GPM Data Utilization Handbook

First Edition

September, 2014

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 will be subsequently performed at both NASA and JAXA.

After the end of the initial functional verification phase, the GPM products of Level 1 to Level 3 will be opened for public access online at JAXA Earth Observation Satellite Data Distribution System “G-Portal” (https://www.gportal.jaxa.jp).

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.

September, 2014
Japan Aerospace Exploration Agency
GPM/DPR Project team
Earth Observation Research Center
Mission Operations System Office
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Chapter 1 INTRODUCTION

The Global Precipitation Measurement (GPM) Core Satellite was launched by H-IIB 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 six 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, and also describes the details of specification of DPR sensor and GMI sensor;

Section 3: Introduces the outline of JAXA and NASA ground system related to GPM;

Section 4: Describes the outline of data processing algorithm and data format of standard products and near–real–time products provided by JAXA;

Section 5: 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 6: 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 hours 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 river 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 SATELLITE SYSTEM

This chapter provides not only the overview of the GPM spacecraft subsystems but the specification of its onboard instruments such as DPR sensor and GMI sensor.

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.

![GPM Constellation of Satellites](image)

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 Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Centre National D’Etudes Spatiales (CNES), and Indian Space Research Organisation (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

<table>
<thead>
<tr>
<th></th>
<th>NASA</th>
<th>JAXA</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite bus</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Instruments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPR</td>
<td></td>
<td>○</td>
<td>Developed with NICT</td>
</tr>
<tr>
<td>GMI</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Launch</td>
<td></td>
<td>○</td>
<td>H-IIA Launch Vehicle</td>
</tr>
<tr>
<td>Tracking and Control</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data processing</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Data distribution</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Constellation satellites</td>
<td>NASA(USA), NOAA(USA), CNES(France)/ISRO(India), EUMETSAT(EU), JAXA, etc.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.1.2. Outline of GPM Core Satellite

GPM Core Satellite carries a 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 degree to the north latitude about 65 degree, 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.

The swaths of DPR instrument are 125 and 245 km (78 and 152 mile) for a Ka–band precipitation radar (KaPR) 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).

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 is shown in Figure 2.1–3.
Table 2.1–2 Main Characteristics of GPM Core Satellite

<table>
<thead>
<tr>
<th>Main Characteristics</th>
<th>GPM Core Observatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launcher</td>
<td>H–IIA Launch Vehicle No.23 (from Tanegashima Space Center)</td>
</tr>
<tr>
<td>Launch date</td>
<td>February 27, 2014 (UTC)</td>
</tr>
<tr>
<td>Orbit</td>
<td>Non–Sun–synchronous Circular Orbit</td>
</tr>
<tr>
<td>Altitude</td>
<td>Approx. 407 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>Approx. 65 degrees</td>
</tr>
<tr>
<td>Semi–major axis</td>
<td>Approx. 6776 km</td>
</tr>
<tr>
<td>Transmission path</td>
<td>Via NASA/Tracking and Data Relay Satellite (TDRS)</td>
</tr>
<tr>
<td>Design life</td>
<td>3 years and 2 months</td>
</tr>
<tr>
<td>Instruments</td>
<td>Dual–frequency Precipitation Radar (DPR)</td>
</tr>
<tr>
<td></td>
<td>GPM Microwave Imager (GMI)</td>
</tr>
<tr>
<td>Weight</td>
<td>Approx. 3850 kg</td>
</tr>
<tr>
<td>Dimensions</td>
<td>13.0m × 6.5m × 5.0m</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Sensor</th>
<th>Satellite</th>
<th>Period</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRMM Microwave Imager (TMI)</td>
<td>Tropical Rainfall Measuring Mission (TRMM)</td>
<td>1997–in operation</td>
<td>NASA</td>
</tr>
<tr>
<td>Sensor</td>
<td>Satellite</td>
<td>Period</td>
<td>Organization</td>
</tr>
<tr>
<td>---------------------------------------------</td>
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<td>---------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Advanced Microwave Scanning Radiometer2 (AMSR2)</td>
<td>Global Change Observation Mission – Water 1 (GCOM–W)</td>
<td>2012– in operation</td>
<td>JAXA</td>
</tr>
<tr>
<td>ATMS</td>
<td>NPP</td>
<td>Suomi NPP:2011– in operation</td>
<td>NASA</td>
</tr>
</tbody>
</table>
2.2. Outline of 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 appearance diagram of DPR is shown in Figure 2.2–1 and the main characteristics of DPR are shown in Table 2.2–1.

![Appearance of DPR](image)

**Table 2.2–1 Main Characteristics of DPR**

<table>
<thead>
<tr>
<th>Main Characteristics</th>
<th>KuPR</th>
<th>KaPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar Type</td>
<td>Active Phased Array Radar</td>
<td>Slotted Waveguide Antenna</td>
</tr>
<tr>
<td>Antenna</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>Ku-band</td>
<td>Ka-band</td>
</tr>
<tr>
<td></td>
<td>13.6GHz</td>
<td>35.55GHz</td>
</tr>
<tr>
<td>Peak Transmit Power</td>
<td>&gt; 1000W</td>
<td>&gt; 140W</td>
</tr>
<tr>
<td>Range Resolution</td>
<td>250 m</td>
<td>250 m / 500 m</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>1.67 microseconds</td>
<td>1.67 microseconds /</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.34 microseconds</td>
</tr>
<tr>
<td>Horizontal Resolution</td>
<td>5.2 km(at nadir)</td>
<td></td>
</tr>
<tr>
<td>Beam Width</td>
<td>0.71 degrees +/− 0.02 degrees (at nadir)</td>
<td></td>
</tr>
</tbody>
</table>
Main Characteristics

<table>
<thead>
<tr>
<th></th>
<th>KuPR</th>
<th>KaPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Repetition Frequency (PRF)</td>
<td>variable</td>
<td></td>
</tr>
<tr>
<td>Swath Width</td>
<td>245 km</td>
<td>125 km</td>
</tr>
<tr>
<td>Scan Interval</td>
<td>0.7 sec</td>
<td></td>
</tr>
<tr>
<td>Observable Range</td>
<td>19 km to Surface</td>
<td></td>
</tr>
<tr>
<td>Minimum Detectable Rain Rate</td>
<td>0.5 mm/hr</td>
<td>0.2 mm/hr</td>
</tr>
<tr>
<td>Receiver power accuracy</td>
<td>+/- 1 dB</td>
<td></td>
</tr>
<tr>
<td>Beam-matching Error</td>
<td>&lt;= 1000 m</td>
<td></td>
</tr>
<tr>
<td>Design life</td>
<td>3 years and 2 months</td>
<td></td>
</tr>
<tr>
<td>Data Rate</td>
<td>&lt;= 109 kbps</td>
<td>&lt;= 81 kbps</td>
</tr>
<tr>
<td>Mass</td>
<td>&lt;= 472 kg</td>
<td>&lt;= 336 kg</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>&lt;= 446 W</td>
<td>&lt;= 344 W</td>
</tr>
<tr>
<td>Dimensions</td>
<td>2.5 m x 2.4 m x 0.6 m</td>
<td>1.4 m x 1.2 m x 0.8 m</td>
</tr>
</tbody>
</table>

(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.
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>
<thead>
<tr>
<th>Operational Mode</th>
<th>Description</th>
<th>Frequency(*)</th>
<th>Note for data utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation Mode</td>
<td>During this mode, the KuPR and KaPR instruments perform normal rain echo measurements with a ( \pm 17.04 ) degree scanning capability (49 beams) for KuPR and with a ( \pm 8.52 ) degree scanning capability (49 beams) for KaPR.</td>
<td>usual</td>
<td>DPR L1 product with modes except “Observation Mode” is not able to use for physical quantities calculation like rain rate. It is necessary to check “operational mode” and to process “Observation Mode” data only.</td>
</tr>
<tr>
<td>External Calibration Mode</td>
<td>During this mode, DPR calibration and beam matching measurements between KuPR and KaPR are</td>
<td>8 times / year</td>
<td></td>
</tr>
<tr>
<td>Operational Mode</td>
<td>Description</td>
<td>Frequency(*)</td>
<td>Note for data utilization</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------</td>
<td>--------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Internal Calibration Mode</td>
<td>During this mode, DPR receiver calibration is performed by using a loopback RF signal of FCIF.</td>
<td>once / week</td>
<td>The missing value is stored in the DPR L2 product which mode is not &quot;Observation Mode&quot;.</td>
</tr>
<tr>
<td>SSPA Analysis Mode</td>
<td>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.</td>
<td>twice / year</td>
<td></td>
</tr>
<tr>
<td>LNA Analysis Mode</td>
<td>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.</td>
<td>twice / year</td>
<td></td>
</tr>
<tr>
<td>Health–Check Mode</td>
<td>Health–Check of internal function of SCDP is performed.</td>
<td>when DPR operational mode transition occurs</td>
<td></td>
</tr>
<tr>
<td>Stand–by Mode</td>
<td>This mode is used for re–loading phase code and VPRF data, changing timing offset between KuPR and KaPR, and dumping current parameters.</td>
<td>when DPR operational mode transition occurs</td>
<td></td>
</tr>
<tr>
<td>Safety Mode</td>
<td>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.</td>
<td>when anomaly of Spacecraft or DPR</td>
<td></td>
</tr>
</tbody>
</table>

