Earth Observation Research Center (EORC), Japan Aerospace Exploration Agency (JAXA)

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Data Format Description for
Global Rainfall Map in Near Real Time (GSMaP_NRT) Version 5

This document describes data format and information of Global Rainfall Map in Near Real Time (hereafter refers as GSMaP_NRT) for algorithm version 5. The GSMaP (Global Satellite Mapping of Precipitation) project is based on the heritage of the study "Production of a high-precision, high-resolution global precipitation map using satellite data," sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002-2007. Since 2007, GSMaP project activities are promoted by the JAXA Precipitation Measuring Mission (PMM) Science Team.

1. Product Overview

Table 1 Summary of GSMaP_NRT Version 5 Products

No	Parameter [unit]	Data format	Coverage	Grid size	Horizontal resolution	Temporal resolution	FTP directory
1	Hourly Rain Rate [mm/h]	4-byte float plain binary, little-endian	Global (60°N-60°S)	3600 x 1200	0.1 degree grid box	Hourly	/realtime_ver/v5/hourly/**YYYY**/**MM**/**DD**/
2	Satellite Information Flag	4-byte singed integer plain binary, little-endian					/realtime_ver/v5/sateinfo/**YYYY**/**MM**/**DD**/
3	Observation Time Flag	4-byte float plain binary, little-endian					/realtime_ver/v5/timeinfo/**YYYY**/**MM**/**DD**/
4	Hourly Rain Rate in text format [mm/h]	ASCII, CSV format	Global but divided to 54 areas	200 rows x 400 lines			/realtime_ver/v5/txt/**AAABBBB**/**YYYY**/**MM**/**DD**/
5	Daily Rainfall in 0.25-deg [mm/h]	4-byte float plain binary, little-endian	Global (60°N-60°S)	1440 x 480	0.25 degree grid box	Daily (averaged from 00Z to 23Z of the specified day)	/realtime_ver/v5/daily/00Z-23Z/**YYYYMM**/
6						Daily (averaged from 12Z of previous day to 11Z of the specified day)	/realtime_ver/v5/daily/p12Z-11Z/**YYYYMM**/
7	Daily Rainfall in 0.1-deg [mm/h]			3600 x 1200	0.1 degree grid box	Daily (same as **5**)	/realtime_ver/v5/daily0.1/00Z-23Z/**YYYYMM**/
8						Daily (same as **6**)	/realtime_ver/v5/daily0.1/p12Z-11Z/**YYYYMM**/

Note: **YYYY**: 4-digit year, **MM**: 2-digit month, **DD**: 2-digit day, **AAA**: latitude of the corner of left-top position (2-degit latitude + S or N), **BBBB**: longitude of the corner of left-top position (3-degit longitude + E or W).

2. Hourly Rainfall and Flag Files in Binary (products (1)-(3))

2.1. Basic Information

Temporal resolution:	1 hour (hourly data)
Grid resolution:	0.1 degrees latitude/longitude grid (10km at the equator).
	Latitude and longitude of the first grid [1, 1] is [59.95°N, 0.05°E].
Domain:	Global (60°N-60°S)
Data archived period:	10 October 2008 - 2 September 2014

2.2. FTP Directory Information

Hourly Rain Rate data;	/realtime_ver/v5/hourly/**YYYY**/**MM**/**DD**/
Satellite Information Flag;	/realtime_ver/v5/sateinfo/**YYYY**/**MM**/**DD**/
Observation Time Flag;	/realtime_ver/v5/timeinfo/**YYYY**/**MM**/**DD**/

where;

YYYY: 4-digit year;
MM: 2-digit month; and
DD: 2-digit day.

2.3. File Naming Rules

Data and flag files are named according to the following rules;

Hourly Rain Rate data:	gsmap_nrt.**YYYYMMDD**.**HH00**.dat
Satellite Information Flag:	gsmap_nrt.**YYYYMMDD**.**HH00**.sateinfo.dat
Observation Time Flag:	gsmap_nrt.**YYYYMMDD**.**HH00**.timeinfo.dat

where;

YYYY: 4-digit year;
MM: 2-digit month;
DD: 2-digit day; and
HH: 2-digit hour.

2.4. Data Format

All binary files are produced in little-endian byte order platform, and archived with compressed using “gzip”. Grid of those files consists of 3600 rows x 1200 lines, which are longitude-latitude elements corresponding to a 0.1 x 0.1 degree grid that covers the global region from 60°N to 60°S. The center longitude and latitude of the first pixel [1, 1] (left top corner) are [0.05°E, 59.95°N] (Figure 1).

