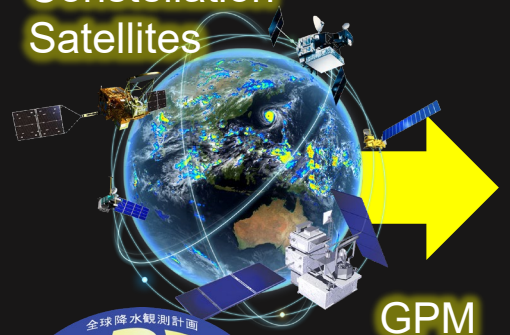
Precipitation monitoring by GSMaP and introduction of GSMaP Local Integration tool with gauges (G-LINT)

Nao Yoshida
Earth Observation Research Center
Japan Aerospace Exploration Agency

Satellite-based global rainfall map:

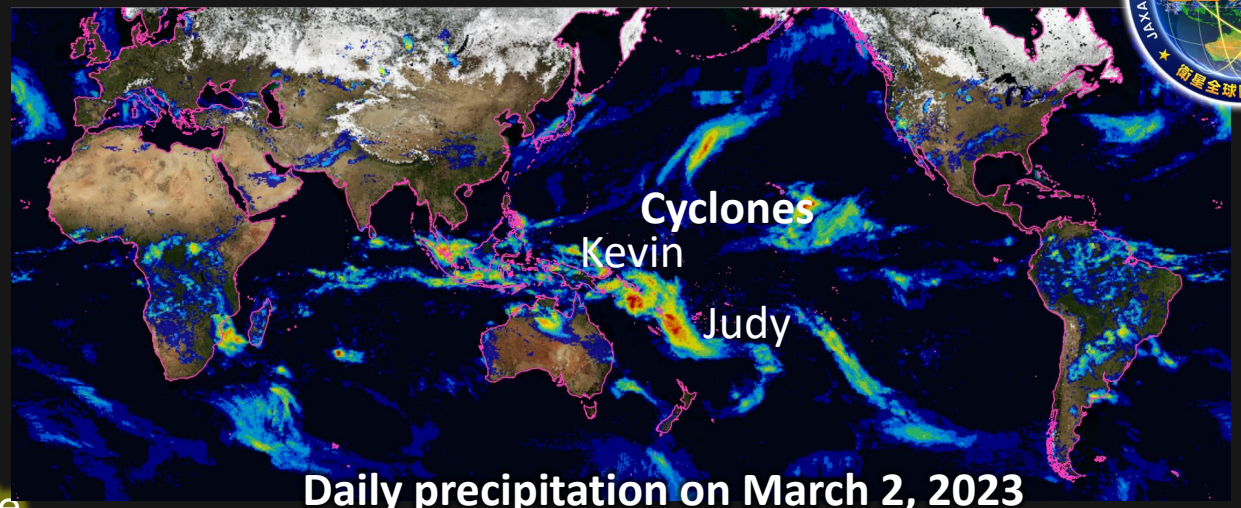
GSMaP
GLOBAL SATELLITE MAPPING OF PRECIPITATION
衛星全球降水マップ

GPM Constellation Satellites



GPM Core Satellite

全球降水観測計画 GPM GLOBAL PRECIPITATION MEASUREMENT



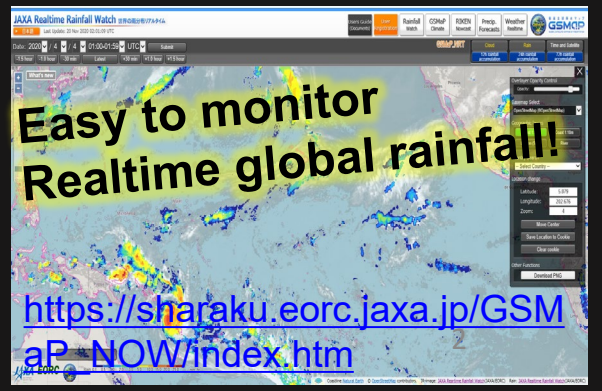
Daily precipitation on March 2, 2023

- **Hourly global** rainfall data
- Spatial resolution: about **11x11km**
- Various version such as **real-time for monitoring** or **long-term gauge-adjusted for climatological purposes**

17,475
registered users
from 163
countries/regions
(as of Jan. 2026)
+ website users
(not registered)

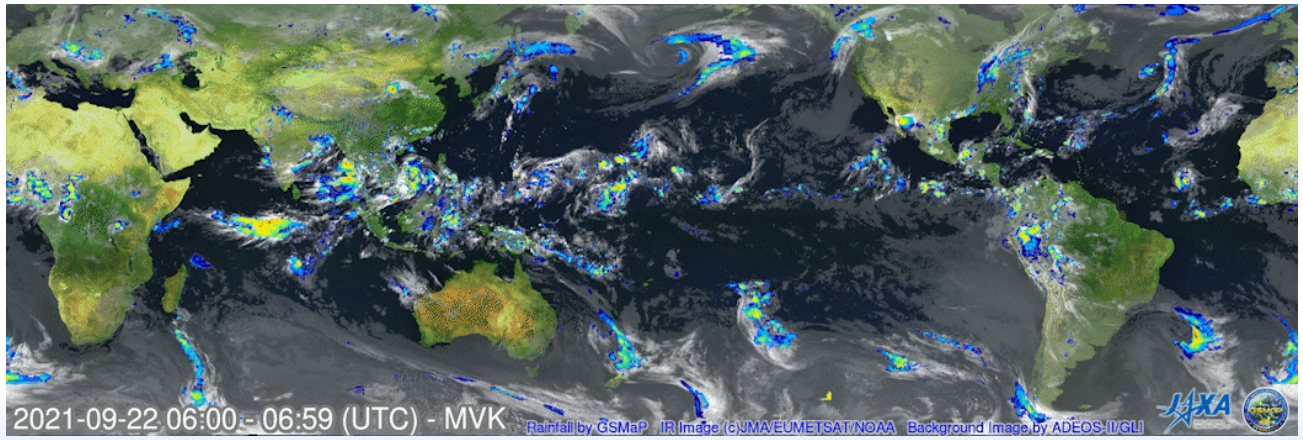
The unique advantage of GSMaP

- Space-based rainfall observations allow us to capture the rainfall even in the area lack of ground-based observations.
- Rainfall can be measured globally, continuous and same interval, and consistent accuracy.
- Open and freely available via web-based GUI, FTP site and data analysis cloud platforms (ex. GEE)
- Long-term archive data for more than 25 years (since 1998)



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

Various application fields



Climate monitoring	Weather Monitoring/ forecasts	Water-related disasters	Agriculture	Energy	Public health	Educations
						
WMO extremes monitoring	Asia-oceania met services	Flood analysis and predictions by disaster management offices	Flood security and insurance for farmers	Hydropower development planning	Researches on infectious diseases	Educational tools

Use cases are collected in the book “Case studies demonstrated by TRMM/GPM/GSMaP”

https://www.eorc.jaxa.jp/GPM/doc/data_utilization/latest_jireishu_e.pdf

GSMaP Family

We provide various kind of GSMaP for various utilization purposes

Based on multi-satellites

GSMaP MVK (standard)	GSMaP NRT (near-realtime)	GSMaP NOW (realtime)
* 3-day latency * past duration available since Jan 1998	* 4-hour latency * past duration available since Mar 2000	* On quasi-realtime (a few minutes latency)

Gauge-adjusted using NOAA/CPC daily precipitation (Chen et al. 2008)

GSMaP Gauge (standard)	GSMaP Gauge NRT (near-realtime)	GSMaP Gauge NOW (realtime)
* 3-day latency * past duration available since Jan 1998	* 4-hour latency * past duration available since Mar 2000	* On quasi-realtime (a few minutes latency)

Higher Accuracy ☺ / **Lower Latency** ☹

☹ / ☺ **Lower Accuracy** / **Better Latency**

Expected Purposes

Long-term Analysis for climate, Agricultural monitor	Flood Analysis and/or prediction	Weather Realtime Monitoring

GSMaP

GLOBAL SATELLITE MAPPING OF PRECIPITATION

Introduction of use cases

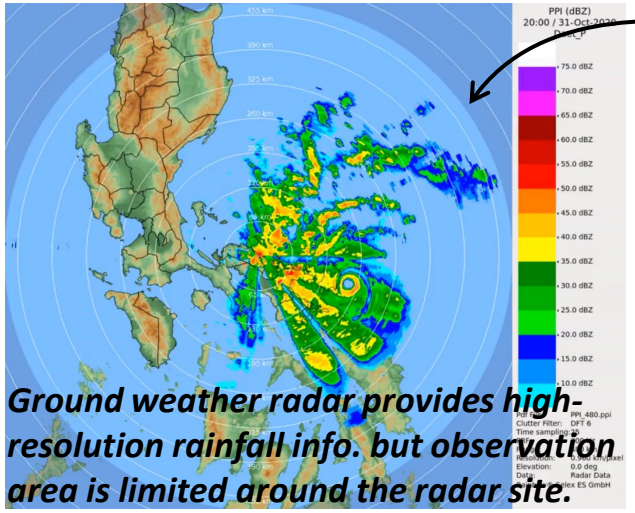
Cyclone Monitoring

https://youtu.be/K9T2N5sa9Zk

Space-based information like GSMaP can help;

- *capturing the amount and distributions of rainfall even over the oceans and the area lack of ground-based observations*
- *as a complementary tool of ground-based radars in case of trouble and unavailability*

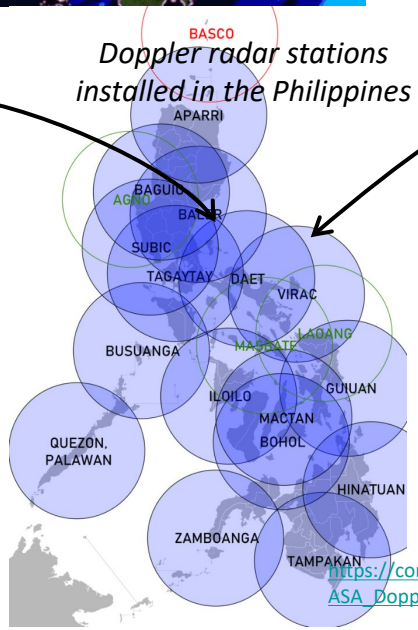
Radar image at Daet station by PAGASA



Ground weather radar provides high-resolution rainfall info. but observation area is limited around the radar site.

https://twitter.com/dost_pagasa/status/1322645728213176320

Doppler radar stations installed in the Philippines



https://commons.wikimedia.org/wiki/File:PAGASA_Doppler_Radar_Network.png

Typhoons are usually approaching from the eastern ocean.
-> Virac radar can play an important role for rainfall monitoring.

Photo from PAGASA / MANILA BULLETIN
https://mb.com.ph/2020/11/03/pagasa-weather-radar-among-rolly-casualties-in-catanduanes/

Flood Forecasting

UNESCO Pakistan flood project "Strategic Strengthening of Flood Warning and Management Capacity"

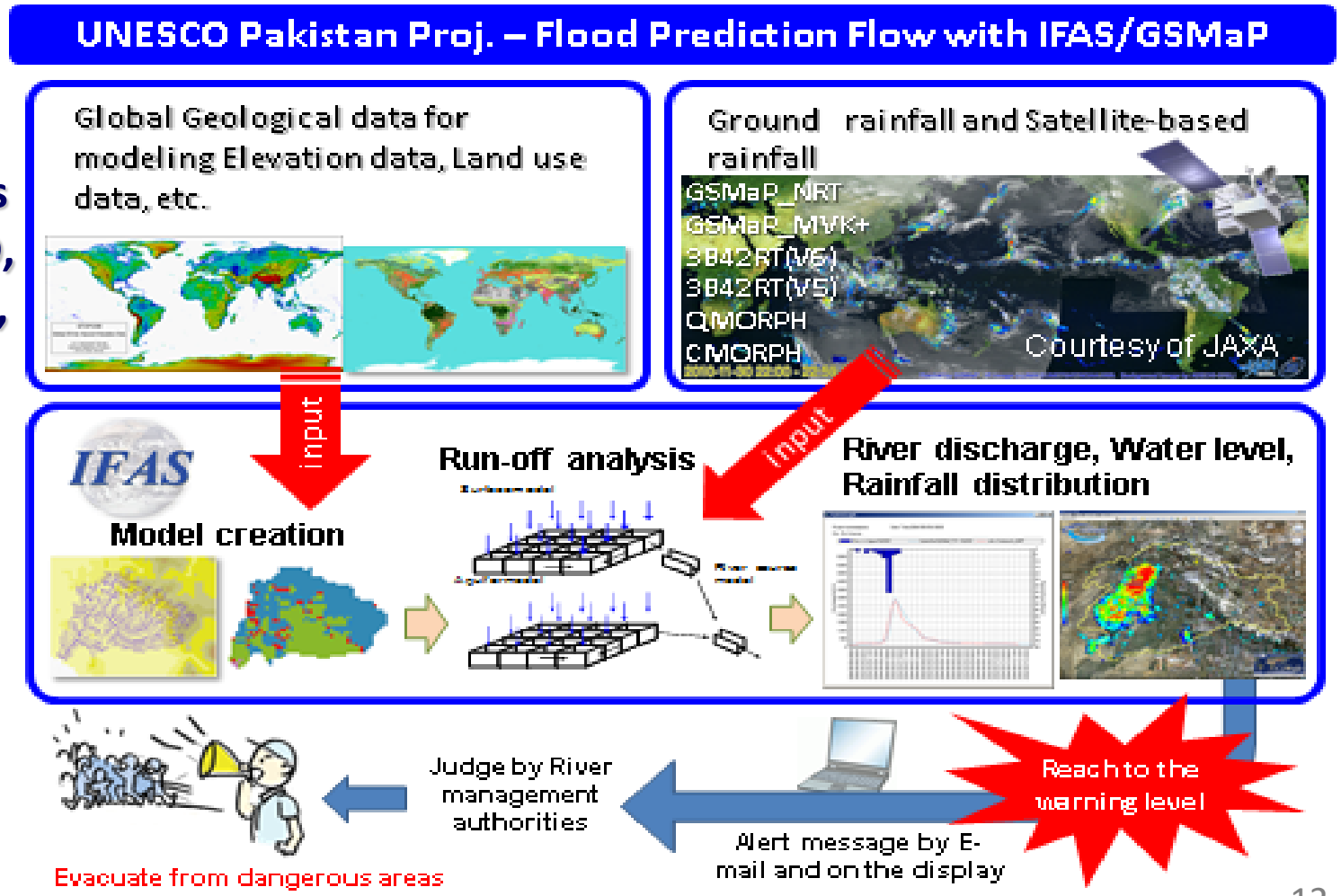
Combination usage of hydrological tool (IFAS/RRI) and data (GSMaP)

- **Funded by the Japan International Cooperation Agency (JICA)**
- **Implementing Agency: UNESCO**
- **Agencies involved: Pakistani Stakeholders (Planning Commission Pakistan, FFD, PMD, SUPARCO, WAPDA, NDMA NUST, PCRWR, SAWCRI), ICHARM, and JAXA**

Main Activities:

(a) flood early warning system development using ICHARM's Integrated Flood Analysis System (IFAS)

(b) capacity-building in Pakistan to manage the floods



United Nations Educational, Scientific and Cultural Organization

Japan International Cooperation Agency

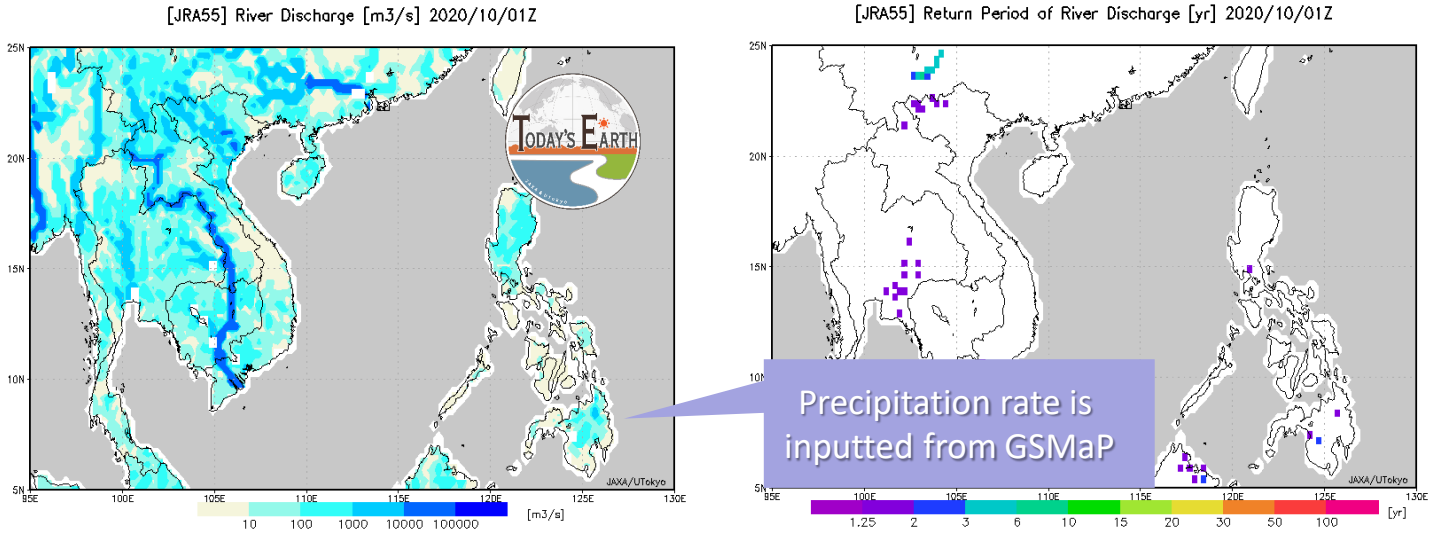
Acknowledgement: UNESCO, JICA, and ICHARM

Global terrestrial hydrological simulation system using GSMaP

Mr. Yoshida (JAXA) will present it in Training Workshop Ⅷ.