(*)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
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 degree sector centered about the spacecraft ground track vector. The remaining angular sector is used for performing calibration; i.e. observation of cold space as well as observation of a hot calibration target. The 140 degree 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.
### Table 2.2-3 Main Characteristics of GMI

<table>
<thead>
<tr>
<th>Main Characteristics</th>
<th>GMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>10.65GHz(V/H), 18.7GHz(V/H), 23.8GHz, (V) 36.5GHz(V/H), 89.0GHz(V/H), 165.5GHz(V/H), 183.31±3GHz(V), 183.31±8GHz(V)</td>
</tr>
<tr>
<td>Horizontal Resolution</td>
<td>6 to 26 km</td>
</tr>
<tr>
<td>Swath Width</td>
<td>904 km</td>
</tr>
<tr>
<td>Scan Interval</td>
<td>1.875 sec</td>
</tr>
<tr>
<td>Design life</td>
<td>3 years and 2 months</td>
</tr>
<tr>
<td>Data Rate</td>
<td>&lt; 25 kbps</td>
</tr>
<tr>
<td>Weight</td>
<td>&lt; 153 kg</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>&lt; 141 W</td>
</tr>
<tr>
<td>Dimensions (diameter of antenna)</td>
<td>1.2 m</td>
</tr>
</tbody>
</table>
Chapter 3 OUTLINE OF GPM GROUND SYSTEM

This chapter describes the outline of the ground systems related to GPM operation.

3.1. GPM Ground System

GPM Ground System and its major facilities are shown in Fig.3.1-1.

GPM Core Satellite is operated by Mission Operation Center (MOC) that exists in Goddard Space Flight Center (GSFC) of NASA via Tracking and Data Relay Satellite (TDRS). The telemetry (remote measurement signal) and the observational data are received in the White Sands Complex ground station (WSC) in the United States via Tracking and Data Relay Satellite System (TDRSS) as well as the command transmission. The received data is sent to the Precipitation Processing System (PPS) immediately via MOC, and DPR, GMI, and the DPR/GMI combined higher-level processing are executed.

APID Sorted Data (ASD) is transmitted from PPS to EORC Information System (EIS) in Japan, and a standard and near–real–time processing are done in Data Processing Subsystem (DPS). The processed data are stored to EIS and provide to Earth Observation Satellite Data Distribution System “G–Portal “. The registered user (researcher etc.) search and obtain the GPM product from G–Portal.

![Figure 3.1-1 GPM Ground System](image-url)
3.2. JAXA Facility

(1) GPM/DPR Mission Operation System

The GPM/DPR mission operation system manages the mission operation of Dual-frequency Precipitation Radar (DPR) installed in GPM Core Satellite, and acquires, processes, preserves, and distributes the GPM observation data, etc.

This system consists of 2 subsystems, DPS that processes the ASD derived from NASA and EIS that manages the preservation of products and the data distribution inside and outside of this system.

(a) Data Processing Subsystem (DPS)

DPS consists of following four functions;
1) Planning of GPM/DPR mission operation
2) Monitoring, Trend analysis and Calibration processing of House Keeping (HK) data
3) Observation data processing for near–real–time and standard, re–processing
4) Algorithm test and evaluation

(b) EORC Information System (EIS)

EIS consists of following three functions;
1) Receiving and Transmission of data/products
2) Products distribution to JMA
3) Preservation management of data/products

(c) JAXA Earth Observation Satellite Data Distribution System “G-Portal”

G-Portal is a data dissemination system to search and obtain observation data preserved in the Earth Observation Satellite mission operation system for the user (general researcher etc.) through Internet.

G-Portal is aimed to provide one–stop service to search and obtain many Earth Observing Satellites data. This system also has the potential to work by small system improvement even if dissemination data increases, and can improve the performance by adding hardware.

(d) Automatic Alert System (AAS)

An Automatic Alert System is a system that receives the abnormal detection alert detected by the ground facilities including the GPM/DPR mission operation system through the mail system based on the specification, and notices promptly to proper people by the mail.

The escalation, the emergency level, etc. of each alert are managed at each facilities. The
status to alert is also managed.

(2) GPM Data Analysis System

A GPM Data Analysis System develops algorithms and software to retrieve GPM/DPR observation data, and evaluates the characteristics of DPR sensor, calibration and products. The validated software and parameters are provided to GPM/DPR mission operation system.

(3) GCOM-W Mission Operating System


This system is also gateway system in JAXA side between the Japan Meteorological Agency and JAXA, and the GPM/DPR mission operation system obtains meteorological data via the GCOM–W mission operation system.

(4) Earth observation Analysis Core and Hub system (EACH)

An Earth observation Analysis Core and Hub system (EACH) is core computing and network equipment including mission operation system and data analysis system in TKSC. This equipment is aimed to data preservation, support of data analysis and processing, data dissemination and operation management of Earth Observation data.

3.3. NASA Facility

(1) TDRSS

The role of Tracking and Data Relay Satellite System, TDRSS, is to track satellites orbit, and to relay command/telemetry between satellites and ground facilities. TDRSS ground terminals are located in White Sands, and operated remotely by MOC in Goddard Space Flight Center (GSFC).

(2) NASA/MOC

The Mission Operation Center (MOC) consists of following satellite operation related functions;
(a) Real–time housekeeping (HK) data of S/C and instruments processing (limit checking)
(b) Health and safety assessment for all instrument HK data (archival and performance trending)
(c) Generation of uplink commands
(d) Network, spacecraft, and instrument planning and scheduling
(e) Flight dynamics support

It receives telemetry from space–ground link, and performs protocol processing to close space/ground file delivery protocol (CCSDS File Delivery Protocol: CFDP).

MOC also provides to JAXA the Web–accessible monitoring system (ASIST) and Trend Analysis System (ITPS) to support DPR status monitoring. MOC manages DPR operation requests from JAXA via PPS.

(3) NASA/PPS

The Precipitation Processing System (PPS) is NASA’s measurement–based data processing system intended to support TRMM, GPM, and other NASA precipitation missions or programs.

The PPS will provide processing, information, and archiving for the joint NASA–JAXA Global Precipitation Measurement (GPM) Mission. PPS consists of following four functions;

1) Sensor Data Processing Segment (SDPS)
2) Science Data processing and Information Segment (SDIS)
3) GPM Science data Distribution Segment (SDS)
4) The Science Data Archive (SDA)

JAXA interfaces directly with two of these components: the SDPS and the SDS.

3.3.2. External Organization and facility

(1) Constellation Satellite Data Distribution Organization

Constellation Satellite Data Distribution Organization is JAXA, NASA, the National Oceanic and Atmospheric Administration (NOAA), the Department of Defense (DoD), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the Centre National d’Etudes Spatiales (CNES) of France and the Indian Space Research Organisation (ISRO). These organizations provide microwave radiometer/sounder observation data (L1) to NASA/PPS.

List of constellation satellites joined or will join to GPM is shown in Table 2.1–3. URLs are also shown below;

1) JAXA: http://global.jaxa.jp/
3) NOAA: http://pmm.nasa.gov/GPM
4) EUMETSAT: http://www.eumetsat.int/website/home/index.html
6) ISRO: http://www.isro.org/
(2) JMA

As part of Japan’s government, the Japan Meteorological Agency (JMA) implements its services with the following ultimate goals in compliance with the Act for Establishment of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Meteorological Service Act:

- Prevention and mitigation of natural disasters
- Safety of transportation
- Development and prosperity of industry
- Improvement of public welfare

To meet these goals, JMA focuses its efforts on monitoring the earth’s environment and forecasting natural phenomena related to the atmosphere, the oceans and the earth, as well as on conducting research and technical development in related fields. JMA also engages in international cooperation activities regarding both meteorology and seismology to meet Japan’s international obligations and to promote partnerships with National Meteorological and Hydrological Services as well as various related international agencies.

URL: http://www.jma.go.jp/jma/indexe.html

① GPM Data Utilization in JMA

GPM data is used for validation and accuracy evaluation of numerical weather forecasting and improvement of objective analysis, long term re–analysis, marine meteorological forecasts, typhoon analysis and geostationary meteorological satellites products.

② JMA Data Utilization in GPM

JMA data is used for the quality assurance of data and the improvement of algorithm through the comparison meteorological data with precipitation intensity and the relating metrological element obtained from GPM/DPR and GMI. JMA data is also used in higher–level processing to calculate precipitation from the data obtained from GPM/DPR, GMI and the microwave radiometer of the constellation satellites.

Global Analysis (GANAL) data is interpolated to the footprint of GPM Core Satellite and constellation satellites sensors, and distributed to users as the environmental grid data (higher–level product).

The quality assurance and the algorithm of data of the precipitation intensity obtained from DPR, GMI of GPM, and the microwave radiometer etc. of the constellation satellite and the relating metrological element is improved through the comparison with meteorological data.

(3) ICHARM

The mission of International Centre for Water Hazard and Risk Management (ICCHARM) is to serve as the Global Centre of Excellence for Water Hazard and Risk Management by providing an
adequate strategy based on the realities of various places and supporting the practice.

URL: http://www.icharm.pwri.go.jp/index.html

ICHARM develops methodologies to predict water-related hazards (floods, droughts, landslides, debris flows, tsunamis, storm surges, water contamination, and snow and ice disasters), supporting assessment of water-related risks based on Earth Observation data and Global Satellite Precipitation Map (GSMaP) provided by JAXA.

