Development and Future Plans of Water-related Microwave Missions in Japan

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Japanese Earth Observation Satellites/Sensors

Targets (JFY: Apr-Mar)

2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025

Disasters Management & Land Monitoring

JERS1/OPS, SAR (1992-1998)
ADEOS-I/AVNIR
ALOS/AVNIR2, PALSAR (2006-2011)

[Land and disaster monitoring]
ALOS-2 / PALSAR-2
[Land and disaster monitoring]
ALOS-4/Advanced SAR
[Land and disaster monitoring]
ALOS-3/Advanced Optical

Climate System

•Climate change

ADEOS-I/OCTS (1996-1997)
ADEOS-II/GLI (2003)

[Vegetation, aerosol, cloud, SST, ocean color]
GCOM-C / SGLI
[Cloud and aerosol 3D structure]
EarthCARE / CPR
with ESA

•Water Cycle

ADEOS-II/AMSR (2003)
Aqua/AMSR-E (2002-2011)

TRMM / PR
[Precipitation 3D structure]
with NASA
GPM / DPR
with NASA
ACCP Pre-phase A
PMM(TBD) Phase A
[Wind, SST , water vapor, rainfall]
GCOM-W / AMSR2
[Wind, SST , water vapor, precipitation]
GOSAT-GW/AMSR3
GOSAT-GW/TANSO-3
[CO_2, CH_4, NO_2] *MOE*

•Greenhouse gases

[CO_2, CH_4]
GOSAT / FTS, CAI
with MOE
[CO_2, CH_4, CO]
with MOE
GOSAT-2

JMA geostationary meteorological satellites

MTSAT-1R
(Himawari-6)
MTSAT-2 (Himawari-7)
Himawari-10/11 planning
[Cloud, aerosol, SST]
Himawari-8
Himawari-8 (standby)
Himawari-9 (standby)
Himawari-9

Mission status: Completed | On orbit | Development | Pre-phase-A | Phase-A

Water-related Microwave Missions in Japan

1985 1990 1995 2000 2005 2010 2015 2020 2025 2030

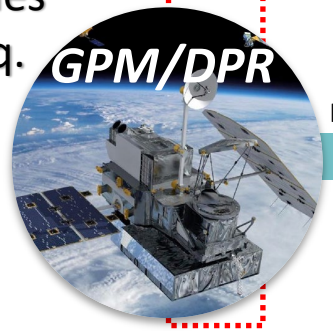
Ku-band (13.8GHz) radar

1997 - 2015

From tropics to mid latitudes & from single to dual freq.

Overlap to CAL/VAL

W-band (94 GHz) radar with Doppler



Ku- (13.6GHz) & Ka-band (35.5GHz) radar

2014 -

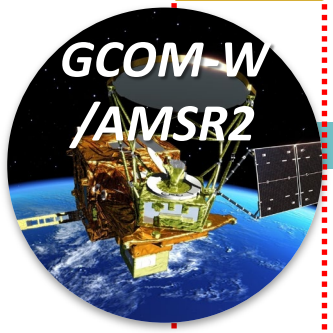
C-to-W-band microwave imager

2002 - 2011

slow rotation mode

Overlap to CAL/VAL

Next Precipitation Radar



C-to-W-band microwave imager

2012 -

Overlap to CAL/VAL

K-band microwave imager

1987

C-to-W-band microwave imager

2002-2003

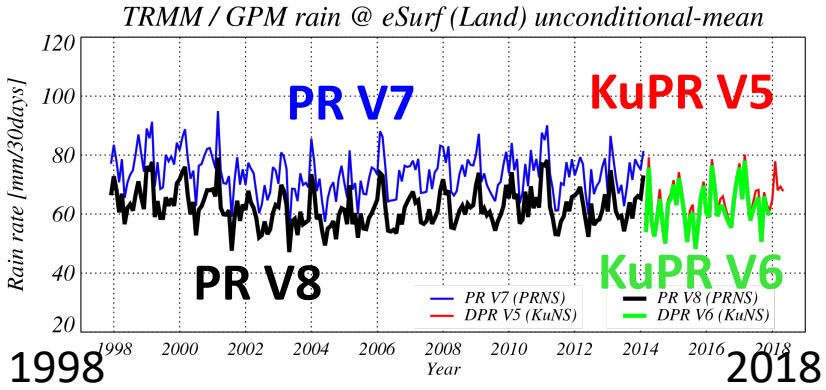
C-to-X-band microwave imager

2023 -

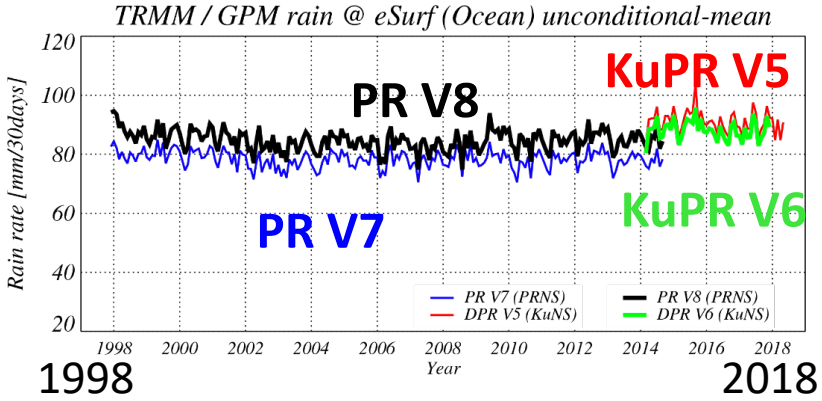
Constructing long-term precipitation radar datasets by TRMM/PR (1997-2015) and the GPM/DPR (2014-)

