APPENDIX 1
OVERVIEW OF THE GLOBAL CHANGE OBSERVATION MISSION (GCOM)

1. Introduction

Comprehensive observation, understanding, assessment, and prediction of global climate change are common and important issues for all mankind. This is also identified as one of the important socio-economic benefits by the 10-year implementation plan for Earth Observation that was adopted by the Third Earth Observation Summit to achieve the Global Earth Observation System of Systems (GEOSS). International efforts to comprehensively monitor the Earth by integrating various satellites, in-situ measurements, and models are gaining importance. As a contribution to this activity, the Japan Aerospace Exploration Agency (JAXA) plans to develop the Global Change Observation Mission (GCOM). GCOM will take over the mission of the Advanced Earth Observing Satellite-II (ADEOS-II) and develop into long-term monitoring of the Earth.

As mentioned in the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), warming of the climate system is unequivocal as is now evident from observations of increases in global average air and ocean temperatures and widespread melting of snow and ice. However, climate change signals are generally small and modulated by natural variability, and are not necessarily uniform over the Earth. Therefore, the observing system of the climate variability should be stable, and should cover a long term over the entire Earth.

To satisfy these needs, GCOM consists of two medium-size, polar-orbiting satellite series and multiple generations (e.g., three generations) with one-year overlaps between consecutive generations for inter-calibration. The two satellite series are GCOM-W (Water) and GCOM-C (Climate). Two instruments were selected to cover a wide range of geophysical parameters: the Advanced Microwave Scanning Radiometer-2 (AMSR2) on GCOM-W and the Second-generation Global Imager (SGLI) on GCOM-C. The AMSR2 instrument will perform observations related to the global water and energy cycle, while the SGLI will conduct surface and atmospheric measurements related to the carbon cycle and radiation budget. This chapter presents an overview of the mission objectives, observing systems, and data products of GCOM.

2. Mission Objectives

The major objectives of GCOM can be summarized as follows.

- Establish and demonstrate a global, long-term Earth-observing system for understanding climate variability and the water-energy cycle.
- Enhance the capability of climate prediction and provide information to policy makers through process studies and model improvements in concert with climate model research institutions.
- Construct a comprehensive data system integrating GCOM products, other satellite data, and in-situ measurements.
- Contribute to operational users including weather forecasting, fishery, and maritime agencies by providing near-real-time data.
- Investigate and develop advanced products valuable for understanding of climate change and water cycle studies.

Detailed explanations of the objectives are as follows.

(1) Understanding global environment changes

A) Establish and demonstrate a global, long-term Earth-observing system that is able to observe valuable geophysical parameters for understanding global climate variability and water cycle mechanisms.

B) Contribute to improving climate prediction models by providing accurate values of model parameters.
C) Clarify sinks and sources of greenhouse gases.
D) Contribute to validating and improving climate prediction models by forming a collaborative framework with climate model institutions and providing long-term geophysical datasets to them.
E) Detect trends of global environment changes (e.g., global warming, vegetation changes, desertification, variation of atmospheric constituents, wide area air pollution, and depletion of ozone layers) from long-term variability of geophysical parameters by extracting short-term (three- to six-year) natural variability.
F) Advance process studies of Earth environmental changes using observation data.
G) Estimate radiative forcing, energy and carbon fluxes, and albedo by combining satellite geophysical parameters, ground in-situ measurements, and models.
H) Advance the understanding of the Earth’s system through the activities above.
I) Contribute to an international environmental strategy utilizing the results above.

(2) Direct contribution to improving people’s lives

A) Improvement of weather forecast accuracy (particularly typhoon track prediction, localized severe rain, etc.).
B) Improvement of forecast accuracy for unusual weather and climate.
C) Improvement of water-route and maritime information.
D) Provision of fishery information.
E) Efficient coastal monitoring.
F) Improved yield prediction of agricultural products.
G) Monitoring and forecasting air pollution including yellow dust.
H) Observation of volcanic smoke and prediction of the extent of the impact.
I) Detection of forest fires.

3. Observing Systems

3.1. Overall concept

As mentioned in the previous section, the entire GCOM will consist of two satellite series spanning three generations. However, a budget will be approved for each satellite. Currently, only the GCOM-W satellite has been launched as the first satellite in the GCOM series. Both GCOM-W and GCOM-C satellites will be medium-size platforms that are smaller than the ADEOS-II satellite. This is to reduce the risk associated with large platforms having valuable and multiple observing instruments. Also, since the ADEOS-II problem was related to the solar paddle, a dual solar-paddle design was adopted for both satellites. To assure data continuity and consistent calibration, follow-on satellites will be launched so as to overlap the preceding satellite by one year. The concept is summarized in Fig. 1.

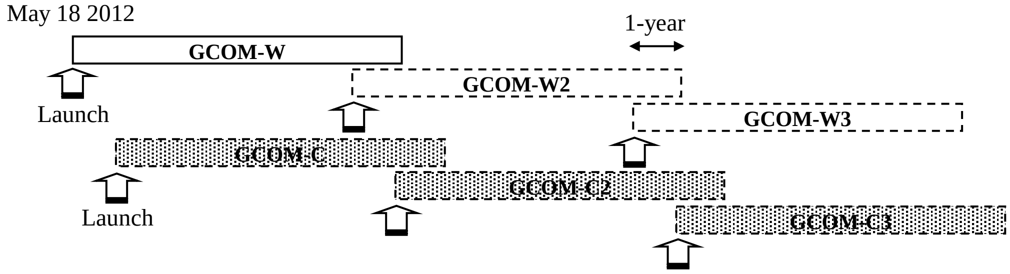

Figure 1: **GCOM Concept**

3.2. GCOM-W and AMSR2 instrument

Figure 2 presents an overview of the GCOM-W satellite; its major characteristics are listed in Table 1. GCOM-W will carry AMSR2 as the sole onboard mission instrument. The satellite will orbit at an altitude of about 700km and will have an ascending node local time of 13:30, to maintain consistency with Aqua/AMSR-E observations.