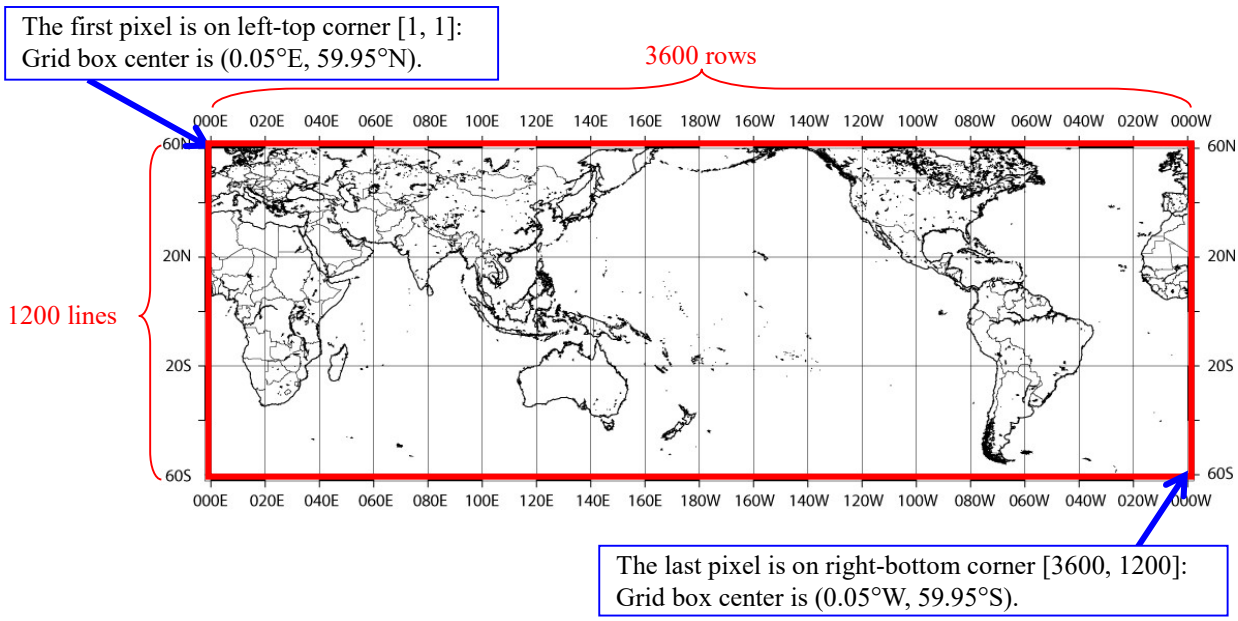

Figure 1 Data Coverage Map (Rain and Flag data)

2.5. Stored Values of Hourly Rain Rate

"Hourly Rain Rate" data are stored in 4-byte float plain binary format. Unit is [mm/hr]. Negative value denotes missing in observation data or no retrieval was done in microwave retrieval algorithm. Detailed description for missing data is shown in Table 2.

Table 2 Stored Values of Hourly Rain Rate

Value	Description
(positive)	Hourly rain rate [mm/hr].
−4	Missing due to sea ice in microwave retrieval algorithm.
-8	Missing due to low temperature in microwave retrieval algorithm.
−99	Missing due to no observation by IR and/or microwave.

2.6. Stored Values of Satellite Information Flag

"Satellite Information Flag" data are stored in 4-byte integer plain binary format. Satellite and sensor name are assigned to each bit, and the flag indicates all satellite/sensor which are used in estimation of rainfall at each pixel during one-hour time period. If the flag shows 0, there is no satellite observation by both microwave and geo-stationary IR. If flag shows negative value, there is NO microwave radiometer observation. Following meanings are assigned to each bit in 32-bit integer (Table 3).

For example, if the stored value is 1073741952, the value is the sum of "Merged IR data (1073741824)" and "NOAA-19 (128)".

Table 3 Stored Values of Satellite Information Flag

Pixel Value		Description	
Value	**Bit**	**Sensor Category**	**Satellite/Sensor**
1	0	Microwave imager and/or sounder aboard low orbital satellite	TRMM/TMI
2	1		Aqua/AMSR-E
4	2		DMSP-F13/SSM/I
8	3		DMSP-F14/SSM/I
16	4		DMSP-F15/SSM/I
32	5		DMSP-F16/SSMIS
64	6		DMSP-F17/SSMIS
128	7		NOAA-19/AMSU-A/MHS
256	8		MetOp-A/AMSU-A/MHS
512	9		DMSP-F18/SSMIS
1024	10		GCOM-W/AMSR2
2048−32768	11-15		not used
65536	16	Infrared Imager aboard Geo-stationary meteorological satellite (before 22Z 28 Mar. 2012)	GOES-EAST
131072	17		GOES-WEST
262144	18		INDEX
524288	19		METEOSAT
1048576	20		MTSAT
2097152−536870912	21−29		not used
1073741824	30	Infrared Imager aboard Geo-stationary meteorological satellite (since 23Z 28 Mar. 2012)	
−(negative)	31	No microwave radiometer observation	

