JAXA's Earth Observation Missions from Planning to Realization

Riko OKI

Director, Earth Observation Research Center (EORC)

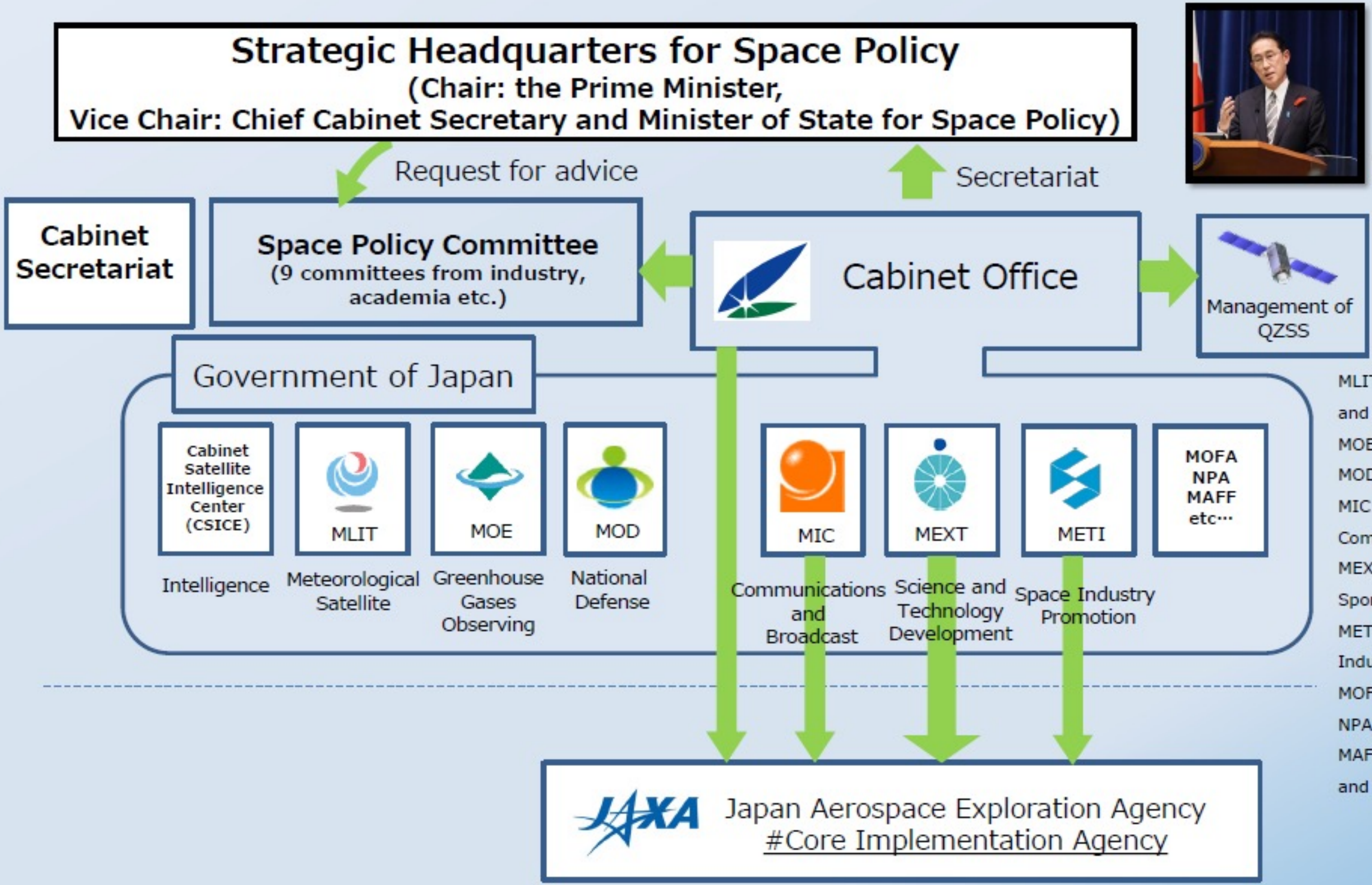
Japan Aerospace Exploration Agency (JAXA)

July 7, 2024@9th GEWEX-OSC, Space Agency Event

Contents

- Japan’s Space-related ministries & agencies
- Japan’s Basic Plan on Space Policy
- Key players in the Space Policy development
- Flow of satellite project planning/developing/operating
- Example of ideas contributing to mission designs – case of precipitation/cloud
- Collaboration with model community
- How to propose “science mission” in JAXA

Japan’s Space-Related Government Ministries & Agencies



© Cabinet Public Relations Office

MLIT: Ministry of Land, Infrastructure and Transport
MOE: Ministry of the Environment
MOD: Ministry of Defense
MIC: Ministry of Internal Affairs and Communications
MEXT: Ministry of Education, Culture, Sports, Science and Technology
METI: Ministry of Economy, Trade and Industry
MOFA: Ministry of Foreign Affairs
NPA: National Police Agency
MAFF: Ministry of Agriculture, Forestry and Fisheries

Japan’s Basic Plan on Space Policy (latest update: Jun. 13, 2023)

Targets and Future Vision

(1) Ensuring space security

(2) Contribution to national reliance, response to global issues, and realizing innovation

