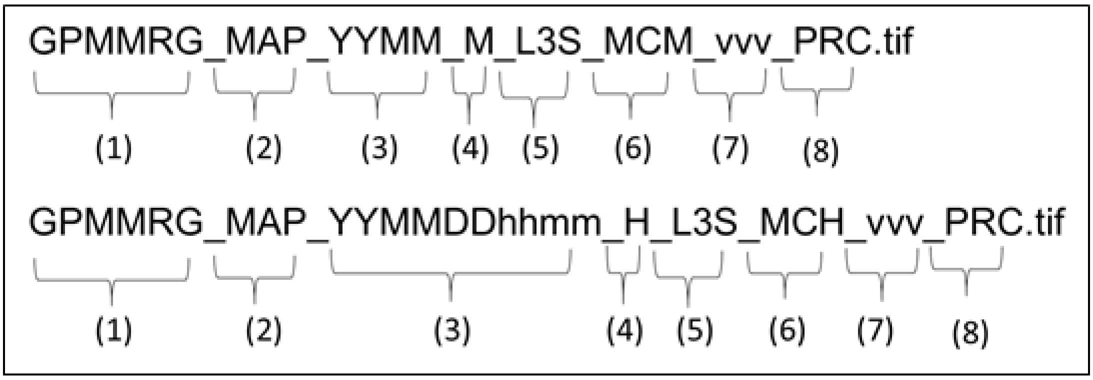
$$\underbrace{\text{GPMCOR}}_{(1)}\_\underbrace{\text{DPR}}_{(2)}\_\underbrace{\text{YYMM}}_{(3)}\_\underbrace{\text{M}}_{(4)}\_\underbrace{\text{L3S}}_{(5)}\_\underbrace{\text{xxx}}_{(6)}\_\underbrace{\text{vvv}}_{(7)}\text{.h5}$$

	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), xxx (COR: GPM core satellite, etc. See Table 3.1-15)
(2)	Sensor ID	3	sss (KUR: KuPR, KAR: KaPR, CMB: DPR/GMI combined, etc. See Table 3.1-15)
(3)	Scene Start (UTC)	4	YYMM (UTC)
(4)	Process Unit	1	M (Monthly)
(5)	Process Level	3	L3 (Level 3, fixed) S (Standard, fixed)
(6)	Algorithm Key	3	Identify Algorithm name & Developer See Table 3.1-16
(7)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)

(6) GSMaP L3 Standard products (GeoTIFF)

GSMaP level 3 (GeoTIFF) falls under this category. Table 3.1-11 shows the naming convention for GSMaP L3 (Hourly, GeoTIFF) standard products and GSMaP L3 (Monthly, GeoTIFF) standard products.

Table 3.1-11 Naming Convention for L3 GSMaP (GeoTIFF) Standard Products



	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), MRG (GPM merge, fixed)
(2)	Sensor ID	3	MAP (Global Precipitation Map, fixed)
(3)	Scene Start (UTC)	4,10	YYMM (UTC) YYMMDDhhmm (UTC)
(4)	Process Unit	1	M (Monthly), H (Hourly)
(5)	Process Level	3	L3 (Level 3, fixed) S (Standard, fixed)
(6)	Algorithm Key	3	MCH (Hourly)/MCM (Monthly)
(7)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)
(8)	Variable	3	PRC (Precipitation Rate, fixed)

(7) DPR L3 Standard Products (GeoTIFF)

DPR level 3 (Daily, GeoTIFF) and DPR level 3 (Monthly, GeoTIFF) falls under this category. Table 3.1-12 shows the naming convention for DPR L3 (Daily, GeoTIFF) standard products.

Table 3.1-12 Naming Convention for L3 DPR (GeoTIFF) Standard Products

$\underbrace{\text{GPMCOR}}_{(1)}\text{\_}\underbrace{\text{DPR}}_{(2)}\text{\_}\underbrace{\text{YYMMDD}}_{(3)}\text{\_}\underbrace{\text{D}}_{(4)}\text{\_}\underbrace{\text{L3S}}_{(5)}\text{\_}\underbrace{\text{xxx}}_{(6)}\text{\_}\underbrace{\text{vvv}}_{(7)}\text{\_}\underbrace{\text{PRC}}_{(8)}\text{\_}\underbrace{\text{O}}_{(9)}\text{.tif}$

$\underbrace{\text{GPMCOR}}_{(1)}\text{\_}\underbrace{\text{DPR}}_{(2)}\text{\_}\underbrace{\text{YYMM}}_{(3)}\text{\_}\underbrace{\text{M}}_{(4)}\text{\_}\underbrace{\text{L3S}}_{(5)}\text{\_}\underbrace{\text{xxx}}_{(6)}\text{\_}\underbrace{\text{vvv}}_{(7)}\text{\_}\underbrace{\text{PRC}}_{(8)}\text{\_}\underbrace{\text{SSS}}_{(10)}\text{\_}\underbrace{\text{RTY}}_{(11)}\text{.tif}$

	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), COR (GPM core satellite, fixed)
(2)	Sensor ID	3	DPR (fixed)
(3)	Scene Start (UTC)	4, 6	YYMMDD (Daily, UTC), YYMM (Monthly, UTC)
(4)	Process Unit	1	D (Daily)/M (Monthly)
(5)	Process Level	3	L3 (Level 3, fixed) S (Standard, fixed)
(6)	Algorithm Key	3	D3Q (Daily)/D3M (Monthly)
(7)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)
(8)	Variable	3	PRC (Hourly Precipitation Rate, fixed)
(9)	Orbit Type	1	O (A: Ascending, D: Descending)
(10)	Sensor Type	3	SSS（KUF: KuFS, KAF: KaFS, DPF: DPRFS）
(11)	Rain Type	3	RTY（STR：Stratiform, CON: Convective, ALL: All）

(8) GPM Latent Heating L3 Standard products(Orbital)

3GSLH, 3GCSH, 3GSLHT, 3GCSHT falls under this category. Table 3.1-13 shows the naming convention for LH L3 Standard product.

Table 3.1-13 Naming Convention for LH Standard Products

GPMCOR_DPR_YYMMDDhhmm_hhmm_nnnnnn_L3S_SLG_vvv.h5

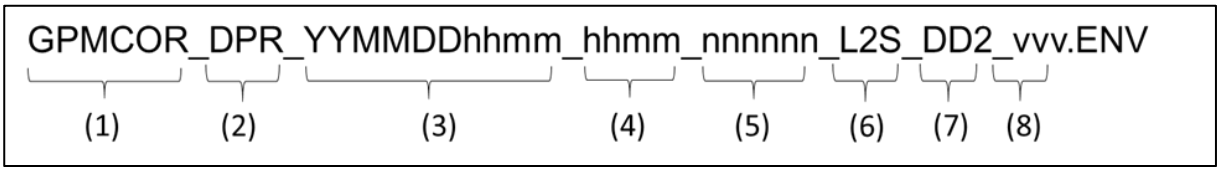
(1) (2) (3) (4) (5) (6) (7) (8)

	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), COR (GPM core satellite) / TRM (TRMM satellite)
(2)	Sensor ID	3	DPR (for SLH, fixed) CMB (for CSH or CSHT) KUR (for SLHT, fixed)
(3)	Scene Start (UTC)	8	YYMMhhmm (UTC)
(4)	Scene End (UTC)	4	hhmm (UTC)
(5)	Orbit Number	6	nnnnnn: 000000–999999
(6)	Process Level	3	L3 (Level 3, fixed) S (Standard, fixed)
(7)	Algorithm Key	3	SLG (SLH L3 gridded orbit), LHG (SLHT L3 gridded orbit), CSG (CSH L3 gridded orbit), CSH (CSHT L3 gridded orbit)
(8)	Product Version	3	VV (01–99, Major ; count up at re-processing) v (A–Z, Minor)

(9) GPM Environment Auxiliary (ENV) Products

KuPR, KaPR, DPR Environment Auxiliary (ENV) products falls under this category. Table 3.1-14 shows the naming convention for ENV L2 standard products.

Table 3.1-14 Naming Convention for GPM Environment Auxiliary (ENV) Products



	JAXA field name	Field Width	Description
(1)	Mission ID (Mission name + Satellite ID)	6	GPM (GPM mission, fixed), COR (GPM core satellite)/TRM (TRMM satellite)
(2)	Sensor ID	3	sss (KUR: KuPR, KAR:KaPR, DPR:DPR)
(3)	Scene Start (UTC)	10	YYMMDDhhmm (UTC)
(4)	Scene End (UTC)	4	hhmm (UTC)
(5)	Orbit Number	6	nnnnnn (000001–999999)
(6)	Process Level	3	LL (L2: Level 2) S (Standard)
(7)	Algorithm Key	3	DU2 (KuPR L2), DA2 (KaPR L2), DD2 (DPR L2), PU2 (PR L2)
(8)	Product Version	3	VV (01–99, Major; count up at re-processing) v (A–Z, Minor)

As complementary information on the naming conventions, see Table 3.1-15 for satellite IDs and sensor IDs, and Table 3.1-16 for algorithm keys.

Table 3.1-15 Satellite IDs and Sensor IDs

Satellite	Sensor	Satellite ID (3 char)	Sensor ID (3 char)
GPM Core	KuPR	COR	KUR
	KaPR	COR	KAR
	DPR	COR	DPR
	GMI	COR	GMI
	Combined Products	COR	CMB
	Map Products	MRG	MAP
Megha Tropiques	MADRAS	MGT	MDR
	SAPHIR	MGT	SPH
GCOM-W	AMSR2	GW1	AM2
DMSP F16	SSMIS	F16	MIS
DMSP F17	SSMIS	F17	MIS
DMSP F18	SSMIS	F18	MIS
DMSP F19	SSMIS	F19	MIS
NOAA-18	MHS	N18	MHS
NOAA-19	MHS	N19	MHS
NPP	ATMS	NPP	ATS
NOAA-20	ATMS	N20	ATS
NOAA-21	ATMS	N21	ATS
METOP-A	MHS	MTA	MHS
METOP-B	MHS	MTB	MHS
METOP-C	MHS	MTC	MHS
TRMM	PR	TRM	KUR
	TMI	TRM	TMI
	VIRS	TRM	VIR
	Combined Products	TRM	CMB

Table 3.1-16 Algorithm Keys

Processing Algorithm	Algorithm Key (3 char)
KuPR Level 1B	DUB
KaPR Level 1B	DAB
KuPR Level 2	DU2
KaPR Level 2	DA2
DPR Level 2	DD2
DPR Level 3 (Daily, Text)	D3D
DPR Level 3 (Daily, HDF5)	D3Q

Processing Algorithm	**Algorithm Key (3 char)**
DPR Level 3 (Daily, Ascending, GeoTIFF)	D3Q
DPR Level 3 (Daily, Descending, GeoTIFF)	D3Q
DPR Level 3 (Monthly, HDF)	D3M
DPR Level 3 (Monthly, GeoTIFF)	D3M
GMI Level 1B (PPS processing)	G1B
GMI Level 1C (PPS processing)	G1C
GMI Level 2 (PPS processing)	GL2
GMI Level 3 (PPS processing)	GL3
DPR/GMI Combined Level 2 (PPS processing)	CL2
DPR/GMI Combined Level 3 (PPS processing)	CL3
MWI/MWS Level 1C (PPS processing)	Sensor ID Refer to Table 3.1-16
GSMaP (Hourly, Standard, HDF5)	MCH
GSMaP (Hourly, Standard, Text)	MCT
GSMaP (Hourly, Standard, GeoTIFF)	MCH
GSMaP (Hourly, Standard, NetCDF)	MCN
GSMaP (Hourly, Near-Real-Time, HDF5)	MFW
GSMaP (Hourly, Near-Real-Time, Text)	MFT
GSMaP (Monthly HDF)	MCM
GSMaP (Monthly GeoTIFF)	MCM
GSMaP (Monthly NetCDF)	MCN
SLH-DPR Level 2 (Pixel Swath)	SLP
SLH-DPR Level 3 (Gridded Orbit)	SLG
SLH-DPR Level 3 (Monthly)	SLM
DPR/GMI Combined LH Level 3 (Gridded Orbit)	CSG
DPR/GMI Combined LH Level 3 (Monthly)	CSM
KuPR Environment Auxiliary data	DU2
KaPR Environment Auxiliary data	DA2
DPR Environment Auxiliary data	DD2
PR Level 1B	PU1
PR Level 2	PU2
SLH-PR Level 2 (Pixel Swath)	LHP
PR Level 3 (Daily, Text)	P3Q
PR Level 3 (Daily, HDF5)	P3D
PR Level 3 (Monthly, HDF)	P3M
SLH-PR Level 3 (Gridded Orbit)	LHG
SLH-PR Level 3 (Monthly)	LHM
TMI Level 1B (PPS processing)	TMI
TMI Level 2 (PPS processing)	TL2
TMI Level 3 (PPS processing)	TL3
PR/TMI Combined Level 2 (PPS processing)	TC2

Processing Algorithm	Algorithm Key (3 char)
PR/TMI Combined Level 3 (PPS processing)	TC3
VIRS Level 1B (PPS processing)	V1B
PR Environment Auxiliary data	PU2

Note: SLH: Spectral Latent Heating, LH: Latent Heating

The following products are originally named by NASA/PPS, then renamed to meet the granule ID conventions and provided via G-Portal. The naming conventions described in this subsection are the ones after renamed.

- GPM core satellite, sensor ID: GMI/CMB, all level
- GPM constellation satellites, level 1C

Therefore, please note that products above are provided with different names between JAXA and NASA/PPS.

3.1.6. Products Format

(1) GPM products Format

GPM Product are provided on HDF (Hierarchical Data Format) file format. This file format is internally compressed format and useful to address multi-dimensional arrays. GPM products adopt HDF5 ver1.8.9. TKIO can manage data in HDF5 files, specified by user programs.

(2) What is HDF?

HDF is a set of file formats developed by the NCSA (The National Center for Supercomputing Application / University of Illinois) and platform independent formats. There are 2 types of HDF, HDF4 and HDF5. HDF5 modified some problems of HDF4 (limitation of data size, multiple data types and others). HDF file consists of 2 parts, the one part is “Attribute” which contains attribute information and the other is “Dataset” which contains product data itself. Attribute of GPM products contains metadata, and Dataset contains product data such as observation data, latitude/longitude data and others.

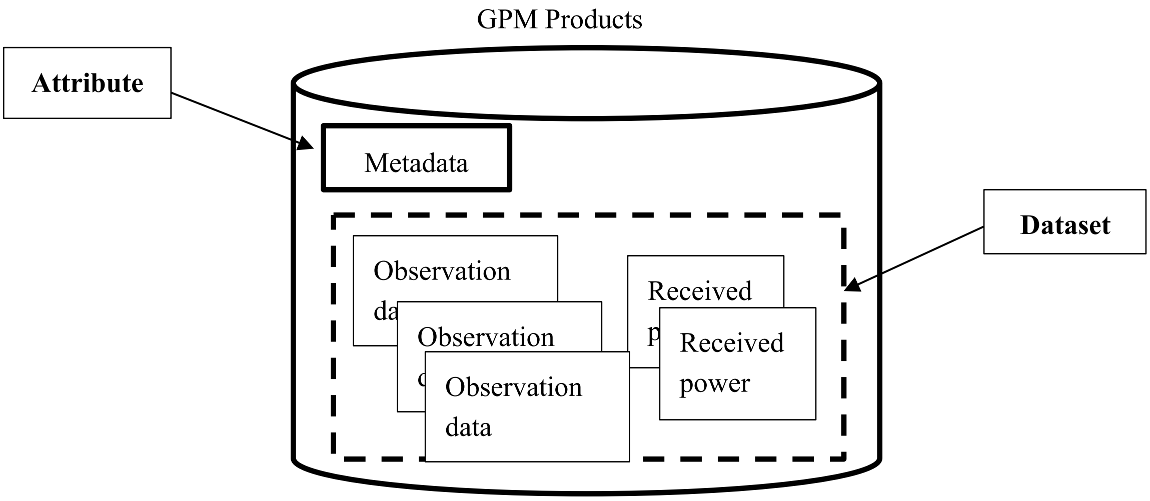


Figure 3.1-6 Structure of HDF file

(3) How to get HDF5 library

HDF5 library files are available at the HDF group website. The latest version of HDF5 library is available on the website shown below;

https://portal.hdfgroup.org/downloads/index.html

The Table 3.1-17 shows the library files as of June 2014. You can download the HDF5 library suitable for your platform. Although GPM Products' version of HDF5 is different from current library, the library version is compatible with GPM Products'.

Table 3.1-17 HDF5 library

Platform	Filename	Notes
All Platform	src/hdf5-1.8.13.tar.gz	Source Code
Linux 2.6 i686	hdf5-1.8.13-linux-shared.tar.gz	Binary (shared)
Linux 2.6 x86_64	hdf5-1.8.13-linux-x86_64-shared.tar.gz	Binary (shared)

HDF library uses the sz library. You need to download sz library if you don't install.

Table 3.1-18 sz library

URL	Notes
https://support.hdfgroup.org/ftp/lib-external/szip/	

(4) Data Structure Outline of GPM Products using HDF5

Figure 3.1-7 shows the data structure outline of level 1B Ku product (V05C) as an example. The level 1B Ku product consists of two components. The first component is product metadata (Product Metadata) and the second is science data (Data Group). Product metadata has six variables; FileHeader, InputRecord, NavigationRecord, FileInfo, JAXAInfo and DPRKuInfo. On the other hand, science data has one metadata and several data groups. Each variable is specific array type and byte size.

Data structure of GPM products is described in each product format documentation.