- GPM/DPR's calibration factors was changed in V05 released on May 2017, and TRMM/PR's calibration factors was also changed in TRMM/PR-L1 V8 (GPM TRMM V05) L1 released on Oct. 2017.
- Better continuity was realized in the TRMM/PR-L2 V8 (GPM TRMM V06) and GPM/DPR-L2 V06 released in Oct. 2018, by using common precipitation estimation algorithms between the TRMM/PR and the GPM/KuPR.

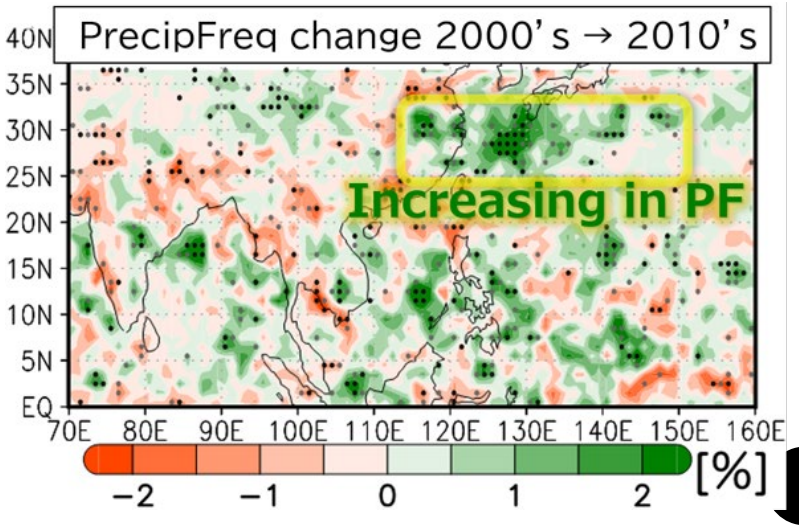
Over-land surface precipitation rates averaged in 35S-35N.



Over-ocean surface precipitation rates averaged in 35S-35N.



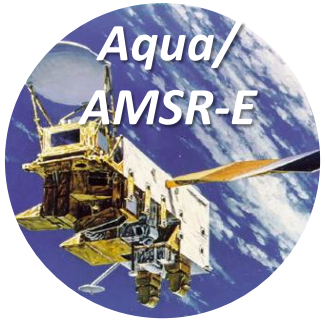
Takahashi and Fujinami (2021) showed **recent decadal enhancement of Meiyu-Baiu heavy rainfall** over the East Asia using the TRMM/PR & GPM/DPR dataset.



→These dataset was used long-term precipitation analyses.

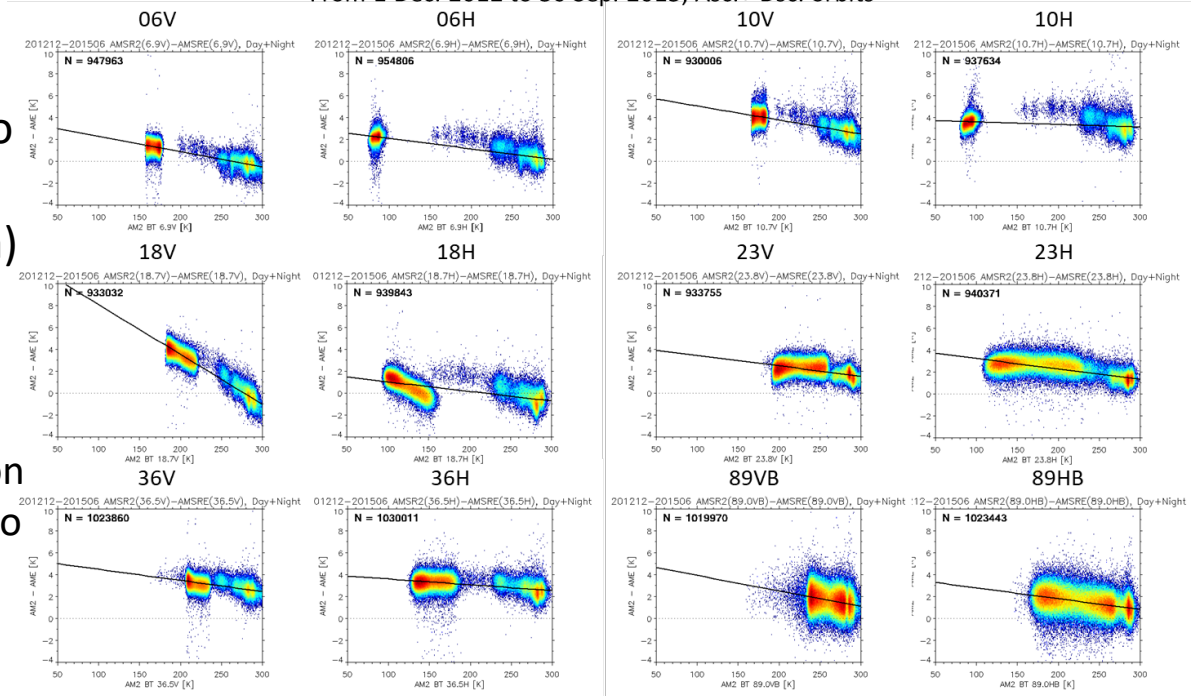
Takahashi, H.G., Fujinami, H. Recent decadal enhancement of Meiyu–Baiu heavy rainfall over East Asia. *Sci. Rep.* 11, 13665 (2021).
https://doi.org/10.1038/s41598-021-93006-0
https://earth.jaxa.jp/en/earthview/2021/08/02/5584/index.html

