Japan's Satellite Missions toward the Synergetic Understanding of Aerosol, Cloud, and Precipitation

Riko Oki (JAXA/EORC)

19th Jan. (Tue.) 2021 9:00-11:00 (JST)

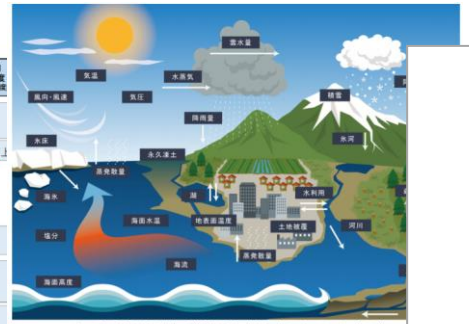
The Joint PI Meeting of JAXA Earth Observation Missions FY2020

Introduction

- Background
  - As has been discussed in this PI meeting, a variety of results have been obtained in each satellite related research area.
  - On the other hand, it will become increasingly necessary to conduct cross-disciplinary research that is not limited to each research area.

- Current status in Japan

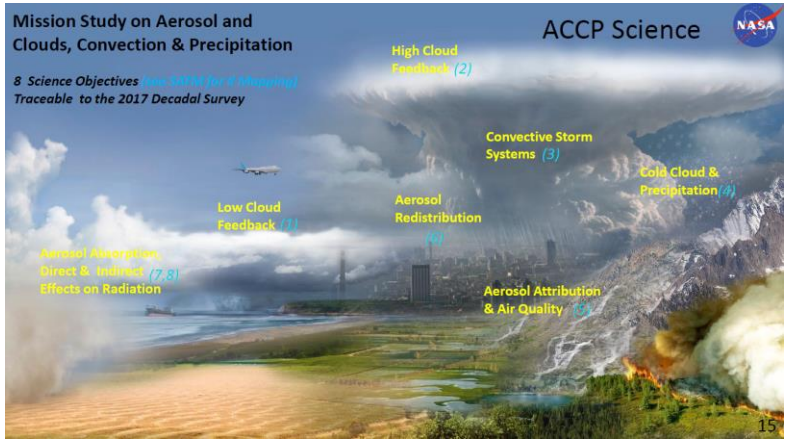
Implementation Plan of Committee on National Space Policy



Grand Plan for Satellite Observation of Water Cycle (JAXA)

Grand Design for Satellite Earth Observation (Task Force in Earth Observation Community)

- International status
  - NASA ACCP (Aerosol, Cloud, Convection and Precipitation) study



- In this session, we picked up **Aerosol, Cloud, and Precipitation related research**, which has many areas of mutual overlap, as one of the examples of interdisciplinary collaboration.

Role of Satellites in Earth Environmental Change Studies

Major Scientific Thesis regarding Earth Environment

1. To where heat energy goes?
2. How fresh water variates?
3. To where carbon and pollutant goes?

based on WCRP Grand Challenges, IPCC AR5

Monitoring and Prediction of Earth Environment

- Monitoring and prediction of climate
- Monitoring of atmospheric environment
- Prediction of water resource
- Monitoring and prediction of extreme weather

Earth environment is 4-dimensional dynamic system

- Understanding of process is a key
- Need temporal/spatial seamless understanding

"Understanding PAST, knowing PRESENT, and predicting FUTURE"

Role of Satellite Data

PAST: Archive of global uniform observation data
PRESENT: Monitoring of Earth environment
FUTURE: (Short-term) Assimilation, Improve initial value
(Long-term) Understanding process, Validation

Observation of Essential Climate Variables (ECVs)

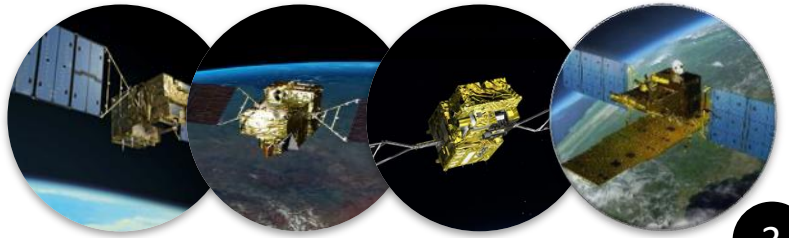
Energy Budget

GCOM-C GCOM-W GPM EathCARE

Water Cycle

GCOM-C GCOM-W GPM ALOS series

Carbon and Material Cycle



GOSAT GOSAT-2 GCOM-C ALOS series

Current JAXA Earth Observation Missions Contributing to Science and Societal Benefits

Cloud/ Aerosols/ Vegetation

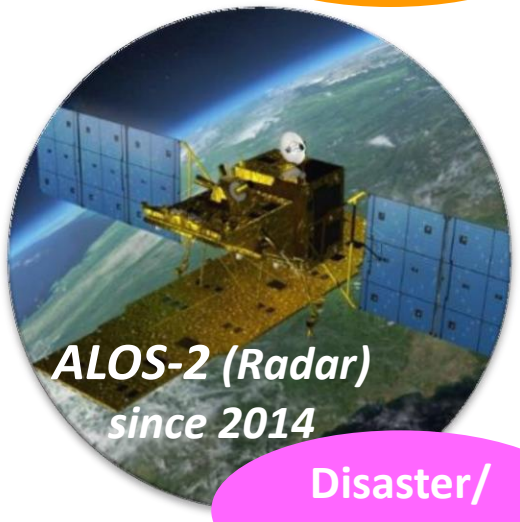
Greenhouse gases

Greenhouse gases

Water Cycle

NASA-JAXA joint mission

Precipitation



Disaster/ Forest

Climate Monitoring by GCOM-C

Global Change Observation Mission - Climate (GCOM-C)

GCOM-C

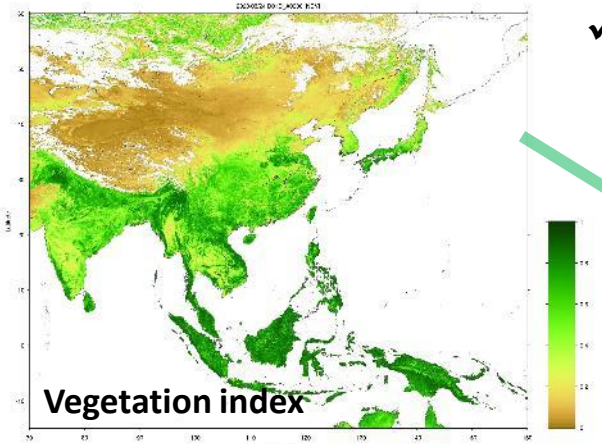
Energy Budget

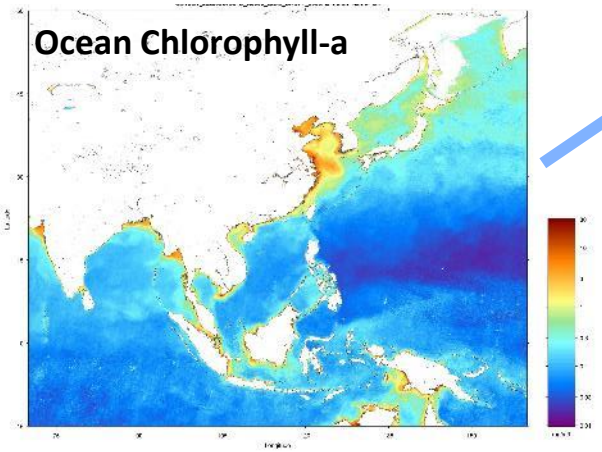
Carbon & Material Cycle

JAXA/GCOM-C observation:

- ✓Spatial distribution
- ✓Seasonal change
- ✓Year-to-year change
- ✓…

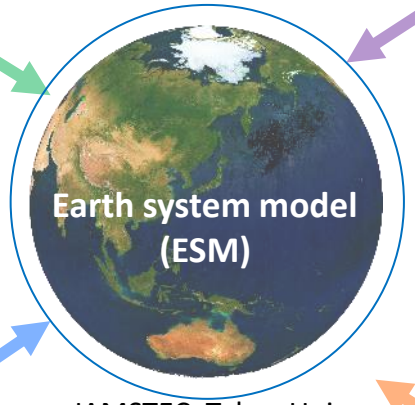
Global ecosystem change





8-day mean during 24-31 Mar. 2020

✓ Aerosol and cloud processes and radiative forcing



JAMSTEC, Tokyo Univ.

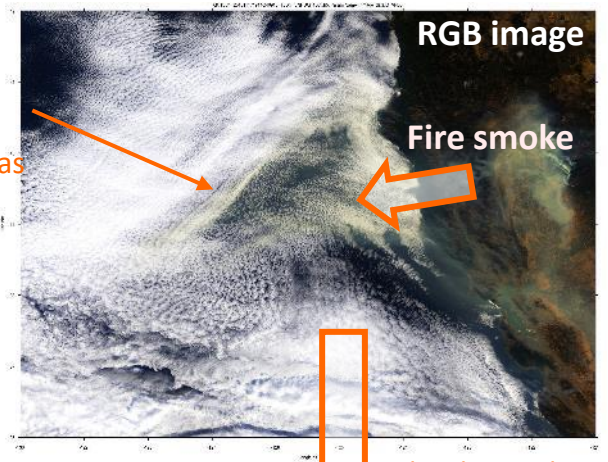
- ✓ Model-Observation comparison
- ✓ Correlation among variables
- ✓ …

→ **Improvement of the ESM**

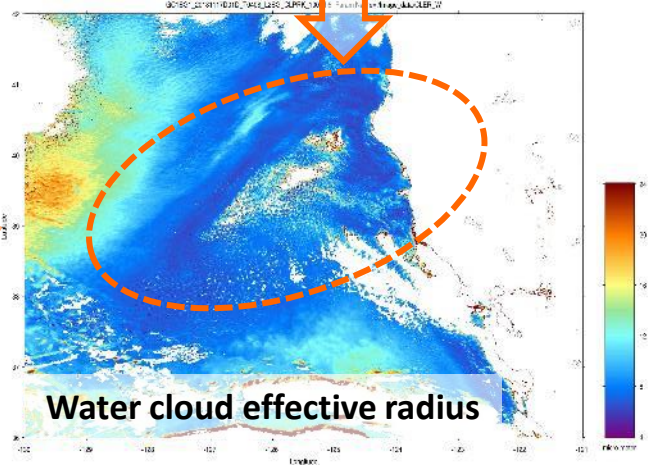
→ **Improvement of future prediction of the future global environment**

Aerosol and clouds by SGLI bands

The SGLI 380nm channel clearly shows aerosols (fire smoke) as brown color areas

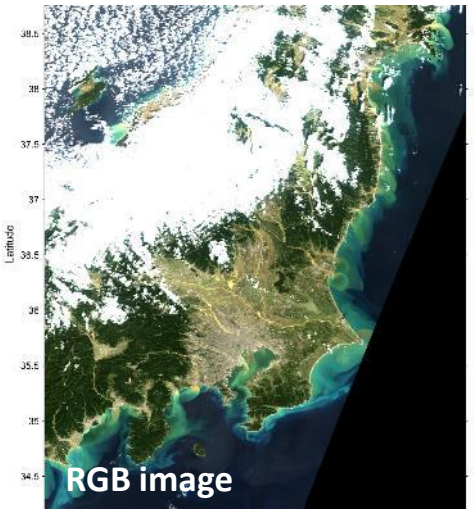


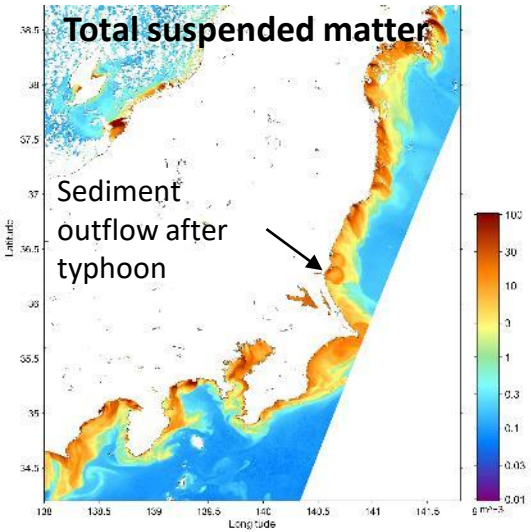
Cloud particle radius is affected by the aerosol