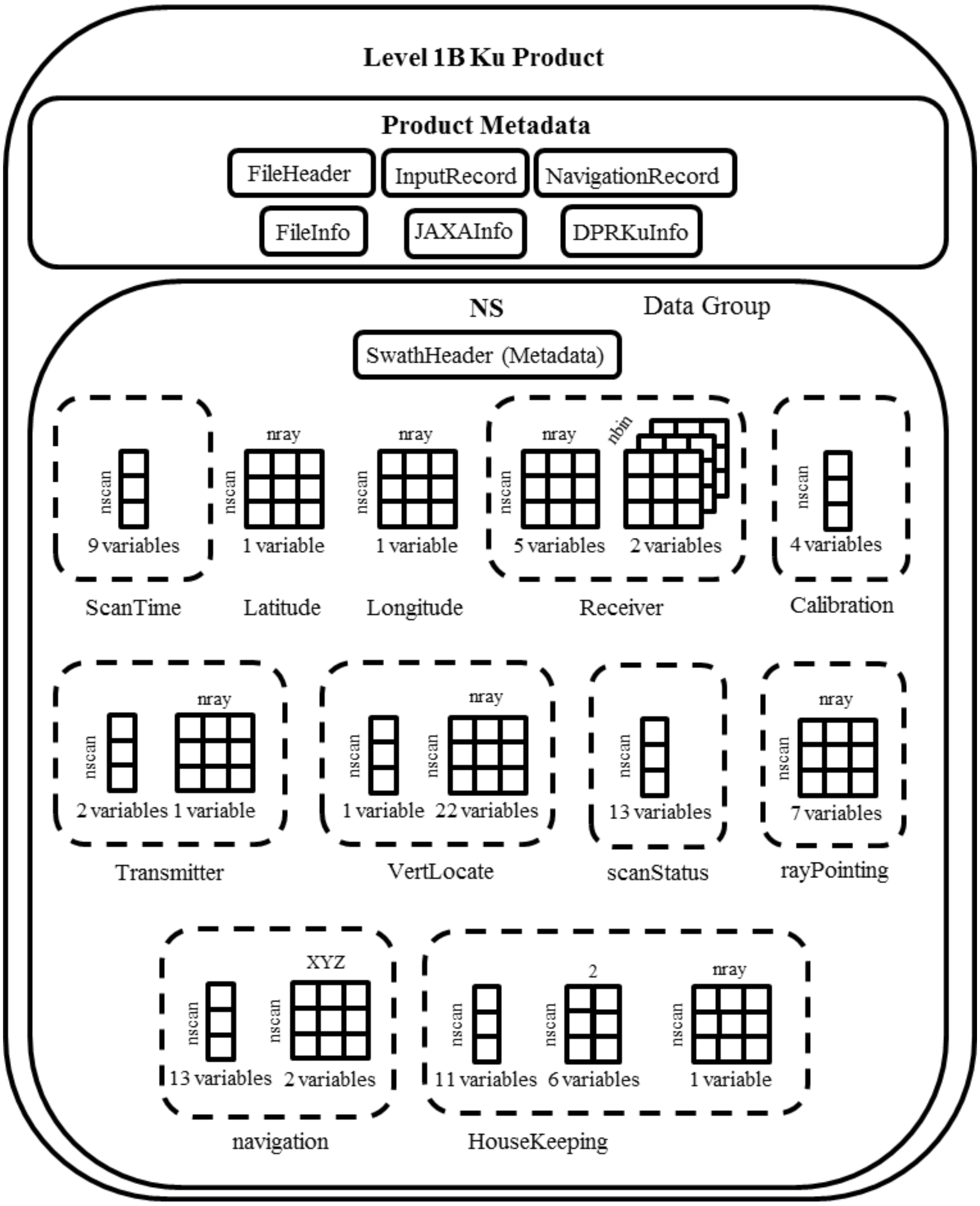


Figure 3.1-7 The Data Structure Outline of Level 1B Ku Product

3.1.7. Conceptual Explanation of Product/Algorithm Versions

Product/Algorithm versions are controlled by JAXA responsible for data distribution, and version up depending on the results from calibration and validation process during operational phase after the launch. Product versions is shown in 2.4 File Naming Conventions as the products definition including product version by 3 numbers of characters; Major (2 digits, such as 01, 02, 03…) + Minor (1 letter, such as a, b, c…), where major shows increment at re-processing after the launch from 01.

3.2. Processing Description

3.2.1. DPR Product

(1) Level 1

In DPR level 1B standard processing, a level 1A product is read as input data and a product containing a received power profile and geometric information, such as observation positions, is outputted. During the course of processing, radiometric correction is carried out, missing data is processed based on missing data information, scan time is corrected and geometric calculation of the time, latitude, longitude, and height of each piece of scan data in each range bin is performed.

The processing described above is carried out for KuPR and KaPR radar input values. Figure 3.2-1 shows the processing flow.

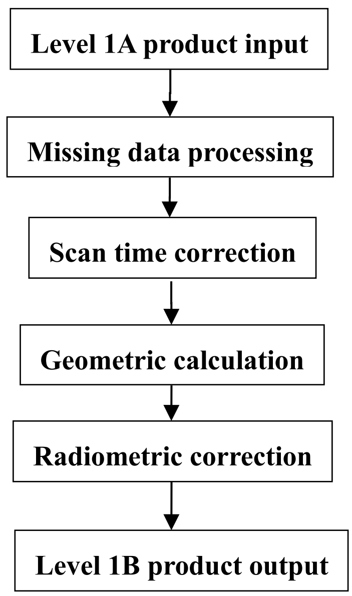


Figure 3.2-1 Level 1B Standard Processing Flow

(2) Level 2

The level 2 processing algorithm of the dual frequency precipitation radar additionally uses received power value profiles observed by KuPR and KaPR to estimate a precipitation intensity profile. It also estimates precipitation type, precipitation top height, and bright band height.

"Figure 3.2-2 DPR L2 Processing Flow" shows the flow of the algorithm.

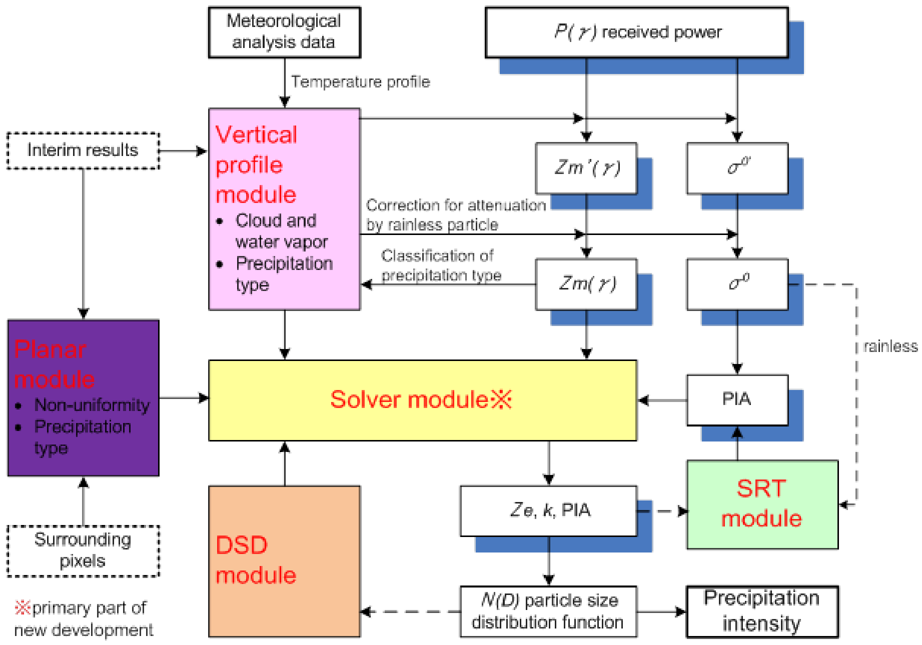


Figure 3.2-2 DPR L2 Processing Flow

Level 2 algorithm input data is a level 1 DPR product (P (γ) calibrated radar echo power value profile), and level 2 algorithm output data is a level 2 product (precipitation intensity profile).

KuPR, KaPR, and dual frequency precipitation radar (DPR) products are created by the standard algorithm. For a KuPR product, the level 2 algorithm uses only observation data obtained by KuPR to estimate precipitation. For a KaPR product, the level 2 algorithm uses only observation data obtained by KaPR to estimate precipitation. For a dual frequency precipitation product, the algorithm uses KuPR and KaPR observation data to estimate precipitation. In areas with the KuPR observation, the level 2 algorithm uses the observation data by KuPR and also information obtained from observation by KuPR and KaPR.

(3) Level 3

Level 3 standard processing algorithm flow is shown in Figure 3.2-3. A/D means Ascending/Descending. Monthly products are created by 28−30 daily products on data stack. HDF products, daily/monthly, are processed by the algorithm developed by NASA and text product, daily, is processed by the algorithm developed by JAXA.

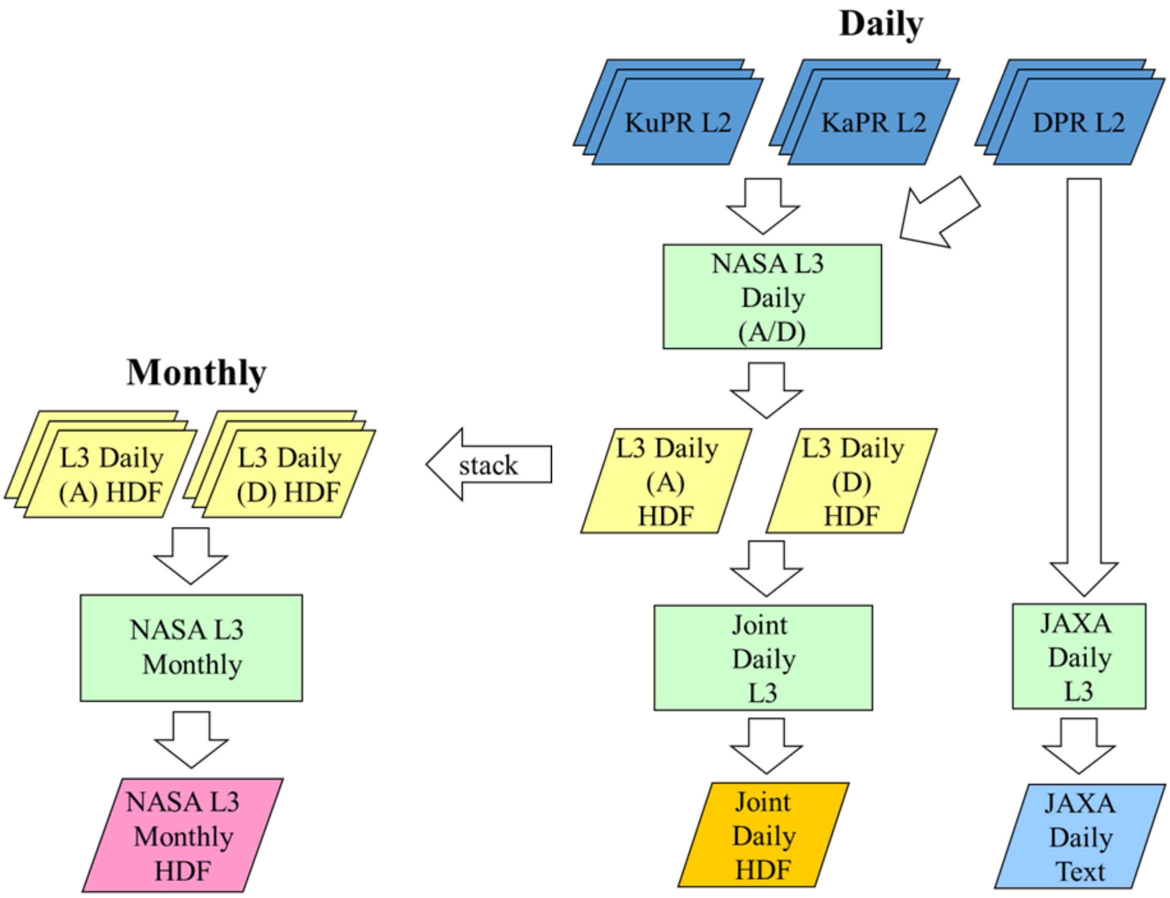


Figure 3.2-3 Flow of the L3 Processing Algorithm

(4) Environment Auxiliary (ENV)

Environment Auxiliary (ENV) is Meteorological analysis data used as an input data to the level 2 processing shown. They are the Japanese Global Analysis model data (GANAL) used to provide atmospheric environmental conditions.

In the current algorithm formulation, only the analysis data such as analysis data, must be integrated from an external source during combined algorithm processing.

Analysis data are required to produce initial estimations of environmental parameters such as total precipitable water, TPWanal, cloud liquid water path, CLWPanal, surface skin temperature, Tsfcanal, and 10m altitude wind speed, U10manal. The current algorithm design requires space-time interpolation of these data from the Japanese Meteorological agency's (JMA) global analysis (GANAL) during standard algorithm processing. The data are interpolated to the DPR footprint/range bin locations and overpass times in the Vertical Profile Submodule (VER) of the Level 2 Radar Algorithm and then output. For near realtime processing, the JMA forecast fields, but if these fields are not received in time for any reason, the climate value data are substituted for the JMA analysis/forecast data in the VER processing.

Table 3.2-1 Environment Auxiliary (ENV)

Auxiliary	Description
GPM KuPR Environment Auxiliary (ENV)	Main parameters: Air temperature, Air pressure, Water vapor, Cloud liquid water Swath width: ≥ Approx. 245 km* Resolution: ≥ Approx. 5 km* (horizontal), 125 m (vertical)
GPM KaPR Environment Auxiliary (ENV)	Main parameters: Air temperature, Air pressure, Water vapor, Cloud liquid water Swath width: ≥ Approx. 245 km* Resolution: ≥ Approx. 5 km* (horizontal), 125/250 m (vertical)
GPM DPR Environment Auxiliary (ENV)	Main parameters: Air temperature, Air pressure, Water vapor, Cloud liquid water Swath width: ≥ Approx. 245 km* Resolution: ≥ Approx. 5 km* (horizontal), 125/250 m (vertical)

* These values are before the rise of the satellite altitude. See the table 2.2-1 and 2.2-3 since the rise of the altitude in November 2023.

(5) Spectral Latent Heating Product

At level 2 processing, spectrum latent heating (2HSLH), and vertical distribution of Q1-QR and Q2 is obtained from DPR rain rate product. Granule size is one orbit.

In Gridded Orbital Spectral Latent Heating (3GSLH) products, latent heating of 0.5 degree grid and vertical distribution of Q1-QR and Q2 are obtained from DPR rainfall.

The Monthly Spectral Latent Heating (3HSLH) products are processed by same procedure 3GSLH. In the composite *product*, Gridded Orbital Convective Stratiform Heating from the Combined (3GCSH) product, 0.25 degrees grid and the just below the orbit apparent heating profile are obtained from convective and stratiform rainfall of the ground surface. And Monthly Convective Stratiform Heating from Combined (3HCSH) obtained apparent heating profile from convective and stratiform rainfall of the land surface of 0.25 degrees grid.

3.2.2. Global Satellite Mapping of Precipitation

The global satellite mapping of precipitation (GSMaP) algorithm is a map creation algorithm whose accuracy has been improved by DPR data and information. It generates a map of global satellite mapping of precipitation, which is a spatial-temporally averaged level 3 product, by combining: estimated precipitation based on readings of multiple microwave radiometers (imager/sounder) including a GPM microwave radiometer (GMI); and cloud travel information obtained from geostationary infrared (IR) data. “Figure 3.2-4 GSMaP Processing Flow” gives an overview of the processing flow.

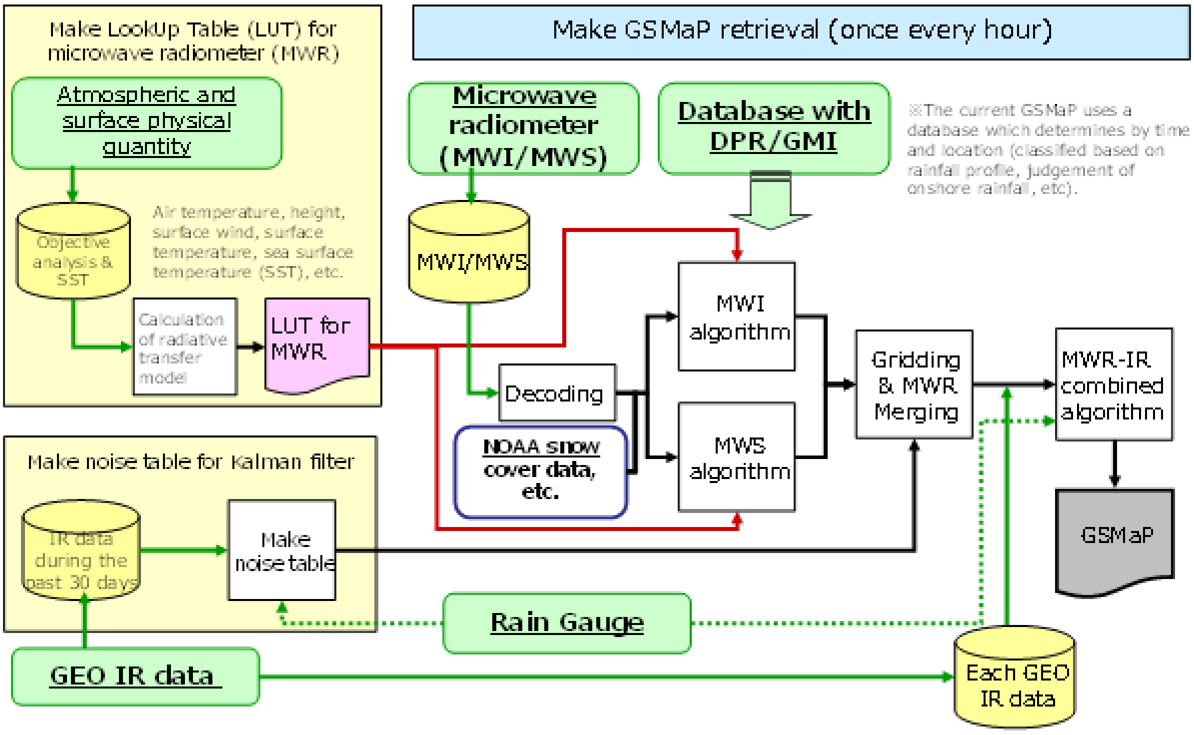


Figure 3.2-4 GSMaP Processing Flow

The GSMaP algorithm can be roughly divided into the following three algorithms: microwave imager (MWI) algorithm, microwave sounder (MWS) algorithm, and microwave-Infrared (IR) combined (MVK) algorithm.