(3) Creation of new knowledge and industry through space science exploration

(4) Enhancement of comprehensive basis supporting space activities

Approach

a. Next-generation communication service

b. Remote sensing

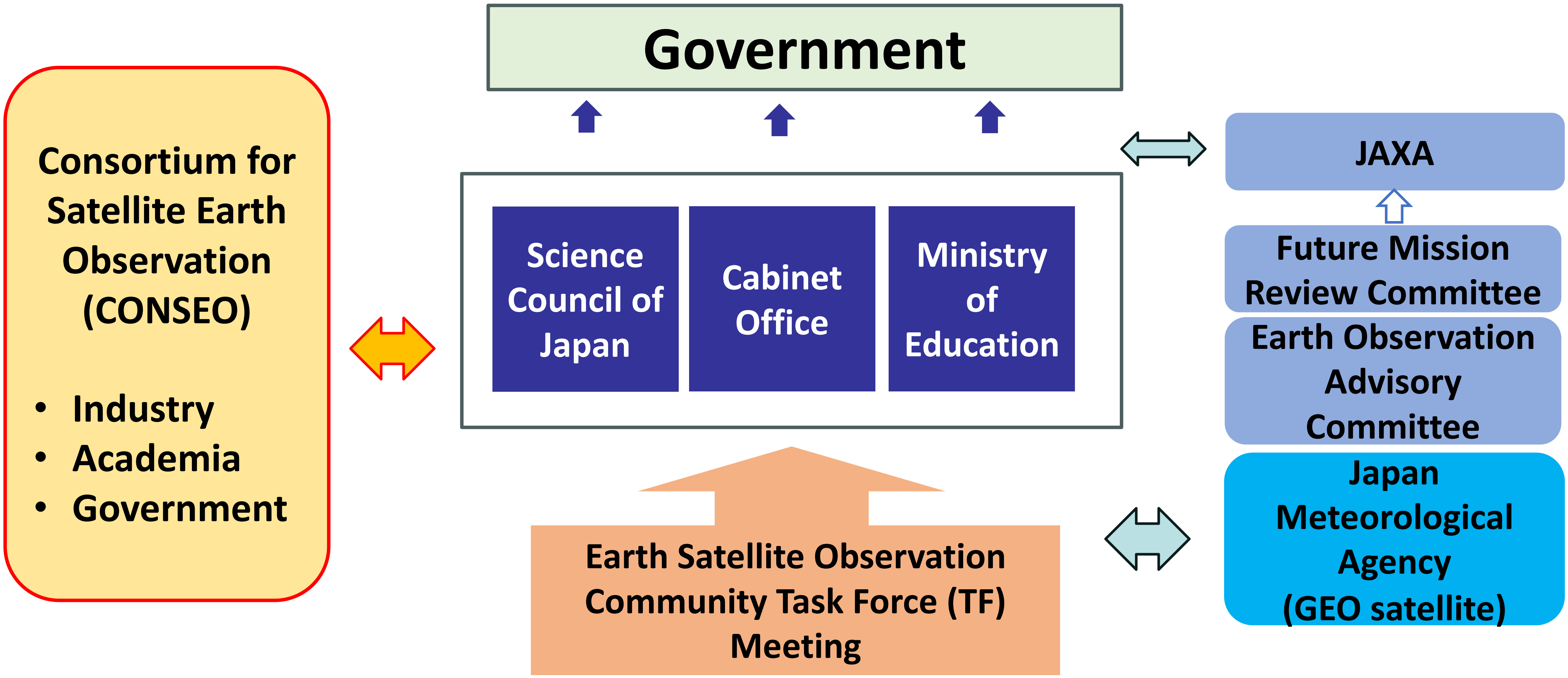
c. Quasi-Zenith Satellite System (QZSS)

d. Ampliation of satellite development and utilization basis

b. Remote Sensing

- Satellite development/operation and promotion of data utilization toward disaster management & mitigation, national resilience and global issues. (Himawari-10 in JFY2029, GOSAT-GW in JFY2024, discussion of response to loss of ALOS-3, development of precipitation radar mission, etc.)
- Support to development and demonstration of state-of-art satellite-related technologies (demonstration for establishment of SAR satellite constellation in 2025, etc.)

Key Players in Japan`s Space Policy Development



Background of CONSEO Establishment

Before CONSEO establish

Government

内閣府
Cabinet Office

Committee on National Space Policy

Satellite Development and Demonstration Subcommittee

文部科学省
MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

Space exploration Utilization Committee

Industry, Government, and Academia Collaboration Platform

Satellite Positioning Working Group	JAXA Academia	Space ICT Promotion Initiative Forum
Positioning Satellite	**Earth Observation satellite**	**Communication Satellite**

In recent years, Satellite Earth Observation industry have become active businesses domain with New and Old Space Companies.