Offshore California on 17 Nov. 2018

Environmental monitoring by 250m

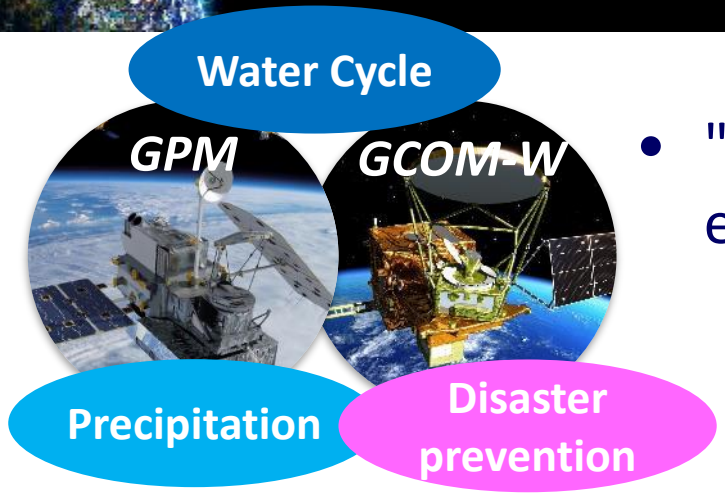




Near Japan on 13 Oct. 2018

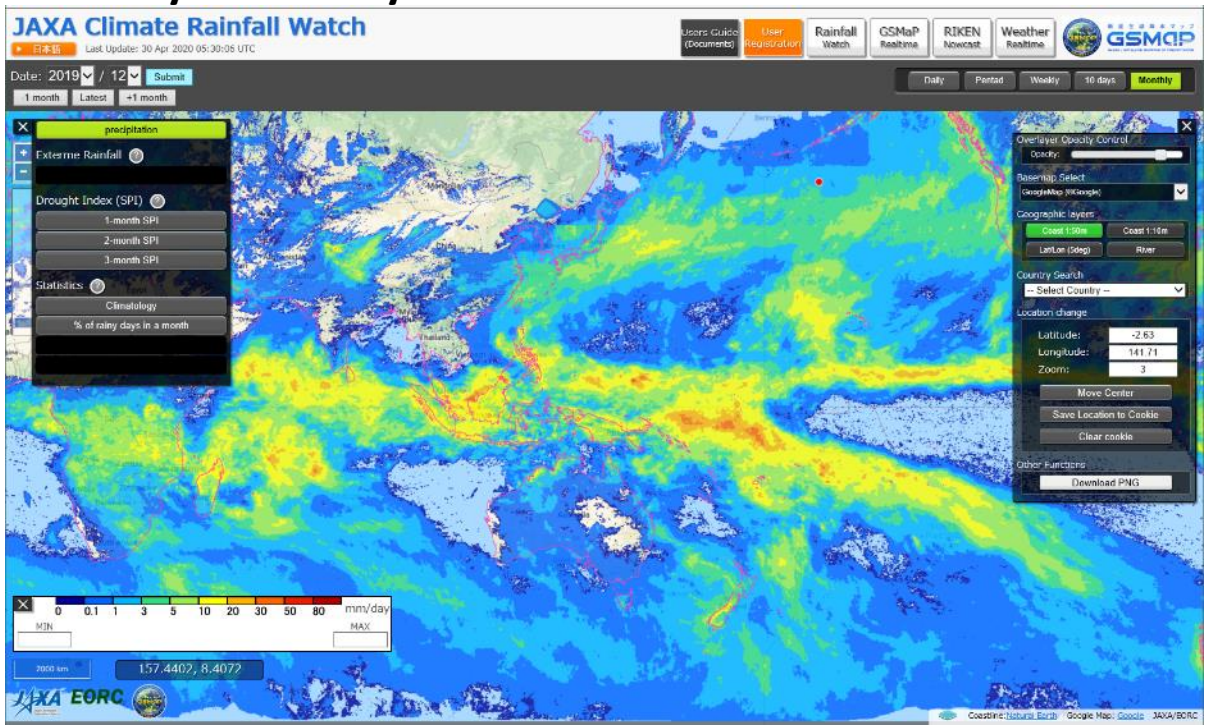
Extreme Heavy Rainfall and Drought by GSMaP

Global Satellite Mapping of Precipitation (GSMaP)

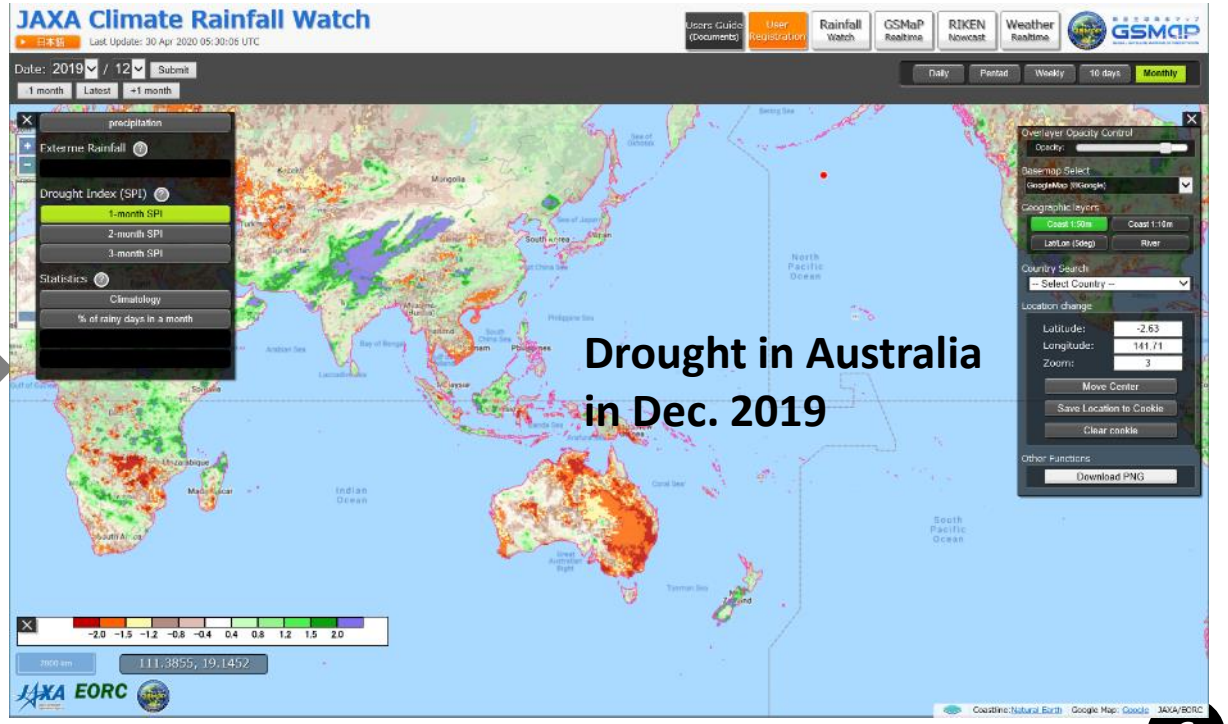


- "JAXA Climate Rainfall Watch", which provides information about extreme heavy rainfall and drought over the world, is now available.
  - Easily monitor global extreme weather and climate by displaying accumulated rainfall in some temporal scale (daily, pentad, weekly, 10-days and monthly), indices related to Extreme heavy rainfall (percentiles) and Drought index (SPI).