ICHARM utilizes and evaluates GSMaP data through IFAS (*1) operation, and its outcome is provided to JAXA and IDI. ICHARM validates GPM data by using Gauge-based analysis data, and its outcome is provided to JAXA.

(*1) IFAS is “Integrated Flood Analysis System” using satellites-based rainfall data developed by ICHARM for more effective and efficient flood forecasting in developing countries.

(4) IDI

Infrastructure Development Institute - Japan promotes international assistance in the development of infrastructure essential to nations’ economic development as well as to the safety and comfort of their citizens.

URL: http://www.idi.or.jp/english/00index.htm

IDI utilizes and evaluates GSMaP data through GFAS (*2) operation, and its outcome is provided to JAXA and ICHARM.

(*2) GFAS is “Global Flood Alert System” operated by International Flood Network (IFnet) to provide flood early warning and forecasting based on Earth Observation satellite precipitation data. IDI is the secretariat of IFnet.

(5) NICT

As Japan’s sole independent administrative institution specializing in the field of information and communications technology, the National Institute of Information and Communications Technology (NICT) is charged with promoting ICT sector as well as research and development in ICT, which drives economic growth and creates an affluent, safe and secure society.


NICT developed DPR installed in GPM Core Satellite as a core instrument in cooperation with JAXA. NICT monitors the performance and confirms the secular distortion of radar, and improves the precipitation presumption algorithm by DPR observation data calibration and validation (*3). As a result, highly accurate precipitation distribution information using DPR observation data is provided.
The validation of the observational data is conducted with simultaneous observation by C-band Precipitation Radar (COBRA) located in Okinawa Electromagnetic Technology Center of NICT and X-band phased-array weather radar Doppler rider integrated system (PANDA: Phased Array radar Network Data system) completed in March 2014. Also, the validation of the algorithm is carried out with balloon observation with the aim to observe the precipitation particle inside of the melting layer where snow or ice melts into raindrops in detail.
Chapter 4 GPM PRODUCT

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

4.1. Outline of the Products

4.1.1. Definition of Processing Levels

The definitions of the processing levels are shown in Table 4.1–1.

<table>
<thead>
<tr>
<th>Processing level</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>The processing input APID Sorted Data (data originated in GPM core 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.</td>
</tr>
<tr>
<td>Level 1A</td>
<td>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.</td>
</tr>
<tr>
<td>Level 1B, Level 1C</td>
<td>The processing input Level 1A data, conduct geometric corrections, and convert into received powers, brightness temperatures and so on.</td>
</tr>
<tr>
<td>Level 2</td>
<td>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, and so on.</td>
</tr>
<tr>
<td>Level 3</td>
<td>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 are one month, one day or one hour (this goes for GSMaP).</td>
</tr>
</tbody>
</table>
4.1.2. GPM Processing Diagram

Figure 4.1–1 shows the processing flow of GPM products.

4.1.3. Products

Table 4.1–2 and Table 4.1–3 respectively show JAXA standard and near–real–time 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>
<thead>
<tr>
<th>Group</th>
<th>Product</th>
<th>File size</th>
<th>Scene unit (*)</th>
<th>Provision frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR product</td>
<td>KuPR Level 1</td>
<td>Approx. 17 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>KaPR Level 1</td>
<td>Approx. 18 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>KuPR Level 2</td>
<td>Approx. 50 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>KaPR Level 2</td>
<td>Approx. 44 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>DPR Level 2</td>
<td>Approx. 93 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>DPR Level 3 (Daily average) (TEXT)</td>
<td>Approx. 10 MB</td>
<td>Global (0.1° grid, 67° N~67° S)</td>
<td>one file/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>DPR Level 3 (Daily average) (HDF)</td>
<td>Approx. 3 MB</td>
<td>Global (0.25° grid, 67° N<del>67° S; 5° grid, 70° N</del>70° S)</td>
<td>one file/ day</td>
</tr>
<tr>
<td>DPR product</td>
<td>DPR Level 3 (Monthly average)</td>
<td>Approx. 50 MB</td>
<td>Global (0.25° grid, 67° N<del>67° S; 5° grid, 70° N</del>70° S)</td>
<td>one file / month</td>
</tr>
<tr>
<td>GMI product</td>
<td>GMI Level 1B</td>
<td>Approx. 55 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>GMI product</td>
<td>GMI Level 1C</td>
<td>Approx. 25 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>GMI product</td>
<td>GMI Level 2</td>
<td>Approx. 7 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>GMI product</td>
<td>GMI Level 3 (Monthly average)</td>
<td>Approx. 3 MB</td>
<td>Global (0.25° grid, 90° N~90° S)</td>
<td>one file/ month</td>
</tr>
<tr>
<td>DPR/GMI combined product</td>
<td>DPR/GMI combined (Comb) Level 2</td>
<td>Approx. 85 MB</td>
<td>one orbit</td>
<td>Approx. 16 files/ day</td>
</tr>
<tr>
<td>DPR/GMI combined product</td>
<td>DPR/GMI combined (Comb) Level 3 (Monthly average)</td>
<td>Approx. 8 MB</td>
<td>Global (0.25° grid, 67° N<del>67° ; 5° grid, 70° N</del>70° S)</td>
<td>one file/ month</td>
</tr>
<tr>
<td>Group</td>
<td>Product</td>
<td>File size</td>
<td>Scene unit (*)</td>
<td>Provision frequency</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------------</td>
<td>------------</td>
<td>----------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>GSMaP product</td>
<td>GSMaP Level 3 (Hourly average) (HDF)</td>
<td>Approx. 4 MB</td>
<td>Global (0.1° grid, 90° N~90° S)</td>
<td>24 files/ day</td>
</tr>
<tr>
<td></td>
<td>GSMaP Level 3 (Hourly average) (TEXT)</td>
<td>Approx. 5 MB</td>
<td>Global (0.1° grid, 90° N~90° S)</td>
<td>one file/ day</td>
</tr>
<tr>
<td></td>
<td>GSMaP Level 3 (Monthly average)</td>
<td>Approx. 4 MB</td>
<td>Global (0.1° grid, 90° N~90° S)</td>
<td>one file/ month</td>
</tr>
<tr>
<td>Constellation satellite</td>
<td>DMSP F16 SSMIS Level 1C</td>
<td>Approx. 23 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td>L1C product</td>
<td>DMSP F17 SSMIS Level 1C</td>
<td>Approx. 23 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>DMSP F18 SSMIS Level 1C</td>
<td>Approx. 23 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>MetopA MHS Level 1C</td>
<td>Approx. 4 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>MetopB MHS Level 1C</td>
<td>Approx. 4 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>NOAA-18 MHS Level 1C</td>
<td>Approx. 4 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>NOAA-19 MHS Level 1C</td>
<td>Approx. 4 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>NPP ATMS Level 1C</td>
<td>Approx. 20 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>Megha Tropiques SAPHIR Level 1C</td>
<td>Approx. 10 MB</td>
<td>one orbit</td>
<td>14 files/ day</td>
</tr>
<tr>
<td></td>
<td>GCOM-W AMSR2 Level 1C</td>
<td>Approx. 85 MB</td>
<td>one orbit</td>
<td>15 files/ day</td>
</tr>
<tr>
<td></td>
<td>TRMM TMI Level 1C</td>
<td>Approx. 15 MB</td>
<td>one orbit</td>
<td>16 files/ day</td>
</tr>
</tbody>
</table>

(*) Table 4.1–4 shows the definitions of scene unit for products created in GPM mission operation system.
### Table 4.1-3 List of Near-real-time Products

