Recent progresses of the Global Satellite Mapping of Precipitation (GSMaP) Products

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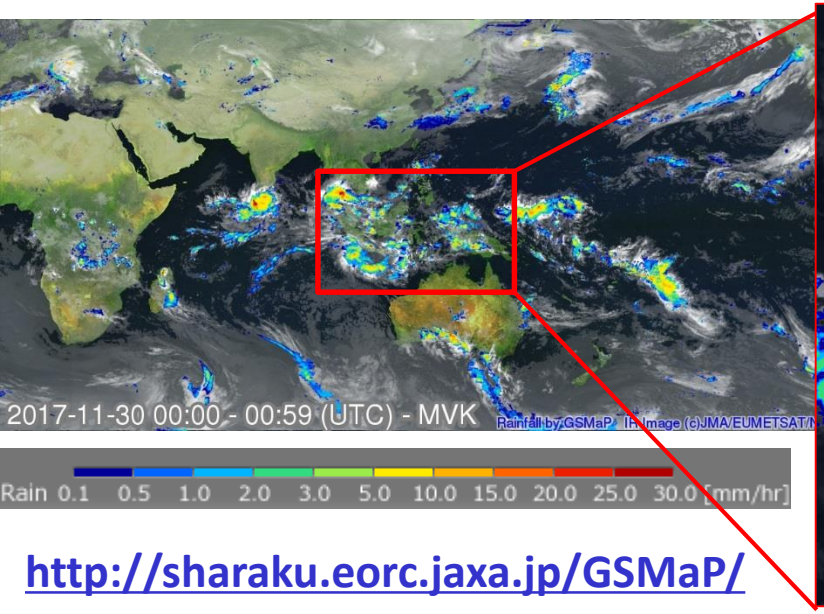
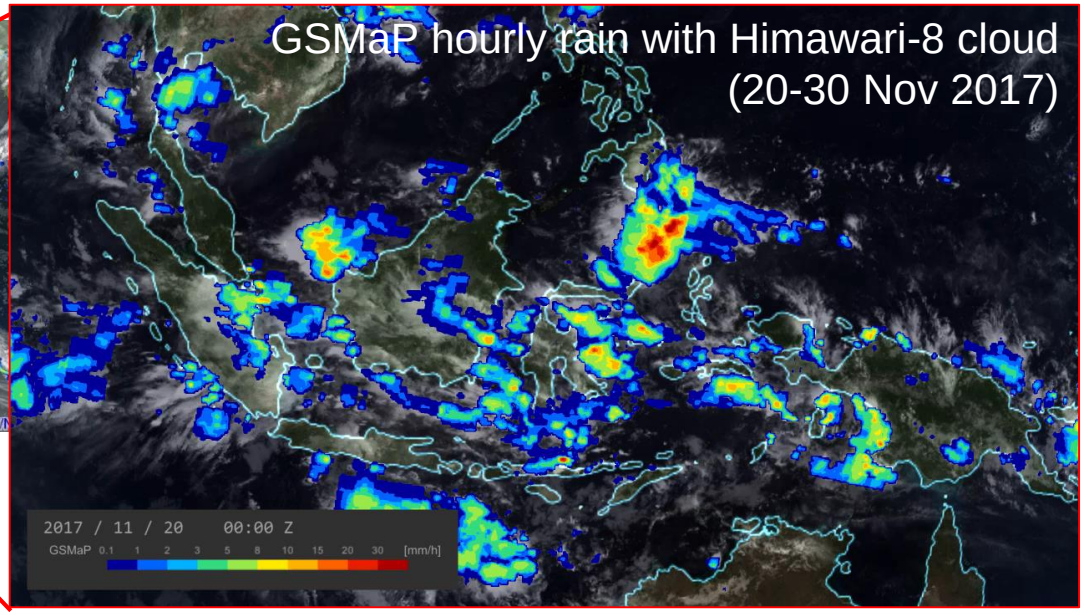
Precipitation Extremes Monitoring

- Precipitation extremes
  - Heavy precipitation events can trigger natural disasters, such as floods and landslides.
  - Drought events affects agriculture, water management, and so on.
- A long-term trend of precipitation extremes is a big issue (e.g., IPCC report, Aguilar et al. 2005, Alexander et a. 2006)
  - Discussions for future projections of the hydrological cycles (e.g., Madakumbura et al. 2019)
- A need to better utilize and improve monitoring of extreme precipitation events
  - Distributions of the rain gauge so limited (e.g. Kidd et al. 2017)
  - Satellite remote sensing will be helpful by their wide coverages.

