JAXA Earth Observation Missions

Keiji Imaoka + many contributors

Earth Observation Research Center (EORC)

Japan Aerospace Exploration Agency (JAXA)

Mini-Workshop on A-Train Science

Tokyo, Japan

March 8, 2013

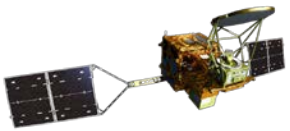
Current and Near-Term Future Missions

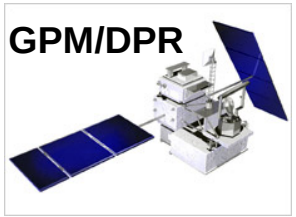
JAXA Satellite Programs

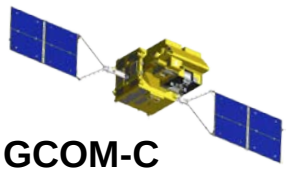
Late 1990s | 2000s | 2003 (JAXA established)

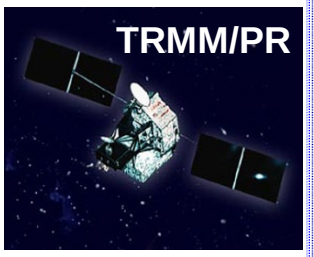
Earth Observation

Climate Change/Water





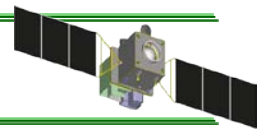




Global Warming

Land Use

Disaster Monitoring



Communications

COMETS | **DRTS** | **WINDS**

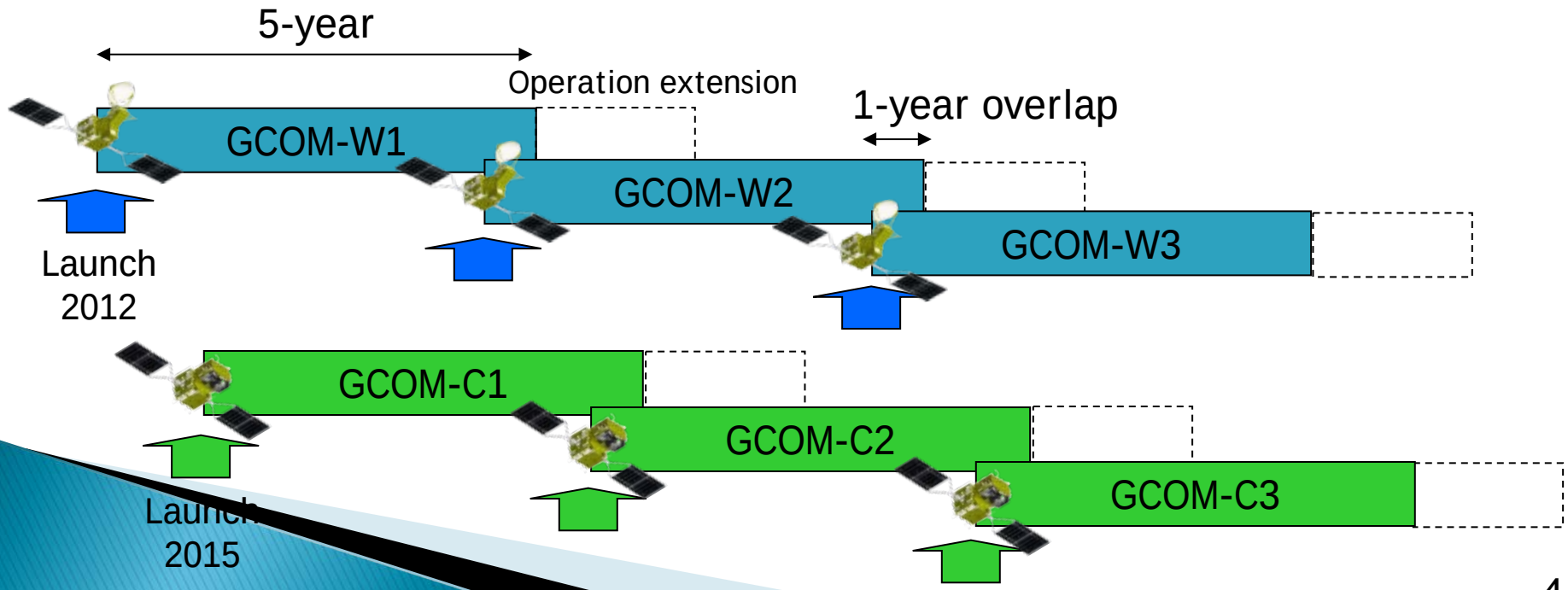
Technology Development

Positioning | **QZSS**

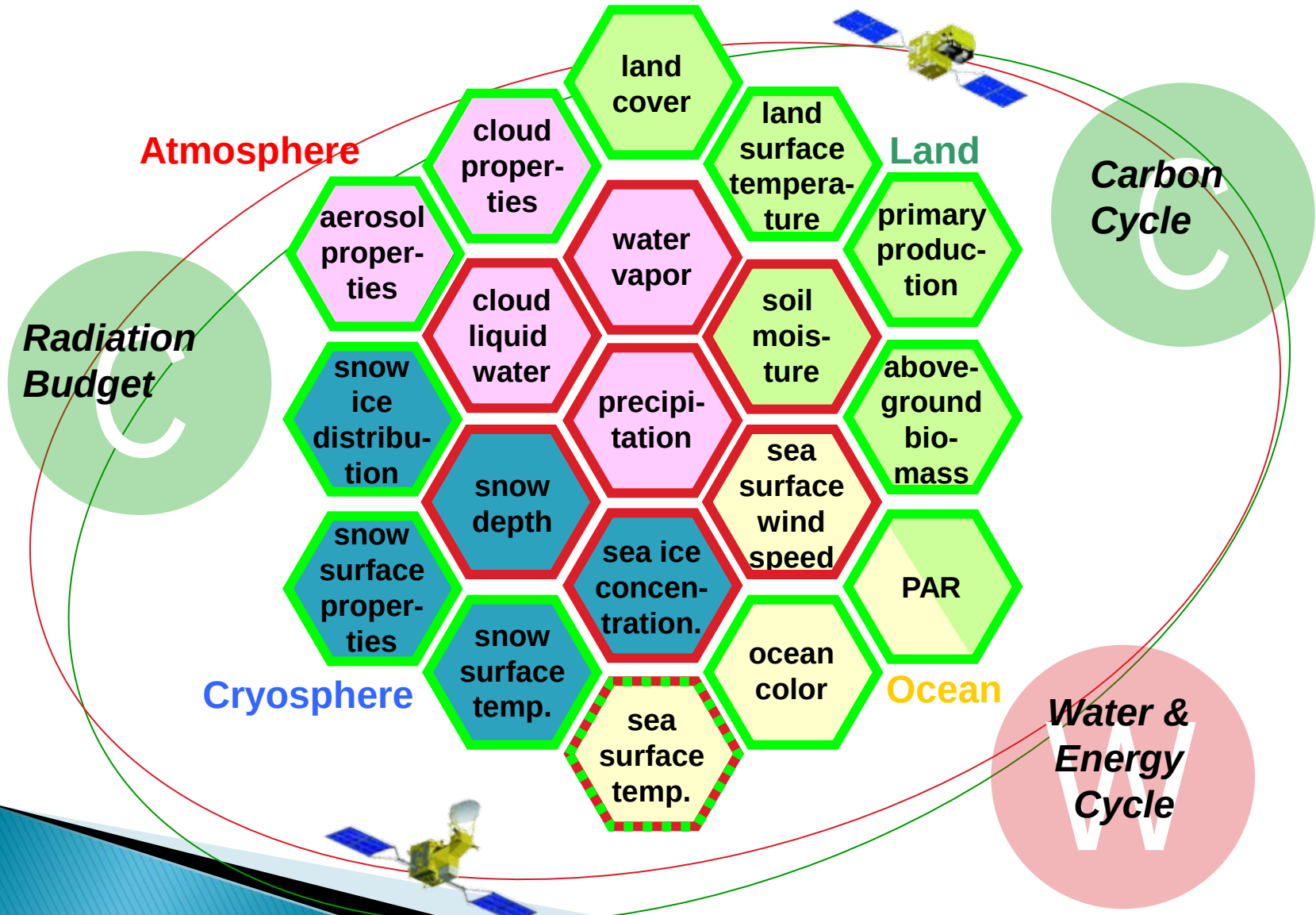
ETS-Ⅵ | **ETS-Ⅶ** | **OICETS** | **ETS-Ⅷ**

Global Change Observation Mission - GCOM -

- Demonstrate long-term global observation of various geophysical parameters for understanding climate variability and water cycle.
- Two medium-sized satellites with three generations to ensure 10-15 years stable data records.



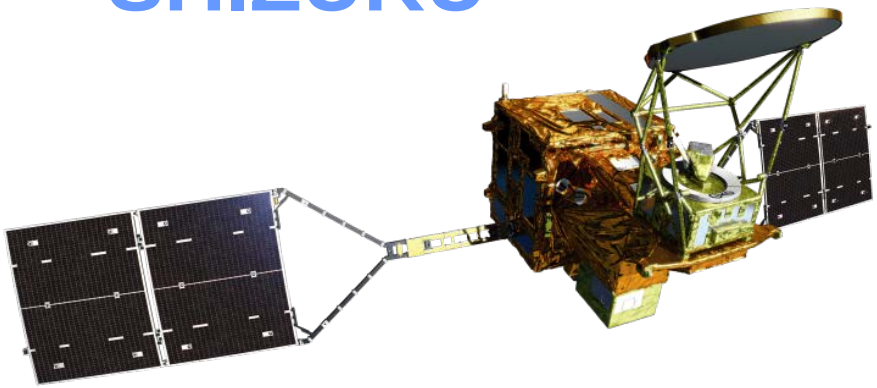
Overview of GCOM Products

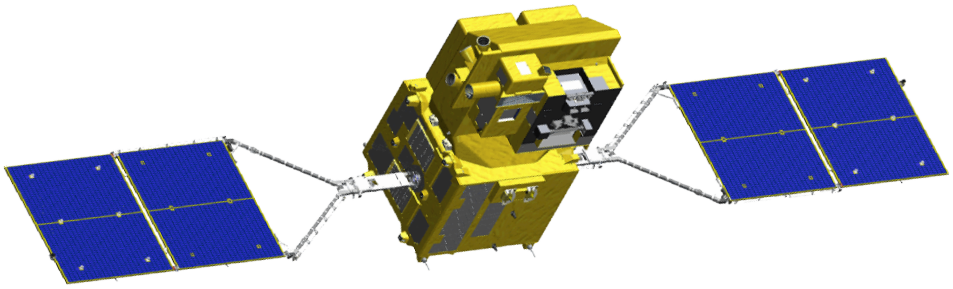


GCOM 1st Generation Satellites

- 2 types of medium-sized satellites and 3 generations: 10-15 years observation

"SHIZUKU"





