

JAXA Earth Observation Program and Data Product

JAXA operates various kind of satellite sensors and opens the products to the public. We keep developing and improving the products to address the climate issues.

The major updates since CGMS-51 is that the reprocessing during about 25 years for the new version of the Global Satellite Mapping of Precipitation (GSMaP) was completed. JAXA improved the GSMaP algorithm in December 2021 (algorithm version 8) and released 25-year precipitation data in September 2023. GCOM-C has achieved the 6-year in Dec. 2023. GCOM-W has achieved 12-year in May 2024 and several new research products are available. JAXA will launch three missions in JFY2024; the joint Japanese-European EarthCARE mission in May 2024; the ALOS-4 satellite with L-band SAR in June 2024; and the GOSAT-GW satellite with GHG sensor and microwave imager in JFY2024.

In terms of the WMO project for monitoring extremes, JAXA contributes to the WMO Space-based Weather and Climate Extremes Monitoring (SWCEM) Project by providing more than 25-yr GSMaP rainfall product with climate normal.

JAXA also contributes to the Global Greenhouse Gas Watch (G3W) by defining the role of satellite products. Since May 2023, JAXA is continuously providing JAXA/GHG products in public.

Moreover, JAXA will host the 11th Workshop of the International Precipitation Working Group (IPWG) at Tokyo Institute of Technology from July 15th to 18th, 2024, in collaboration with the IPWG, which is co-sponsored by the CGMS and WMO.

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1 INTRODUCTION

Purpose of the paper is as follows;

- 1) to update the status of JAXA's Earth Observation satellite program and data product in operation and to be launched shown in Table 1 (Sections 2 and 3),
- 2) to introduce the contribution to WMO Space-based Weather and Climate Extremes Monitoring (SWCEM) Project (Section 4), and
- 3) to report the status of the next generation Precipitation Radar discussed in JAXA, following to the TRMM/PR and the GPM/DPR (Section 5).

Table 1. Line-up of the JAXA Earth Observation Satellites and Sensors

Satellites and/or Sensors		Launch (UTC)
In operation		
GOSAT***	Greenhouse gases Observing SATellite	23 Jan. 2009
GCOM-W	Global Change Observation Mission -Water	17 May 2012
GPM/DPR*	Dual-Frequency Precipitation Radar onboard the Global Precipitation Measurement Mission Core Observatory	27 Feb. 2014
ALOS-2	Advanced Land Observing Satellite-2	24 May 2014
GCOM-C	Global Change Observation Mission - Climate	23 Dec. 2017
GOSAT-2***	Greenhouse gases Observing SATellite-2	29 Oct. 2018
ALOS-3	Advanced Land Observing Satellite-3	Launch failed in 7 Mar. 2023
To be launched		
ALOS-4	Advanced Land Observing Satellite-4	Jun. 2024 (Planned)
EarthCARE/CPR**	Cloud Profiling Radar onboard the Earth Cloud, Aerosol and Radiation Explorer	May 2024 (Planned)
GOSAT-GW***	Global Observing SATellite for Greenhouse gases and Water cycle	JFY2024 (Planned)
ISS/MOLI	Multi-footprint Observation Lidar and Imager (MOLI) installed in the Exposed Facility of the Japanese Experiment Module (JEM) of the International Space Station (ISS)	JFY2026 (As target)

* Joint mission with NASA

** Joint mission with ESA

*** Joint with the Ministry of the Environment (MOE) in Japan and National Institute for Environment Studies (NIES).

2 CURRENT SATELLITE MISSIONS AND PRODUCTS

The GOSAT data since 2009 and GOSAT-2 data since 2019 have been distributed through the GOSAT Data Archive Service (GDAS; https://data2.gosat.nies.go.jp/index_en.html). Simultaneously-observed GOSAT and GOSAT-2 data have been inter-compared and their products are cross-calibrated. Their research products with both total and partial column (lower and upper troposphere) densities of CO₂, CH₄, and H₂O are available at the JAXA GOSAT EORC site (<https://www.eorc.jaxa.jp/GOSAT/index.html>). JAXA contributes to the Global Greenhouse Gas Watch (G3W) by defining the role of satellite products. In May 2023, JAXA started to distribute the latest version of JAXA/GHG products.