Global Satellite Mapping of Precipitation (GSMaP)

- The Global Precipitation Measurement (GPM) is an international mission consisting of the Core Observatory and Constellation Satellites for high accurate and frequent global precipitation observation.



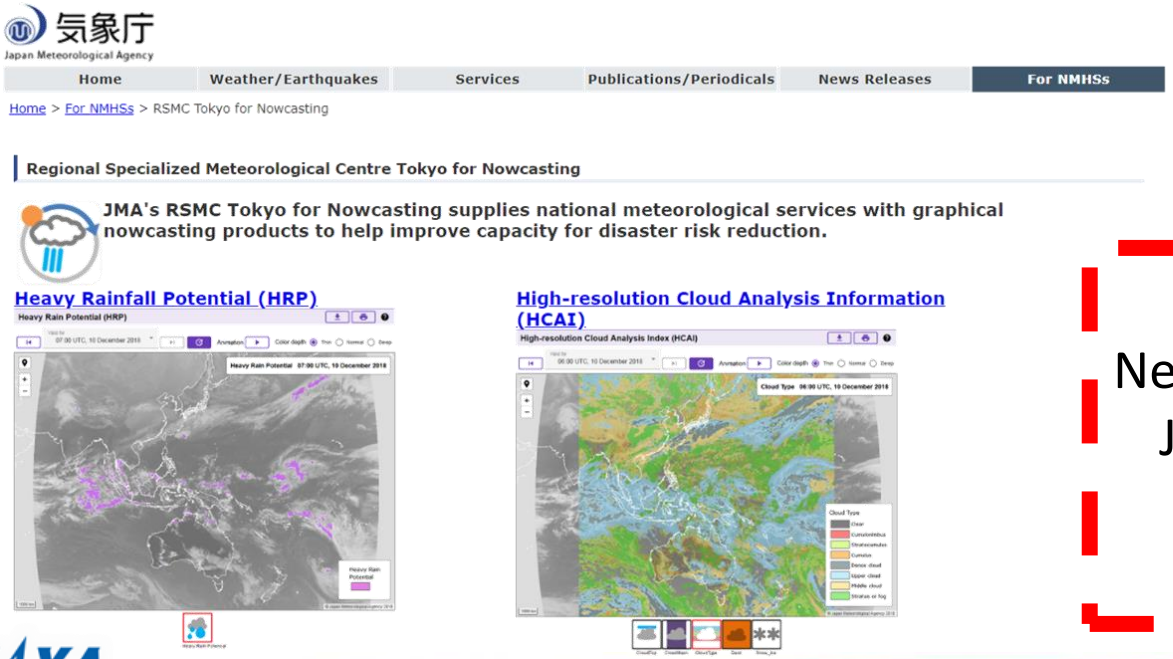


http://sharaku.eorc.jaxa.jp/GSMaP/

- GSMaP is the Japanese GPM product, and a multi-satellite product from a blended Passive Microwave radiometer(PMW)-IR algorithm.
  - Grid resolution: 0.1 deg. lat/lon, Temporal resolution: 1 hour
  - Here we report a new version of the GSMaP **released in December 2021**.

Collaboration with JMA for the GSMaP utilization

- WMO's Regional Specialized Meteorological Centre Tokyo for Nowcasting (RSMC Tokyo for Nowcasting) operated by JMA supplies National Meteorological and Hydrological Services (NMHSs) with graphical nowcasting products to help improve capacity for disaster risk reduction.
- **JAXA and JMA** have been collaborating toward the utilization of **GSMaP data** in the issuance of warnings by NMHSs in Asia and Pacific region through the RSMC Tokyo for Nowcasting.



Top page of the JMA website "Regional Specialized Meteorological Centre Tokyo for Nowcasting"
https://www.jma.go.jp/jma/jma-eng/jma-center/nowcasting/

New product using JAXA GSMaP is expected!!

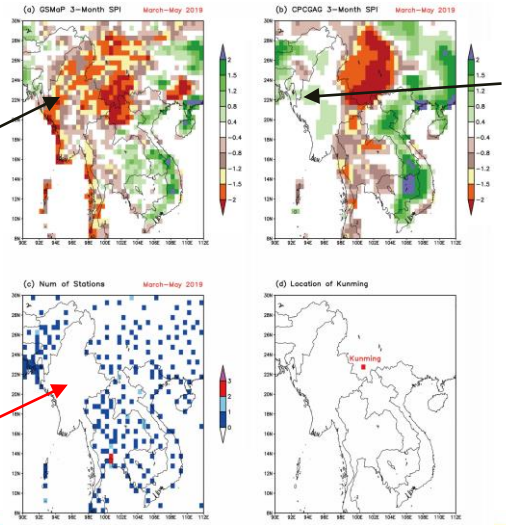
Contribution of longer data records to extremes monitoring.