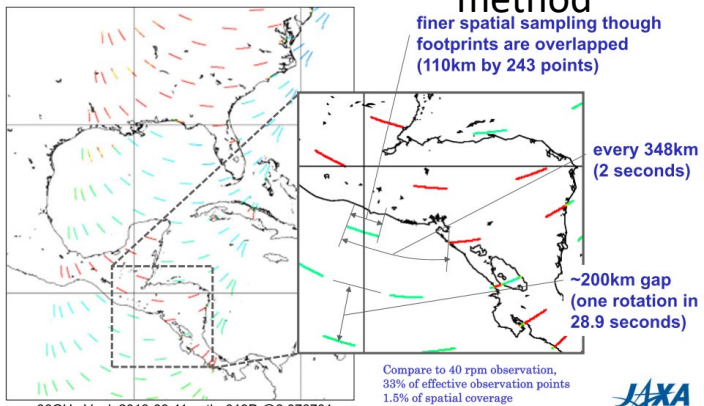
AMSR-E/AMSR2 Cross-Calibration for Continuous Dataset

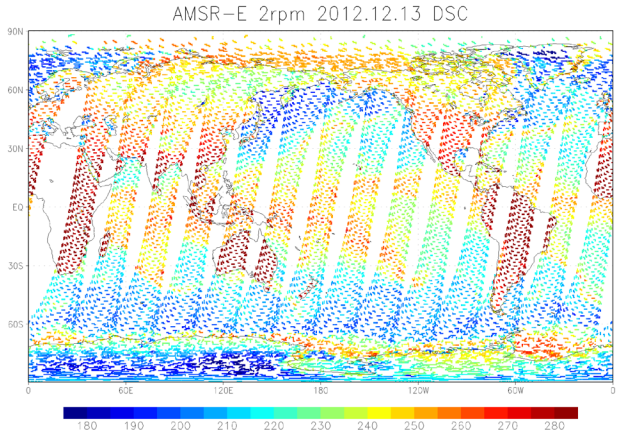


- Cross-calibration to calculate coefficients to translate AMSR2 Tb to AMSR-E equivalent Tb, since some AMSR2 L2 algorithms are optimized to AMSR-E Tb.
- AMSR-E made observation in slow rotation (2rpm) mode from Dec. 2012 to Dec. 2015 in the same observation conditions to AMSR2
- Procedure
  - Match-up AMSR-E and AMSR2 Tbs at same location
  - Calculate linear expression to transfer AMSR2 Tb to AMSR-E equivalent Tb by making scatter plots for Asc. and/or Dsc. orbits using Double Difference method

Scatter plots of (AMSR2 Tb - AMSR-E (L1S) Tb) VS (AMSR-E (L1S) Tb)
From 1 Dec. 2012 to 30 Sep. 2015, Asc.+ Dsc. orbits