GCOM-W is operating normally, and all Advanced Microwave Scanning Radiometer 2 (AMSR2) standard products, including near-real-time products, are freely available via the JAXA G-Portal system (<https://gportal.jaxa.jp/gpr/>). In addition, several research products, including soil moisture research product that reflects dynamic change of vegetation and was developed for AMSR3, have been distributed through the GCOM-W Research Product Distribution Service (https://suzaku.eorc.jaxa.jp/GCOM_W/research/resdist.html). New AMSR2 research products, Soil Moisture Content (SMC) and Vegetation Water Content (VWC) based on the Land Data Assimilation Methodology, and Thin Ice Thickness, were released to public in March 2024. For better continuity between AMSR2 and AMSR-E on EOS Aqua satellite, JAXA also provides the reprocessed AMSR-E products applying the latest AMSR2 algorithms at the G-Portal system. An integrated web site of AMSR series with the Data Catalogue (https://www.eorc.jaxa.jp/AMSR/index_en.html) is available and new function of the AMSR Earth Environment Viewer (https://www.eorc.jaxa.jp/AMSR/viewer/index_e.html) to display average of specific period (5-day, half-monthly, and monthly) and its anomaly from climatology calculated from AMSR series is available since July 2023.

GCOM-C carrying Second-generation Global Imager (SGLI) (launched in Dec. 2017) has achieved the 5-year nominal mission phase, and the operation has been continued as the post-mission phase since Jan. 2023. SGLI has 14 channels of 250-m resolution, three channels of 1-km channels from near-UV (380 nm) to thermal infrared (12 μm) wavelengths, and 1-km polarization channels in red and near infrared wavelengths. The standard products about cloud, aerosol, snow/ice, surface temperature, vegetation, and ocean colour from SGLI have been open to the public (the first version products since December 2018, and revised as Ver.3 since November 2021) via JAXA G-Portal system, and the some research products including evapotranspiration are available in JAXA JASMES web page (<https://www.eorc.jaxa.jp/JASMES/>).

ALOS-2 was launched on May 24, 2014, and it is currently operating very well even more than its target mission life of seven years since launching the satellite. The mission objectives are as follows;

- 1) Disaster monitoring of damage areas, both in considerable detail, and when these areas may be large,
- 2) continuous updating of data archives related to national land and infrastructure

information,

3) effective monitoring of cultivated areas, and

4) global forest monitoring in support of carbon cycle science.

To achieve its missions, ALOS-2 carries the Phased Array type L-band Synthetic Aperture Radar-2 (PALSAR-2), which is an active microwave SAR instrument using the 1.2 GHz frequency known as L-band. Compared to the PALSAR instrument onboard its predecessor ALOS satellite, the PALSAR-2 instrument has enhanced features (e.g. finer spatial resolution, spotlight mode, dual-polarisation ScanSAR).

The standard product of ALOS-2 is basically delivered in commercial bases, but the high-level product and the research dataset i.e., annual global mosaics and the forest/non-forest classification maps are distributed from JAXA EORC website free of charge (https://www.eorc.jaxa.jp/ALOS/en/index_e.htm). It is also started the open and free data of PALSAR-2 ScanSAR data from July 2022 (https://www.eorc.jaxa.jp/ALOS/en/dataset/alos_open_and_free_e.htm).

Global Precipitation Measurement Mission (GPM) / Dual-frequency Precipitation Radar (DPR) product is available from JAXA G-Portal system (<https://gportal.jaxa.jp/gpr/>). For better continuity between GPM and the Tropical rainfall Measurement Mission (TRMM) whose operation had been terminated after its 17 years long service, level 1 calibration factors for both Precipitation Radar (PR) onboard TRMM and GPM/DPR have been communized since 2017.

After the nominal mission operation phase of GPM mission, the scan pattern of the DPR has been changed since 21 May 2018. The new standard product applied to the new scan pattern was released as Version 07 in December 2021. The long-term TRMM/GPM level-2/3 product with common algorithm (Version 07) and data format is currently being reprocessed, and will be distributed via G-Portal system.