- JAXA has participated WMO Space-based Weather and Climate Extremes Monitoring (SWCEM) project with about 22-yr GSMaP data.
- A case study of the Mainland Southeasth Asia drought clearly demonstrates the value of space-based rainfall estimates for drought detection and monitoring, especially for regions where rain gauge observations are limited or unavailable

Mainland Southeasth Asia drought case study (Tashima et al. 2020)

Tashima et al. (2020, *IEEE JSTARS.)* https://doi.org/10.1109/JSTARS.2020.3014881.)

3-mon Standardized Precipitation Index (SPI) by GSMaP in March-May 2019



3-mon SPI by NOAA/CPC Gauges in March-May 2019

No available rain gauges in Myanmar

GSMaP updates

https://sharaku.eorc.jaxa.jp/GSMaP/index.htm

- GSMaP conducted the major update in Dec. 2021.

Date	Product version	Algorithm Version
Sep. 2014	V03	v6
Jan. 2017	V04	v7
Dec. 2021	**V05**	**v8**

  - A review paper of GPM-GSMaP V03 & V04: Kubota et al. (2020), https://doi.org/10.1007/978-3-030-24568-9_20
- Standard/NRT versions of GPM-GSMaP V05 (algorithm version 8) were released in 1st Dec. 2021.
  - https://www.eorc.jaxa.jp/GPM/doc/product_info/release_note_gsmapv05-v8_en.pdf
- We plan the reprocessing of the GPM-GSMaP V05 in a period during the past 24 years "since Jan. 1998" using JAXA super computer system (JSS3).
  - Reprocessing in the previous version was "since Mar. 2000" .

Features in the new version (GPM-GSMaP V05)

Passive microwave (PMW) algorithm

- Retrievals extended to the pole-to-pole (PMW only)
- Update of Database
  - ✓ Frozen precipitation depth was newly installed in by Dr. Aonashi (Kyoto Univ./JAXA)
- Heavy Orographic Rainfall Retrievals
  - ✓ A basic idea using Low-level static stability is based upon Shige and Kummerow (2016) .
- Several improvements in PMW retrieval technique

Normalization module for PMW retrievals

Newly installed in V05, described in Yamamoto and Kubota (2020, 2022)

PMW-IR Combined algorithm

A basic idea is using morphing and Kalman filter (Ushio et al. 2009). In addition, histogram matching method by Hirose et al. (2022) was implemented in V05.

Hirose et al., 2022: Histogram Matching to Improve Homogeneity in Satellite Merged Precipitation Products, *IEEE GRSL*, *accepted*.

Gauge-adjustment algorithm

A basic idea is adjustment using the NOAA CPC Global Unified Gauge-Based Analysis of Daily Precipitation (Mega et al. 2019). Artificial patterns appeared in V04 were mitigated in V05.

GPM-GSMaP V05: Hourly HDF format

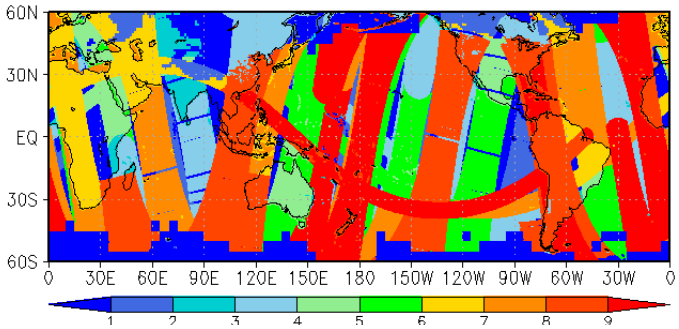
Group Name	Variables [Array]	Missing (_fill Value)	Minimum Value	Maximum Value	Unit	Data Type
Grid	Latitude [nlat x nlon]	-9999.9	-90	90	[degrees]	4B float
	Longitude [nlat x nlon]	-9999.9	-180	180	[degrees]	4B float
	hourlyPrecipRate [nlat x nlon]	-9999.9	0		[mm/hr]	4B float
	satelliteInfoFlag [nlat x nlon]	-9999	0			8B int
	observationTimeFlag [nlat x nlon]	-9999.9				4B float
	hourlyPrecipRateGC [nlat x nlon]	-9999.9	0		[mm/hr]	4B float
	gaugeQualityInfo [nlat x nlon]	-9999	0		[counts/day]	2B int
	snowProbability [nlat x nlon]	-9999	0	100	[%]	2B int
	reliabilityFlag [nlat x nlon]	0	1	10		1B int
	surfaceType [nlat x nlon]	-9999	-8	2		2B int
	orographicRainFlag [nlat x nlon]	-9999	0			4B int