Background of CONSEO Establishment

After CONSEO establish

Government

内閣府
Cabinet Office

文部科学省
MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

Committee on National Space Policy

Satellite Development and Demonstration Subcommittee

Space exploration Utilization Committee

Industry, Government, and Academia Collaboration Platform

Satellite Positioning Working Group

Positioning Satellite

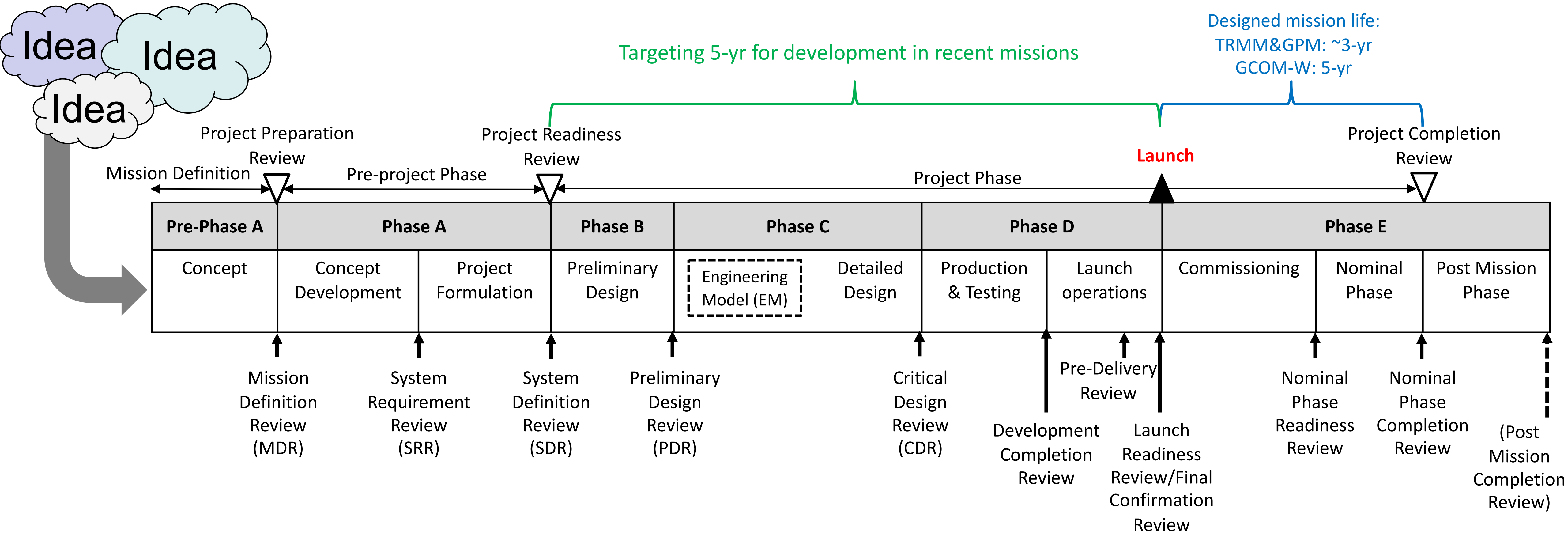
CONSEO

Earth Observation satellite

Space ICT Promotion Initiative Forum

Communication Satellite

Satellite Project Flow in JAXA



TRMM	Pre-Phase A 1986-1990	Phase A/B/C/D 1990-1997 (7-yr)		Nominal Phase 1997-2001 (~3-yr)	Post-Mission 2001-2015
GPM	Pre-Phase A 1993-2002	Phase A 2002-2003 (2-yr)	Phase B/C/D 2003-2014 (11-yr)	Nominal Phase 2014-2017 (~3-yr)	Post-Mission 2017-now
GCOM-W	Pre-Phase A 2003*-2005	Phase A 2005-2007 (2-yr)	Phase B/C/D 2007-2012 (5-yr)	Nominal Phase 2012-2017 (5-yr)	Post-Mission 2017-now

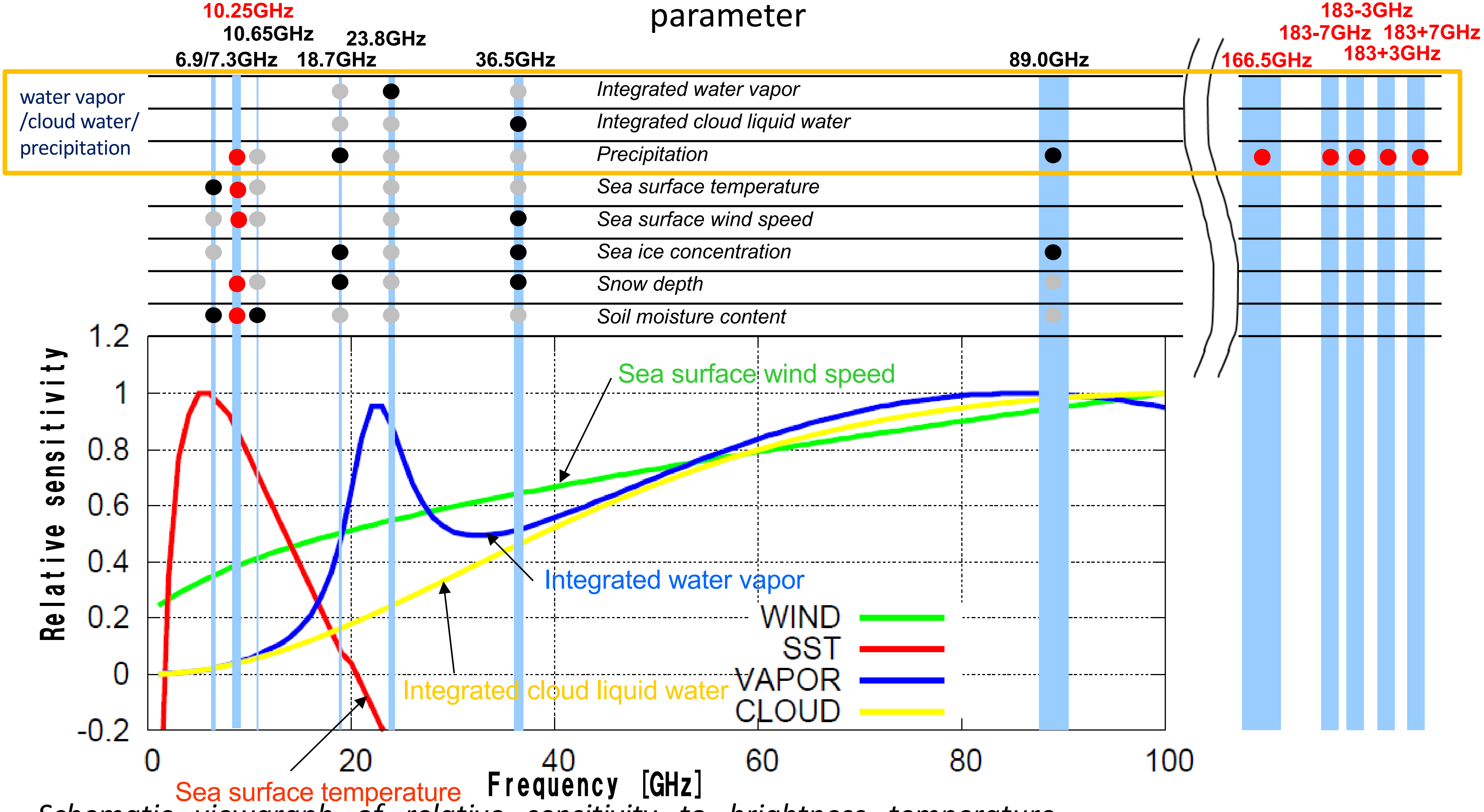
* GCOM-W mission definition discussion quickly started after the failure of ADEOS-II in 2003

Ideas to Propose/Start the Satellite Missions

- Initial ideas of the instrument
  - Enhancement of the current instrument, combination, or new observation concept/technology
  - New technology is usually demonstrated on the ground at first → airborne → spaceborne
  - New and advanced instrument sometime needs longer period (~10-yr) to realize
- Design of mission concept
  - Mission proposal/objective → changes with time and/or countries
  - Outcome → increasing requirements from the society (not totally science)
  - Mission configuration → requirements to instrument capability, orbit design, satellite platform, launcher, needs of constellation, domestic/international collaboration, etc.
  - Requirements versus Feasibility → need discussion among scientists, engineers, stakeholders, and space agency
  - Mission requirement → to be re-configurated/represented as "System Requirement"
- Case of international/domestic collaboration mission
  - Need to define effective mission objective to both agencies
  - Need to assign role and appointment of each agency
  - Coordination of schedule for budget and/or technology development of instrument in each agency
- Actual cases are totally different depending on timing of the projects – some examples from cloud-precipitation related satellite missions will be shown in later slides.