<table>
<thead>
<tr>
<th>Group</th>
<th>Product</th>
<th>File size</th>
<th>Scene unit (*1)</th>
<th>Provision frequency</th>
<th>Provision latency from the observation (*2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR product</td>
<td>KuPR Level 1R</td>
<td>Approx. 10 MB</td>
<td>30 minutes</td>
<td>48 files/ day</td>
<td>Approx. 60 minutes</td>
</tr>
<tr>
<td></td>
<td>KaPR Level 1R</td>
<td>Approx. 8 MB</td>
<td>30 minutes</td>
<td>48 files/ day</td>
<td>Approx. 60 minutes</td>
</tr>
<tr>
<td></td>
<td>KuPR Level 2R</td>
<td>Approx. 16 MB</td>
<td>30 minutes</td>
<td>48 files/ day</td>
<td>Approx. 65 minutes</td>
</tr>
<tr>
<td></td>
<td>KaPR Level 2R</td>
<td>Approx. 14 MB</td>
<td>30 minutes</td>
<td>48 files/ day</td>
<td>Approx. 65 minutes</td>
</tr>
<tr>
<td></td>
<td>DPR Level 2R</td>
<td>Approx. 30 MB</td>
<td>30 minutes</td>
<td>48 files/ day</td>
<td>Approx. 65 minutes</td>
</tr>
<tr>
<td>GMI product</td>
<td>GMI Level 1BR</td>
<td>Approx. 4 MB</td>
<td>5 minutes</td>
<td>288 files/ day</td>
<td>Approx. 20 minutes</td>
</tr>
<tr>
<td></td>
<td>GMI Level 1CR</td>
<td>Approx. 2 MB</td>
<td>5 minutes</td>
<td>288 files/ day</td>
<td>Approx. 20 minutes</td>
</tr>
<tr>
<td></td>
<td>GMI Level 2R</td>
<td>Approx. 1 MB</td>
<td>5 minutes</td>
<td>288 files/ day</td>
<td>Approx. 20 minutes</td>
</tr>
<tr>
<td>DPR/GMI combined product</td>
<td>DPR/GMI combined (Comb) Level 2R</td>
<td>Approx. 30 MB</td>
<td>30 minutes</td>
<td>48 files/ day</td>
<td>Approx. 85 minutes</td>
</tr>
<tr>
<td>GSMaP product</td>
<td>GSMaP Level 3R (HDF)</td>
<td>Approx. 4 MB</td>
<td>global (0.1° grid, 90° N~90° S)</td>
<td>24 files/ day</td>
<td>Approx. 255 minutes</td>
</tr>
<tr>
<td></td>
<td>GSMaP Level 3R (TEXT)</td>
<td>Approx. 2 MB</td>
<td>global (0.1° grid, 90° N~90° S)</td>
<td>24 files/ day</td>
<td>Approx. 255 minutes</td>
</tr>
<tr>
<td>Constellation satellite L1C product</td>
<td>DMSP F16 SSMIS Level 1CR</td>
<td>Approx. 23 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 130 minutes</td>
</tr>
<tr>
<td></td>
<td>DMSP F17 SSMIS Level 1CR</td>
<td>Approx. 23 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 150 minutes</td>
</tr>
<tr>
<td></td>
<td>DMSP F18 SSMIS Level 1CR</td>
<td>Approx. 23 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 130 minutes</td>
</tr>
<tr>
<td></td>
<td>MetopA MHS Level 1CR</td>
<td>Approx. 4 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 155 minutes</td>
</tr>
<tr>
<td>Group</td>
<td>Product</td>
<td>File size</td>
<td>Scene unit (*1)</td>
<td>Provision frequency</td>
<td>Provision latency from the observation (*2)</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------</td>
<td>-----------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>MetopB MHS Level 1CR</td>
<td>Approx. 4 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 105 minutes</td>
<td></td>
</tr>
<tr>
<td>NOAA-18 MHS Level 1CR</td>
<td>Approx. 4 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 300 minutes</td>
<td></td>
</tr>
<tr>
<td>NOAA-19 MHS Level 1CR</td>
<td>Approx. 4 MB</td>
<td>1 orbit</td>
<td>14 files/ day</td>
<td>Approx. 160 minutes</td>
<td></td>
</tr>
</tbody>
</table>

(*1) Table 4.1-4 shows the definitions of scene unit for products created in GPM mission operation system.

(*2) The values are based on the actual operation from July 5th to 9th, 2014.
Table 4.1–4 Scene Definitions of Products

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Scene definition</th>
<th>Pattern diagram</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard product</td>
<td>1 orbit of observation swath from just after a southern edge to the next southern edge.</td>
<td><img src="image" alt="Pattern diagram" /></td>
<td>The lengths of orbits are different by satellites. As for GPM core satellite, it is about 92 minutes.</td>
</tr>
<tr>
<td>(Level 1/Level 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near-real-time product</td>
<td>A fixed time range.</td>
<td><img src="image" alt="Pattern diagram" /></td>
<td>Observed regions are different by scenes as scenes are not defined by dividing orbits (from a southern edge to the next). The lengths of the scenes are different by data types.</td>
</tr>
<tr>
<td>(Level 1/Level 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard product</td>
<td>A fixed spatial coverage, in which data are arrayed in a grid.</td>
<td><img src="image" alt="Pattern diagram" /></td>
<td>The grid sizes and the coverages are different by data types.</td>
</tr>
<tr>
<td>Near-realtime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Level 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.1.4. File Naming Conventions

Granule IDs are employed as file names of products. Granule ID identifies the earth observation satellite data. Granule IDs of GPM 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

KuPR level 1 (standard: STD), KuPR level 2 (STD), KaPR level 1 (STD), KaPR level 2 (STD), DPR level 2 (STD), GMI level 1B (STD), GMI level 1C (STD), GMI level 2 (STD), DPR/GMI combined level 2 (STD) and MWI/MWS L1C (STD) fall under this category. Table 4.1–5 shows the naming convention for L1 and L2 standard products.

<table>
<thead>
<tr>
<th>Table 4.1–5 Naming Convention for L1 and L2 standard products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GPMxxx _ sss _ YYMMDDhhmm _ hhmm _ nnnnnn _ LLS _ aaa _ VVv . h5</strong></td>
</tr>
<tr>
<td><strong>Field name</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>(1) Mission ID</td>
</tr>
<tr>
<td>(2) Sensor ID</td>
</tr>
<tr>
<td>(3) Scene Start</td>
</tr>
<tr>
<td>(4) Scene End</td>
</tr>
<tr>
<td>(5) Orbit Number</td>
</tr>
<tr>
<td>(6) Process Level (Level+Type)</td>
</tr>
<tr>
<td>(7) Algorithm Key</td>
</tr>
<tr>
<td>(8) Product Version</td>
</tr>
</tbody>
</table>
(2) L1 and L2 Near-real-time Products

KuPR level 1 (near-real-time: NRT), KuPR level 2 (NRT), KaPR level 1 (NRT), KaPR level 2 (NRT), DPR level 2 (NRT), GMI level 1B (NRT), GMI level 1C (NRT), GMI level 2 (NRT) and MWI/MWS level 1C (NRT) fall under this category. Table 4.1–6 shows the naming convention for L1 and L2 near-real-time products.

Table 4.1–6 Naming Convention for L1 and L2 Near-real-time Products

<table>
<thead>
<tr>
<th>JAXA field name</th>
<th>Field Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission ID</td>
<td>6</td>
<td>GPM (GPM mission, fixed), xxx (COR: GPM core satellite, etc. See Table 4.1–10)</td>
</tr>
<tr>
<td>Sensor ID</td>
<td>3</td>
<td>sss (KUR: KuPR, KAR: KaPR, CMB: DPR/GMI combined, etc. See Table 4.1–10)</td>
</tr>
<tr>
<td>Scene Start (UTC)</td>
<td>10</td>
<td>YYMMDDhhmm(UTC)</td>
</tr>
<tr>
<td>Scene End (UTC)</td>
<td>4</td>
<td>hhmm(UTC)</td>
</tr>
<tr>
<td>Process Level</td>
<td>3</td>
<td>LL (1B:Level 1B, 1C:Level 1C, L2:Level 2) R (Near real time, fixed)</td>
</tr>
<tr>
<td>Algorithm Key</td>
<td>3</td>
<td>Identify Algorithm name &amp; Developer See Table 4.1–11</td>
</tr>
<tr>
<td>Product Version</td>
<td>3</td>
<td>VV (01<del>99, Major ; count up at re-processing) v (A</del>Z, Minor)</td>
</tr>
</tbody>
</table>
(3) L3 (Hourly) Standard/Near-real-time Products

Global Satellite Mapping of Precipitation level 3 (NRT and STD) fall under this category. Table 4.1-7 shows the naming convention for L3 (Hourly) standard/near-real-time products.

Table 4.1-7 Naming Convention for L3 (Hourly) Standard/Near-real-time Products

<table>
<thead>
<tr>
<th>JAXA field name</th>
<th>Field Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Mission ID</td>
<td>6</td>
<td>GPM (GPM mission, fixed), MRG (GPM merge, fixed)</td>
</tr>
<tr>
<td>(2) Sensor ID</td>
<td>3</td>
<td>MAP (Global Satellite Mapping of Precipitation, fixed)</td>
</tr>
<tr>
<td>(3) Scene Start (UTC)</td>
<td>10</td>
<td>YYMMDhhmm(UTC)</td>
</tr>
<tr>
<td>(4) Process Unit</td>
<td>1</td>
<td>H (Hourly, fixed)</td>
</tr>
<tr>
<td>(5) Process Level</td>
<td>3</td>
<td>L3 (Level 3, fixed), t (S:Standard, N:Near real time)</td>
</tr>
<tr>
<td>(6) Algorithm Key</td>
<td>3</td>
<td>Identify Algorithm name &amp; Developer, See Table 4.1-11</td>
</tr>
<tr>
<td>(7) Product Version</td>
<td>3</td>
<td>VV (01<del>99, Major; count up at re-processing), V (A</del>Z, Minor)</td>
</tr>
</tbody>
</table>
(4) L3 (Daily) Standard Products

DPR level 3 falls under this category. Table 4.1–8 shows the naming convention for L3 (Daily) standard products.

### Table 4.1–8 Naming Convention for L3 (Daily) Standard Products

<table>
<thead>
<tr>
<th>JAXA field name</th>
<th>Field Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Mission ID</td>
<td>6</td>
<td>GPM (GPM mission, fixed)</td>
</tr>
<tr>
<td>(2) Sensor ID</td>
<td>3</td>
<td>DPR (DPR: DPR, fixed)</td>
</tr>
<tr>
<td>(3) Scene Start (UTC)</td>
<td>6</td>
<td>YYMMDD(UTC)</td>
</tr>
<tr>
<td>(4) Process Unit</td>
<td>1</td>
<td>D (Daily)</td>
</tr>
<tr>
<td>(5) Process Level</td>
<td>3</td>
<td>L3 (L3: Level 3, fixed)</td>
</tr>
<tr>
<td>(6) Algorithm Key</td>
<td>3</td>
<td>Identify Algorithm name &amp; Developer</td>
</tr>
<tr>
<td>(7) Product Version</td>
<td>3</td>
<td>VV (01~99, Major ; count up at re-processing)</td>
</tr>
</tbody>
</table>
(5) L3 (Monthly) Standard Products

DPR level 3, DPR/GMI combined level 3, Global Satellite Mapping of Precipitation level 3 and GMI level 3 fall under this category. Table 4.1–9 shows the naming convention for L3 (Monthly) standard products.