The GPM Core Observatory (GPM-CO) satellite performed two orbit boost maneuvers on Nov. 7 and 8, 2023 that raised its altitude by 35km. The goal of these boosts is to restore the GPM-CO's lifespan closer to the original estimates of ending in the early 2030's. Recent lifespan estimates had been getting shorter due to unexpectedly high solar activity, which causes additional atmospheric drag on the spacecraft. The primary goal of restoring GPM-CO's lifespan is to allow the GPM mission to overlap with the satellites associated with the future Atmosphere Observing System (AOS) mission planned by NASA, JAXA, and other agencies, allowing for intercalibration of instruments between the GPM and AOS missions.

NASA and JAXA started to provide the DPR products, experimentally corresponding to the GPM Orbit Boost, in January 2024, and resumed distribution of the standard DPR products in March 2024.

As the applications of the GPM/DPR, the Japan Meteorological Agency (JMA) has assimilated the DPR data in the meso-NWP system since March 2016. The assimilation technique for the DPR by the JMA was improved on 30th June 2022.

In addition to the above product, some multi-satellite products are open to the public. Under the GPM mission, Global Satellite Mapping of Precipitation (GSMaP) has been developed and provided via JAXA G-Portal and JAXA/EORC website (<https://sharaku.eorc.jaxa.jp/GSMaP/index.htm>). The GSMaP is basically generated by using GPM constellation satellites, including GCOM-W/AMSR2, and is available since March 2000. It has some types for user purposes including real-time version, gauge-adjusted version, and so on. The GSMaP products are validated by in-situ

observation in worldwide under collaboration with the WMO-CGMS International Precipitation Working Group (IPWG).

JAXA improved the algorithm in December 2021 (algorithm version 8). Currently, JAXA is reprocessing the past GSMaP dataset since 1998. The reprocessing since Jan. 1998 was completed and distributed the dataset to the public in September 2023.

The GSMaP near-real-time gauge-adjusted version has been used in the WMO SWCEM project; details are described in Section 4.

JAXA has also developed the geophysical retrieval algorithms for the geostationary satellite “Himawari-8” and “Himawari-9”, which are operated by the JMA, in an attempt to seek synergies between Himawari and JAXA’s Earth observation satellites, especially with GCOM-C. We have distributed browse images, geophysical data products (SST, cloud, aerosol properties, wildfire, chlorophyll-a concentration, and surface shortwave radiation), and model assimilated data (aerosol properties and SST) from the Himawari and other satellite data through the JAXA Himawari Monitor and P-Tree system (<https://www.eorc.jaxa.jp/ptree>). Several algorithms developed for GCOM-C was applied to Himawari data to produce consistent dataset, taking the opportunity of both satellites loading a multispectral imaging sensor. Currently, the system routinely processes and distributes “Himawari-9” data as well as archived “Himawari-8” data.

3 MISSIONS AND PRODUCTS IN NEAR FUTURE

ALOS-4 is planned to be launch in June 2024 by the H3 Launch Vehicle Flight 3 (H3F3). ALOS-4 is a follow-on mission of ALOS-2, and will observe the Earth's surface using its onboard the Phased Array type L-band Synthetic Aperture Radar-3 (PALSAR-3). The data will be utilized for monitoring disaster, forest, sea ice, infrastructure, and many other applications with the advantages of Synthetic Aperture Radar (SAR) such as all-weather and day-and-night observation capability. With further improved observation performance compared to the predecessor PALSAR-2 aboard ALOS-2, the satellite aims at achieving both high resolution and a wider observation swath.

EarthCARE will be launched in May 2024, which observes clouds, aerosols, and radiation on a global scale to improve the accuracy of climate change predictions. JAXA is developing the CPR on the EarthCARE, which will be the world's first W-band (94GHz) Doppler radar aboard a satellite.

GOSAT-GW, joint mission of GOSAT-2 follow-on (TANSO-3) and GCOM-W/AMSR2 follow-on (AMSR3) has completed the Critical Design Review (CDR) in October 2023 and has been in Manufacturing & Testing phase (Phase-D). TANSO-3, a grating imaging spectrometer, will be the mission of Ministry of the Environment in Japan (MOE) and National Institute for Environment Studies (NIES). Orbit of the joint satellite will be 666 km altitude (same as GOSAT) and 13:30 Local Time in Ascending node (same as GCOM-W). Sensor specification of the AMSR3 is almost equivalent to AMSR2 with some additional channels. New high frequency channels of 165.5 GHz, 183.31+3 GHz, and 183.31+7 GHz V-polarization are available in AMSR3 for