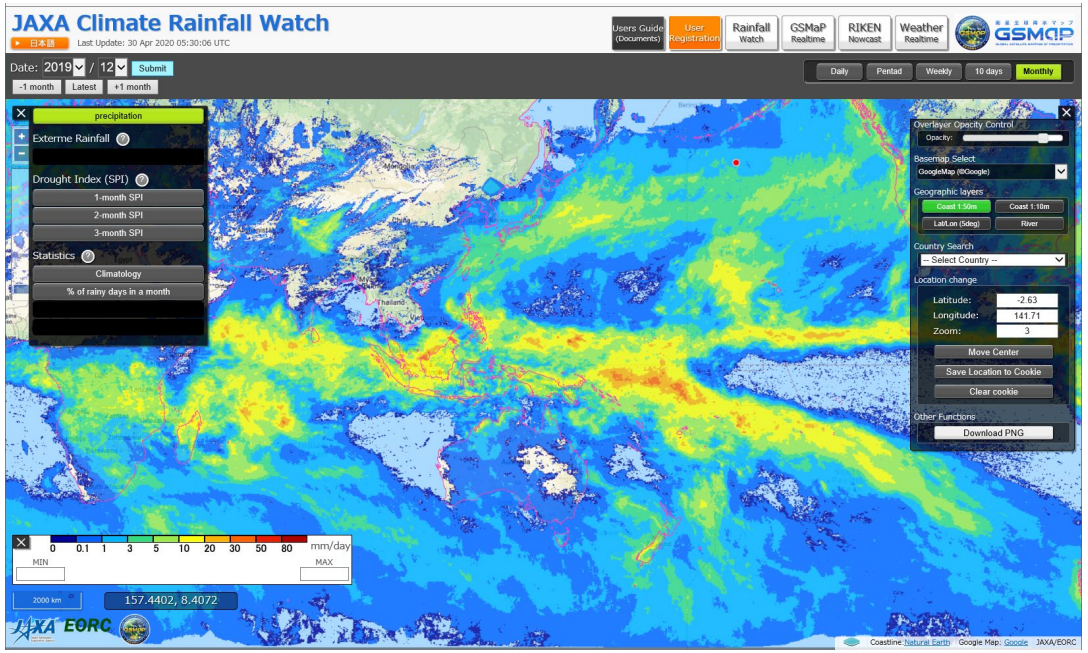


Frequency [GHz] (H/V)	Ascending		Descending		Ascending + Descending	
	Slope	Intercept	Slope	Intercept	Slope	Intercept
6.9 (V)	-0.01395	3.75442	-0.01357	3.52119	-0.0139	3.67421
6.9 (H)	-0.00966	3.10936	-0.00906	2.94066	-0.0094	3.03663
10.65 (V)	-0.01267	6.44474	-0.01255	6.11618	-0.01289	6.34775
10.65 (H)	-0.00189	3.85311	-0.00227	3.69259	-0.00221	3.79624
18.7 (V)	-0.04571	12.77339	-0.04435	12.27115	-0.04524	12.57562
18.7 (H)	-0.00735	1.90245	-0.00925	1.78223	-0.00858	1.89574
23.8 (V	-0.01179	4.86124	-0.00745	3.97509	-0.00957	4.40435
23.8 (H)	-0.00927	4.29221	-0.0093	3.99323	-0.00947	4.1871
36.5 (V)	-0.01107	5.66375	-0.00928	5.31924	-0.01019	5.49799
36.5 (H)	-0.00568	4.24643	-0.00534	4.08753	-0.00561	4.19181
89 (B) (V)	-0.01597	5.86118	-0.0113	4.57687	-0.01403	5.32379
89 (B) (H)	-0.01134	4.0913	-0.00807	3.36449	-0.0098	3.75174

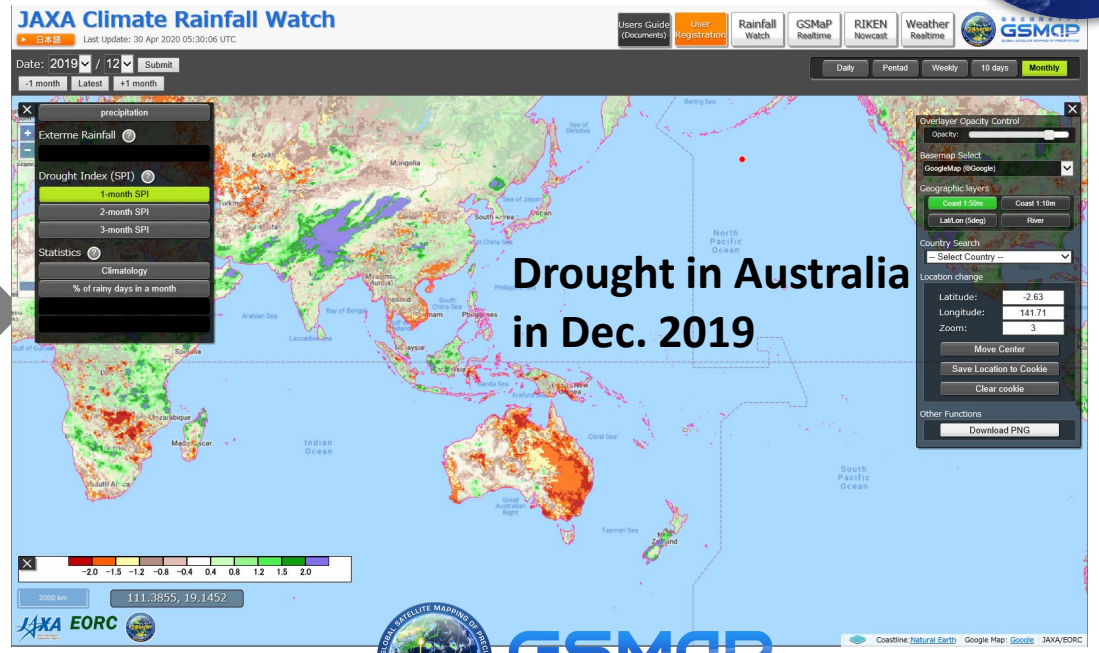
Monitoring of Extreme Heavy Rainfall and Drought based upon 21-yr Statistics of the GSMaP Precipitation Data

- JAXA has developed the Global Satellite Mapping of Precipitation (GSMaP) in the Global Precipitation Measurement (GPM) mission (Kubota et al. 2020, https://doi.org/10.1007/978-3-030-24568-9_20).
- "JAXA Climate Rainfall Watch", which provides information about extreme heavy rainfall and drought over the world, is now available.
  - Calculated based upon 21-yr statistics with **Standardized Precipitation Index (SPI)** (Tashima et al. 2020, https://doi.org/10.1109/JSTARS.2020.3014881)