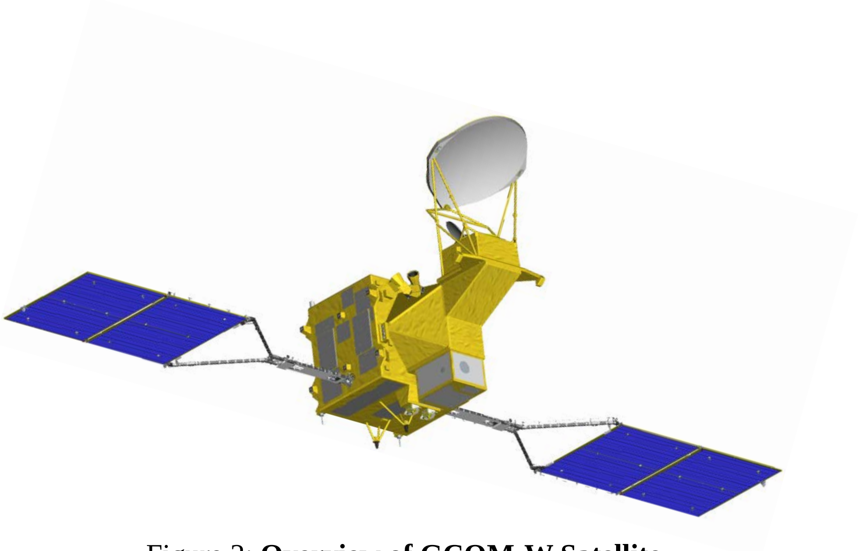

Figure 2: **Overview of GCOM-W Satellite**

Table 1: **Major Characteristics of GCOM-W Satellite**

Instrument	Advanced Microwave Scanning Radiometer-2 (AMSR2)
Orbit	Sun-synchronous orbit Altitude: 700km (over the equator)
Size	5.1m (X) * 17.5m (Y) * 3.4m (Z) (on-orbit)
Mass	1991kg
Power	More than 3880W (EOL)
Launch	May 18, 2012 by H-IIA Rocket
Design Life	5 years
Status	Phase-D

Figure 1 presents an overview of the AMSR2 instrument in two different conditions. Also, basic characteristics including center frequency, bandwidth, polarization, instantaneous field of view (FOV), and sampling interval are indicated in Table 2. The basic concept is almost identical to that of AMSR-E: a conical scanning system with a large offset parabolic antenna, feed horn cluster to realize multi-frequency observation, external calibration with two temperature standards, and total-power radiometer systems. The 2.0m diameter antenna, which is larger than that of AMSR-E, provides better spatial resolution at the same orbit altitude of around 700km. The antenna will be developed based on the experience gained from the 2.0m diameter antenna for ADEOS-II AMSR except the deployment mechanism. For the C-band receiver, we adopted additional 7.3GHz channels for possible mitigation of radio-frequency interference. An incidence angle of 55 degrees (over the equator) was selected to maintain consistency with AMSR-E. The swath width of 1450km and the selected satellite orbit will provide almost complete coverage of the entire Earth's surface within two days independently for ascending and descending observations.

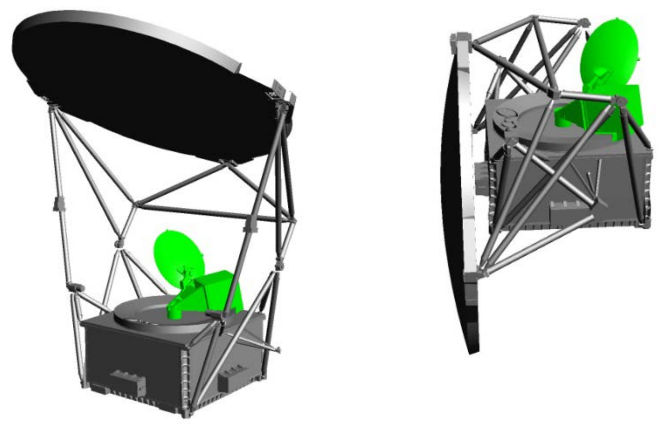

Figure 3: **Sensor Unit of AMSR2 Instrument in Deployed (left) and Stowed (right) Conditions.**

Table 2: **Major Characteristics of AMSR2 Instrument**

Parameter	**Performance and characteristics**					
Center Frequency (GHz)	6.925/7.3	10.65	18.7	23.8	36.5	89.0
Bandwidth (MHz)	350	100	200	400	1000	3000
Polarization	Vertical and Horizontal polarization					
NEΔT (K) [1]	< 0.34/0.43	< 0.70	< 0.70	< 0.60	< 0.70	< 1.20/1.40 [2]
Dynamic range (K)	2.7 to 340					
Nominal incidence angle (deg.)	55.0					55.0/54.5 [2]
Beam width (deg.)	1.8	1.2	0.65	0.75	0.35	0.15
IFOV (km) Cross-track x along-track	35x62	24x42	14x22	15x26	7x12	3x5
Approximate sampling interval (km)	10					5
Swath width (km)	> 1450					
Digital quantization (bits)	12					
Scan rate (rpm)	40					

3.3. GCOM-C and SGLI instrument

Figure 4 gives an overview of the GCOM-C satellite; its major characteristics are listed in Table 3. GCOM-C will carry SGLI as the sole mission onboard instrument. The satellite will orbit at an altitude of about 800km; the descending node local time will be 10:30, to maintain a wide observation swath and reduce cloud interference over land.

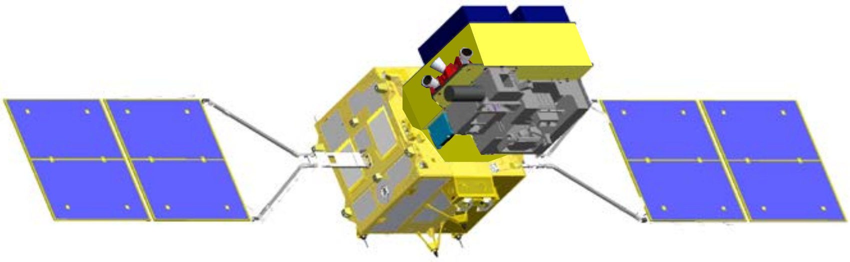

Figure 4: **Overview of GCOM-C Satellite**

Table 3: **Major Characteristics of GCOM-C Satellite**

Instrument	Second-generation Global Imager (SGLI)
Orbit	Sun-synchronous orbit Altitude: 798km (over the equator)
Size	4.6m (X) * 16.3m (Y) * 2.8m (Z) (on orbit)
Mass	2093kg
Power	More than 4000W (EOL)
Launch	JFY2016 by H-IIA Rocket
Design Life	5 years
Status	Phase-C

The SGLI instrument has two major new features: 250m spatial resolution for most of the visible channels and polarization/multidirectional observation capabilities. The 250m resolution will provide enhanced observation capability over land and coastal areas where the influences of human activity are most obvious. The polarization and multidirectional observations will enable us to retrieve aerosol information over land. Precise observation of global aerosol distribution is a key for improving climate prediction models.