**Table 4.1–9 Naming Convention for L3 (Monthly) Standard Products**

<table>
<thead>
<tr>
<th>JAXA field name</th>
<th>Field Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission ID</td>
<td>6</td>
<td>GPM (GPM mission, fixed), xxx (COR: GPM core satellite, etc. See Table 4.1–10)</td>
</tr>
<tr>
<td>Sensor ID</td>
<td>3</td>
<td>sss (KUR: KuPR, KAR: KaPR, CMB: DPR/GMI combined, etc. See Table 4.1–10)</td>
</tr>
<tr>
<td>Scene Start (UTC)</td>
<td>4</td>
<td>YYMM (UTC)</td>
</tr>
<tr>
<td>Process Unit</td>
<td>1</td>
<td>M (Monthly)</td>
</tr>
<tr>
<td>Process Level</td>
<td>3</td>
<td>L3 (Level 3, fixed) S (Standard, fixed)</td>
</tr>
<tr>
<td>Algorithm Key</td>
<td>3</td>
<td>Identify Algorithm name &amp; Developer See Table 4.1–11</td>
</tr>
<tr>
<td>Product Version</td>
<td>3</td>
<td>VV (01<del>99, Major; count up at re-processing) v (A</del>Z, Minor)</td>
</tr>
</tbody>
</table>

As complementary information on the naming conventions, see Table 4.1–10 for satellite IDs and sensor IDs, and Table 4.1–11 for algorithm keys.

**Table 4.1–10 Satellite IDs and Sensor IDs**

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Sensor</th>
<th>Satellite ID (3 char)</th>
<th>Sensor ID (3 char)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPM Core</td>
<td>KuPR</td>
<td>COR</td>
<td>KUR</td>
</tr>
<tr>
<td></td>
<td>KaPR</td>
<td>COR</td>
<td>KAR</td>
</tr>
<tr>
<td></td>
<td>DPR</td>
<td>COR</td>
<td>DPR</td>
</tr>
<tr>
<td></td>
<td>GMI</td>
<td>COR</td>
<td>GMI</td>
</tr>
<tr>
<td></td>
<td>Combined Products</td>
<td>COR</td>
<td>CMB</td>
</tr>
<tr>
<td></td>
<td>Map Products</td>
<td>MRG</td>
<td>MAP</td>
</tr>
<tr>
<td>Satellite</td>
<td>Sensor</td>
<td>Satellite ID (3 char)</td>
<td>Sensor ID (3 char)</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Megha Tropiques</td>
<td>MADRAS</td>
<td>MGT</td>
<td>MDR</td>
</tr>
<tr>
<td></td>
<td>SAPHIR</td>
<td>MGT</td>
<td>SPH</td>
</tr>
<tr>
<td>GCOM–W</td>
<td>AMSR2</td>
<td>GW1</td>
<td>AM2</td>
</tr>
<tr>
<td>DMSP F16</td>
<td>SSMIS</td>
<td>F16</td>
<td>MIS</td>
</tr>
<tr>
<td>DMSP F17</td>
<td>SSMIS</td>
<td>F17</td>
<td>MIS</td>
</tr>
<tr>
<td>DMSP F18</td>
<td>SSMIS</td>
<td>F18</td>
<td>MIS</td>
</tr>
<tr>
<td>DMSP F19</td>
<td>SSMIS</td>
<td>F19</td>
<td>MIS</td>
</tr>
<tr>
<td>NOAA–18</td>
<td>MHS</td>
<td>N18</td>
<td>MHS</td>
</tr>
<tr>
<td>NOAA–19</td>
<td>MHS</td>
<td>N19</td>
<td>MHS</td>
</tr>
<tr>
<td>NPP</td>
<td>ATMS</td>
<td>NPP</td>
<td>ATS</td>
</tr>
<tr>
<td>METOP–A</td>
<td>MHS</td>
<td>MTA</td>
<td>MHS</td>
</tr>
<tr>
<td>METOP–B</td>
<td>MHS</td>
<td>MTB</td>
<td>MHS</td>
</tr>
<tr>
<td>TRMM</td>
<td>TMI</td>
<td>TRM</td>
<td>TMI</td>
</tr>
</tbody>
</table>

**Table 4.1–11 Algorithm Keys**

<table>
<thead>
<tr>
<th>Processing Algorithm</th>
<th>Algorithm Key (3 char)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KuPR Level 1B</td>
<td>DUB</td>
</tr>
<tr>
<td>KaPR Level 1B</td>
<td>DAB</td>
</tr>
<tr>
<td>KuPR Level 2</td>
<td>DU2</td>
</tr>
<tr>
<td>KaPR Level 2</td>
<td>DA2</td>
</tr>
<tr>
<td>DPR Level 2</td>
<td>DD2</td>
</tr>
<tr>
<td>DPR Level 3 (Daily, Text)</td>
<td>D3D</td>
</tr>
<tr>
<td>DPR Level 3 (Daily, HDF5)</td>
<td>D3Q</td>
</tr>
<tr>
<td>DPR Level 3 (Monthly)</td>
<td>D3M</td>
</tr>
<tr>
<td>GMI Level 1B</td>
<td>G1B</td>
</tr>
<tr>
<td>GMI Level 1C</td>
<td>G1C</td>
</tr>
<tr>
<td>GMI Level 2</td>
<td>GL2</td>
</tr>
<tr>
<td>GMI Level 3</td>
<td>GL3</td>
</tr>
<tr>
<td>DPR/GMI Combined Level 2</td>
<td>CL2</td>
</tr>
<tr>
<td>DPR/GMI Combined Level 3</td>
<td>CL3</td>
</tr>
<tr>
<td>MWI/MWS Level 1C</td>
<td>Sensor ID</td>
</tr>
<tr>
<td></td>
<td>Refer to Table 4.1–10</td>
</tr>
<tr>
<td>GSMaP (Hourly, Standard, HDF5)</td>
<td>MCH</td>
</tr>
<tr>
<td>GSMaP (Hourly, Standard, Text)</td>
<td>MCT</td>
</tr>
<tr>
<td>GSMaP (Hourly, Near–Real–Time, HDF5)</td>
<td>MFW</td>
</tr>
<tr>
<td>GSMaP (Hourly, Near–Real–Time, Text)</td>
<td>MFT</td>
</tr>
<tr>
<td>GSMaP (Monthly)</td>
<td>MCM</td>
</tr>
</tbody>
</table>

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.
4.2. DPR Product

4.2.1. Processing Description

(1) Level 1

DPR level 1 algorithm consists of DPR level 1A algorithm and DPR level 1B algorithm. The algorithms for KuPR and KaPR are developed independently from each other. Therefore, there are 4 algorithms.

Figure 4.2–1 shows the processing flow of DPR level 1A algorithm. The input data are the science telemetries, the HK telemetries and satellite ancillary data. The output data is DPR level 1A data. The main works of DPR level 1A algorithm are to cut out data included in the granule and to check telemetries against the predefined limits.

Figure 4.2–2 shows the processing flow of DPR level 1B algorithm. The input data are DPR level 1A data, attitude data and orbit data. The output is DPR level 1B product (received power profile, latitude, longitude, propagation distance, etc.). There are 3 main works on DPR level 1B algorithm. The first one is the limit check of system noise and satellite altitude. The second one is radiometric correction (thermal correction and received power calculation including calibration). The last one is geometric calculation. The secondary works are quality flag judgment, missing data handling, and so on.
(2) Level 2

Figure 4.2–3 shows the processing flow of DPR level 2 algorithm. The algorithm estimates precipitation intensities with complementary use of received power profiles observed by KuPR and KaPR. It also clears side lobe clutters, and estimates precipitation types, precipitation top heights and bright band heights. The algorithm was developed based on TRMM/PR standard algorithm, being added the function to use information obtained by dual-frequency observation. In TRMM/PR level 2 standard processing, there are 3 main algorithms. In DPR, those are treated as a single algorithm including several modules. The algorithm was developed so as to be able to apply both TRMM/PR and KuPR in order to create long duration data.

The input data are level 1 products (received power profile, etc.). The output data are level 2 products (precipitation intensity profile, etc.).

The standard algorithm creates KuPR, KaPR and DPR products. The KuPR products are created by using only KuPR observations and cover the wide swath (about 245 km width). The KaPR products are created by using only KaPR observations and cover the narrow swath (about 125 km width). DPR products are created by using for narrow swath both KuPR and KaPR observations, and for wide swath KuPR observations and extrapolated information from KuPR and KaPR observations on narrow swath.

(3) Level 3

The level 3 algorithm inputs the level 2 products (precipitation intensity profile, etc.) and
outputs the level 3 products (daily/monthly-averaged precipitation amount). The algorithm conducts spatial and temporal statistical processing to the outputs of level 2 standard algorithm. There are only standard algorithms in level 3.