GCOM-W1 (Water)

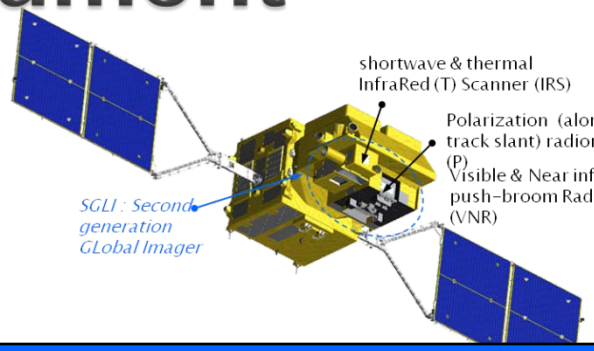
Instrument	**Advanced Microwave Scanning Radiometer-2**
Orbit	Sun Synchronous orbit Altitude：699.6km (on Equator) Inclination: 98.2 degrees Local sun time: 13:30+/-15 min
Size	5.1m (X) * 17.5m (Y) * 3.4m (Z) (on-orbit)
Mass	1991kg
Power gen.	More than 3880W (EOL)
Launch	May 18, 2012
Design Life	5-years

GCOM-C1 (Climate)

Instrument	**Second-generation Global Imager**
Orbit	Sun Synchronous orbit Altitude：798km (on Equator) Inclination: 98.6 deg. Local sun time: 10:30+/- 15min
Size	4.6m (X) * 16.3m (Y) * 2.8m (Z) (on orbit)
Mass	2093kg
Power gen.	More than 4000W (EOL)
Launch	JFY 2015 (TBD)
Design Life	5-years

SGLI Instrument

- Improvement of land, coastal, and aerosol observations.
  - fine (250m) spatial resolution
  - polarization/along-track slant view



250m over land or coastal area, and 1km over offshore

GCOM-C SGLI characteristics (Current baseline)	
Orbit	Sun-synchronous (descending local time: 10:30) Altitude: 798km, Inclination: 98.6deg
Launch Date	Jan. 2014 (HII-A)
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 direction	Nadir for VN, SW and T, +45 deg and -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

Multi-angle obs. for 674nm and 869nm

SGLI channels						
CH	λ VN, P, SW: nm T: μm	Δλ	L_{std} VN, P: W/m²/sr/μm T: Kelvin	L_{max}	SNR at Lstd VN, P, SW: - T: NEΔT	IFOV m
VN1	380	10	60	210	250	250
VN2	412	10	75	250	400	250
VN3	443	10	64	400	300	250
VN4	490	10	53	120	400	250
VN5	530	20	41	350	250	250
VN6	565	20	33	90	400	250
VN7	673.5	20	23	62	400	250
VN8	673.5	20	25	210	250	250
VN9	763	12	40	350	1200(@1km)	250
VN10	868.5	20	8	30	400	250
VN11	868.5	20	30	300	200	250
P1	673.5	20	25	250	250	1000
P2	868.5	20	30	300	250	1000
SW1	1050	20	57	248	500	1000
SW2	1380	20	8	103	150	1000
SW3	1630	200	3	50	57	250
SW4	2210	50	1.9	20	211	1000
T1	10.8	0.7	300	340	0.2	500/250
T2	12.0	0.7	300	340	0.2	500/250

250m-mode possibility

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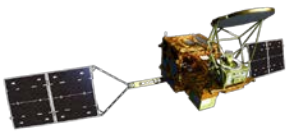
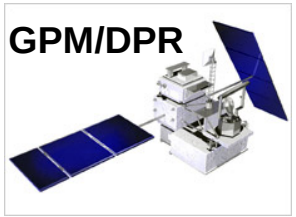
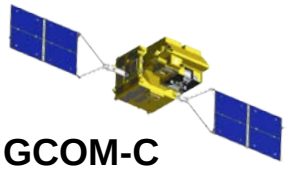
Earth Observation







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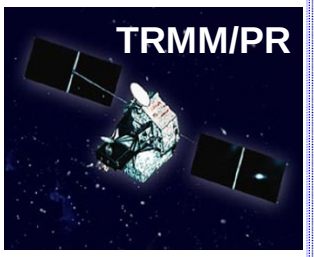

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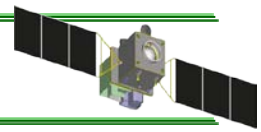

Communications

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Technology Development

Positioning | **QZSS**

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Spaceborne Cloud & Precipitation Radar Development

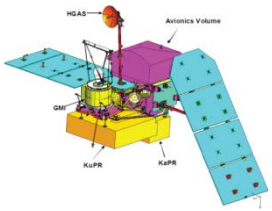
1995 2000 2005 2010 2015 2020

TRMM/PR
(by JAXA/NICT)
Ku-band（13.8GHz)

1997～Today

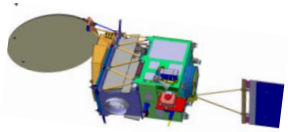
GPM/DPR
(by JAXA/NICT)
Ku-band（13.6GHz）
Ka-band（35.5GHz）

2014～



EarthCARE/CPR
(by JAXA/NICT)
W-band（94.05GHz)
（Doppler radar）

2015～



CloudSat/CPR
(by NASA)
W-band（94GHz)

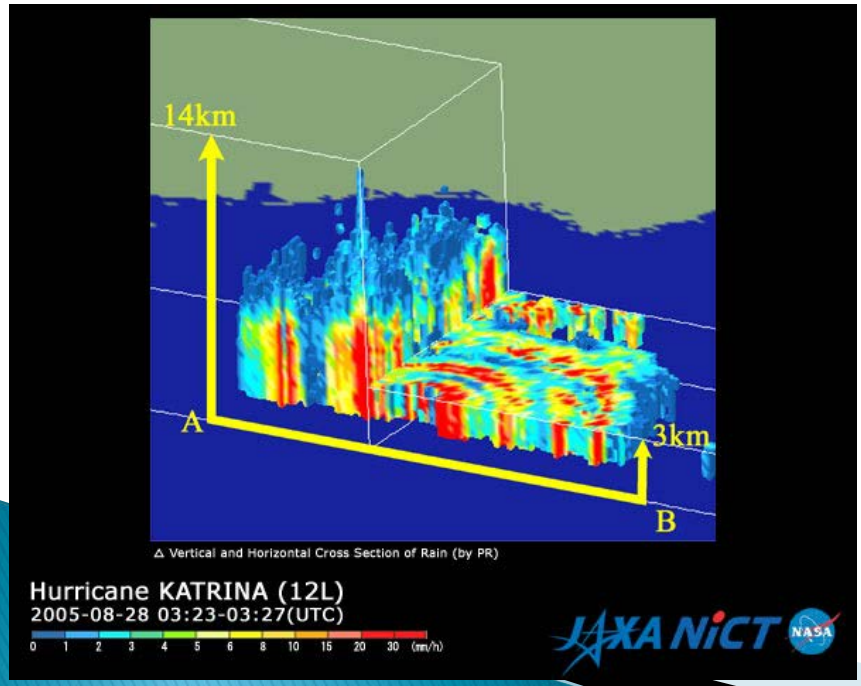
2006～Today

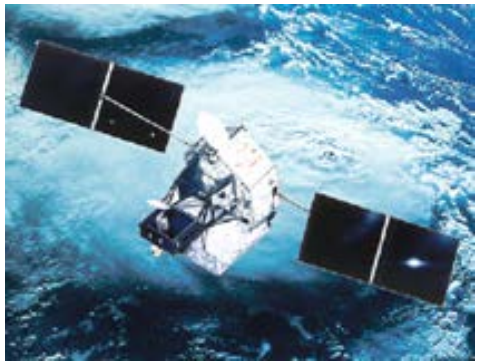
long term global precipitation record

full spectrum of cloud and precipitation (cloud - weak rain- heavy rain)

Tropical Rainfall Measuring Mission
- TRMM -

- Focused on rainfall observation. First instantaneous rainfall observation by three different sensors (PR, TMI, VIRS). PR, active sensor, can observe 3D structure of rainfall.
- Targeting tropical and subtropical region, and chose non-sun-synchronous orbit (inc. angle 35 degree) to observe diurnal variation.