SGLI consists of two major components: the Infrared Scanner (IRS) and the Visible and Near-infrared Radiometer (VNR). An overview of the SGLI instrument is shown in Fig. 5 for the entire radiometer layout, IRS, and VNR components. Also, requirements for sensor performance are listed in Tables 4 and 5. VNR can be further divided into two components: VNR-Non Polarized (VNR-NP) and VNR-Polarized (VNR-P). VNR-NP and VNR-P are the 11-channel multi-band radiometer and the polarimeter with three polarization angles (0, 60, and 120 degrees). VNR-P has a tilting function to meet the scatter angle requirement from aerosol observation. The IRS is an infrared radiometer covering wavelengths from 1μm to 12μm. It consists of short infrared (SWI; 1.05 to 2.21μm) and thermal infrared (TIR 10.8 and 12.0μm) sensors. It employs a scanning mirror system with a 45-degree tilted flat mirror rotating continuously to realize an 80-degree observation swath and calibration measurement in every scan.

Through intensive discussions and optimizing studies, the number of SGLI channels was decreased from the 36 channels of GLI aboard ADEOS-II to 19 channels, while the number of SGLI standard products will increase compared to those of GLI.

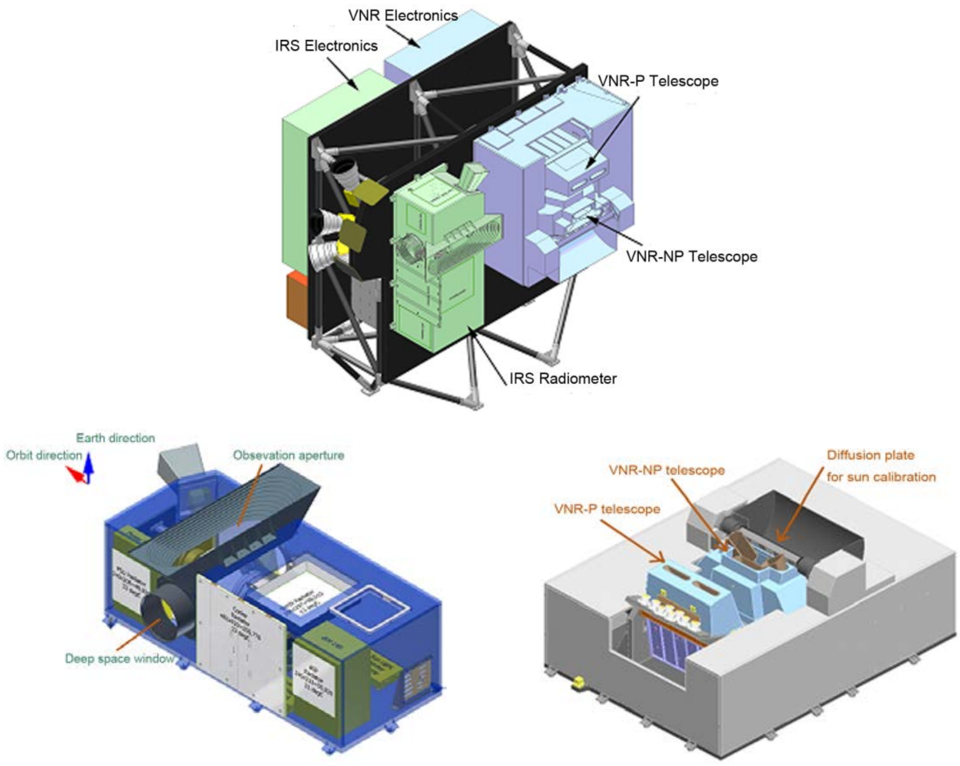

Figure 5: **Overview of SGLI Radiometer Layout (upper), IRS Instrument (lower-left), and VNR Radiometers (lower-right).**

Table 4: **SGLI Major Performance Requirements**

Item	Requirement
Spectral Bands	VNR-NP ：11CH 380-865nm VNR-P ：2CH 673.5, 868.5nm / 0, 60, 120deg Polarization IRS SWI ：4CH 1.05-2.21μm IRS TIR ：2CH 10.8, 12.0μm
Scan Angle	VNR-NP ：70deg (Push broom scanning) VNR-P ：55deg (Push broom scanning) IRS SWI/TIR ：80deg (45deg rotation mirror scanning)
Swath width	1150km for VNR-NP/P 1400km for IRS SWI/TIR
Instantaneous field of view (IFOV) at nadir	VNR-NP ：250m VNR-P ：1000m IRS SWI ：250m(SW3CH), 1000m(SW1,2,4CH) IRS TIR ：500m (250m: option)
Observing direction	±45 degrees in along track direction for VNR-P Nadir for VNR-NP, IRS SWI, and IRS TIR
Quantization	12bit
Absolute Calibration Accuracy	VNR： ≤3% IRS ： ≤5% TIR ： ≤0.5K
Lifetime	5 Years

Table 5: **SGLI Observation Requirement Details**

	CH	λ	Δλ	IFOV	SNR	L (for SNR)
		nm: VNR, IRS SWI μm: IRS TIR		m	SNR: VNR, IRS SWI NEΔT(K): IRS TIR	$W/m^2/sr/\mu m$
VNR-NP	VN1	380	10	250	250	60
	VN2	412	10	250	400	75
	VN3	443	10	250	300	64
	VN4	490	10	250	400	53
	VN5	530	20	250	250	41
	VN6	565	20	250	400	33
	VN7	673.5	20	250	400	23
	VN8	673.5	20	250	250	25
	VN9	763	12	250	1200 (@1km IFOV)	40
	VN10	868.5	20	250	400	8
	VN11	868.5	20	250	200	30
VNR-P	P1	673.5	20	1000	250	25
	P2	868.5	20	1000	250	30
IRS SWI	SW1	1050	20	1000	500	57
	SW2	1380	20	1000	150	8
	SW3	1630	200	250	57	3
	SW4	2210	50	1000	211	1.9
IRS TIR	T1	10.8	0.74	1000/500/250	0.2 (@500m IFOV)	300 (K)
	T2	12.0	0.74	1000/500/250	0.2 (@500m IFOV)	300 (K)

4. Products

Geophysical products made available by GCOM-W and GCOM-C are listed in Tables 6, 7, and 8. There are two categories of data products: standard product and research product. A “standard” product is defined as a product with proven accuracy that is to be operationally processed and distributed. In contrast, a “research” product is a prototype for a standard product and is processed on a research basis. Both tables indicate standard products with shading.