4.3. GMI Product

4.3.1. Product Description

GMI products are created by processing on NASA/PPS. There are level 1B, 2 and 3 products. Additionally, there are level 1C products, which are intended to use in order to calibrate brightness temperatures of microwave radiometers.

4.3.2. Processing Description

(1) Level 1

The Level 1 processing transforms Level 0 counts into antenna temperatures and brightness temperatures. Antenna temperatures are obtained by utilizing the sensor radiometric calibration and geometric transformation. Brightness temperatures are obtained from antenna pattern Correction (APC) and antenna temperatures.
(2) Level 2

An algorithm called GPROF is applied to GMI level 2 processing as well as constellation satellite microwave sensor level 2 processing. In this algorithm, brightness temperatures observed by the microwave sensor are compared with those calculated beforehand based on meteorological observation model data, ground radars, TRMM/PR and so on.

This algorithm searches an a–priori database of potential rain profiles and retrieves a weighted average of these entries based upon the proximity of the observed brightness temperature to the simulated brightness temperature corresponding to each rain profile. The output data are near–real–time (NRT) products, standard products and climatological products.

(3) Level 3

The level 3 processing inputs level 2 products, and averages precipitation amounts and related physical quantities over one month for each of 0.25 degree grids.

4.4. DPR/GMI Combined Product

4.4.1. Product Description

DPR/GMI combined products are created by processing on NASA/PPS, inputting KuPR level 2, DPR level 2 and GMI level 1C products. There are the level 2 and 3 products. A level 2 product is created by utilizing 1 scene of DPR and GMI data. Its resolution is same as DPR. The level 3 products show monthly–averaged precipitation amounts calculated from the level 2 products. Its resolution is 5 degree square or 0.25 degree square.

4.4.2. Processing Description

(1) Level 2

DPR/GMI combined products are a kind of precipitation products and derived with complementary use of DPR and GMI. In order to estimate precipitation intensities, the algorithm uses atmospheric physical parameters and earth surface property parameter, e.g. cloud water amounts or water vapor contents, which cannot be directly derived from DPR but can from GMI. The input data are DPR L2 and GMI L1 products (brightness temperature for each frequency channel). The output is precipitation intensity profiles.

(2) Level 3

The level 3 processing inputs level 2 products, and averages precipitation amounts and related physical quantities over one month for each of 0.25 degree grids.
4.5. Global Satellite Mapping of Precipitation

4.5.1. Product Description

Global Satellite Mapping of Precipitation (GSMaP) is temporal and spatial averaged Level 3 rain rate product, which is derived from precipitation retrieval data observed by microwave Imagers/sounders including the GPM Microwave Imager (GMI) and cloud moving information by geostationary satellite infrared (IR) images.

The coverage of GSMaP is global (from 90 deg. North to 90 deg. South). The spatial resolution of grid is 0.1 degree, and temporal resolution is 1 hour. The global rainfall map is offered hourly in Near–Real–Time (available four hours after observation).

4.5.2. Processing Description

An overview of the processing flow is shown in Figure 4.5–1. The input data are database with DPR/GMI, microwave radiometer (MWI/MWS) data, geostationary satellite IR data, rain–gauge data, and, atmosphere and surface physical quantity. The output data is GSMaP (hourly and monthly rainfall rate).

![Figure 4.5–1 GSMaP Processing Flow](image-url)
4.6. Constellation Satellite Level 1C Product

4.6.1. Product Description

The constellation satellites Level 1C products are common inter-calibrated microwave brightness temperature (Tc) products for GPM Core and Constellation satellites using the GPM Microwave Imager (GMI) as the reference standard. These products are used as input data to GSMaP. Please refer Table 4.1–2 for current list of Level 1C products available from G-Portal.

The L1C products contain brightness temperatures that have been converted from microwave radiometer (MWI/MWS) antenna temperature to brightness temperature, and inter-calibrated using the GMI as the reference standard. In the standard products, data coverage is aligned to south to south of each constellation satellite orbit.

4.7. Product File Format

GPM Level 1 to 3 products are written in HDF5 (Hierarchical Data Format 5). See chapter 6 for the data dump or visualize tools like THOR and HDFVIEW.

Some of Level 3 products are plain text format.

Please refer Appendix 3 for the detailed product format specification.

4.8. 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 data 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.

4.8.1. 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 4.8–1. 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 4.8-1 External Calibration and Internal Calibration

<table>
<thead>
<tr>
<th>Mode</th>
<th>Contents</th>
<th>Measurement items</th>
</tr>
</thead>
<tbody>
<tr>
<td>External calibration</td>
<td>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.</td>
<td>transmitting power and received power antenna pattern for alongtrack direction and crosstrack direction beam matching between KuPR and KaPR</td>
</tr>
<tr>
<td>Internal calibration</td>
<td>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.</td>
<td>the I/O characteristic of SCDP and FCIF</td>
</tr>
</tbody>
</table>

#### 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>
<thead>
<tr>
<th>Mode</th>
<th>Frequency</th>
<th>Place</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>External calibration</td>
<td>two seasons per year (5 times per season)</td>
<td>Pass over radar calibrator set point (around Tsukuba area)</td>
<td>about 5 minutes</td>
</tr>
<tr>
<td>Internal calibration</td>
<td>approximately once per week</td>
<td>When delta V maneuver performs</td>
<td>about 30 minutes</td>
</tr>
</tbody>
</table>

#### 4.8.2. 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, by reflecting the results to level 2 and 3 algorithms.
Table 4.8–3 Success Criteria of GPM/DPR Project

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

(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 are 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 4.8-4 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>
<thead>
<tr>
<th>Level</th>
<th>Algorithm</th>
<th>Product</th>
<th>Target for calibration/validation</th>
<th>Data used for calibration/validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>KuPR</td>
<td>Received power</td>
<td>External calibration data, Internal calibration data</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KaPR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td>DPR</td>
<td>reflection intensity, precipitation profile</td>
<td>Ground-based radar (in Okinawa and Sapporo), X-net of National Research</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KuPR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>KaPR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DPR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(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

You can see the result of product evaluation on the page whose URL is below.

http://www.eorc.jaxa.jp/GPM/doc/cal_val_e.htm
Chapter 5 GETTING GPM PRODUCTS AND IMAGES

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

5.1. 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>
<thead>
<tr>
<th>Provided thing</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard products</strong></td>
<td>JAXA &gt; G–Portal</td>
</tr>
<tr>
<td>They are the products with the accuracy</td>
<td><a href="https://www.gportal.jaxa.jp/">https://www.gportal.jaxa.jp/</a></td>
</tr>
<tr>
<td>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 4.</td>
<td>sftp.gportal.jaxa.jp</td>
</tr>
<tr>
<td><strong>Research products</strong></td>
<td>NASA &gt; Precipitation Processing System (PPS)</td>
</tr>
<tr>
<td>They are not accuracy–guaranteed, but provided as they are useful.</td>
<td>Data Products Ordering Interface (STORM)</td>
</tr>
<tr>
<td></td>
<td><a href="https://storm-pps.gsfc.nasa.gov/">https://storm-pps.gsfc.nasa.gov/</a></td>
</tr>
<tr>
<td><strong>Images and results of application researches</strong></td>
<td>JAXA &gt; Earth Observation Research Center &gt; GPM</td>
</tr>
<tr>
<td>They are created from data of GPM and other satellite, and show precipitation amounts or typhoons in an easy–to–understand way.</td>
<td><a href="http://www.eorc.jaxa.jp/GPM">http://www.eorc.jaxa.jp/GPM</a></td>
</tr>
<tr>
<td></td>
<td>NASA &gt; Precipitation Processing System (PPS)</td>
</tr>
<tr>
<td></td>
<td>Data Products Ordering Interface (STORM)</td>
</tr>
<tr>
<td></td>
<td><a href="https://storm-pps.gsfc.nasa.gov/">https://storm-pps.gsfc.nasa.gov/</a></td>
</tr>
<tr>
<td><strong>Operational information on the satellite and sensors</strong></td>
<td>JAXA &gt; G–Portal</td>
</tr>
<tr>
<td>The information regarding operation status and data missing are provided.</td>
<td><a href="https://www.gportal.jaxa.jp/">https://www.gportal.jaxa.jp/</a></td>
</tr>
<tr>
<td></td>
<td>NASA &gt; Precipitation Processing System (PPS)</td>
</tr>
<tr>
<td></td>
<td><a href="http://pps.gsfc.nasa.gov/">http://pps.gsfc.nasa.gov/</a></td>
</tr>
</tbody>
</table>
5.1.1. 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 5.1.5 for the usage note.

(1) JAXA G-Portal [https://www.gportal.jaxa.jp/](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. 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 5.1–1.

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 SFTP is also provided for users who want to get a large amount of data at one time. See Figure 5.1–2. In order to use the functionality, you should make and register a public key in advance.

You can directly get near–real–time products from the SFTP 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 5.1–3. The near–real–time products are removed from the SFTP 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.

See 5.2 and/or G–Portal user manual for the usage of G–Portal, the procedure to create and register a public key, and so on.
Figure 5.1-1  JAXA Standard Product Providing Service (G-Portal homepage)

Figure 5.1-2  G-Portal SFTP Server
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).