2.7. Stored Values of Observation Time Flag

"Observation Time Information Flag" are in 4-byte float plain binary format. The Flag indicates relative time of latest microwave radiometer observation at each pixel, and 0 means start time of the file (**HH** in file name). Values are stored as indicated in Table 4.

Table 4 Stored Values of Observation Time Flag

Value	Description
$0 \leq X < 1$	If value is positive, microwave radiometer observation is available at the pixel during current one-hour period. X ($0 \leq X < 1$) indicates relative observation time of latest microwave radiometer, and is stored as differences from the start time of the file. For example, if UTC of the file (**HH**) = "01" and X = 0.2, observation time of the pixel will be 01:12 UTC.
$X \leq 0$	If value is negative, NO microwave radiometer observation is available at the pixel during time period of the file. X ($X \leq 0$) indicates relative observation time of latest microwave radiometer, and stored as differences from the start time of the file. For example, if UTC of the file (**HH**) = "01" and X = −2.5, latest observation time of microwave radiometer at the pixel will be 22:30 UTC of previous day.
X = −999	No microwave observation (Missing)

2.8. GrADS Control File

Sample control files of the Grid Analysis and Display System (GrADS) for each product are also available from ftp server.

Hourly Rain Rate data: /realtime_ver/v5/sample/GSMaP_NRT.hourly.rain.ctl
Satellite Information Flag: /realtime_ver/v5/sample/GSMaP_NRT.hourly.sat.ctl
Observation Time Flag: /realtime_ver/v5/sample/GSMaP_NRT.hourly.time.ctl

About usage of GrADS tool, please see GrADS home page (http://cola.gmu.edu/grads/grads.php).

2.9. File Size

Approximately 800 Kbyte (with gzip), and 17 Mbyte (uncompress) for each file.

3. Hourly rainfall in text format (product (4))

3.1. Basic Information

Temporal resolution: 1 hour (hourly data)
Grid resolution: 0.1 degrees latitude/longitude grid (10km at the equator).
Domain: Global (60°N-60°S), but data are divided into 54 subset area files (area of 40 degree for latitude, 20 degree for longitude).
Data archived period: 10 October 2008 - 2 September 2014

3.2. FTP Directory Information

Data files are archived at following directory;

/realtime_ver/v5/txt/**AAABBBB**/**YYYY**/**MM**/**DD**/

where;

YYYY: 4-digit year;
MM: 2-digit month;
DD: 2-digit day;
AAA: The corner of left-top position is appeared with Latitude (2-degit latitude + S or N); and
BBBB: The corner of left-top position is appeared with Longitude (3-degit longitude + E or W).

3.3. File Naming Rules

Data files are named according to following rules;

gsmap_nrt.**YYYYMMDD**.**HH00**.**AAABBBB**.csv

where;

YYYY: 4-digit year;
MM: 2-digit month;
DD: 2-digit day;
HH: 2-digit hour;
AAA: The corner of left-top position is appeared with Latitude (2-degit latitude + S or N); and
BBBB: The corner of left-top position is appeared with Longitude (3-degit longitude + E or W).

3.4. Data Format

Text files are stored in CSV format. Unit is [mm/hr]. Negative value denotes missing in observation data or no retrieval same as binary format data (see Table 2).

Each file is one of global coverage fractionated 54 areas and consists of 200 rows x 400 lines which is longitude-latitude elements corresponding to a 0.1 x 0.1 degree grid that covers each fractionated area. The number of effective digits is zero pint two digits. This file is available to open using Microsoft Excel directory. Figure 2 is example of data coverage for the case of **AAABBBB** = 60N140E.

List of area code **AAABBBB** and its corresponding latitude and longitude of left-top and right-bottom pixels are stored in following file; /realtime_ver/v5/txt/area_list.pdf.