Table 6: **Standard Geophysical Products of GCOM-W**

Product	Areas	Resolution (km)	Accuracy [1] Release threshold	Accuracy [1] Standard	Accuracy [1] Goal	Range	
Integrated water vapor	Global, over ocean	15	±3.5 kg/m^2	±3.5 kg/m^2	±2.0 kg/m^2	0-70 kg/m^2	Vertically integrated (columnar) water vapor amount. Except sea ice and precipitating areas.
Integrated cloud liquid water	Global, over ocean	15	±0.10 kg/m^2	±0.05 kg/m^2	±0.02 kg/m^2	0-1.0 kg/m^2	Vertically integrated (columnar) cloud liquid water. Except sea ice and precipitating areas.
Precipitation	Global, except cold latitudes	15	Ocean ±50 % Land ±120 %	Ocean ±50% Land ±120 %	Ocean ±20% Land ±80 %	0-20 mm/h	Surface precipitation rate. Accuracy is defined as relative error (ratio of root-mean-square error to average precipitation rate) in 50km grid average.
Sea surface temperature	Global, over ocean	50	±0.8 °C	±0.5 °C	±0.2 °C	-2-35 °C	Except sea ice and precipitating areas. Goal accuracy is defined as monthly mean bias error in 10 degrees latitudes.
Sea surface wind speed	Global, over ocean	15	±1.5 m/s	±1.0 m/s	±1.0 m/s	0-30 m/s	Except sea ice and precipitating areas.
Sea ice concentration	Polar region, over ocean	15	±10 %	±10 %	±5 %	0-100 %	Accuracy is expressed in absolute value of sea ice concentration (%).
Snow depth	Land	30	±20 cm	±20 cm	±10 cm	0-100 cm	Except ice sheets and dense forest areas. Accuracy is expressed in snow depth and defined as mean absolute error of instantaneous observations.
Soil moisture	Land	50	±10 %	±10 %	±5 %	0-40 %	Volumetric water content over global land areas including arid and cold regions, except areas covered by vegetation with 2kg/m^2 water equivalent. Accuracy is defined as mean absolute error of instantaneous observations.

1 Accuracy is defined as root-mean-square error of instantaneous values unless otherwise stated. Assumed validation methodologies are not explained here.

Table 7: **Research Products of GCOM-W**

Products	Area	Resolution (km)	Target accuracy	Range
All-weather sea surface wind speed	Ocean	60	± 7 m/s	0 - 70 m/s
High-resolution (10-GHz) sea surface temperature	Ocean	30	± 0.8 °C	9 - 35 °C
Soil moisture and vegetation water content based on the land data assimilation	Africa, Australia	25	soil moisture: ± 8% vegetation water: ± 1 kg/m^2	soil moisture: 0 - 100 % vegetation water: 0 - 2 kg/m^2
Land surface temperature	Land	15	forest area: ± 3 °C nondense vegetation: ± 4 °C	0 - 50 °C
Vegetation water content	Land	10	± 1 kg/m^2	0 - 4 kg/m^2
High resolution sea ice concentration	Ocean in high latitude	5	± 1 %	0 - 100 %
Thin ice detection	Okhotsk sea	15	± 80 %	N/A
Sea ice moving vector	Ocean in high latitude	50	2 components: 3 cm/s	0 - 40 cm/s

Table 8: **Geophysical Products of GCOM-C (1/3)**

Area	*Group*	*Product*	*Category*	*Developer*	*Day/night*	*Production unit*	*Grid size*	*Release threshold**2	*Standard accuracy**2	*Target accuracy**2
common	Radiance	TOA radiance (including system geometric correction)	Standard	JAXA	TIR and land 2.2μm: both, Other VNR, SWI: daytime (+special operation)	Scene	VNR,SWI Land/coast: 250m, offshore: 1km, polarimetory:1km TIR Land/coast: 500m, offshore: 1km	Radiometric 5% (absolute)*3 Geometric<1 pixel	VNR,SWI: 5% (absolute), 1% (relative) *3 TIR: 0.5K (@300K) Geometric<0.5 pixel	VNR,SWI: 3% (absolute), 0.5% (relative) *3 TIR: 0.5K (@300K) Geometric<0.3 pixel
Land	Surface reflectance	Precise geometric correction	Standard	JAXA	Both	Tile, Global (mosaic 1, 8 days, month)	250m	<1pixel	<0.5pixel	<0.25pixel
		Atmospheric corrected reflectance (incl. cloud detection)	Standard	JAXA	Daytime	Tile , Global (1, 8 days, month)	250m	0.3 (<=443nm), 0.2 (>443nm) (scene) *7	0.1 (<=443nm), 0.05 (>443nm) (scene) *7	0.05 (<=443nm), 0.025 (>443nm) (scene)*7
	Vegetation and carbon cycle	Vegetation index	Standard	PI/JAXA	Daytime	Tile , Global (1, 8 days, month)	250m	Grass: 25%, forest: 20% (scene)	Grass: 20%, forest: 15% (scene)	Grass: 10%, forest: 10% (scene)
		fAPAR	Standard	PI/JAXA				Grass: 50%, forest: 50%	Grass: 30%, forest:20%	Grass: 20%, forest: 10%
		Leaf area index	Standard	PI/JAXA				Grass: 50%, forest: 50%	Grass: 30%, forest:30%	Grass: 20%, forest: 20%
		Above-ground biomass	Standard	PI	Daytime	Tile , Global (1, 8 days, month)	1km	Grass: 50%, forest: 100%	Grass: 30%, forest: 50%	Grass: 10%, forest: 20%
		Vegetation roughness index	Standard				1km	Grass and forest: 40% (scene)	Grass and forest: 20% (scene)	Grass and forest: 10% (scene)
		Shadow index	Standard				250m, 1km	Grass and forest: 30% (scene)	Grass and forest: 20% (scene)	Grass and forest: 10% (scene)
	Temperature	Surface temperature	Standard	PI	Both	Tile , Global (1, 8 days, month)	500m	<3.0K (scene)	<2.5K (scene)	<1.5K (scene)
	Application	Land net primary production	Research	PI	Daytime	Global (month, year)	1km	N/A	N/A	30% (yearly)
		Water stress trend	Research	PI	N/A	Tile , Global (1, 8 days, month)	500m	N/A	N/A	10% *13 (error judgment rate)
		Fire detection index	Research	PI	Both*12	Scene or Tile	500m	N/A	N/A	20% *14 (error judgment rate)
		Land cover type	Research	PI/JAXA	Daytime	Global (month, season)	250m	N/A	N/A	30% (error judgment rate)
		Land surface albedo	Research	JAXA/PI	N/A	Tile , Global (1, 8 days, month)	1km	N/A	N/A	10%
Atmosphere	Cloud	Cloud flag/Classification	Standard	PI	Both	Tile , Global（1, 8 day, month）	1km	10% (with whole-sky camera)	Incl. below cloud amount	Incl. below cloud amount
		Classified cloud fraction	Standard		Daytime	Global（1, 8 day, month）	1km (Tile), 0.1deg (global)	20% (on solar irradiance)*9	15% (on solar irradiance)*9	10% (on solar irradiance)*9
		Cloud top temp/height	Standard		Both	Tile , Global（1, 8 day, month）		1K*4	3K/2km (top temp/height)*5	1.5K/1km (temp/height)*5
		Water cloud OT/effective radius	Standard		Daytime	Tile , Global（1, 8 day, month）		10%/30% (Cloud OT/radius)*6	100% as CLW*7	50%*7 / 20%*8
		Ice cloud optical thickness	Standard		Daytime	Tile , Global（1, 8 day, month）		30%*6	70%*8	20%*8
		Water cloud geometrical thickness	Research	PI	Daytime	Tile , Global（1, 8 day, month）		N/A	N/A	300m
	Aerosol	Aerosol over the ocean	Standard	JAXA	Daytime	Tile , Global（1, 8 day, month）		0.1 (Monthly τa_670,865)*10	0.1(scene τa_670,865)*10	0.05 (scene τa_670,865)
		Land aerosol by near UV	Standard		Daytime	Tile , Global（1, 8 day, month）		0.15 (Monthly τa_380)*10	0.15 (scene τa_380)*10	0. 1(scene τa_380)
		Aerosol by Polarization	Standard	PI	Daytime	Tile , Global（1, 8 day, month）		0.15 (Monthly τa_670,865)*10	0.15 (scene τa_670,865)*10	0.1 (scene τa_670,865)
	Radiation budget	Long-wave radiation flux	Research	TBD	Daytime	Tile , Global（1, 8 day, month）		N/A	N/A	Downward 10W/m2, upward 15W/m2 (monthly)
		Short-wave radiation flux	Research	JAXA/PI	Daytime	Tile , Global（1, 8 day, month）		N/A	N/A	Downward 13W/m2, upward 10W/m2

