Status and Plan of Japanese Microwave Precipitation-related Missions

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Japanese Earth Observation Satellite/Sensors

Targets (JFY: Apr-Mar)

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

Disasters & Resources

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

•Water Cycle

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

TRMM / PR *with NASA*
[Precipitation 3D structure]
Feasibility study
GPM / **DPR** *with NASA*
[Wind, SST , water vapor, rainfall]
GCOM-W / AMSR2
[Wind, SST , water vapor, precipitation]
GOSAT-GW/AMSR3

•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*

•Greenhouse gases

[CO_2, CH_4]
GOSAT / FTS, CAI *with MOE*
[CO_2, CH_4, CO]
GOAT-GW/TANSO-3 *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

History of Passive Microwave Observations

- With experience of development and operation of MSR, JAXA developed 1st generation of AMSR (AMSR and AMSR-E) with large antenna size and C-band channels. AMSR-E continuous its science observation about 9.5-year, and its high capabilities enable to expand utilizations in operational and research areas.
- 2nd generation of AMSR (AMSR2) was launched in 2012 and succeeds AMSR-E observations to establish its data utilization in various areas.
- 3rd generation of AMSR (AMSR3) was recently approved as project to be launched in JFY2023.

1987

MSR

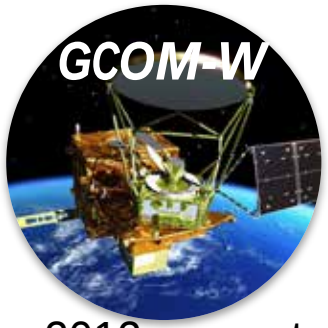
- 2-channel in 23GHz & 32GHz
- Antenna size: 0.5m
- Spatial resolution: 23-32km
- Swath width: 317km

2002-2011

AMSR

AMSR-E

- 6-frequency, 14-channel
- Antenna size: 1.6m
- Spatial resolution: 6-74km
- Swath width: 1450km



2012-present

Succeed AMSR-E observation

AMSR2

- Improved onboard calibration
- Additional 7GHz channels to mitigate impact of RFIs

after 2023

Continue & improve AMSR-E/AMSR2 observation

AMSR3

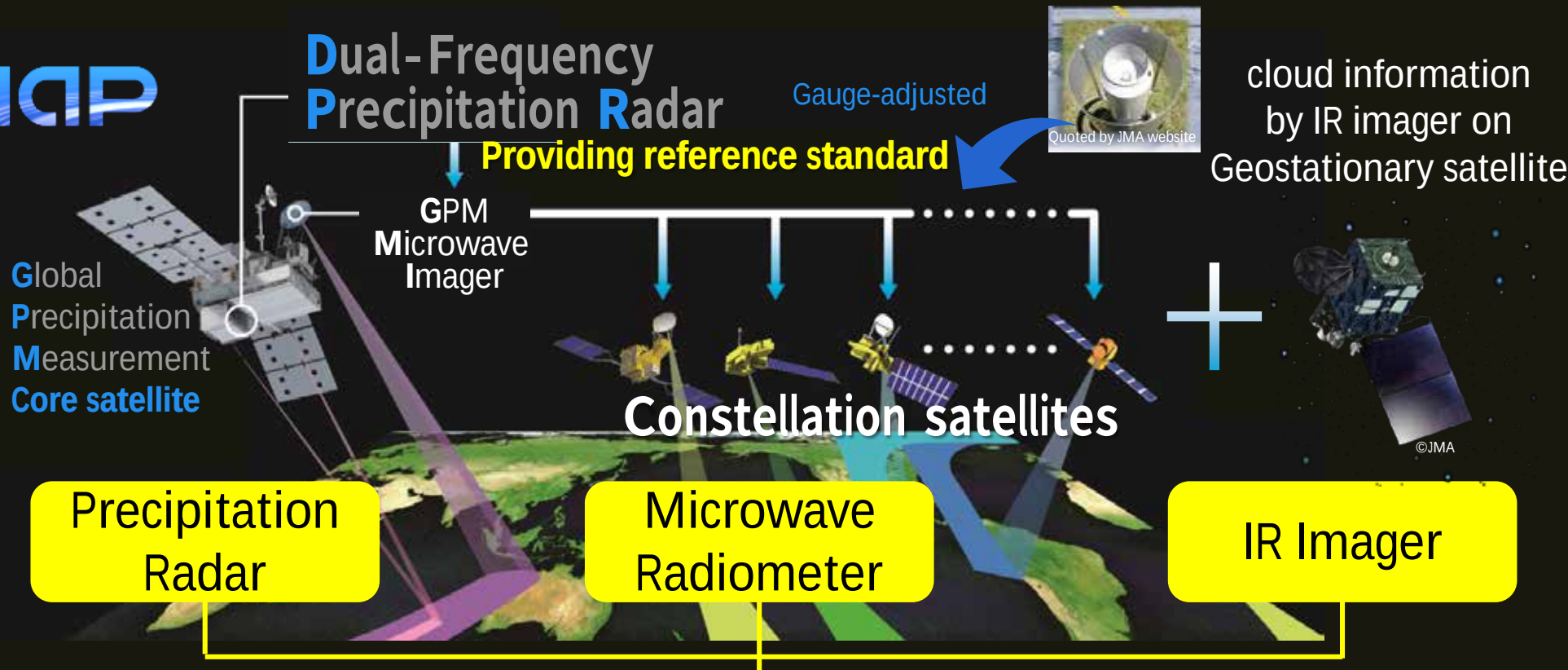
- New high-frequency channels for snowfall and NWP
- Additional 10GHz channels with better NEDT for robust SST

Japanese Multi-satellite Precipitation Product
Global Satellite Mapping of Precipitation (GSMaP)

GSMaP

Registered users:
6061 users
131 countries
(May 2020)

Recently, a GSMaP's review paper, Kubota et al. (2020) was published.
https://doi.org/10.1007/978-3-030-24568-9_20