Monthly Rainfall by GSMaP in Dec. 2019



Drought index in Dec. 2019

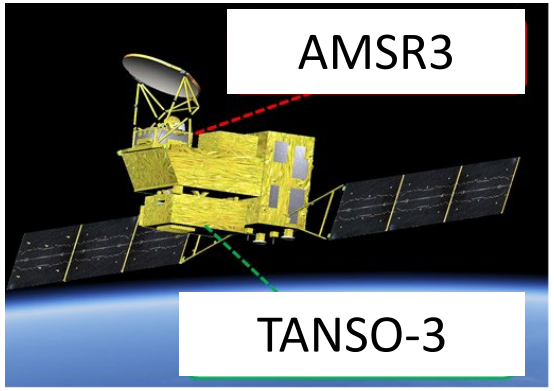


https://sharaku.eorc.jaxa.jp/GSMaP_CLM/

GSMaP GLOBAL SATELLITE MAPPING OF PRECIPITATION

AMSR3 on GOSAT-GW: Global Observation SATellite for Greenhouse gases and Water cycle

- GOSAT-GW will carry two instruments, AMSR3 & TANSO-3.
  - AMSR3, led by JAXA, will succeed AMSR series observations adding new high-frequency channels for solid precipitation retrievals and water vapor analysis in NWP.
  - TANSO-3, led by Japanese Ministry of the Environment (MOE) and National Institute of Environment Studies (NIES) , will improve observation capability of greenhouse gases from GOSAT-2/TANSO-2.
  - Target launch is JFY2023 (Apr. 2023 - Mar. 2024)



GOSAT-GW Satellite Specifications

Orbit	Type	Sun-synchronous, Sub-recurrent orbit
	Altitude	**666km, recurrent cycle 3days** (same as GOSAT)
	MLTAN	13:30±15min (same as GCOM-W)
Mass		2.6 ton (Including propellant)
Power		> 5.3 kW
Design life		**> 7 years**
Launch vehicle		H-IIA rocket
Mission data downlink rate		Direct transmission with X-band: 400 Mbps Direct transmission with S-band: 1 Mbps (Only for AMSR3)
Instrument		TANSO-3 (for GHG) AMSR3 (for Water Cycle)

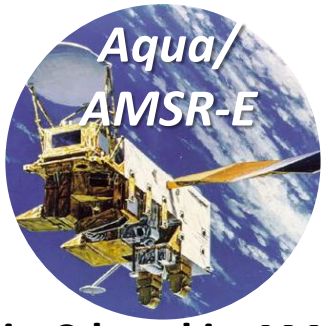
AMSR3 Channel Sets

Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1σ)	Beam width (spatial resolution)
6.925 7.3	H/V	350	< 0.34 K	1.8° (34km x 58km)
10.25	**H/V**	**500**	**< 0.34 K**	**1.2° (22km x 39km)**
10.65	H/V	100	< 0.70 K	1.2° (22km x 39km)
18.7	H/V	200	< 0.70 K	0.65° (12km x 21km)
23.8	H/V	400	< 0.60 K	0.75° (14km x 24km)
36.42	H/V	**840***	< 0.70 K	0.35° (7km x 11km)
89.0 A/B	H/V	3000	< 1.20 K	0.15° (3km x 5km)
165.5	**V**	**4000**	**< 1.50 K**	**AZ=0.23° / EL=0.30° (4km x 9km)**
183.31±7	**V**	**2000 × 2**	**< 1.50 K**	**AZ=0.23° / EL=0.27° (4km x 8km)**
183.31±3	**V**	**2000 × 2**	**< 1.50 K**	**AZ=0.23° / EL=0.27° (4km x 8km)**

Red: Changes from AMSR2 including additional CHs

* Changed the specification of Ka-band passband to reduce the future risk of RF interference from 5-G mobile communication system

