From science to a mission design
JAXA Earth Observations

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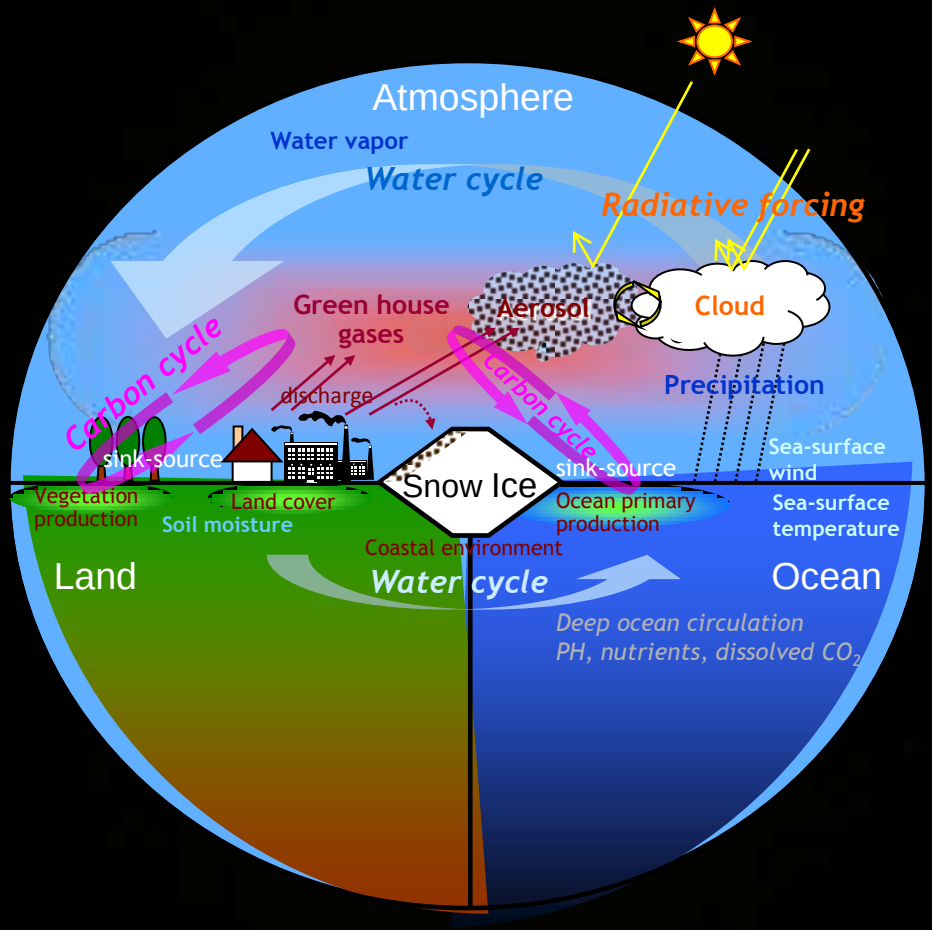
JAXA

The Earth



Earth as a Complex System

Photo by Hayabusa (ISAS/JAXA) © 2004 JAXA

National, Regional and Global Observation Systems

Europe/Africa



esa

cnes

DLR

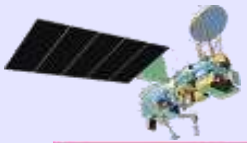
Copernicus (GMES)

Asia


JAXA

Sentinel Asia

Americas



NASA

USGS

SERVIR

CONAE

CEOS

Coordination body for GEOSS space segment

27 space agencies, 21 associates

In-situ observation organizations

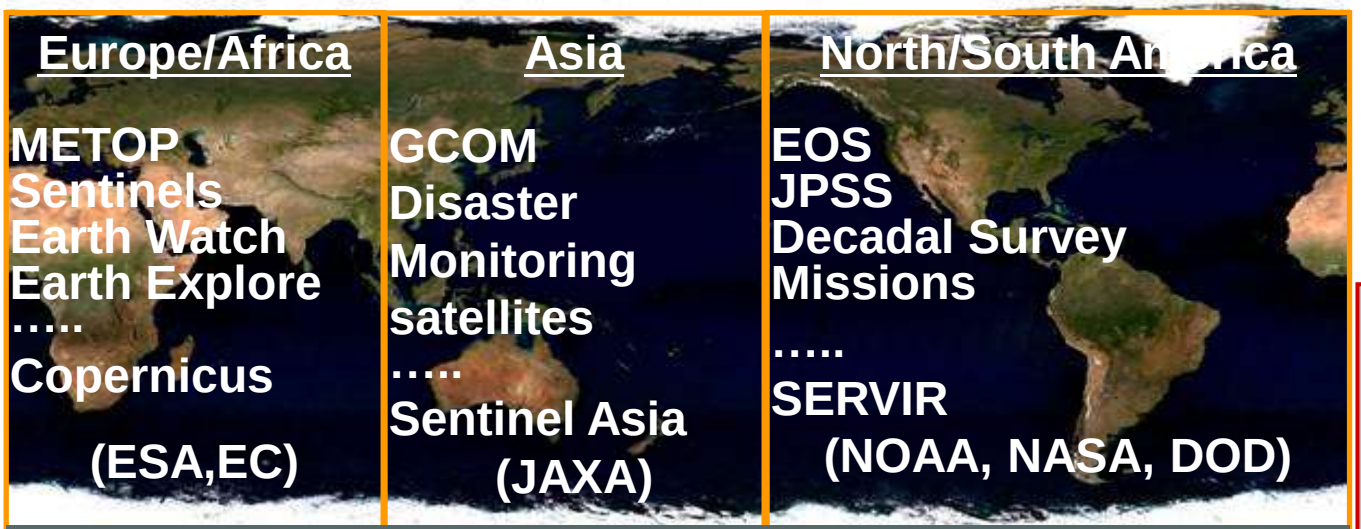


Requirements

GEOSS

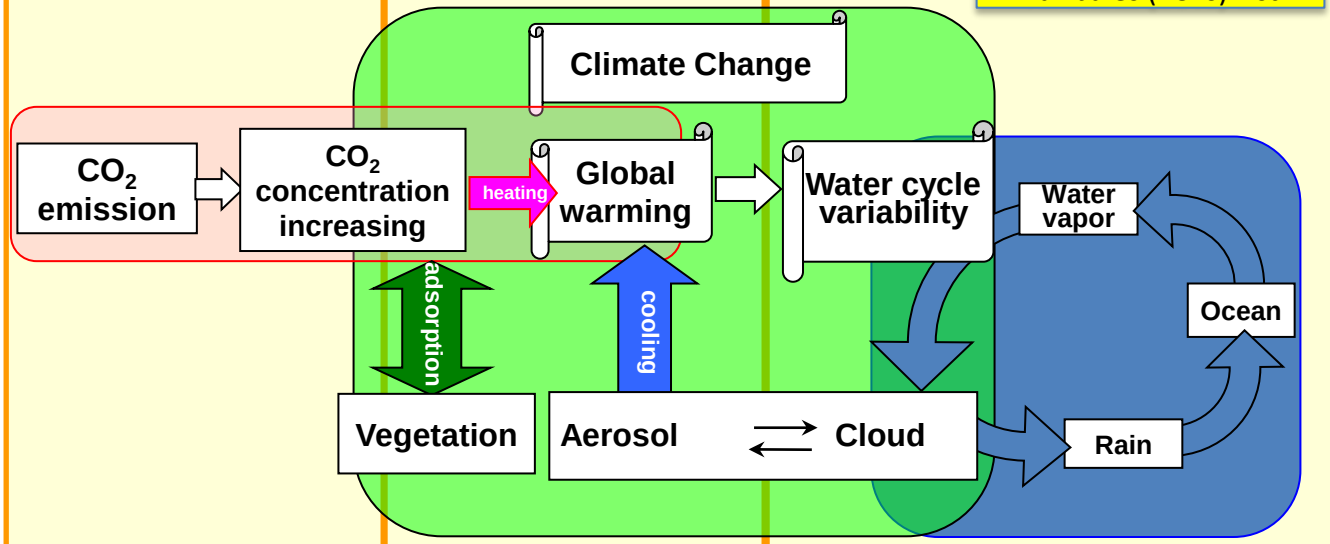
Realization of global Earth observation system of systems within 10 years for 9 SBAs.
72 countries, EC and 52 int'l organizations

Global Warming and Climate Change



CEOS, GCOS (+IPCC)

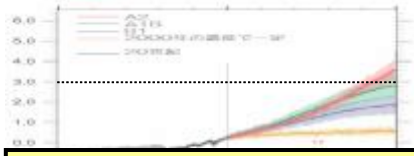
Essential Climate Varibales (ECVs) List



Concrete global observation systems

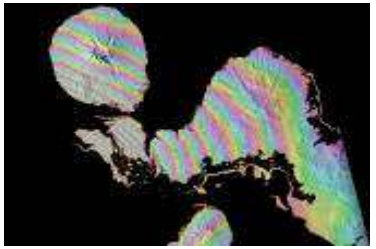
GEOSS

Global Forest Monitoring System



Greenhouse Gases Monitoring System

Global Water Cycle Monitoring System



Global Disaster Monitoring System

Essential Climate Variables (ECVs) : Physical Parameters

Atmosphere

Upper-Air	Cloud Properties	Composition	Aerosol Properties
	Earth Radiation Budget (including Solar Irradiance)		Carbon Dioxide
	Temperature		Methane and other Long-Lived Green House Gases
	Water Vapor		Ozone
	Wind Speed and Direction		Precursors (supporting the Aerosols and Ozone ECVs)
Surface	Surface Air Pressure		
	Surface Air Temperature		
	Surface Precipitation		
	Surface Radiation Budget		
	Water Vapour (Surface humidity)		
	Near-Surface Wind Speed and Direction		

Ocean

Surface	Carbon Dioxide Partial Pressure
	Current
	Ocean Acidity
	Ocean Color
	Phytoplankton
	Sea Ice
	Sea Level
	Sea State
	Sea Surface Salinity
	Sea Surface Temperature

Land

River Discharge	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
Water Use	Leaf Area Index (LAI)
Ground Water	Above Ground Biomass
Lakes	Fire Disturbance
Snow Cover	Soil Moisture
Glacier and Ice Caps	Soil Carbon
Permafrost	Ice Sheets
Land Cover(including Vegetation Type)	

subsurface

Sub-Surface	Carbon
	Current
	Nutrients
	Ocean Acidity
	Oxygen
	Salinity
	Temperature
	Tracers
	Global Ocean Heat Content

Current major scientific discussions in Japan

Water Cycle
- Aerosol-Cloud-Precipitation process / Radiation budget
- Precipitation/Land process(Flood, High tide, River discharge)

Air Pollution
- Aerosol (incl. PM2.5 / Air Quality (incl. short life climate pollutants)

Carbon Cycle
- CO_2 concentration in atmosphere
- Net Primary Production in land
- Primary Production in ocean

Ocean
- Sea Surface Temperature, SS Color, SS Height
- Coastal Monitoring

Land
- Crustal Movement(incl. uplift and subsidence)
- Vegetation / Agriculture
- Land use (incl. Urbanization)

Cryosphere
- Arctic area change

Climate
- Integrated Model (Atmosphere/Ocean/Land) > Climate change

Science to Mission

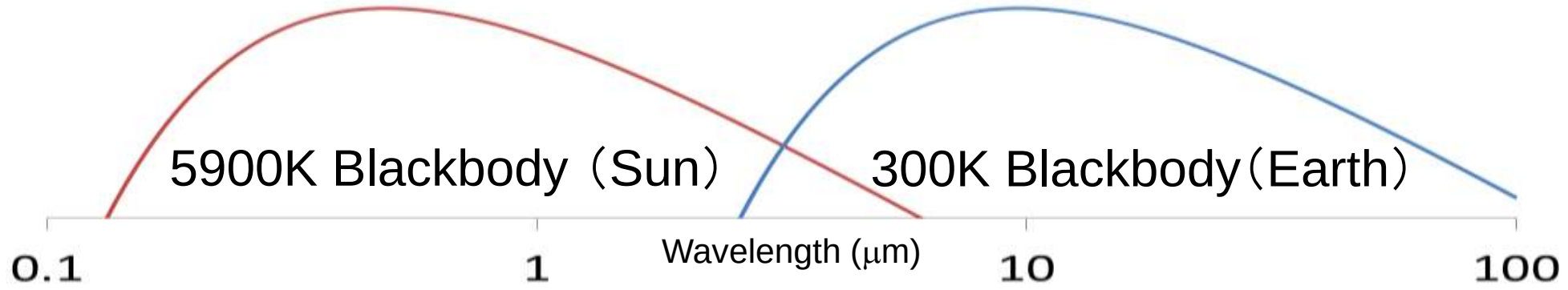
So How to ?