Monthly Rainfall by GSMaP in Dec. 2019

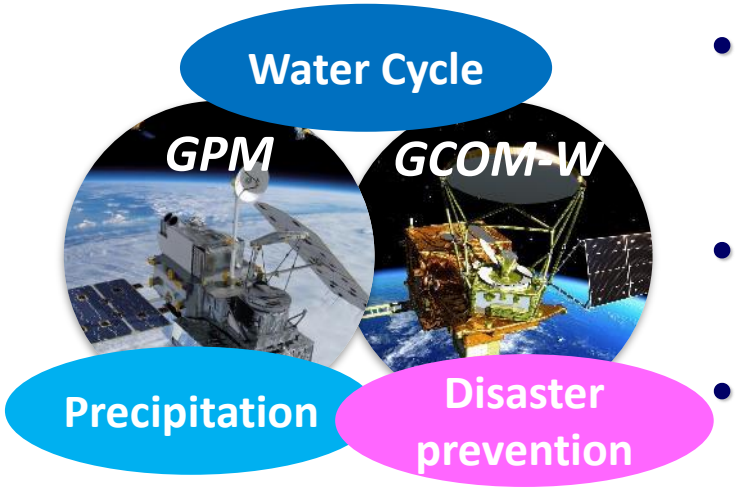


Drought index in Dec. 2019



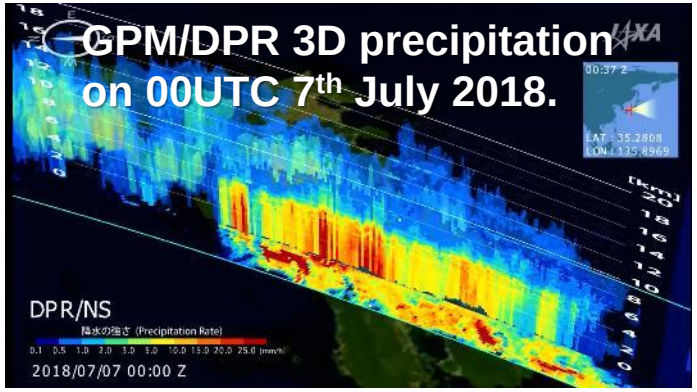
https://sharaku.eorc.jaxa.jp/GSMaP_CLM/

Utilization of Satellite Obs. Data in NWP

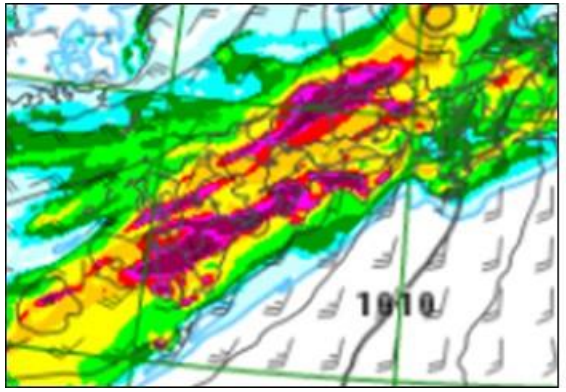


- The Japan Meteorological Agency (JMA) started the GCOM-W/AMSR2 assimilation in the NWP system in Sep. 2013, and GMI and GPM/DPR assimilation in Mar. 2016.
- Assimilation of AMSR2, GMI and DPR improved the prediction of rainfall location, which is important for disaster prevention.
- Especially, the DPR 3-dimensional information which cannot be detected by microwave radiometer can be a unique factor for rainfall forecasting as well as disaster prevention.

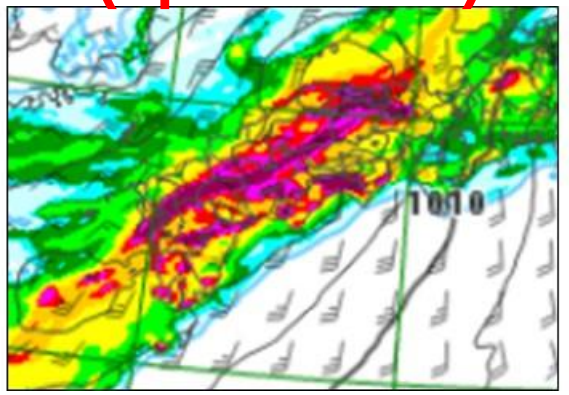
Case study for heavy rainfall in July 2018, causing serious damage in western part of Japan.



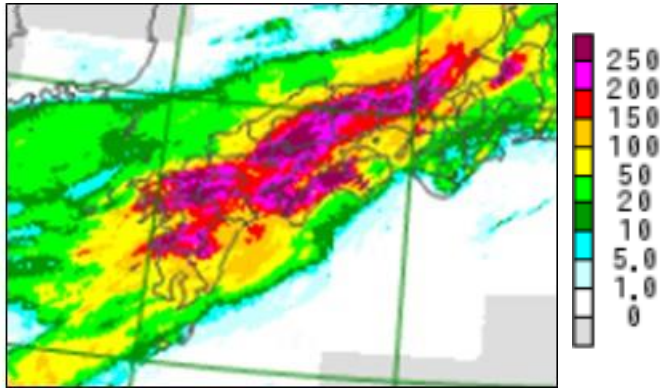
without DPR



with DPR (operational)



