USER'S GUIDE FOR
Global Rainfall Map in Near-Real-Time by JAXA Global Rainfall Watch (GSMaP_NRT)

Version 2.5

Updated July 2013

Earth Observation Research Center
Japan Aerospace Exploration Agency

1. Introduction

We offer hourly Global Rainfall Map in Near-Real-Time (GSMaP_NRT), available four hours after observation, using the JAXA Global Rainfall Watch System. The system is based on the combined MW-IR algorithm using TRMM TMI, Aqua AMSR-E, GCOM-W1 AMSR2, DMSP SSM/I and SSMIS, NOAA-19 AMSU and MetOp-A AMSU, and GEO IR developed by the GSMaP (Global Satellite Mapping of Precipitation) project.

The GSMaP project was promoted for 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).

The main feature of the GSMaP algorithm is utilization of various attributes derived from TRMM PR that is the first spaceborne precipitation radar.

2. Description of rainfall data

Table 1 summarizes major specification of rainfall data.

Table 1 Description of rainfall data

Variable	Rainfall rate (mm/hr)
Domain	Global (60N - 60S)
Grid resolution	0.1 degree latitude/longitude
Temporal resolution	1 hour

3. Algorithms

1) Microwave Imager Algorithm

The GSMaP microwave imager algorithm retrieves global rainfall from brightness temperatures (Tbs) observed by satelliteborne microwave radiometers. The GSMaP microwave imager algorithm is based on Aonashi and Liu (2000). The common retrieval algorithm is applied to Tbs from the TMI, AMSR-E, and AMSR. The algorithm for the SSM/I and SSMIS, which is not supplied with Tbs of 10GHz, is modified in terms of weighted averages over ocean based on Hashizume *et al.* (2006).

The basic idea of the algorithm is to find the optimal precipitation that gives radiative transfer model (RTM)-calculated, field-of-view averaged Tbs that fit best with the observed Tbs. For the 4-stream RTM calculation of Liu (1998), the spatial precipitation inhomogeneity is estimated from Tbs and the freezing level height from the Japan Meteorological Agency Global Analysis (GANAL) is used.

Furthermore, the algorithm has been improved in terms of, in particular, rain/no-rain classification methods over land (Seto *et al.*, 2005) , the RTM calculation using rainfall-rate profiles classified by the rain types from the TRMM Precipitation Radar (PR), which is developed by Dr. Hirose and Dr. Takayabu based on Takayabu and Katayama (2004), the melting layer model (Nishituji-model; Takahashi and Awaka, 2005), which has been proposed to explain the reflectivity profile of radio wave attenuation observations in the RTM calculation, and the scattering algorithm improved using 85GHz and 37GHz polarization corrected temperatures.

Please see Aonashi *et al.* (2009) for detail.

2) Microwave Sounder Algorithm

The GSMaP microwave sounder algorithm to retrieve rainfall over the ocean is developed by Shige *et al.* (2009), based on the GSMaP microwave imager algorithm. The algorithm combines an emission-based estimate from Tbs at 23 GHz and a scattering-based estimate from Tbs at 89 GHz, depending on a scattering index computed from Tbs at both 89 and 150 GHz. Precipitation inhomogeneities are also taken into account. Please see Shige *et al.* (2009) for detail.

Development of GSMaP_AMSU algorithm for land portion is currently underway. Therefore, the Microwave Surface and Precipitation Products System (MSPPS) Day-2 rainfall products (Ferraro *et al.*, 2005), which are provided by NOAA, are used as input rainfall over the land in GSMaP_NRT V2.2.

3) Microwave-IR Combined Algorithm

The GSMaP microwave-IR combined algorithm produces GSMaP_MVK product by combining retrieved rainfall from microwave imagers and sounders and cloud information observed by the IR imagers aboard the geostationary satellites with high temporal and spatial resolution. The technique uses the Kalman filter to compute the estimates of the current surface rain fall rates at each 0.1 degree pixel of the infrared brightness temperature by the GEO-IR satellites. The filter predict the precipitation rate from the microwave imagers and sounders and its morphed product obtained in a similar way as Joyce *et al.* (2004), and then refine the prediction based on the relationship between the IR brightness temperature and surface rainfall rate. See Ushio *et al.* (2009) for detail.