A global satellite mapping of precipitation can be subject to standard processing or near real-time processing. In standard processing, hourly observation data is processed and data is averaged monthly. Near real-time processing provides a higher data frequency than standard processing (every hour).

3.2.3. PR Product

(1) Level 1

In PR Level 1B standard processing, a Level 1A product is read as input data and a product containing a received power profile and geometric information, such as observation positions, is outputted. During the course of processing, radiometric correction is carried out, missing data are processed based on missing data information, and geometric calculation of each footprint is performed. Figure 3.2-5 shows the processing flow.

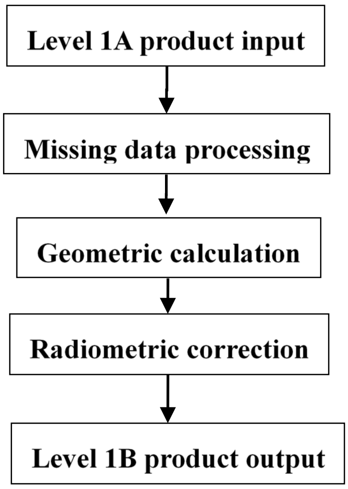


Figure 3.2-5 Level 1B Processing Flow

(2) Level 2

Level 2 processing of the TRMM/PR is same as that of the GPM/DPR, described in Section 3.2.1(2) except for no-input of the KaPR product. TRMM/PR is a Ku-band radar and corresponds to the GPM/KuPR. We provide long-term homogeneous products, by applying common processing algorithms in TRMM and GPM, as well as product format.

(3) Level 3

Level 3 processing of the TRMM/PR is same as that of the GPM/DPR, described in Section 3.2.1(3), except for no-inputs of the KaPR and the DPR dual-frequency products. TRMM/PR is a Ku-band radar and corresponds to the GPM/KuPR. We provide long-term homogeneous products, by applying common processing algorithms in TRMM and GPM, as well as product format.

(4) Environment Auxiliary (ENV)

Environment auxiliary (ENV) is meteorological analysis data used as input data to the Level 2 processing, and same as that of the GPM/DPR, described in Section 3.2.1(4), except for no-outputs of the KaPR and the DPR dual-frequency ENV products.

(5) Spectral Latent Heating Product

TRMM Spectral Latent Heating Product is same as that of the GPM/DPR, described in Section

3.2.1(5) We provide long-term homogeneous products, by applying common processing algorithms in TRMM and GPM, as well as product format.

3.3. Calibration and Validation

The Global Precipitation Measurement Project (GPM) is an mission to measure global precipitation using one GPM core satellite with the Dual-frequency Precipitation Radar (DPR) and the GPM Microwave Imager (GMI) onboard and constellation of several other satellites with a microwave radiometer (imager/sounder) onboard. The DPR consists of a Ka-band precipitation radar (KaPR) and a Ku-band precipitation radar (KuPR), and simultaneous measurements of KaPR and KuPR makes possible to obtain accurate precipitation date including weak rainfall and snowfall. The Global Satellite Mapping of Precipitation (GSMaP) is generated hourly from the combination of GMI and constellation satellites. The purpose of GPM is to assess and predict the global water cycle variation, to contribute industrial utilization, and to generate and disseminate these accurate, high frequent and constant products. To achieve this, accurate, uniform and stabilized for long term is required.

By the GPM calibration and verification, we keep data quality through the series of the works, like the sensor test and construction of sensor model before launch, data evaluation in orbit, calibration, precision evaluation of physical value especially rain rate, and to exposure the result of the evaluation result after launch.

3.3.1. Calibration

The calibration of DPR decides the coefficient of the sensor model using in Level 1 algorithm by the ground examination result and the data evaluation in orbit in cooperation with the sensor development team. In the work, the experience in the TRMM/PR calibration is used and executed as far as possible. The external calibration method is examined by considering dual frequency in addition to improving to acquire insufficient information in the case of TRMM/PR calibration work through the reexamination of a ground test and an analytical item before launch. The result obtained from PR is reflected to the sensor model of the received power calculation. The calibration process, method and tools are prepared and performed efficiently based on the result of PR. It is necessary to prepare several more efficient radar calibrators for DPR calibration.

(1) Outline of Calibration Plan

The outline of calibration is described in the “GPM/DPR Calibration Plan”. The calibration of DPR consists of 3 operation phases, development phase before launch, initial checkout phase just after launch, and nominal operation phase.

(2) Calibration Items

① Initial Checkout Phase

The coefficient of the sensor model using in Level 1 algorithm is updated based on internal calibration result in orbit and external calibration result in orbit using radar calibrator set in the ground. The contents of the calibration are listed in Table 3.3-1. As the DPR has KuPR, KaPR dual frequency beam, the adjustable parameter to match the observation volume for the radar operation is optimized and reflected to Level 1 algorithm.

Table 3.3-1 External Calibration and Internal Calibration

Mode	Contents	Measurement items
External calibration	External calibration is performed when GPM passes over radar calibrator set in the ground, and DPR is operated in an external calibration mode which is different from a usual observation mode, and absolute calibration of transmitting power, the antenna pattern, and the received power etc. of DPR are executed.	transmitting power and received power antenna pattern for alongtrack direction and crosstrack direction beam matching between KuPR and KaPR
Internal calibration	The measurement of the I/O characteristic of DPR is executed by using the internal loopback signal in SCDP (System Control Data Processing) and FCIF (Frequency Converter / IF unit) of DPR.	the I/O characteristic of SCDP and FCIF

② Nominal Operation Phase

The calibration in nominal operation phase decreases its frequency from initial checkout phase. After this work, Level 1 algorithm is updated.

Table 3.3-2 Calibration in Nominal Operation Phase

Mode	Frequency	Place	Duration
External calibration	two seasons per year (5 times per season)	Pass over radar calibrator set point (around Tsukuba area)	about 5 minutes
Internal calibration	approximately once per week	When delta V maneuver performs, etc.	about 5–30 minutes

3.3.2. Validation

The validation of GPM products are conducted with the maximum use of the experiences on TRMM/PR. Ground-based observation data, practical data obtained by meteorological or ocean organization in various countries and data obtained in various scientific projects are used to the maximum. From the experiences of TRMM/PR validation, needed is validation focusing on the algorithm development. The long-term precipitation data by TRMM/PR are also used to the maximum. The purpose of the validation is to improve the accuracies of products and meet the target accuracies and success criteria in Table 3.3-3, by reflecting the results to level 2 and 3 algorithms.

Table 3.3-3 Success Criteria of GPM/DPR Project

Mission requirement	Minimum success (time to judge: 1 year after the end of the initial C/O)	Full success (time to judge: end of mission period [3 years])	Extra success (time to judge: mission end review)
estimate accuracy of latitude distribution of monthly-averaged global precipitation amount: +/- 10% or smaller	Difference between DPR and AMeDAS on domestic precipitation amount averaged through 12 months: around +/- 10%	Difference between DPR and ground-based rain gauges around the world on long-term average of precipitation amount: +/- 10% or smaller	-
Always-on observation with 0.2 mm/hr sensitivity from non-Sun-synchronous orbit with 65 degrees of orbital inclination	Always-on observation with 0.5 mm/hr sensitivity by KuPR or KaPR	DPR meets functional and performance requirements and can always observe precipitation with 0.2 mm/hr sensitivity.	Beyond the mission period, DPR meets functional and performance requirements and can always observe precipitation with 0.2 mm/hr sensitivity.

(1) Outline of Validation Plan

The validation should be smoothly conducted by using the experiences on TRMM/PR. As the precipitation changes, rapidly with time or place, it is not sufficient to simply compare the instantaneous values of physical quantities between the satellite-mounted precipitation radar and ground-based instruments including radar whose special observation objects are different from each other in sizes and shapes. From this point of view, validations in GPM are conducted under the following policies.

- As well as end-to-end validation, the physics models supposed in the algorithms should be also validated. It is helpful to make effective use of the results of ground validation experiment.
- Super sites (in Okinawa, Sapporo, etc.) should be established, where observational instruments are concentrated to obtain long-term data used for validations of physics models.
- Data obtained from ground should be used rather than from airplanes.
- By utilizing data of the observation network, long-term and wide-scope data should be compared.

As the approaches and measures are different from each other, the validations of GPM/DPR are separated into algorithm validations and product validations. Algorithm validations are intended to develop and improve the level 2 and 3 algorithms, and conducted continuously before the launch of GPM core satellite. In product validations, products created by the level 2 and 3 algorithms are validated. Especially the accuracy of precipitation amounts is evaluated and check whether it meets the target accuracies and success criteria. The results of the accuracy evaluations in the product validations are provided to users (PI researchers, practical utilization organization, collaborative research organization and general researchers) and fed back to algorithm developers to improve the accuracy of products. Compared with TRMM/PR, validations corresponding to higher accuracy and higher sensitivity are needed for GPM/DPR. In other words, validations of weaker precipitation and solid precipitations are needed. Regarding solid precipitation, amount estimation algorithm and validation method have not been established yet. Therefore, characteristics about snow should be investigated first. From that point of view, starting algorithm validations before the launch is very important.

(2) Product Validation

In product validations, standard products created by the level 2 and 3 algorithms are validated, and eventually it is checked whether the target accuracies and success criteria are met.

To reduce the sampling error and the error resulting from area characteristics, as long-term and wide-scope data as possible are used for product validations. The data collection and comparative validations are conducted as below.

- By using data compiled by TRMM/PR, TMI and GSMaP, statistical values (average, trend, histogram, etc.) are compared.
- By collecting existing steady observation data from AMeDAS, X-net, etc., statistical values (average, trend, histogram, etc.) are compared with reflection intensities and precipitation amounts included in products created by level 2 and 3 algorithms.
- The match-up data and long-term statistical values obtained from other satellite project, e.g. GCOM-W/AMSR2 and EarthCARE/CPR, are used for comparative validation.
- Under mutual cooperation with NASA GV team, steady local observation data around world are collected and used for the product validations.
- The validations are conducted under cooperation with Asian countries with a view to the promotion of utilization (skill development and education).

Table 3.3-4 shows data used for the validation of each product. Validations described above are conducted for each product, and each algorithm is improved in accuracy. Eventually, it is evaluated whether the success criteria of GPM/DPR project are achieved.

Table 3.3-4 Data Used for Validations of Standard Products

Level	Algorithm	Product	Target for calibration/validation	Data used for calibration/validation
L1	KuPR		Received power	External calibration data, Internal calibration data
	KaPR			
L2	DPR	KuPR	reflection intensity, precipitation profile	Ground-based radar (in Okinawa and Sapporo), X-net of National Research Institute for Earth Science and Disaster Prevention (NIED), Precipitation intensity from GMI, Data from other satellites (GCOM-W/AMSR2, EarthCARE/CPR, etc.)
		KaPR		
		DPR		
	DPR/GMI Combined			
L3	DPR		Ground precipitation amount	AMeDAS, radar AMeDAS, X-net of National Research Institute for Earth Science and Disaster Prevention (NIED), Precipitation intensity from GMI, Data from other satellites (GCOM-W/AMSR2, EarthCARE/CPR, etc.), Precipitation map products, Rain gauge network, Validation data from Asia
	DPR・GMI Combined			
	GSMaP			

(3) Algorithm Validation

The algorithm validations can be divided into two main categories. The one is validation by ground-based observations. The other is validation by simulated data.

① Validation by Ground-based Observations

It is helpful in development and improvement of DPR, DPR/GMI combined and GSMaP algorithms to validate errors on various parameters included within precipitation estimation algorithm related to attenuation by precipitation particles, distribution of diameters of raindrops, fall velocity and density of snow, and so on. In order to achieve this purpose, it is now under consideration to introduce 2 of ground-based Ka-band radar, instead of using existing ground-based instruments.

The observation sites are established and operated, where observation instruments are concentrated to obtain various parameters needed for the algorithms. As the ground-based observations described above are necessary for algorithm development, they are conducted before the launch of the core satellite.

② Validation by Simulated Data

By using the reproduced nature based on data obtained from ground or that from numerical models, the forward calculations are conducted and simulated observation data (corresponding to L1: received power and brightness temperature) are created. By comparing the results of L2 algorithm inputting this data with the reproduced nature, the algorithms are validated.

(4) Product Evaluation

In this section, the evaluation results pertaining to the requirements of data release are mentioned.

① DPR Level 2 product

The data accuracy requirement for data release is as follows:

- The differential of radar scatter cross-section between KuPR and PR is less than ± 2 dB at sea surface (1 month, no precipitation, and at the angle bins where the wind effect is negligible)
- The differential of radar scatter cross-section between KaPR and KuPR/PR is less than ± 2 dB at sea surface (1 month, no precipitation, and at the angle bins where the wind effect is negligible) considering the difference in radio frequency
- The ratio of rain intensity between KuPR and PR is less than 50% for 0.7 mm/h to 30 mm/h (2 months, over ocean, ± 30° in latitude, all angle bin, and at surface)
- The ratio of rain intensity between KaPR to KuPR and KaPR to PR is less than 50% for 0.7 mm/h to 10 mm/h (2 months, over ocean, ± 30° in latitude, all angle bin, and at surface)
- The ratio of rain intensity between DPR and KuPR and DPR and PR is less than 50% for 0.7 mm/h to 30 mm/h (2 months, over ocean, ± 30° in latitude, all angle bin, and at surface)

Figure 3.3-1 is the radar cross-section calculated under the condition from the requirement for data release. The results of differences at 5.3° of incident angle are 0.0 dB, 0.4 dB, and 0.2 dB for KuPR-PR, KaPR (MS)-PR, and KaPR (HS)-PR, respectively, and thus DPR L2 products fulfilled the first and second requirements.

A formula to evaluate the ratio of rain amount between different sensors is defined as follows:

$$\text{Ratio} = |\text{Sensor} - \text{PR}|/(\text{Sensor} + \text{PR}) \times 200\ [\%]$$

Figure 3.3-2 shows the rain rate of zonal mean in a width of 5°in latitude over ocean and a ratio under the condition as the requirement defines. The data period is 2 months, i.e., June 2014–July 2014. When KaPR is compared with the inner swath of PR, the obtained average ratios are 1.9%, 11%, and 2.9% for KuPR, KaPR (MS), and KaPR (HS), respectively. Thus, the DPR L2 products fulfilled the rest of the requirements.

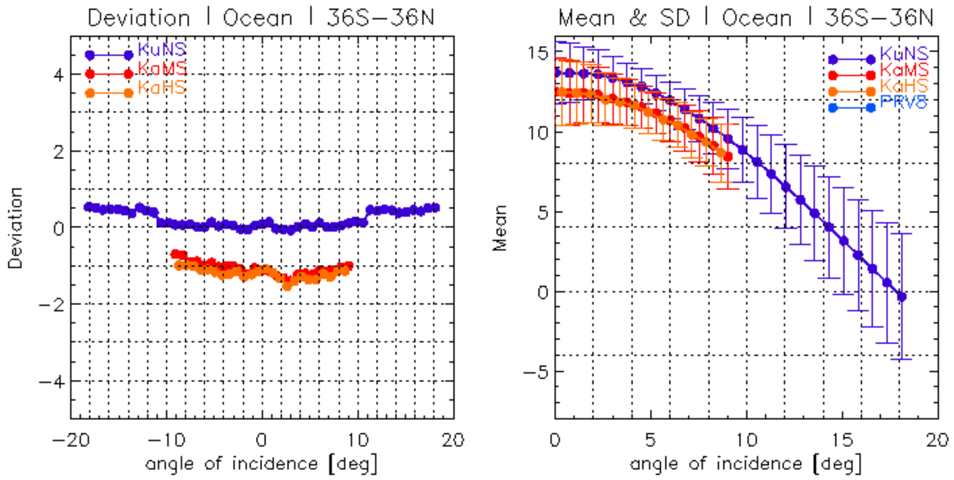


Figure 3.3-1 (Left) the deviation of radar scatter cross-section; (right) monthly average and standard deviation of radar scatter cross-section

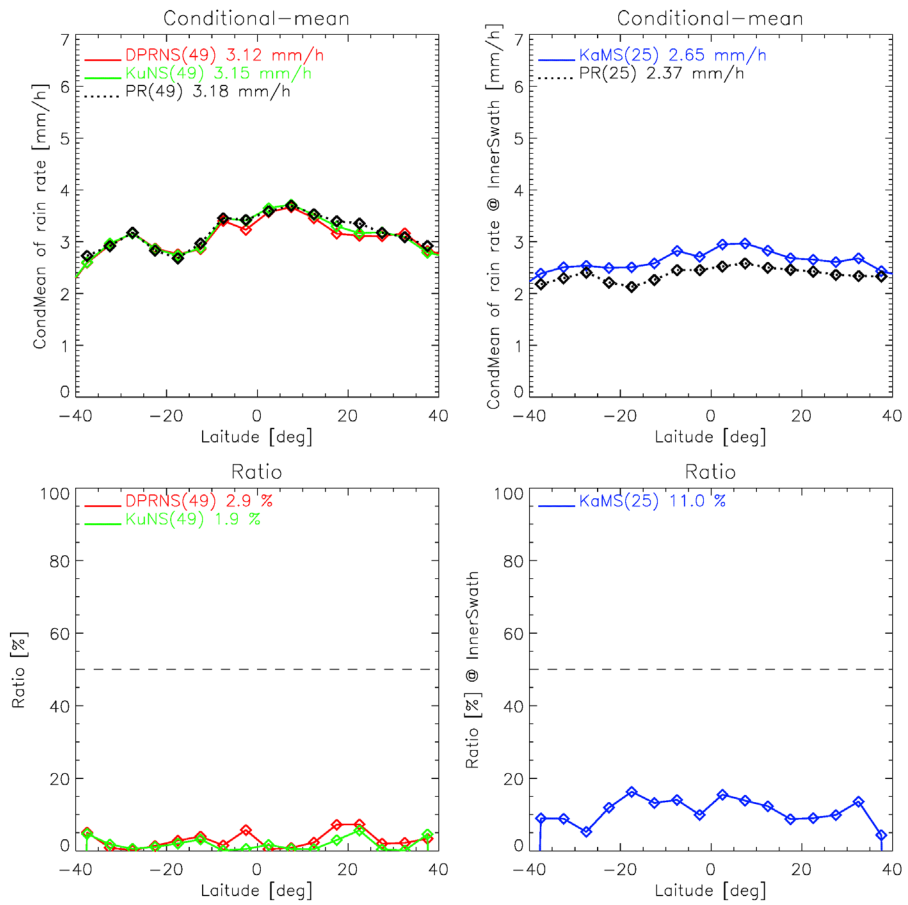


Figure 3.3-2 Zonal mean of rain (Top) and Ratio(Bottom) in V05 product

② Combined Level 2 product

The data accuracy requirement for data release is as follows:

- The error for the rain intensity of 1 mm/h is less than 50%, while the error for 10 mm/h is less than 25% at a horizontal resolution of 50 km.