Example (1): Observing Frequency Requirements for Microwave Imager

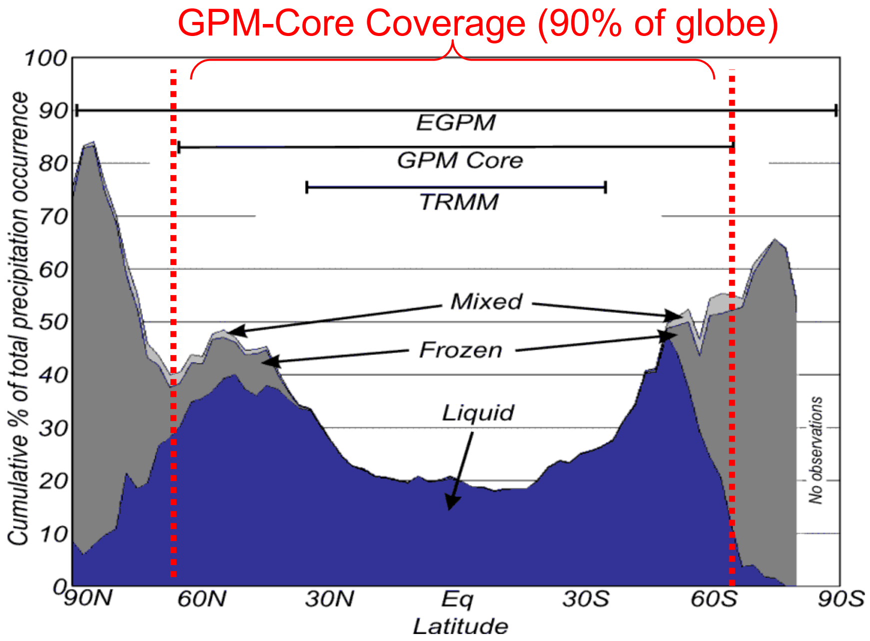
AMSR2 (black) & AMSR3 (black & red) frequency channels for retrievals of each geophysical parameter



Schematic viewgraph of relative sensitivity to brightness temperature changes (normalized by maximum) for oceanic geophysical parameters.

- Requirements for water particle observation for AMSR2
  - **Global** observation of **water vapor/cloud water/rainfall** in **high-resolution** & frequently
  - **Continuation** of AMSR-E
- GCOM-W/AMSR2 (2012)
  - →6-89GHz channels
  - →2-m antenna
  - →Polar orbit in A-train constellation
- Requirements AFTER AMSR2
  - Information of **snowfall and upper water vapor**
  - Continuation of AMSR2
- GOSAT-GW/AMSR3 (JFY2024)
  - →Addition of **166-183GHz** to current 6-89GHz
  - →2m antenna
  - →Polar orbit (keep 13:30LST)
- What's NEXT to AMSR3?

Example (2): Observation Requirements for Precipitation and Clouds



Cumulative % of total precipitation occurrence by COADS data (C. Kidd, personal communication)

- Light precipitation becomes increasingly important towards the polar regions
- COADS data shows light precipitation occurrence >80%; ~50% in mid-latitudes

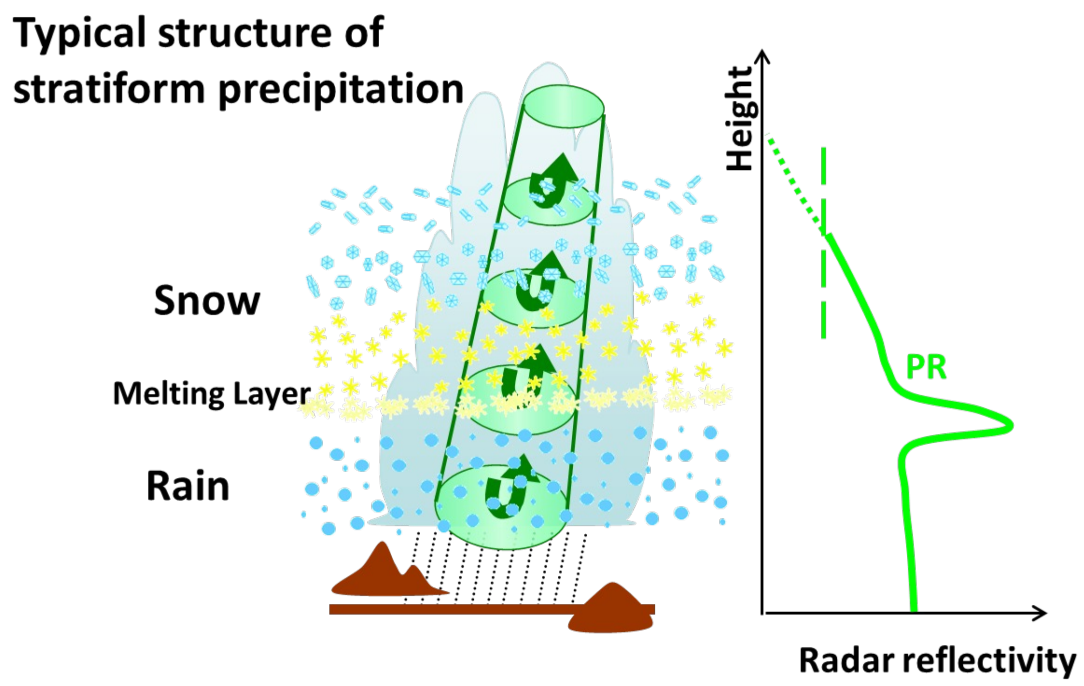
- Original user requirements for precipitation observation BEFORE TRMM
  - –Information of **vertical structure** of rainfall in addition to vertically-accumulated rainfall observation by microwave imager
  - –Measurement of **tropical rainfall over ocean** that related to El Niño/La Niña
  - –Large **diurnal variation** of rainfall in the tropics
- TRMM/PR (1997)
  - →Ku (13.6GHz) radar for rainfall
  - →Orbit inclination angle of 35deg (non-sun-synchronous orbit) to cover tropics
- User requirements AFTER TRMM
  - –Expand vertical rainfall observation to **high-latitude**
  - –Need to observe **snowfall**
- GPM-Core/DPR (2014)
  - →Ka (36GHz) radar in addition to Ku radar for snowfall
  - →Orbit inclination angle of 65deg to cover high-latitude (non-sun-synchronous)
- User requirement AFTER GPM
  - –Information of wind motion inside precipitation system
- PMM
  - →Ku radar with doppler capability (observe motion of precipitation particles)