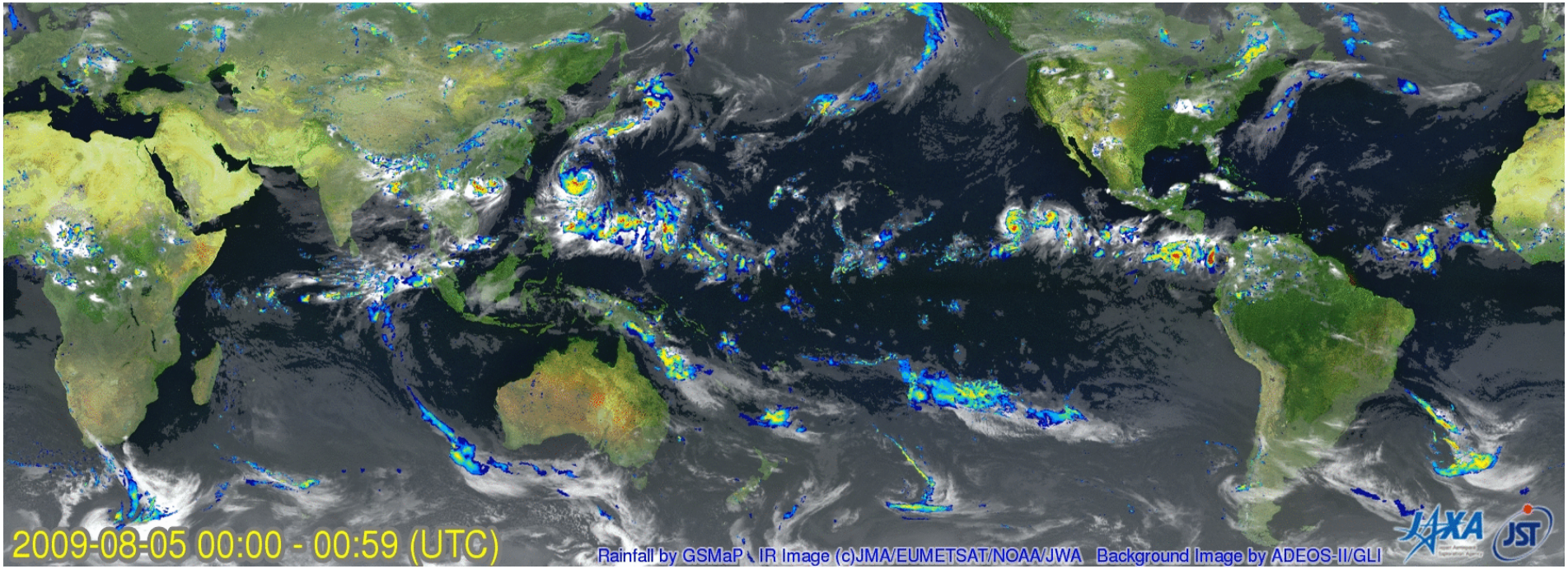
US-Japan joint mission

Japan: PR, launch

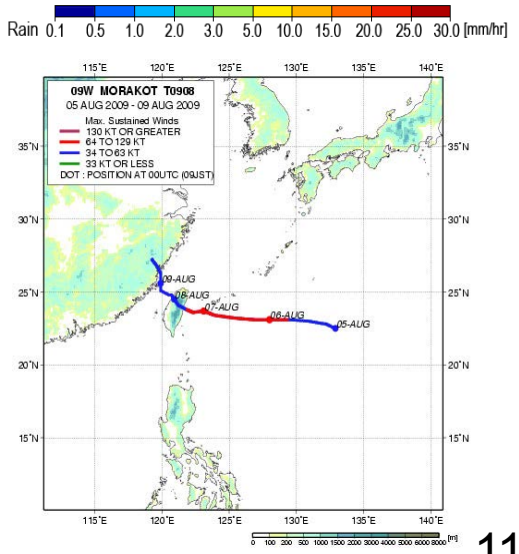
US: satellite, TMI, VIRS, CERES, LIS, operation

Launch	28 Nov. 1997 (JST)
Altitude	About 350km (since 2001, boosted to 402km to extend mission operation)
Inc. angle	About 35 degree, non-sun-synchronous orbit
Design life	3-year and 2month (still operating)
Instruments	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible Infrared Scanner (VIRS) Lightning Imaging Sensor (LIS) CERES (not in operation)

GSMaP



Typhoon MORAKOT (09W): Aug. 5 – 10, 2009 (Big impact in Chinese Taipei)

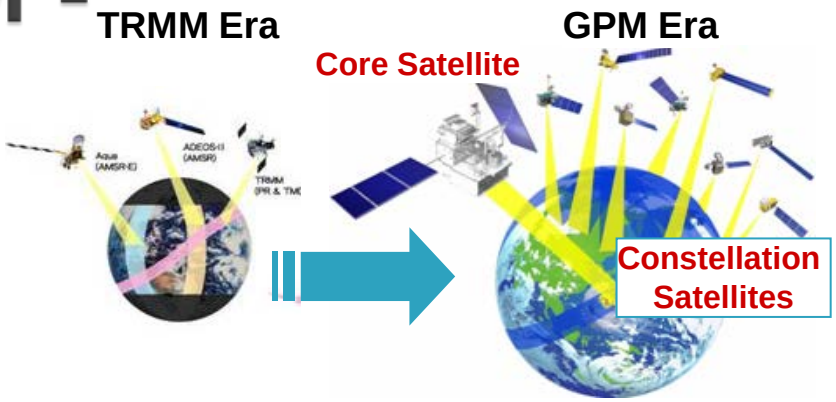


- Rapidly changing precipitation phenomena need frequent observations.
- Global rainfall map merging TRMM, polar orbiting microwave radiometer/sounders, and geostationary infrared radiometers.

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

Global Precipitation Measurement
- GPM -

- GPM: An international satellite mission to be launched by JAXA and NASA in 2014 for precipitation measurements worldwide



Core Satellite (JAXA, NASA)

Dual-frequency precipitation radar (DPR)

GPM Microwave Imager (GMI)

- **Precipitation with high precision**
- **Discrimination between rain and snow**
- **Adjustment of data from constellation satellites (The core satellite will fly in non-sun-synchronous orbit.)**

(launch in 2014)

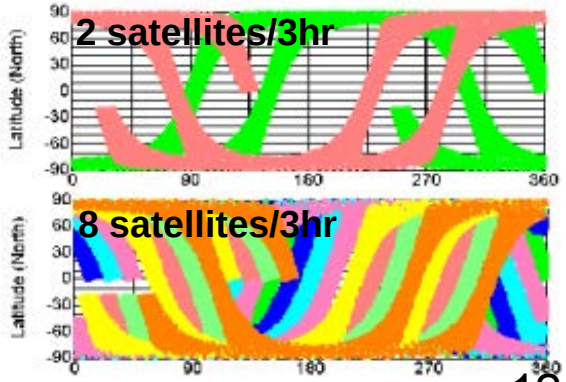
Constellation Satellites (International Partners)

Microwave radiometers

Microwave sounders

- **Global precipitation every 3 hours**

(launch around 2014)

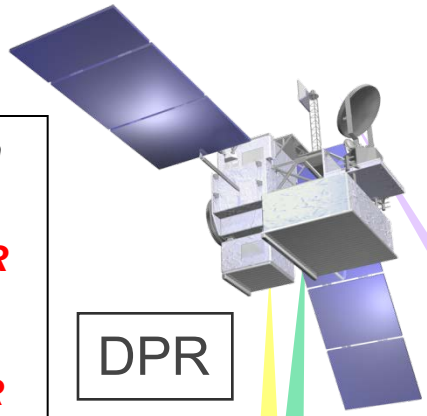


- Improve the accuracy of both long-term and short-term weather forecasts
- Improve water resource management in river control and irrigation systems for agriculture

DPR on GPM Core Satellite

Dual-frequency precipitation radar (DPR) consists of
-Ku-band (13.6GHz) radar : KuPR (similar to TRMM/PR)
and
-Ka-band (35.5GHz) radar : KaPR

The DPR was developed by JAXA and NICT.



DPR

GMI

Flight direction

407 km altitude, 65 deg inclination

GMI: GPM Microwave Imager

Range resolution = 250m and 500m

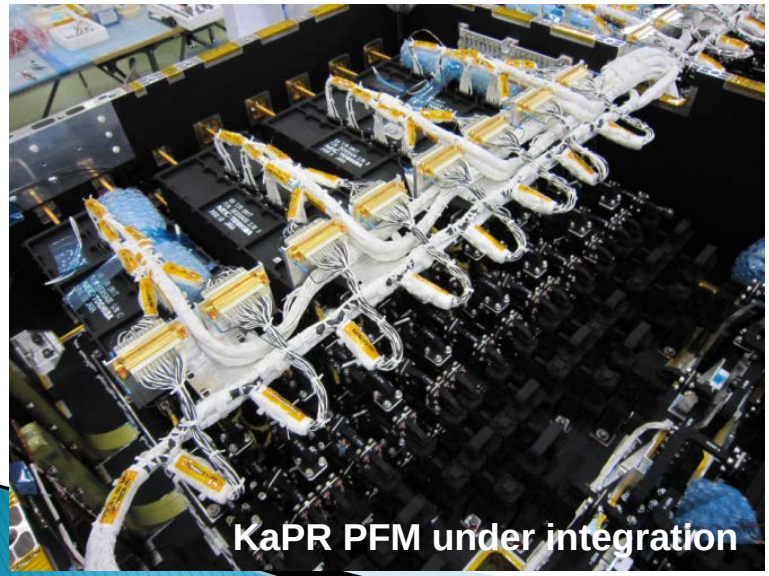
KuPR (13.6GHz) Swath width = 245km

KaPR (35.5GHz) Swath width = 120km

Microwave radiometer Swath width = 800 km

5km

Preparation in Progress



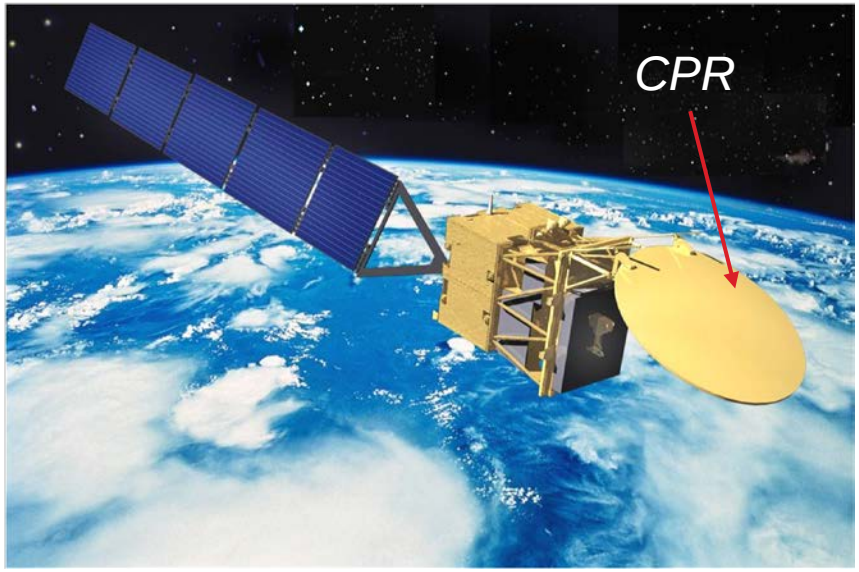
Satellite Photo Credit: NASA

Earth Cloud, Aerosol and Radiation Explorer (EarthCARE)

To reduce the uncertainties in global warming prediction by measuring the three dimensional structure of clouds and aerosols, which are most uncertain parameter in the numerical climate models.

- Joint Mission by Europe and Japan
- 3 years lifetime
- 400 km altitude
- Sun-synchronous orbit (Local time: 14:00)

EarthCARE Instruments



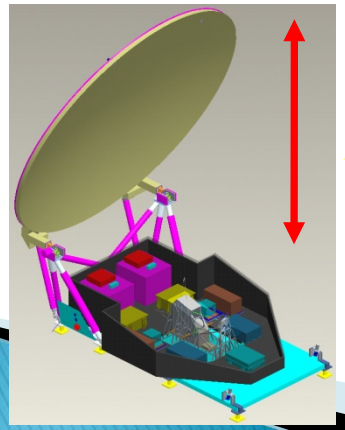
- ✓ Four instruments
  - Cloud Profiling RADAR (JAXA/NICT)
  - Atmospheric LIDAR (ESA)
  - Multi-Spectral Imager (ESA)
  - Broad Band Radiometer (ESA)

CPR Engineering Model

Overview of CPR

- EarthCARE CPR is the first millimeter-wave Doppler radar in space for Earth observation developed by JAXA and NICT.
- 94GHz of W-band is selected for center frequency to penetrate deep into the clouds from the orbit and retrieve the cloud vertical profiles and motions.
- The antenna employs offset Cassegrain type, and has a deployable main reflector with the largest aperture for W-band Earth observation satellite.
- CPR observes clouds along the sub-satellite track.