Actions for Radio Frequency Interference (RFI) in AMSR Series

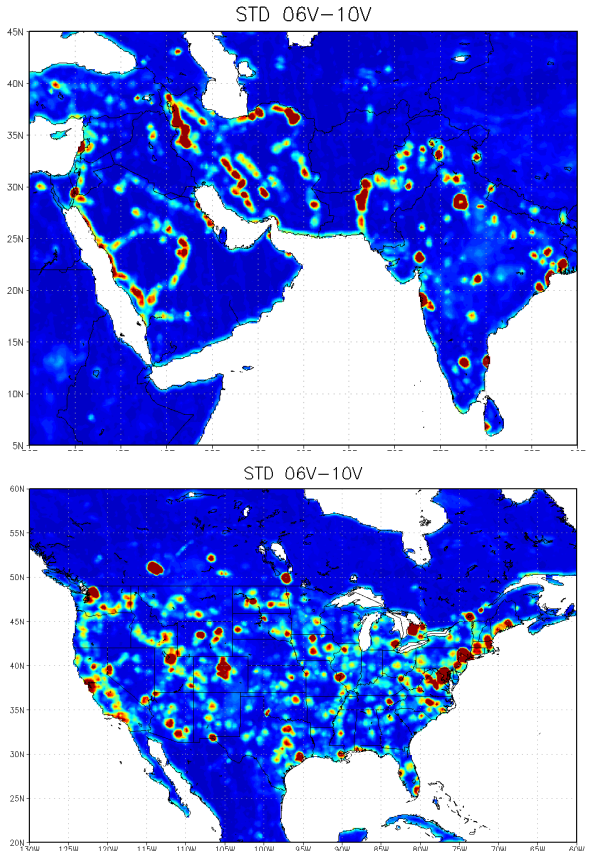


Addition of 7.3GHz channels

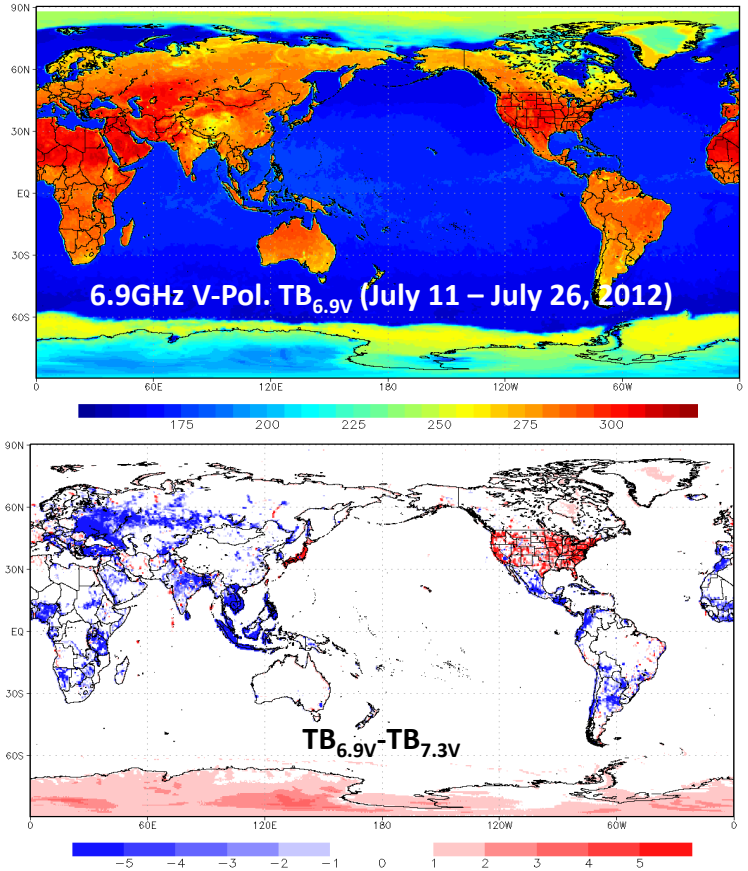
Addition of 10.25GHz channels

Modification of 36GHz bandwidth

RFI in C-band in AMSR-E



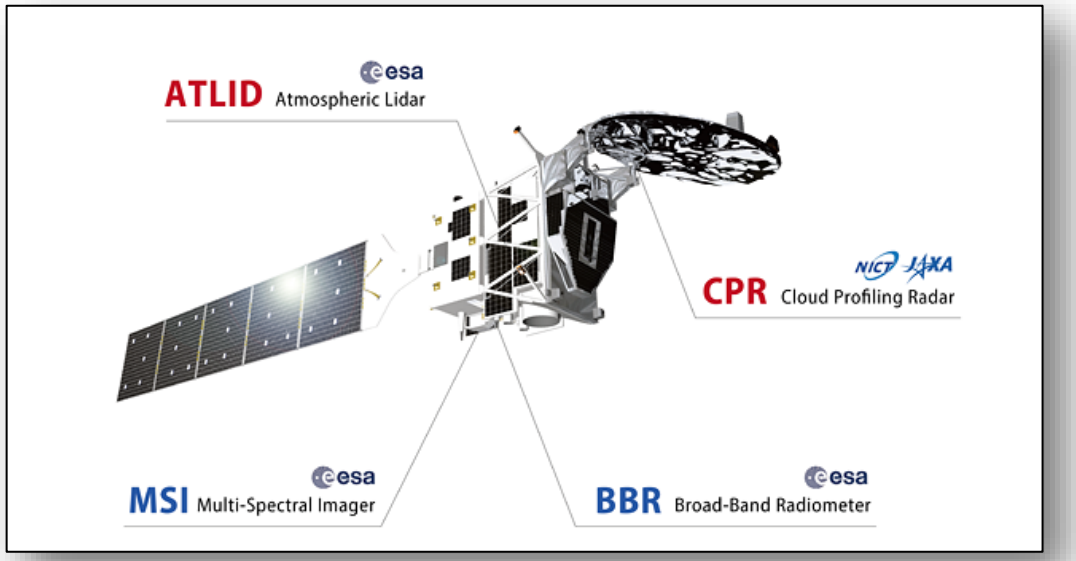
RFI in C-band in AMSR2



- In AMSR3, JAXA modifies sensor characteristics to mitigate possible RFI impacts.
- **C-band**:
  - Keep both 6.9/7.3GHz
- **X-band**:
  - Add new 10.25GHz as well as 10.65 GHz
  - JAXA plans to introduce similar method to detect RFI used in C-band
- **K-band**:
  - For 36GHz, specification of 36GHz passband is changed to 840MHz to reduce the future risk of RFI from 5G mobile communication system
  - For 23GHz, there will be buffer band of 250MHz and its impact will be negligible by improving the out-of-band frequency characteristic