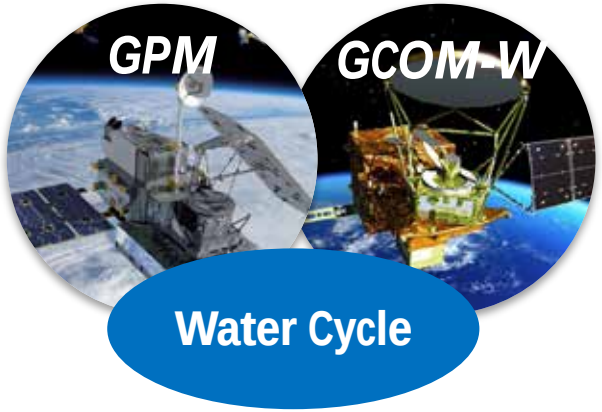
Multi-satellite Precipitation Product

- hourly global rainfall data
- 0.1x0.1deg. lat/lon
- Various version such as realtime for monitoring or long-term gauge-adjusted for climatological purposes

distribution
- website
- netCDF
- GeoTIFF
- CSV
- Binary
- png

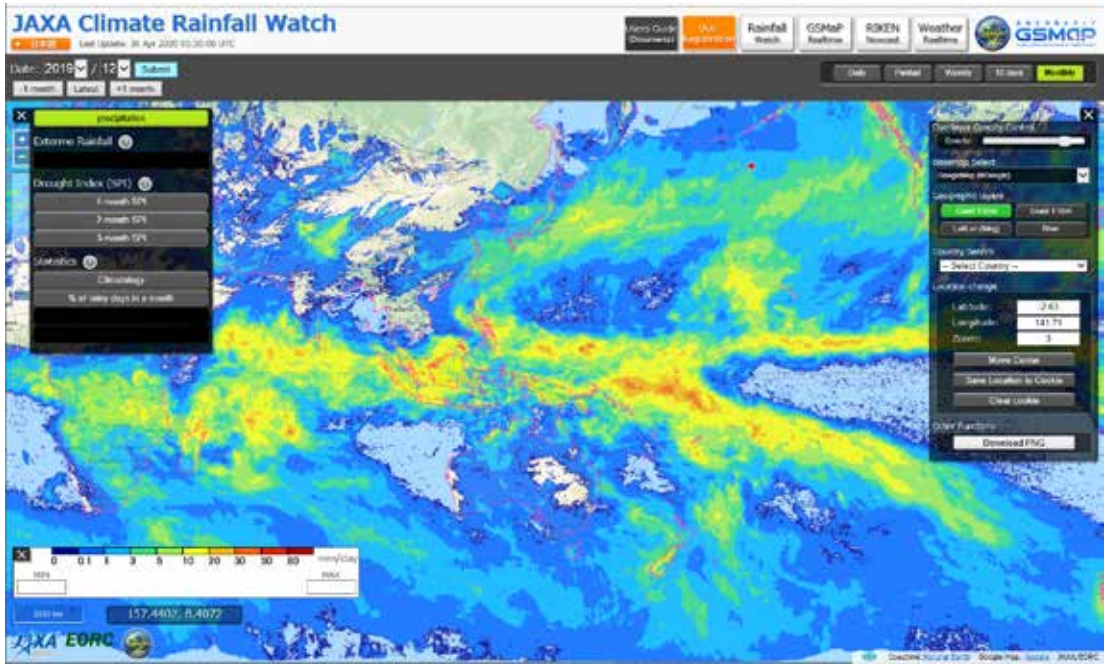
Extreme Heavy Rainfall and Drought by GSMaP

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

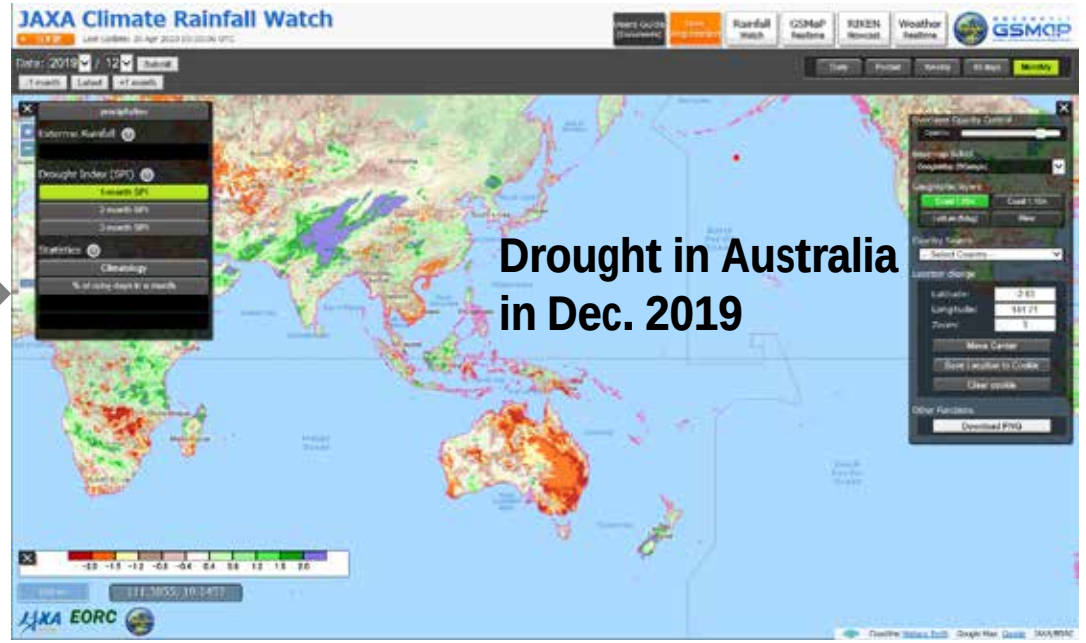


- "JAXA Climate Rainfall Watch", which provides information about extreme heavy rainfall and drought over the world, is now available.
  - Easily monitor global extreme weather and climate by displaying accumulated rainfall in some temporal scale, indices related to Extreme heavy rainfall (percentiles) and Drought index (SPI).
  - Calculated based upon 20-yr statistics (Tashima et al. 2020, *JSTARS*, in revision)