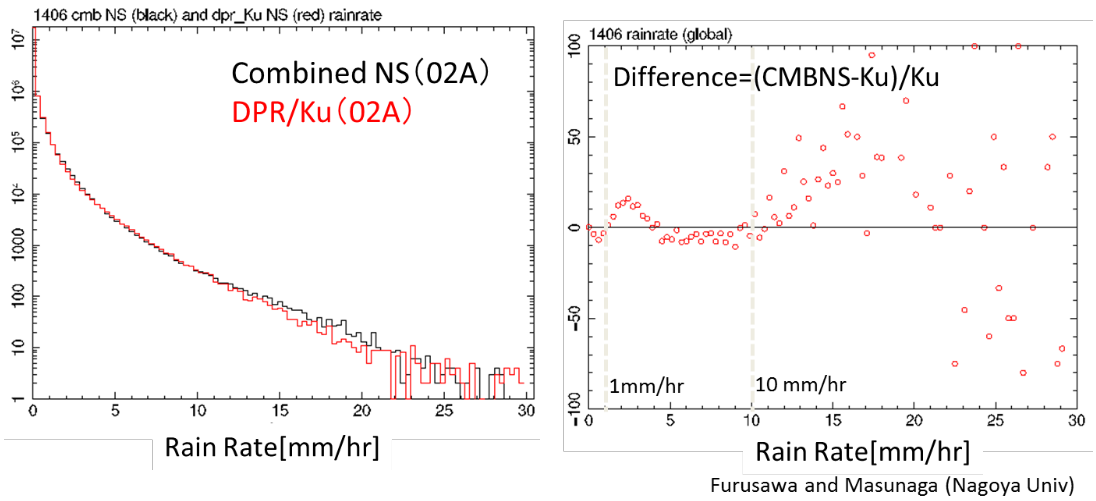


Figure 3.3-3 (Left) the histogram of precipitation intensity; (right) the difference of rain frequency

The error at 1 mm/h rain rate is approximately ± 5% and that at 10 mm/h is approximately ± 15%. Thus, the accuracy of the combined L2 product meets the release requirement.

③ GSMaP Level 3

- Global precipitation distribution and moving average of rain between GSMaP with GPM/GMI and GSMaP without GPM/GMI is consistent. As this is to confirm GMI data as a new input, this requirement should be verified at the first data release itself.
- The average of root means square error to daily accumulated rain amount of Radar-AMeDAS in 0.25° grid is less than 0.7 mm/h.

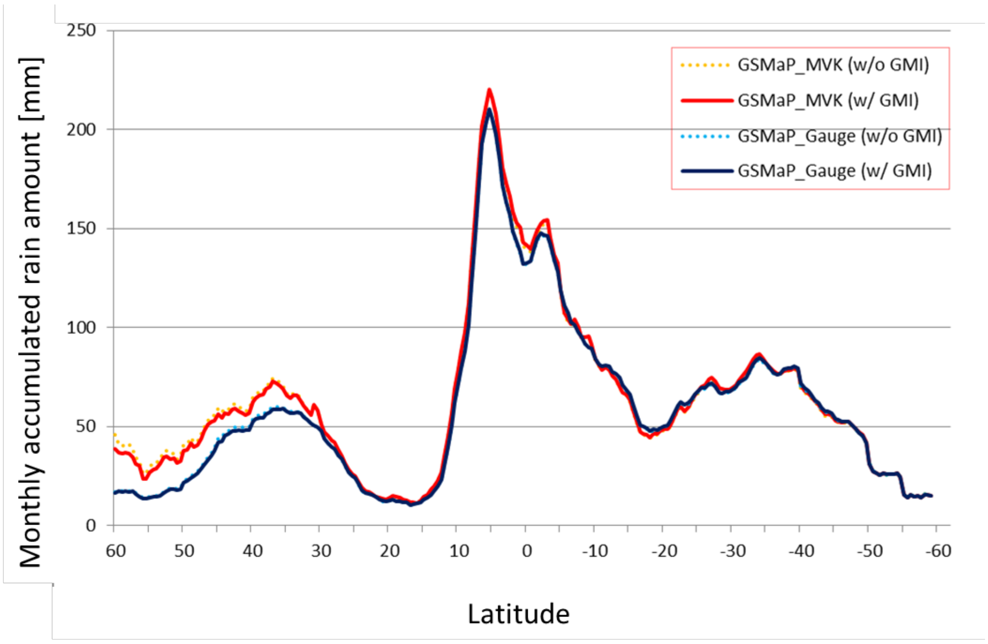


Figure 3.3-4 Monthly accumulated rain amount of GSMaP with GMI and GSMaP without GMI (April 2014)

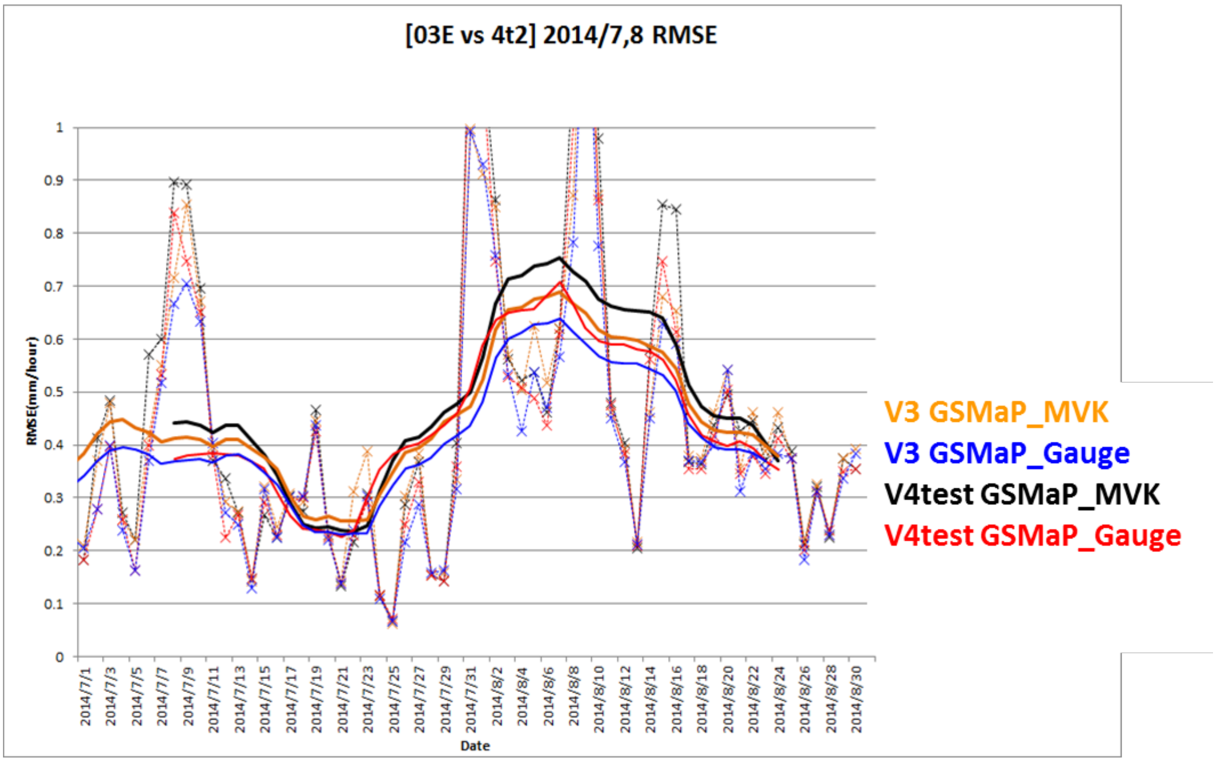


Figure 3.3-5 Time series of RMSE from July 1, 2014 to August 31, 2014. Daily value is represented in dotted lines and 15-day moving average in solid lines

The consistency between “GSMaP with GMI” and “GSMaP without GMI” is clear as shown in Figure 3.3-4. The difference for GSMaP_MVK is 0.97% and that for GSMaP_Gauge is 0.46%. Since the average values of RMSE for 2 months are 0.43 mm/h (GSMaP_Gauge) and 0.47 mm/h (GSMaP_MVK), GSMaP meets the release requirement.

3.3.3. Calibration of TRMM

(1) External Calibration of TRMM PR

External calibration for TRMM PR had carried out about 10 to 20 times per year and it guaranteed the stability of the observation through the operational period. Now, the new version 8 is released, TRMM/PR calibration was reexamined with new knowledge obtained from experience in GPM/DPR's calibration.

Radar calibration is to determine the radar constant C in equation (1) through the measurement of received power Pr by an active radar calibrator (ARC).

$$P_r(\mathrm{r}) = \frac{C|K_w|^2}{r^2} Z_m(r) \qquad \ldots(1)$$

Here, C and Kw and other symbols are;

$$\mathrm{C} = \frac{\pi^3 c\tau}{2^{10}\lambda^2 \ln 2} P_t G_{t0} G_{r0} \sqrt{\theta_{t1}\theta_{t2}\theta_{r1}\theta_{r2}} \qquad \ldots(2)$$

$$\mathrm{K_w} = \frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{n^2 - 1}{n^2 + 2} \qquad \ldots(3)$$

P_t	: Transmitting power
G_{t0}、G_{r0}	: Antenna gain
θ_{t1}、θ_{t2}、θ_{r1}、θ_{r2}	: Beam width
λ	: Wave length
τ	: Pulse width
c	: Speed of light
ϵ_r	: Dielectric constant of water

Reexamination of external calibration consists of the updates of those parameters, pulse shape, and definition of pulse width and improvement of the beam mismatch correction. In addition, the antenna gains and the calibration instruments and its technique was improved.

In consequence, reflectively factor (Zm) increased by about 1.1 dB from the PR V7. PR's normalized surface cross section (σ0) statistics shows good agreement with DPR's σ0 by -0.02 dB during the overlapping period.

(2) External Calibration of TRMM PR

A new parameter, adjustment factor is introduced in PR & DPR L2 PRE module to offer homogeneous and continuous data between PR and DPR to detect the long-term variation of precipitation. Base adjustment is 0.02 dB for σ0 and Zm, respectively to make PR's σ0 and DPR'sσ0 exactly matching.

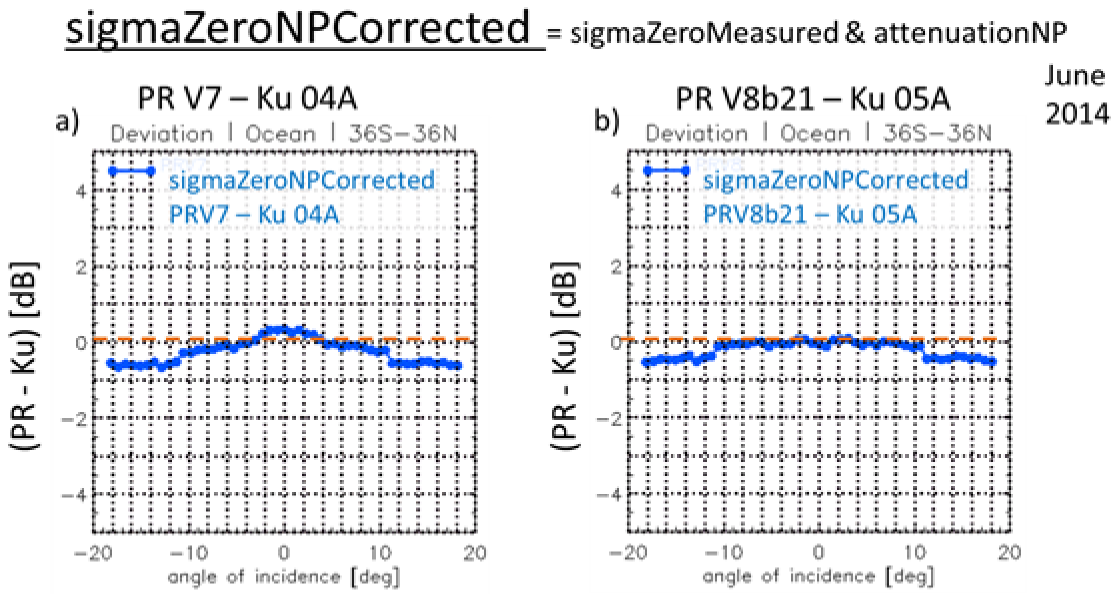


Figure 3.3-6 Difference of PR's σ0 and KuPR' sσ0 in case of no precipitation

(Left: PR V7 - KuPR V04, Right: PR V8 - KuPR V05.

There is underestimation of PR's σ0 in outer angle due to the lack of oversampling.)

Addition to this, the minor calibration drift during TRMM operational period, a temporal adjustment factor which has orbit number dependency is introduced. It varies from -0.23 to +0.27dB and cancel the time-series of σ0 change.

As a result, stable TRMM PR V8 continues to KuPR V05 seamlessly.

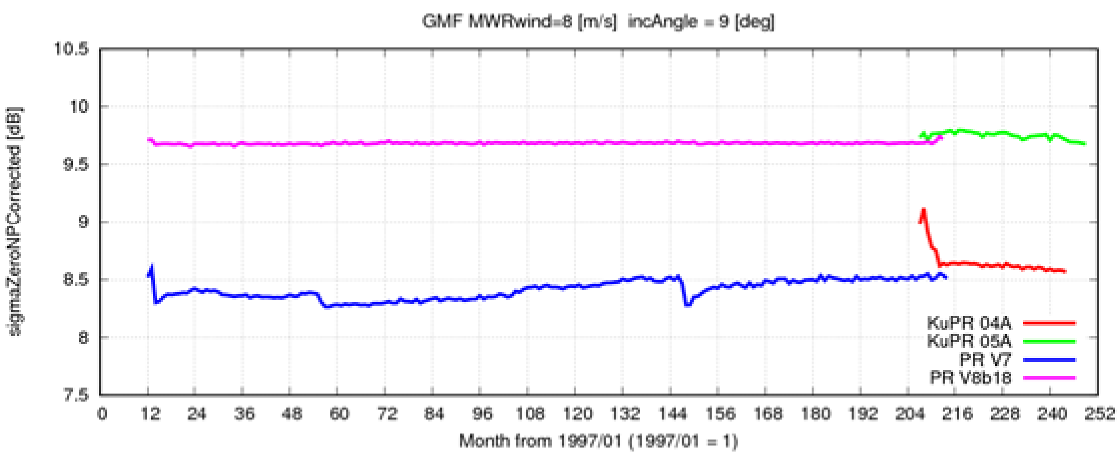


Figure 3.3-7 Time series of σ0 under the condition of sea surface wind by microwave imagers is 8 m/s, incident angle is 9 degrees, and atmospheric attenuation was corrected. PR is with TMI、 KuPR is with GMI. PR V8 b18 is comparable to V8. The data of sea surface wind was offered from Remote sensing systems. Figure by Dr. Kaya Kanemaru, AORI, University of Tokyo.

(3) Conditions

PR V8 L2 algorithm is comparable to GPM KuPR V05 except for sidelobe rejection routine and the database for surface reference method. PR V8 still holds the effect of orbit transition (2001/08) and FCIF switching (2009/06). Please note that the PR and KuPR are comparable at the calibration, but their sensitivity is different.

Chapter 4 GETTING GPM PRODUCTS AND IMAGES

This chapter introduces the services providing GPM products, images and related information.

4.1. Service Descriptions

As a general rule, GPM products are provided on the Internet. Research products, images, results of application researches, operational information on the satellite and the sensors, and so on, as well as standard products, are available from the website of JAXA and NASA. The services are listed in the following table and described in detail in the subsections below.