5.1.2. 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

http://www.eorc.jaxa.jp/GPM

The research products of JAXA are available from EORC website. As of now, there is no research product for GPM. There are links to research outcome of TRMM on the site.
(2) NASA STORM  [https://storm-pps.gsfc.nasa.gov/](https://storm-pps.gsfc.nasa.gov/)

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.

### 5.1.3. 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

http://www.eorc.jaxa.jp/GPM

In “Data & Brows” tab of the site, you can find the links to G–Portal, which provides the standard products, and that to “JAXA Global Rainfall Watch” page. You can also find “JAXA Global Rainfall Watch” banner on the right side of “Home” tab.

![Figure 5.1-6](image)

(a) JAXA Global Rainfall Watch  http://sharaku.eorc.jaxa.jp/GSMaP/index_e.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.
(b) Tropical Cyclone Database and Real-Time Monitoring

http://sharaku.eorc.jaxa.jp/TYP_DB/index_e.shtml
http://sharaku.eorc.jaxa.jp/TYPHOON_RT/index_j.html

From Tropical Cyclone Database site, you can download data of tropical cyclones around the world, which are obtained by the earth observation satellites (TRMM/PR, TMI, VIRS, GCOM–W/AMSR2, Aqua/AMSR–E and ADEOS–II/AMSR). The images of tropical cyclones for the latest 2 weeks are available from Real–Time Monitoring site.

Data from GPM will come into those sites.
Figure 5.1-8  Tropical Cyclone Database
(2) NASA Precipitation Measurement Mission (PMM)  [http://pmm.nasa.gov/](http://pmm.nasa.gov/)

In “Science” and “Application” tabs of NASA/PMM site, images of GPM data are introduced with interpretations.
5.1.4. 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.

NASA/PPS: http://pps.gsfc.nasa.gov/ (under “Documentation”)

Figure 5.1–11 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.
Figure 5.1-12  Links to Movies Introducing the Observation

Figure 5.1-13  Link to the Format Specification
Figure 5.1-14  Link to the Tools to Display and Analyze the Products

5.1.5. 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.

<table>
<thead>
<tr>
<th>Kind of data</th>
<th>Credit</th>
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</thead>
<tbody>
<tr>
<td>DPR, GMI and COMB</td>
<td>The NASA/JAXA GPM project and the other GPM Partners</td>
</tr>
<tr>
<td>GSMAp</td>
<td>JAXA</td>
</tr>
</tbody>
</table>

5.2. Usage of the Data Distribution Service

5.2.1. Service Descriptions

JAXA G–Portal provides products of various earth observation satellites of JAXA. Once you complete the user registration, you can search and download various products with it. Without user registration, you can search data and get information like operation status of satellites, format specification, toolkits, and so on.

In the following subsections, the procedure to get GPM products from G–Portal is shown.
5.2.2. User Registration

You should complete user registration to order and download products by using this service. Please note that the user registration is not required if you want only to search and browse products. The following outlines the procedures required for user registration.

2. Click “User Registration” from the menu.

![Figure 5.2-1 Webpage of G-Portal #1](image1)

3. To be registered, you should agree to the terms of use. Read through the terms and click the “Registration agree” button.

![Figure 5.2-2 Webpage of G-Portal #2](image2)

4. Enter all required information (user account, name, email address, organization/department, country name, language used for email, purpose of use, and Notification Email for ready) and click the “Next” button.
5. The user information you have entered will be displayed, so check that the details are correct. Click the “Register” button to temporarily register the user.

6. With the following page displayed, the temporary registration is done. A “User Registration Confirmation Email” will be sent to the email address you specified. At this phase, the user registration is not yet complete, so you cannot log in.

7. Access the URL included in the “User Registration Confirmation Email” to complete the registration.
8. The following page will be displayed and you will receive the “User Registration Confirmation Email”. The registration is complete. You can now log in with the account and get GPM products.

![Figure 5.2-5 Webpage of G-Portal #5](image)

**5.2.3. Login**

You should log in with a registered account to order and download GPM products.

2. Enter the user account and password at the top of the window.
3. Click the “Login” button.

![Figure 5.2-6 Webpage of G-Portal #6](image)

4. “Login complete” will be displayed at the top of the window after you have successfully logged in.

Below are the possible causes of the login failure:
- the user account and/or the password are incorrect.
- the user account is locked
5.2.4. Product search and Download

(1) Direct Download

The direct download functionality via SFTP employs a public key authentication. You should make and register a public key in advance. See G–Portal user manual (https://www.gportal.jaxa.jp/gportal_file/contents/help/UserManual_ja.pdf) for details. Here, the procedure is briefly described.

① Generating a Public Key

a) UNIX (including Mac OS X)

1. Open a terminal window and run the following command.

   $ ssh-keygen

2. The following message will be displayed requesting you to enter the directory where public and private keys will be saved.

   Enter file in which to save the key (/Users/Username/.ssh/id_rsa)

   Enter the directory name and save file name if you want to specify them.

   Pressing [enter] without entering a name will configure the default directory /Users/Username/.ssh as the location to save id_rsa (private key) and id_rsa.pub (public key).

3. The following message will be displayed requesting you to enter the passphrase to decode the private key.

   Enter passphrase(empty for no passphrase):

   Enter a passphrase if you want to configure to request it when connecting with SFTP.

   By the procedure above, a pair of a public and a private keys are generated.

② Registering the Public Key

1. After logging in G–Portal with your user account, click “View/Change User Property” from the menu. The View/Change User Property window will be displayed.
2. Click “Register/Update Public Key” link. The Register/Update Public Key window will be displayed.

3. Click the “Browse” button to specify the public key file. If a public key has already been registered, it will be overwritten to the specified public key. Click “Register” button. The Registration Complete window will be displayed and the new...
public key will be registered with the system.

![Figure 5.2-10 Webpage of G-Portal #10](image)

4. Public Key Registration Complete dialog box will be displayed.

![Figure 5.2-11 Webpage of G-Portal #11](image)

3. **Downloading**
   
   ◆ access
   
   1. Enter the following command to access G-Portal via SFTP.
      
      ```
      $ sftp -oPort=2051[Account]@sftp.gportal.jaxa.jp
      ```
   
      2. “Password:” will be displayed. Enter your password.
      
      The following will be displayed if you have logged in successfully:
      
      ```
      sftp>
      ```
   
   ◆ list
      
      Enter
      
      ```
      sftp> ls
      ```
      
      to display a list of files and directories.
   
   ◆ change directories
      
      Enter
      
      ```
      sftp> cd [Directory Name]
      ```
      
      to move to a specific directory.
   
      * Note: Due to access restrictions, you might not be able to move to a directory even if it is displayed in the list.
download a file

Enter
sftp> get [File Name]
to get a file.
The specified file will be downloaded and saved in a directory on your computer.

close

Enter
sftp> exit
to close SFTP.

Figure 5.2–12 and Figure 5.2–13 show the directory structure. Please note that there are not “Processing Products” for GPM.

**Figure 5.2–12** Directory structure of G–Portal direct download (standard product)
(2) Download with a Web Browser

To get products by using a web browser, you should first search the products, and should then order and download the products. There are 3 approaches to search the products, i.e. (a) by physical quantities, (b) by spacecrafts/sensors and (c) by saved condition. See G–Portal user manual (https://www.gportal.jaxa.jp/gportal_file/contents/help/UserManual_ja.pdf) for details. Here, the procedure is briefly described.

Figure 5.2–14 Webpage of G–Portal #12

① Searching Products

(a) Search by Physical Quantities

You can search products by specifying physical quantities, periods and regions.

1. Click the “Select by Physical Quantities” button at the center of the home window or click
the “Search Products” -> “Select by Physical Quantities” link from the menu. The window will switch to the Physical Quantities Selection window.

2. Click the name of the physical quantities. You can click multiple physical quantities. Click the “Next” button at the top of the window.

3. A physical quantity list contained in the physical quantities that you clicked in 2 will be displayed.
   Click the physical quantity name to be searched. You can click multiple physical quantity names.
   Click the “Next” button at the top of the window.
4. Specify the period to be searched.

5. Specify the region to be searched.
6. Click the “Search” button at the top of the page to start the search.

(b) Search by Spacecrafts/sensors

1. Click the “Select by Spacecrafts/Sensors” button at the center of the home window or click the “Search Products” → “Select by Spacecrafts/Sensors” link from the menu. The window will switch to the Spacecrafts/Sensors Selection window.

2. A list of spacecrafts/sensors will be displayed in the Spacecrafts/Sensors Selection window. Click the button of the spacecrafts/sensors to be searched. You can click multiple spacecrafts/sensors. Click the “Next” button at the top of the window.
3. The products contained in the spacecrafts/sensors that you selected in 2 will be displayed. Click the product name to be searched. You can click multiple products. Click the “Next” button at the top of the window.

4. The subsequent operation is the same as (a).

(c) Search by Saved Condition
1. Click the “Load saved conditions” button at the center of the home window or click the
“Search Products” → “Load saved conditions” link from the menu.
A pop-up window will be displayed.
2. Select one of the conditions, and click “Load”.
3. A window will be displayed with the search conditions entered, and allowing you to specify the period and region. Check the search conditions and click the “Search” button at the top of the window to start the search.

② Ordering and Downloading Products

You can order and download products only when you log in.