Monthly Rainfall by GSMaP in Dec. 2019



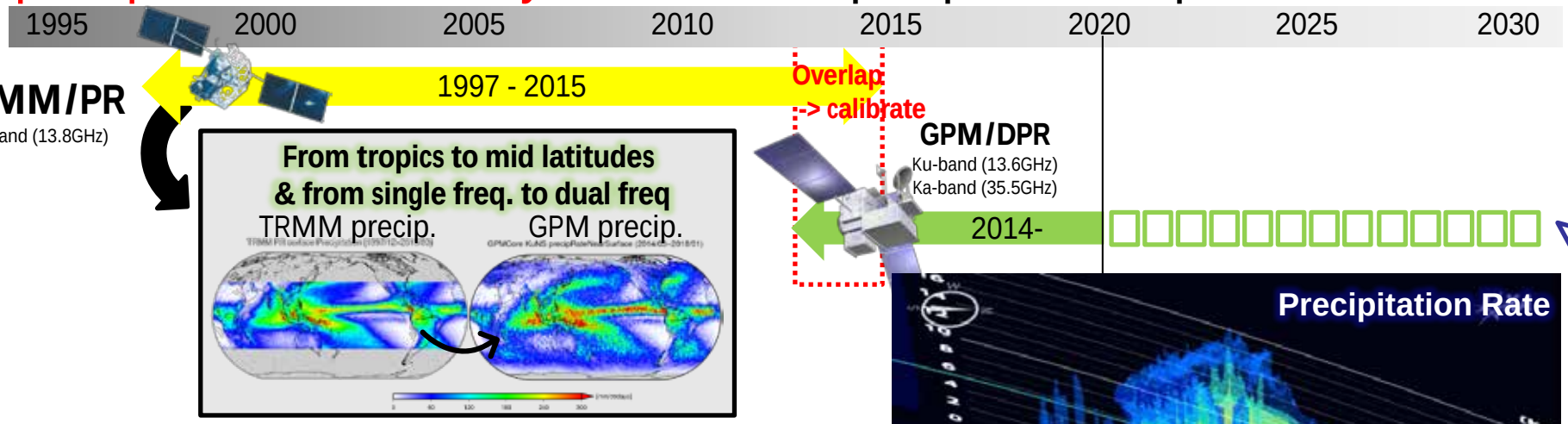
Drought index in Dec. 2019

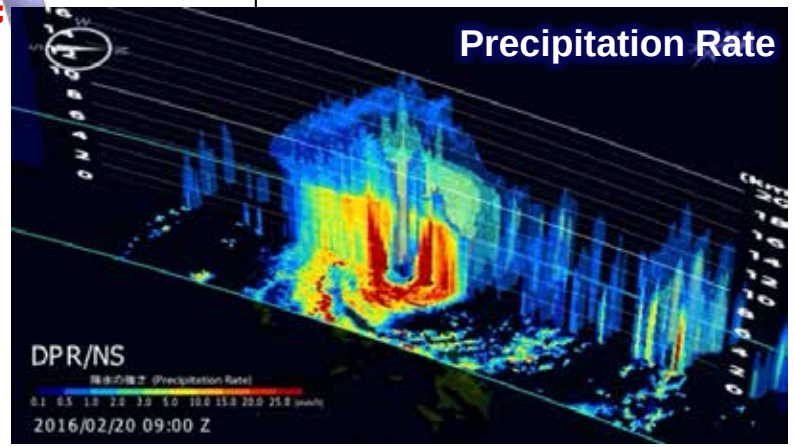


https://sharaku.eorc.jaxa.jp/GSMaP_CLM/

History of Active Microwave Observations

- JAXA has developed the spaceborne precipitation radars such as Precipitation Radar (PR) onboard Tropical Rainfall Measuring Mission (TRMM) launched in 1997 and Dual-frequency Precipitation Radar (DPR) aboard Global Precipitation Measurement (GPM) Mission Core Observatory launched in 2014.
- Both radars have been developed to observe three-dimensional structure of global precipitation accurately, under the equal partnership with NASA.

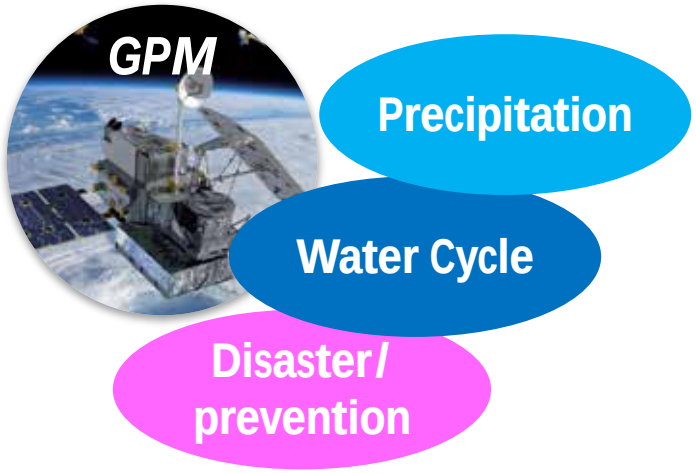




The data record of spaceborne precipitation radars is more than 20 years!

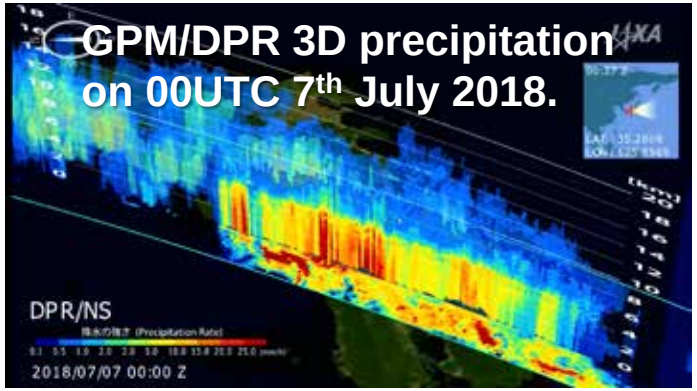
The product developed by considering the continuity between TRMM and GPM is available with common algorithm and data format.