Ground observation



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

Aerosol products by Himawari-8 Satellite

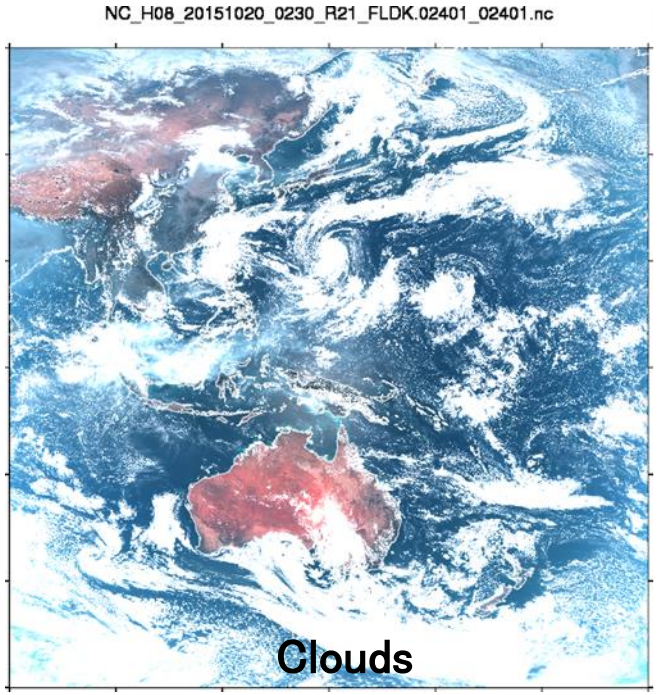
Water Cycle

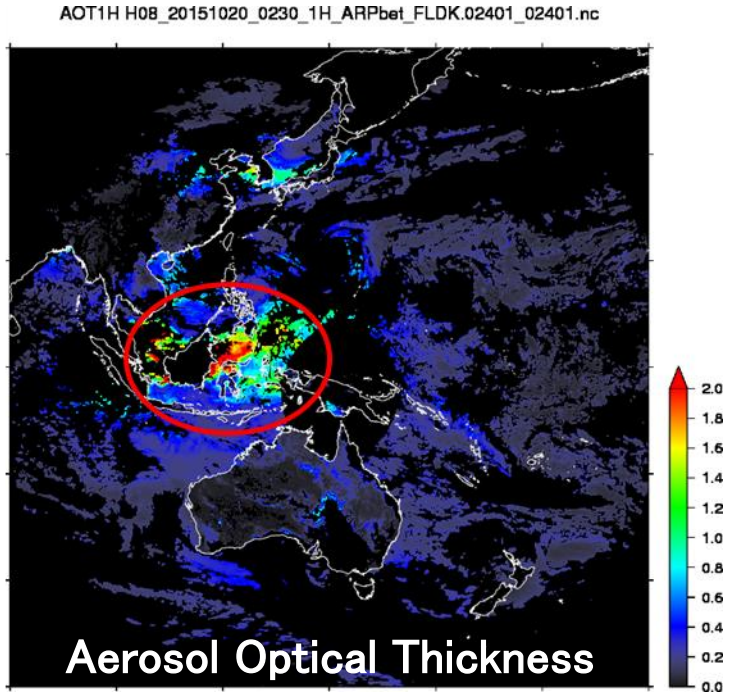
Energy Budget

- Himawari-8 is a Japanese Geostationary Satellite operated by Japan Meteorology Agency (JMA)
- Loads a multiwavelength imager called Advanced Himawari Imager (AHI)

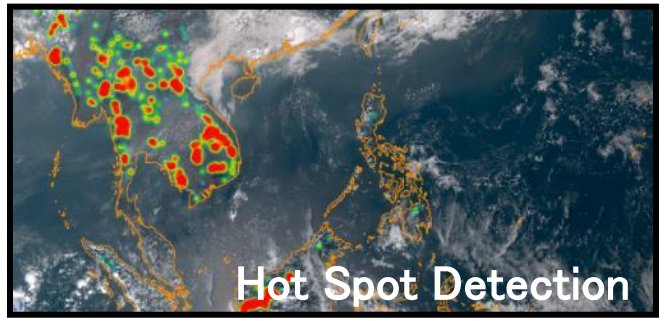
Center Wavelength of Himawari-8/AHI

Band	Wavelength (μm)	Resolution (km)	Band	Wavelength (μm)	Resolution (km)
1	0.47	1	9	6.9	2
2	0.51		10	7.3	
3	0.64	0.5	11	8.6	
4	0.86	1	12	9.6	
5	1.6	2	13	10.4	
6	2.3		14	11.2	
7	3.9		15	12.4	
8	6.2		16	13.3	





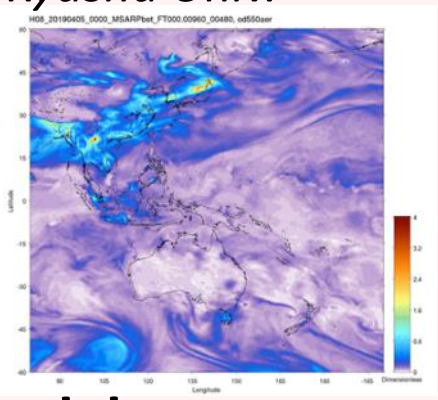
- JAXA EORC applied the aerosol algorithm developed for JAXA LEO missions (GCOM-C, EarthCARE, GOSAT-2) to Himawari-8
- Wild fire in Borneo Island (Indonesia), atmospheric pollutant from Chinese continent and hot spot over Southeast Asia



Satellite and Model Collaborations toward Earth Environment Predictions

Alert for Public Health

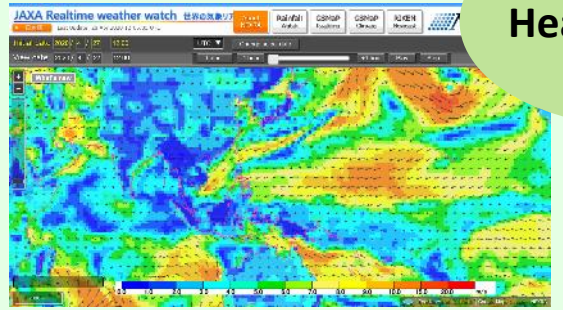
with JMA, MRI, NIES, Kyushu Univ.