snowfall retrievals and water vapor analysis in numerical weather prediction in meteorological agencies. Also, additional 10.25 GHz V- and H-polarization channels with wider band width and improved NEDT will be added to current 10.65 GHz channels to improve robustness of higher resolution SST retrievals especially for fisheries. To prepare future considerable impacts by 5G communication, center-frequency and band width of 36.5 GHz channels are slightly modified from those of AMSR2. TANSO-3 uses imaging spectrometer technology to measure CO₂, CH₄ and NO₂ globally with medium and locally with high spatial resolution. The GOSAT-GW satellite is scheduled to be launched in the latter half of JFY2024.

The Multi-sensing Observation LiDAR and Imager (MOLI) will be installed in the Exposed Facility of the Japanese Experiment Module (JEM) "Kibo" of the International Space Station (ISS). It has two sensors: LiDAR and imager. The imager makes us possible to understand forest conditions around the footprint by shooting at the same time as LiDAR observation, although it has a narrow observation swath. MOLI is currently under Phase A study.

4 CONTRIBUTIONS TO WMO SPACE-BASED WEATHER AND CLIMATE EXTREMES MONITORING (SWCEM)

JAXA has participated in the WMO SWCEM by providing the GSMaP Near-real-time Gauge-adjusted Rainfall Product (GNRT). Based upon experiences in the SWCEM, JAXA started to operate a website "JAXA Climate Rainfall Watch", which provides information about extreme heavy rainfall and drought over the world using the GNRT.

Recently Tashima et al. (2020*) summarized the usefulness of precipitation extremes monitoring in the East Asia and Western Pacific region using the GNRT version 6 (GNRT6). In the paper, the drought in mainland Southeast Asia in March-May 2019 was examined.

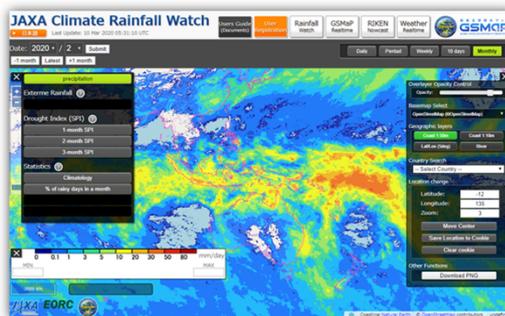


Fig. 1 Graphical User Interface of the "JAXA Climate Rainfall Watch" website (https://sharaku.eorc.jaxa.jp/GSMaP_CLM/)

As one of cooperation activities of the SWCEM, JAXA extended the data coverage 'eastward' for covering whole region of responsibility for the WMO Pacific RCC-

* Tashima, T., T. Kubota, T. Mega, and T. Ushio, and Riko Oki, 2020: Precipitation extremes monitoring using the near-real-time GSMaP product, *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.* <https://doi.org/10.1109/JSTARS.2020.3014881>.

Network, and update climate normal for 20 years in April 2020.

In June 2022, JAXA started to distribute the GSMaP real time data (GSMaP_NOW) to the SWCEM members, corresponding to the recommendation in the 4th Session of WMO Steering Group for the SWCEM in East Asia and Western Pacific (SG-SWCEM-EAWP-4) held during 23-24 March 2022. In addition, the climate normal was updated to 22-year values of the GSMaP.

Furthermore, JAXA improved the algorithm in December 2021 (algorithm version 8), and reprocessed the past GSMaP dataset since 1998. JAXA started to provide more than 25-yr GSMaP rainfall product with climate normal in April 2024. Through these efforts, the JAXA is contributing to precipitation extremes monitoring activities using satellite data in the WMO SWCEM.

Moreover, JAXA will host the 11th Workshop of the International Precipitation Working Group (IPWG) at Tokyo Institute of Technology from July 15th to 18th, 2024, in collaboration with the IPWG, which is co-sponsored by the CGMS and WMO.

5 NEXT GENERATION SPACEBORNE PRECIPITATION RADAR MISSION

JAXA has discussed the next generation precipitation radar mission with Japanese science team and user community since 2008. JAXA has large heritage of the TRMM/PR and GPM/DPR, and the data record of spaceborne precipitation radars is more than 20 years.