Utilization of Precipitation Radar in NWP
Assimilation of 3D information derived by GPM/DPR in JMA

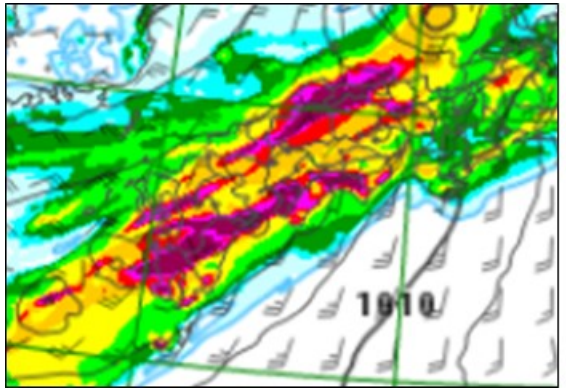


- The Japan Meteorological Agency (JMA) started the DPR assimilation in the meso-NWP system on March 24, 2016.
- Assimilation of GPM/DPR improved the prediction of rainfall location in meso-scale, which is important for disaster prevention.
- The DPR 3-dimensional information which cannot be detected by microwave radiometer can be an essential factor for rainfall forecasting as well as disaster prevention.

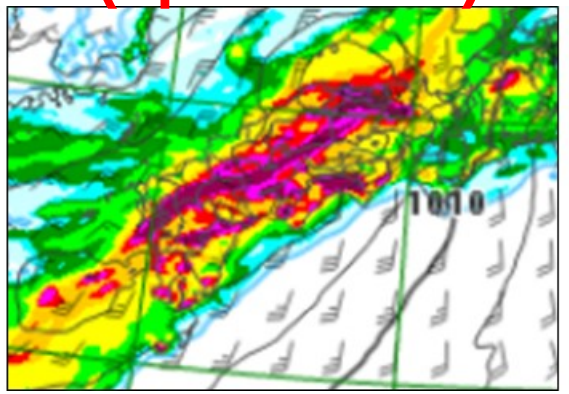
Case study for heavy rainfall in July 2018, causing serious damage in western part of Japan.



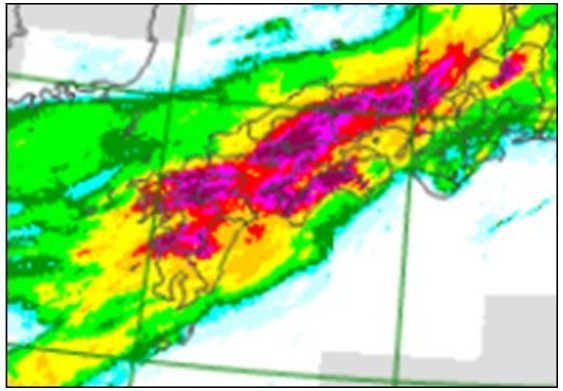
without DPR



with DPR
(operational)



Ground observation



24h forecasts of precipitation (00UTC 7th July 2018) provided by JMA

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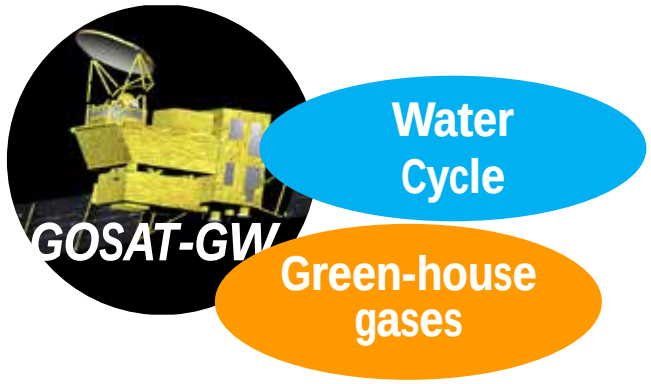
Himawari-9

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

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

- GOSAT-GW will carry two instruments, AMSR3 and 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 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)
- Mission targets of AMSR3
  - To produce long-term continuous data record
  - To enhance operational utilization of near-real time data
    - weather forecast including hurricane analysis
    - fishery in coastal area
    - navigational assistance on arctic shipping route
    - New geophysical parameter products



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)

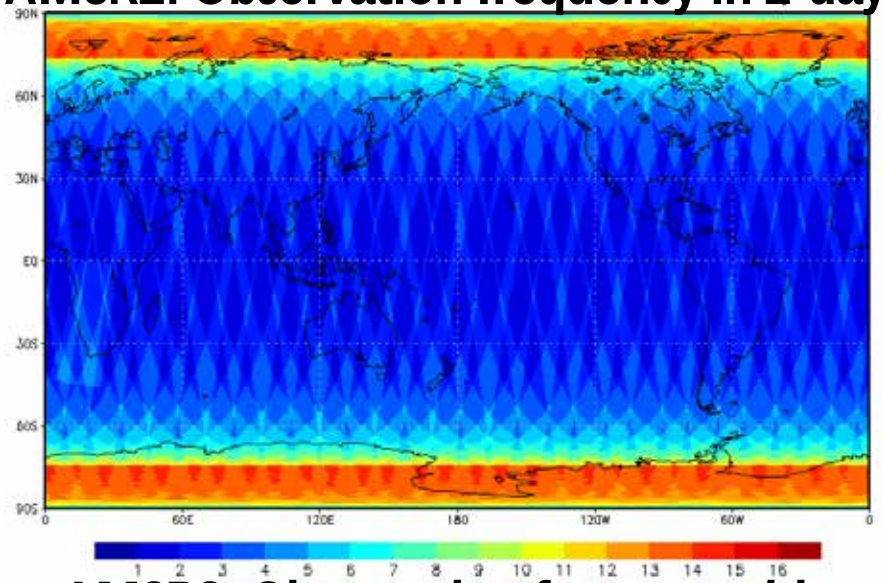
Comparison of Orbit Specifications

- Orbit specification of GOSAT-GW is decided to satisfy requirements from both AMSR3 and TANSO-3 missions.
- Ascending orbit will be during daytime (same as GCOM-W), orbit altitude is same as GOSAT, and local sun time is same as GCOM-W. Orbiting number of one recurrent day is 44 and smaller compared to that of GCOM-W (233), so there are some differences in observation frequency.