Table 8: **Geophysical Products of GCOM-C (2/3)**

Area	*Group*	*Product*	*Category*	*Developer*	*Day/night*	*Production unit*	*Grid size*	*Release threshold*[*2]	*Standard accuracy*[*2]	*Target accuracy*[*2]
Ocean	Ocean color	Normalized water-leaving radiance (incl. cloud detection)	Standard	PI	Daytime	Scene, Global (1, 8 days, month)	Coast: 250m Offshore: 1km Global: 4-9km	60% (443~565nm)	50% (<600nm) $0.5W/m^2/str/um$ (>600nm)	30% (<600nm) $0.25W/m^2/str/um$ (>600nm)
		Atmospheric correction parameter	Standard					80% (AOT@865nm)	50% (AOT@865nm)	30% (AOT@865nm)
		Photosynthetically available radiation	Standard	JAXA/ PI	Daytime	Scene, Global (1, 8 days, month)		20% (10km/month)	15% (10km/month)	10% (10km/month)
		Euphotic zone depth	Research	PI	Daytime	Scene, Global (1, 8 days, month)		N/A	N/A	30%
	In-water	Chlorophyll-a concentration	Standard	JAXA/PI	Daytime	Scene, Global (1, 8 days, month)		−60 to +150% (offshore)	−60 to +150%	−35 to +50% (offshore), −50 to +100% (coast)
		Total suspended matter concentration	Standard	PI				−60 to +150% (offshore)	−60 to +150%	−50 to +100%
		Colored dissolved organic matter	Standard	PI				−60 to +150% (offshore)	−60 to +150%	−50 to +100%
		Inherent optical properties	Research	PI	Daytime	Scene, Global (1, 8 days, month)		N/A	N/A	a (440): RMSE<0.25, bbp (550): RMSE<0.25
	Temperature	Sea-surface temperature	Standard	JAXA	Both	Scene, Global (1, 8 days, month)	Coast: 500m Others: Same as above	0.8K (daytime)	0.8K (day & night time)	0.6K (day and night time)
	Application	Ocean net primary productivity	Research	PI	Daytime	Scene, Global (1, 8 days, month)	Coast: 500m Others: Same as above	N/A	N/A	70% (monthly)
		Phytoplankton functional type	Research	PI	Daytime	Scene, Global (1, 8 days, month)	Coast: 250m Others: Same as above	N/A	N/A	error judgment rate of large/ small phytoplankton dominance<20%; or error judgment rate of the dominant phytoplankton functional group <40%
		Red tide	Research	PI	Daytime	Scene, Global (1, 8 days, month)		N/A	N/A	error judgment rate <20%
		multi sensor merged ocean color	Research	JAXA/PI	Daytime	Area, Global (1, 8 days, month)	Coast: 250m Offshore: 1km	N/A	N/A	−35 to +50% (offshore), −50 to +100% (coast)
		multi sensor merged SST	Research	TBD	Both			N/A	N/A	0.8K (day & night time)
Cryosphere	Area/ distribution	Snow and Ice covered area (incl. cloud detection)	Standard	PI/JAXA	Daytime	Tile, Global (1, 8 days, month)	250m (Tile), 1km (global)	10% (vicarious val with other sat. data)	7%	5%
		Okhotsk sea-ice distribution	Standard		Daytime	Area (1day)	250m	10%	5%	3%
		Snow and ice classification	Research		Daytime	Global (8 days, month)	1km	N/A	N/A	10%
		Snow covered area in forests and mountains	Research	JAXA	Daytime	Area (1, 8 days)	250m	N/A	N/A	30%
	Surface properties	Snow and ice surface Temperature	Standard	PI	Daytime	Tile, Global (1, 8 days, month)	500m (Tile), 1km (global)	5K (vicarious val with other sat. data and climatology)	2K	1K
		Snow grain size of shallow layer	Standard		Daytime	Tile, Global (1, 8 days, month)	250m (Tile), 1km (global)	100% (vicarious val. with climatology between temp-size)	50%	30%
		Snow grain size of subsurface layer	Research		Daytime	Tile, Global (1, 8 days, month)	1km	N/A	N/A	50%
		Snow grain size of top layer	Research		Daytime	Tile, Global (1, 8 days, month)	250m (Tile), 1km (global)	N/A	N/A	50%
		Snow and ice albedo	Research	PI	Daytime	Global (1, 8 days, month)	1km	N/A	N/A	7%