- To mitigate water related disasters, it is important not only to observe the rainfall itself but also to determine where and how much actual rainfall collects on the ground.
- JAXA has developed the global terrestrial hydrological simulation system "**Today's Earth (TE)**" under the joint research with the University of Tokyo.

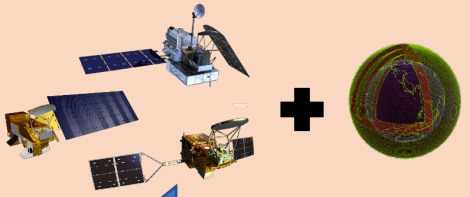
Typhoon impacts in Philippines and Vietnam in 2020



- As well as the daily river discharge (left figure), its return period can be estimated by Today's Earth. "Return period" is one index of "how extreme the current event was" based on past statistics.

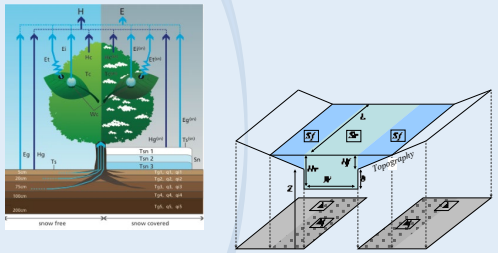
TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

Atmospheric Forcing Based on Observation



Validation

Model Simulation Based on Land Information



Disaster Estimation

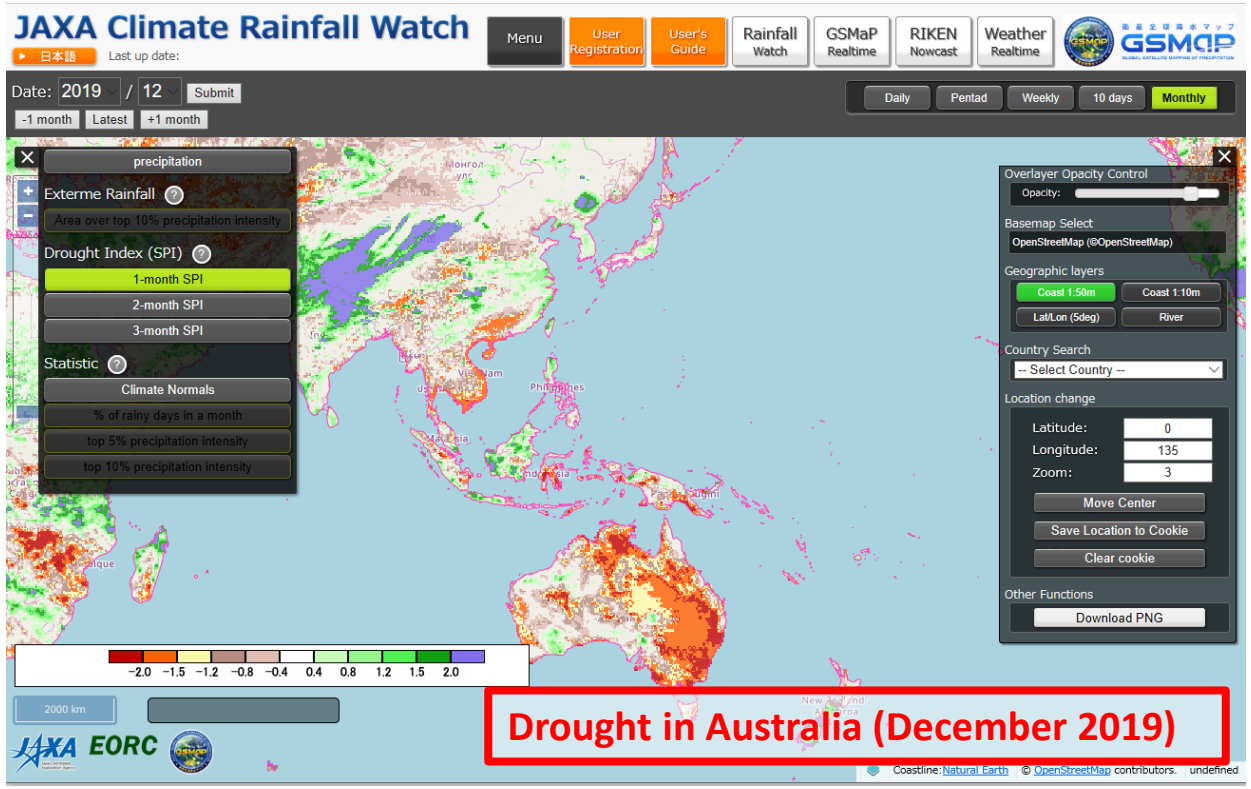
Data Distribution Through Web Page

https://www.eorc.jaxa.jp/water/

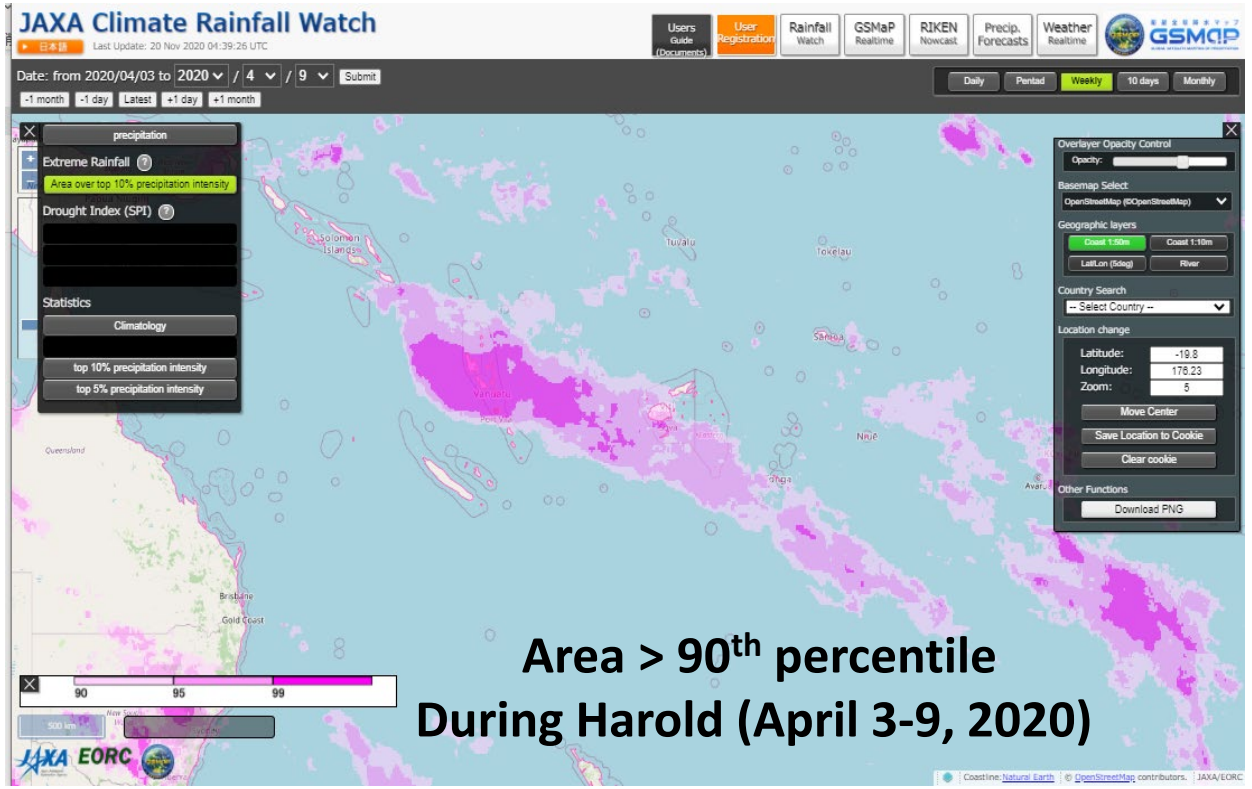
Drought and Heavy Rainfall Monitoring

We started to operate a website "**JAXA Climate Rainfall Watch**", which provides information about **extreme drought and heavy rainfall** over the world based on the GSMaP statistics.

Displaying accumulated rainfall in some temporal scale (daily, pentad, weekly, 10-days and monthly) and 25-year climate normal.



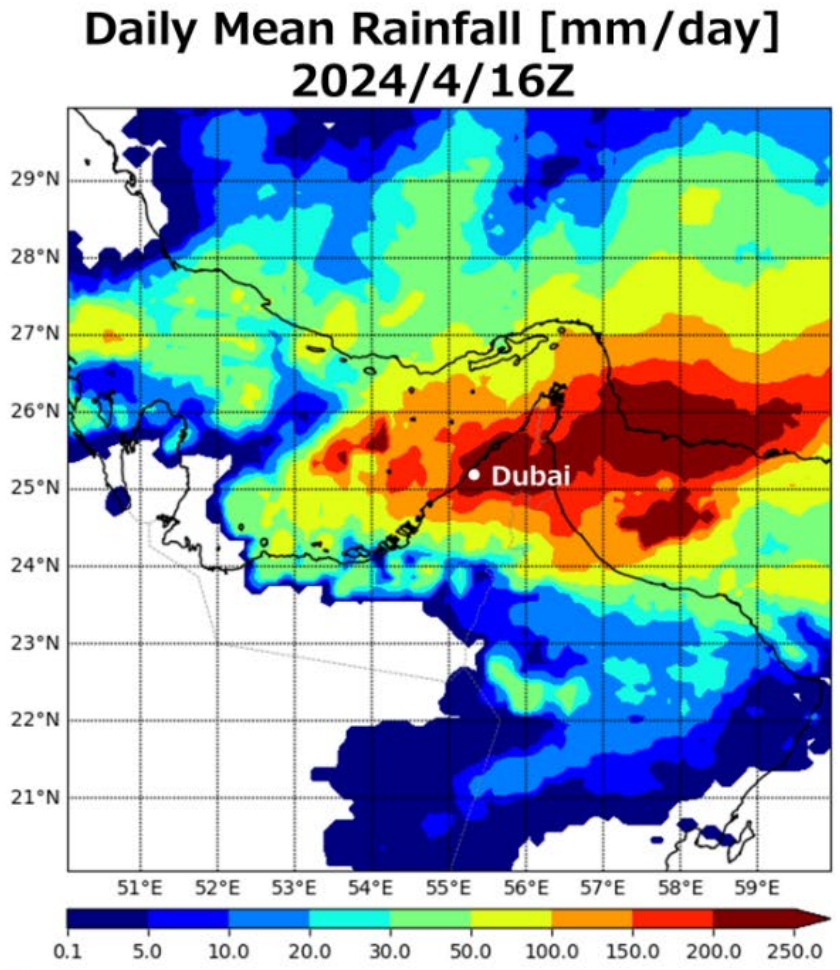
Drought in Australia (December 2019)

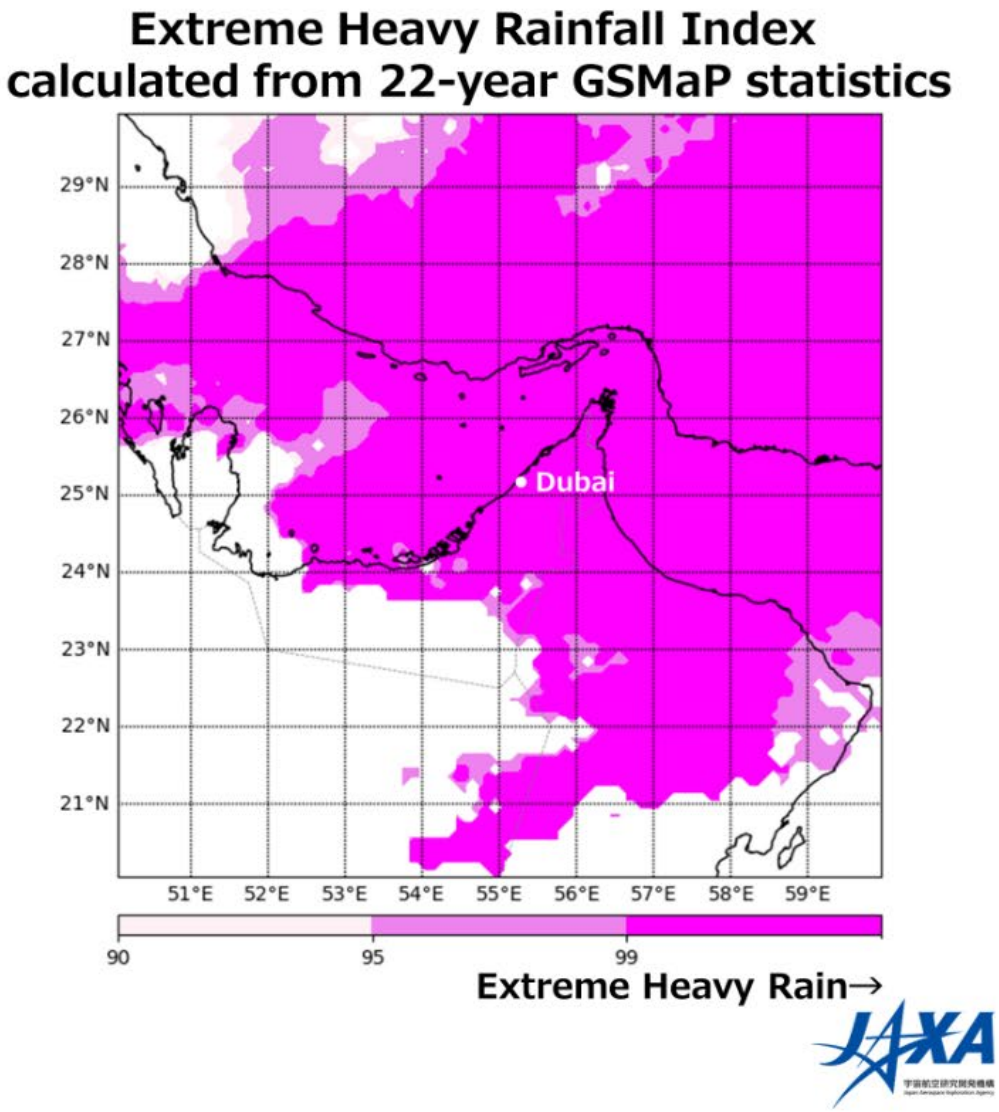


Area > 90th percentile
During Harold (April 3-9, 2020)

Graphical User Interface of the "JAXA Climate Rainfall Watch" website
(https://sharaku.eorc.jaxa.jp/GSMaP_CLM/)

Heavy rainfall in UAE (April 2024)