- Requirements for cloud observation
  - –Information of vertical structure of cloud & motion in global
- EarthCARE/CPR :
  - →94GHz radar with doppler capability
  - →Polar orbit (sun-synchronous)

Observation Concept from TRMM to GPM

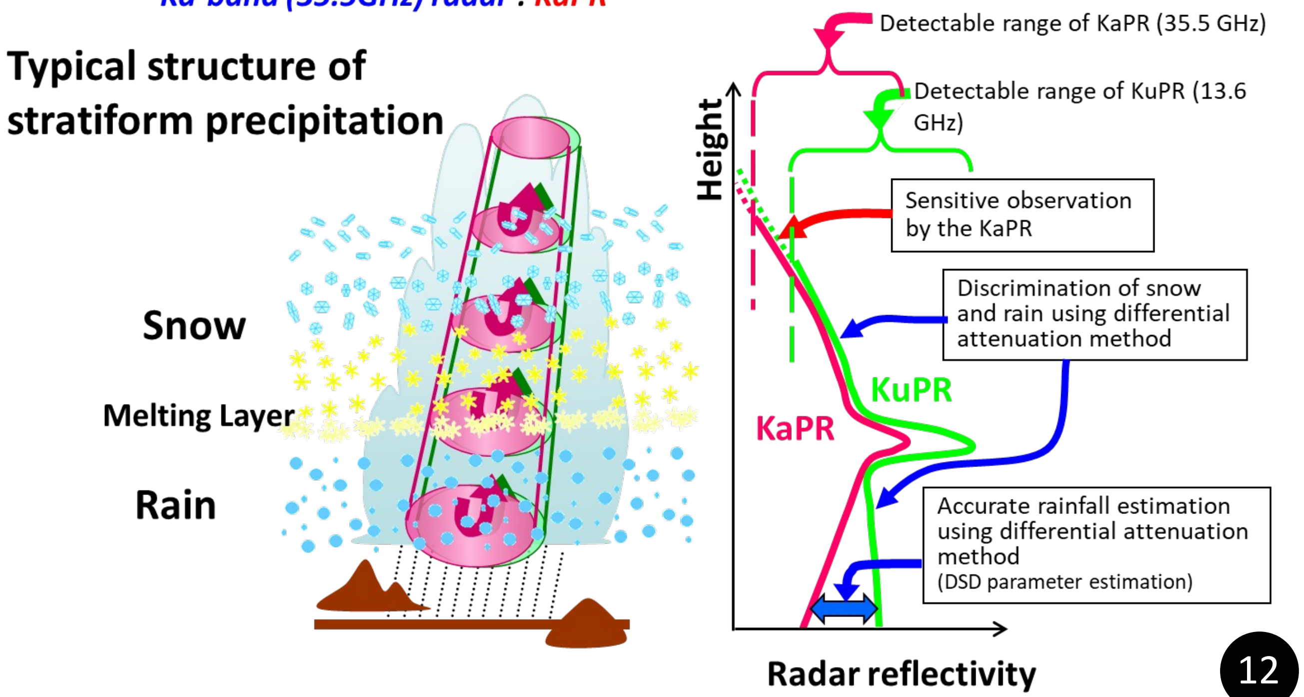
TRMM/PR

The PR is Ku-band (13.8GHz) radar and observes backscatter from precipitation.



GPM-Core/DPR

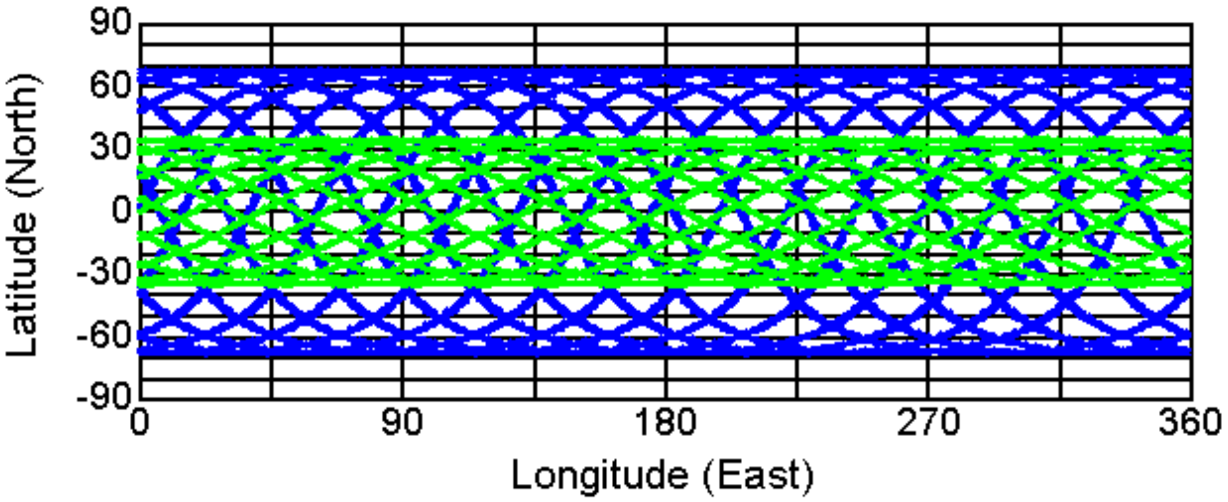
Dual-frequency precipitation radar (DPR) consists of
-Ku-band (13.6GHz) radar : KuPR
-Ka-band (35.5GHz) radar : KaPR