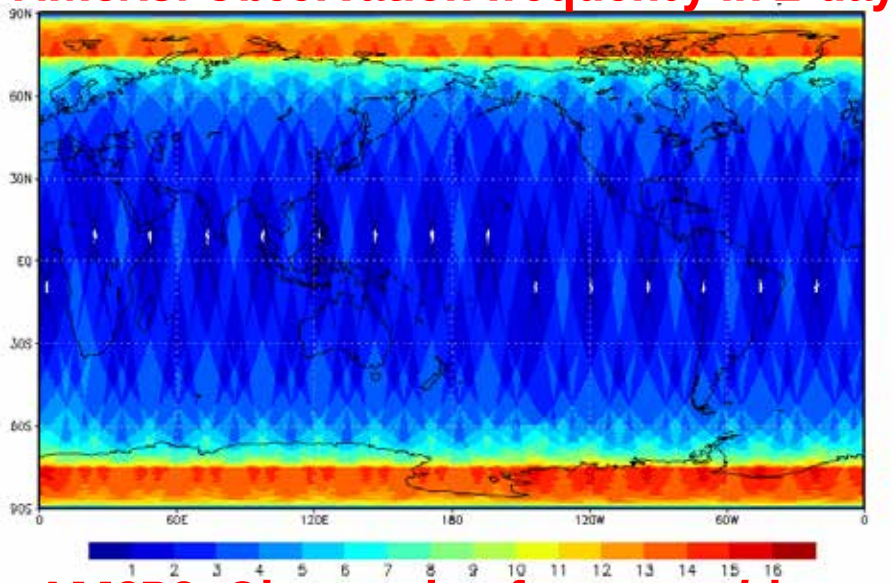
Orbit conditions	GCOM-W/AMSR2	GOSAT-GW/AMSR3
Altitude	699.6 km	665.96 km
Inclination angle	98.2 degrees	98.06 degrees
Local sun time in Ascending node	13:30	13:30
Swath width	1600 km	1530 km
Recurrent day	16 days (233 orbits)	3 days (44 orbits)

AMSR3 Observation Frequency

AMSR2: Observation frequency in 2-day

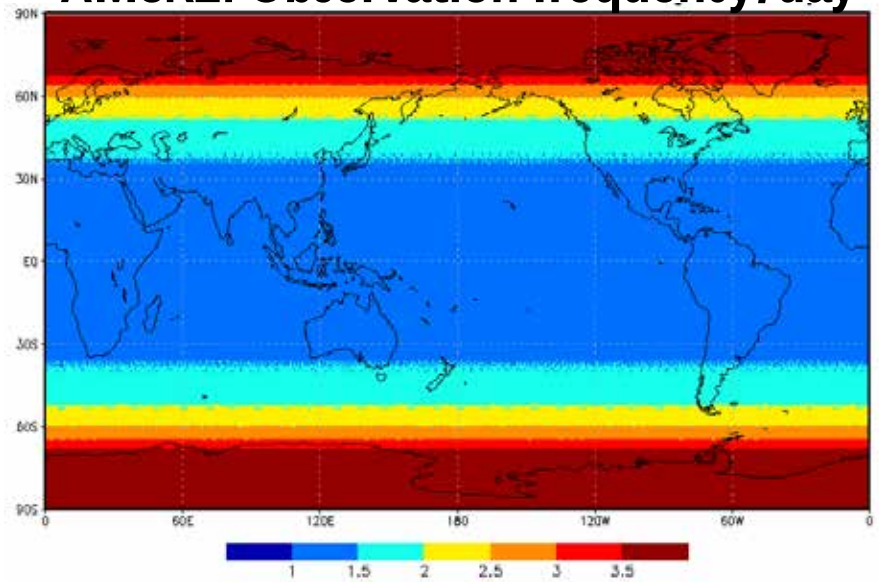


AMSR3: Observation frequency in 2-day

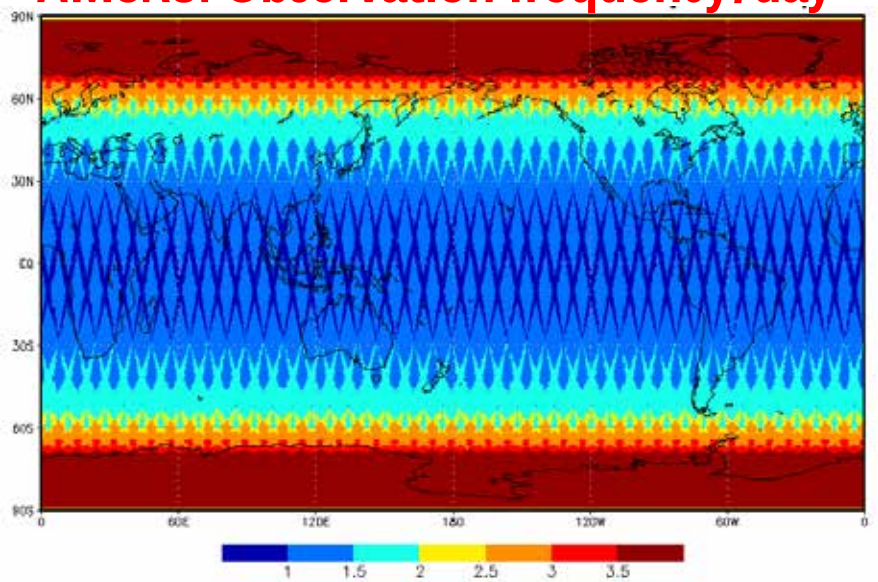


Unlike AMSR2, **AMSR3 cannot cover global area within 2-day** and small missing areas (white) are remained.