4. Algorithm inputs

1) Geostationary satellite data

Until 22Z 28 March 2012, pixel-resolution data of MTSAT (operated by Japan Meteorological Agency), METSOSAT-7/-8 (operated by EUMETSAT), GOES-11/-12 (operated by NOAA), provided by the Japan Weather Association (JWA) was used. Satellite zenith angle correction method, which is developed and distributed by NOAA Climate Prediction Center (CPC), has been applied in merging each IR data.

Since 23Z 28 March 2012, Globally-merged, full-resolution (~4km) IR Data, which is merged from the ~11 micron IR channels aboard the MTSAT, METSOSAT-7/-8, and GOES-11/-12, produced by NOAA/CPC, has been used.

The range of the latitude is 60N-60S. The temporal resolution is 1 hour in this product.

2) Low Earth Orbit satellite data

Table 2 Summary of input low Earth orbit data

<table>
<tr><th>Satellite</th><th>Height (km)</th><th>Instrument</th><th>Category</th><th>frequency (GHz)</th><th>Note</th></tr>
<tr><td>TRMM</td><td>402</td><td>TMI</td><td>imager</td><td>10, 19, 21, 37, 85</td><td></td></tr>
<tr><td>AQUA</td><td>705</td><td>AMSR-E</td><td>imager</td><td>7, 10, 19, 24, 37, 89</td><td>Not operational since 4 Oct. 2011</td></tr>
<tr><td>GCOM-W1</td><td>705</td><td>AMSR2</td><td>imager</td><td>7, 10, 19, 24, 37, 89</td><td>Introduced into GSMaP_NRT system since 1 Jul. 2013</td></tr>
<tr><td>DMSP-F13</td><td>833</td><td>SSM/I</td><td rowspan="3">imager</td><td rowspan="3">19, 22, 37, 85</td><td>Not operational since 18 Nov. 2009</td></tr>
<tr><td>DMSP-F14</td><td>833</td><td>SSM/I</td><td>Not operational since 24 Aug. 2008</td></tr>
<tr><td>DMSP-F15</td><td>833</td><td>SSM/I</td><td>Only rain over the ocean has been used since Aug. 2006</td></tr>
<tr><td>DMSP-F16</td><td>833</td><td>SSMIS</td><td rowspan="3">imager/ sounder</td><td rowspan="3">19.4, 22.2, 37, 91.7, 60-63, 50-59, 150, 183.31±1, 183.31±3, 183.31±7</td><td rowspan="2">Introduced into GSMaP_NRT system since 11 Jun. 2010</td></tr>
<tr><td>DMSP-F17</td><td>850</td><td>SSMIS</td></tr>
<tr><td>DMSP-F18</td><td>850</td><td>SSMIS</td><td>Introduced into GSMaP_NRT system since 1 Jul. 2013</td></tr>
<tr><td>NOAA-N19</td><td>870</td><td>AMSU-A/ MHS</td><td rowspan="2">sounder</td><td rowspan="2">23.8-89.1 (AMSU-A), 89, 157, 183.311±3, 183.311±5, 190.311 (MHS)</td><td rowspan="2">Introduced into GSMaP_NRT system since 1 Aug. 2011</td></tr>
<tr><td>MetOp-A</td><td>817</td><td>AMSU-A/ MHS</td></tr>
</table>

3) Ancillary Data

- JMA Global Analysis (GANAL)
- JMA Merged satellite and in situ data Global Daily Sea Surface Temperatures (MGDSST)

5. Difference from GSMaP standard (V4.6) rainfall products

GSMaP NRT rainfall products differ from standard products (V4.6 by JST/CREST GSMaP project) in terms of input datasets, although the algorithms are the same for both. Table 3 summarizes the differences. Data available within three hours from observation are utilized in the GSMaP NRT system.