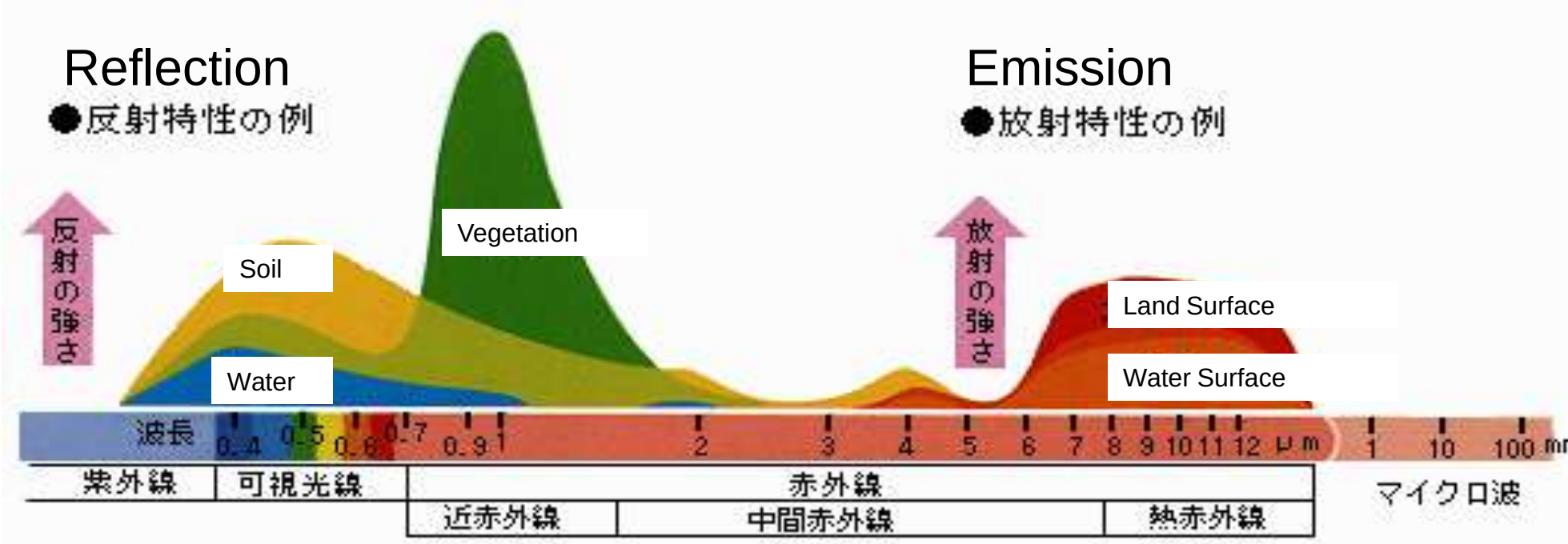
Firstly should know

Earth natural character and
Remote sensing fundamentals

Following discussion is only electro-magnetic wave observation

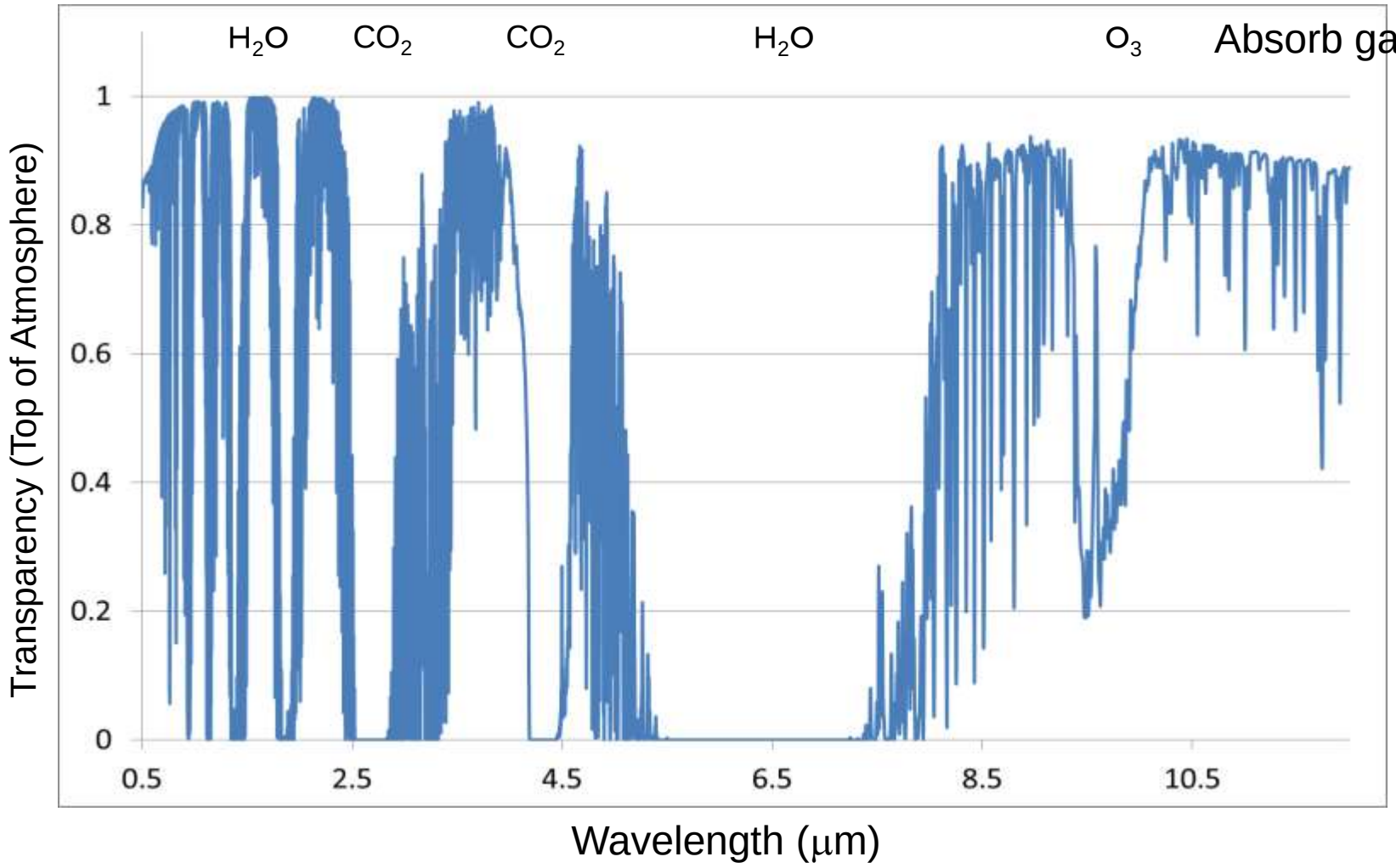
Spectral characteristics Sun-reflection and Earth-emission





UV Visible Near IR Infrared Mid IR Thermal IR Microwave

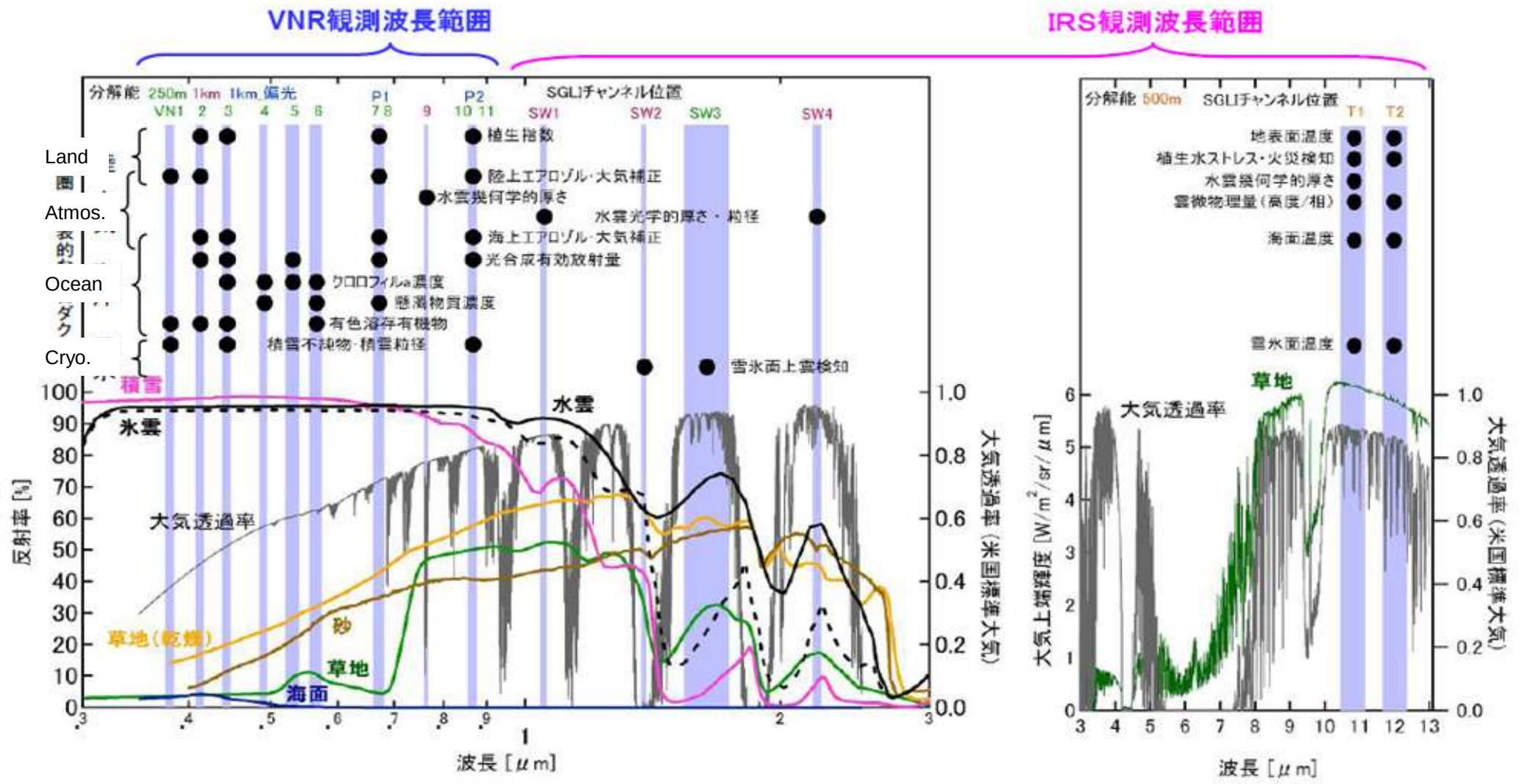
Line absorption of atmosphere



Calculation result of MODTRAN

Radiometric band design

GCOM-C1/SGLI products



Observational character vs Instruments

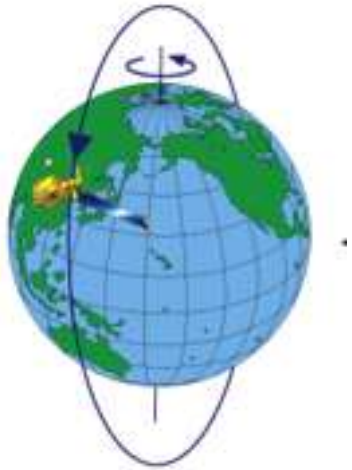
• Reflectivity/Emissivity / Photometry	Panchromatic / Hi-res.
• Spectral character (band differential / ratio)	Imaging Radiometer
• Absorption line shape (for sounding)	Spectrometer
• Polarization	Polarimeter
• Bi-directional character	Multi-angle
• Vertical	Radar / Lidar Occultation

Define necessary scheme to be used for the target considering SNR for necessary precision

Geometrical / Orbit design

LEO (about 400~800km alt)
Sun-synchronous Orbit

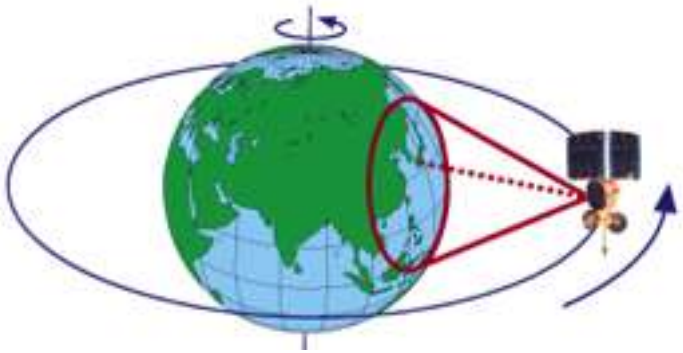
= Fixed local time
suitable for global



Low Altitude
- Narrow Swath
(low frequency)
- Fine resolution

GEO (about 36,000km alt)
Geostationary Orbit

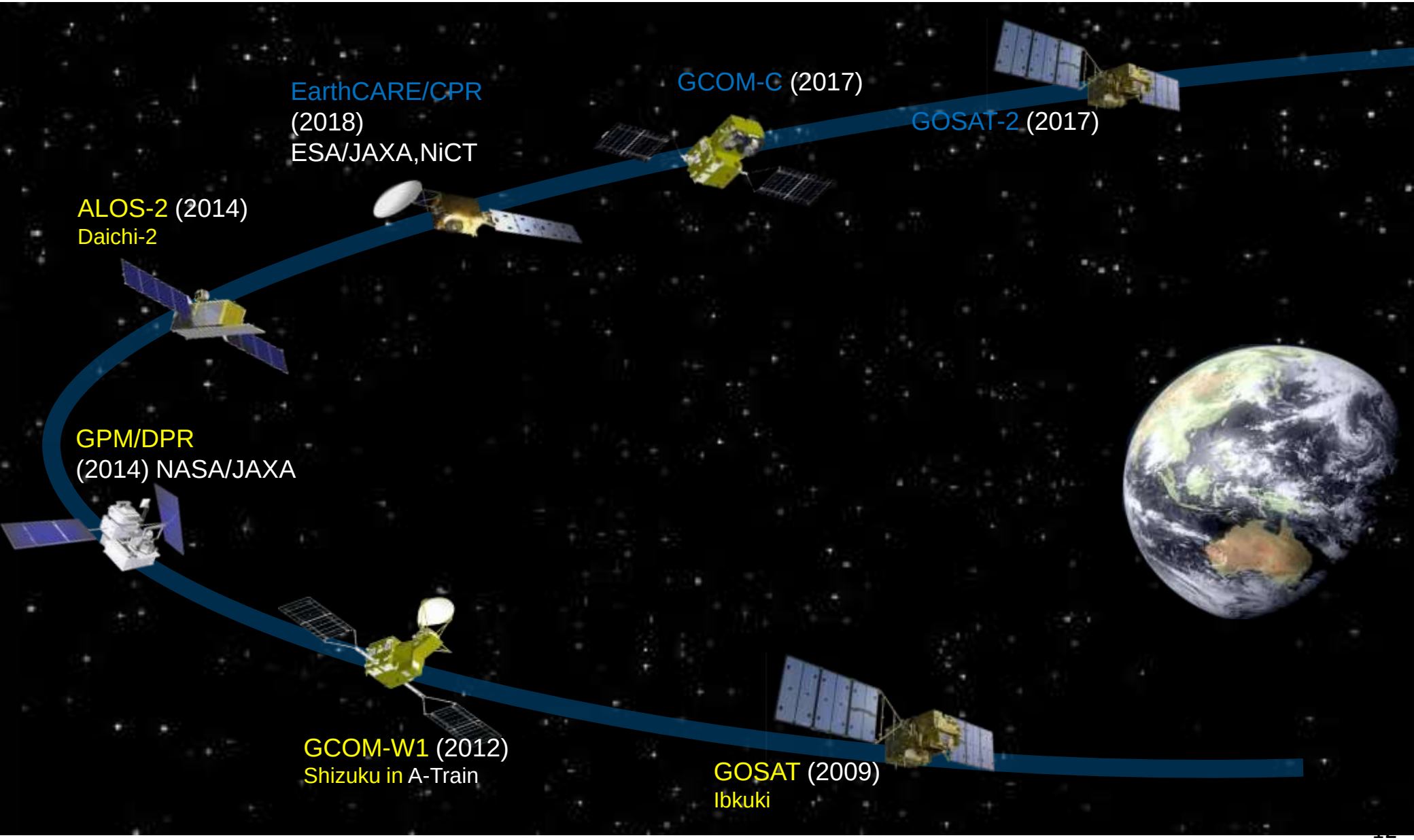
= Real time (LT not Fixed)
Not suitable for global