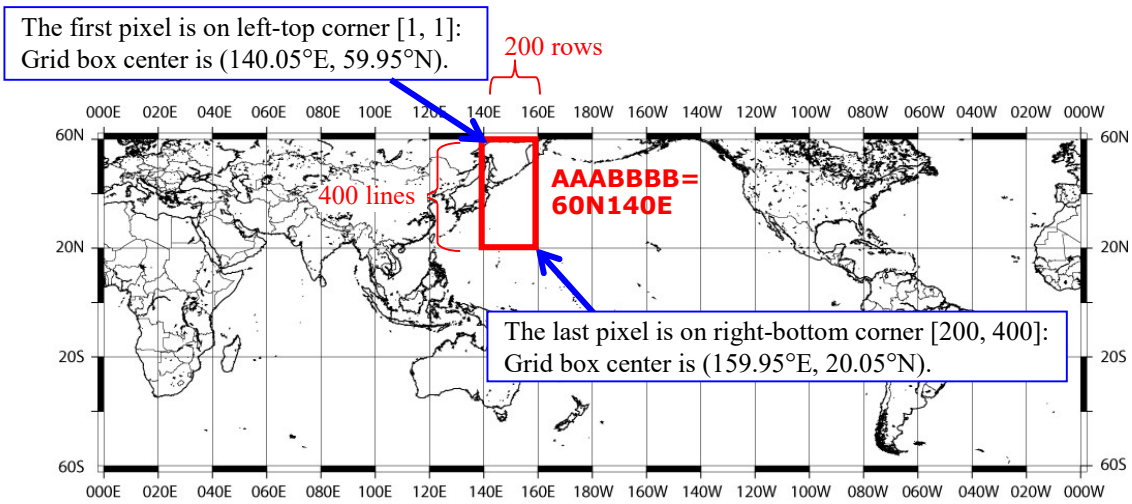

Figure 2 Example of Data Coverage (Text file)

3.5. File Size

Approximately 5 Kbyte (with gzip), and 560 Kbyte (uncompress) for each file.

4. Daily rainfall in 0.25-deg (products (5)-(6))

4.1. Basic Information

Temporal resolution:	24 hours average (daily data)
	Two definitions of "daily":
	00Z-23Z average: from 00Z to 23Z of the day
	12Z-11Z average: from 12Z of the previous day to 11Z of the day
Grid resolution:	0.25 degrees latitude/longitude grid (25km at the equator)
Domain:	Global (60°N-60°S)
Data archived period:	10 October 2008 - 2 September 2014

4.2. FTP Directory Information

Data files are archived at following directories;

Daily data (00Z-23Z average); /realtime_ver/v5/daily/00Z-23Z/**YYYYMM**/
Daily data (12Z-11Z average); /realtime_ver/v5/daily/p12Z-11Z/**YYYYMM**/

where;
YYYY: 4-digit year; and
MM: 2-digit month.

4.3. File Naming Rules

Data files are named according to following rules;

Daily data (00Z-23Z average); gsmap_nrt.**YYYYMMDD**.0.25d.daily.00Z-23Z.dat
Daily data (12Z-11Z average); gsmap_nrt.**YYYYMMDD**.0.25d.daily.p12Z-11Z.dat

where;

YYYY: 4-digit year;
MM: 2-digit month; and
DD: 2-digit day.

4.4. Data Format

All binary files are produced in little-endian byte order platform, and archived with compressed using "gzip". Unit is [mm/hr]. Missing value is -999.9.

Grid of those files consists of 1440 x 480 pixels, which are longitude-latitude elements corresponding to a 0.25 x 0.25 degree grid that covers the global region from 60°N to 60°S. The center longitude and latitude of the first pixel [1, 1] (left top corner) is [0.125°E, 59.875°N].

4.5. GrADS Control File

Sample control files of the Grid Analysis and Display System (GrADS) for each product are also available from ftp server.

Daily data (00Z-23Z average); /realtime_ver/v5/sample/GSMaP_NRT.daily.00Z-23Z.ctl
Daily data (12Z-11Z average); /realtime_ver/v5/sample/GSMaP_NRT.daily.p12Z-11Z.ctl

About usage of GrADS tool, please see GrADS home page (http://cola.gmu.edu/grads/grads.php).

4.6. File Size

Approximately 800 Kbyte (with gzip), and 2.7 Mbyte (uncompress) for each file.

5. Daily rainfall in 0.1-deg (products (7)-(8))

5.1. Basic Information

Temporal resolution:	24 hours average (daily data) Two definitions of "daily": 00Z-23Z average: from 00Z to 23Z of the day 12Z-11Z average: from 12Z of the previous day to 11Z of the day
Grid resolution:	0.1 degrees latitude/longitude grid (10km at the equator)
Domain:	Global (60°N-60°S)
Data archived period:	1 January 2014 - 2 September 2014

5.2. FTP Directory Information

Data files are archived at following directories;

Daily data (00Z-23Z average); /realtime_ver/v5/daily0.1/00Z-23Z/**YYYYMM**/
Daily data (12Z-11Z average); /realtime_ver/v5/daily0.1/p12Z-11Z/**YYYYMM**/

where;

YYYY: 4-digit year; and
MM: 2-digit month.