Table 3 Difference between GSMaP_NRT and standard product

Input data	Sensor	GSMaP_NRT	GSMaP Standard
Passive microwave imager and/or sounder	TRMM/TMI	NASA/GSFC Realtime Version	NASA/GSFC Standard Version
	Aqua/AMSR-E	JAXA/EORC	JAXA/EORC
	DMSP/SSMI (F13, 14, 15)	NOAA/NWS	Remote Sensing Systems
	DMSP/SSMIS (F16, 17)	NOAA/NWS	Not used
	NOAA-N19/ AMSU-A/MHS	NOAA/NWS	Not used (only used in MVK+ product)
	MetOp-A/ AMSU-A/MHS	NOAA/NWS	Not used (only used in MVK+ product)
GEO Infrared radiometer	MTSAT, METEOSAT-7/8, GOES-11/12	Globally-merged pixel-resolution data by JWA (before 22Z 28 Mar. 2012) and NOAA/CPC (after 23Z 28 Mar. 2012)	Globally-merged pixel-resolution data by NOAA/CPC
Atmospheric information	---	JMA GANAL	JMA GANAL
Sea Surface Temperature	---	JMA MGDSST	JMA MGDSST

6. Some caveats for data users

- Although JAXA/EORC has taken every care to manage the current site, JAXA assumes no responsibility regarding the safety of the contents of the Site or the reliability of information provided on the Site. JAXA is not responsible to you for any damage that may be caused by the use of the Site and/or the information on the Site.
- Please contact the TRMM Realtime office (Z-trmm_real@jaxa.jp) in advance if you want to distribute images or data from this site to many people, such as in a pamphlet or internet. Also, please check JAXA Site Policy for details (http://www.jaxa.jp/policy_e.html).
- Anyone wishing to publish any results using the data from the JAXA Global Rainfall Watch should clearly acknowledge the ownership of the data in the publication (for example, ' Global Rainfall Map in Near-Real-Time (GSMaP_NRT) by JAXA Global Rainfall Watch)' was produced and distributed by the Earth Observation Research Center, Japan Aerospace Exploration Agency). If you have benefited from GSMaP rainfall products, please cite the major papers listed in Section 8 along with any of the papers listed

at http://www-ipwg.kugi.kyoto-u.ac.jp/IPWG/sat_val_Japan.html that you have benefited from.

- We would appreciate receiving a preprint and/or reprint of publications in which you utilize our data. Relevant publications should be sent to:
  TRMM Real-Time Office
  Earth Observation Research Center, Japan Aerospace Exploration Agency
  2-1-1, Sengen, Tsukuba-city, Ibaraki 305-8505 Japan
  Fax +81-29-868-2961
  E-mail: Z-trmm_real@jaxa.jp
- Please contact us at the TRMM Realtime office (Z-trmm_real@jaxa.jp) if you have any questions.

7. Acknowledgments

The GSMaP_NRT and JAXA Global Rainfall Watch system was developed based on heritage of the GSMaP Project led by Prof. K. Okamoto (Osaka Prefecture University, Osaka, Japan) under R&D of Hydrological Modeling and Water Resources System in the Core Research for Evolutional Science and Technology program of the Japan Science and Technology Agency (JST). We would like to thank JST and the members of the GSMaP Project.

8. Papers describing the GSMaP project

K. Okamoto, T. Iguchi, N. Takahashi, K. Iwanami and T. Ushio, 2005: The global satellite mapping of precipitation (GSMaP) project. *25th IGARSS Proceedings*, 3414-3416.

T. Kubota, 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(7)**, 2259-2275.

K. Aonashi, 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.

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.

S. Shige, T. Yamamoto, T. Tsukiyama, S. Kida, H. Ashiwake, T. Kubota, S. Seto, K. Aonashi and K. Okamoto, 2009: The GSMaP precipitation retrieval algorithm for microwave sounders. Part I: Over-ocean algorithm. *IEEE Trans. Geosci. Remote Sens*, **47**, 3084-3097.

M. Kachi, T. Kubota, T. Ushio, S. Shige, S. Kida, K. Aonashi, and K. Okamoto, 2011:

Development and utilization of "JAXA Global Rainfall Watch" system. *IEEJ Transactions on Fundamentals and Materials*, **131**, 729-737. (In Japanese)

T. Ushio, and M. Kachi, 2009: Kalman filtering application for the Global Satellite Mapping of Precipitation (GSMaP). *Chapter for "Satellite Rainfall Applications for Surface Hydrology" (Editedy by Mekonnen Gebremichael and Faisal Hossain)*, Springer, ISBN978-9048129140, 105-123.

Additional related papers are listed on the JST/CREST GSMaP Project Website.
(http://www-ipwg.kugi.kyoto-u.ac.jp/IPWG/sat_val_Japan.html)