New variables in GPM V05 HDF (available in G-Portal)

Validation efforts: “Reliability Characterization”

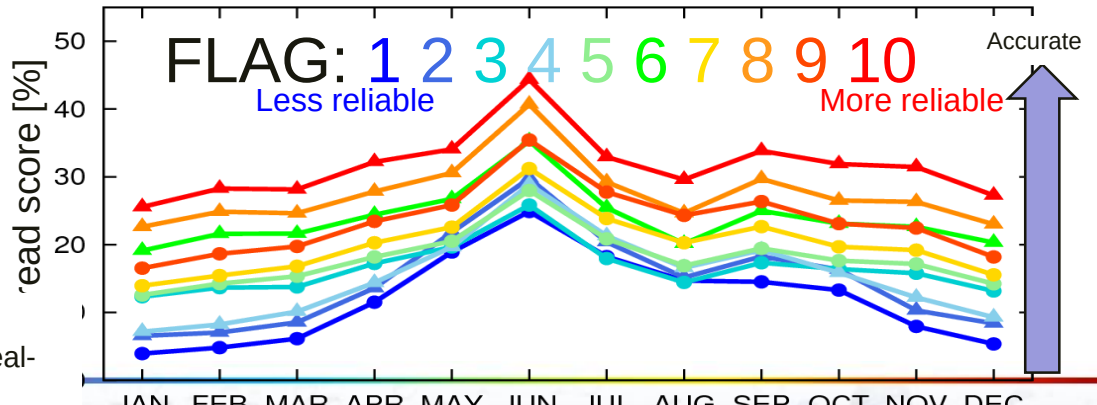
- A reliability flag has been available in the GSMaP since May 2017 because user communities strongly requested a measure of the reliability for the precipitation estimates.
  - 10 levels (10 being the best and 1 the worst) considering surface type reliability, low temperature reliability, and MVK propagation reliability.
- Yamaji et al. (2021, *JMSJ*) was published in June 2021.
  - https://doi.org/10.2151/jmsj.2021-033
  - described the reliability flag and verified the effectiveness by classifying the GSMaP skills with reference to ground radar validation results around Japan.

A snapshot of the reliability flag for GSMaP_NRT



M. Yamaji, T. Kubota, and M. K, Yamamoto, 2020b: An Approach to Reliability Characterization of GSMaP Near-Real-Time Precipitation Product, *J. Meteor. Soc. Japan*. https://doi.org/10.2151/jmsj.2021-033