AMSR2: Observation frequency/day



AMSR3: Observation frequency/day

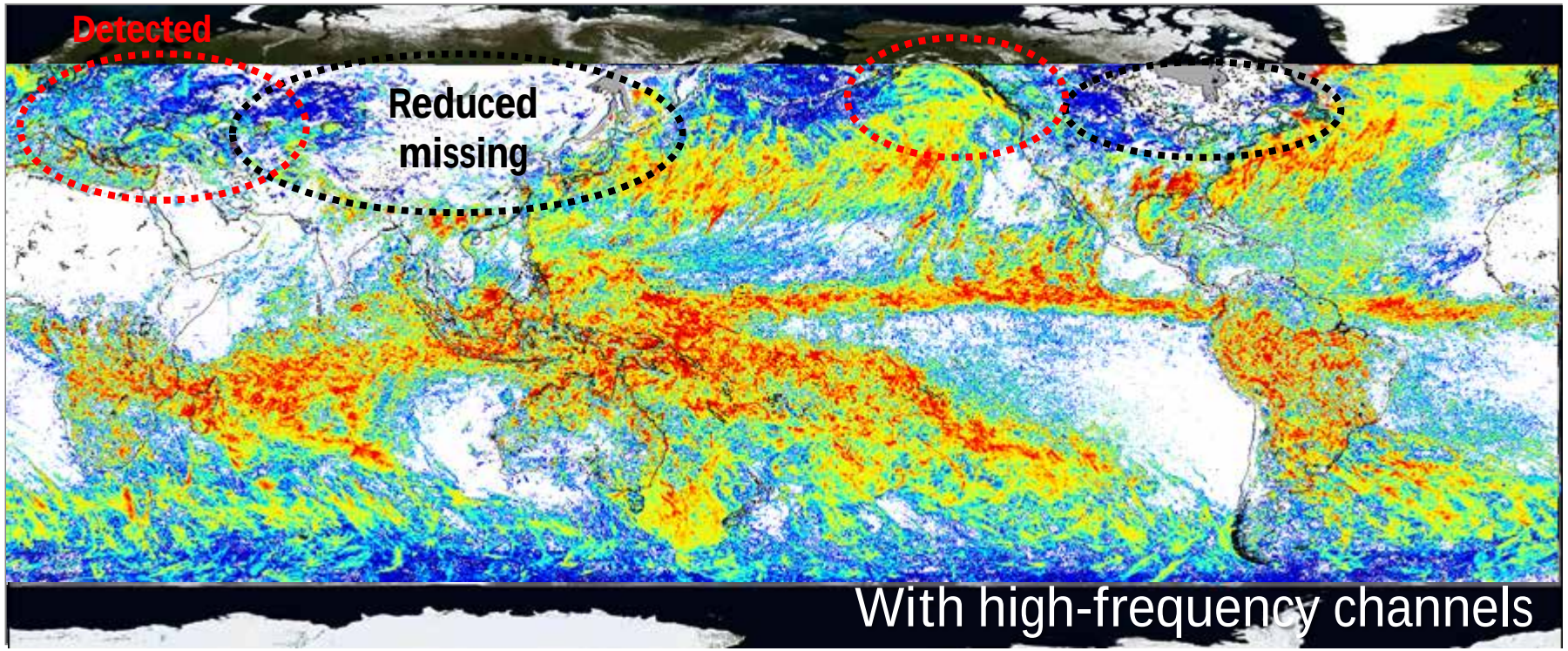


Observation frequency of AMSR3 is **NOT homogeneous** for every longitude and there are fixed areas less than 1 observation/day (blue).

Impact Evaluation of High-frequency Channels

- Impacts of new high-frequency channels were carefully evaluated during MDR, SRR and SDR to consider optional channels of 166H and 183+-3V in addition to nominal channels of 166V and 183+-7V.
- Final decision is to add **166V, 183+-3V and 183+-7V** channels to AMSR3 for snowfall retrieval and water vapor analysis in NWP.

GSMaP-GMI in Jan. 2015



Specification of AMSR3 Instrument

AMSR3 Sensor Characteristics

Sensor type	Conical scanning total power microwave radiometer
Antenna	Off-set parabolic antenna (ϕ2.0m aperture)
Swath width	> 1530km
Quantization	12 bit
Incidence angle	55 deg. except 89GB, 166G,183G
X-polarization	< -20dB
Beam efficiency	> 90%
Range	2.7-340K
Sampling interval	5-10km
Data rate	87.4 kbps (average)
Life time	7 years

* Red indicates differences from AMSR2

AMSR3 Channel Sets

Center frequency [GHz]	Polari-zation	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 (TBD)	H/V	500 (TBD)	< 0.34 K (TBD)	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)
36.5	H/V	1000	< 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 (TBD)	0.3 ° (TBD) (6km×10km)
183.31±7	V	2000×2	< 1.50 K (TBD)	0.28 ° (TBD) (5km×9km)
183.31±3	V	2000×2	< 1.50 K (TBD)	0.28 ° (TBD) (5km×9km)

List of AMSR3 Products

Standard Product
Brightness Temperature (6-183GHz) (L1B)
Resampled Brightness Temperature (L1R)
Total Precipitable Water (over ocean & land)
Integrated Cloud Liquid Water Content (over ocean)
Precipitation (liquid & solid)
Sea Surface Temperature (6GHz & 4-frequency)
Sea Surface Wind Speed
All Weather Sea Surface Wind Speed
Sea Ice Concentration
High-resolution Sea Ice Concentration
Soil Moisture Content
Snow Depth (snow depth & SWE)