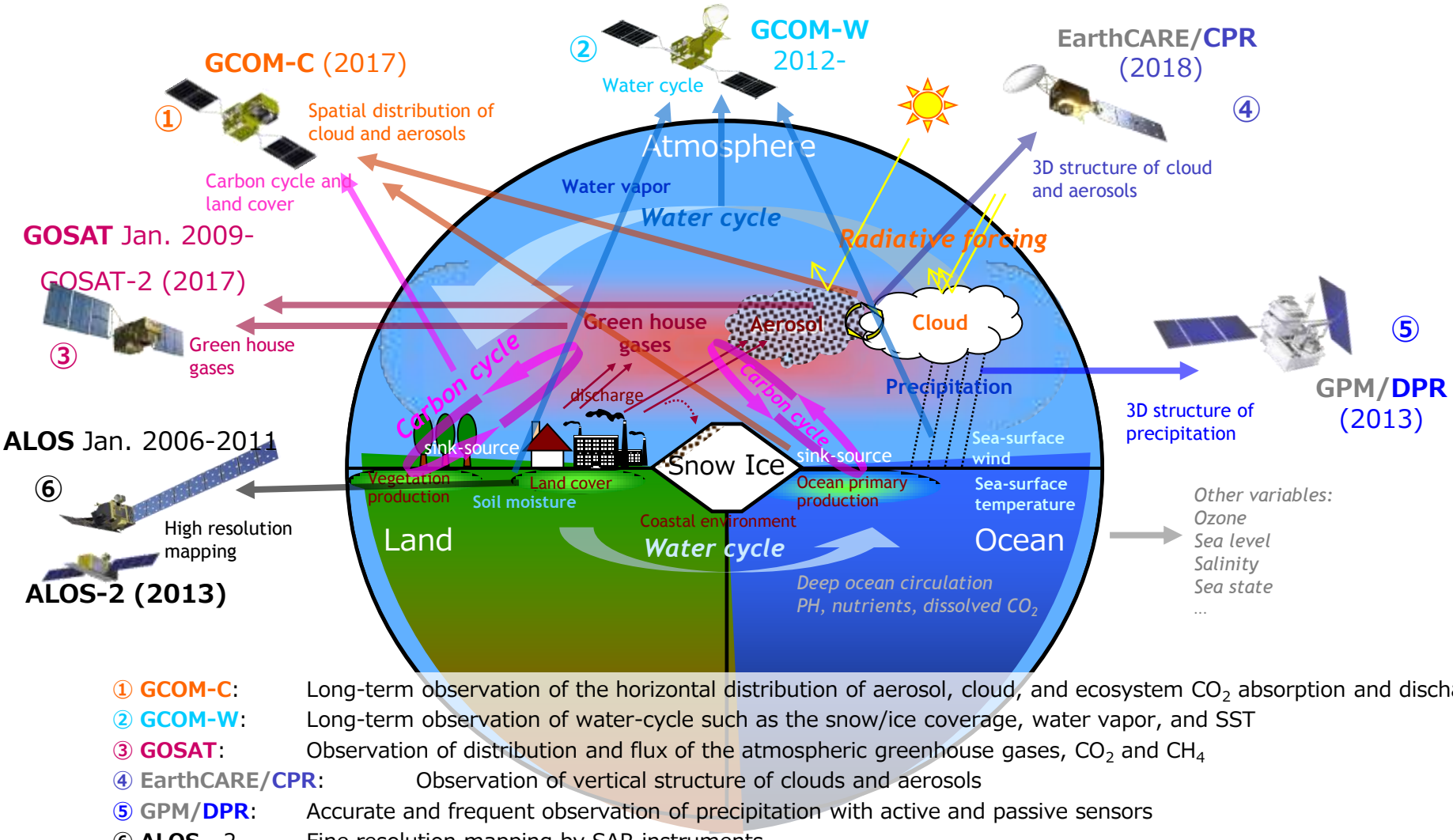
High Altitude
- Wide Swath
(High frequency)
- Coarse resolution

Define ground resolution and observational frequency

JAXA Operating and Planned EO Satellites



JAXA Earth Environment Observation Satellites



① **GCOM-C**: Long-term observation of the horizontal distribution of aerosol, cloud, and ecosystem CO_2 absorption and discharge

② **GCOM-W**: Long-term observation of water-cycle such as the snow/ice coverage, water vapor, and SST

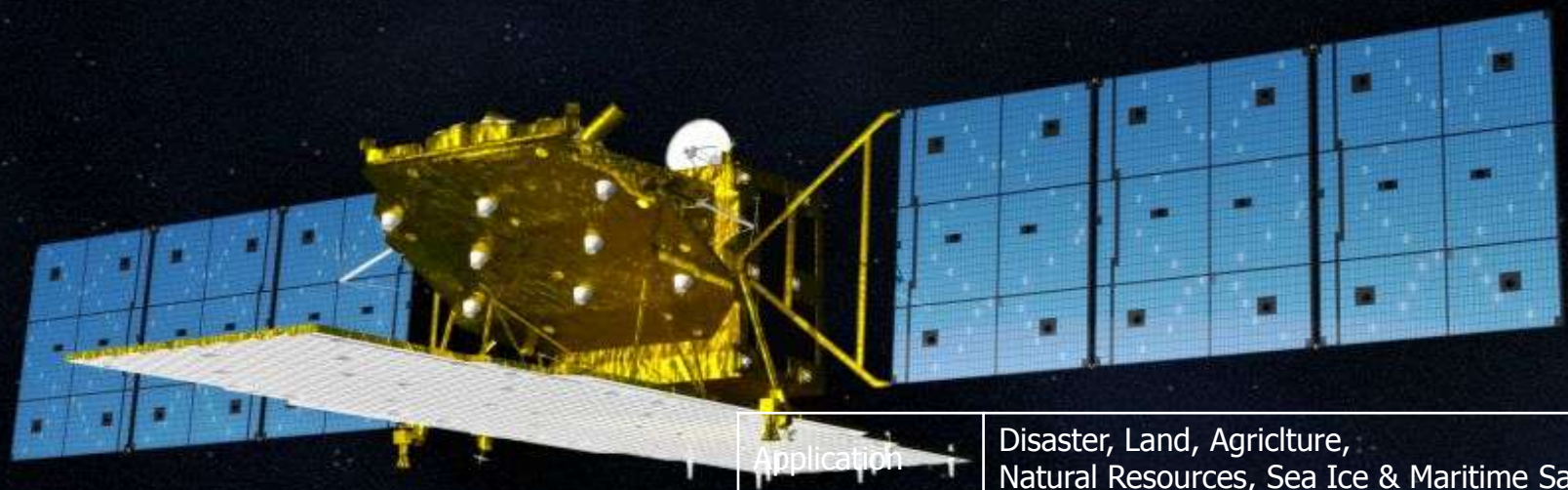
③ **GOSAT**: Observation of distribution and flux of the atmospheric greenhouse gases, CO_2 and CH_4

④ **EarthCARE/CPR**: Observation of vertical structure of clouds and aerosols

⑤ **GPM/DPR**: Accurate and frequent observation of precipitation with active and passive sensors

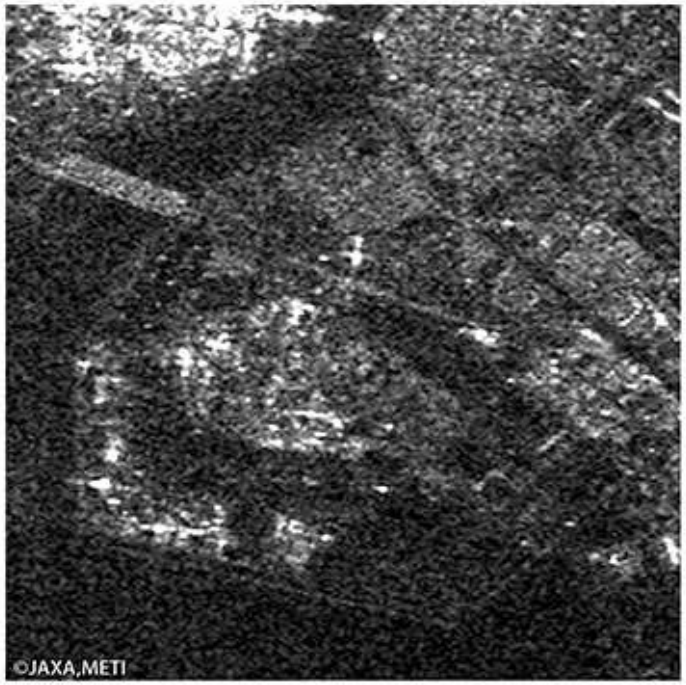
⑥ **ALOS**, -2 Fine resolution mapping by SAR instruments

ALOS-2



Application	Disaster, Land, Agriclture, Natural Resources, Sea Ice & Maritime Safety
L-band SAR (PALSAR-2)	Stripmap: 3 to 10m res., 50 to 70 km swath ScanSAR: 100m res., 350km/490km swath Spotlight: 1×3m res., 25km swath
Orbit	Sun-synchronous orbit Altitude: 628km Local sun time : 12:00 +/- 15min Revisit: 14days Orbit control: ≦+/-500m
Life time	5 years (target: 7 years)
Launch	CY2014, H-IIA launch vehicle
Downlink	X-band: 800Mbps(16QAM) 400/200Mbps(QPSK) Ka-band: 278Mbps (Data Relay)
Experimental Instrument	Compact InfraRed Camera (CIRC) Space-based Automatic Identification System Experiment 2 (SPAISE2)

Comparison of images taken by PALSAR-2 and previous satellites



FUYO-1 SAR,
April 21, 1992,
(Resolution: about 18 m)

DAICHI PALSAR,
April 27, 2006,
(Resolution: about 10 m)

DAICHI-2 PALSAR-2,
June 19, 2014
(Resolution: about 3 m)

(Urayasu City, Tokyo Disney Land Area)