Seasonal march of thread score for each level of the flag



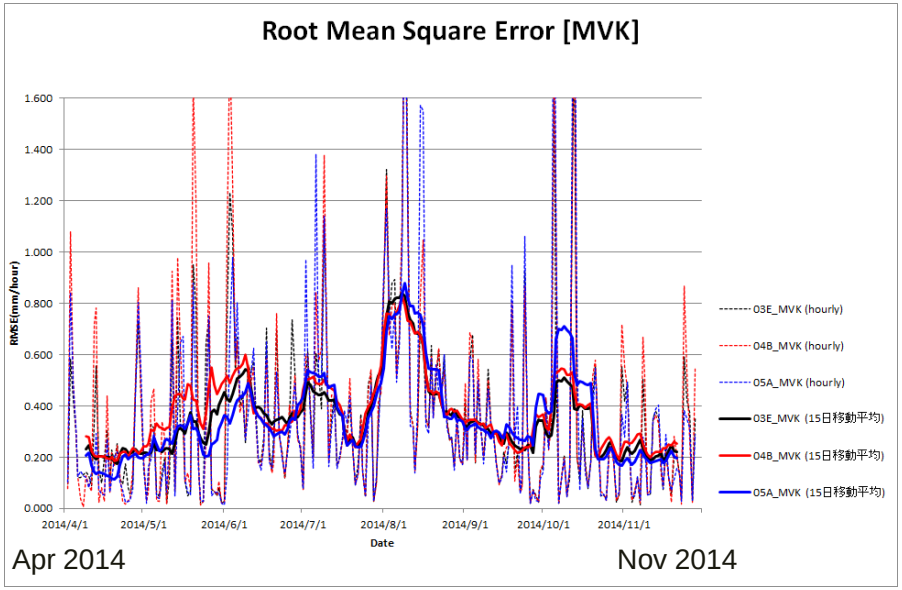
GPM-GSMaP V05: Monthly HDF format

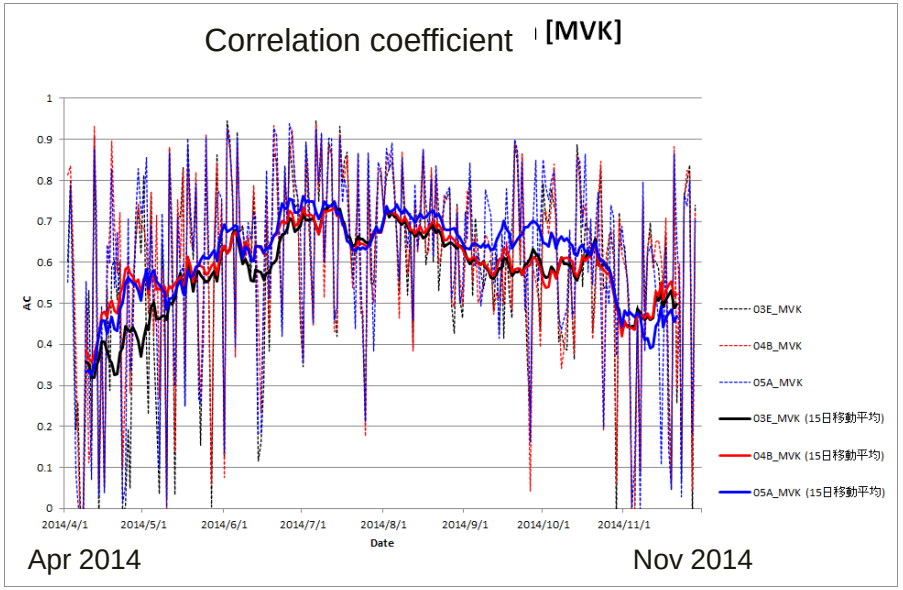
Group Name	Variables [Array]	Missing (_fill Value)	Minimum Value	Maximum Value	Unit	Data Type
Grid	Latitude [nlat x nlon]	-9999.9	-90	90	[degrees]	4B float
	Longitude [nlat x nlon]	-9999.9	-180	180	[degrees]	4B float
	monthlyPrecipRate [nlat x nlon]	-9999.9	0		[mm/hr]	4B float
	observationNumber [nlat x nlon]	-9999	0		[counts/month]	4B int
	standardDeviation [nlat x nlon]	-9999.9	0		[mm/hr]	4B float
	monthlyPrecipRateGC [nlat x nlon]	-9999.9	0		[mm/hr]	4B float
	gaugeQualityInfo [nlat x nlon]	-9999	0		[counts/month]	2B int
	snowProbability [nlat x nlon]	-9999	0	100	[%]	2B int
	orographicRainRatio [nlat x nlon]	-9999	0	100	[%]	2B int

New variables in GPM V05 HDF (available in G-Portal)

Validation over the Japan

- Preliminary validation results using the gauge-adjustment ground radar data over the Japan (land) confirmed better results in V05 satellite only products.





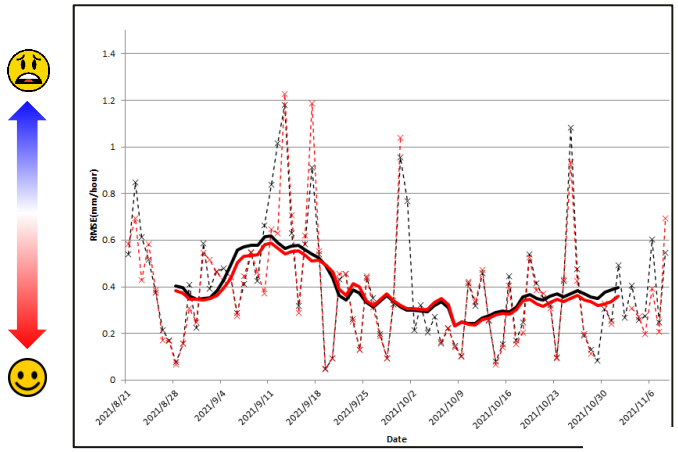
Apr-Nov 2014 mean RMSE	
v03 GSMaP_MVK	0.345 mm/h
v04 GSMaP_MVK	0.371 mm/h
v05 GSMaP_MVK	0.348 mm/h