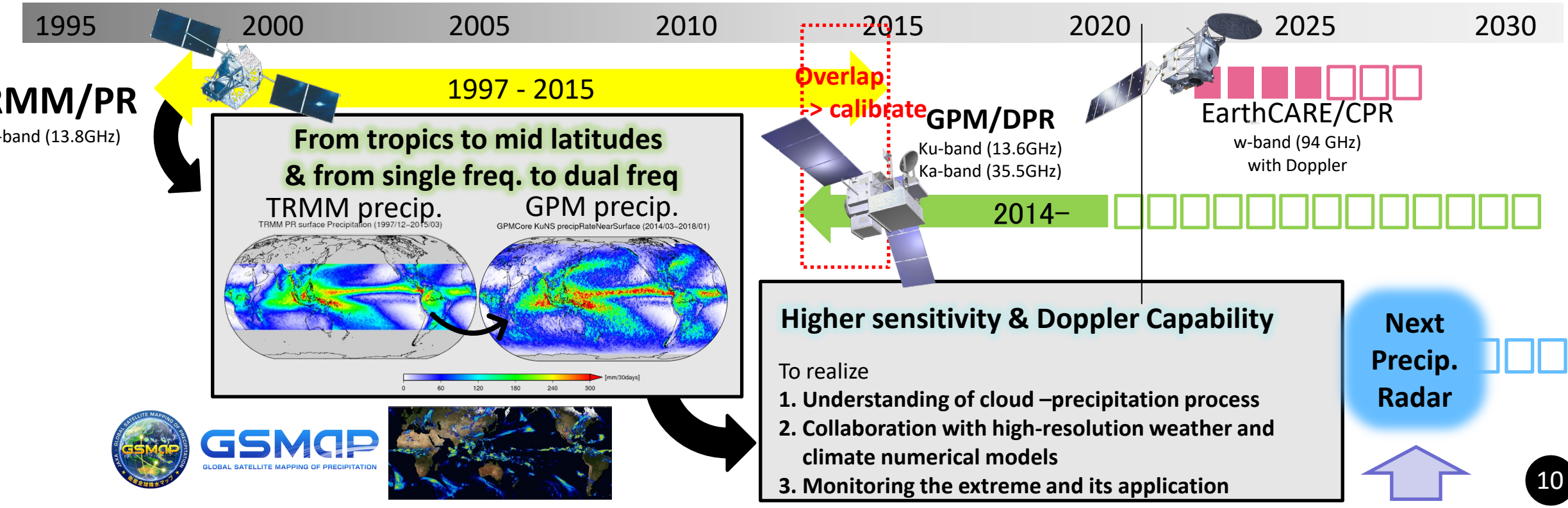
Cloud Profiling Radar with Doppler capability in EarthCARE mission

- The Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) jointly with ESA observes clouds, aerosols, and radiation on a global scale to improve the accuracy of climate change predictions.
  - ✓ planned to be launched in JFY2023.
- JAXA and NICT are developing Cloud Profiling Radar (CPR) with doppler capability.
  - ✓ It will be the world's first spaceborne W-band (94GHz) radar with doppler capability.
- The CPR will provide observations of not only cloud but also snowfall and light rainfall.



JAXA's Next-generation Precipitation Radar Project status (1)

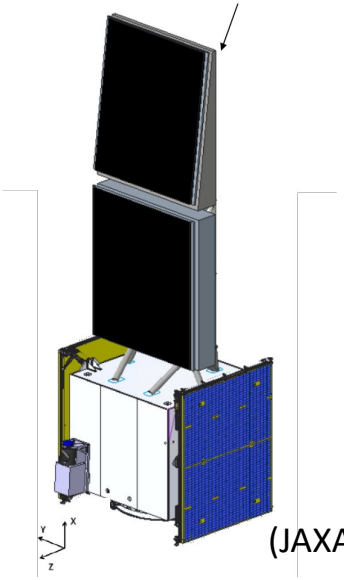
- The JAXA has studied a feasibility of a next generation precipitation radar, and the Mission Definition Review (MDR) for the next generation Precipitation Radar satellite was completed in August 2021.
  - ✓ JAXA has participated in NASA's Aerosol, Could, Convection and Precipitation (ACCP) Pre-Phase A activities.
- Our targets for the next generation precipitation radar will be **Doppler Observations, Higher sensitivity measurements with scanning capability.**
  - In January 2022, Precipitation Measuring Mission (PMM) Pre-Project Team was established on for the JAXA Spacecraft carrying the Ku-band Doppler Precipitation Radar.