Aerosol Model

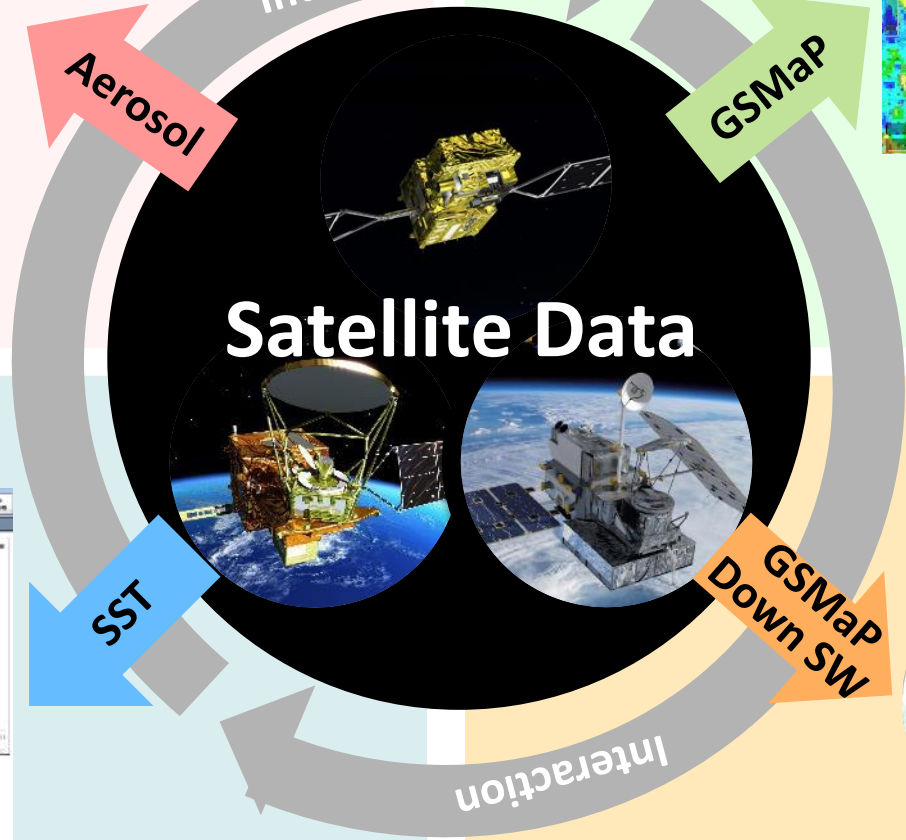
with U. Tokyo, RIKEN

Severe Weather Heavy Rainfall, Flood

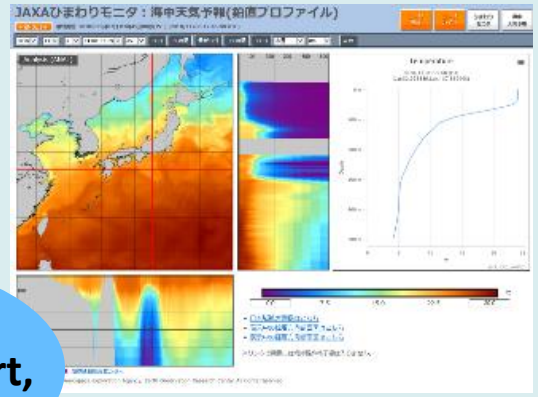


NEXRA

Atmospheric Model



Ocean Model



Fishery, Ocean Transport, Climate

with JAMSTEC, RIKEN

Land/River Model

TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

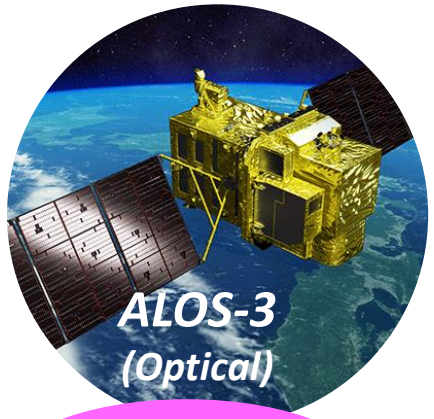
with U. Tokyo

Drought, Flood, Water-related Hazard

Future Earth Observation Missions in JAPAN

JFY 2021 — 2022 — 2023

ALOS-3 (2021) | ALOS-4 (2022) | EarthCARE (2022) | GOSAT-GW (2023)



Disaster/ Mapping

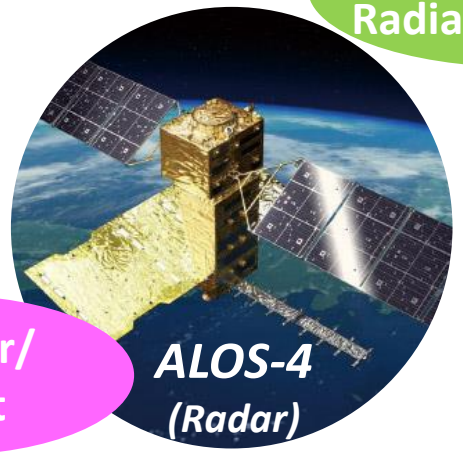
Cloud/Aerosol Radiation Budget

EarthCARE CPR: Cloud Profiling Radar

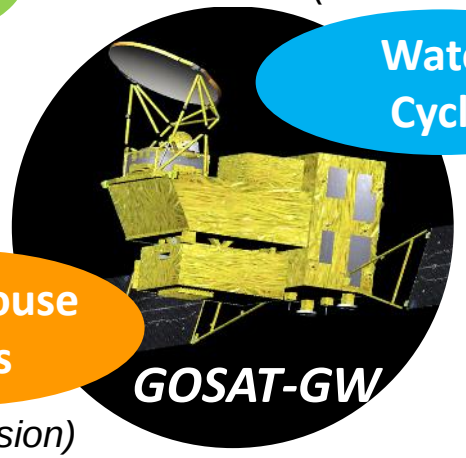
Next Generation Precipitation Radar

Water Cycle

(JAXA Mission)



Disaster/ Forest



Water Cycle

Greenhouse gases

(MOE Mission)

SGLI follow-on

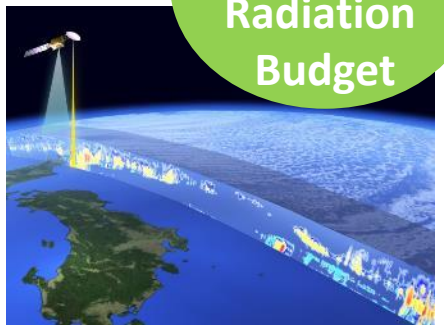
Water Cycle

Cloud/Aerosol Radiation Budget

Future Missions for Climate & Water: EarthCARE (2022) & GOSAT-GW (2023)

To be launched in JFY2022

Cloud/ Aerosol Radiation Budget



- Europe-Japan joint mission
- 3 dimensional global distributions of cloud and aerosol to contribute to precise understanding of climate change
- JAXA and NICT provides world's first satellite-based cloud vertical motion by the Clod Profiling Radar (CPR) with 94 GHz with Doppler Capability at 0.8 km spatial resolution.

Orbit	Sun-synchronous sub-recurrent orbit Altitude: approx. 400km Inclination angle: 97.05° Local Sun Time at Desc.: 14:00 Revisit time: 25 days
Instruments	**- Cloud Profiling Radar (CPR)** by NICT & JAXA - Atmospheric Lidar (ATLID) by ESA - Multi-Spectral Imager (MSI) by ESA) - Broad-Band Radiometer (BBR) by ESA
Mass	Approx. 2.2 tons at launch
Designed lifetime	3 years

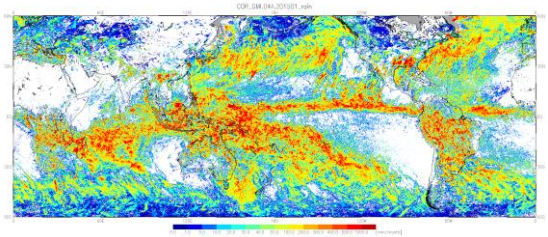
To be launched in JFY2023

Water Cycle

Green-house gases

- Carrying two instruments, AMSR3 and TANSO-3.
  - AMSR3 (JAXA) will succeed AMSR series observations adding new high frequency channels (166 & 183 GHz) for snow fall retrievals and water vapor analysis for numerical weather prediction.
  - TANSO-3 (led by Ministry of Environment in Japan) uses imaging spectrometer technology to measure CO2, CH4 and NO2 globally with medium and locally with high spatial resolution.