Apr-Nov 2014 mean CC	
v03 GSMaP_MVK	0.573
v04 GSMaP_MVK	0.594
v05 GSMaP_MVK	0.605

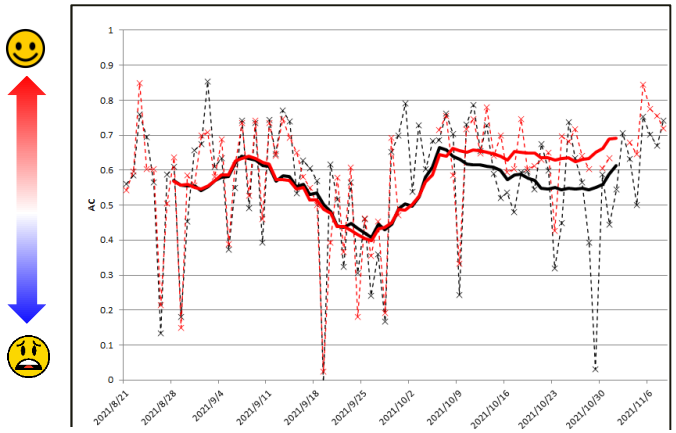
Updates in the GSMaP realtime version (GSMaP_NOW) [1/2]

- The GSMaP real-time version (GSMaP_NOW) with the new algorithm was released in 6th December 2021.
  - The previous GSMaP_NOW algorithm was for V03, and the GSMaP algorithm for V05 was applied to the GSMaP_NOW system after 6th Dec 2021.
    - We don't have a plan of the reprocessing in the GSMaP_NOW.
  - Accuracy improvements have been confirmed by validations with the gauge-adjustment ground radar data over the Japan.

RMSE (root mean square error)



Correlation Coefficient



Mean RMSE

NOW(V03) 0.399 mm/h

NOW(V05) 0.382 mm/h

Mean CC

NOW(V03) 0.563

NOW(V05) 0.588

Better in the new version

Updates in the GSMaP realtime version (GSMaP_NOW) [2/2]

- Binary and CSV (text) formats have been available in the GSMaP_NOW.
- After 6th Dec., we added the NetCDF format, corresponding to user requirements.
  - Please see the Data Format Description document.
    - https://sharaku.eorc.jaxa.jp/GSMaP/document/new/DataFormatDescription_NOW.pdf

5. Hourly Rain Rate (GSMaP_NOW), Gauge-calibrated Rain Rate (GSMaP_Gauge_NOW), and Major Flags in NetCDF format (products (4)-(5))

5.1. Basic Information

There are two kinds of NetCDF product provided from the ftp site.

Product (4) as "Hourly Rain Rate & Gauge-calibrated Rain Rate" is same as product (1) and product (2) except for the format of NetCDF and adding latitude and longitude information. Users who would like to use real time rainfall data can use this simple NetCDF data (product (4)). Please see Table 4.

Table 4 Stored variables in "Hourly Rain Rate & Gauge-calibrated Rain Rate" (product (4))

Variable [unit]	Long Name	Type	Grid Size	Horizontal resolution	Temporal resolution	Subsection
Latitude [degrees north]	Latitude	float	3600 x 1800 (FillValue over the area of 60°N-90°N and 60°S-90°S)	0.1 x 0.1 degree grid box	Hourly	-
Longitude [degrees east]	Longitude	float				-
hourlyPrecipRate [mm/hr]	precip_now	float				See section 5.5
hourlyPrecipRateGC* [mm/hr]	precip_gauge_now	float				See section 5.6

*GC: Gauge-calibrated

Summary

- A new version, GPM-GSMaP V05 (algorithm version 8) was released in Dec. 2021.
  - https://www.eorc.jaxa.jp/GPM/doc/product_info/release_note_gsmapv05-v8_en.pdf
  - We plan the reprocessing of the GPM-GSMaP V05 in a period during the past 24 years since Jan. 1998.
- There are several features in the new version, including the histogram matching method by Hirose et al. (2022).
- Preliminary validation results over the Japan confirmed better results in V05 satellite only products.
- The new version of the GSMaP is available from JAXA GSMaP homepage (**http://sharaku.eorc.jaxa.jp/GSMaP/**) & JAXA G-Portal (**https://gportal.jaxa.jp/gpr/?lang=en**).