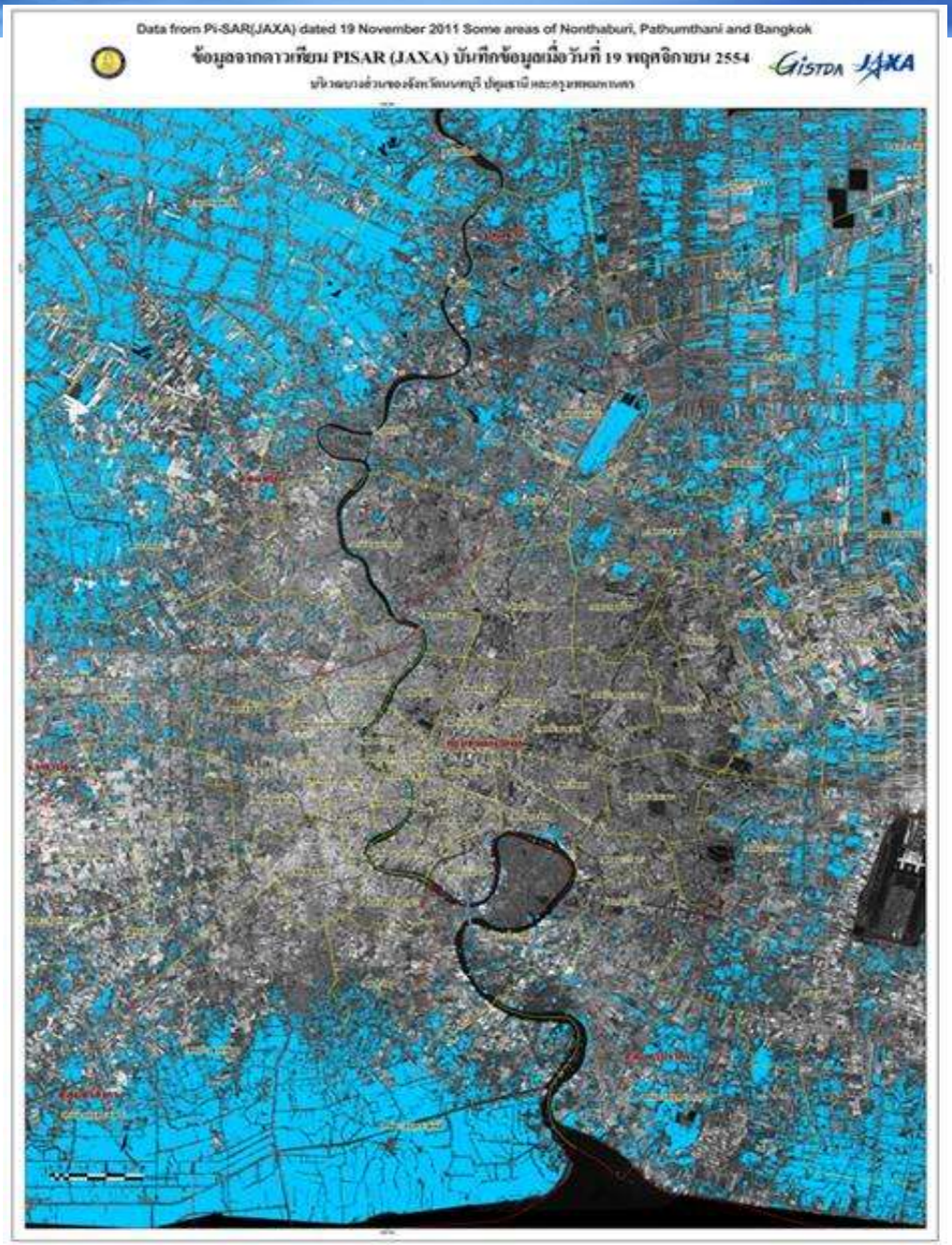
- The images of the same area taken by two other L-band synthetic aperture radars are also displayed. One was shot by the ALOS, which was launched in 2006 and acquired the image in the same year, and the other is the Japanese Earth Recourse Satellite-1 (JERS-1 or FUYO-1), which was launched in 1992 and observed the area in the same year.
- You can see the resolution of the DAICHi-2 is higher compared to past satellites.

Flood Monitoring by Synthetic Aperture Radar

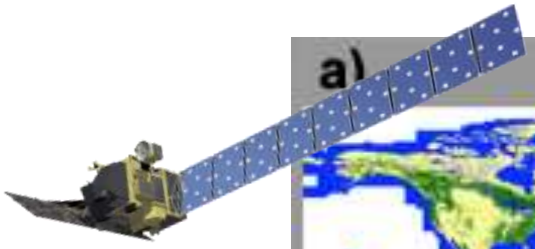
Data on 19 Nov 2011
Some areas of Nonthaburi, Pathumthani and Bangkok

Analyzed by GISTDA

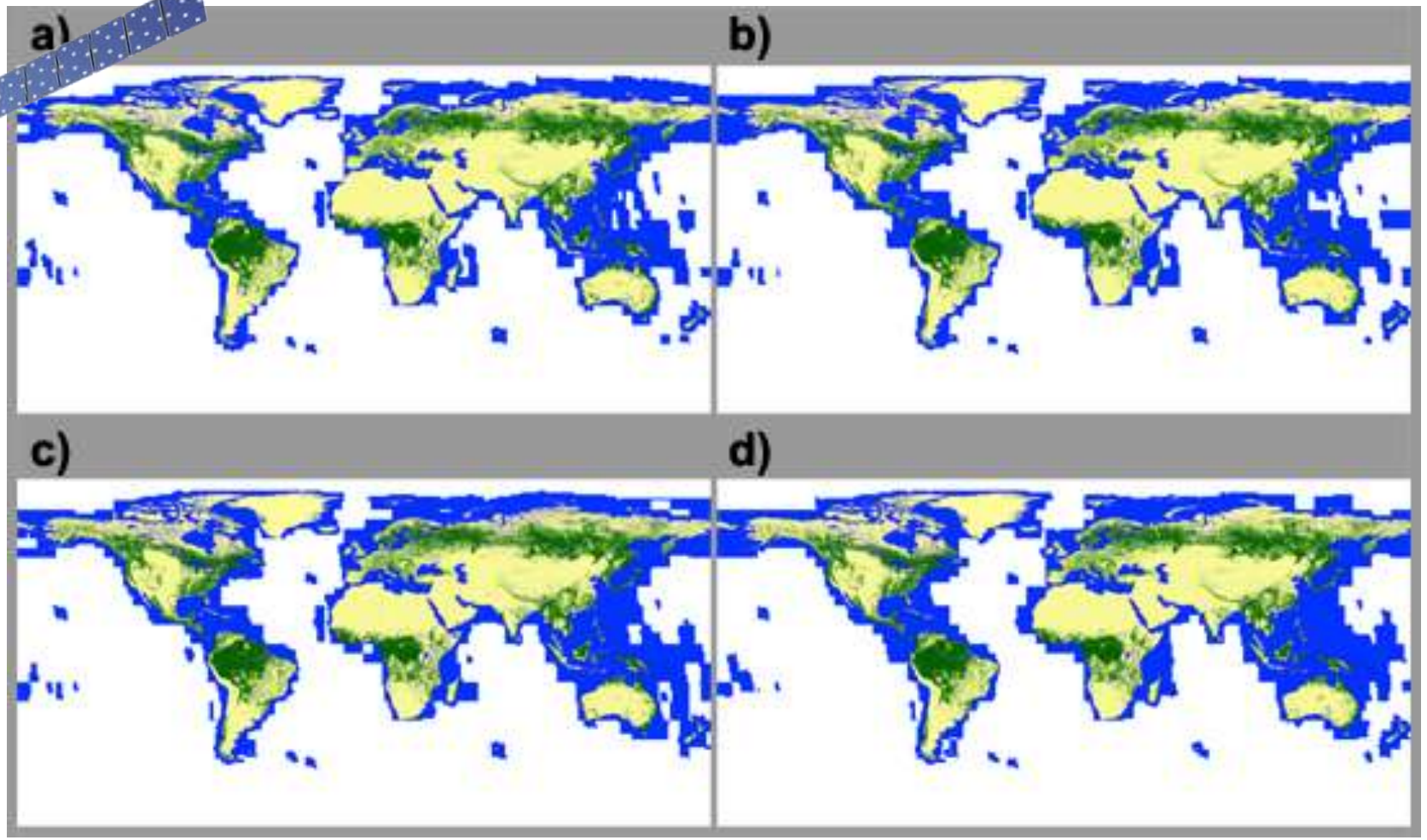
Obtained by JAXA's Polarimetric and Interferometric Airborne Synthetic Aperture Radar (Pi-SAR)



Global Map of FOREST/Non-Forest map by PALSAR



ALOS
Daichi



New Forest/Non-forest map (a) 2007, b) 2008, c) 2009, d) 2010
(25m/100m resolution)

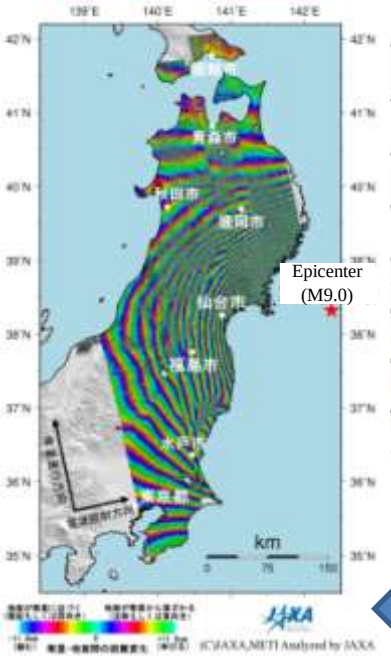
REF:http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

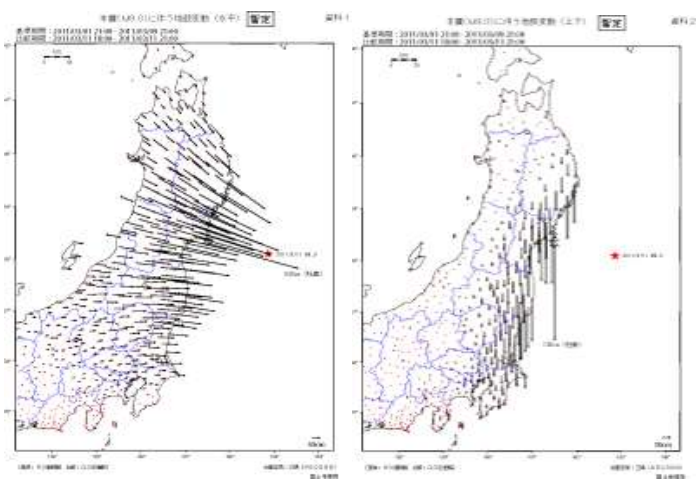
Great East Japan Earthquake observed by ALOS

Before the Earthquake taken by "DAICHI" (ALOS) on Dec. 4 2008

3 days after the Earthquake taken by THEOS on Mar 14. 2011

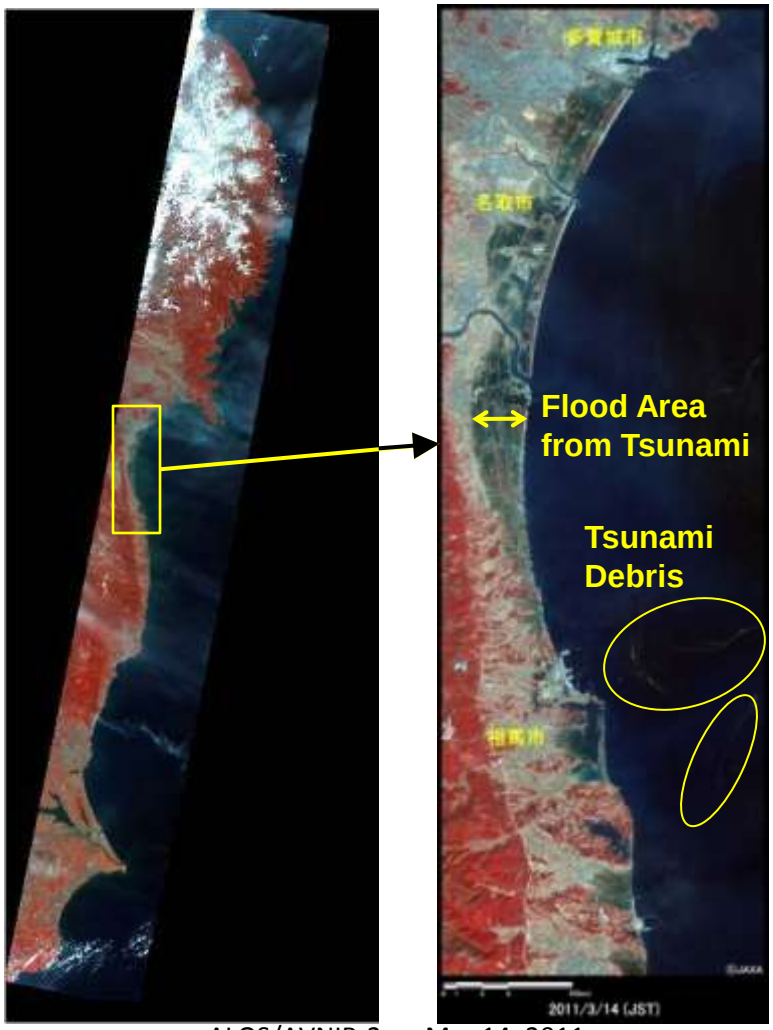
Detailed monitoring of Tsunami Damage with "DAICHI" ALOS/PRISM