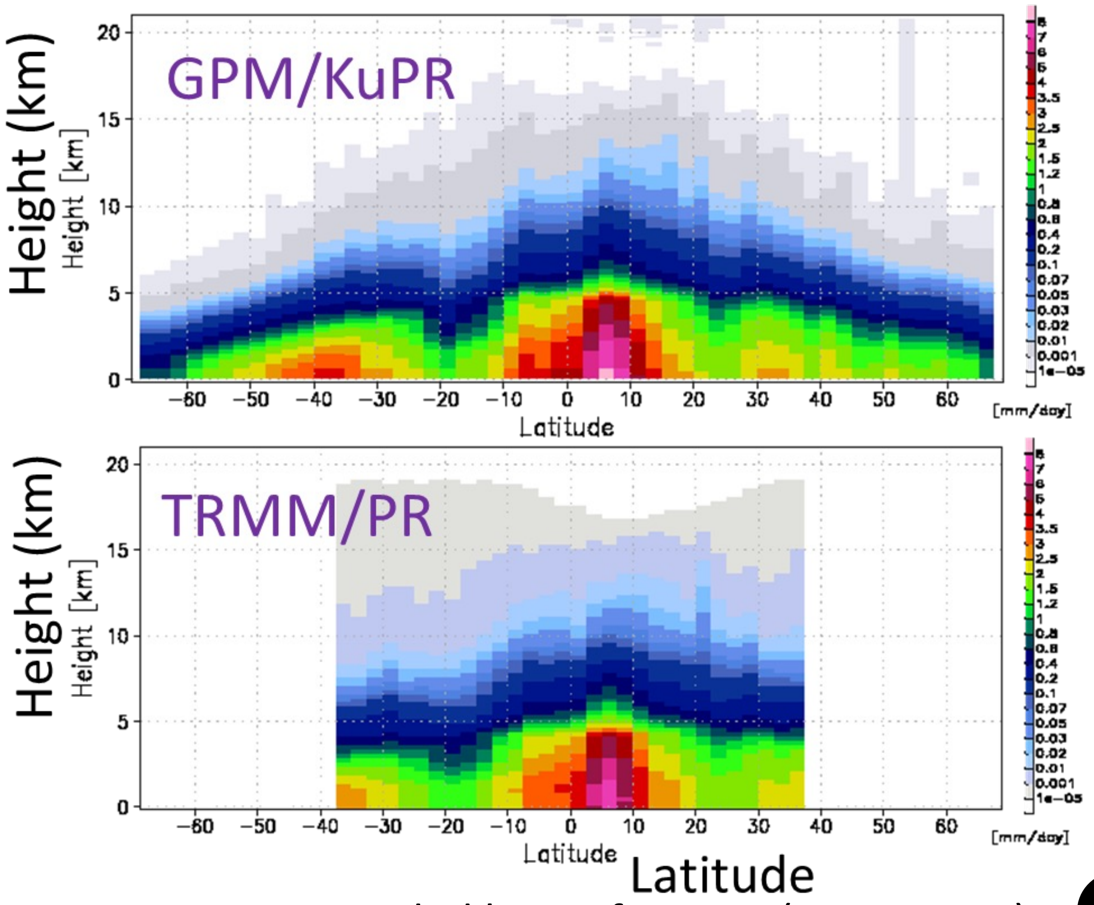
Coverage from Tropics to Global

- GPM Core Observatory flies in Non-sun-synchronous orbit like TRMM satellite, but the inclination of the GPM-Core is 65 deg (TRMM: 35 deg.) to extent observation coverage from tropics to global area

1-day orbits of TRMM(PR) and GPM-Core(DPR)



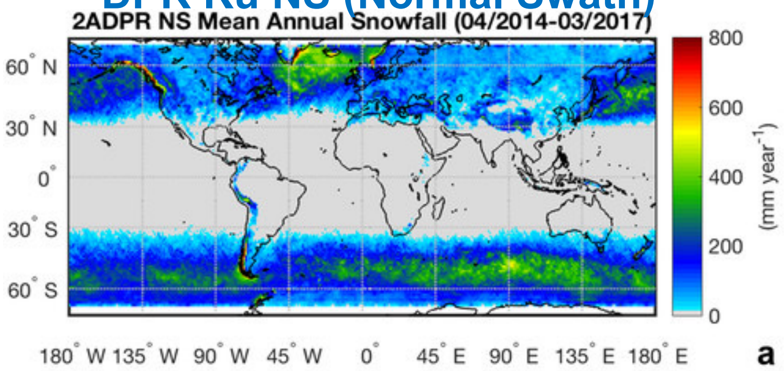
Vertical latitiude section of precipitation profiles over the ocean Apr.-Aug. 2014, Nadir-only



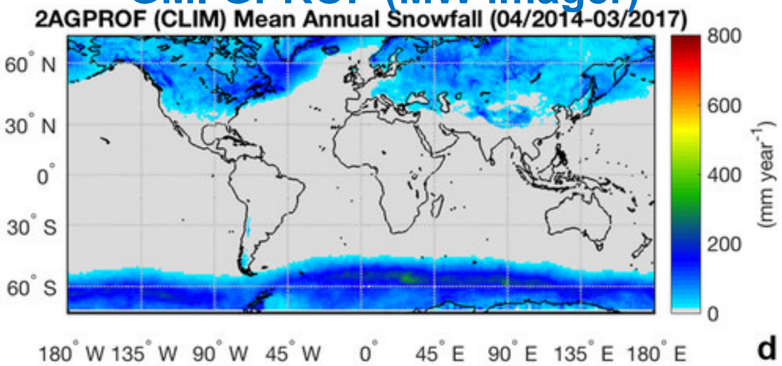
Provided by Prof. Hirose (Meijo Univ.)