Table 4.1-1 Services

Provided thing	Service
Standard products They are the products with the accuracy assurance by JAXA or NASA. The near-real-time products are treated as equivalent to the standard products, while between them there are some differences on the input auxiliary data or the file coverage. See Chapter 3.	JAXA > G-Portal https://gportal.jaxa.jp/gpr/
	NASA > Precipitation Processing System (PPS) > Data Products Ordering Interface（STORM） https://storm.pps.eosdis.nasa.gov/storm/
Research products They are not accuracy-guaranteed, but provided as they are useful.	JAXA > Earth Observation Research Center > GPM https://www.eorc.jaxa.jp/GPM
	NASA > Precipitation Processing System (PPS) > Data Products Ordering Interface（STORM） https://storm.pps.eosdis.nasa.gov/storm/
Images and results of application researches They are created from data of GPM and other satellite, and show precipitation amounts or typhoons in an easy-to-understand way.	JAXA > Earth Observation Research Center > GPM https://www.eorc.jaxa.jp/GPM/en/index.html
	NASA > Precipitation Measurement Missions (PMM) https://gpm.nasa.gov/
Operational information on the satellite and sensors The information regarding operation status and data missing are provided.	JAXA > G-Portal https://www.gportal.jaxa.jp/
	NASA > Precipitation Processing System（PPS） https://arthurhou.pps.eosdis.nasa.gov/

4.1.1. Getting Standard Products

The standard products are available from the data providing site of JAXA and NASA.

There are the common standard products between JAXA and NASA, as well as individual ones of each of them.

There are level 1, 2 and 3 common standard products. They are available from the website of JAXA and NASA. The algorithms of the level 2 and 3 common products are jointly developed by JAXA and NASA. It is recommended to download them from the domestic, i.e. nearer, site, as it takes a long time to download them from the overseas site due to the long roundtrip time (RTT). Please note that JAXA and NASA publish a common product in different file names.

The individual standard products are provided only on each website of JAXA and NASA. As an example of the individual products, JAXA and NASA provide the global precipitation map products named "GSMaP" and "iMerge" respectively.

Please respect the copyright of the data when using them. See 4.1.5 for the usage note.

(1) JAXA G-Portal https://www.gportal.jaxa.jp/

The JAXA standard products are available from G-Portal, which is an earth observation data providing system. You can cross-search and download earth observation data of JAXA, e.g. GCOM-W, TRMM and ADEOS. You can refine your search by selecting the kind of physical quantities.

In the same manner as existing services, you can refine your search by specifying satellites, sensors, geographical areas and dates. In addition to that, you can find data by specifying kinds of physical quantities. That functionality is helpful for users not familiar with the satellite and sensors.

G-Portal provides the functionality of searching with specifying kinds of the physical quantity. See Figure 4.1-1.

The data search functionality mentioned above is useful for users who want to get specified geographical areas, periods or events like typhoons. The direct download functionality via FTP is also provided for users who want to get a large amount of data at one time. See Figure 4.1-2.

You can directly get near-real-time products from the FTP server of G-Portal. Between near-real-time products and standard products, there are some differences on the input auxiliary data or the file coverage in order to shorten latency for near-real-time products. See Figure 4.1-3. The near-real-time products are removed from the FTP server after 7 days from the publication because the standard products are published after about 3 hours to several days from the observation depending on kinds of products.

Earth observation data are reprocessed along with improvement of calibration parameters and/or processing algorithm. G-Portal provides basically latest version products, while it can provide the previous version products by request from users.

G-Portal user manual (https://gportal.jaxa.jp/gpr/assets/mng_upload/COMMON/upload/GPortalUserManual_en.pdf) for the usage of G-Portal, the procedure to create and register a public key, a nd so on.

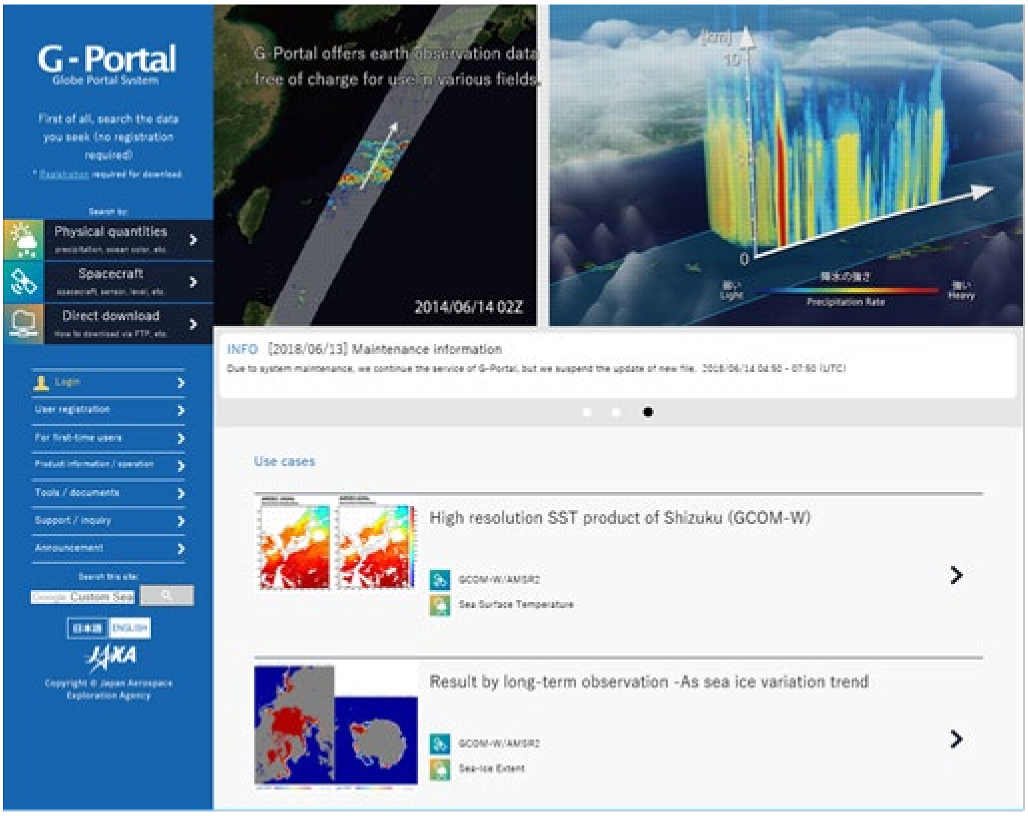


Figure 4.1-1 JAXA Standard Product Providing Service (G-Portal homepage)

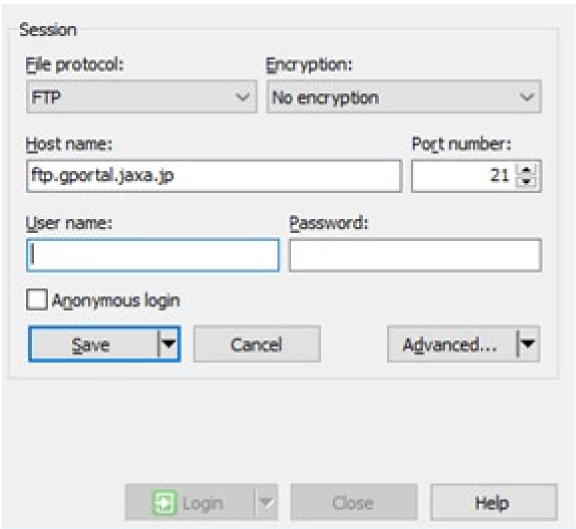


Figure 4.1-2 G-Portal FTP Server

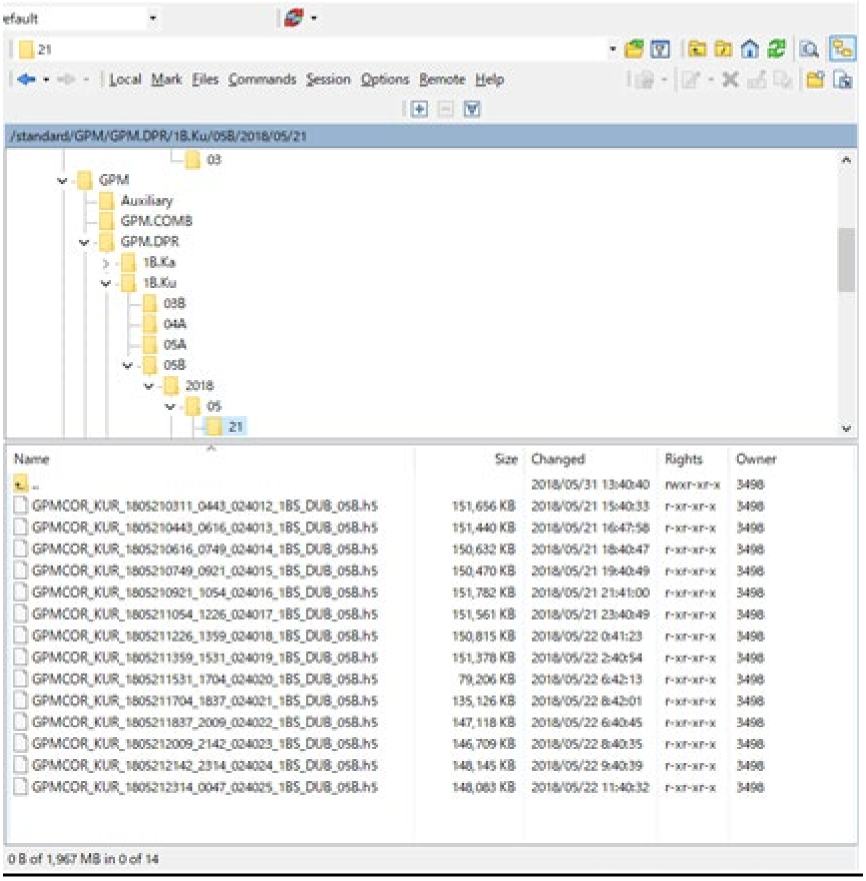


Figure 4.1-3 Example of G-Portal FTP Direct Download

(2) NASA STORM https://storm.pps.eosdis.nasa.gov/storm

The standard and research products of the precipitation measurement missions of NASA, i.e. GPM and TRMM, are available from Data Products Ordering Interface (STORM) of Precipitation Processing System (PPS).

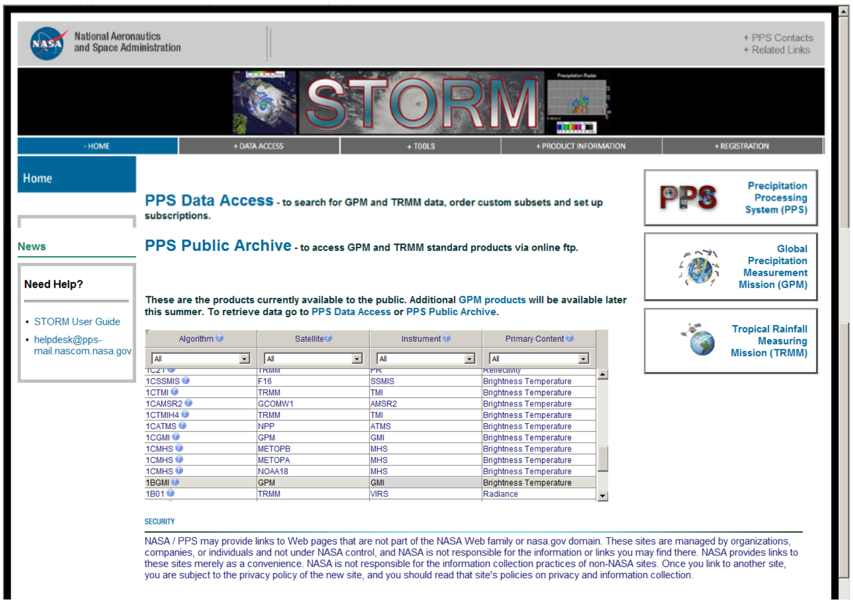


Figure 4.1-4 NASA Standard Product Providing Service (STORM homepage)

4.1.2. Getting Research Products

The research products are available from the data providing site of JAXA Earth Observation Research Center (EORC) and NASA/PPS.

(1) JAXA Earth Observation Research Center (EORC) GPM

https://www.eorc.jaxa.jp/GPM/en/index.html

The research products of JAXA are available from EORC website.

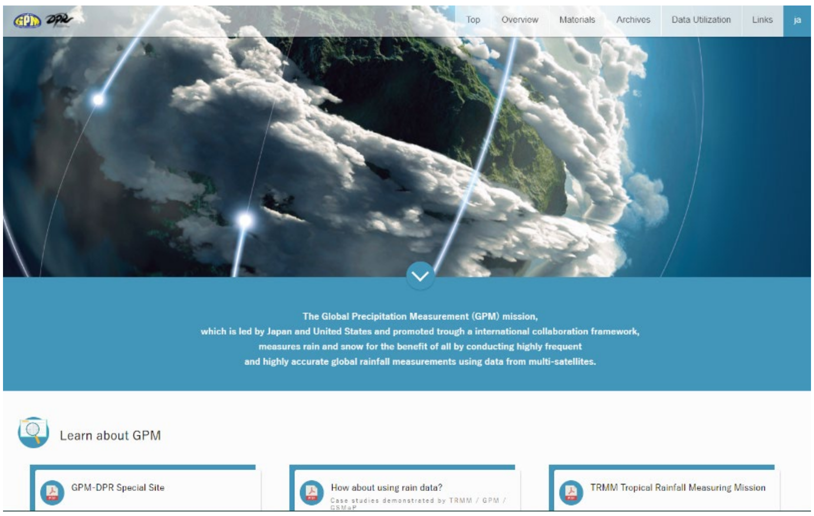


Figure 4.1-5 Homepage of JAXA/EORC GPM Application and Research

(2) NASA STORM https://storm.pps.eosdis.nasa.gov/storm

On STORM, NASA/PPS provides the products which are treated as standard products in U.S., but not agreed standard products of Japan and U.S.

4.1.3. Browsing Images and Results of Application Researches

Dedicated tools or software are needed to visualize and/or analyze standard or research product of earth observation data, which are HDF5 or binary format. You can get an image from JAXA/G-Portal, after searching and selecting a product. In this subsection, introduced are websites where you can find images easy-to-understand for the general users.

What data from satellites tell us and results of analyses are published on the websites as they come.

(1) JAXA Earth Observation Research Center (EORC) GPM

https://www.eorc.jaxa.jp/GPM/en/index.html

In "View observation data" "using observation data" menu of the site, you can find the links to G-Portal, which provides the standard products, and that to "JAXA Global Rainfall Watch" page.

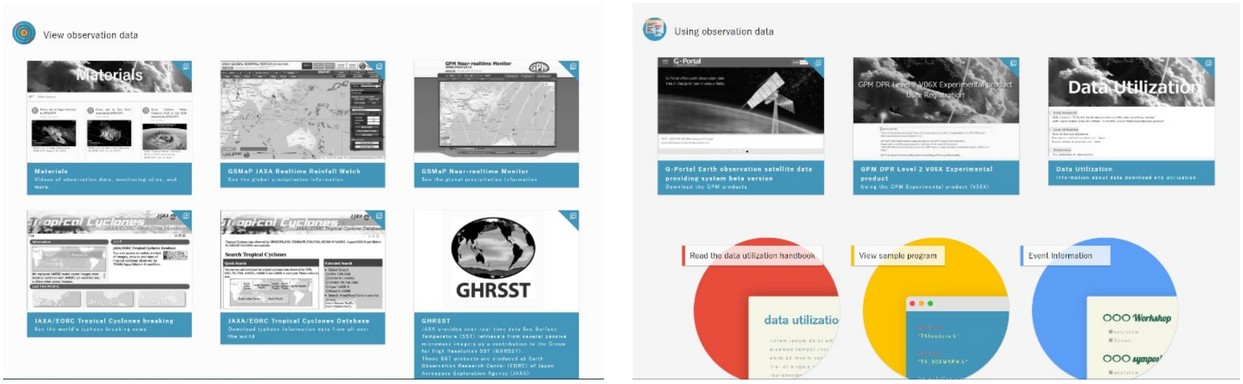


Figure 4.1-6 link to "View observation data" "using observation data"

(a) JAXA Global Rainfall Watch https://sharaku.eorc.jaxa.jp/GSMaP/index.htm

In this site, provided is the global distribution of rainfall derived from data of satellites. It is updated every hour in near-real-time (about 4 hours after the observations). Using Google Map, you can easily change focus from global to local.

You can browse overlaid images of rainfall distribution and cloud images observed from geostationary meteorological satellites for the specified date from past to current at will. You can also see the rainfall distribution images of the latest 10 hours side-by-side and the animation of the transition in the latest 24 hours. Furthermore, you can get the rainfall distribution in Google KMZ format and display it on Google Earth if it is installed in your PC.

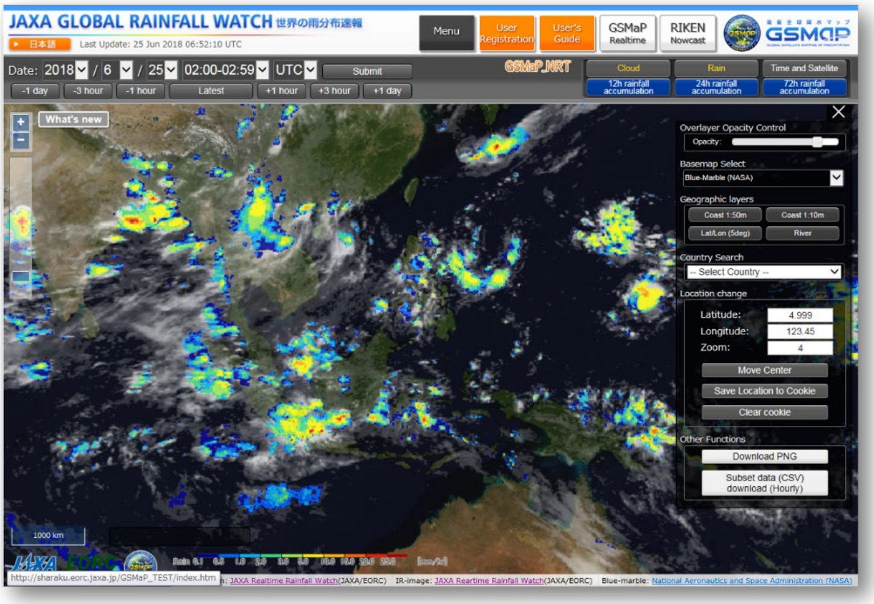


Figure 4.1-7 JAXA Global Rainfall Watch

(b) Tropical Cyclone Database and Real-Time Monitoring

https://sharaku.eorc.jaxa.jp/TYP_DB/index_e.html
https://sharaku.eorc.jaxa.jp/cgi-bin/typhoon_rt/main.cgi?lang=en

From Tropical Cyclone Database site, you can download data of tropical cyclones around the world, which are obtained by the earth observation satellites (GPM/DPR, GMI, TRMM/PR, TMI, VIRS, GCOM-W/AMSR2, Aqua/AMSR-E and ADEOS-II/AMSR).