Table 8: **Geophysical Products of GCOM-C (3/3)**

Area	*Group*	*Product*	*Category*	*Developer*	*Day/night*	*Production unit*	*Grid size*	*Release threshold*2*	*Standard accuracy*2*	*Target accuracy*2*
Cryosphere	Surface properties	Snow impurity	Research	PI	Daytime	Tile, Global (1, 8 days, month)	250m (Tile), 1km (global)	N/A	N/A	50%
		Ice sheet surface roughness	Research	PI	Daytime	Area (Season)	1km	N/A	N/A	0.05 *15
	Boundary	Ice sheet boundary monitoring	Research	JAXA	Daytime	Area (Season)	250m	N/A	N/A	<500m

Common notes:
*1. Heritage levels from ADEOS-II/GLI study are shown by A-C; A: high heritage, B: Remaining issues, C: new or many issues remaining to be resolved
*2. The “release threshold” is minimum levels for the first data release at one year from launch. The "standard" and "research" accuracies correspond to full and extra success criteria of the mission. Accuracies are basically shown by RMSE.

Radiance data notes:
*3. Absolute error is defined as offset + noise; relative error is defined as relative errors among channels, FOV, and so on. Release threshold of radiance is defined as estimated errors from vicarious, onboard solar diffuser, and onboard blackbody calibration because of lack of long-term moon samples

Atmosphere notes:
*4. Vicarious val. on sea-surface temperature and comparison with objective analysis data
*5. Inter comparison with airplane remote sensing on water clouds of middle optical thickness
*6. Release threshold is defined by vicarious val. with other satellite data (e.g., global monthly statistics in the mid-low latitudes)
*7. Comparison with cloud liquid water by in-situ microwave radiometer
*8. Comparison with optical thickness by sky-radiometer (the difference can be large due to time-space inconsistence and large error of the ground measurements)
*9. Comparison with in-situ observation on monthly 0.1-degree
*10. Estimated by experience of aerosol products by GLI and POLDER

Land data notes:
*11. Defined with land reflectance~0.2, solar zenith<30deg, and flat surface. Release threshold is defined with AOT@500nm<0.25
*12. Night time 250m product can be produced by special observation requests of 1.6μm channel
*13. Evaluate in semiarid regions (steppe climate, etc.)
*14. Fires >1000K occupying >1/1000 on 1km pixel at night (using 2.2um of 1 km and thermal infrared channels)

Cryosphere notes:
*15. Defined as height/width of the surface structures

APPENDIX 2

OVERVIEW OF
THE GLOBAL PRECIPITATION MEASUREMENT (GPM)
AND
THE TROPICAL RAINFALL MEASURING MISSION
(TRMM)

1. Introduction

"Precipitation" is one of most important environmental parameters. Changes in its amount and distribution may affect our everyday life, and they may cause serious damages to human lives and properties. Too much precipitation causes floods, and too less of it causes droughts. Agricultural production depends on precipitation. It is one of the three foremost weather prediction variables along with temperature and wind. Precipitation is a true global variable that determines the general circulation through latent heating, which is an "engine" for circumglobal winds, and reflects climate changes. It is a key component of air-sea interaction and eco-hydrometeorological modeling.

Although there is no doubt that precipitation is such an important component of our environment, it is one of the least known physics components of cloud, weather and climate prediction models. Because of its large variability in space and time, its distribution over the globe is not accurately known. Knowledge of the spatial and temporal distribution of global precipitation is a key to improving our understanding of weather and climate systems.

The Tropical Rainfall Measuring Mission (TRMM) satellite, which is still flying and archiving tropical/subtropical rainfall data more than 11 years, is a joint Japan-US mission. TRMM, launched in the end of November 1997 by the Japanese H-II rocket, focuses on measuring tropical/subtropical rainfall and their diurnal variations, and covers latitude from 35S to 35N. TRMM has three precipitation sensors: the Precipitation Radar (PR), the world first space-borne precipitation radar developed by Japan, and the TRMM Microwave Imager (TMI) and the Visible Infrared Scanner (VIRS) developed by the U.S., which enables observation of rainfall structures by multiple sensors, simultaneously.

Because of the success of the TRMM satellite, several requirements for the successor mission emerged from the science and operational user community. The Global Precipitation Measurement (GPM) mission was proposed to fulfill those requirements. GPM is a satellite program to measure the global distribution of precipitation accurately in a sufficient frequency so that the information provided by this program can drastically improve weather predictions, climate modeling, and understanding of water cycles. Its feasibility has been studied at Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA). Accurate measurement of precipitation will be achieved using the Dual-frequency Precipitation Radar (DPR) installed on the GPM Core Observatory. The DPR on the GPM Core Observatory is being developed by JAXA and the National Institute of Information and Communications Technology (NICT).

2. The Tropical Rainfall Measuring Mission (TRMM)

The Tropical Rainfall Measuring Mission (TRMM) satellite (Figure 1) was launched by H-II rocket No. 6 in November 1997, and completed its mission in April 2015.

Major characteristics of the TRMM satellite are described in Table 1. TRMM is joint mission between Japan (JAXA (former NASDA) and NICT (former CRL)) and the U.S. (NASA). The major objective of TRMM is to determine accurate rainfall amount associated with tropical convective activities, which is a drive source of global atmospheric circulation. To this purpose, the TRMM satellite focuses on rainfall observation, and carries the world's first satellite-borne Precipitation Radar (PR) developed by Japan, in addition to conventional instruments such as infrared imager and microwave imager (TRMM Microwave Imager: TMI). The combination use of PR and TMI has greatly improved the estimation of rainfall amount and has succeeded in observing climate changes, as with El Niño and La Niña. Since the three-dimensional structure of rainfall over the land and ocean can be derived from PR, TRMM has also revealed the three-dimensional structure of typhoons over the ocean, which was rarely observed before TRMM. The success of TRMM shows the potential of satellite remote sensing contributions for understanding the water cycle on Earth and improving weather forecasts.

The TRMM satellite also targets rainfall observation in the tropics and sub-tropics. In order to measure tropical rainfall that has large diurnal variation, it flies in non-sun-synchronous orbit with an inclination angle of 35°. Although the designed lifetime of the satellite was about 3 years, the satellite altitude was boosted from 350 km to 402.5 km in August 2001 to extend the lifetime by reducing atmospheric drag. In March 2009, more than 11 years after the satellite's launch, it continues its excellent observation and provides valuable meteorological and climatological data relating to precipitation, through long-term observation of the current status of rainfall in the tropics and sub-tropics, for understanding water cycle mechanisms.