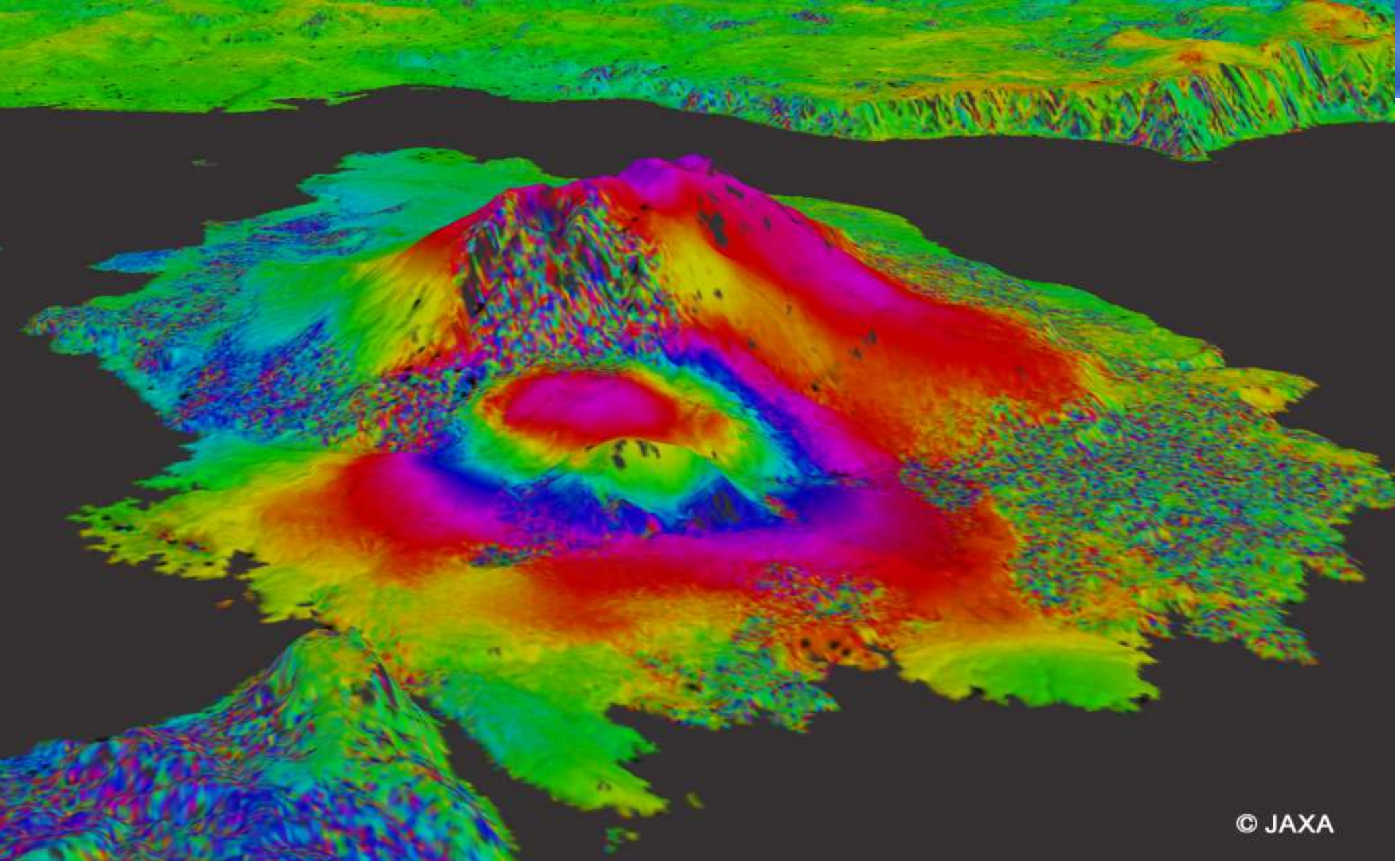
Earthquake deformation using GEONET
Copyright: CSI

Mosaic image of PALSAR interferogram (ascending orbits) showing deformation map



ALOS/AVNIR-2 on Mar 14. 2011

Wide-area monitoring of Tsunami Damage with "DAICHI" ALOS/AVNIR-2



Erupting volcano Sakurajima (Japan)this figure is PALSAR-2 (3m res) interferogram, overlaid with global surface model of ALOS
Result shows max. 16cm movement during 8 month.

GCOM-W1 with A-TRAIN

The Global Change Observation Mission 1st Water (GCOM-W1) satellite observes water circulations and collect concerned data to reveal the mechanism of the climate change.

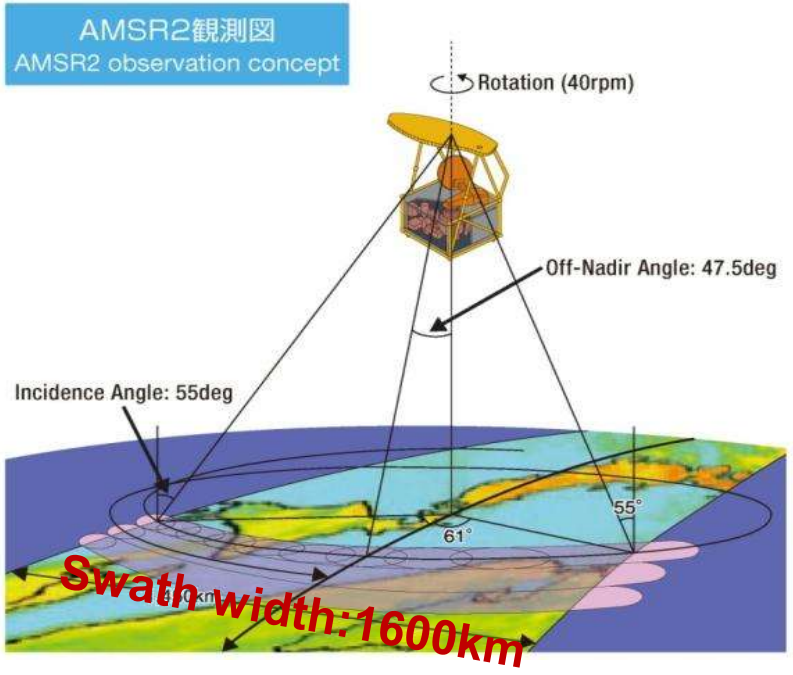
16th Sep. 2012
(by SHIZUKU/AMSR2)

AMSR2 instrument

(AMSR2: Advanced Microwave Scanning Radiometer-2)

Advanced Microwave Scanning Radiometer (AMSR) is a multi-frequency passive microwave radiometer (PMR) aiming at measuring geophysical parameters related to global water and energy cycle.

AMSR2 observation concept



- ***Frequency range: 6.9-89GHz***
- ***Conical scanning with constant incidence angle of 55 degrees***

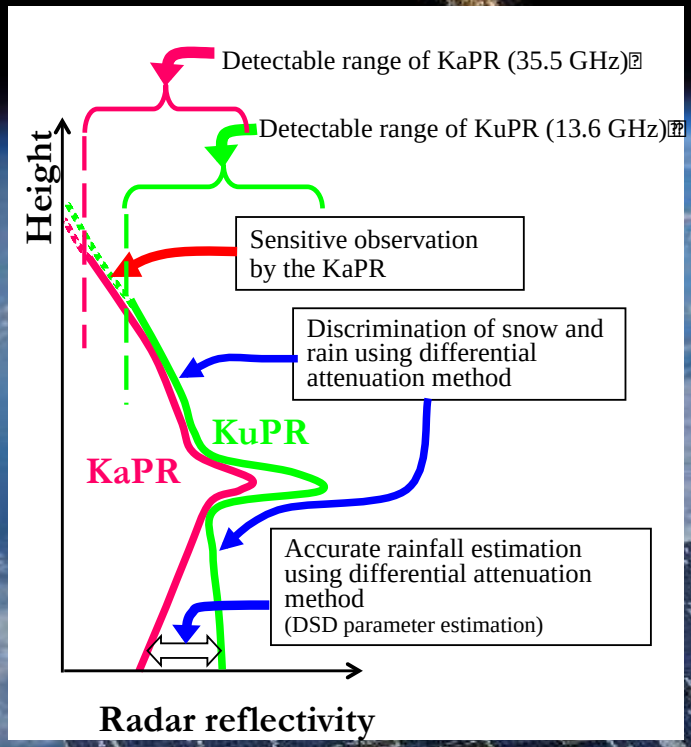
AMSR2 daily ascending coverage

AMSR2 channel specification

Center Freq. GHz	Band width MHz	Polarization	Beam width degree	IFOV(Ground Res.) km
6.925/7.3	350	V/H	1.8	35 x 62
10.65	100		1.2	24 x 42
18.7	200		0.65	14 x 22
23.8	400		0.75	15 x 26
36.5	1000		0.35	7 x 12
89.0	3000		0.15	3 x 5

GPM: Global Precipitation Measurement

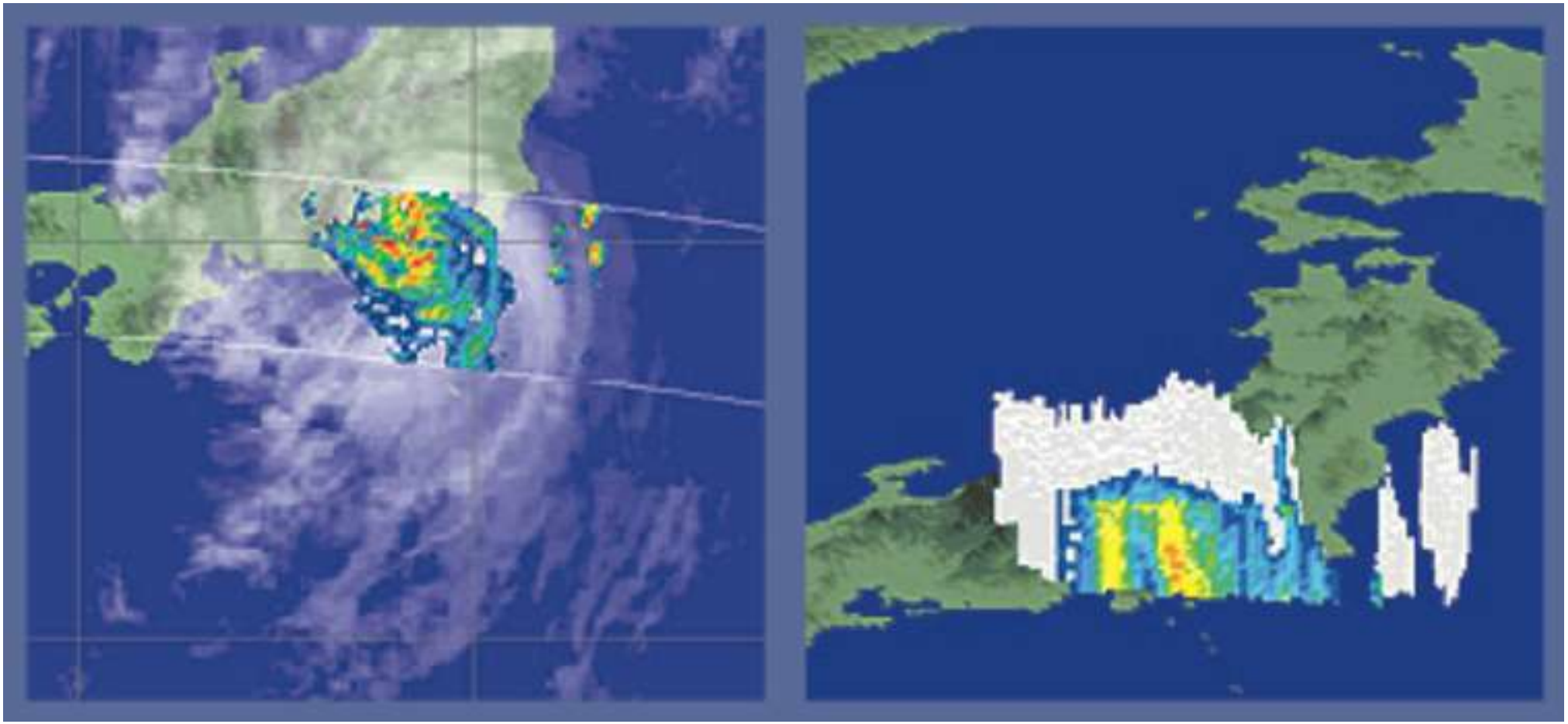
Constellation Satellites (International Partners) : measuring global precipitations every 3hrs.



GPM Core Observatory (JAXA&NASA) : measuring global precipitations with high precisions

© NASA

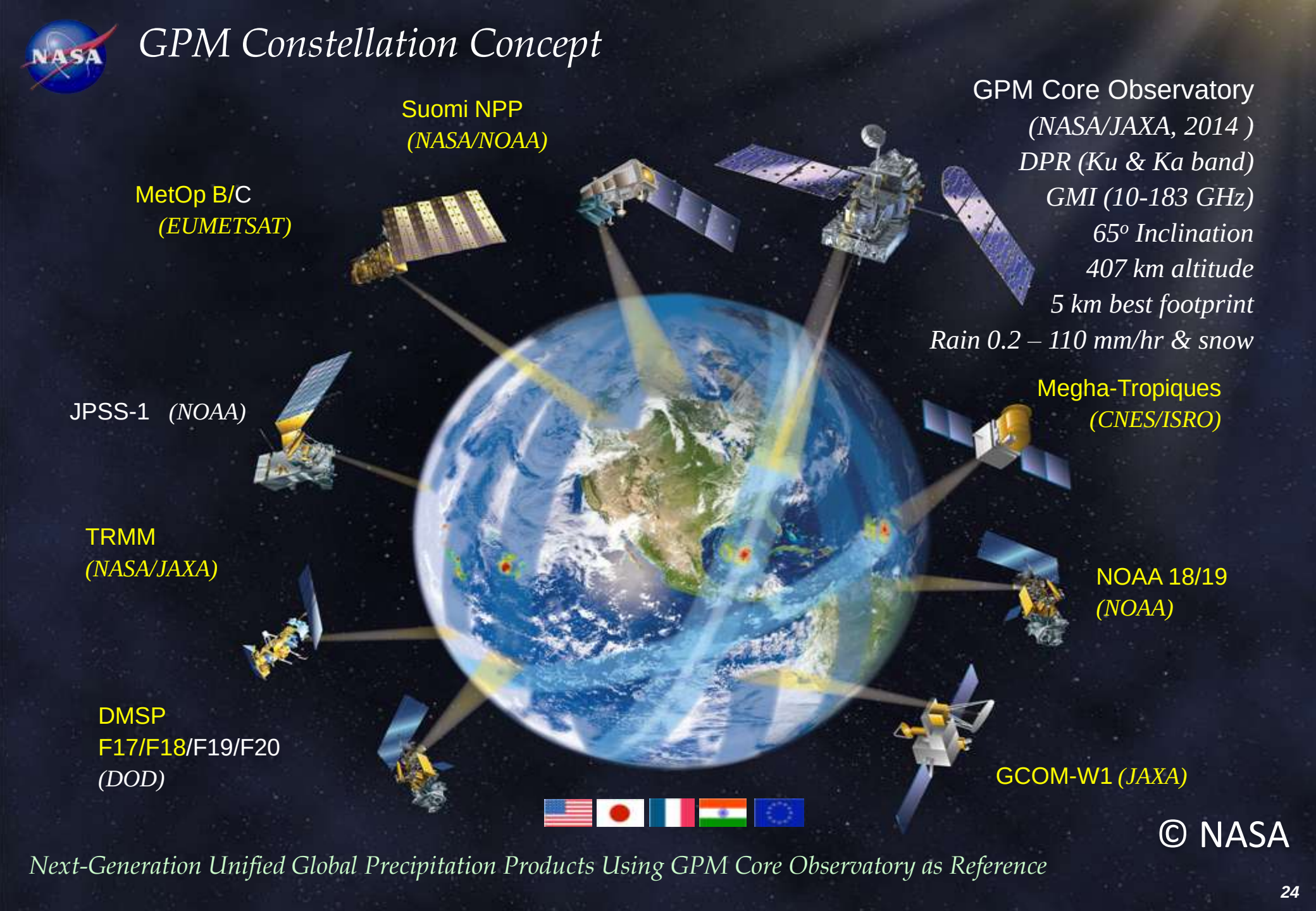
Typhoon Observation by previous satellite (TRMM)