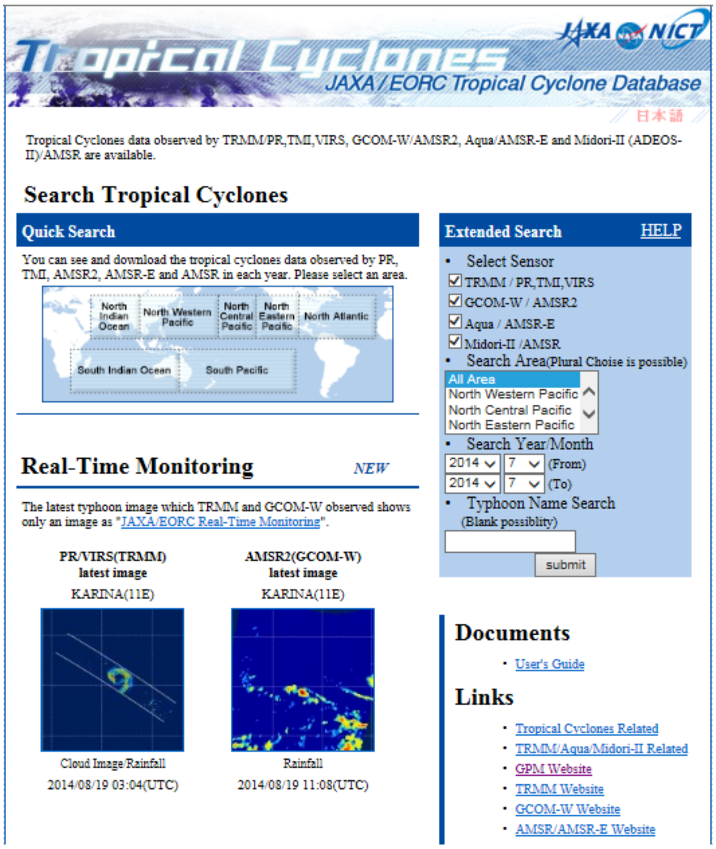


Figure 4.1-8 Tropical Cyclone Database

The images of tropical cyclones for the latest 2 weeks are available from Real-Time Monitoring site, and the observation of GPM/DPR can verify precipitation images such as a typhoon and hurricane.

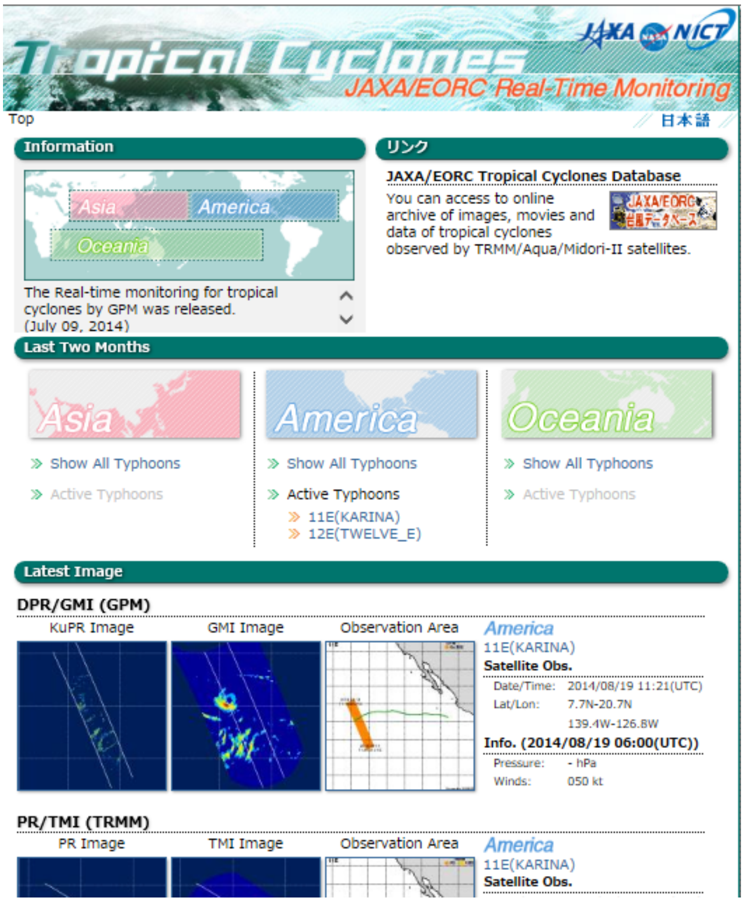


Figure 4.1-9 Tropical Cyclone Real-Time Monitoring

(2) NASA Precipitation Measurement Mission（PMM） https://gpm.nasa.gov/

In “Science” and “Application” tabs of NASA/PMM site, images of GPM data are introduced with interpretations.

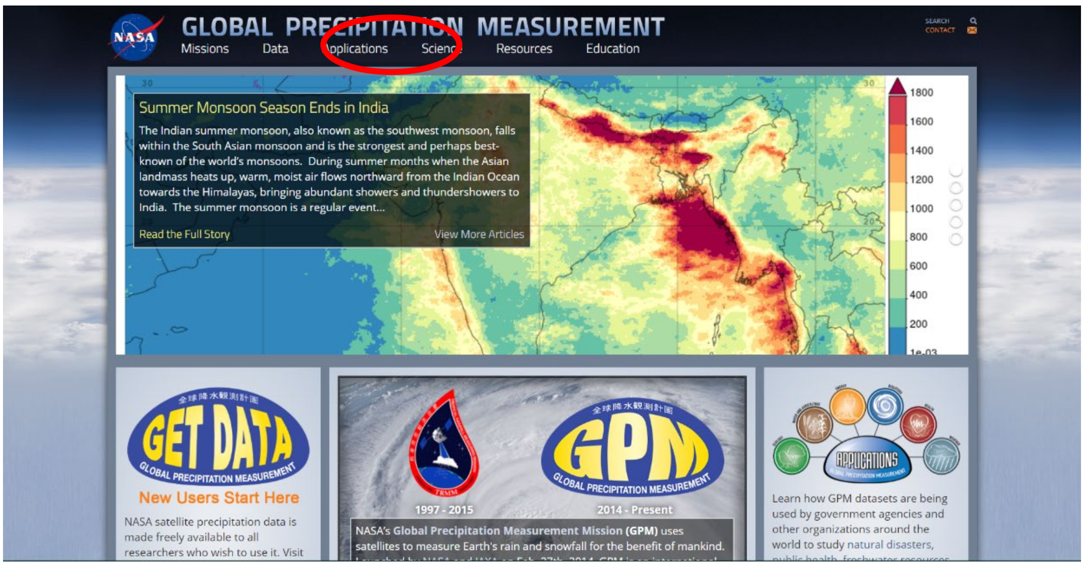


Figure 4.1-10 NASA/PMM site

4.1.4. Operational Information on the Satellite and Sensors

Depending on operational status of the satellite and the sensors, some of data are missing or unusable for statistical processing from the point of view of quality. G-Portal and PPS provide users with the information on operational status and data missing.

If data in a file, i.e. an orbit, of GPM standard products are wholly missing or unusable from the point of view of quality, an "Empty Granule", which includes only header information like observation start/end time, are provided on G-Portal/SFTP server and PPS server. That allows users to distinguish errors in downloads from data missing.

JAXA/G-Portal: https://gportal.jaxa.jp/gpr/information/product

NASA/PPS: https://gpm.nasa.gov/data/news

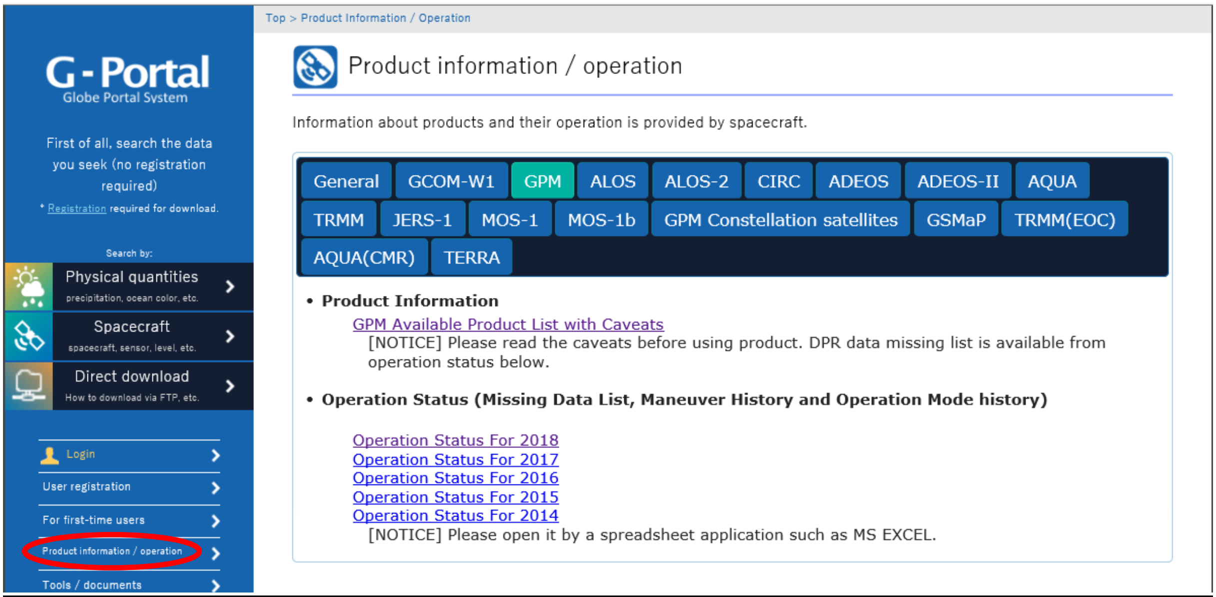


Figure 4.1-11 Operational Information on the Satellite and Sensors

The mission concept, observation outline, product outline and format, analysis tools, user manuals, and so on are introduced in websites of JAXA and NASA.

・The mission concept

JAXA/EORC: https://www.eorc.jaxa.jp/GPM/en/overview.html

NASA/PPS:https://gpm.nasa.gov/missions/GPM

・Product outline and format

JAXA/EORC: https://www.eorc.jaxa.jp/GPM/en/archives.html

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

・Analysis tools

JAXA/EORC: https://www.eorc.jaxa.jp/GPM/en/data_utilization.html

NASA/PPS:https://gpm.nasa.gov/data/tutorials

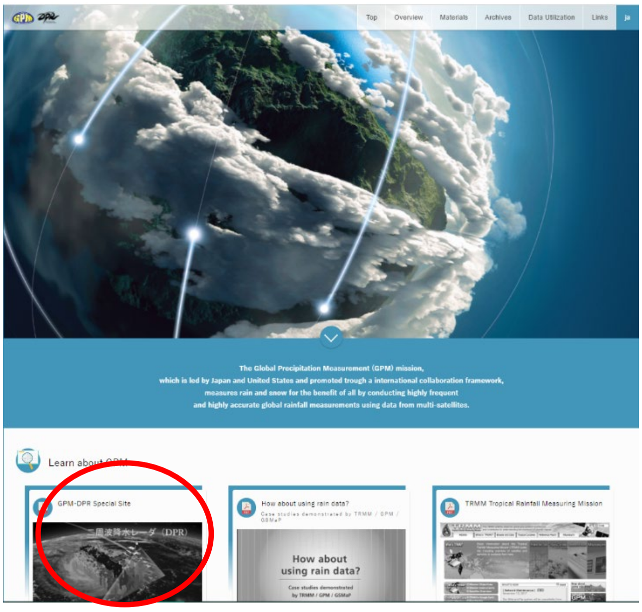


Figure 4.1-12 Links to Movies Introducing the Observation

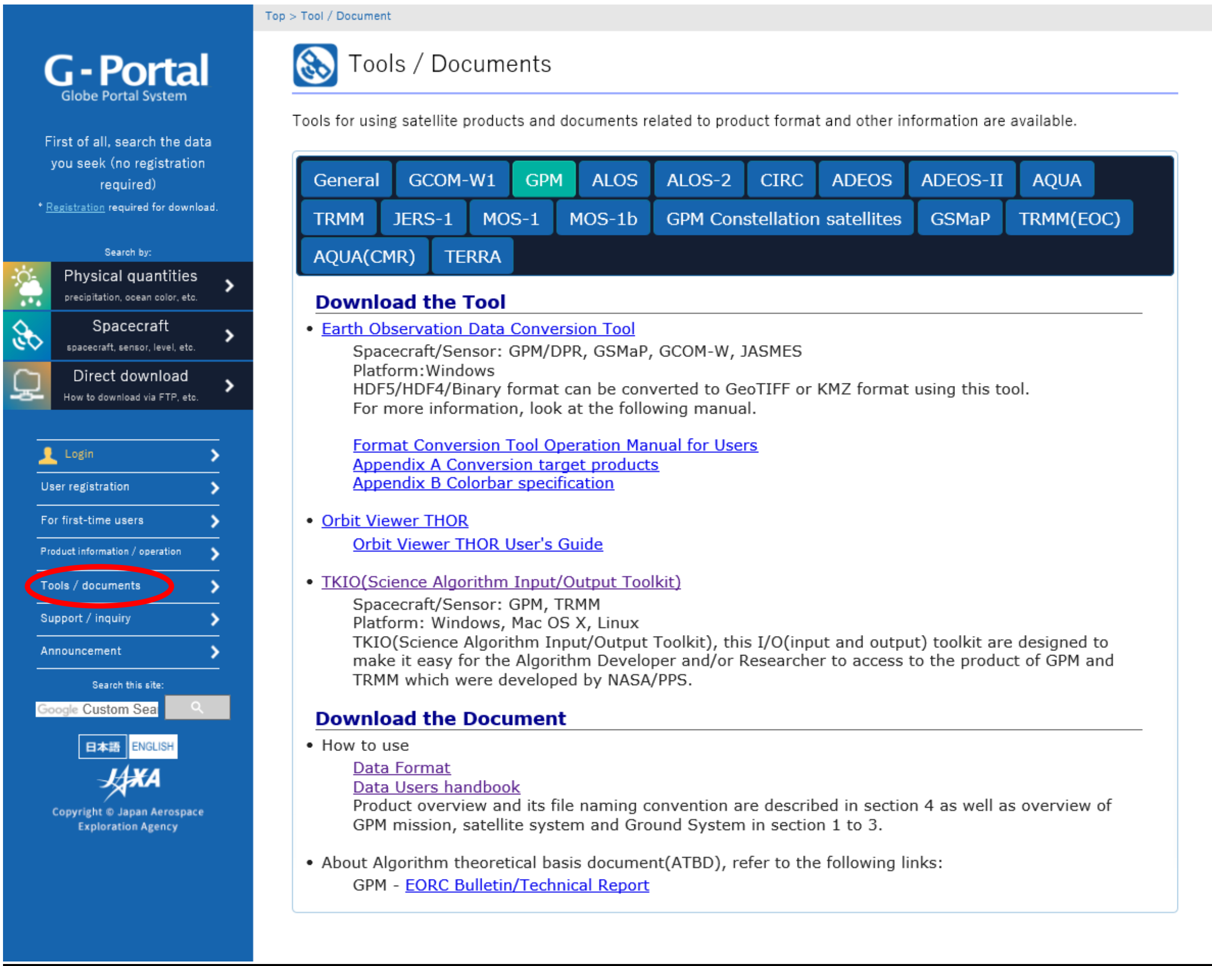


Figure 4.1-13 Link to the Format Specification and tools

4.1.5. Usage Note

GPM products and images provided on JAXA or NASA site are all copyrighted. You should be compliant with the terms of use.

The credits of the standard products are as below.

Kind of data	Credit
DPR, GMI and COMB	The NASA/JAXA GPM project and the other GPM Partners
GSMaP	JAXA

Chapter 5 UTILIZATION OF GPM/TRMM DATA

In this chapter, the outline features of the software tools to visualize or analyze GPM/TRMM data are described, as well as the information to get them.

5.1. Data Visualization Tools

5.1.1. THOR

THOR (Tool for High-Resolution Observation Review) is a tool to visualize TRMM and GPM products, developed by PPS (Precipitation Processing System) team in NASA.

With easy operations, it visualizes HDF-format data files in the forms of images, charts or texts. A dataset in a product is displayed on the global map view. You can zoom in an area if you want. It can also display a cross-section view parallel with or orthogonal to the path or at an altitude. Furthermore, it provides a 3D view in the recent versions.

You can download this tool from the URL below.