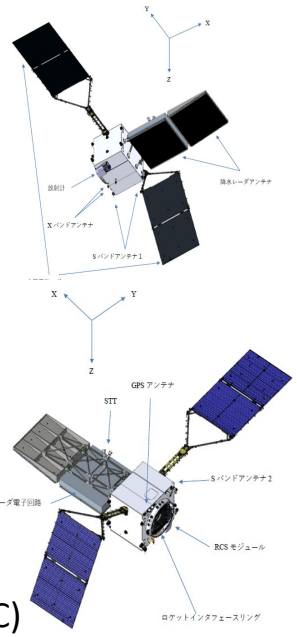


JAXA's Next-generation Precipitation Radar Project status (2)

Expected precipitation radar technical characteristics in the JAXA's feasibility study

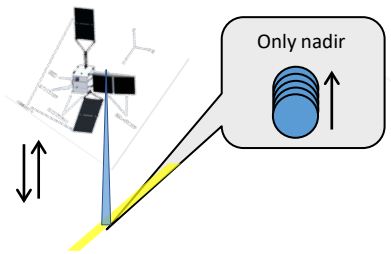
JAXA Ku radar



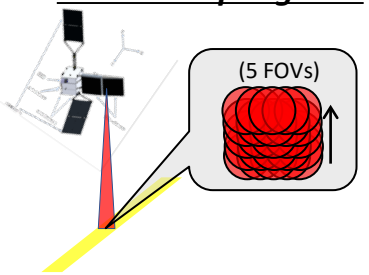


(JAXA/NEC)

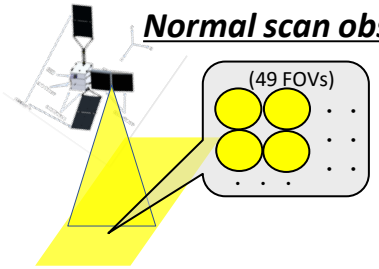
Doppler obs.



Dense sampling obs.

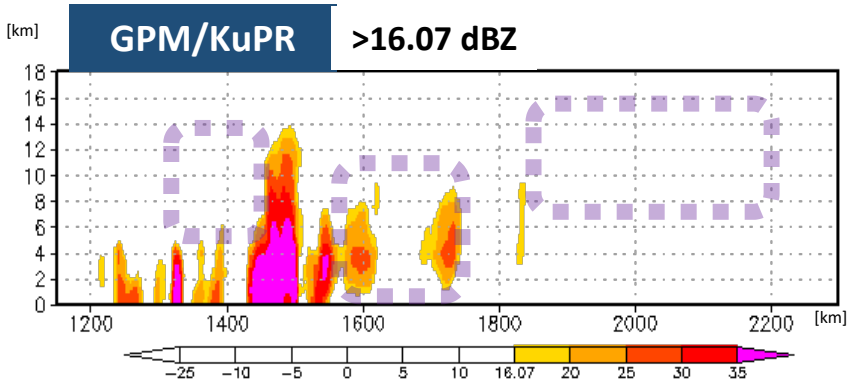


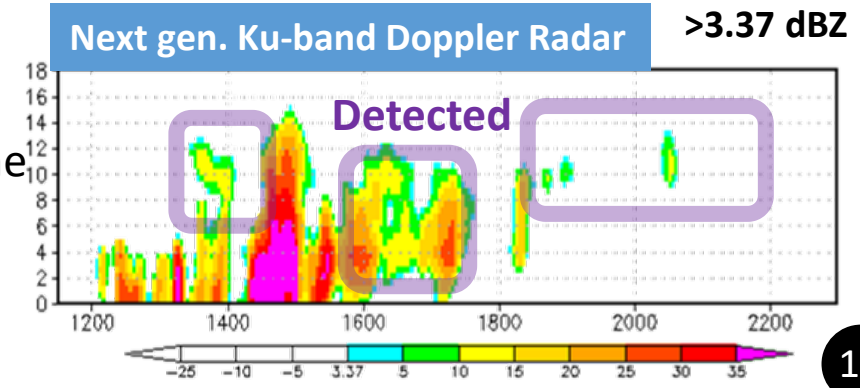
Normal scan obs.



Joint Simulator for Satellite Sensors Joint-Simulator

Simulation results of at-nadir observations by Joint-simulator and NICAM data





Improvements of the sensitivity in the JAXA's Next-generation Precipitation Radar

- Sensitivity of the GPM/KuPR and next generation Ku-band Radar at nadir are compared each other by the Japanese satellite simulator (Joint-Simulator) and the global cloud resolving model (NICAM).
- The sensitivity of the new JAXA Ku-band Doppler Radar is significantly improved from current GPM/KuPR sensitivity.

Concluding Remarks

- JAXA has long history and big heritage of satellite-based water-related observations by both passive and active microwave sensors to produce continuous and consistent long-term datasets.
- Passive microwave sensor
  - Since 2002 to present, AMSR series with large-sized antenna and C-band frequency channels contributes largely to water cycle observations, including GSMaP merged rainfall products.
  - Future AMSR3 on board the GOSAT-GW to be launched in JFY2023 will have additional channels including high-frequency channels for snowfall retrievals and 10.25 GHz for RFI mitigations.
- Active microwave sensor
  - Since 1997 to present, TRMM/PR and GPM/DPR are only reliable references to passive microwave radiometers for precipitation observation. The CPR with doppler capability in the EarthCARE is planned to be launched in JFY2023.
  - The JAXA has studied a feasibility of a next generation precipitation radar, and the MDR for the next generation Precipitation Radar satellite was completed in August 2021.
    - JAXA has participated in NASA's Aerosol, Could, Convection and Precipitation (ACCP) Pre-Phase A activities.