衛星全球降水マップ
GSMaP
GLOBAL SATELLITE MAPPING OF PRECIPITATION

https://earth.jaxa.jp/en/earthview/2024/04/19/8032/index.html –

GSMaP

GLOBAL SATELLITE MAPPING OF PRECIPITATION

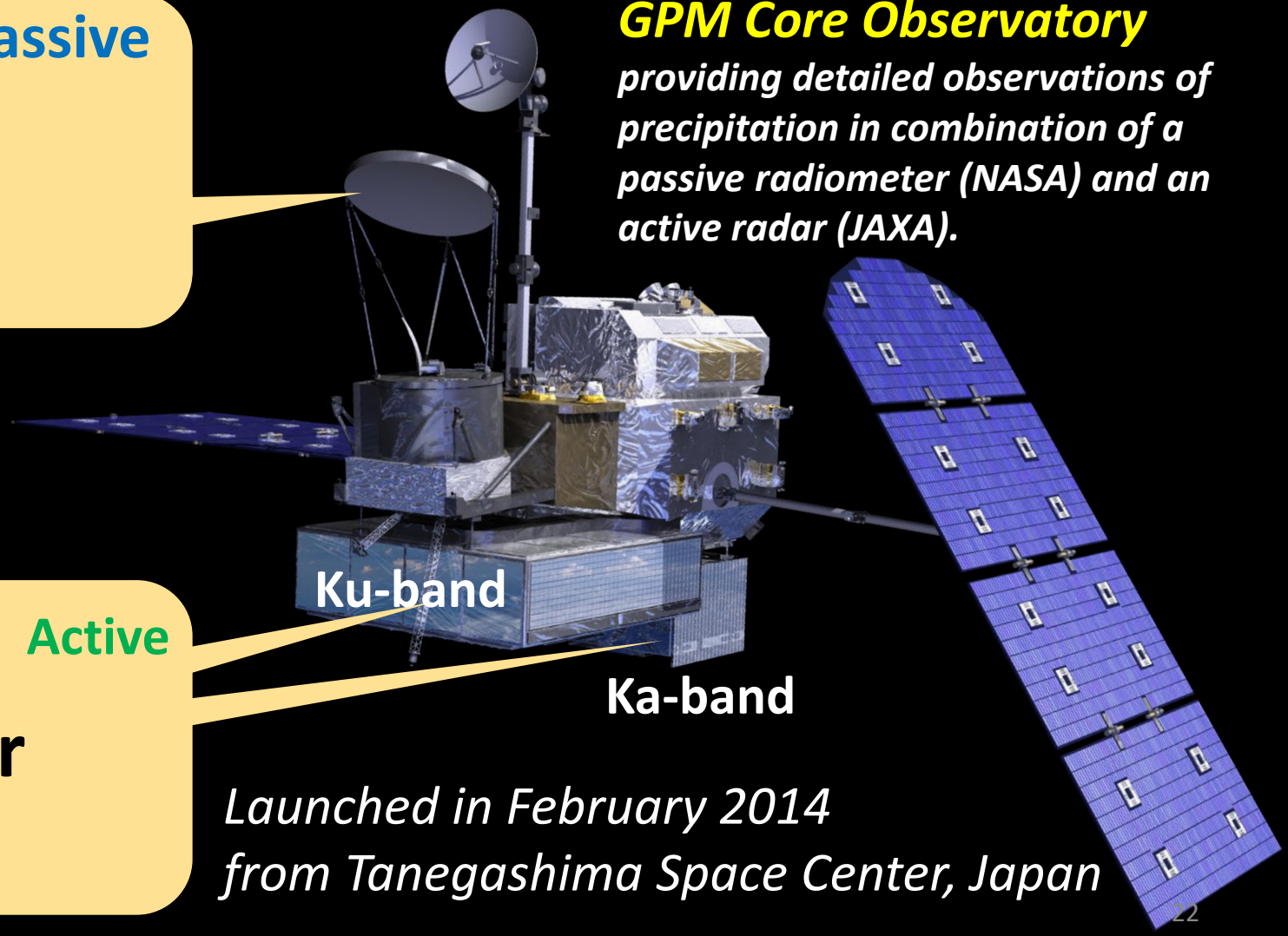
Algorithm of GSMaP

NASA-JAXA Joint Mission

"Global Precipitation Measurement (GPM) Mission"

NASA **GPM Microwave Imager (GMI)** — **Passive**

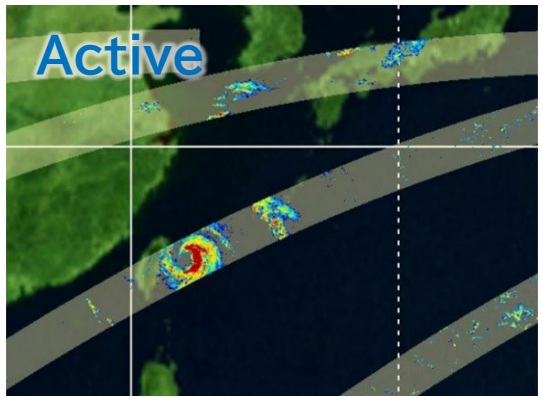
JAXA NICT **Dual-frequency Precipitation Radar (DPR)** — **Active**

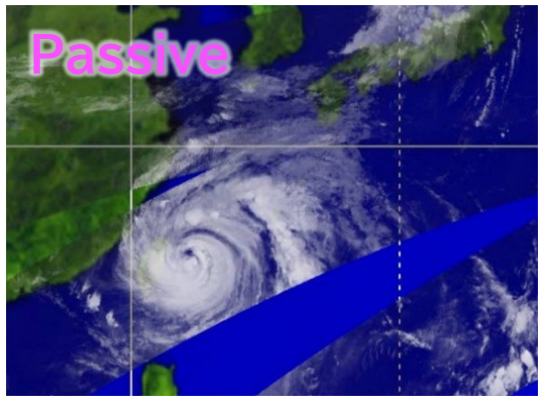


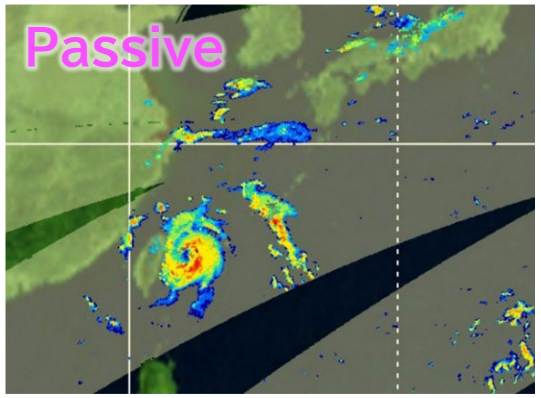
GPM Core Observatory
providing detailed observations of precipitation in combination of a passive radiometer (NASA) and an active radar (JAXA).

Launched in February 2014
from Tanegashima Space Center, Japan

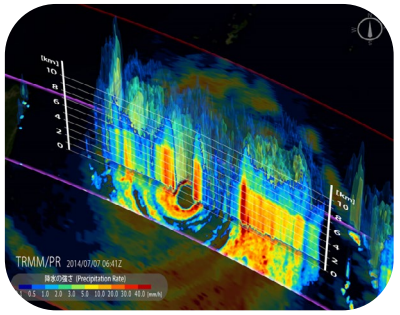
Features of sensors



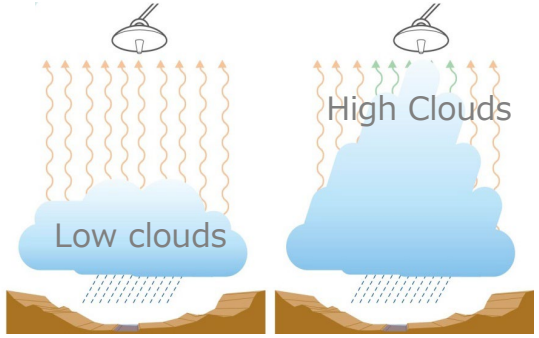




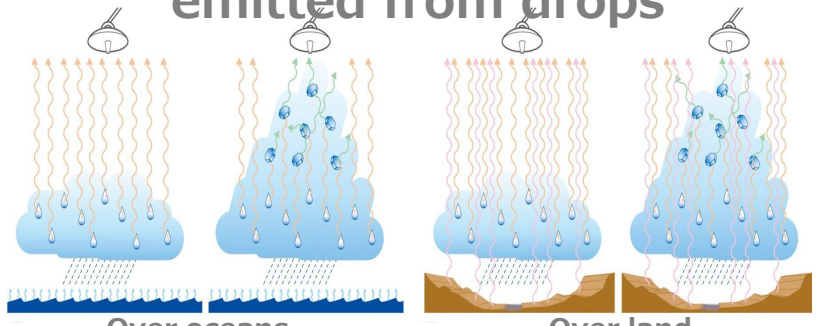
Directly observe vertical structure of precipitation



Measure cloud top temperature



Measure microwave radiation emitted from drops



Precipitation Radar

e.g., GPM/DPR

- Actively emit pulse and measure the echoes reflected back from drops.
- Can detect vertical distributions of precipitation but narrow swath.

Infrared Imager

e.g., Himawari/AHI

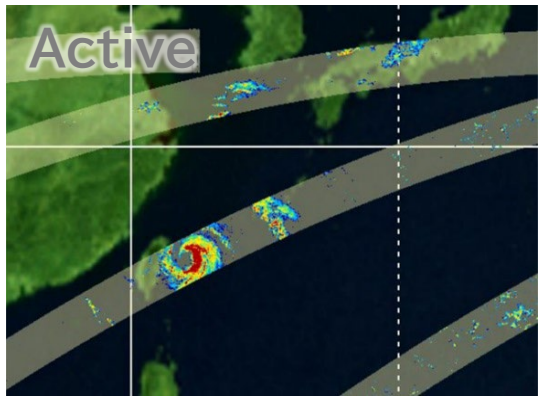
- Measure cloud top temperature.
- Cannot directory observe precipitation.

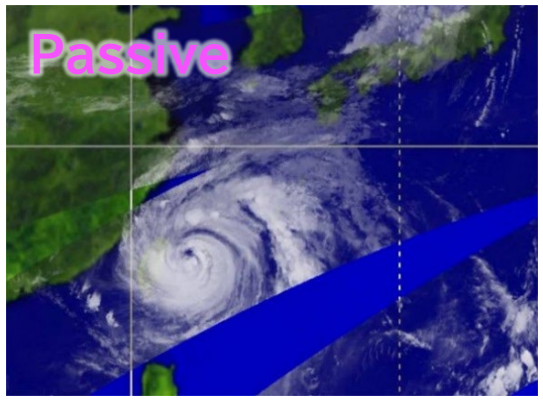
Microwave Radiometer (Imager/Sounder)

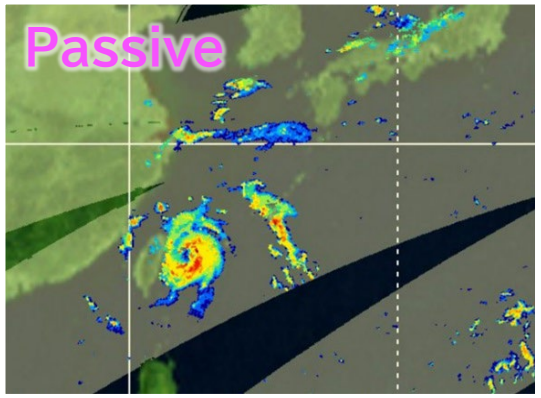
e.g., GPM/GMI

- Measure intensity of microwave radiation that is constantly emitted from raindrops.
- Can estimate spatial distributions of precipitation with wider swath
- There are many microwave radiometers in operation.

Features of sensors







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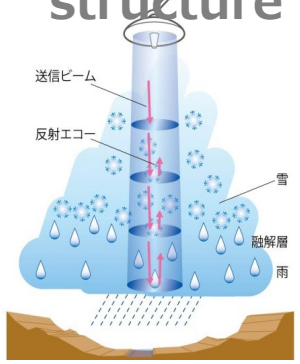

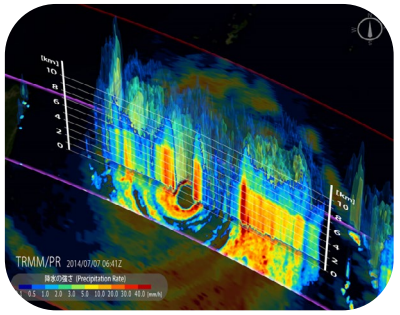

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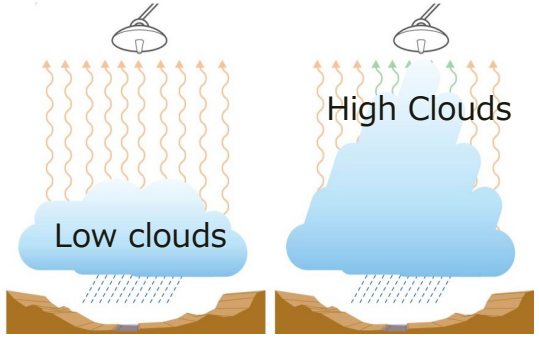

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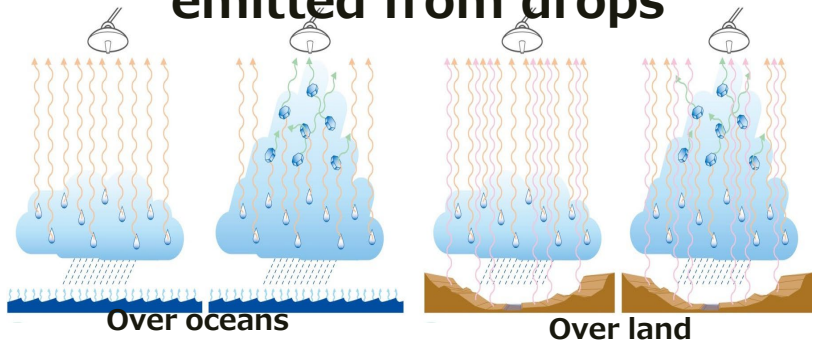

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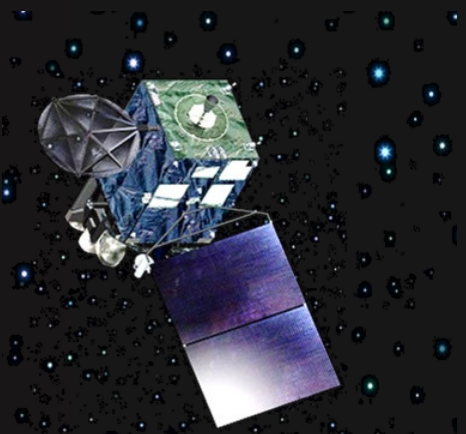
GSMaP Global Satellite Mapping of Precipitation

Dual-frequency Precipitation Radar

DPR

DPR provides "reference standard"