External view of CPR



Observation image by Cloud Profiling Radar

This image is from NASA/CloudSat quick look data and edited

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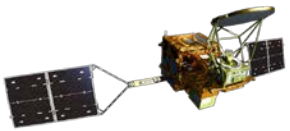

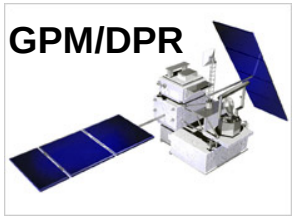

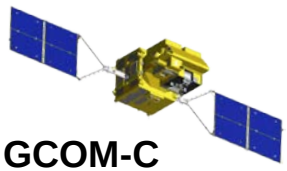

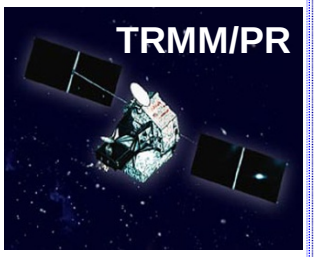

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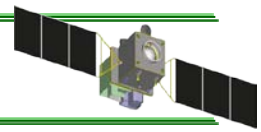

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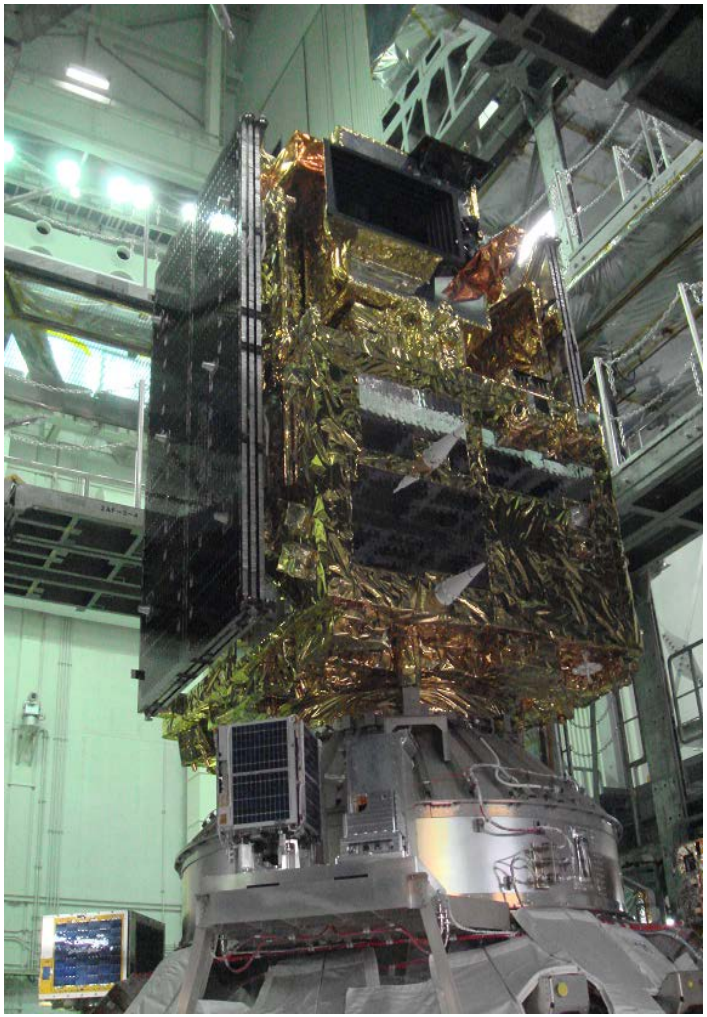
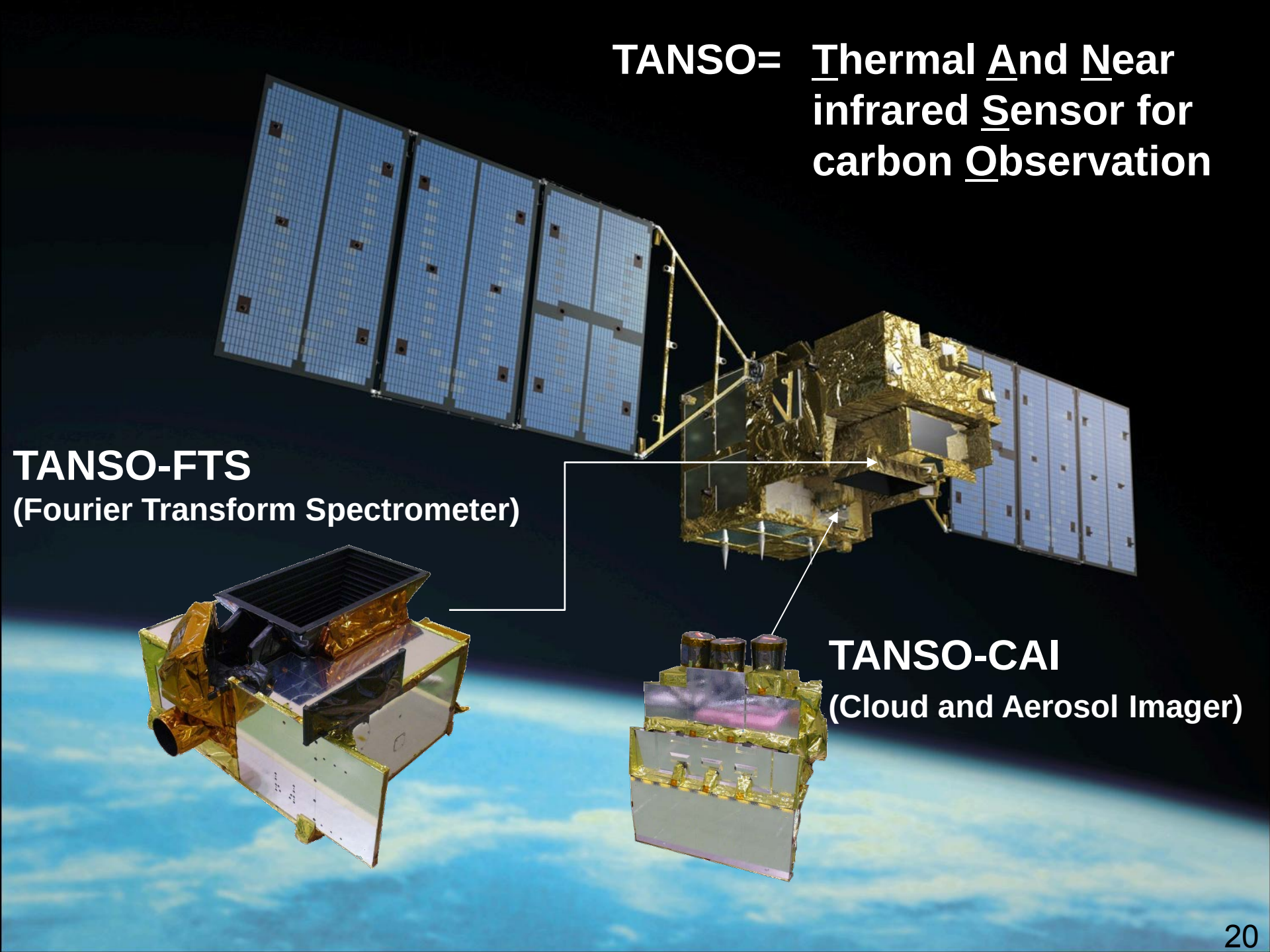
Greenhouse Gases Observing SATellite - GOSAT -

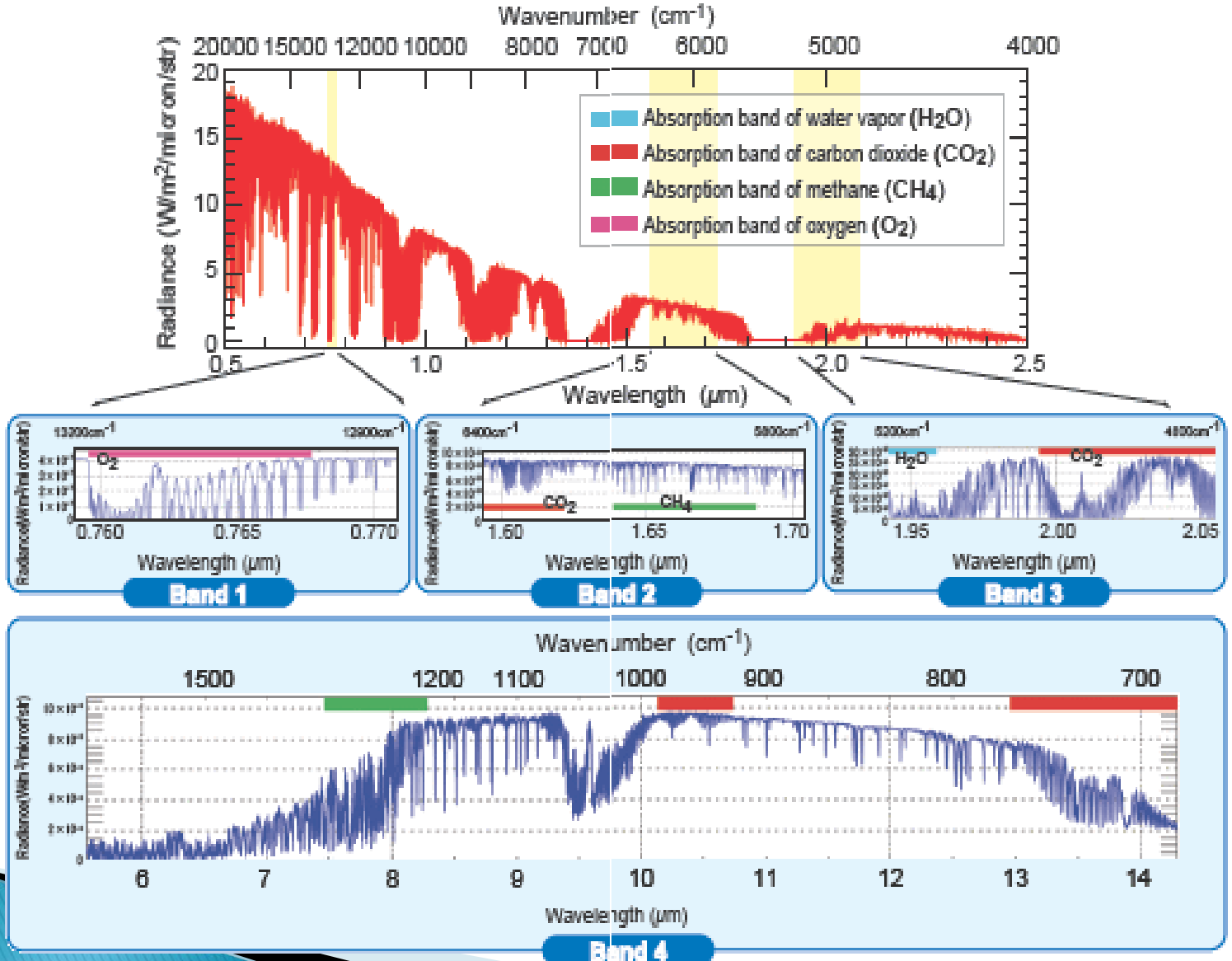
- Monitoring global distribution of Greenhouse Gases from space.
- Observe Carbon dioxide and Methane at 100-1000km spatial scale with relative accuracy of 1% (4ppm) for CO2 and 2% (34ppb) for CH4.
- Joint project by JAXA, NIES (National Institute for Environmental Studies), and MOE (Ministry of the Environment) .
- Launch: 23 January 2009 by H2A launch vehicle
- Mission lifetime: 5 years to 2014