For the usage, see the tutorial page below

① Overview

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

② Tutorial

https://pps.gsfc.nasa.gov/THOR/version_2.2/tutorial.pdf

③ Download and installation

https://gpmweb2https.pps.eosdis.nasa.gov/pub/THOR/

For your reference:

HDF manual: https://portal.hdfgroup.org/documentation/

HDF library installation: https://portal.hdfgroup.org/downloads/index.html

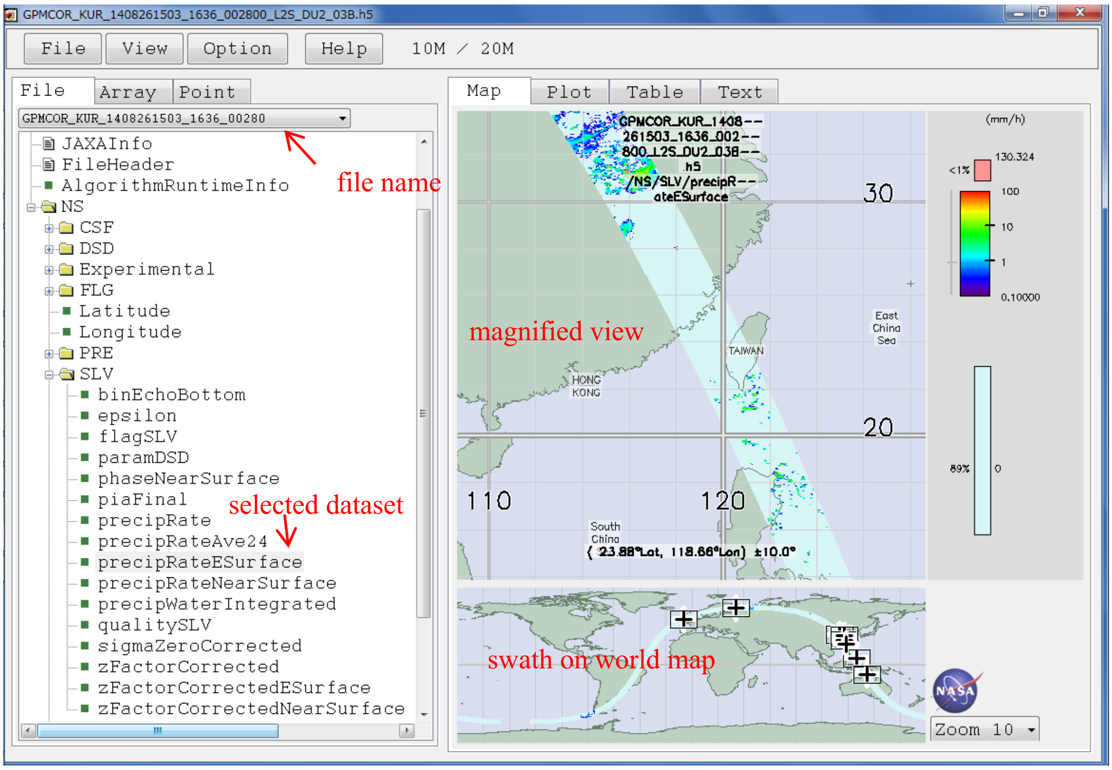


Figure 5.1-1 Screen of THOR (KuPR example)

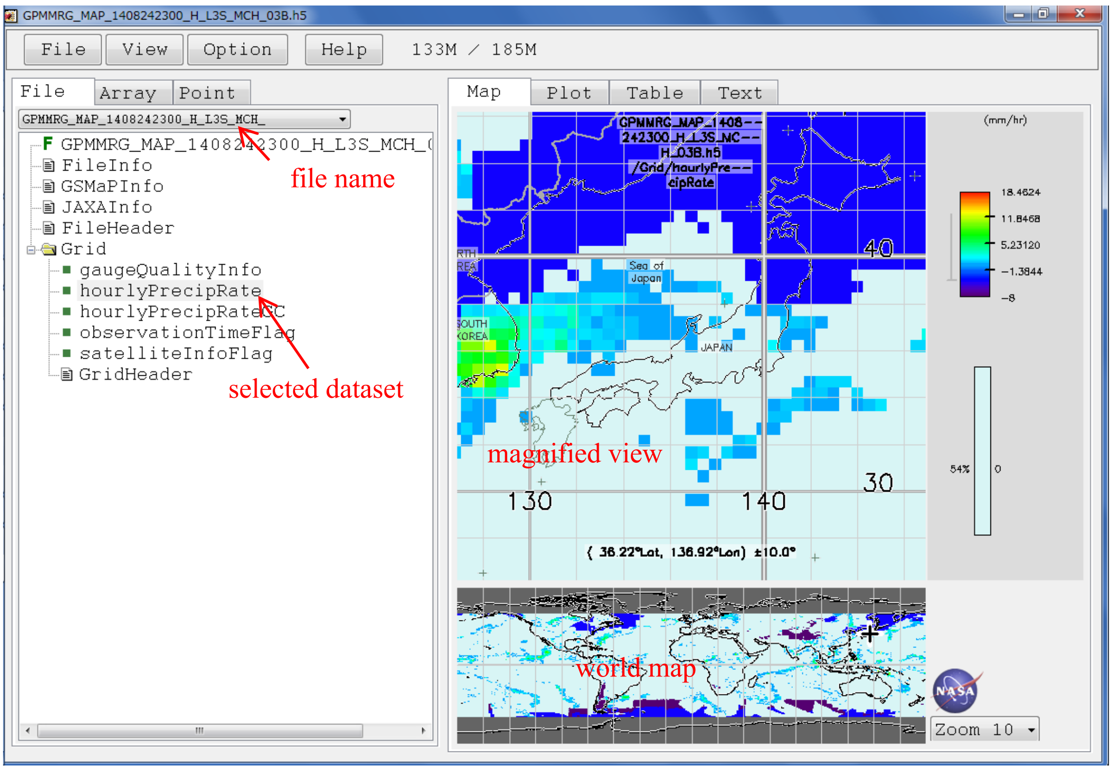


Figure 5.1-2 Screen of THOR (GSMaP example)

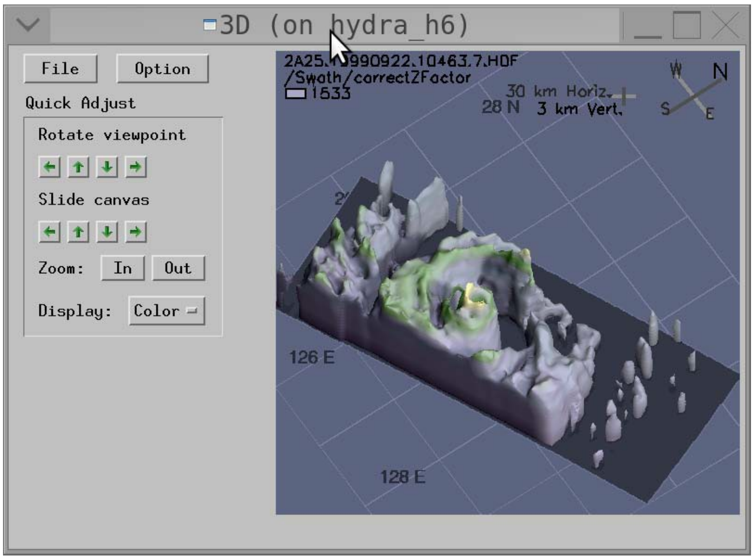


Figure 5.1-3 Screen of THOR (3D example)

5.1.2. HDFVIEW

HDFVIEW is a tool to show data in HDF-format (HDF4 or HDF5) file.

This tool is developed with Java and runs under various OS, e.g. Linux, Windows and Macintosh. Using it, you can easily look headers, or attributes, and rewrite data.

You can download this tool from the URL below.

https://portal.hdfgroup.org/downloads/index.html

For your reference:

HDF manual: https://portal.hdfgroup.org/documentation/index.html

HDF library installation: https://portal.hdfgroup.org/downloads/index.html

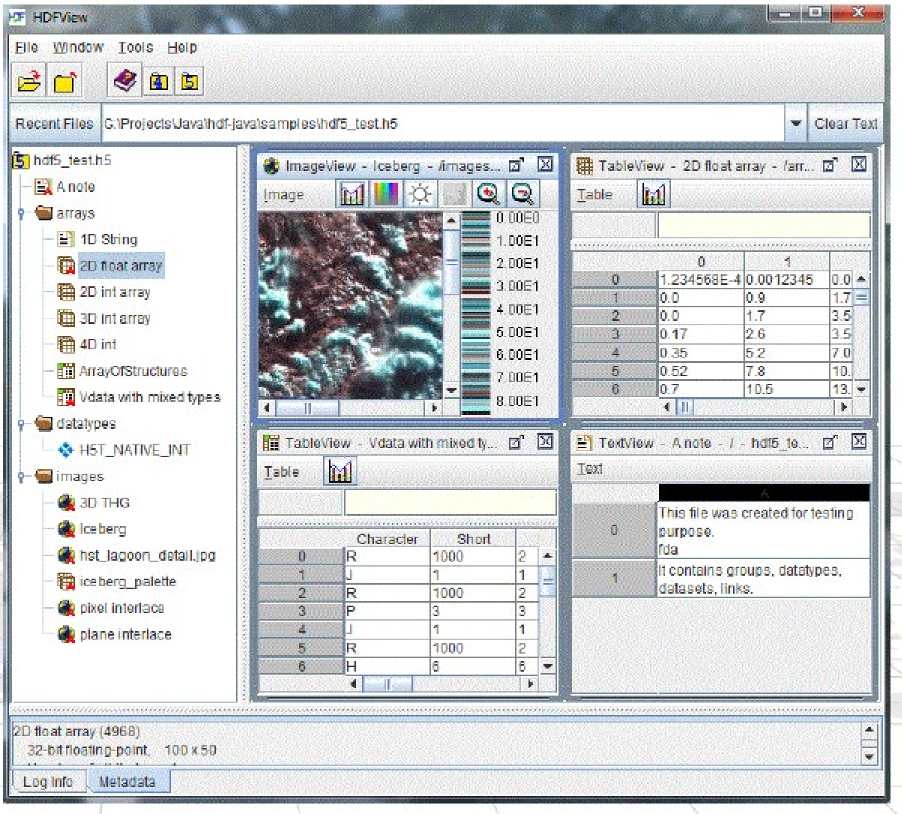


Figure 5.1-4 Sample screen of HDFVIEW

5.2. Data Analysis Tools

5.2.1. TKIO

TKIO (Science Algorithm Input/Output Toolkit) is a tool to read and write GPM and TRMM products from Fortran or C code. It is developed by PPS (Precipitation Processing System) team in NASA.

For the algorithm developers and researchers, it provides commonly used routines and constants, contributing to reduce the code quantities for input/output implementation.

You can download this tool from the URL below.

① Overview

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

② Download and installation

https://gpmweb2https.pps.eosdis.nasa.gov/pub/PPStoolkit/GPM/

For your reference:

HDF manual: https://portal.hdfgroup.org/documentation/index.html

HDF library installation: https://portal.hdfgroup.org/downloads/index.html

The procedure of the environmental setting, download and installation of TKIO are described here.

(1) Confirming the Environment for TKIO Installation

- Linux (64bit if you want to use the writing capability)
- Perl 5 or higher
- HDF5 version 1.8.6 or higher (PPS team recommends 1.8.9)
- HDF4 version 4.2.7 or higher
- ZLIB version 1.2.3 or higher (with libxml 2.6 to 2.7.6 for ZLIB 1.2.3 or lower, libxml 2.7.7 or higher for ZLIB 1.2.4 or higher)
- JPEG version 6b or higher
- GZIP version 1.2.3 or higher
- Math Library 2.5 or higher
- C language: gcc or icc (Intel C Compiler)
- Fortran: Intel® Fortran Composer XE Linux edition

(2) Installing HDF5 Library (ver. 5-1.10.5 case)

① Access to https://support.hdfgroup.org/ftp/HDF5/current/src/.

② Download the library for Linux (hdf5-1.10.5.tar.bz2).

③ Uncompress it.

$ tar –xjvf hdf5-1.10.5.tar.bz2

④ Prepare for the installation.

$ cd hdff5-1.10.5

$ ./configure –prefix=/xxx/xxx/xxx

(/xxx/xxx/xxx: the directory where the library should be installed)

$ make >&log_make.txt

$ make check >& log_make_check.txt

⑤ Install it.

$ make install

(3) Installing TKIO (ver.3.60.2 case)

① Access to https://gpmweb2https.pps.eosdis.nasa.gov/pub/PPStoolkit/GPM/tkio-3.60.2/ .

② Download the toolkit (tkio-3.60.2.tar.gz).

③ Place it in the directory where TKIO should be installed.

④ Uncompress it.

$ tar xvzf tkio-3.60.2.tar.gz

⑤ Prepare for the installation.

$ cd tkio

⑥ Set the environmental variables (for HDF4, HDF5, TKIO, compilers, flags, etc.).

See "(4) Setting the Environmental Variables" for details.

⑦ Compile and check.

$ ./INSTALL.pl compiler

$ cd lib

$ls

Libtkc.a libtkchdf4.a libtkchdf4algs.a libtkchdf5.a libtkchdf5algs.a

Libtkchelper.a libtkcselect.a libtkctkTSDIS.a

(4) Setting the Environmental Variables

The following figures show how to set the environmental variables to use TKIO, in csh and bash case.

gcc case (libralies are installed in /home/tool/home/tool)	icc case (libralies are installed in /home/tool/home/tool)

```
$ setenv CC  gcc
$ setenv FORTC  ifort
$ setenv CFLAGS  "-mcmodel=medium"
$ setenv FFLAGS  "-fpp -mcmodel=medium -shared-intel"
$ setenv HDF_INC  /home/tool/ hdf-4.2.9 /include
$ setenv HDF_LIB  /home/tool/ hdf-4.2.9 /lib
$ setenv HDF4_INC  /home/tool/ hdf-4.2.9 /include
$ setenv HDF4_LIB  /home/tool/ hdf-4.2.9 /lib
$ setenv HDF5_INC  /home/tool/hdff5-1.8.11/include
$ setenv HDF5_LIB  /home/tool/hdff5-1.8.11 /lib
$ setenv TKIO  /home/tool/tkio
$ setenv CLASSPATH  /home/tool/tkio/classes
$ unlimit
```

```
$ setenv CC icc
$ setenv FORTC ifort
$ setenv CFLAGS "- mcmodel=medium -shared-intel "
$ setenv FFLAGS "-fpp -mcmodel=medium -shared-intel"
$ setenv HDF_INC /home/tool/ hdf-4.2.9 /include
$ setenv HDF_LIB /home/tool/ hdf-4.2.9 /lib
$ setenv HDF4_INC /home/tool/ hdf-4.2.9 /include
$ setenv HDF4_LIB  /home/tool/ hdf-4.2.9 /lib
$ setenv HDF5_INC /home/tool/hdff5-1.8.11/include
$ setenv HDF5_LIB /home/tool/hdff5-1.8.11 /lib
$ setenv TKIO /home/tool/tkio
$ setenv CLASSPATH /home/tool/tkio/classes
$ unlimit
```

<u>Figure 5.2-1 How to Set the Environmental Variables in csh (left: gcc, right: icc)</u>

gcc case (libralies are installed in /home/tool/home/tool)	icc case (libralies are installed in /home/tool/home/tool)

```
$ export CC=gcc
$ export FORTC=ifort
$ export CFLAGS="-mcmodel=medium"
$ export FFLAGS="-fpp -mcmodel=medium -shared-intel"
$ export HDF_INC=/home/tool/ hdf-4.2.9 /include
$ export HDF_LIB=/home/tool/ hdf-4.2.9 /lib
$ export HDF4_INC=/home/tool/ hdf-4.2.9 /include
$ export HDF4_LIB= /home/tool/ hdf-4.2.9 /lib
$ export HDF5_INC= /home/tool/hdff5-1.8.11/include
$ export HDF5_LIB=/home/tool/hdff5-1.8.11 /lib
$ export TKIO= /home/tool/tkio
$ export CLASSPATH=/ home/tool/tkio/classes
$ ulimit -s unlimited
```

```
$ export CC=icc
$ export FORTC=ifort
$ export CFLAGS="- mcmodel=medium -shared-intel "
$ export FFLAGS="-fpp -mcmodel=medium -shared-intel"
$ export HDF_INC=/home/tool/ hdf-4.2.9 /include
$ export HDF_LIB=/home/tool/ hdf-4.2.9 /lib
$ export HDF4_INC=/home/tool/ hdf-4.2.9 /include
$ export HDF4_LIB= /home/tool/ hdf-4.2.9 /lib
$ export HDF5_INC= /home/tool/hdff5-1.8.11/include
$ export HDF5_LIB=/home/tool/hdff5-1.8.11 /lib
$ export TKIO= /home/tool/tkio
$ export CLASSPATH= /home/tool/tkio/classes
$ ulimit -s unlimited
```

<u>Figure 5.2-2 How to Set the Environmental Variables in bash (left: gcc, right: icc)</u>

(5) Programming with TKIO

The procedure of programming using TKIO is described below.

① Including the header files

Write statements to include the header files provided by TKIO. There is a header file common to all kind of products as well as dedicated to each sensor.

② Declaring variables of the input-output structure

Declare variables of the input-output structure defined in the TKIO header files. The names of the variables are your choice and used in the subsequent codes.

③ Opening a HDF file

Open a HDF file to be read.

④ Reading the metadata

Read each element of the metadata in the HDF file into a variable.

⑤ Reading data of each scan

If the file is one of GPM level 1 or 2 products, read the dataset for each scan.

⑥ Reading the grid data

If the file is one of GPM level 3 products, read all of the dataset at one time.

⑦ Closing the HDF file

Close the HDF file and finish the data manipulation.