GPM Microwave Imager



©JMA

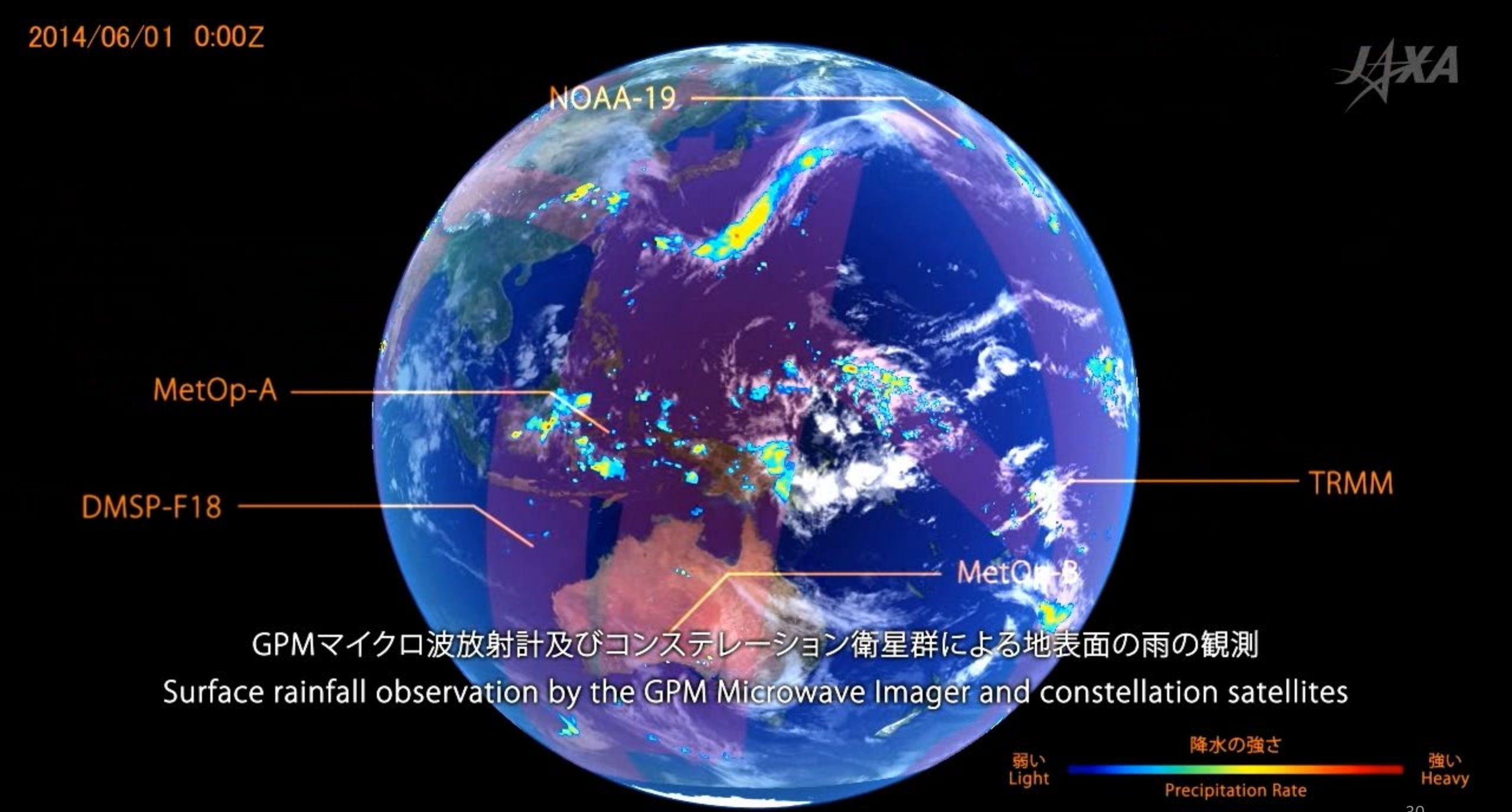
GPM Core Observatory

GPM constellation satellites

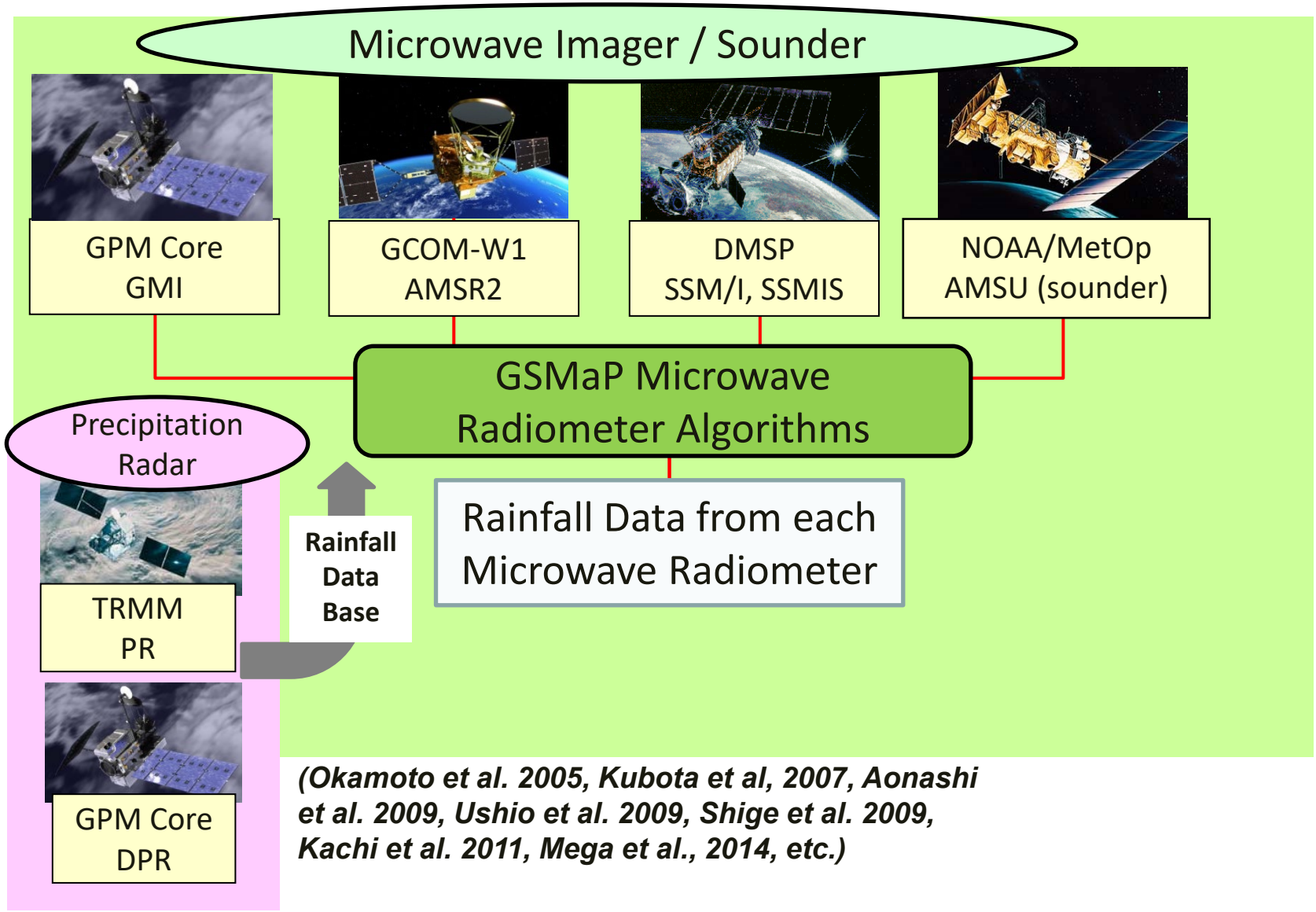
+

Geostationary Satellites

Precipitation Radar	Microwave Radiometer	Infrared Imager


2014/06/01 0:00Z
NOAA-19
MetOp-A
DMSP-F18
TRMM
MetOp-B
GPMマイクロ波放射計及びコンステレーション衛星群による地表面の雨の観測
Surface rainfall observation by the GPM Microwave Imager and constellation satellites
降水の強さ
弱い
Light
強い
Heavy
Precipitation Rate

Overview of GSMaP Algorithm



(Okamoto et al. 2005, Kubota et al, 2007, Aonashi et al. 2009, Ushio et al. 2009, Shige et al. 2009, Kachi et al. 2011, Mega et al., 2014, etc.)

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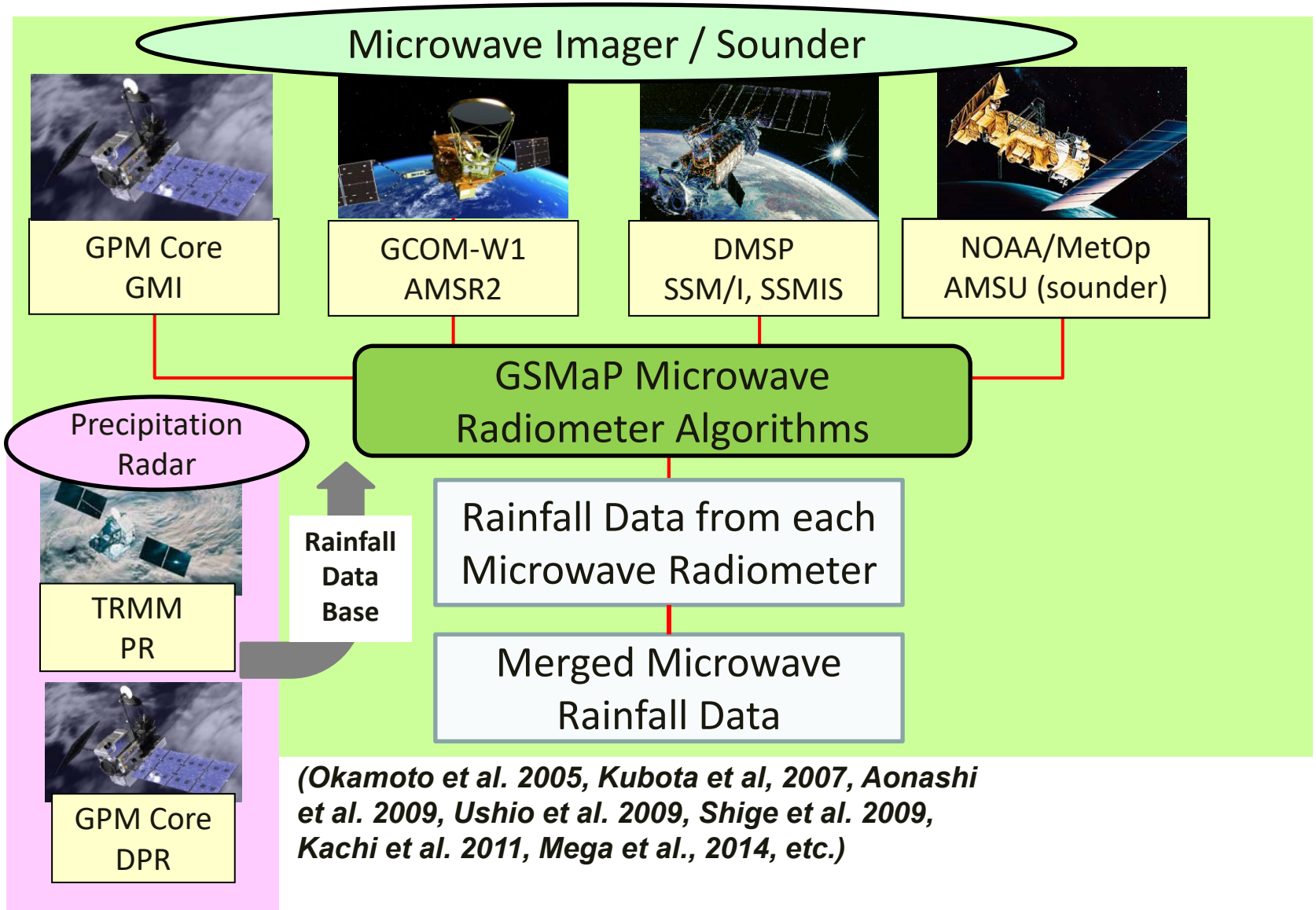

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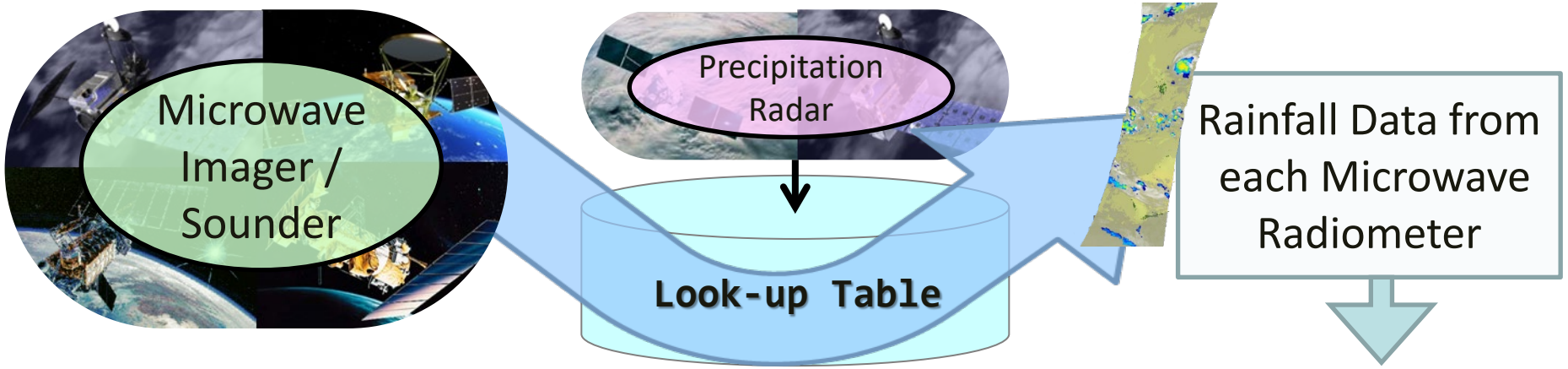
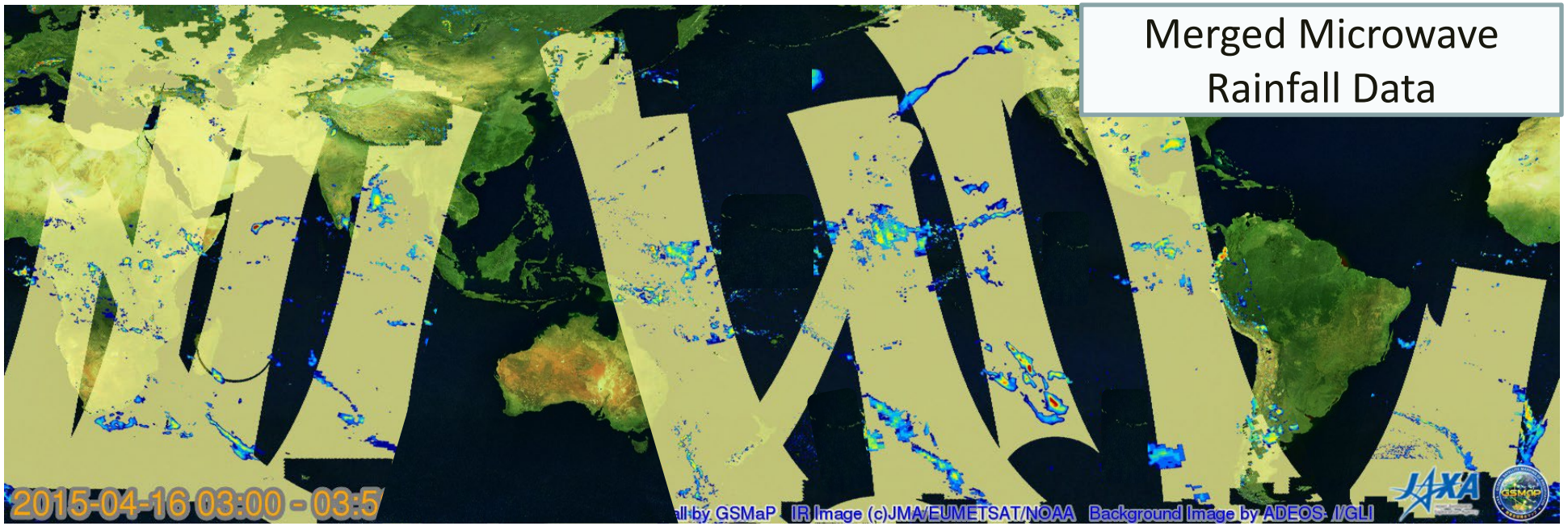
Simplified explanation of Algorithm

(Aonashi and Liu 2000, Kubota et al. 2007, Aonashi et al .2009)





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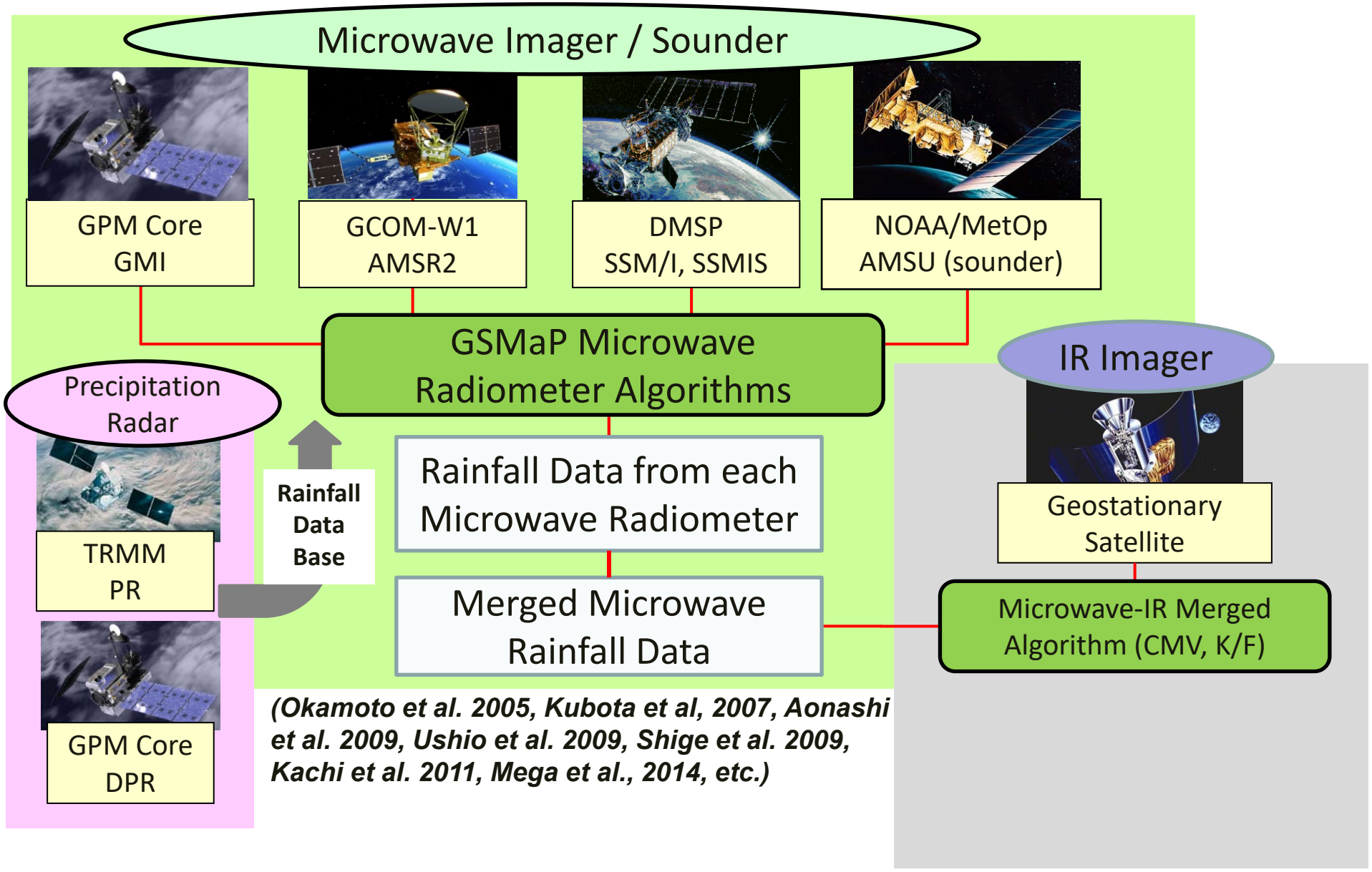