GOSAT satellite at Tanegashima Spece Center


TANSO= Thermal And Near infrared Sensor for carbon Observation
TANSO-FTS
(Fourier Transform Spectrometer)
TANSO-CAI
(Cloud and Aerosol Imager)

TANSO-FTS Spectral Coverage



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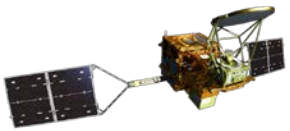

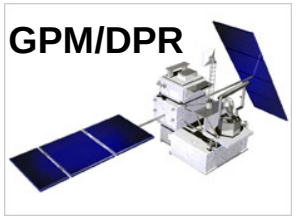

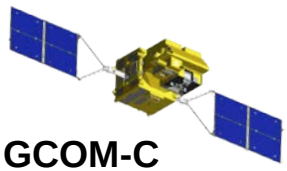

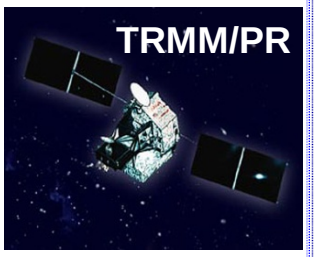

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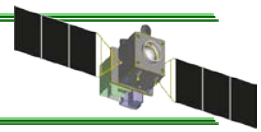


Communications

COMETS | **DRTS** | **WINDS**

Technology Development

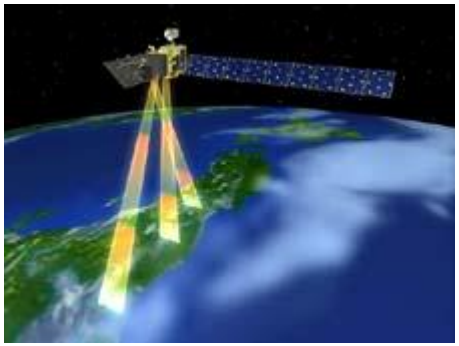
Positioning | **QZSS**

ETS-Ⅵ | **ETS-Ⅶ** | **OICETS** | **ETS-Ⅷ**

Advanced Land Observing Satellite
- ALOS "DAICHI" -

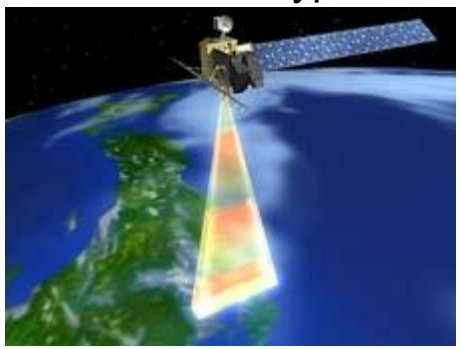
- Operation:
  24 Jan. 2006 by H-2A Rocket #8
  12 May 2011 Mission ended
  ~22 Apr. 2011: Low Load Mode (LLM)
  > 1,934 days=5.3 years
- Objectives:
  - Cartography (1/25,000 scale)
  - Regional environmental monitoring
  - Disaster monitoring, *etc.*

PRISM
Panchromatic Remote sensing Instrument for Stereo Mapping



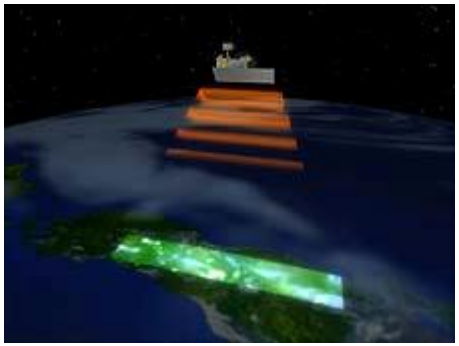
PRISM can acquire triplet stereo imageries by nadir-, forward-, and backward-radiometers with 2.5m spatial resolution in 35km swath.

AVNIR-2
Advanced Visible and Near-Infrared Radiometer type 2



AVNIR-2 can observe with 10m resolution in 70km swath, and it can be changed the observation area by pointing capability within +/-44 deg. in across track.

PALSAR
Phased Array type L-band Synthetic Aperture Radar

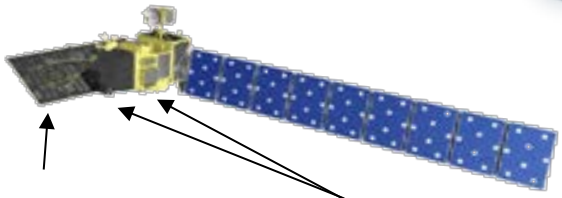


PALSAR can acquire the data in not only daytime but also nighttime as well as cloudy and rainy whether conditions.

ALOS Follow-On Missions

Global and high resolution observation by radar and optical sensors

ALOS (Radar&Optical)



L-band radar antenna

Optical sensors

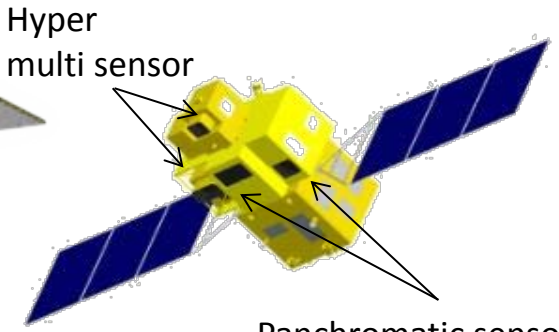
2006 – 2011

ALOS-2 (Radar)

L-band radar antenna

Launch: JFY2013

ALOS-3 (Optical)



Hyper multi sensor

Panchromatic sensor

Launch: JFY2016 (Target)

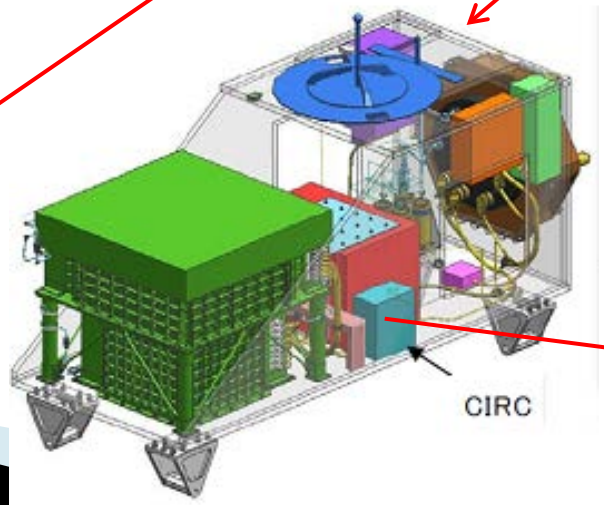
- ✓ High resolution (1-3 m) and wide observation area (50-350 km swath)
- ✓ Fine and clear images under the heavy rain or night condition

Research Activities for Future Missions

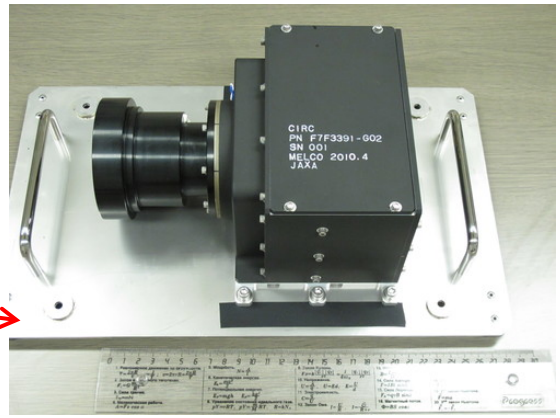
Earth Observation utilizing ISS

- SMILES: Detection of atmospheric limb emission in the submillimeter wave range (624-650GHz) with high sensitivity. NICT and JAXA cooperation.
- JAXA is promoting EO missions such as:
  - Live broadcasting of global phenomena by astronauts
  - Kibo Exposed Facility payloads
    - Compact InfraRed Camera (CIRC)
    - CO2 Lidar, Doppler lidar, etc.