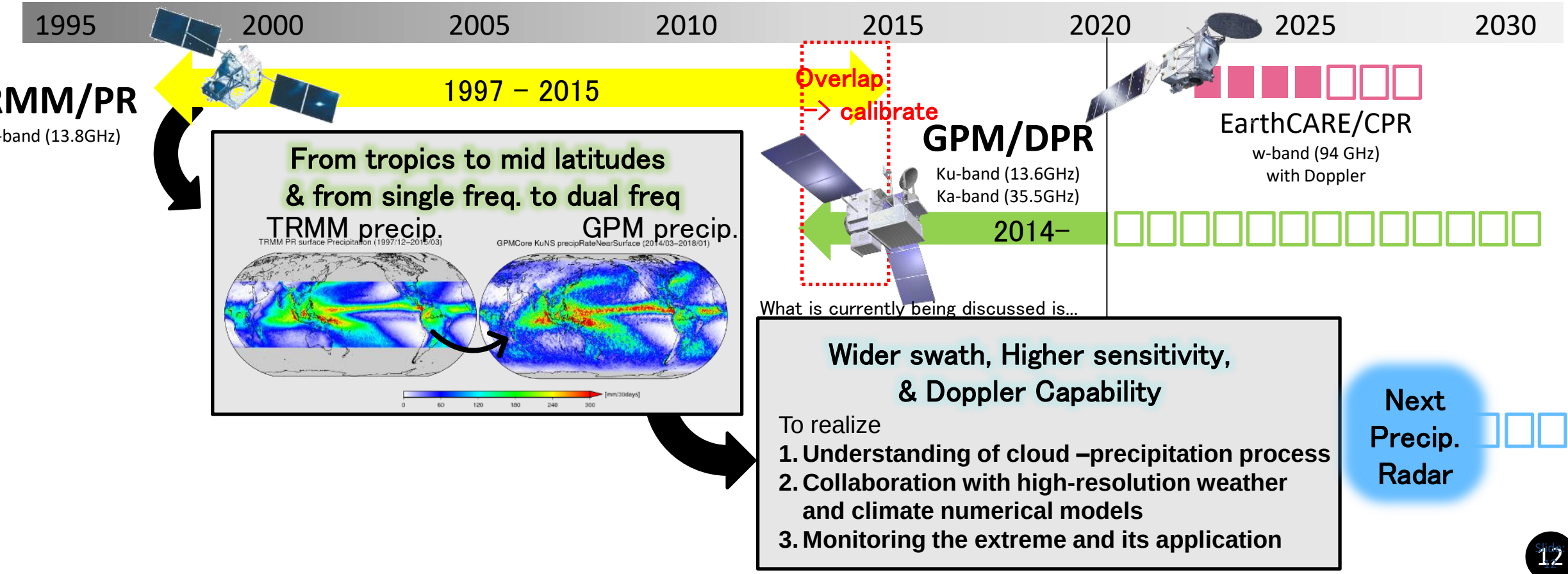
AMSR3 for both snow & rain



Orbit	Sun-synchronous sub-recurrent orbit Altitude: approx. 666km Inclination angle: 98.06° Local Sun Time at Desc.: 1:30 +/- 15 min Revisit time: 3 days
Instruments	**- Advanced Microwave Scanning Radiometer 3 (AMSR3)** - Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3) (for Ministry of Environment in Japan (MOE))
Mass	Approx. 2.6 tons at launch
Designed lifetime	**7 years**