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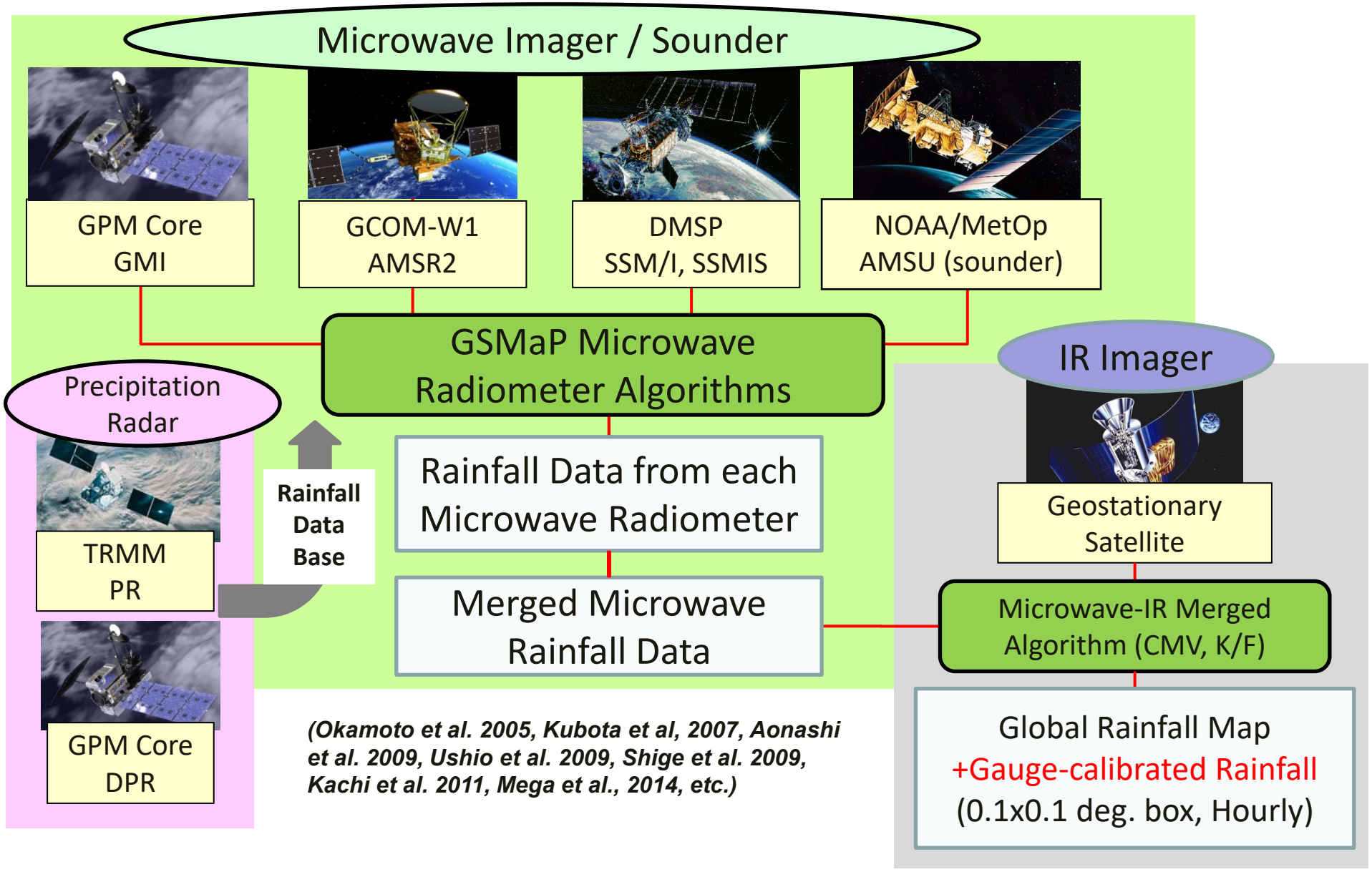

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GSMaP

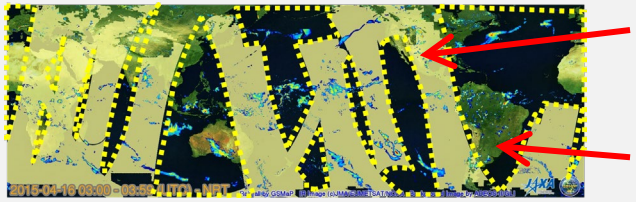
GLOBAL SATELLITE MAPPING OF PRECIPITATION

Investigation of GSMaP Accuracy

Some factors affecting the accuracy of GSMaP

① PMW-retrieved? or PMW-IR estimation?

An example of the PMW overpasses within an hour



Inside of the yellow-shaded areas

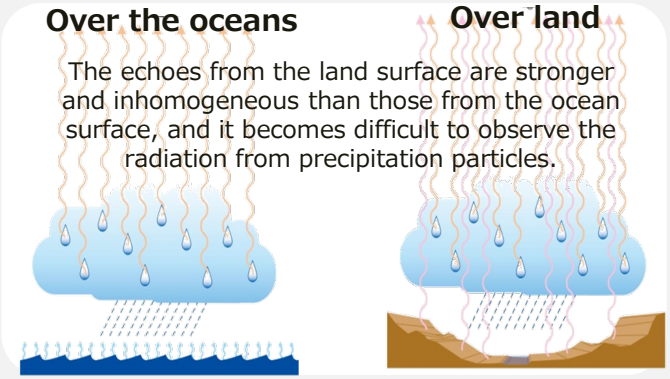
Retrieved by using PMW algorithm -> Better accuracy

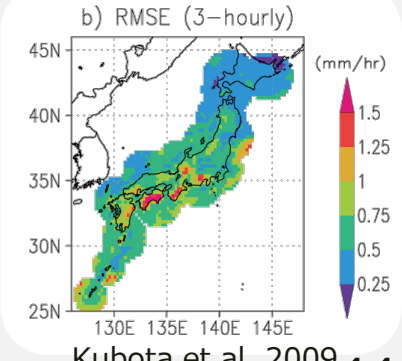
Outside of the yellow-shaded areas

Estimated by PMW-IR combined algorithm -> relatively lower accuracy

② Surface type

- Because of the PMW sensor features, accuracy is generally better over the oceans than over land.
- Over the mountainous regions, orographic rainfall is relatively difficult to be estimated.

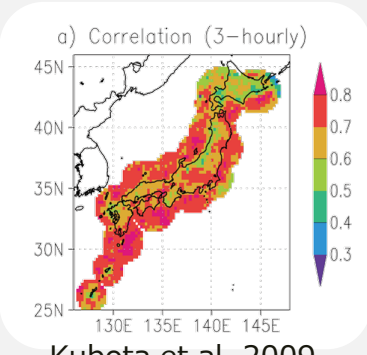




Kubota et al. 2009

③ Low temperature and snow

- Surface snow causes false signals and lowers the accuracy of GSMaP estimates.
- Snow estimation is still in the R&D stage with a large research component



Kubota et al. 2009

From an algorithmic point of view, we know the qualitative error factors.

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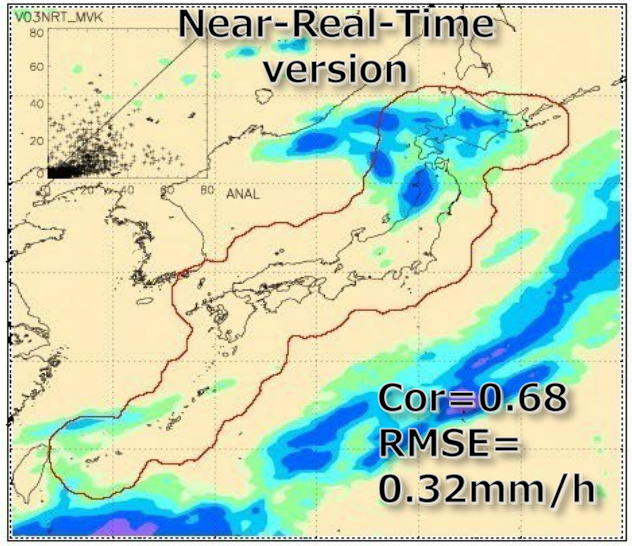
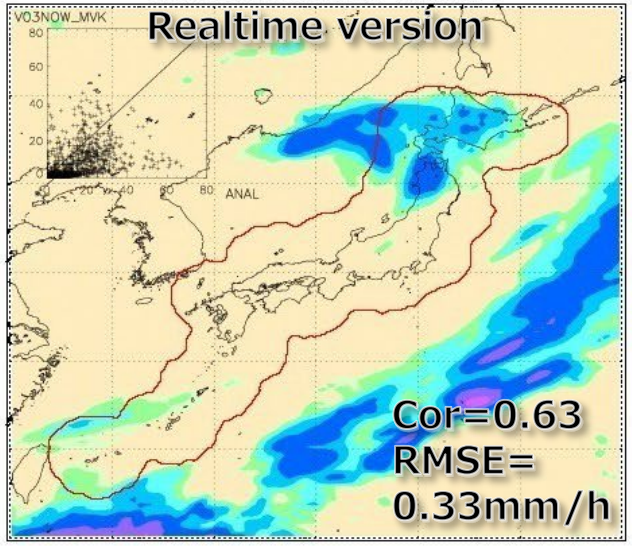
Snapshots of Daily Validation