Recently Japan experiences extreme rain and flood event almost every year, so that monitoring and forecasting heavy rain is crucial for our lives. Against the background, continuous precipitation observations from TRMM/PR and GPM/DPR to the next generation precipitation radar is desirable from the applicational viewpoint as well as the scientific aspect including understanding of cloud-precipitation processes.

As discussed with Japanese science team and user community, JAXA raised three mission objectives for the next generation precipitation radar as follows;

- 1) Elucidation of global water cycle parameters and understanding of cloud-precipitation processes,
- 2) Contribution to enhancement of weather and disaster management,
- 3) Provision of long-term information on water resources infrastructure contributing to global-scale climate and water issues

On the U.S. side, NASA's Architecture Study had been conducted in response to the observations of Aerosol, Cloud, Convection and Precipitation (ACCP), which are the "designated" targeted observables defined in the 2017-2027 Decadal Survey for Earth Science and Applications from Space (ESAS 2017) by the National Academies.

The mission objectives discussed in Japan are quite synergetic to some of the Goals of the ACCP Study. Hence, JAXA has participated in NASA's Atmosphere Observing System (AOS) Pre-Phase-A activities since June 2021, following to the ACCP Architecture Study from 2019 to 2022 in U.S.

JAXA Mission Definition Review (MDR) for the next generation Precipitation Radar satellite was completed in August 2021. The review board confirmed that the JAXA

mission with a spacecraft carrying Ku-band Doppler radar is valuable as a successor of GPM/DPR.

In December 2021, Implementation Plan of the “Basic Plan on Space Policy” noting the Precipitation Radar Satellite Phase A activity was released from Cabinet Office of the Japanese government.

In January 2022, Precipitation Measuring Mission (PMM) Pre-Project Team was established on for the JAXA Spacecraft carrying the Ku-band Doppler Precipitation Radar. System Requirements Review (SRR) was completed in July 2022, and System Definition Review (SDR) was completed in March 2023.

In December 2022, Implementation Plan of the “Basic Plan on Space Policy” noting the Precipitation Radar Satellite Phase B activity targeting the launch of JFY2028 (April 2028 to March 2029) was released from Cabinet Office of the Japanese government.

On 1st June 2023, the project team of PMM, targeting the launch of JFY2028 (April 2028 to March 2029), was organized in JAXA. JAXA would appreciate the supports by CGMS and IPWG.

Related Actions of CGMS

In the CGMS-48 in 2020, WG II recommended the item to the IPWG (**WGII/A48.13**) to review the operational utilizations of spaceborne precipitation radar and to submit a report regarding the necessity of the precipitation radar.

After the CGMS-49, the report titled “A review of the different operational applications of spaceborne precipitation radars within the IPWG community” was endorsed by CGMS members (**Plenary/A49.02**) and published via CGMS webpage. In addition, JAXA received a letter from CGMS (**Plenary/A49.03**) expressing the strong support for the continuity of precipitation radar measurements beyond GPM/DPR, as agreed in the CGMS-49 Plenary. The IPWG report was regarded as requirements from international precipitation communities in the JAXA PMM MDR. JAXA appreciates the efforts by CGMS and IPWG to support the new mission.

The project team of PMM was organized in JAXA, the action item, corresponding to **WGIII/A49.06**, was closed.

6 CONCLUSIONS

JAXA operates various kind of satellite sensors and opens the products to the public. We keep developing and improving the products to address the climate issues.

The major updates since CGMS-51 is that the reprocessing during about 25 years for the new version of the Global Satellite Mapping of Precipitation (GSMaP) was completed. JAXA improved the GSMaP algorithm in December 2021 (algorithm version 8), and released 25-yr precipitation data on September 2023. GCOM-C has achieved the 6-year in Dec. 2023 and been in the post-mission phase. GCOM-W has achieved 12-year in May 2024 and continue its observation in healthy condition and several new research products are available. JAXA will launch three missions in JFY2024, the ESA-JAXA joint EarthCARE mission in May 2024, the ALOS-4 satellite with SAR in June 2024 and the GOSAT-GW satellite with GHG sensor and microwave imager in JFY2024.

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Space-based Weather and Climate Extremes Monitoring (SWCEM) Project by providing more than 25-yr GSMaP rainfall product with climate normal.

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