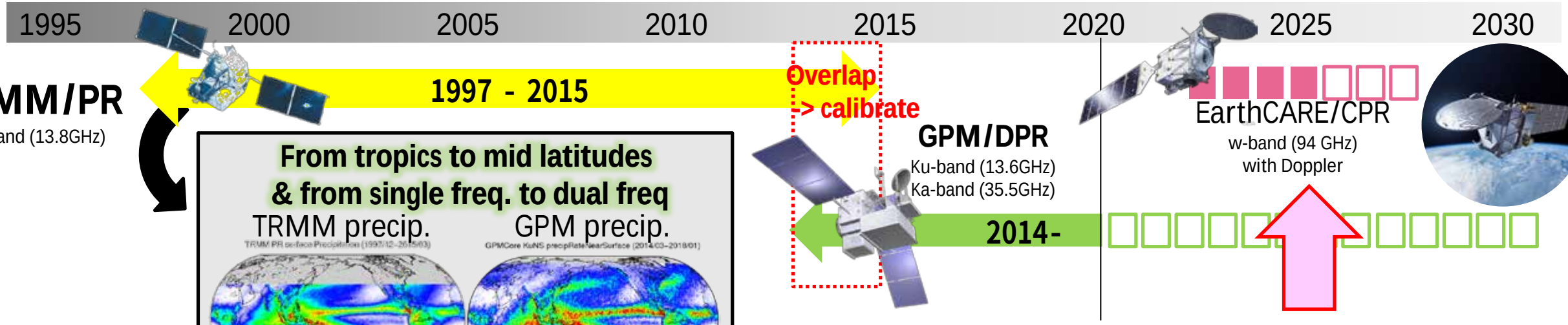
Research Product
High-resolution Brightness Temperature (6-10GHz) (L1H)
High-resolution Sea Surface Temperature (20km res.)
Sea Ice Motion Vector
Land Surface Temperature
Vegetation Water Content
Thin Ice Detection
Soil Moisture Content & Vegetation Water Content by Land Data Assimilation (L4)
Climate Data Record (CDR) for each parameter

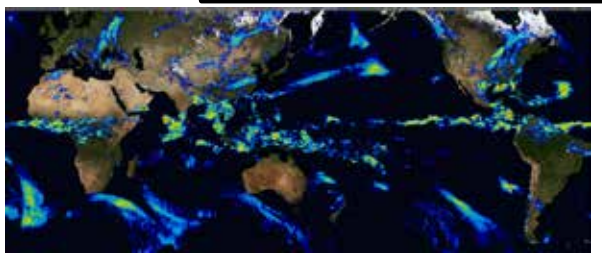
(as of Dec. 2019)

* Red indicates differences from AMSR2

Precipitation and Cloud Profiling Radar developed and planned in JAXA

- JAXA has large heritage of the TRMM/PR and GPM/DPR, and the data record of spaceborne precipitation radars is more than 20 years.
- JAXA and NICT are developing Cloud Profiling Radar (CPR) with doppler capability, onboard the Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) jointly with ESA.

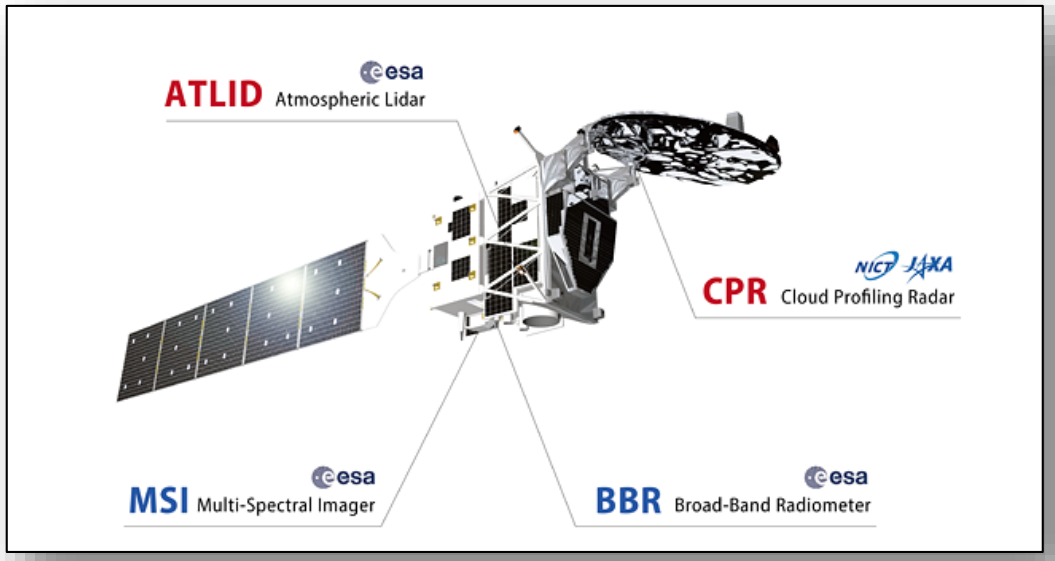




GSMaP

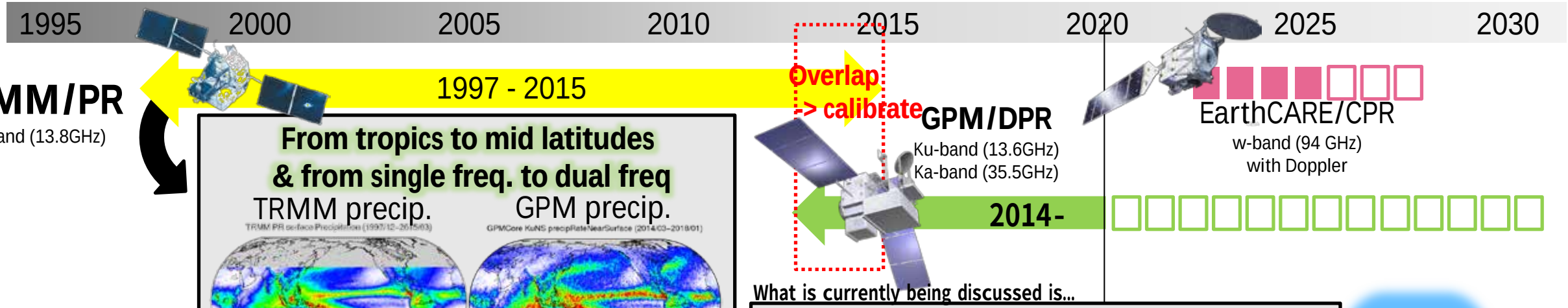
Cloud Profiling Radar with Doppler capability in EarthCARE mission