SMILES



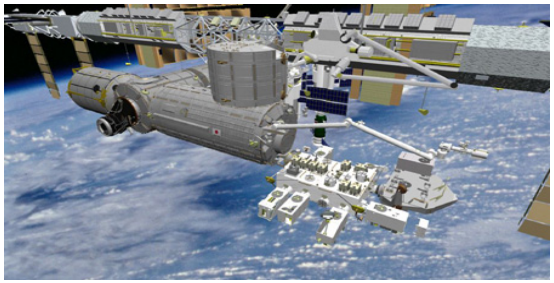
CIRC

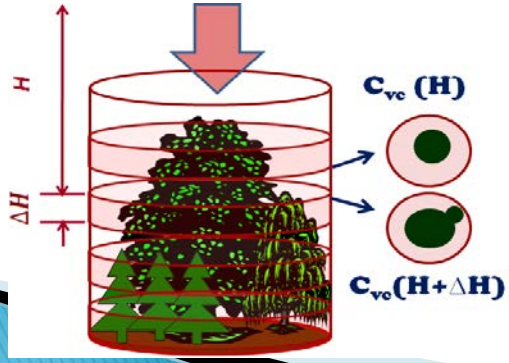


Candidates onboard Kibo-Exposed Facility on ISS

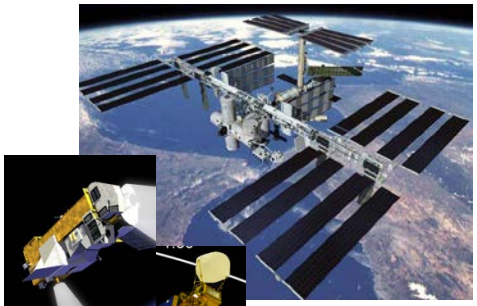
iLOVE
iss-jem Lidar Observation of Vegetation Environment

Tree canopy height, Biomass

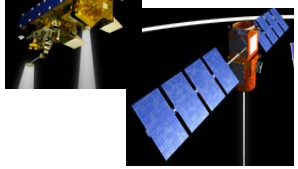




APOLLO
Air PoLLution Observing mission



Kibo-EF on ISS



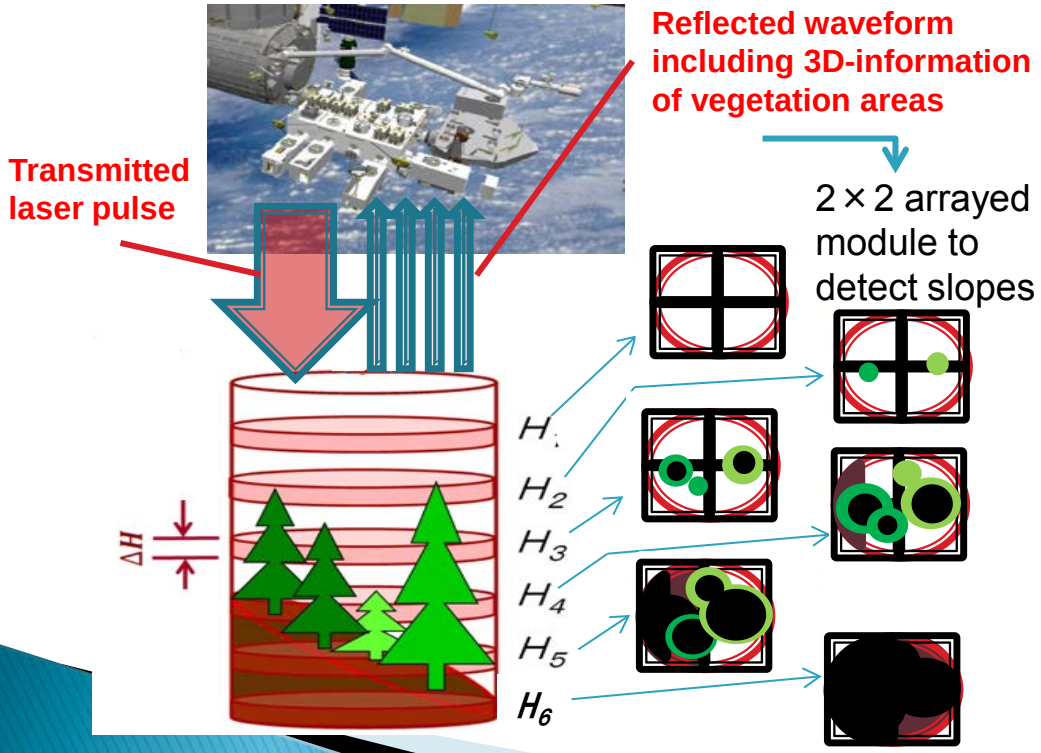
UV-VIS/TIR/MW

- High-spacial resolution observation from low orbit (APOLLO: 1-2km, Other:7-25km)
- Diurnal variation observation from low inclination orbit

Vegetation LIDAR

Observation of canopy height by LiDAR (laser radar) with high accuracy to improve biomass estimations.

- ✓ Experimental proof for future carbon-balance monitoring system of forestry ecosystem.
- ✓ The vegetation lidar observes 3D-sturucture of vegetation including canopy-height, which will enable us to estimate the forestry biomass on the ground.
- ✓ To verify potential of biomass estimation with collaborative observation between the vegetation lidar and a L-band SAR system (such as ALOS-2).



Schematic diagram of the vegetation lidar mission.

Potential observational partner: ALOS-2/L-band SAR

Improve biomass estimations

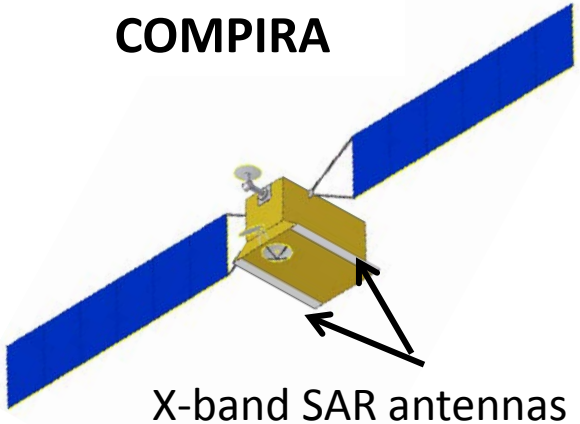
COMPIRA

Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter

Wide-swath altimetry with interferometric SAR

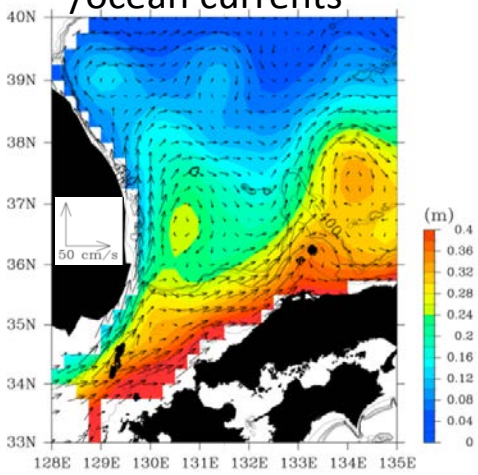
Heritage of SAR
(ALOS-2 L-band SAR)

COMPIRA



X-band SAR antennas

Sea surface height
/ocean currents



T/P, Jason-1, ERS-2, Envisatと漂流ブイデータから計算した平均流速場

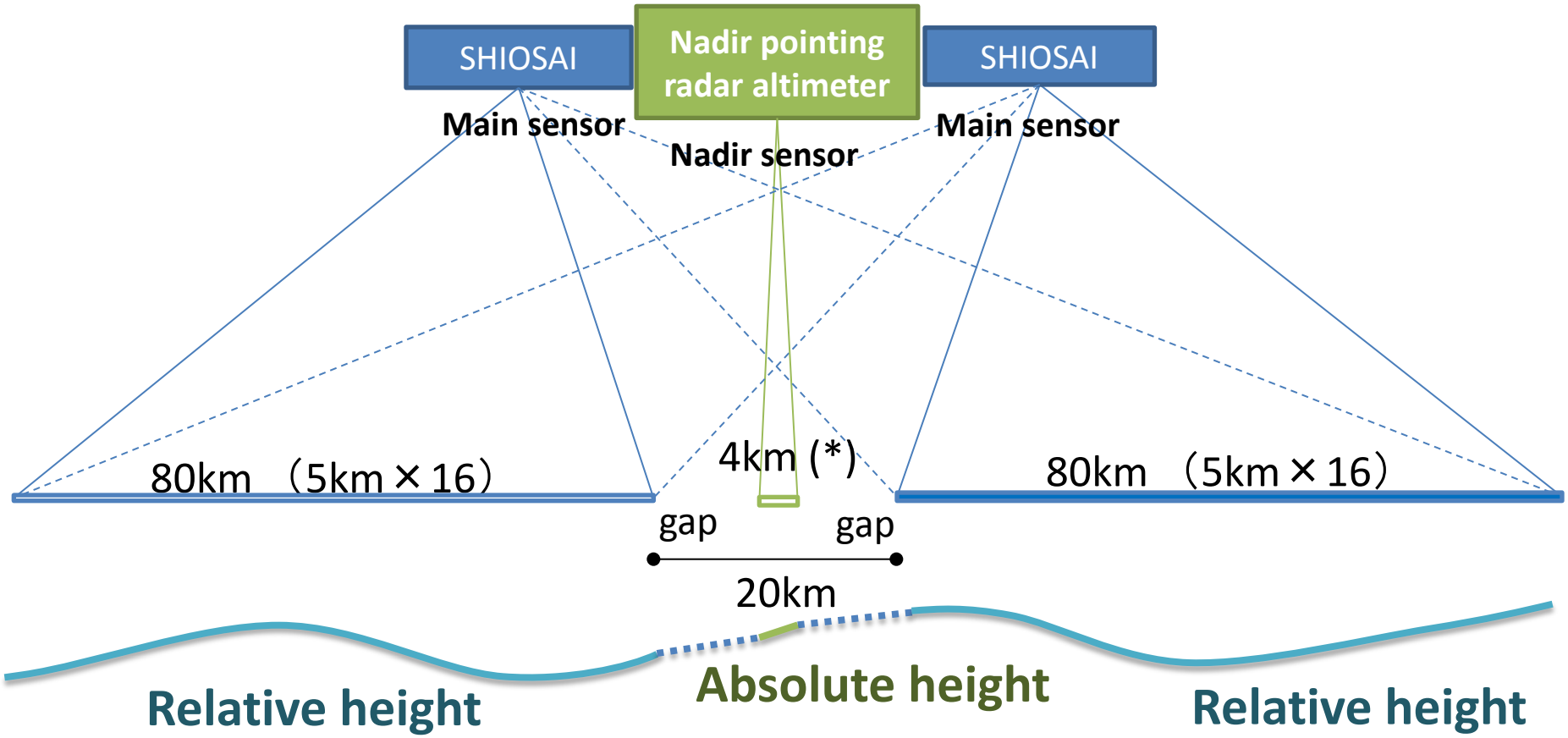
X-band SAR
Cross-track Interferometry

- ✓ COMPIRA measures sea surface height using two SAR antennas.
- ✓ Swath width: 160 km (80 km swath each in left and right side)