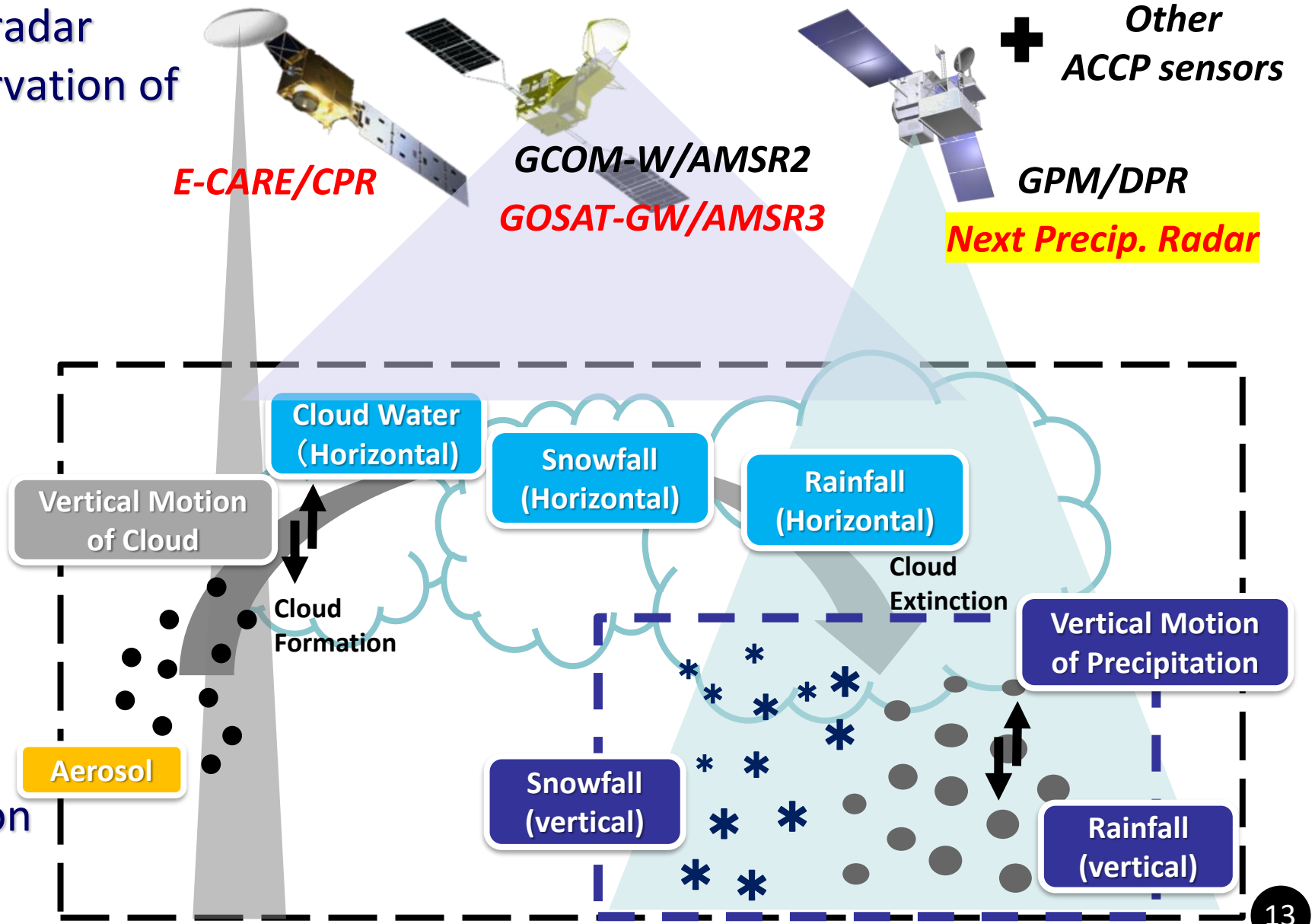
Next Generation Precipitation Radar

- JAXA has large heritage of the TRMM/PR and GPM/DPR, and the data record of spaceborne precipitation radars is more than 20 years.
- As discussed with Japanese science team and user community, JAXA raised three mission objectives for the next generation precipitation radar. We have studied the feasibility and discussed with NASA for ACCP collaboration.



Precipitation Radar in Synergy with Aerosols and Cloud Science

- Japan's next precipitation radar focuses on advanced observation of precipitation
  - Doppler velocity obs.
  - High sensitivity
- Collaboration with other missions enables us to see from cloud formation to precipitation phase
- International collaboration with NASA ACCP missions will bring us integrated understanding of Aerosol~Cloud~Precipitation processes



Precipitation Radar in Synergy with Aerosols and Cloud Science

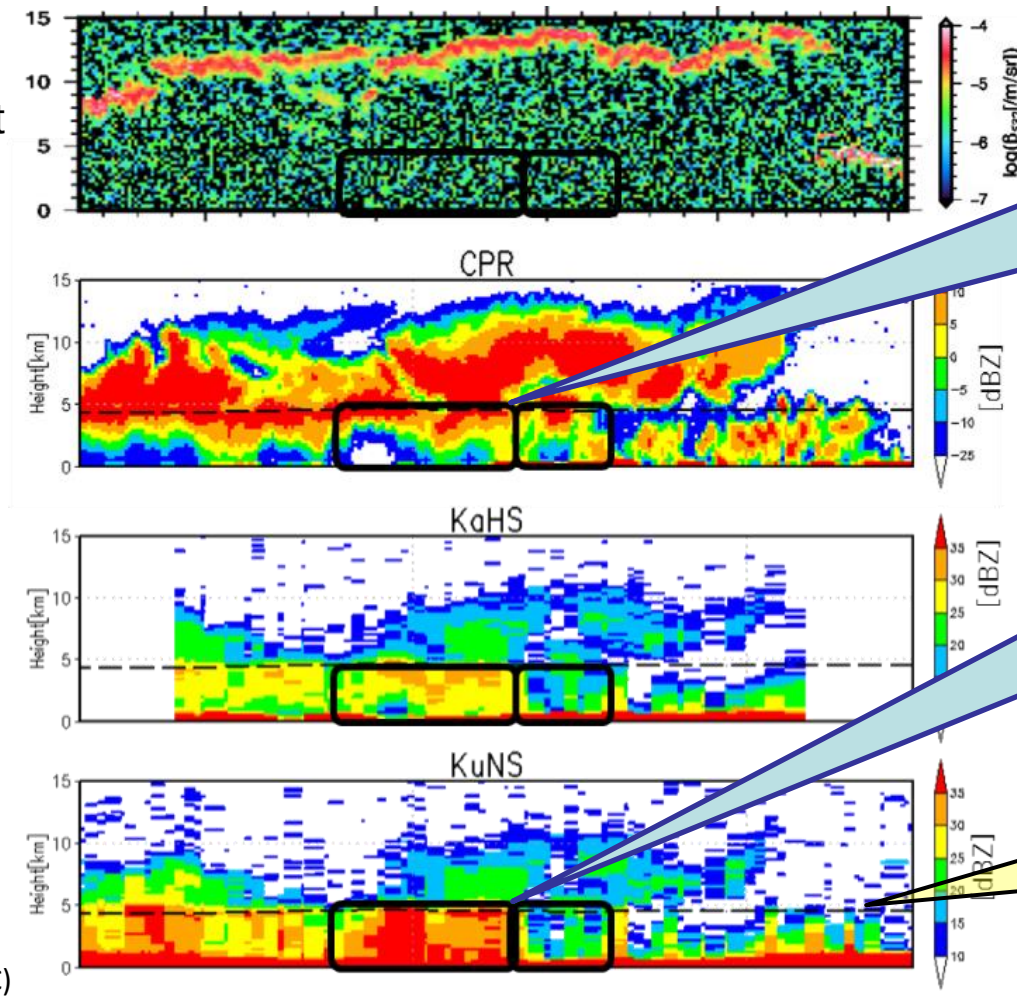
- Plots of match-up data of GPM DPR, CloudSat CPR, CALIPSO CALIOP indicates that the combination of those sensors will give us a complete picture of aerosols~clouds~precipitation system.
- Next generation precipitation radar can add further information by doppler velocity and higher sensitivity observation.

Lidar
Back-scattering coefficient
（CALIPSO/CALIOP）

W band
Radar Reflectivity
（CloudSat/CPR）

Ka band
Radar Reflectivity
（GPM/KaPR）

Ku band
Radar Reflectivity
（GPM/KuPR）



For a thick cloud system, it is difficult for W band (and Ka band) radar to discriminate weak precipitation from attenuation due to strong precipitation

Ku band can detect strong precipitation echo at low altitude

GPM/KuPR has higher sensitivity so that it can detect precipitation with anvil.

Plotted by M.Kikuchi & M.Yamaji (JAXA/EORC)

SUMMARY

JAXA's Earth Observation satellite program and data product in operation

- Contribution to water cycle and climate studies, disaster mitigation, and various operational applications, including weather forecast, fishery, and agriculture, is a big target of JAXA's Earth observation missions.

Earth Observation satellite programs to be launched

- JAXA currently operates six EO satellites/missions in orbit, and will continue those contributions by launching ALOS-3, ALOS-4, ESA-JAXA joint EarthCARE, GOSAT-GW and SGLI follow-on in near future.

Next generation precipitation radar following to the TRMM/PR and the GPM/DPR

- Regarding the next generation precipitation radar mission, JAXA joins the ongoing ACCP (Aerosol, Cloud, Convection and Precipitation) Architecture Study in U.S., and proposes the advanced Ku-band Precipitation Radar with doppler capability, higher sensitivity with wide swath.

Synergetic use with numerical models

- We also collaborate with various model communities to utilize multiple satellite data in their models to enhance future predictions and contribute to science and society.