Typhoon Danas 10th Sep 2001 TRMM

GPM expands detectable precipitation range of TRMM

GPM Constellation Concept

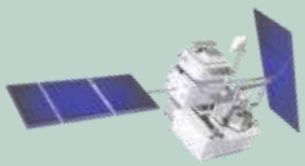


© NASA

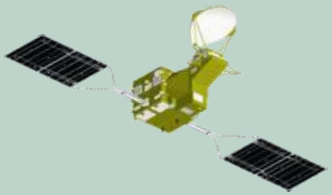
GSMaP: Global Satellite Mapping of Precipitation

Different sensor merge

❖ Satellite-based global hourly precipitation data of 10km grid



TRMM PR/TMI
GPM DPR/GMI



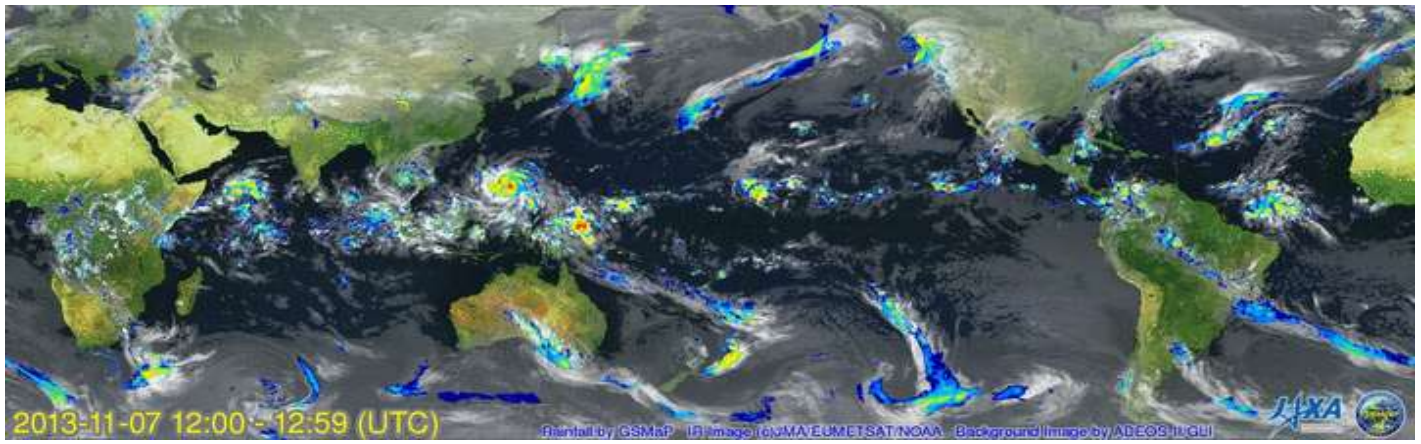
Aqua AMSR-E
GCOM-W AMSR2

DMSP
SSM/I, SSMIS

NOAA&MetOp
AMSU-A/MHS

Geostationary Satellite (Himawari)

Calculate cloud moving vectors



Rain 0.1 0.5 1.0 2.0 3.0 5.0 10.0 15.0 20.0 25.0 30.0 [mm/hr]

GSMaP rainfall in 0.1-deg grid and hourly

http://sharaku.eorc.jaxa.jp/GSMaP/

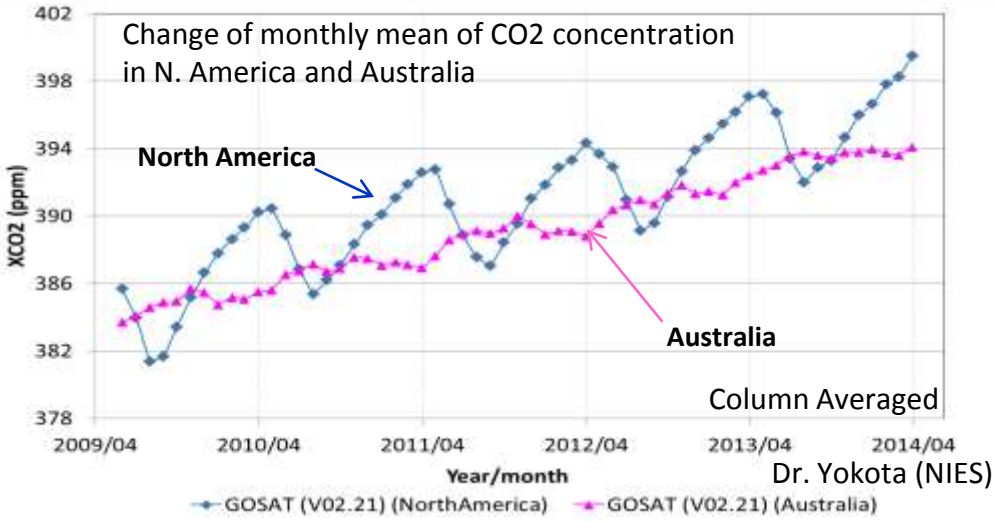
Greenhouse Gases Observing Satellite (GOSAT)

GOSAT "Ibuki"
(Launched at Jan. 2009)

FTS (Fourier Transform Spectrometer)

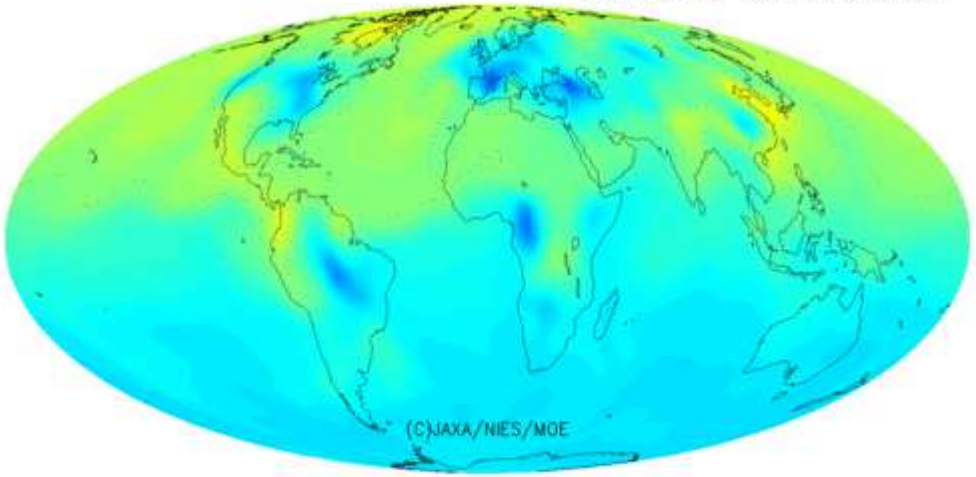
CAI (Cloud and Aerosol Imager)

- **Measure global distribution of GHGs, and understand how their emission is reduced.**
- **The only operation satellite for monitoring CO_2 and methane from space**



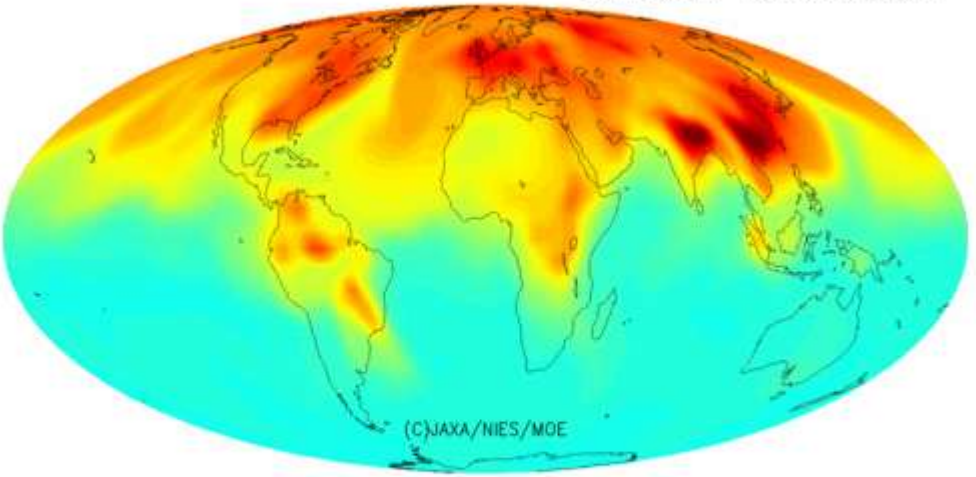
Dr. Yokota (NIES)

GOSAT L4B V02.02 CO_2 (2009/06/01) ETA:925
Simulated Concentration



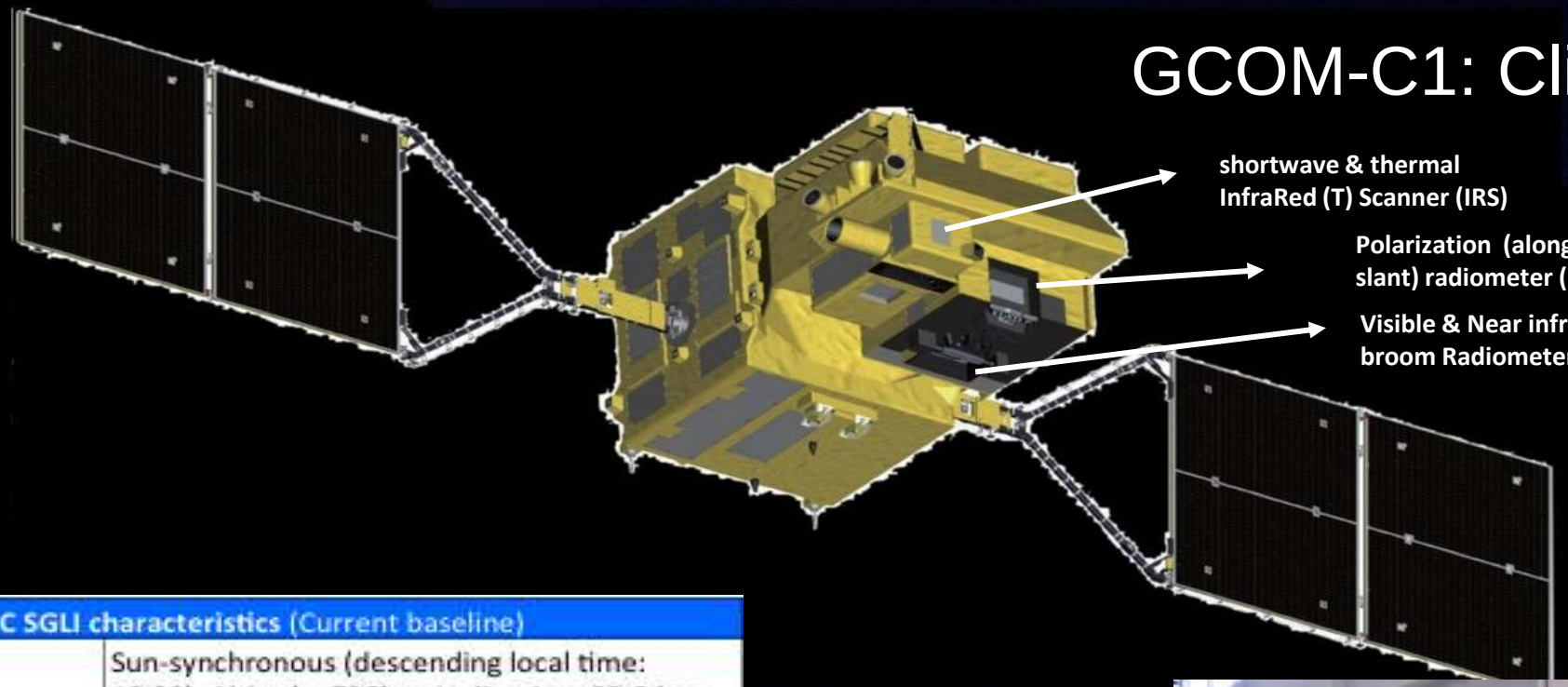
Animation of daily mean of CO2 concentration
(June 2009 - May 2011, at 800 m altitude)