Requirements for Wide-swath measurement of sea surface height

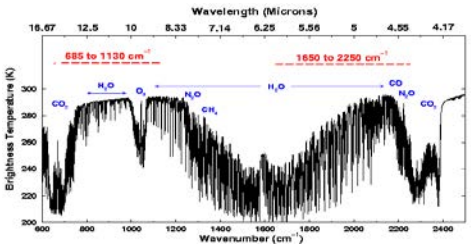
COMPIRA Sensor System

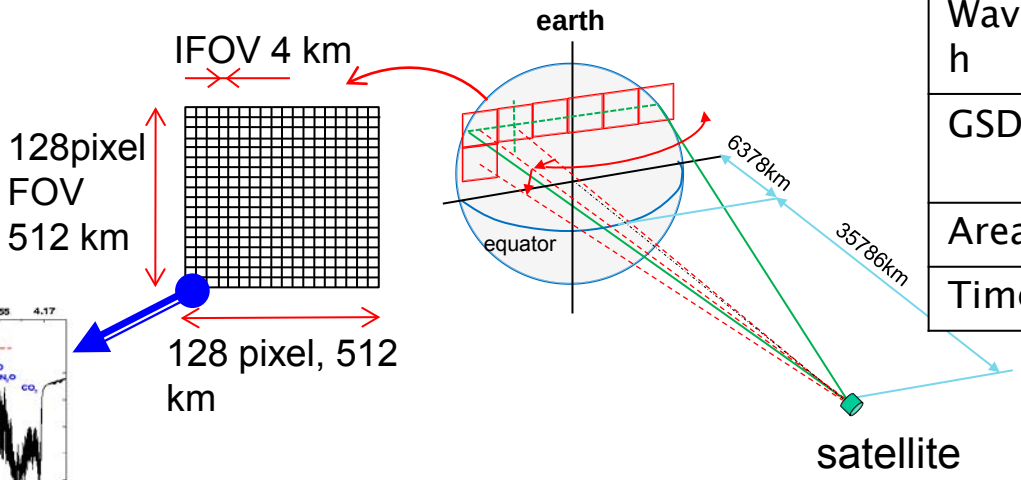
Measurement of absolute sea surface height with wide-swath and high precision will be realized by combining **SHIOSAI (Interferometric SAR sensor; to obtain relative height)** and **nadir pointing radar altimeter (to obtain absolute height).**



(*) with significant wave height of 2 m

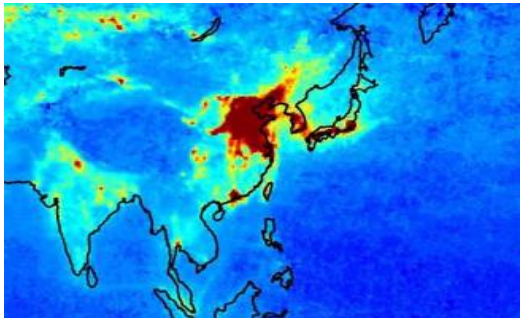
Geostationary Imaging FTS



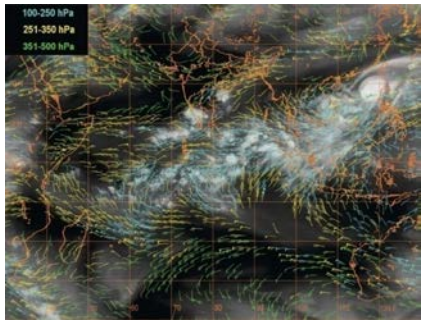


Specifications

Wavelength	MWIR, LWIR
GSD	4km X 4km
Area	Sphere
Time res.	1 hour



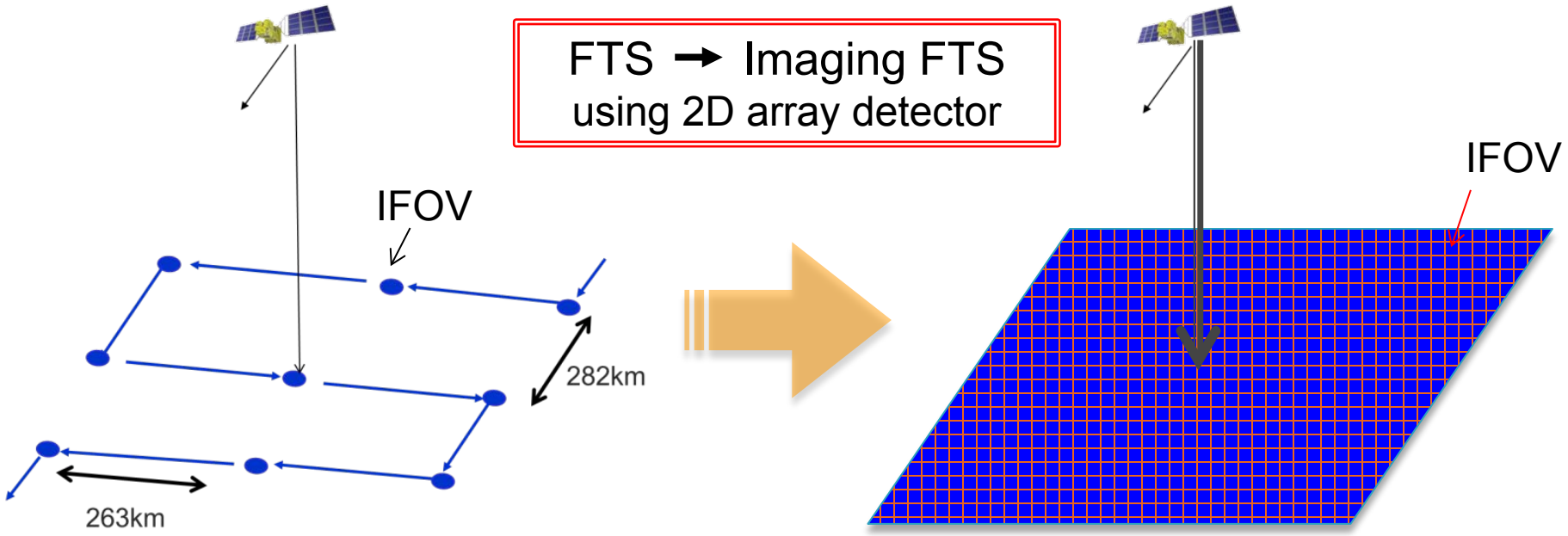
Observation of atmospheric pollution in Asia and trans-boundary pollution



Frequent sounding of temperature, water vapor and wind profiles.

Geostationary Imaging FTS

Expanding the GOSAT FTS technology

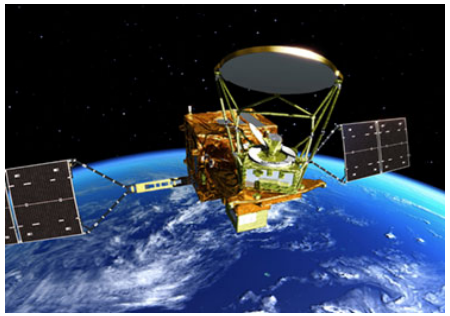


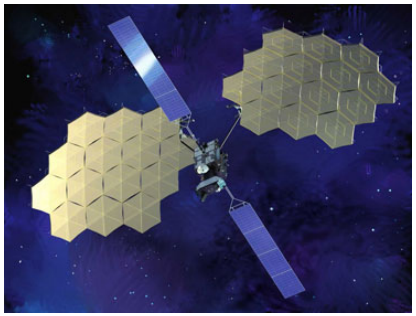
GOSAT observation

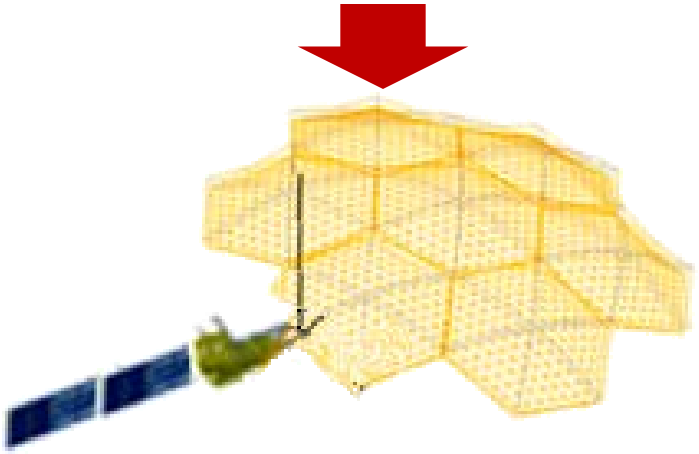
Imaging FTS observation

Large-Aperture MWR

- Experiences and existing technologies in microwave radiometer (MWR) and large deployable reflector (LDR).







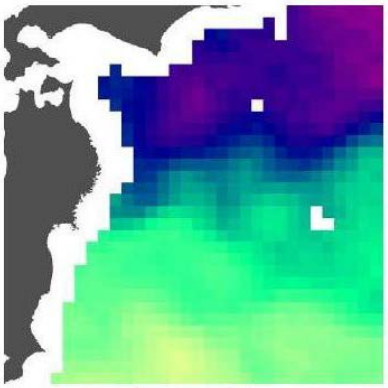
Large-aparture low-freq MWR

Target:

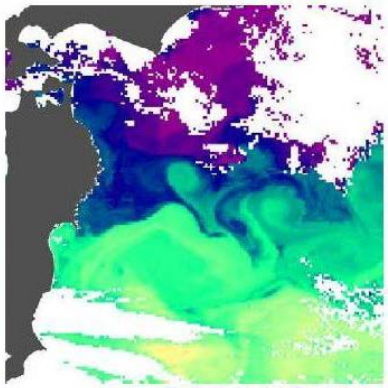
5km @ C-band

20km @ L-band

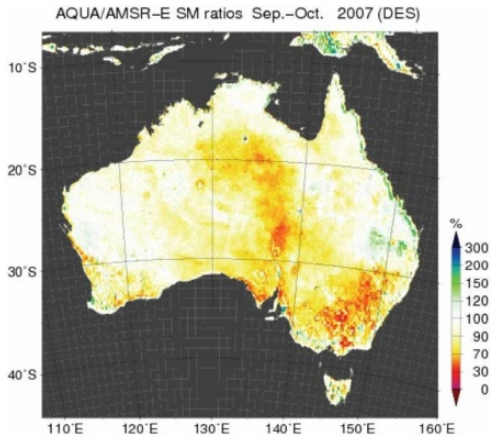
- High-res requirements for lower frequency channels (C and L) to retrieve soil moisture, SST, and SSS.
- Applications in agriculture, food security, and ocean safety.