Annual Snowfall Estimates by GPM

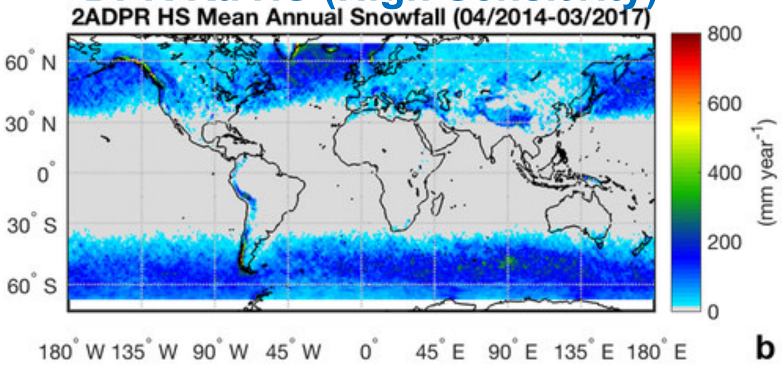
DPR Ku NS (Normal Swath)



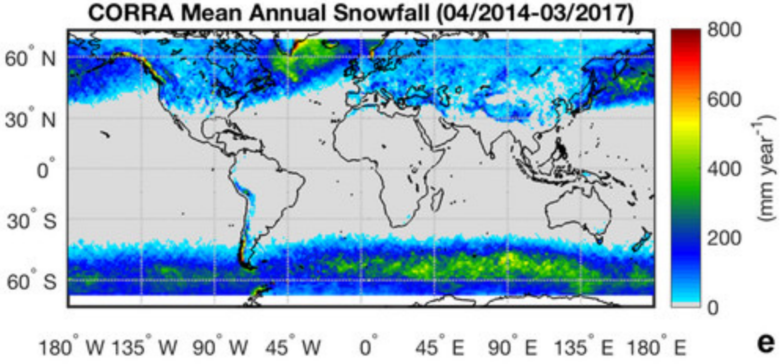
GMI GPROF (MW imager)



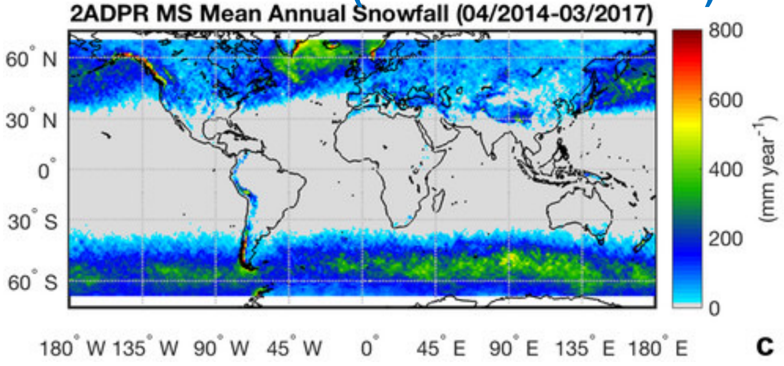
DPR Ka HS (High Sensitvity)



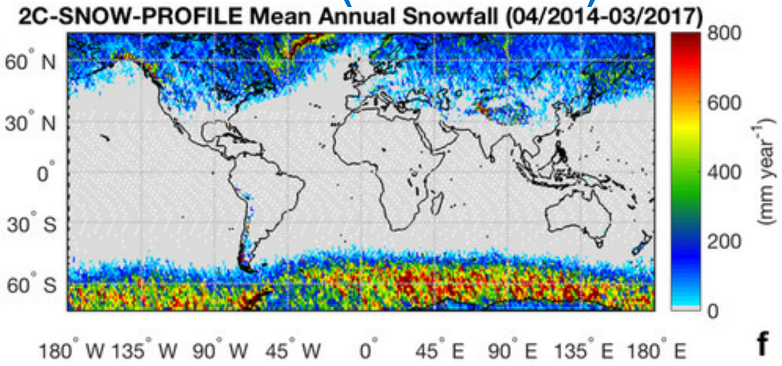
Combined DPR+GMI



DPR Ku+Ka MS (Matched with Ku)



Cloudsat (cloud radar)



There are some obvious and subtler differences between the snow amounts between instruments (precip. radar, cloud radar, microwave imager) due to several reasons including instrument capabilities, sampling, snow–rain classification, and algorithm methodologies.

GPM and CloudSat mean annual snowfall estimates (mm yr−1) for: (a) DPR Ku NS, (b) DPR Ka HS, (c) DPR Ku + Ka MS, (d) GMI GPROF, (e) Combined DPR + GMI CORRA, and (f) CloudSat 2CSP. Observations from April 2014 through March 2017 are used.

(G. Skofronick-Jackson *et al.,* 2019, https://doi.org/10.1175/JAMC-D-18-0124.1)

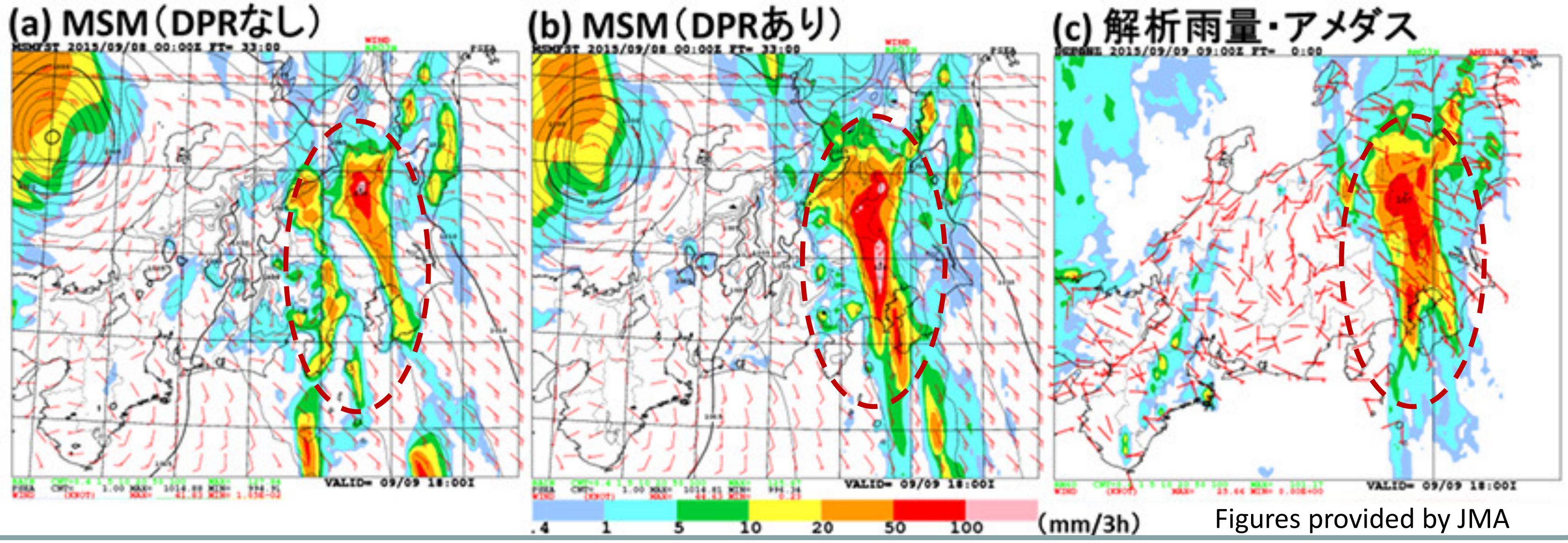
Utilization of GPM/DPR Data in the NWP assimilation