May. 27, 2017, in 0.25 degree grid and daily accumulation

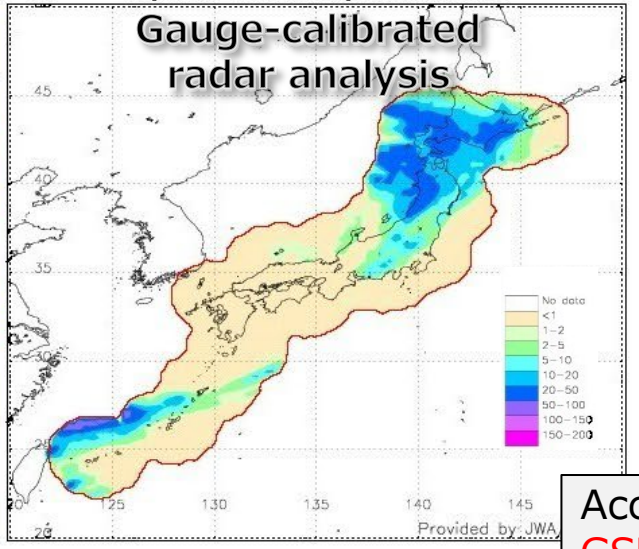
GSMaP_NRT



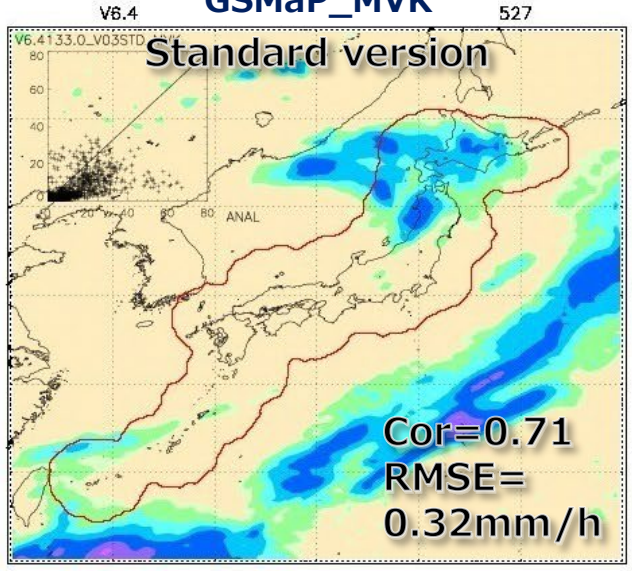
GSMaP_NOW



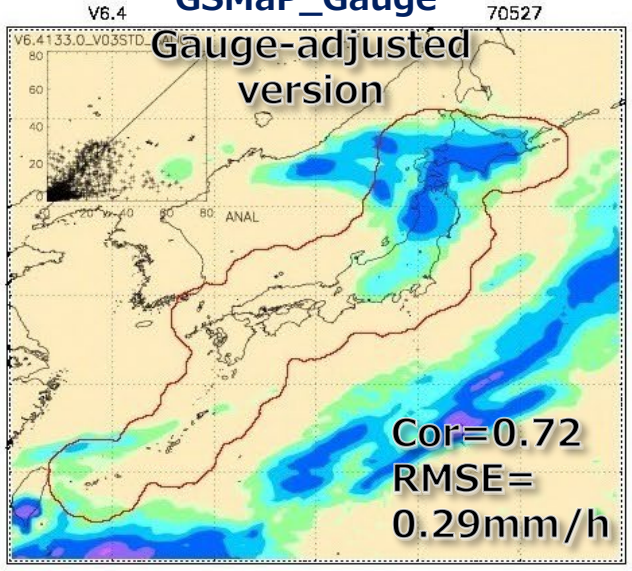
JMA's Radar-AMeDAS



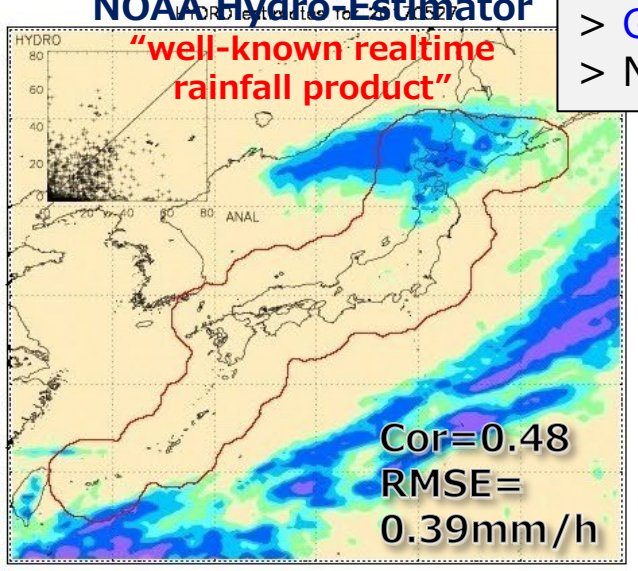
GSMaP_MVK



GSMaP_Gauge

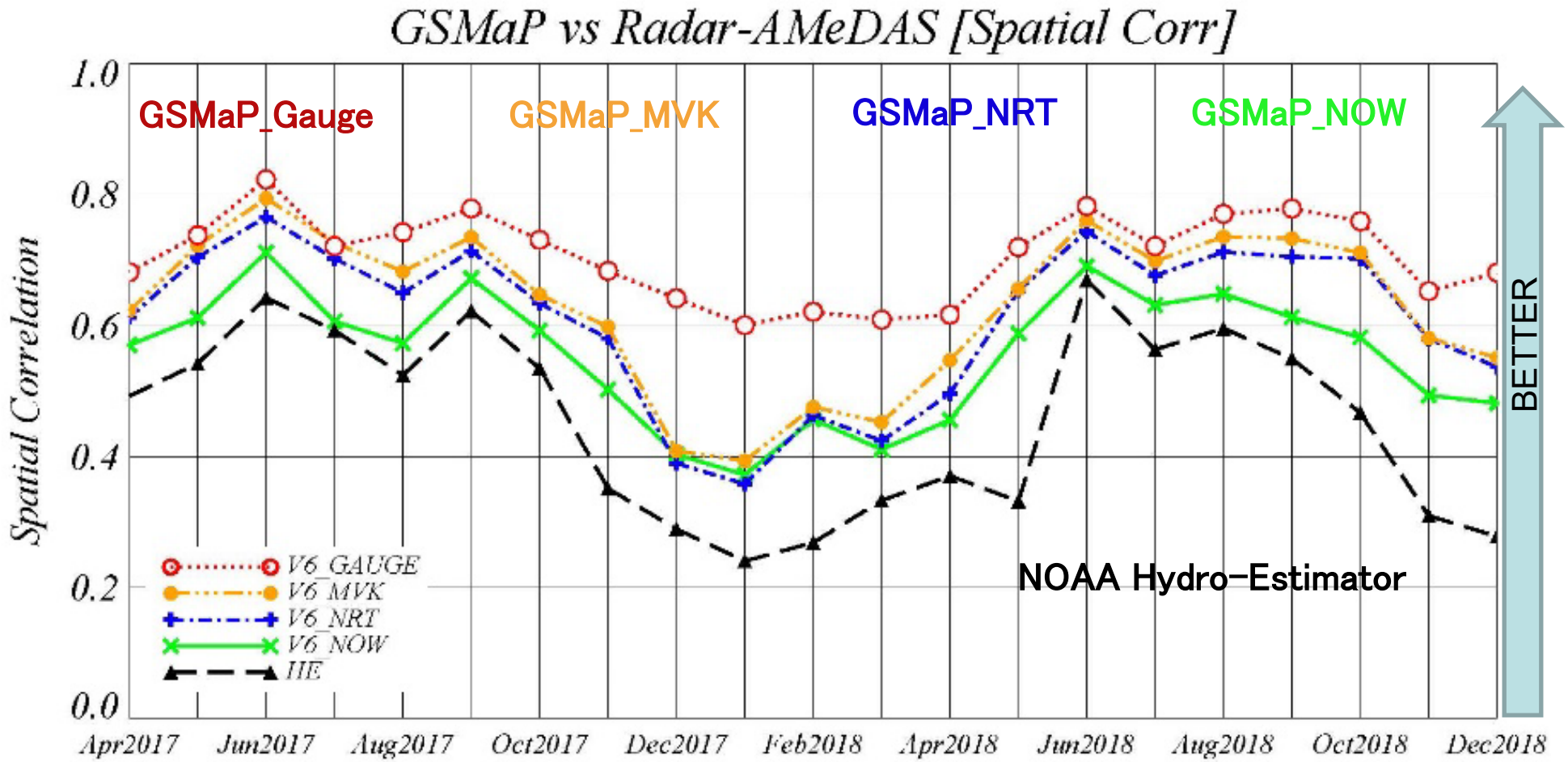


NOAA Hydro-Estimator



Accuracy over Japan is …
GSMaP_Gauge >GSMaP_MVK
> GSMaP_NRT > GSMaP_NOW
> NOAA H-E

Snapshots of Daily Validation



Accuracy over Japan is …
GSMaP_Gauge >GSMaP_MVK
> GSMaP_NRT > GSMaP_NOW
> NOAA H-E

Accuracy varied seasonally around Japan, which suggested that the accuracy depends on some factors like precipitation amount and characteristics.

Demonstration of the GSMaP website

GSMaP websites

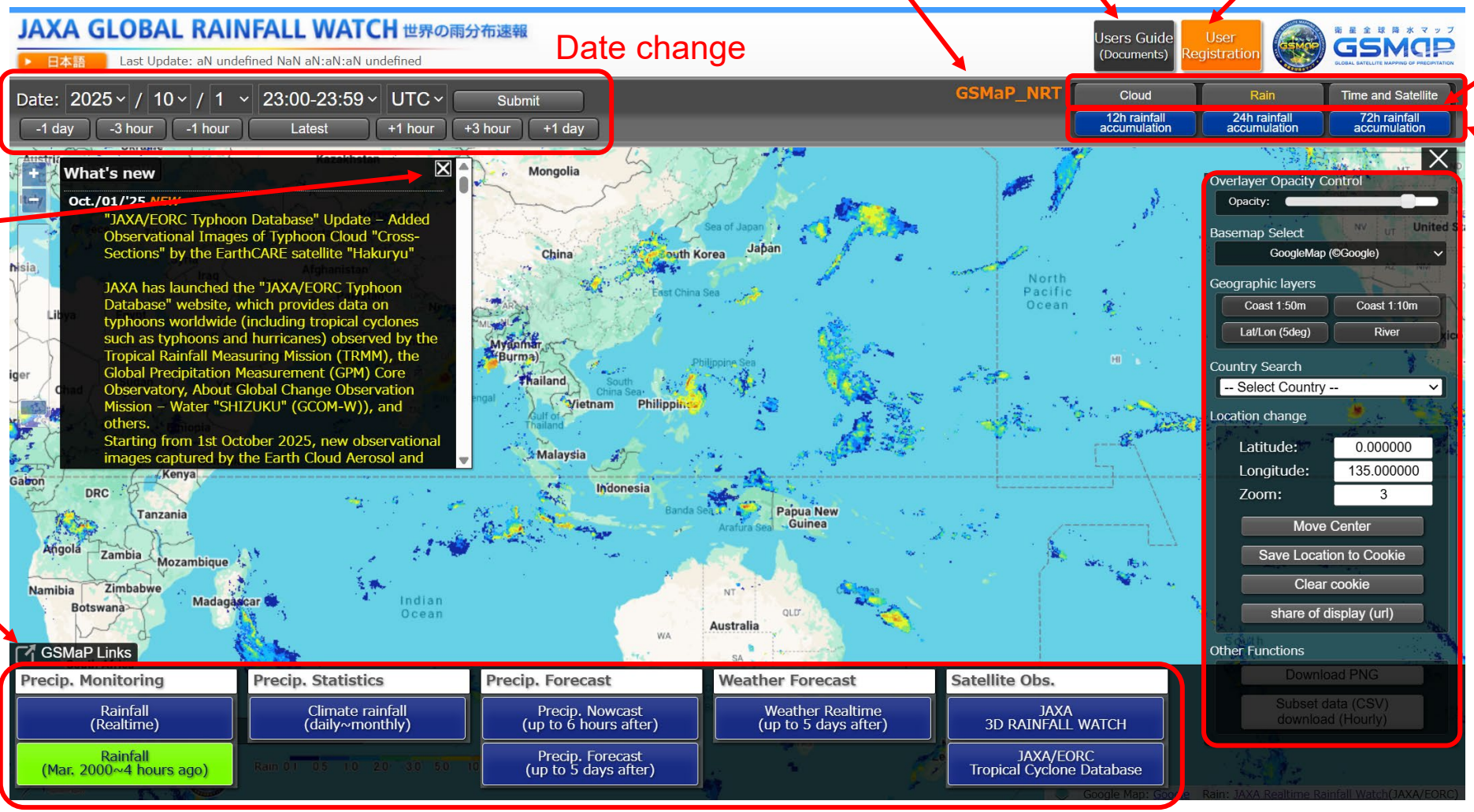
- For users who would like to **monitor precipitation in realtime**
  ...JAXA REALTIME RAINFALL WATCH
  You can see global precipitation map, updated **every 30 minutes**.

- For users who would like to see **precipitation in the past specific date**
  ...JAXA GLOBAL RAINFALL WATCH
  You can see hourly global precipitation map **since March 2000**.

- For users who would like to see **daily or monthly precipitation**
  ...JAXA CLIMATE RAINFALL WATCH
  You can see indices related to **extreme heavy rainfall and drought** as well as accumulated precipitation.