(b) 25 km 海面水温 (AMSR-E)



(c) 5 km 海面水温（仮）

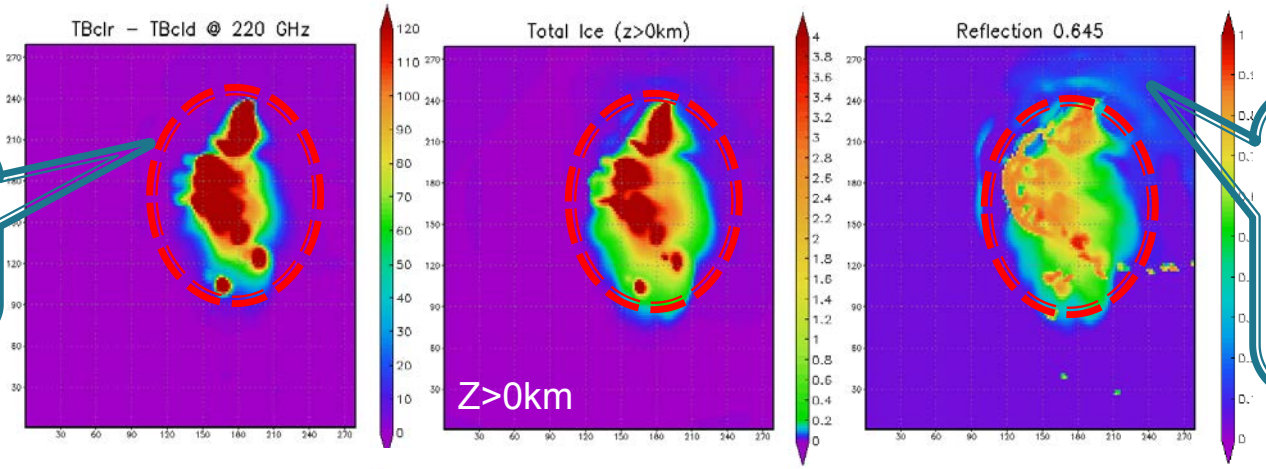


Submillimeter-Wave Radiometer

Submillimeter wave | Cloud Ice | VIS/IR

190GHz

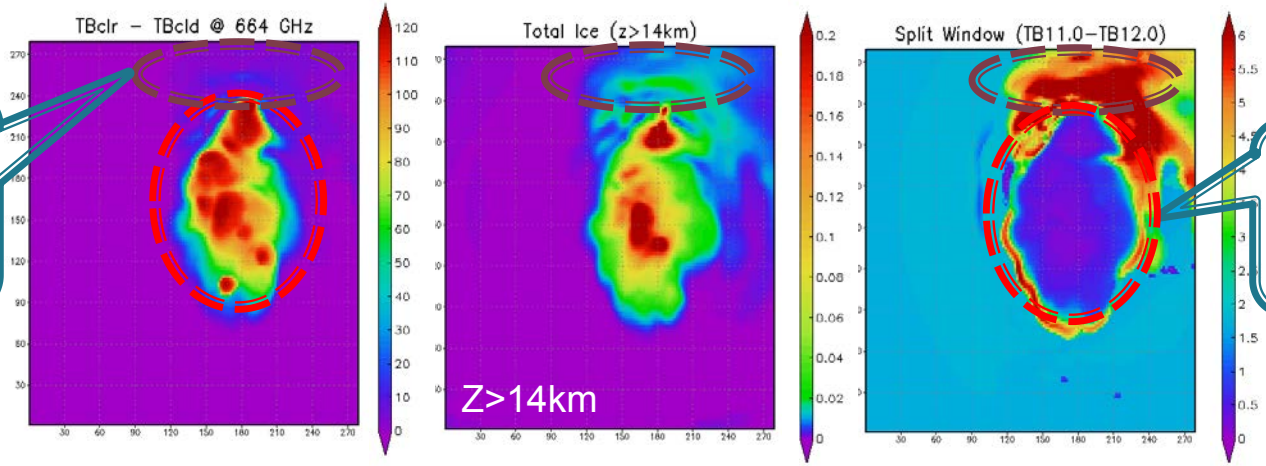
Submm captures columnar ice well



Various information included, but difficulty in quantitative analysis

640GHz

Thin ice cloud layer can be captured by submm and IR

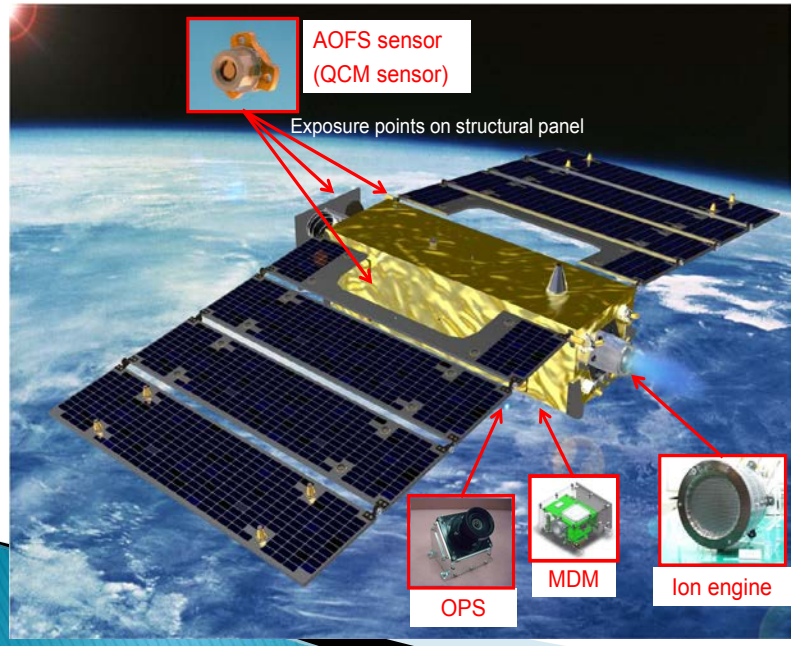


IR saturates at thick ice clouds

Submillimeter wave radiometer (190GHz – 1THz) can capture two dimensional columnar ice amount for both thick convective clouds and anvil clouds.

Super Low Altitude Test Satellite (SLATS)

- Concept of Super Low Altitude Satellite
  - ✓Much lower than LEO altitude: about 200km altitude
  - ✓Cancel the air drag effect by ion engine thrust in order to maintain the altitude
  - ✓Enable high performance earth observation by small resource sensor
    - ➢ High spatial resolution in optical Earth observation
    - ➢ Active sensing such as SAR and LIDAR with low electric power
- "SLATS" is engineering test satellite before operational Super Low Altitude Satellites
  - ✓Verification of super low altitude satellite system, measurement of atmospheric density in super low altitude, and monitoring on-orbit data about atomic oxygen.

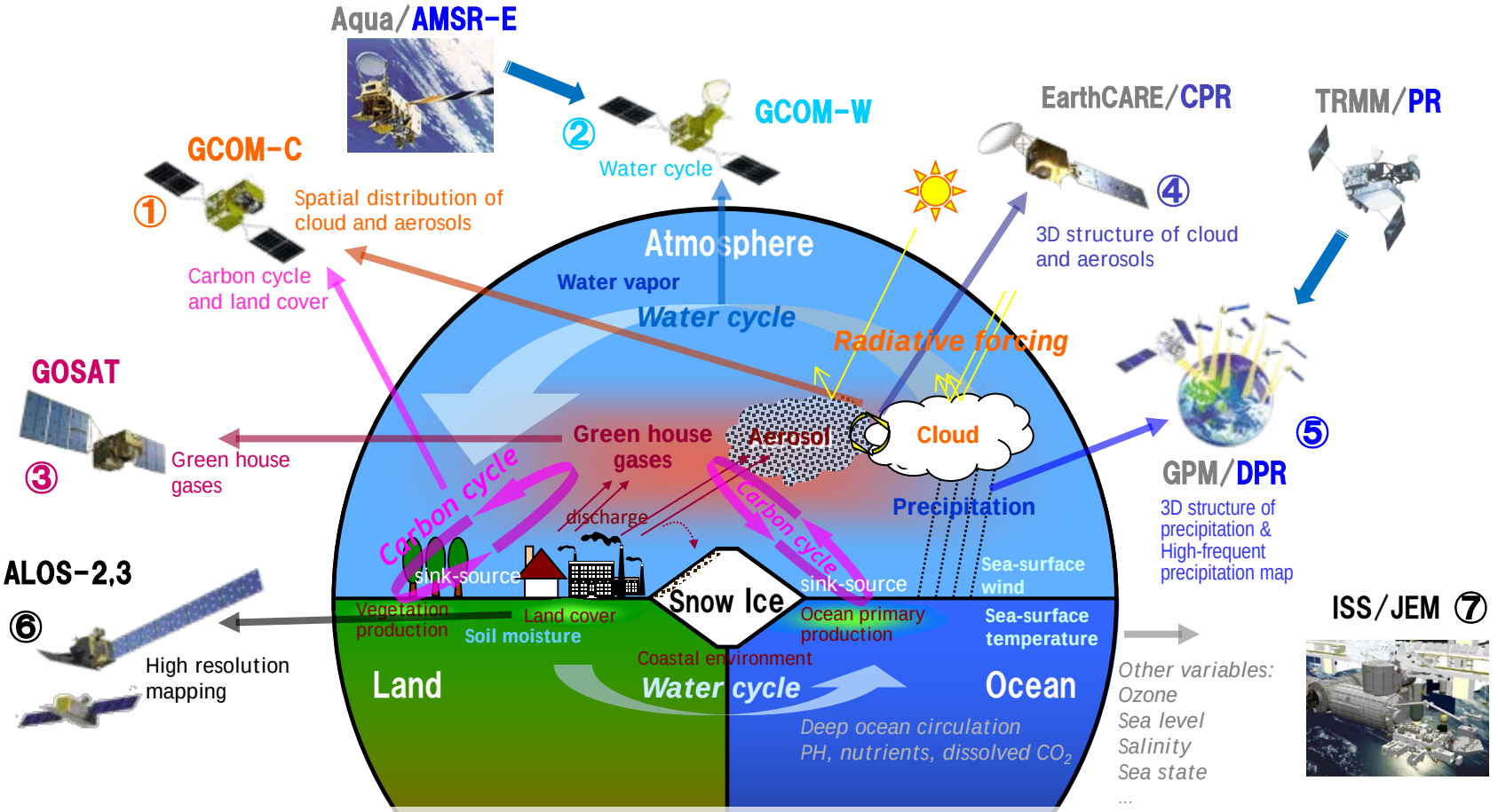


Overview of Super Low Altitude Test Satellite (SLATS)

Orbit	Mission: 250-180km Circular
Size (on-orbit)	2.5m(X)×5.2m(Y)×0.9m(Z)
Mass	about 400kg
Mission life	more than 1.5 year (dependent on injection orbit)
Mission sensor	**(1) AO Monitoring System(AMO)** (a) QCM Sensor and Controller (AOFS) (b) Material Degradation Monitor (Optical Camera)(MDM) **(2) Small Optical Sensor for imaging the earth(OPS)**

Specification of SLATS

Current and Near-Future JAXA EO Missions



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-2,3**: Fine resolution mapping by optical and SAR instruments

⑦ **ISS/JEM**: Demonstration of new missions (e.g., SMILES, GLISM, etc.)

Thank you for your attention.