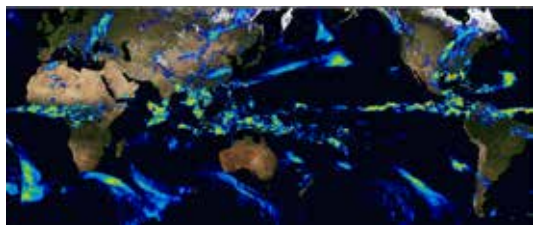
- The Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) jointly with ESA observes clouds, aerosols, and radiation on a global scale to improve the accuracy of climate change predictions.
  - ü planned to be launched in JFY2022.
- JAXA and NICT are developing Cloud Profiling Radar (CPR) with doppler capability.
  - ü 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.



Next Generation Precipitation Radar discussed in JAXA (1)

- The JAXA has studied a feasibility of a next generation precipitation radar with Japanese science team and user community.
  - ü The JAXA has discussed with NASA in the Aerosol and Cloud, Convection and Precipitation (ACCP) study.
- Our targets for the next generation precipitation radar will be **Wider swath, Higher sensitivity, and Doppler Capability.**

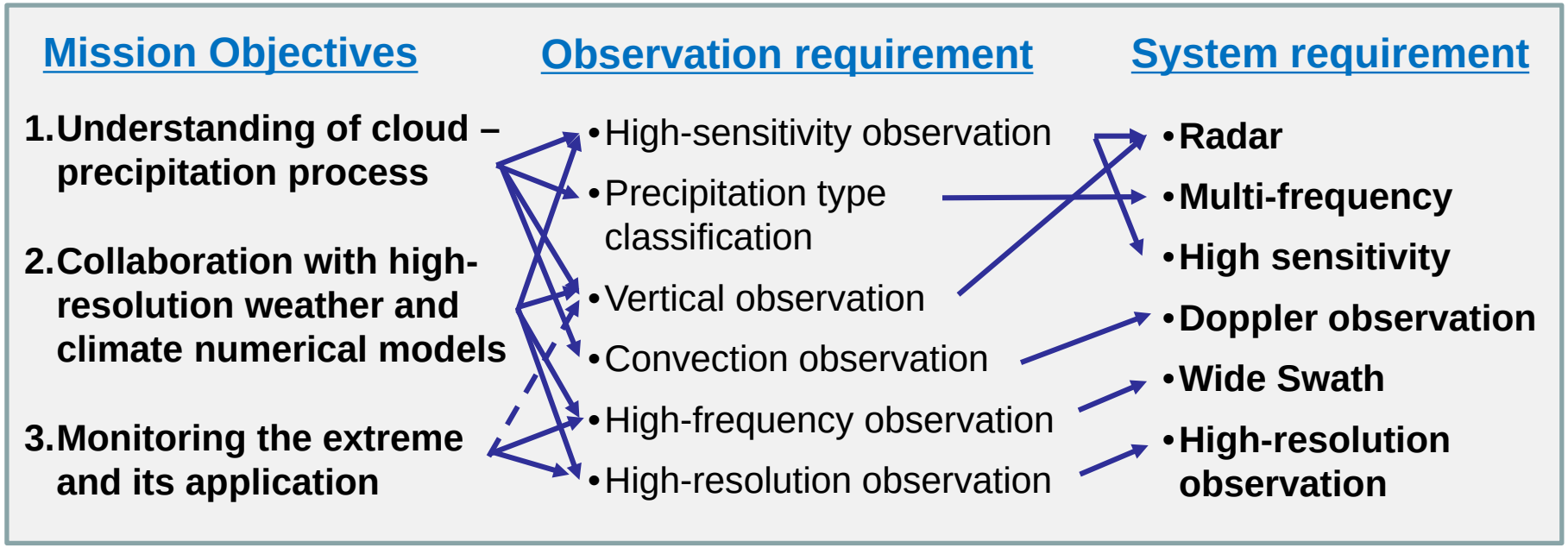




GPM/DPR Wide swath experiment:
Yamamoto et al. (2020, *JSTARS*)
https://doi.org/10.1109/JSTARS.2020.2998724

Next Generation Precipitation Radar discussed in JAXA (2)

- As discussed with Japanese science team and user community, JAXA raised three mission objectives for the next generation precipitation radar as follows;
  - 1) Understanding of cloud-precipitation process,
  - 2) Collaboration with high-resolution weather and climate numerical models,
  - 3) Monitoring the extremes and its applications.
- Figure indicates the connection among the mission objectives, observation requirement and system requirement discussed in JAXA.



Concluding Remarks

- JAXA has long history and big heritage of satellite-based precipitation observation by both passive and active microwave sensors.
- 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 will have additional high-frequency channels for snowfall retrievals to be launched in JFY 2023 (Apr. 2023 – Mar. 2024).
- 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 JFY2022.
  - Next generation of DPR and its targets were discussed with Japanese PMM science team and user community.
- Coordination Group for Meteorological Satellites (CGMS)-48 Working Group (WG)-II action proposed in May 2020
  - The CGMS WG-II requests "IPWG to review operational utilizations of spaceborne precipitation radar and to submit a report regarding the necessity of the precipitation radar, which can be a key factor to continue long-term spaceborne precipitation radar observations."
  - There are plans to write such a document with the IPWG community and that there will be a call for contribution soon.