GSMaP website

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



Product name

User's guide

Registration

Date change

Cloud, satellite info

Accumulated precipitation

What's New On/Off

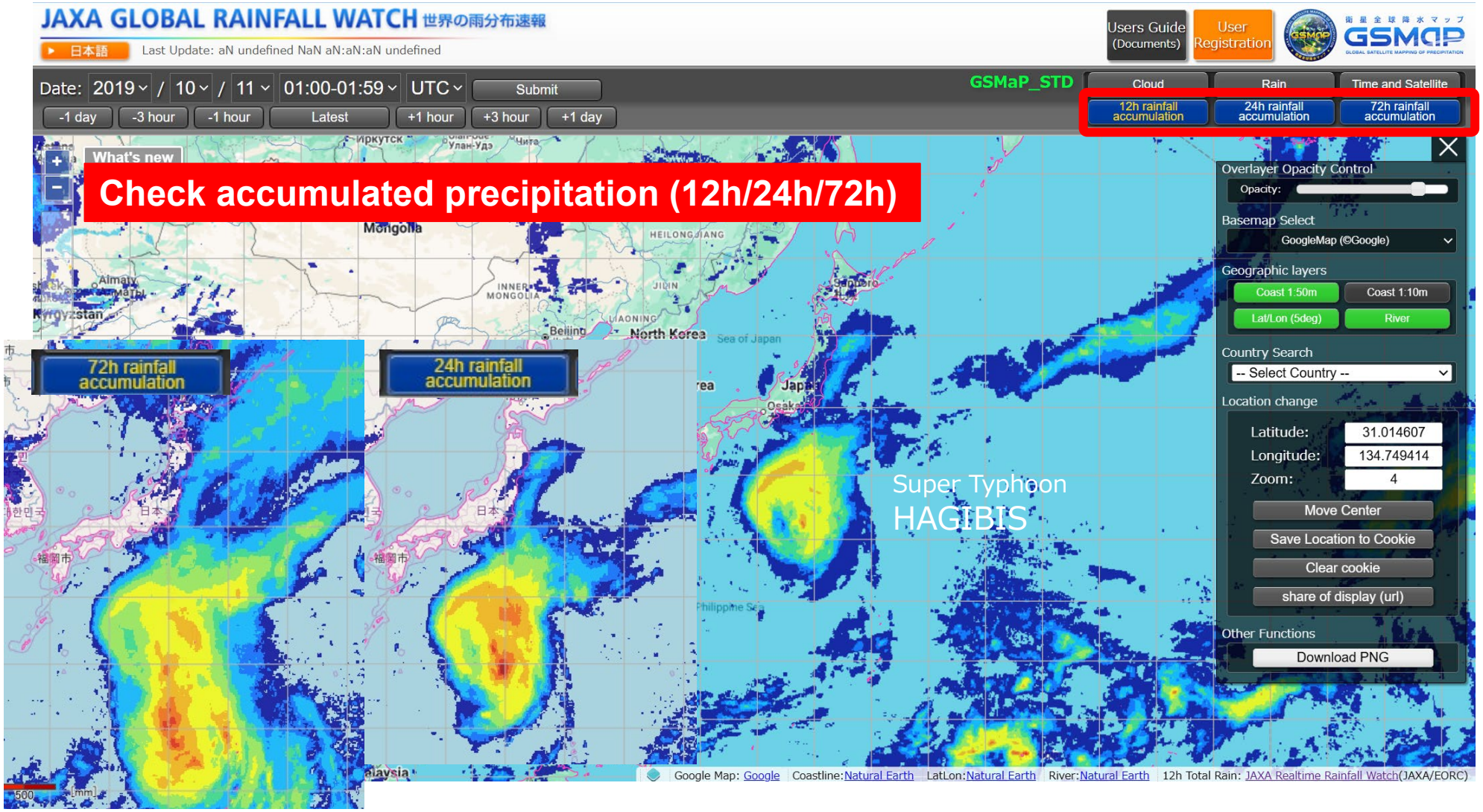
Control panel

GSMaP link On/Off

Select GSMaP and related websites

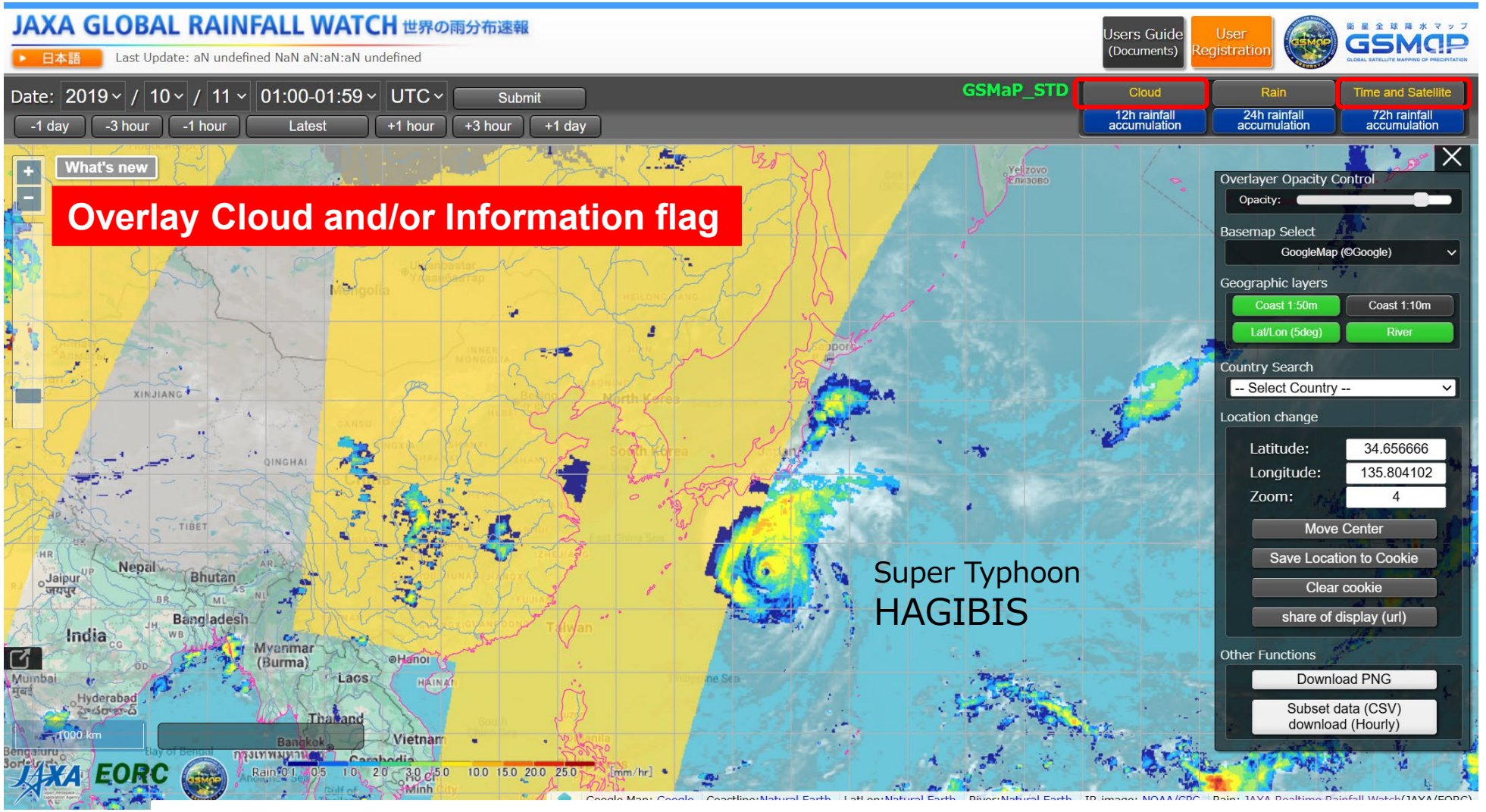
GSMaP website

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



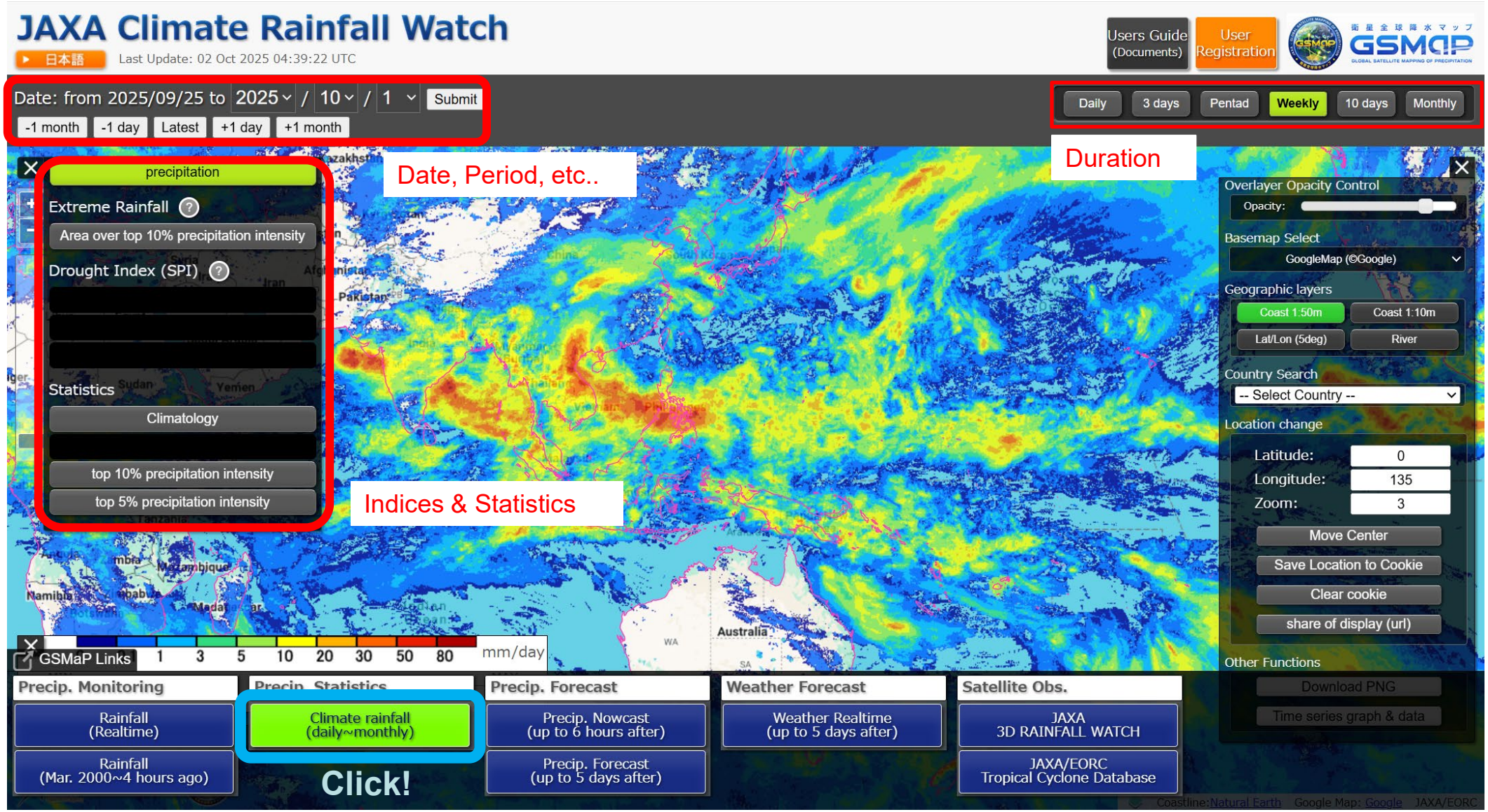
GSMaP website

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



GSMaP Website (GSMaP Climate Rainfall Watch)

Extreme precipitation and drought index (SPI) are available.

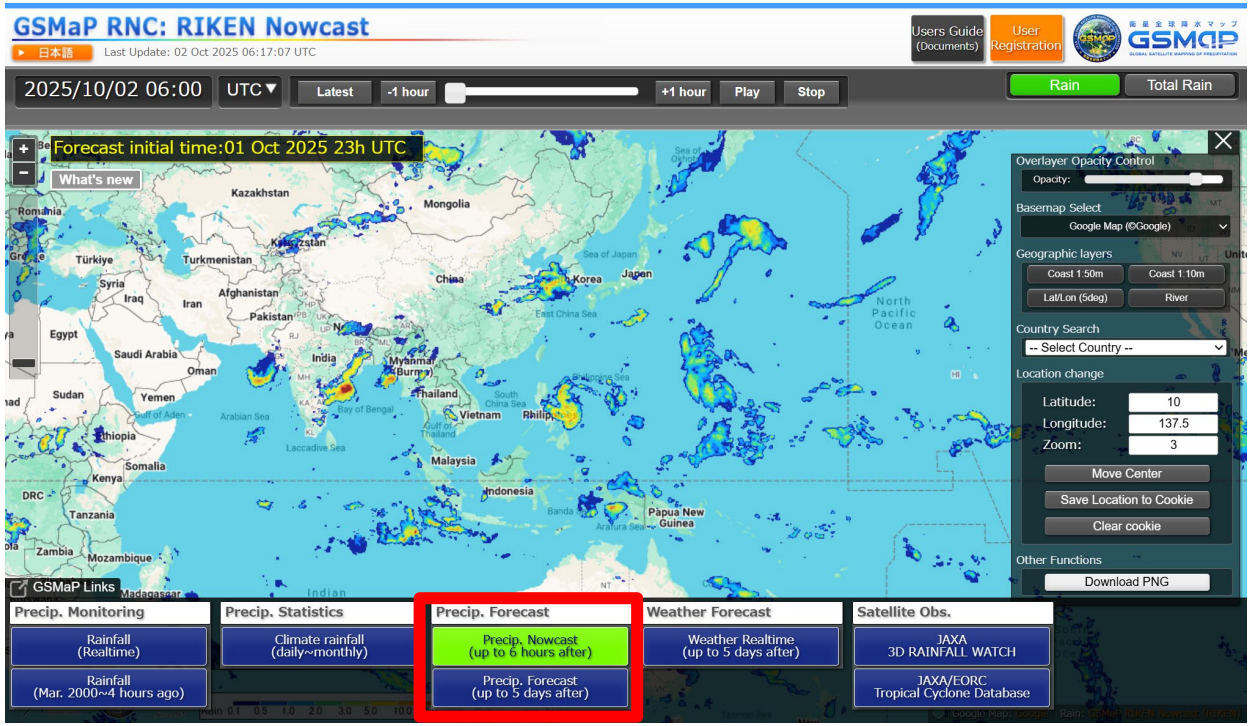


https://sharaku.eorc.jaxa.jp/GSMaP_CLM/index.htm

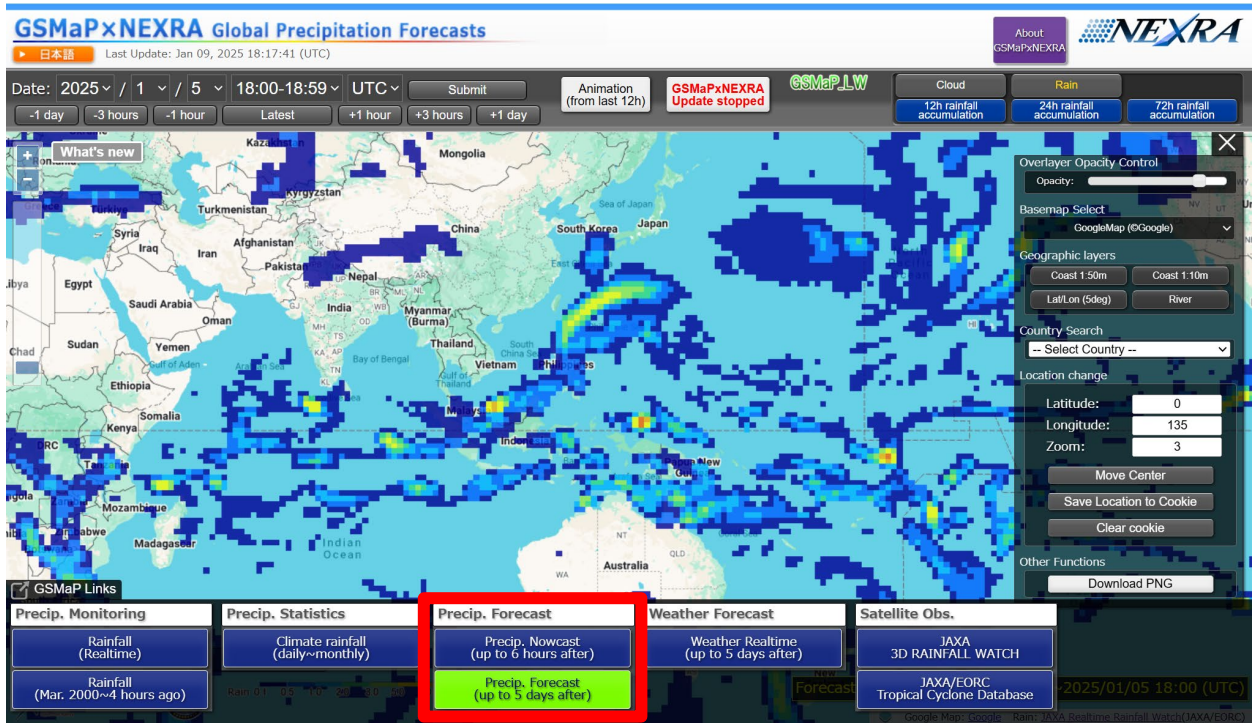
GSMaP website (Precipitation forecast)

Provides two types of websites related to precipitation forecast.

- **GSMaP RNC: RIKEN Nowcast** provides precipitation nowcast up to **6 hours after**.
- **GSMaPxNEXRA Global Precipitation Forecasts** provides precipitation forecast up to **5 days after**.



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



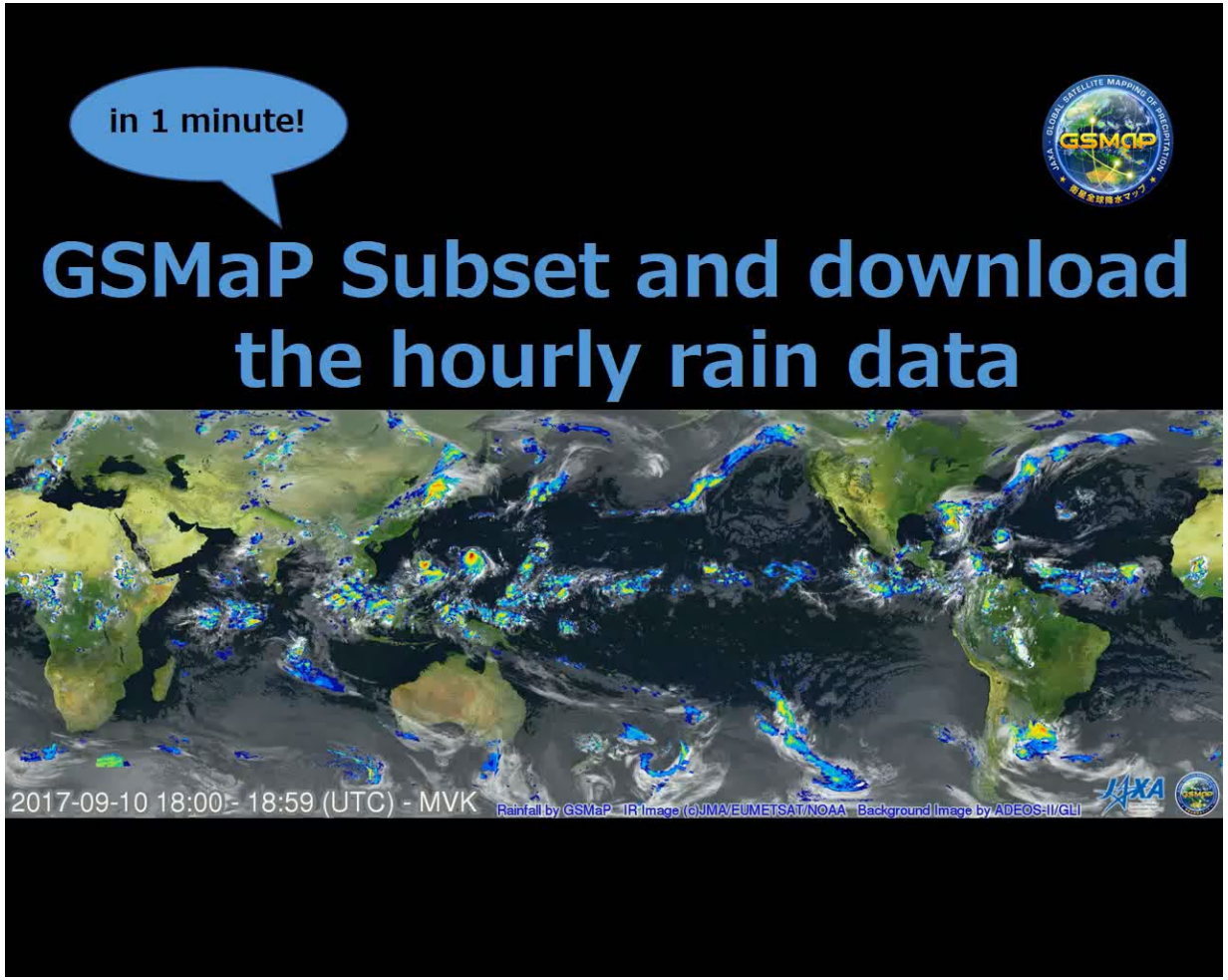
https://sharaku.eorc.jaxa.jp/GSMaPxNEXRA/index.htm

GSMaP websites

How to use GSMaP website in 1 minute!

https://youtu.be/0JanK-fZMt4

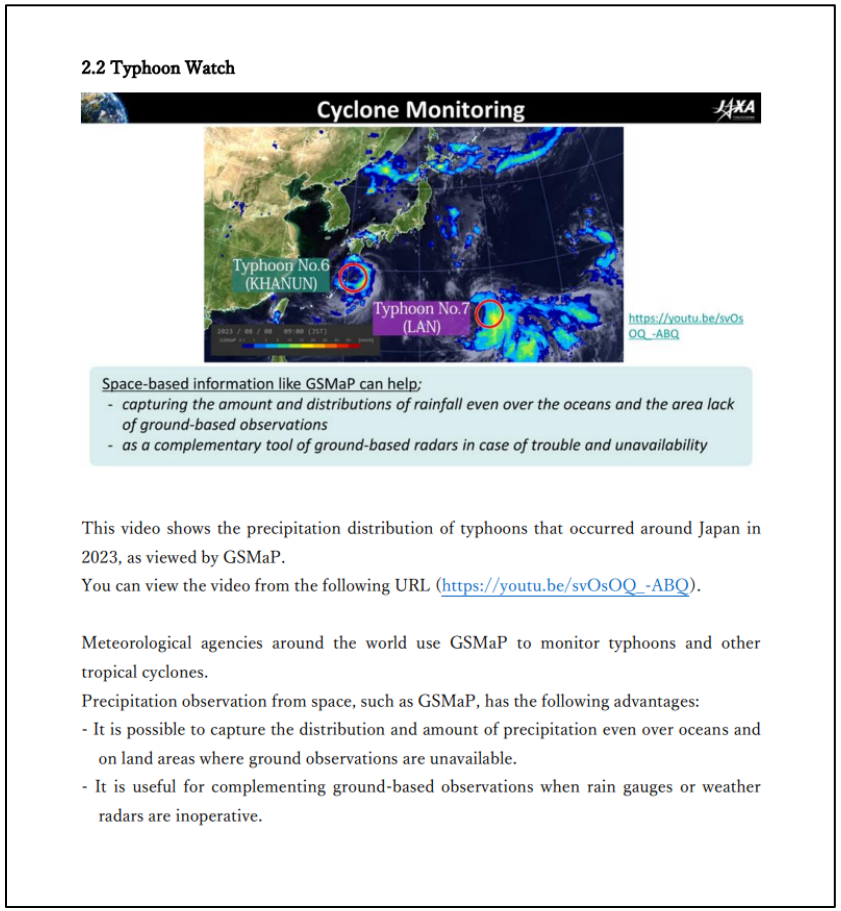
GSMaP subset and
download hourly rain data in 1 minute!



https://youtu.be/VnxH7inZh6g

Guidelines for using the GSMaP

- Guidelines for using the GSMaP has been released in Dec. 2024.
  https://www.eorc.jaxa.jp/GPM/doc/data_utilization/GSMaP_Guidelines_E.pdf
- The contents are similar to this lecture. Guidelines is useful to review the lecture.