- The Japan Meteorological Agency (JMA) started the DPR assimilation in the meso-Numerical Weather Prediction (NWP) system in March 2016 as described in Ikuta et al. (2020, https://doi.org/10.1002/qj.3950)
  - ✓ This was the word's first "operational" assimilation of spaceborne radar data in the NWP system of meteorological agencies!
- Below figures show the case study for **Kanto-Tohoku Heavy Rainfall in 2015**, causing serious damage in eastern part of Japan. Precipitation forecast was similar to the actual precipitation when DPR data was assimilated.

a) 33-hour prediction without the DPR

b) 33-hour prediction with the DPR

c) Observation

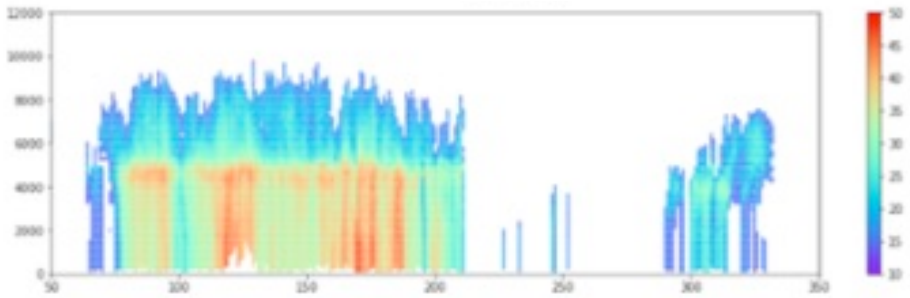


Figures provided by JMA

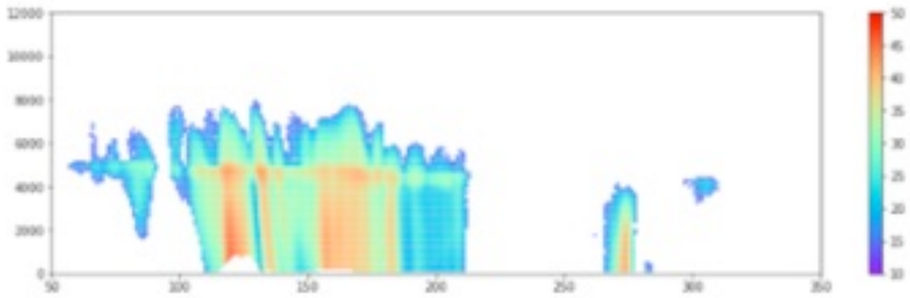
Utilization of GPM/DPR Data in improvements of Cloud Microphysics Scheme in the NWP

- GPM/DPR data were used as a reference in improvements of the Cloud Microphysics Scheme of the Mesoscale Model at the Japan Meteorological Agency (JMA)
  - Ikuta et al. (2021)
- The improved JMA Mesoscale Model has been used in the operational NWP since March 2020.

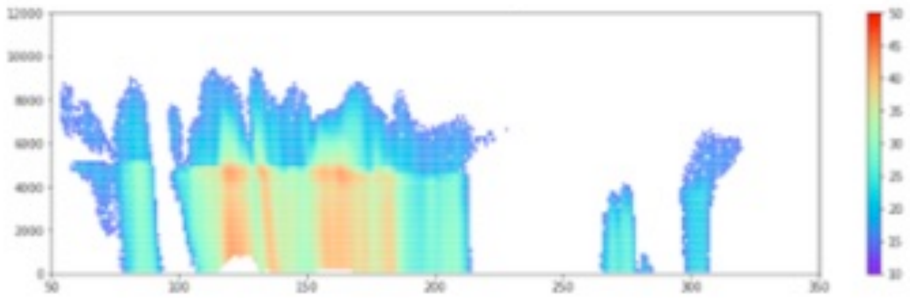
GPM/KuPR observation



Previous results of the JMA Mesoscale Model



Improved results of the JMA Mesoscale Model



Ikuta et al. 2021: Improvement of the Cloud Microphysics Scheme of the Mesoscale Model at the Japan Meteorological Agency Using Spaceborne Radar and Microwave Imager of the Global Precipitation Measurement as Reference, *Monthly Weather Review*, *149*(11), 3803-3819. https://doi.org/10.1175/MWR-D-21-0066.1

To Propose and Design a Science Mission

- In Japan, at least, Earth observation mission needs basis on/requirements from both **science** and **operational application** contributing to societal issues
  - TRMM mission launched in 1997 targeted both science and demonstration of technology at the biggening
    → NASA decided to start near-real-time data distribution later (~3 year after the launch) and evolution of operational application was achieved.
  - Recent GPM and GCOM-W missions target both science and operational application
    → Ask requirements from stakeholders in mission design phase
  - Exception could be ESA-JAXA EarthCARE → but, JAXA recently explains needs of operational application (NWP) to the government
- Recent trend is fostering industries and technology transfer to commercial companies