5.3. File Naming Rules

Data files are named according to following rules;

Daily data (00Z-23Z average); gsmap_nrt.**YYYYMMDD**.0.1d.daily.00Z-23Z.dat
Daily data (12Z-11Z average); gsmap_nrt.**YYYYMMDD**.0.1d.daily.p12Z-11Z.dat

where;
YYYY: 4-digit year;
MM: 2-digit month; and
DD: 2-digit day.

5.4. Data Format

All binary files are produced in little-endian byte order platform, and archived with compressed using "gzip". Unit is [mm/hr]. Missing value is -999.9.

Grid of those files consists of 3600 x 1200 pixels, which are longitude-latitude elements corresponding to a 0.1 x 0.1 degree grid that covers the global region from 60°N to 60°S. The center longitude and latitude of the first pixel [1, 1] (left top corner) is [0.05°E, 59.95°N].

5.5. GrADS Control File

Sample control files of the Grid Analysis and Display System (GrADS) for each product are also available from ftp server.

Daily data (00Z-23Z average); /realtime_ver/v5/sample/GSMaP_NRT.daily0.1.00Z-23Z.ctl
Daily data (12Z-11Z average); /realtime_ver/v5/sample/GSMaP_NRT.daily0.1.p12Z-11Z.ctl

About usage of GrADS tool, please see GrADS home page (http://cola.gmu.edu/grads/grads.php).

5.6. File Size

Approximately 800 Kbyte (with gzip), and 17 Mbyte (uncompress) for each file.

6. Algorithm and references

6.1. Algorithm

Details of the latest GSMaP algorithm are described in following documents and references in Section 6.2.

- Global Satellite Mapping of Precipitation (GSMaP) for GPM: Algorithm Theoretical Basis Document (ATBD)" (https://sharaku.eorc.jaxa.jp/GSMaP/faq/GSMaP_faq15.html).

6.2. References

Please refer the following paper:

- Kubota, T., K. Aonashi, T. Ushio, S. Shige, Y. N. Takayabu, M. Kachi, Y. Arai, T. Tashima, T. Masaki, N. Kawamoto, T. Mega, M. K. Yamamoto, A. Hamada, M. Yamaji, G. Liu and R. Oki 2020: Global Satellite Mapping of Precipitation (GSMaP) products in the GPM era, Satellite precipitation measurement, Springer, https://doi.org/10.1007/978-3-030-24568-9_20.

(Major papers related to GSMaP algorithms)

- Kubota, T., S. Shige, H. Hashizume, K. Aonashi, N. Takahashi, S. Seto, M. Hirose, Y. N. Takayabu, K. Nakagawa, K. Iwanami, T. Ushio, M. Kachi, and K. Okamoto, 2007: Global Precipitation Map using Satelliteborne Microwave Radiometers by the GSMaP Project : Production and Validation, *IEEE Trans. Geosci. Remote Sens.*, **45**, No. 7, 2259-2275, https://doi.org/10.1109/TGRS.2007.895337.

- Aonashi, K., J. Awaka, M. Hirose, T. Kozu, T. Kubota, G. Liu, S. Shige, S., Kida, S. Seto, N.Takahashi, and Y. N. Takayabu, 2009: GSMaP passive, microwave precipitation retrieval algorithm: Algorithm description and validation. *J. Meteor. Soc. Japan*, **87A**, 119-136, https://doi.org/10.2151/jmsj.87A.119.

- T. Ushio, T. Kubota, S. Shige, K. Okamoto, K. Aonashi, T. Inoue, N., Takahashi, T. Iguchi, M.Kachi, R. Oki, T. Morimoto, and Z. Kawasaki, 2009: A Kalman filter approach to the Global Satellite Mapping of Precipitation (GSMaP) from combined passive microwave and infrared radiometric data. *J. Meteor. Soc. Japan*, **87A**, 137-151, https://doi.org/10.2151/jmsj.87A.137.

- Mega, T., T. Ushio, M. T. Matsuda, T. Kubota, M. Kachi, and R. Oki, 2019: Gauge-adjusted global satellite mapping of precipitation. *IEEE Trans. Geosci. Remote Sens.*, **57.4**, 1928-1935, https://doi.org/10.1109/TGRS.2018.2870199.

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