2.2 Typhoon Watch

Cyclone Monitoring

Typhoon No.6 (KHANUN)

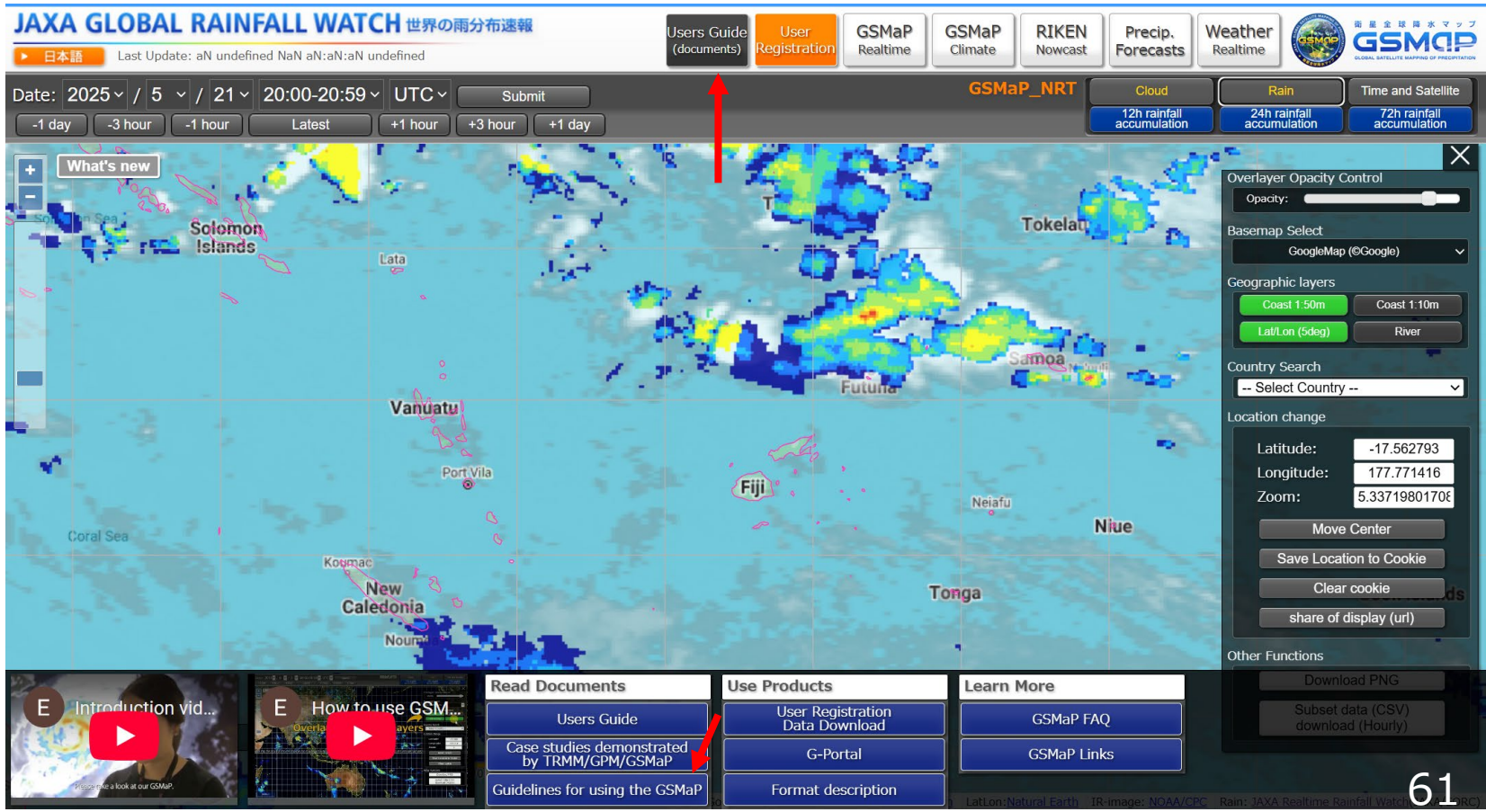
Typhoon No.7 (LAN)

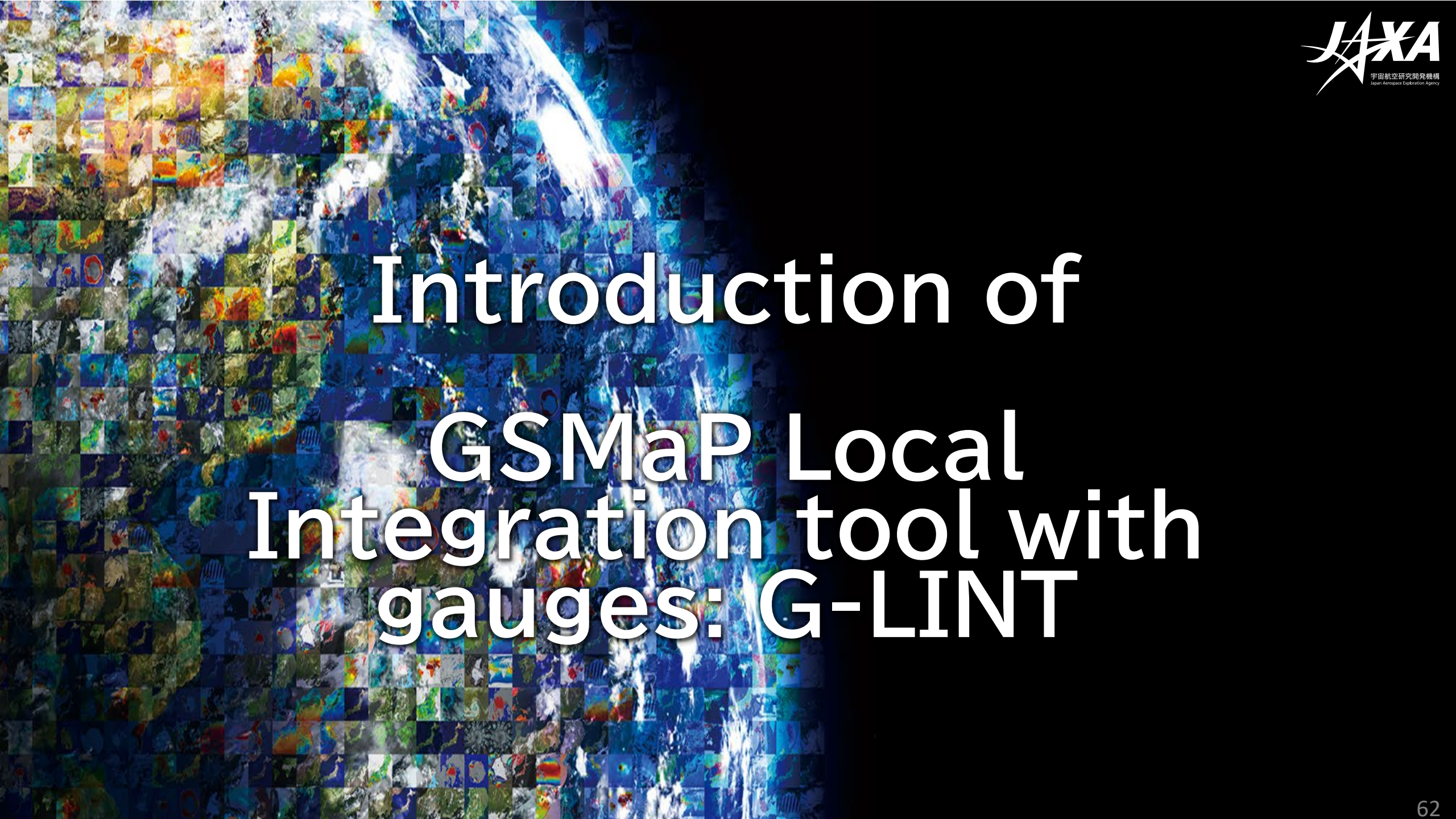
https://youtu.be/svOsOQ_-ABQ

Space-based information like GSMaP can help;
- *capturing the amount and distributions of rainfall even over the oceans and the area lack of ground-based observations*
- *as a complementary tool of ground-based radars in case of trouble and unavailability*

This video shows the precipitation distribution of typhoons that occurred around Japan in 2023, as viewed by GSMaP.
You can view the video from the following URL (https://youtu.be/svOsOQ_-ABQ).

Meteorological agencies around the world use GSMaP to monitor typhoons and other tropical cyclones.
Precipitation observation from space, such as GSMaP, has the following advantages:
- It is possible to capture the distribution and amount of precipitation even over oceans and on land areas where ground observations are unavailable.
- It is useful for complementing ground-based observations when rain gauges or weather radars are inoperative.



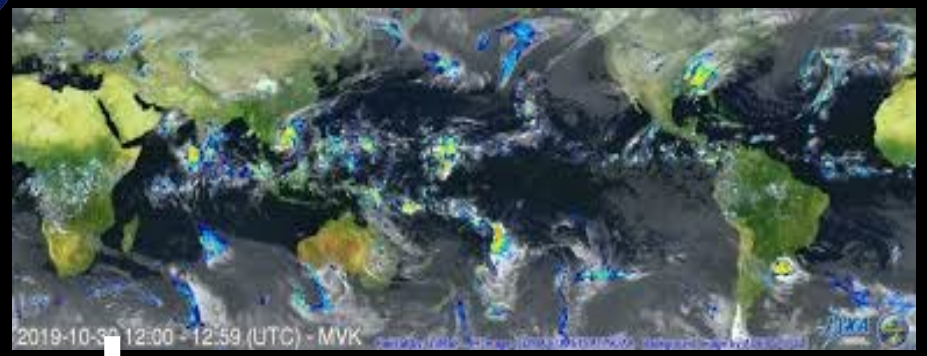


Introduction of

GSMaP Local Integration tool with gauges: G-LINT

GSMaP Local Integration tool with gauges: G-LINT

GSMaP



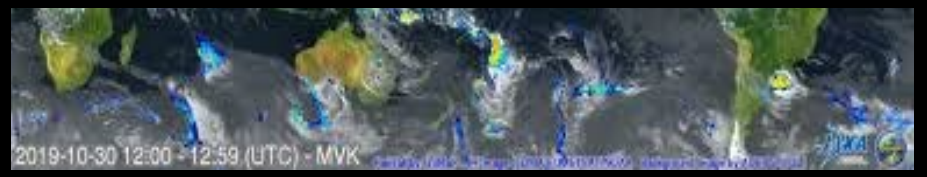
Users

G-LINT

Local gauges observatory data

time	001	002	003
Nov XX 20XX	15	0	11
Nov XX 20XX	16	12	2
Nov XX 20XX	4	2	30

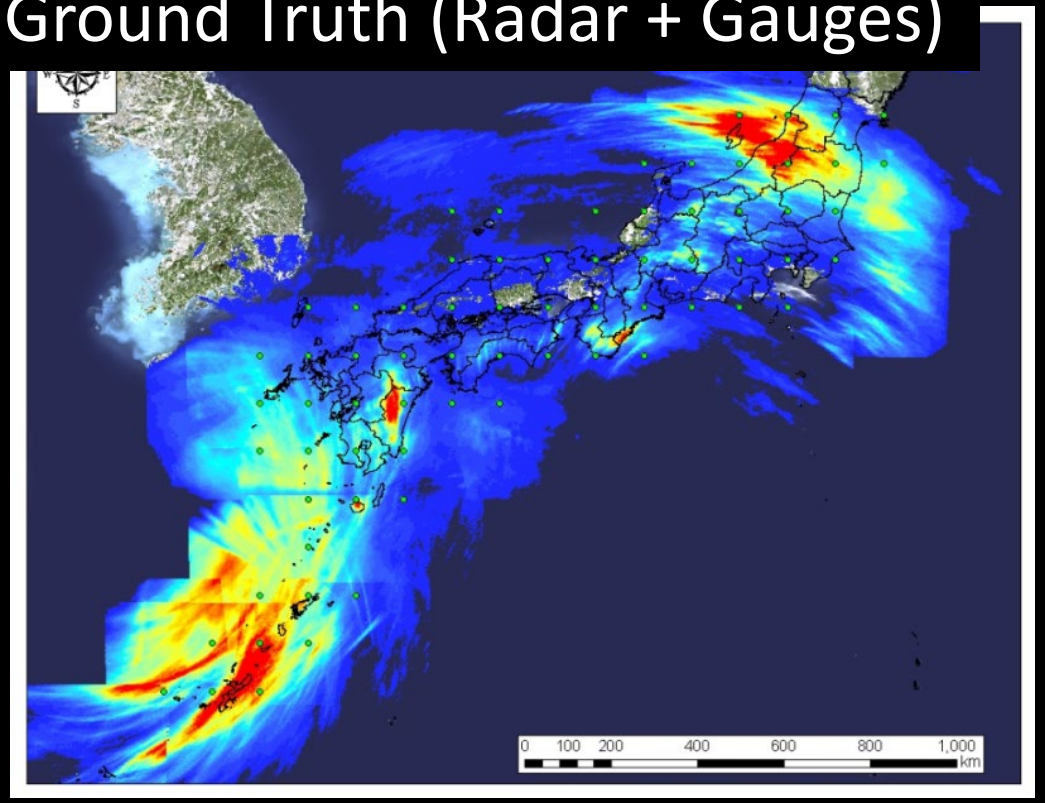
GSMaP
Adjusted by localized gauge



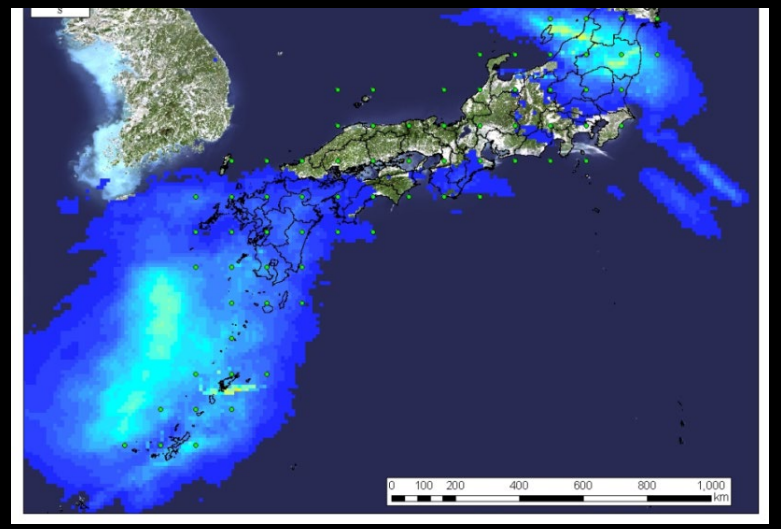
GSMaP Local Integration tool with gauges: G-LINT

Case study over Japan

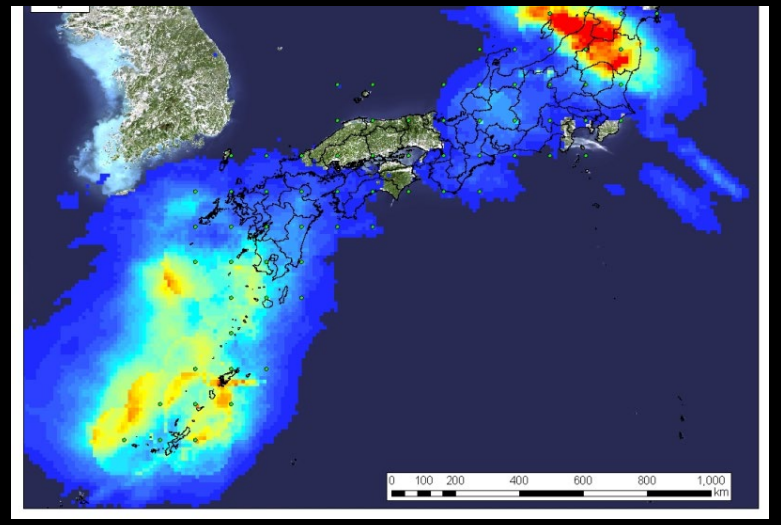
Ground Truth (Radar + Gauges)



GSMaP Before Correction



GSMaP After Correction



How G-LINT works

Local Observatory

Ground rainfall
(Daily/3 hours etc.)

time	001	002	003
Nov XX 20XX	15	0	11
Nov XX 20XX	16	12	2
Nov XX 20XX	4	2	30

GSMaP

Satellite rainfall (Hourly)

Included in the G-LINT package

Elevation Data

GSMaP error correction

Rainfall accumulation (Adjusting time span)

Weight calculation (Triangulated irregular network)

Rainfall correction (Scale & Offset)

Conversion to hourly rainfall

Corrected GSMaP (Hourly)

Schedule

~March 2026
- Tool Development
- Test & Assessment
- Partly release for test users

~March 2027
- Release for public as an open-source tool

If you are interested in G-LINT, we are glad to share it with you as a test users.

Summary for GSMaP & G-LINT

- GSMaP is the **multi-satellite product** by combining passive microwave radiometers, IR imagers, and precipitation radars.
- GSMaP consists of some products, **realtime, near-realtime, standard and their gauge-adjusted versions**.
- We distribute the data or image via website and ftpsite and users can freely access to the data.
- **We develop GSMaP Local Integration tool with gauges (G-LINT).** We are looking forward to your application as test users.

Thank you !