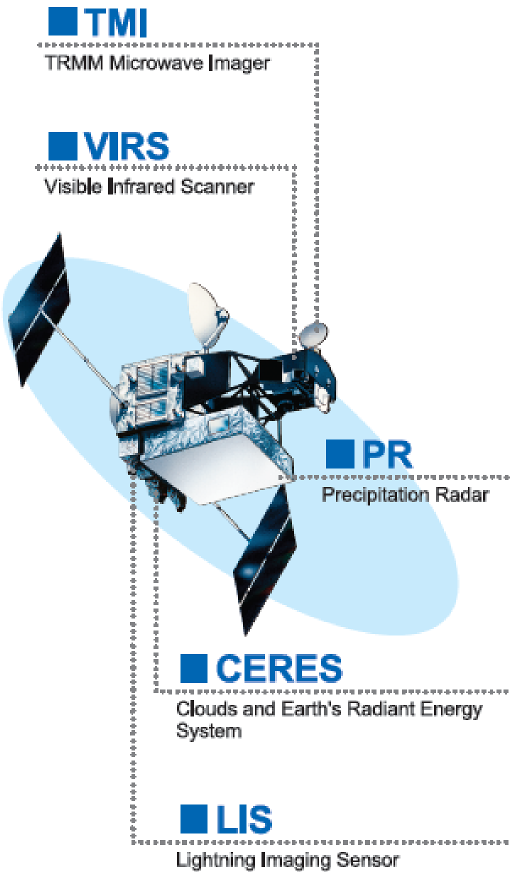

Figure 1 Overview of the TRMM Satellite and the Five on board Sensors

Table 1 Major Characteristics of the TRMM Satellite

Orbit	Non-sun-synchronous circular orbit
Inclination	Approx. 35 degrees
Altitude	Approx. 350 km (402.5 km since August 24, 2001)
Launch date	November 28, 1997 6:54 AM (JST)
Design life	3 years and 2 months
Mission instrument	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible Infrared Scanner (VIRS) Lightning Imaging Sensor (LIS) Clouds and Earth's Radiant Energy System (CERES)

3. The Global Rainfall Measurement (GPM)

3.1 From TRMM to GPM

As accuracy of satellite precipitation estimates improves and observation frequency increases, application of those data to societal benefit areas, such as weather forecasts and flood predictions, is expected, in addition to research of precipitation climatology to analyze precipitation systems. There is, however, limitation on single satellite observation in coverage and frequency. Therefore, the Global Precipitation Measurement (GPM) mission was proposed under international collaboration to fulfill various user requirements that cannot be achieved by the single TRMM satellite.

One major characteristic of GPM as follow-on and expansion of TRMM is to operate the GPM Core Observatory, which carries an active precipitation radar and a passive microwave radiometer, with a non-sun-synchronous orbit as a calibrator to other satellites. The other is a collaboration with a constellation of several satellites developed by each international partner (space agency) that carries passive microwave radiometers and/or microwave sounders, to increase observation frequency. Although the TRMM satellite focused on observation of the tropics, the GPM mission covers broader areas, including high latitudes.

3.2 Concept of the GPM **M**ission

TRMM is single satellite mission for scientific research. On the other hand, the GPM mission (Fig. 2) is an international mission to achieve high-accurate and high-frequent rainfall observation over a global area. GPM is composed of a TRMM-like non-sun-synchronous orbit satellite (GPM Core Observatory) and multi-satellites carrying microwave radiometer instruments (constellation satellites). The GPM Core Observatory carries the Dual-frequency Precipitation Radar (DPR), which is being developed by JAXA and NICT, and the GPM Microwave Imager (GMI) provided by NASA, and will achieve more accurate but narrower observation as a calibrator to other constellation satellites. Constellation satellites, which carry a microwave imager and/or sounder and are planned to be launched around 2014-2018 by each partner agency for its own purpose, and will contribute to extending coverage and increasing frequency.

To take over the results that have been achieved by TRMM and to facilitate development of those results, the GPM mission is planned to meet user requirements that cannot be achieved by TRMM or are expected to be improved in GPM: 1) expansion of observation coverage; 2) increase of observation frequency; and 3) improvement of observation accuracy.