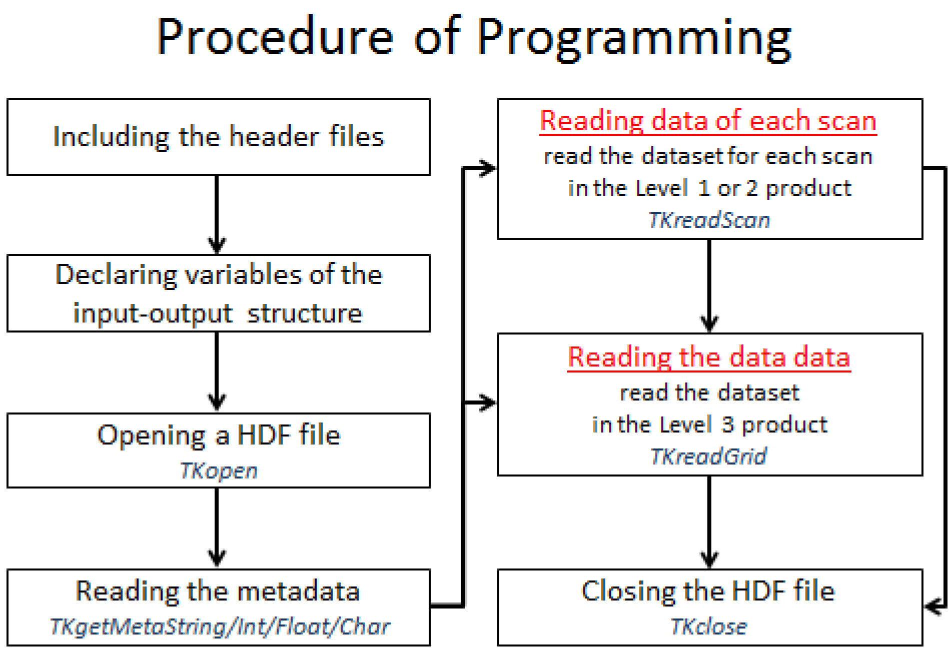


Figure 5.2-3 Procedure of Programming Using TKIO

From the other tools the users can use, h5dump and HDF Explorer are introduced below,

5.2.2. h5dump

h5dump is a command to read HDF5 files. It installed with HDF5 package. It provides the capabilities to display in text format and to clip each element in binary format.

You can download this tool from the URL below.

https://portal.hdfgroup.org/downloads/

For your reference:

HDF manual: https://portal.hdfgroup.org/documentation/index.html

HDF library installation: https://portal.hdfgroup.org/downloads/index.html

5.2.3. HDF Explorer

HDF Explorer is a tool to show data in HDF (HDF4 or HDF5) files.

You can download this tool from the URL below.

https://www.hdfeos.org/software/hdfexplorer.php

For your reference:

HDF manual: https://portal.hdfgroup.org/documentation/index.html

HDF library installation: https://portal.hdfgroup.org/downloads/index.html

5.3. File Format Conversion Tool

When HDF5 (Hierarchical Data Format 5) format is converted to the other format such as GeoTIFF, KMZ format, NetCDF4 etc. under condition of user's purpose and user's analyzing tool, data can be used for more wider purpose. It is also expected to have much more opportunity in many areas.

HDF format is used for satellite numerical data. Because multidimensional arrays and database-like tables can be nested in HDF file. However, it is needed to install some soft wares or libraries for reading HDF product, so it is too hard for the first-use researchers to use HDF products. (See Figure 5.3-1)

While, GeoTIFF format and KMZ format are useful and familiar for general user, which can be handled by general GIS software. Wider users as well as specific researchers get to use GPM products in GeoTIFF or KMZ format by viewing, editing or analyzing the GIS information (precipitation rate or statistics over map) by GIS software such as ArcGIS, QGIS, Google Earth and Image Viewers. (See Figure 5.3-2)

It is better for users, who is familiar with NetCDF4, to use NetCDF4-converted product rather than HDF5.

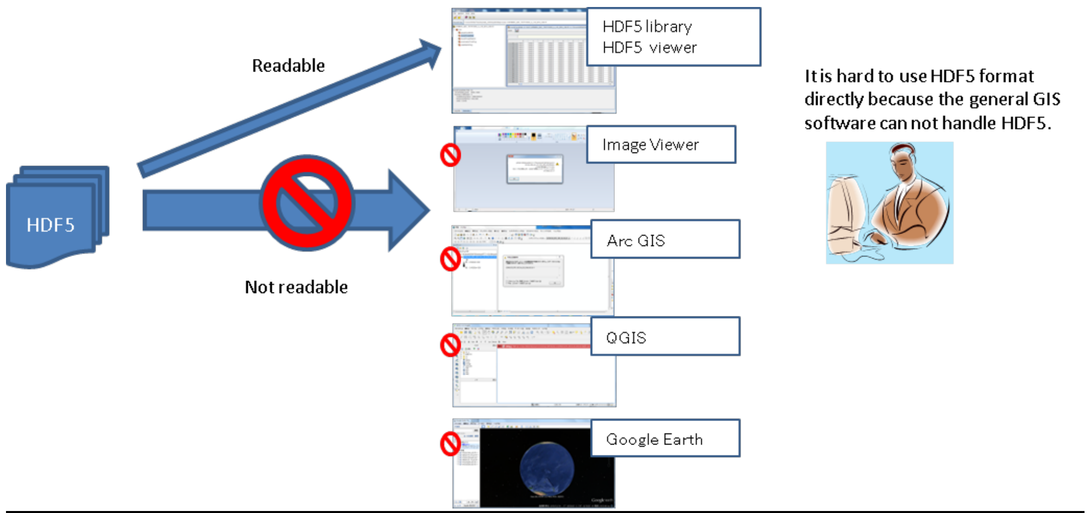


Figure 5.3-1 GPM Data Handling without Format Conversion

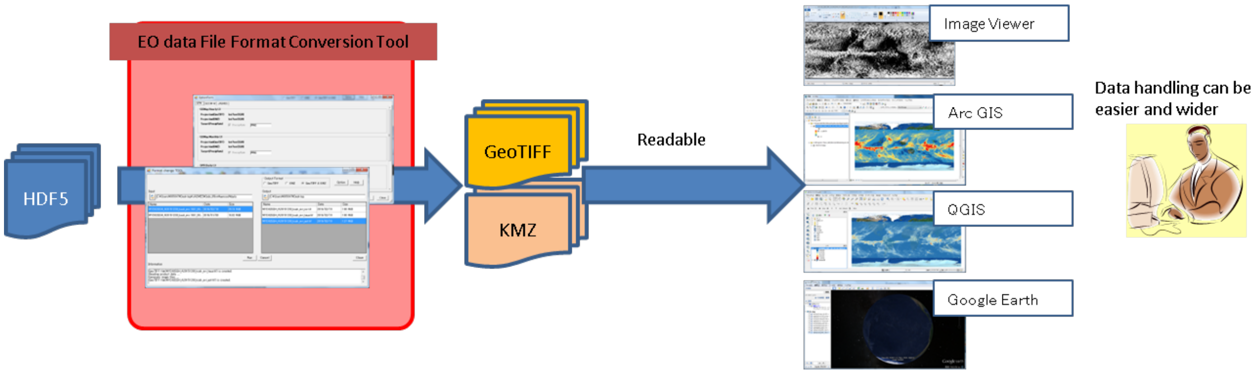


Figure 5.3-2 Expanding Data Utilization after Format Conversion

5.3.1. Earth Observation Satellite Data Format Conversion Tool

"Earth Observation Satellite Data Format Conversion Tool" is used to convert file format from HDF which is used for GPM Level 3 products (DPR L3 daily, DPR L3 monthly, GSMaP hourly and GSMaP monthly) into GeoTIFF and KMZ. This format conversion tool deal with not only GPM products but also GCOM-W/AMSR2 product and JASMES product.

Users can download this tool from the following URL;
https://gportal.jaxa.jp/gpr/information/tool?lang=en

Utilization of GPM product converted in GeoTIFF or KMZ is introduced as below.

(1) Use by Viewers

GeoTIFF format file is readable as image data by popular viewers such as the Paint and the photo viewer.

This image data is easy for editing itself and uploading SNS.

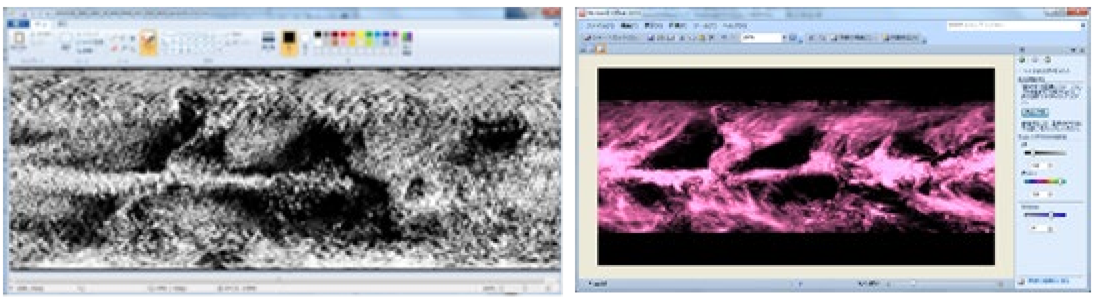


Figure 5.3-3 Example of Viewing Precipitation Data by Viewers

(2) Use by GIS Software

GeoTIFF format file can be handled by popular GIS software such as ArcGIS and QGIS. Using GIS software functions, it is easily to refer the GeoTIFF precipitation data by mapping on world map, and to analyze and edit values of data.

KMZ format file is used for Google Earth. The Google Earth application is a mapping application that offers a bird's-eye view of recorded locations across the globe, and precipitation data can be one of layer.

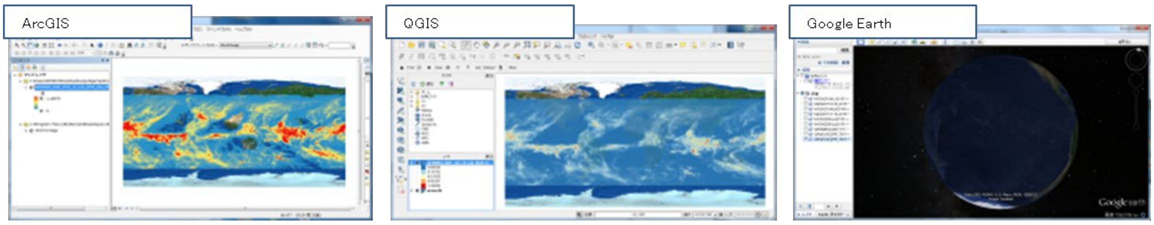


Figure 5.3-4 Example of Mapping Precipitation Data on World Map

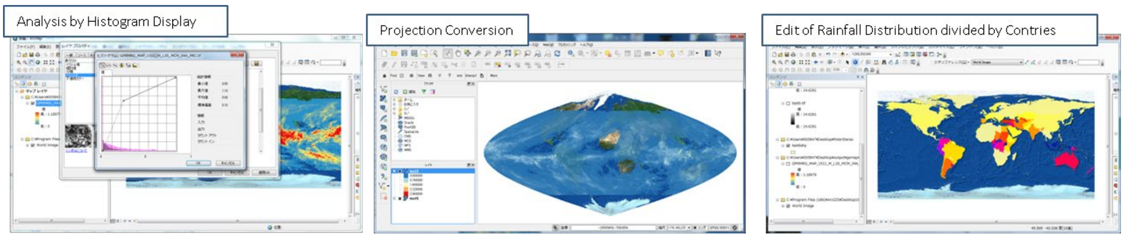


Figure 5.3-5 Example of Analyzing/Editing Precipitation Data by GIS software

(3) Use for Web Service

GeoTIFF format file can be used as image data or numerical data, which can be input source data for Web based service. There is possibility to use GPM precipitation data on web service for weather prediction, disaster prediction, and so on.

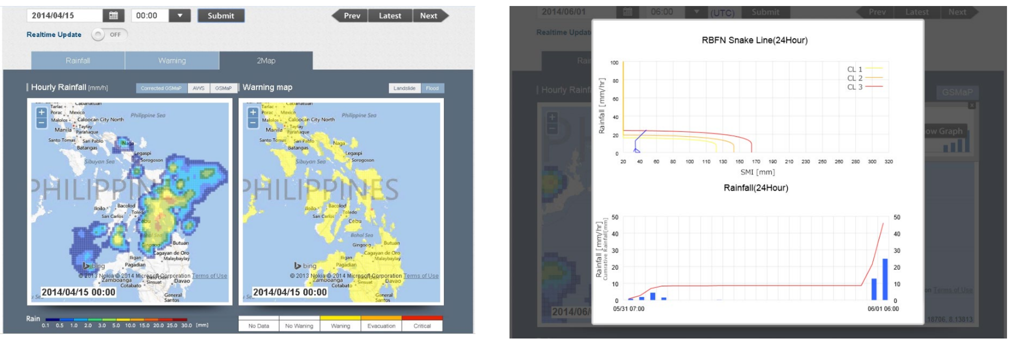


Figure 5.3-6 Example of Weather Prediction Service and Disaster Prediction Service

5.4. Sample Program

Guidebook of sample programs (C, Fortran, and IDL) to use GPM Data will be available in the near future. Japanese guidebook is available from below link;

https://www.eorc.jaxa.jp/GPM/en/data_utilization.html

Appendix 1 ACRONYMS

A

AAS : Automatic Alert System

APID : Application Process Identification

ASIST : the Web-accessible monitoring system

ASD : APID Sorted Data

AMSR2 : Advanced Microwave Scanning Radiometer 2
The sensor carried by GCOM-W

APC : Antenna Pattern Correction

ARC : Active Radar Calibrator

B

C

CFDP : CCSDSFile Delivery Protocol
A protocol for file transmission between satellites and ground systems

CERES : Clouds and the Earth's Radiant Energy System

CNES : Centre National dEtudes SpatialesEtudes Spatiales
The national space laboratory of France

COMB : Combined
Products derived from both DPR and GMI

CSH : Convective Stratiform Heating

CSHT : TRMM Convective Stratiform Heating

D

DOD : United States Department of Defense

DPR : Dual-frequency Precipitation Rader

DPS : Data Processing System

E

EACH : Earth observation Analysis Core and Hub system

EORC : Earth Observation Research Center

EIS : EORC Information System

EUMETSAT : European Organization for the Exploitation of Meteorological Satellites

E-XING : Earth Observation Satellite Mission External Interface Gateway

F

FCIF : Frequency Converter • IF unit

FS : Full Swath

G

GCOM-W1 : Global Change Observation Mission 1st-Water “SHIZUKU”

GPM : Global Precipitation Measurement

GMI : GPM Microwave Imager

G-Portal : JAXA Earth Observation Satellite Data Distribution System

GSFC : Goddard Space Flight Center

GSMaP : Global Satellite Mapping of Precipitation

H

HDF : Hierarchal Data Format

HS : High sensibility beam Scan

I

ICT : Information and Communication Technology

ICHARM : International Centre for Water Hazard and Risk Management

IDI : Infrastructure Development Institute - Japan

ISRO : Indian Space Research Organization

ITPS : Trend Analysis System

J

JAXA : Japan Aerospace Exploration Agency

JMA : Japan Meteorological Agency

K

KaPR : Ka-band Precipitation Radar

KuPR : Ku-band Precipitation Radar

L

LIS : Lightning Imaging Sensor

LNA : Low Noise Amplifier

M

MA : Multi-Access
MOC : Mission Operations Center
MS : Matched beam Scan
MWI : MicroWave Imager
MWS : MicroWave Sounder

N

NICT : National Institute of Information and Communications Technology
NASA : National Aeronautics and Space Administration
NOAA : National Oceanic and Atmospheric Administration
NRT : Near Real Time Data (Directory)

O

P

PR : Precipitation Radar
PRF : Pulse Repetition Frequency
PPS : Precipitation Processing System
PMM : Precipitation Measuring Mission

Q

R

RF : Radio Frequency

S

SCDP : System Control Data Processing
SDPS : Sensor data processing segment
SDIS : Science Data processing and Information Segment
SDS : GPM Science data Distribution Segment
SDA : Science Data Archive
SFTP : SSH File Transfer Protocol
A SSH-based protocol to safely transfer files between computers
SLH : Spectral Latent Heating
SLHT : TRMM Spectral Latent Heating
SSA : Single Service Access
SSPA : Solid-State Power Amplifier
STD : Standard

T

TRMM : Tropical Rainfall Measuring Mission
TDRS : Tracking and Data Relay Satellite
TDRSS : Tracking and Data Relay Satellite System
TMI : TRMM Microwave Imager

U

UNIX : *One of computer operation systems*
URL : Universal Resource Locator

V

VIRS : Visible and Infrared Scanner

W

WSC : White Sands Complex

X

Y

Z

Appendix 2 ASSOCIATED INFORMATION

A2.1 Reference Website

JAXA sites:

(1) JAXA home page:
https://global.jaxa.jp/

(2) GPM/DPR page:
https://global.jaxa.jp/projects/sat/gpm/

(3) JAXA/EORC home page:
https://www.eorc.jaxa.jp/en/index.html/

(4) GPM home page (JAXA/EORC)
https://www.eorc.jaxa.jp/GPM/en/index.html

(5) GPM/DPR special site:
https://www.satnavi.jaxa.jp/gpmdpr_special/

(6) GSMaP home page:
https://sharaku.eorc.jaxa.jp/GSMaP/index.htm

(7) G-Portal home page:
https://gportal.jaxa.jp/gpr/?lang=en

NASA sites:

(1) NASA home page:
https://www.nasa.gov/

(2) GPM home page:
https://gpm.nasa.gov/missions/GPM

(3) PPS home page:
https://arthurhou.pps.eosdis.nasa.gov/

(4) PPS-STORM home page:
https://storm.pps.eosdis.nasa.gov/storm/

(5) HDF home page:
https://portal.hdfgroup.org/

A2.2 Contact information

Inquiries on this handbook:

Satellite Applications and Operations Center (SAOC) Space Technology Directorate I

Japan Aerospace Exploration Agency (JAXA)

2-1-1, Sengen, Tsukuba, Ibaraki 305-8505, Japan

E-mail: GPM-MOS@ml.jaxa.jp

Appendix 3　OVERVIEW OF GPM PRODUCTS

■JAXA site：GPM (JAXA/EORC)　https://www.eorc.jaxa.jp/GPM/index_e.htm

You can download the Release Note, Format Specification, Algorithm Theoretical Basis Document (ATBD), product list and overview of GPM product from the URL below.

https://www.eorc.jaxa.jp/GPM/en/archives.html