GOSAT L4B V01.01 CH_4 (2009/06/01) ETA:925
Simulated Concentration



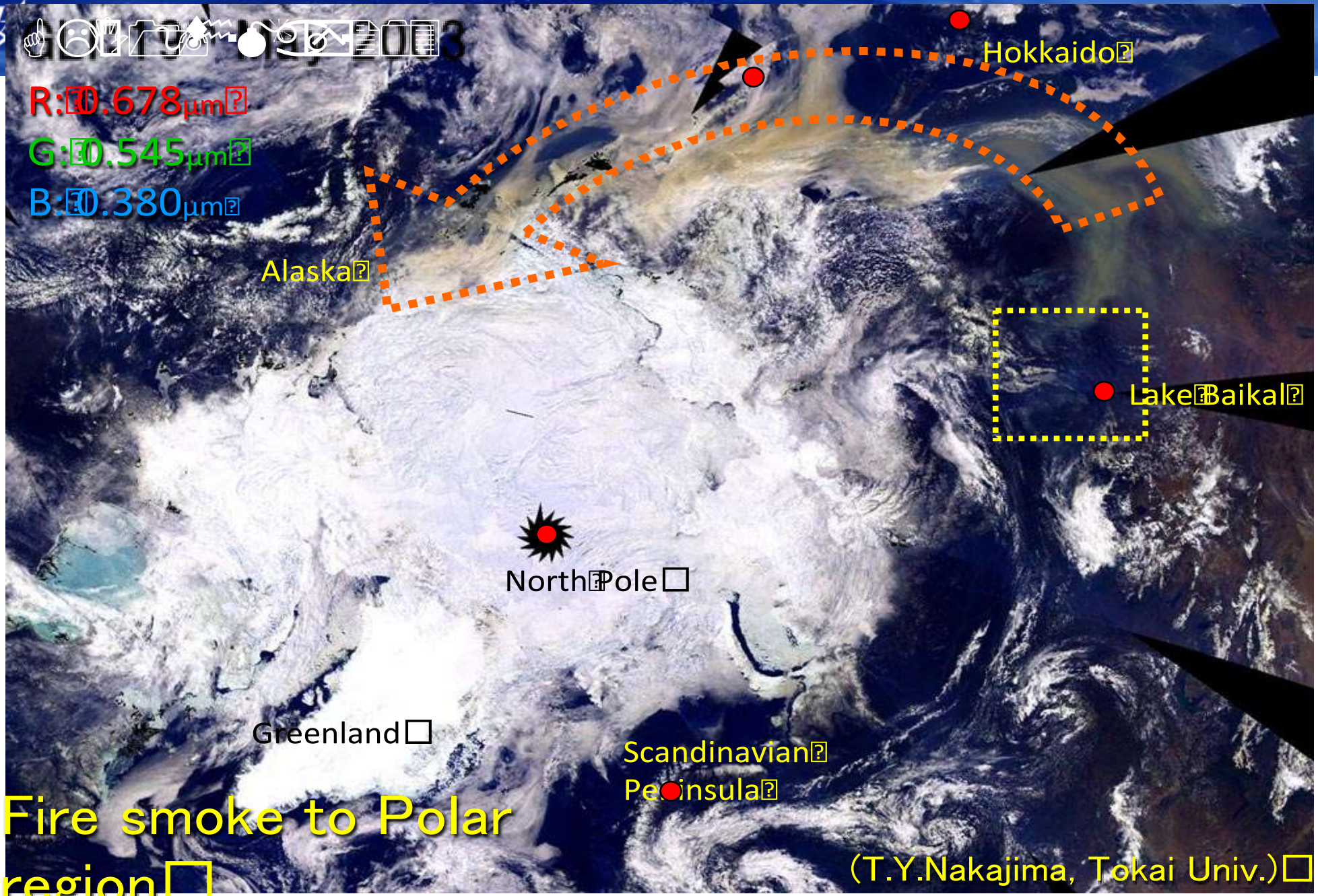
Animation of daily mean of CH4 concentration
(June 2009 - May 2011, at 800 m altitude)

GCOM-C1: Climate

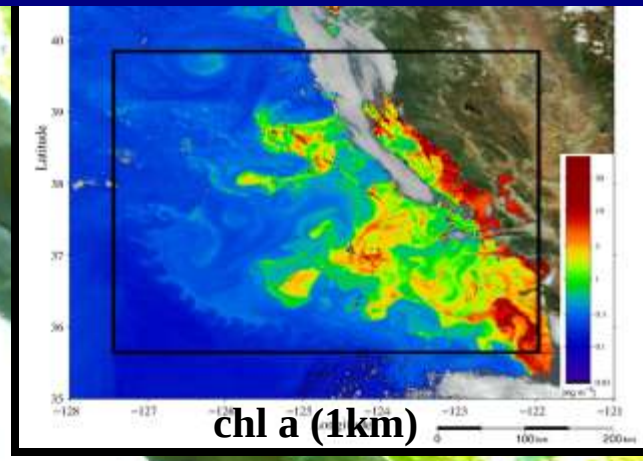


GCOM-C SGLI characteristics (Current baseline)	
Orbit	Sun-synchronous (descending local time: 10:30), Altitude: 798km, Inclination: 98.6deg
Launch Date	JFY 2015 (TBD)
Mission Life	5 years (3 satellites; total 13 years)
Scan	Push-broom electric scan (VNR: VN & P) Wisk-broom mechanical scan (IRS: SW & T)
Scan width	1150km cross track (VNR: VN & P) 1400km cross track (IRS: SW & T)
Digitalization	12bit
Polarization	3 polarization angles for P
Along track tilt	Nadir for VN, SW and T, & +/-45 deg for P
On-board calibration	VN: Solar diffuser, Internal lamp (LED, halogen), Lunar by pitch maneuvers (~once/month), and dark current by masked pixels and nighttime obs. SW: Solar diffuser, Internal lamp, Lunar, and dark current by deep space window T: Black body and dark current by deep space window All: Electric calibration

Satellite under development…

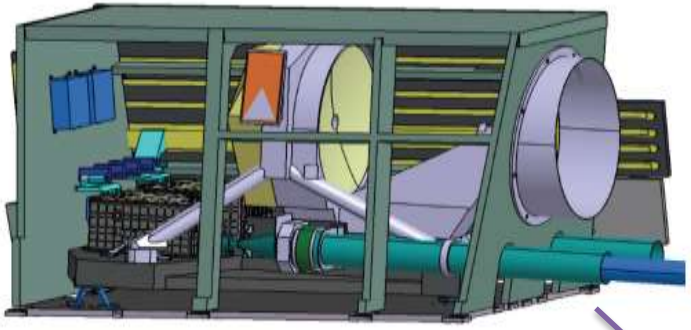

R: 0.678μm
G: 0.545μm
B: 0.380μm
Hokkaido
Alaska
Lake Baikal
North Pole
Greenland
Scandinavian Peninsula
Fire smoke to Polar region
(T.Y.Nakajima, Tokai Univ.)

Results from previous sensor GLI, 250m ocean *GLI 250m* RGB:22/21/20, 2003.5.26

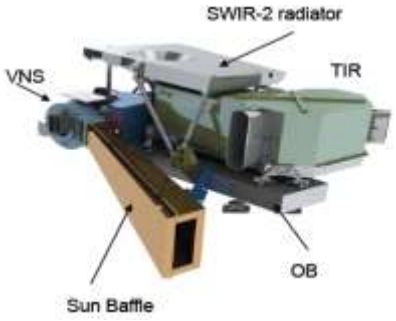


San Francisco

EarthCARE (ESA/JAXA joint mission)



Atmospheric LIDAR (ATLID)



Multi-Spectral Imager (MSI)

EarthCARE Satellite

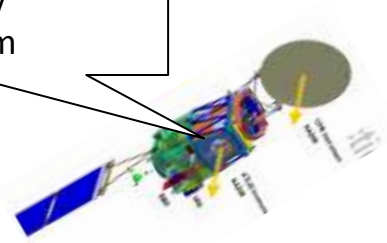
Cloud Profiling RADAR (CPR)
by JAXA/NICT

Board Band Radiometer (BBR)

Courtesy of ESA

Characteristics of EarthCARE observation

Well aligned synergy observation platform



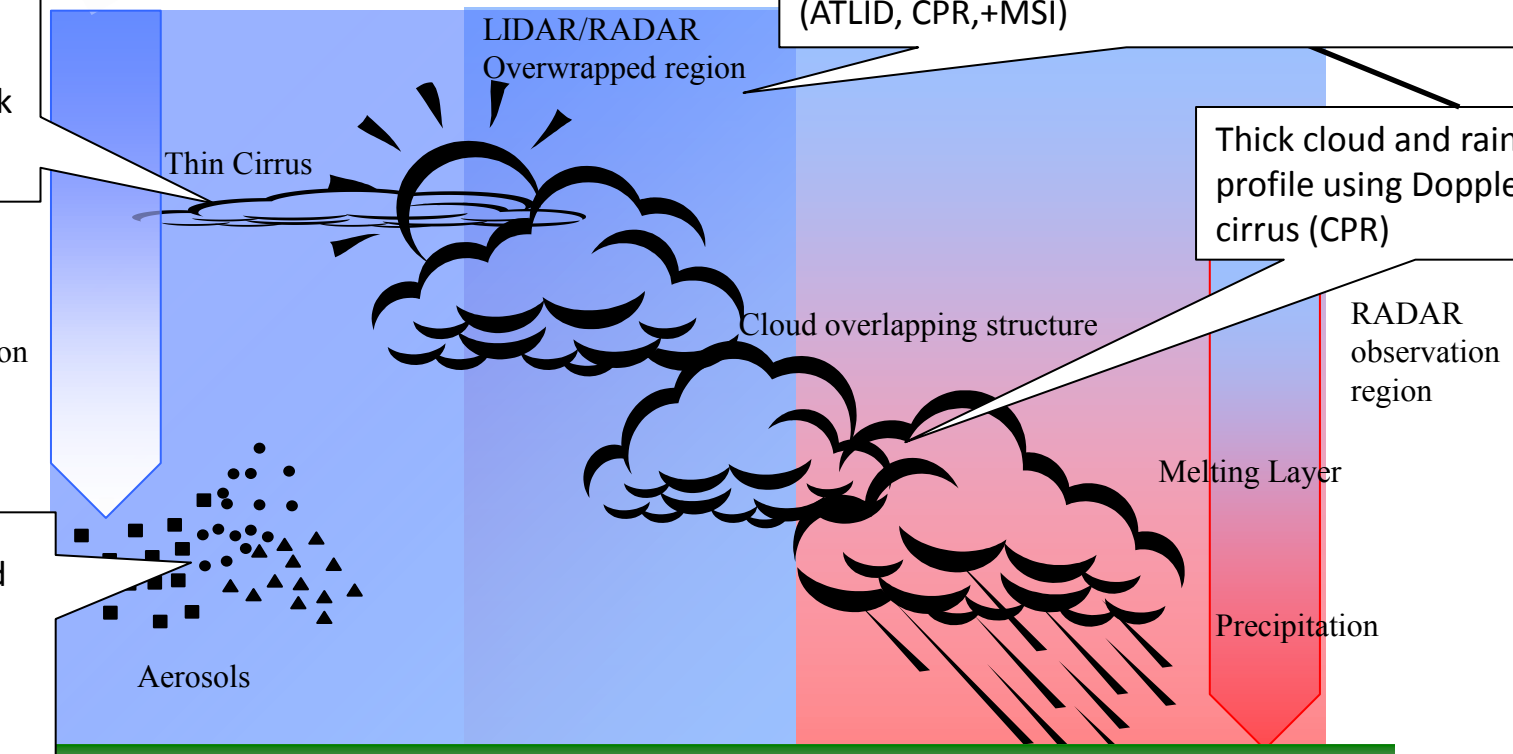
MSI : for scene determination, horizontal / optical information, passive / active correlation
BBR: for checking the consistency of TOA flux

Full range profile (aerosol – cloud – light precip.)

Precise cloud microphysical characteristics (ATLID, CPR,+MSI)

Cloud profile incl. thin Cirrus, NO thick cloud (ATLID)

Thick cloud and rain/snow profile using Doppler, NO thin cirrus (CPR)



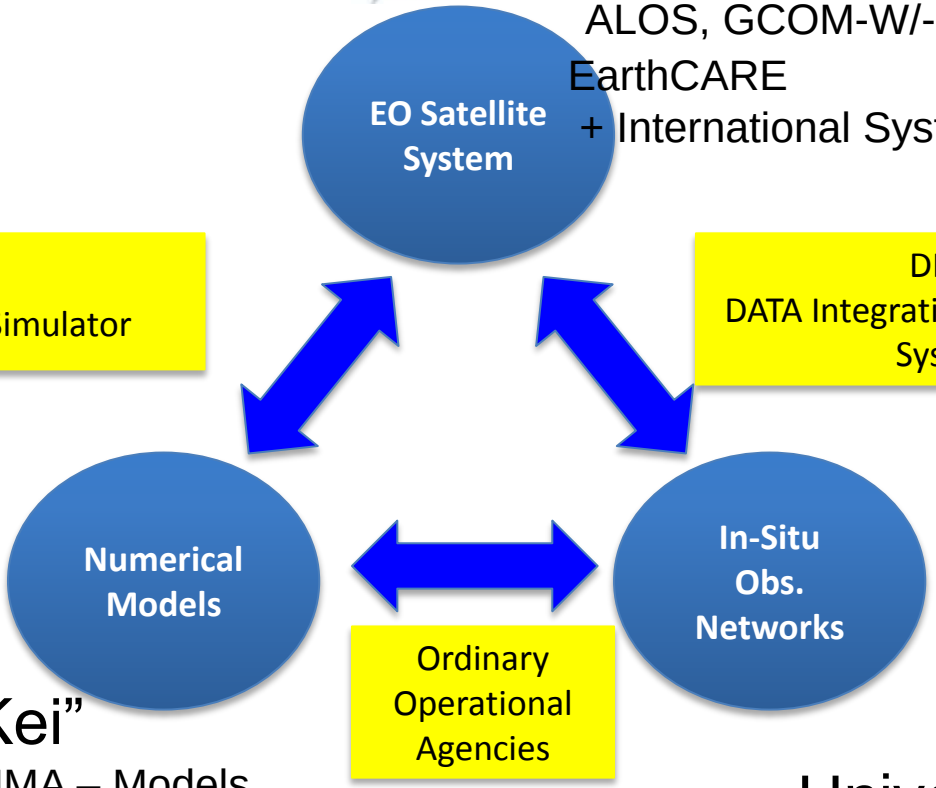
Aerosol profiles and microphysical properties by Types (ATLID + MSI)