(a) Order

You can order products from the search results window.
1. After logging in, search for the products.
   In the search results window, click the products that you want to order, and click the “Next” button.
   The “My List” window will be displayed.
2. Check the My List and click the “Next” button.
3. Check the order details and click the “Order” button.
4. After the order is complete and preparations for the download have been completed, a Notification Email for ready will be sent from the G-Portal system.

(b) Download

You can download products after you have received a Preparation Complete Notification Email from the system.
1. After logging in, click “Download Information” from the menu.
   The Download Information window will be displayed.
2. Enter the order number or order date as the search conditions and click the “Search” button.
   Click the file name to start downloading the product.
Chapter 6 UTILIZATION OF GPM DATA

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

6.1. Data Visualization Tools

6.1.1. THOR

THOR (Tool for High-Resolution Observation Review) is a tool to visualize TRMM and GPM standard 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
   http://pps.gsfc.nasa.gov/thorrelease.html
② Tutorial
③ Download and installation
   ftp://gpmweb2.pps.eosdis.nasa.gov/pub/THOR

For your reference:
HDF library installation: http://www.hdfgroup.org/HDF5/
Figure 6.1-1 Screen of THOR (KuPR example)

Figure 6.1-2 Screen of THOR (GSMaP example)
6.1.2. 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.

http://www.hdfgroup.org/products/java/
(http://www.hdfgroup.org/products/java/hdfview/index.html)

For your reference:

HDF library installation: http://www.hdfgroup.org/HDF5/
Figure 6.1–4 Sample screen of HDFVIEW
6.2. Data Analysis Tools

6.2.1. TKIO

TKIO (Science Algorithm Input/Output Toolkit) is a tool to read and write GPM and TRMM (V6 and V7) 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
   http://pps.gsfc.nasa.gov/ppstoolkit.html

② Download and installation
   ftp://gpmweb2.pps.eosdis.nasa.gov/pub/PPStoolkit/GPM/
   (ftp://gpmweb2.pps.eosdis.nasa.gov/pub/PPStoolkit/GPM/tkio-3.60.2/)

For your reference:
HDF library installation: http://www.hdfgroup.org/HDF5/

6.2.2. TKIO Installation and Programming

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以上
• C language: gcc or icc (Intel C Compiler)
• Fortran: Intel® Fortran Composer XE Linux edition

(2) Installing HDF5 Library (ver. 5-1.8.13 case)

② Download the library for Linux (hdf5-1.8.13.tar.bz2).
③ Uncompress it.
   $ tar -xjvf hdf5-1.8.13.tar.bz2
④ Prepare for the installation.
   $ cd hdf5-1.8.13
   $ ./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)

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” for details.
⑦ Compile and check.
   $ ./*INSTALL.pl compiler
   $ cd lib
   $ ls
   Libtkc.a libtkchdf4.a libtkchdf4algs.a libtkchdf5.a libtkchdf5algs.a
(4) Setting the Environmental Variables

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

**Figure 6.2-1 How to Set the Environmental Variables in csh (left: gcc, right: icc)**

```sh
# gcc case (libraries are installed in /home/tool/home/tool)
$ setenv CC gcc
$ setenv FFLAGS "-mnomodelmedium"
$ setenv HDF_LIB_HOME/tool/lib/hdf4.2.9
$ setenv HDF5_LIB_HOME/tool/lib/hdf5-1.8.11
$ setenv TKIO_HOME/tool/classes
$ unset -a UNISTD

# icc case (libraries are installed in /home/tool/home/tool)
$ setenv CC icc
$ setenv FFLAGS "-mnomodelmedium -shared-intel"
$ setenv HDF_LIB_HOME/tool/lib/hdf4.2.9
$ setenv HDF5_LIB_HOME/tool/lib/hdf5-1.8.11
$ setenv TKIO_HOME/tool/classes
$ unset -a UNISTD
```

**Figure 6.2-2 How to Set the Environmental Variables in bash (left: gcc, right: icc)**

```sh
# gcc case (libraries are installed in /home/tool/home/tool)
$ export CC=gcc
$ export FORT=fort
$ export FFLAGS="-mnomodelmedium"
$ export HDF_LIB_HOME/tool/lib/hdf4.2.9
$ export HDF5_LIB_HOME/tool/lib/hdf5-1.8.11
$ export TKIO_HOME/tool/classes
$ unset -a UNISTD

# icc case (libraries are installed in /home/tool/home/tool)
$ export CC=icc
$ export FORT=fort
$ export FFLAGS="-mnomodelmedium -shared-intel"
$ export HDF_LIB_HOME/tool/lib/hdf4.2.9
$ export HDF5_LIB_HOME/tool/lib/hdf5-1.8.11
$ export TKIO_HOME/tool/classes
$ unset -a UNISTD
```

(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 the 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.

---

**Procedure of Programming**

- Including the header files
- Declaring variables of the input-output structure
- Opening a HDF file `TKopen`
- Reading the metadata `TKgetMetaString/Int/Float/Char`
- Reading data of each scan `TKreadScan` read the dataset for each scan in the Level 1 or 2 product
- Reading the data data `TKreadGrid` read the dataset in the Level 3 product
- Closing the HDF file `TKclose`

*Figure 6.2-3 Procedure of Programming Using TKIO*
6.3. Other Tools

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

6.3.1. 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.
http://www.hdfgroup.org/products/hdf5_tools/

For your reference:
- HDF library installation: http://www.hdfgroup.org/HDF5/

6.3.2. 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.
http://www.space-research.org/

For your reference:
- HDF library installation: http://www.hdfgroup.org/HDF5/
## Appendix 1 ACRONYMS

<table>
<thead>
<tr>
<th>A</th>
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<th>Global Change Observation Mission 1st-Water “SHIZUKU”</th>
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<td>Automatic Alert System</td>
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<tr>
<td>APID</td>
<td>Application Process Identification</td>
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</tr>
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<td>ASIST</td>
<td>the Web-accessible monitoring system</td>
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<td>APID Sorted Data</td>
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<td>Global Precipitation Measurement</td>
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<td>G–Portal</td>
<td>JAXA Earth Observation Satellite Data Distribution System</td>
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<td>Goddard Space Flight Center</td>
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<td>GSMaP</td>
<td>Global Satellite Mapping of Precipitation</td>
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<tr>
<td>B</td>
<td>HDF</td>
<td>Hierarchical Data Format</td>
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<td>C</td>
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<td>CFDP</td>
<td>CCSDS File Delivery Protocol</td>
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<td>DPR</td>
<td>Dual-frequency Precipitation Radar</td>
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<td>Data Processing System</td>
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<td>Earth observation Analysis Core and Hub system</td>
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<td>GMI</td>
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<td>Frequency Converter • IF unit</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>Abbreviation</td>
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<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<td>Near Real Time Data (Directory)</td>
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<td>Pulse Repetition Frequency</td>
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<td>Precipitation Processing System</td>
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<td>UNIX</td>
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</table>
Appendix 2  ASSOCIATED INFORMATION

A2.1 Reference literature

(1) Fundamental Plan for the Operation of GPM Mission Operation System (MAS-130018)
(2) Data Definition (MAS-100094)
(3) EROC Granule ID Establishment (MAS-100089)
(4) DPR Level 1 Product Format Specification (draft)
(5) GPM High-level Product Format Specification (draft)
(6) DPR Level 1B Algorithm Description (beta edition)
(7) Detailed Operational Regulations for Success Criteria Evaluation on Global Precipitation Measurement (GPM) / Dual-frequency Precipitation Radar (DPR)
(8) Mission Operations Interface Specification (MOIS) Between NASA and JAXA
(9) GPM/DPR Mission Operation System Interface Control Document
(10) Global Precipitation Measurement (GPM) Project Core Satellite Flight Operations Plan
(11) G-Portal User Manual (MAS-120025)
(12) Global Precipitation Measurement (GPM) Calibration and Validation Plan (draft)
(13) NASA Global Precipitation Measurement (GPM) Microwave Imager (GMI) Level 1B (L1B) Algorithm Theoretical Basis Document (ATBD)
(14) File Specification for GPM Products (Version 1P20 TKIO 3.50.10)
(15) GPM/DPR Operation Concept (SBG-080002)

A2.2 Reference Website

JAXA sites:
(1) JAXA home page:
   http://www.jaxa.jp/
(2) GPM/DPR page:
(3) JAXA/EORC home page:
   http://www.eorc.jaxa.jp/
(4) GPM home page (JAXA/EORC)
   http://www.eorc.jaxa.jp/GPM/index_e.htm
(5) GPM/DPR special site:
   http://www.satnavi.jaxa.jp/gpmdpr_special/
(6) GSMaP home page:
   http://sharaku.eorc.jaxa.jp/GSMaP/index_e.htm
(7) G–Portal home page:
    https://www.gportal.jaxa.jp/gp/top.html

NASA sites:
(1) NASA home page:
    http://www.nasa.gov/
(2) GPM home page:
    http://pmm.nasa.gov/GPM
(3) PPS home page:
    http://pps.gsfc.nasa.gov/
(4) PPS–STORM home page:
    https://storm-pps.gsfc.nasa.gov
(5) HDF home page:
    http://www.hdfgroup.org/

A2.3 Contact information

Inquiries on this handbook:
    G–Portal support desk
    Japan Aerospace Exploration Agency
    2–1–1, Sengen, Tsukuba, Ibaraki 305–8505, Japan
    E-mail: Z-gportal-support@jaxa.jp