This page includes the products, still in research

Japanese Earth Observation Science infrastructure

Satellite System

ALOS, GCOM-W/-C, GPM, GOSAT, EarthCARE
+ International System

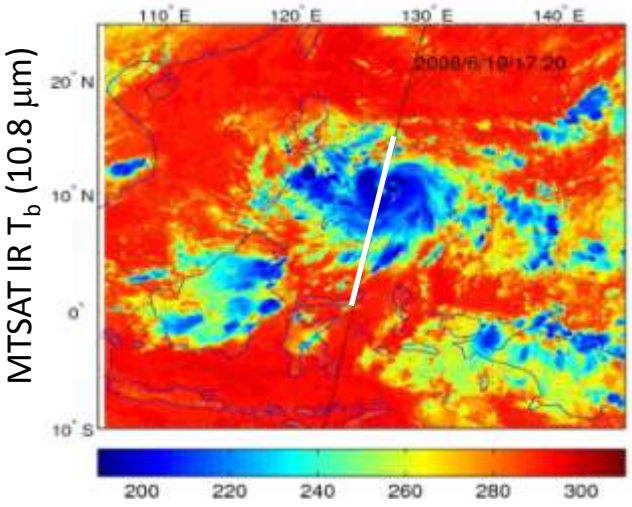


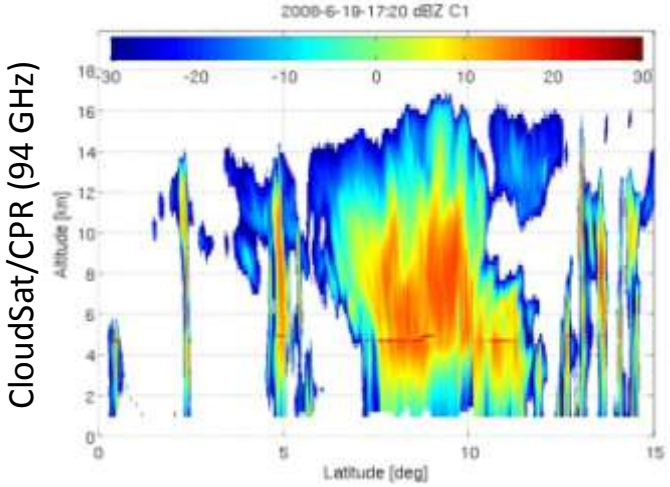
Super Computer “Kei”
for Model engine

JMA – Models
CR-Models “NICAM”,”CReSS”
Climate Model “MIROC”,
“MIROC-ESM”

Universities networks
Operational networks
International networks

Sensor signal simulation; "*J-Simulator*" *COSP like tool*





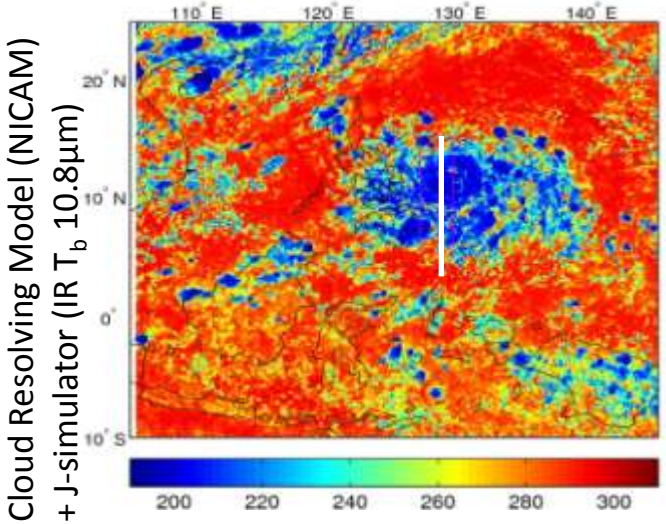
Tropical Cyclone case study

Global Cloud Resolving Model

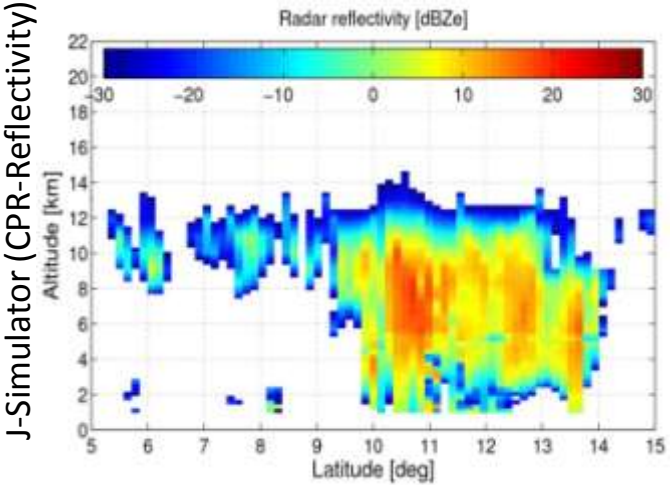
NICAM : Nonhydrostatic ICosahedral Atmospheric Model (Satoh et al. 2008)

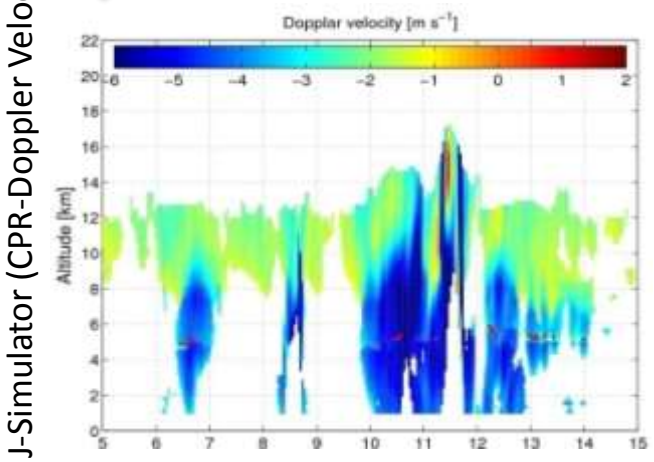
Observation

CRM/Sensor Signal Simulation



Tropical Cyclone simulation (Nasuno et al.2009)



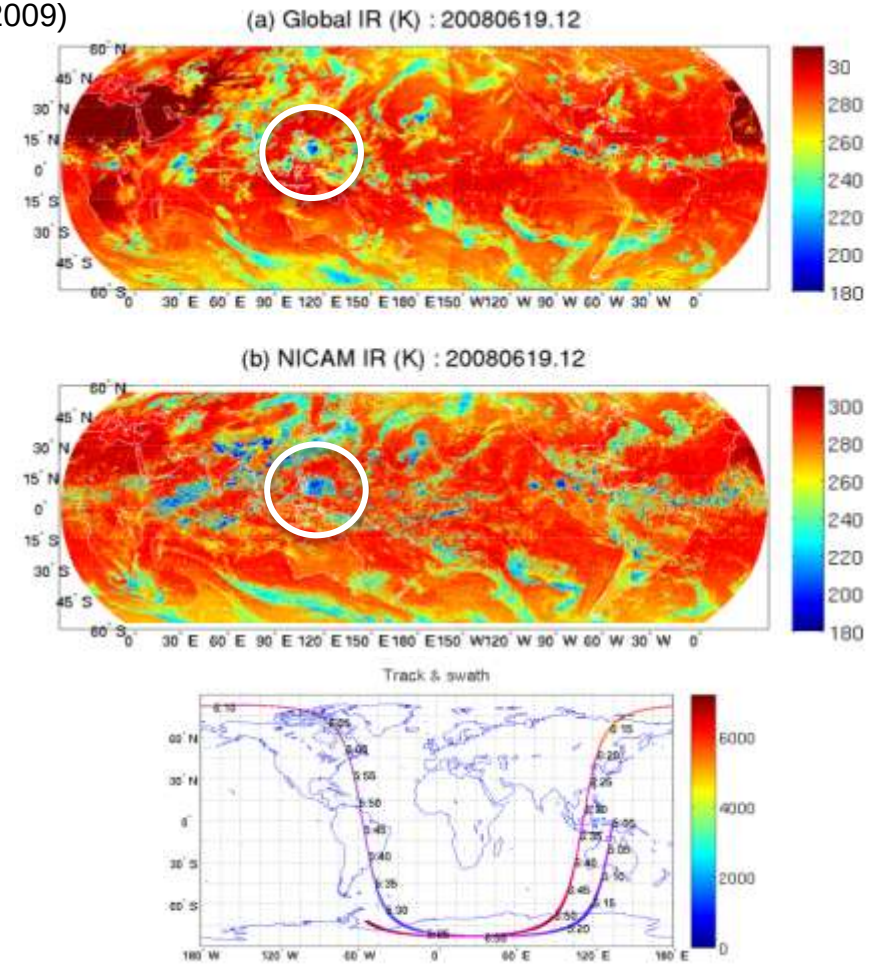


(Hashino, Satoh (U. Tokyo) and Kubota (JAXA))

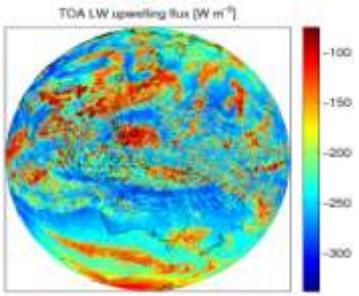
Link to model community

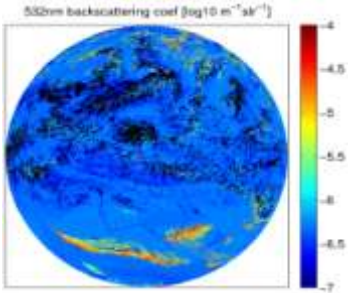
- **Scene generator**
- **COSP, ECSIM, Joint-Simulator**
- **High resolution model; bin aerosol-cloud model**

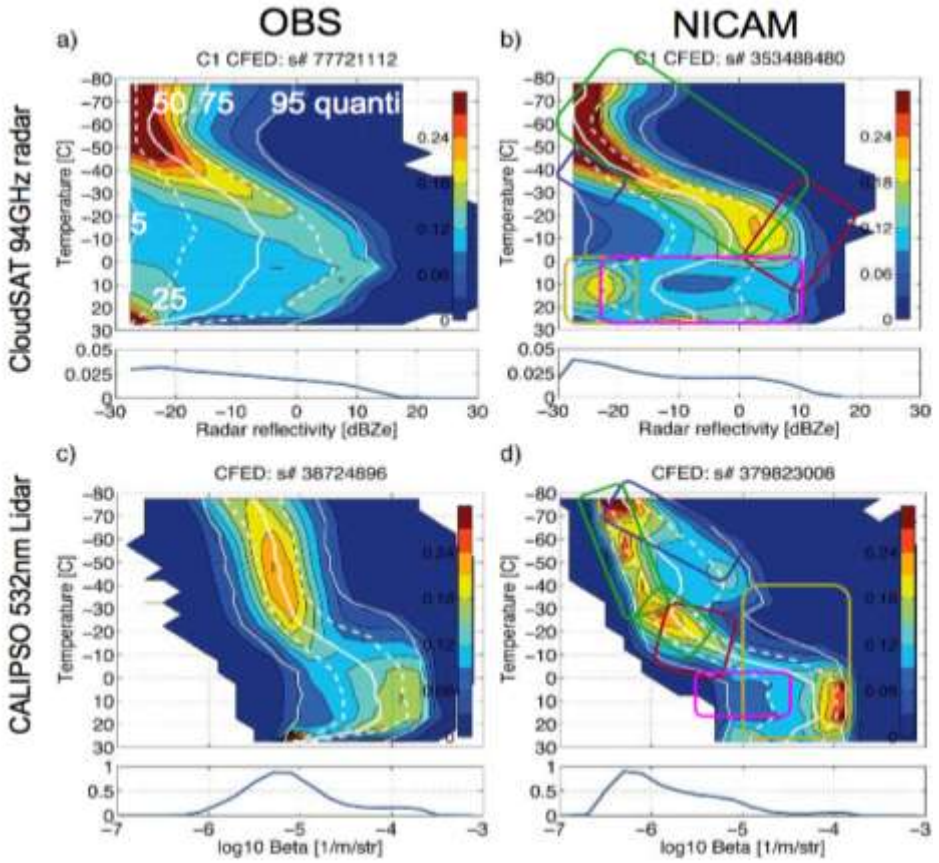
NICAM global simulation : 2008 TC Fengshen (Nasuno et al. 2009)



VIS 0.62 μm







Hashino, M. Satoh (2012)

Summary

- Earth Science Observation requirements to Satellite Earth Observation are internationally discussed in IPCC/GCOS/CEOS/GEOSS framework. Especially for *"climate" , we already have* ECVs list, which is integrated physical parameter to be observed. Other we expect same procedure will be done in other Social Benefit Area.

- Simple *"science to mission design procedure"* was introduced

- Earth science (like water cycle) can not be sufficiently observed with single mission or satellite. So that, cooperation activity from planning phase is important.

- Current JAXA Earth Observation system and missions are introduced

- Not only space part, numerical model and in-situ observation links are crucial


Thank
you !
HD Photo by SELENE spacecraft (JAXA)
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