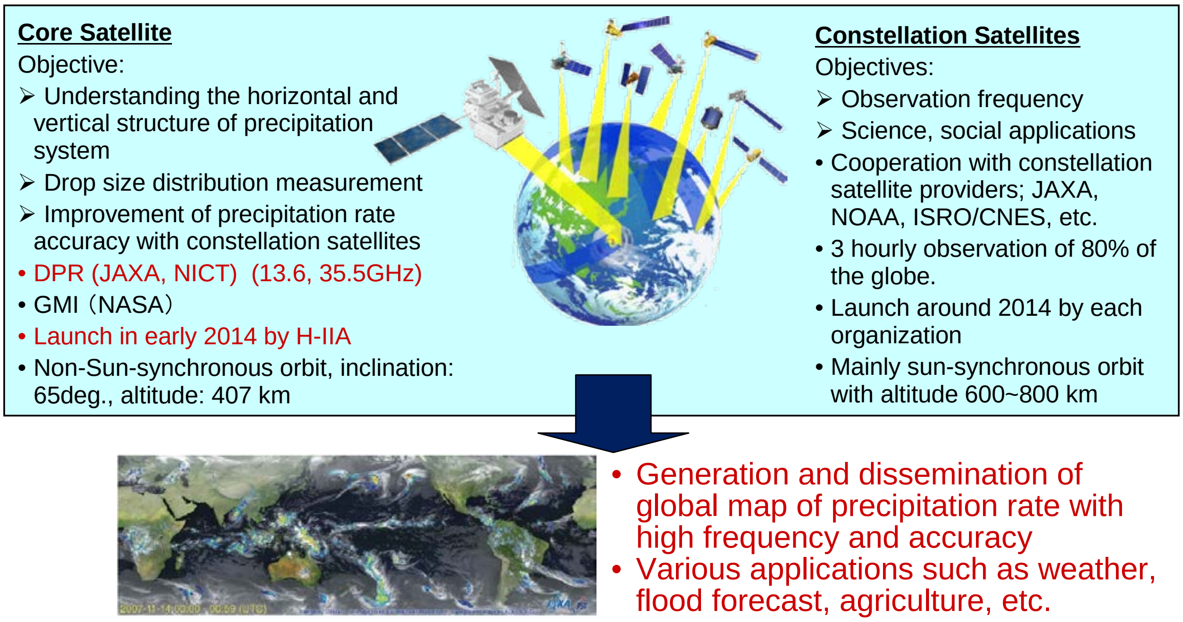

Figure 2 Overview of the GPM Mission

3.3 Overview of the GPM Core Observatory

The GPM Core Observatory (Table 2 and Figure 3), which is being jointly developed by Japan and the U.S., was launched in February 2014. The core satellite carries a Dual-frequency Precipitation Radar (DPR) developed by Japan, and a GPM Microwave Imager (GMI) developed by U.S. The orbit of the core satellite is non-sun-synchronous with an inclination angle of 65°. This orbit was selected to meet certain requirements, such as to measure diurnal variation of rainfall in mid- and high-latitudes as well as the tropics for around 2 months.

Table 2 Major Characteristics of the GPM Core Observatory

Orbit	Non-sun-synchronous
Inclination	65 degrees
Altitude	407 km
Launch date	February 28, 2014 03:36 AM (JST)
Mission life	3 years (target: 5 years)
Mission instrument	Dual-frequency Precipitation Radar (DPR) GPM Microwave Imager (GMI)

The Dual-frequency Precipitation Radar (DPR) on board the GPM Core Observatory is composed of two radars: a Ku-band (13.6-GHz) Precipitation Radar (KuPR) and a Ka-band (35.5-GHz) Precipitation Radar (KaPR). KaPR aims at sensitive observation, and can detect weaker rainfall and snowfall that cannot be measured by KuPR. Since KuPR can detect heavier rainfall, simultaneous observation of KaPR and KuPR will enable accurate measurement of precipitation from heavy rainfall in the tropics to weak snowfall in high latitudes. Rain echo is affected by precipitation attenuation, and its amount depends on radar frequency and raindrop size. By matching position of radar beams and timing of transmitted pulses for KuPR and KaPR, and measuring precipitation particles at the same place simultaneously by dual-frequency, size of precipitation particles (raindrop size distribution) can be estimated by differences in precipitation attenuation. This information cannot be obtained by single-frequency radar, such as TRMM’s PR, and will improve accuracy of precipitation estimation. It is also expected to identify rainfall and snowfall by using differences in precipitation attenuation for dual-frequency.

The GPM Microwave Imager (GMI) instrument on board the GPM Core Observatory is a multi-channel conical-scanning microwave radiometer developed by NASA, and it is based on the TMI on board the TRMM satellite. The major role of the GMI is to improve accuracy of rainfall/snowfall estimates by simultaneous observation with the DPR, and to work as a bridge between highly accurate observation by the core satellite and frequent observations by the constellation satellites. GMI is also expected to serve as a 'radiometric standard' for the other microwave radiometers on board the GPM constellation satellites, and to reduce differences in rain rate estimation arising from biases of instruments. The GMI is characterized by thirteen microwave channels ranging in frequency from 10 GHz to 183 GHz. In addition to carrying channels similar to those on the TRMM Microwave Imager (TMI), the GMI carries four high frequency, millimeter-wave, channels of about 166-GHz (‘window’ channel) and 183-GHz (water vapor channel). Addition of those high frequency channels is expected to contribute to improvements in accuracy of weak rainfall and snowfall estimates, especially over the ocean and land in high-latitudes. With a 1.2 m diameter antenna, the GMI will provide significantly improved spatial resolution over TMI.

The roles of the GPM primary satellite are to collect as much microphysical information as possible for accurate rain estimation by performing synchronous observation with the GMI and the DPR and to provide calibration standards for the other microwave radiometers on the constellation satellites.

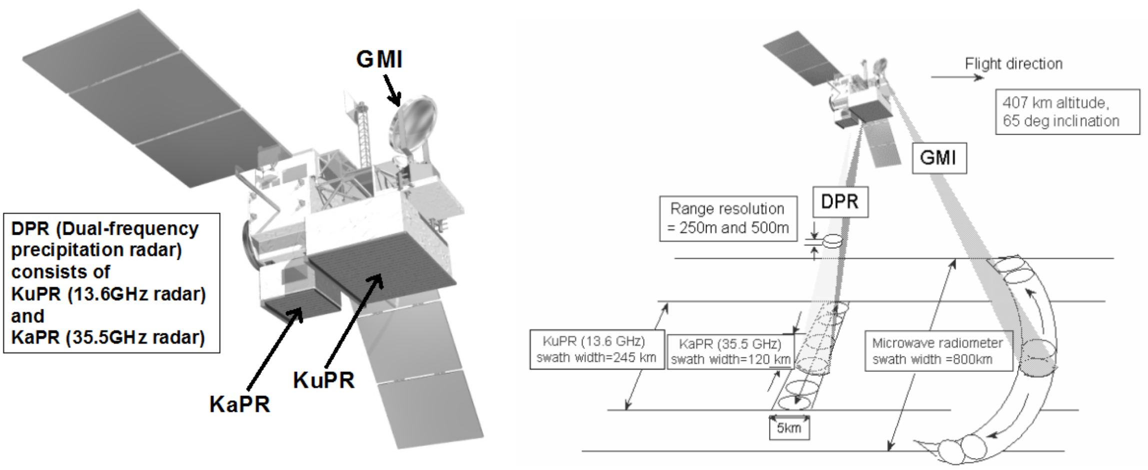

Figure 3 Overview of the GPM Core Satellite and Concept of Precipitation Observation

3.4 Collaboration with Constellation Satellites

In the case of low orbital satellites, such as TRMM and Aqua, single-satellite cannot observe frequently at each local point. To overcome this weakness and achieve frequent observation, the GPM mission will work with other satellite missions in the world. Figure 4 shows how the observation area covered in 3 hours by microwave radiometers on polar-orbiting satellites increases with the number of satellites. As the number increases, the coverage for a given time increases, and hence the sampling interval at a given point decreases. In the GPM era, eight sun-synchronous polar-orbiting satellites enable global observation of precipitation every 3 hours. In the GPM era, one primary satellite and eight constellation satellites will produce 3-hour global precipitation maps that will be delivered to users in near real time.

Constellation of several satellites developed by each international partner (space agency) will carry passive microwave radiometers and/or microwave sounders and be in operation around 2014-2018. The DPR and GMI instruments on board the core satellite will serve as a 'calibrator' for data obtained by constellation satellites.

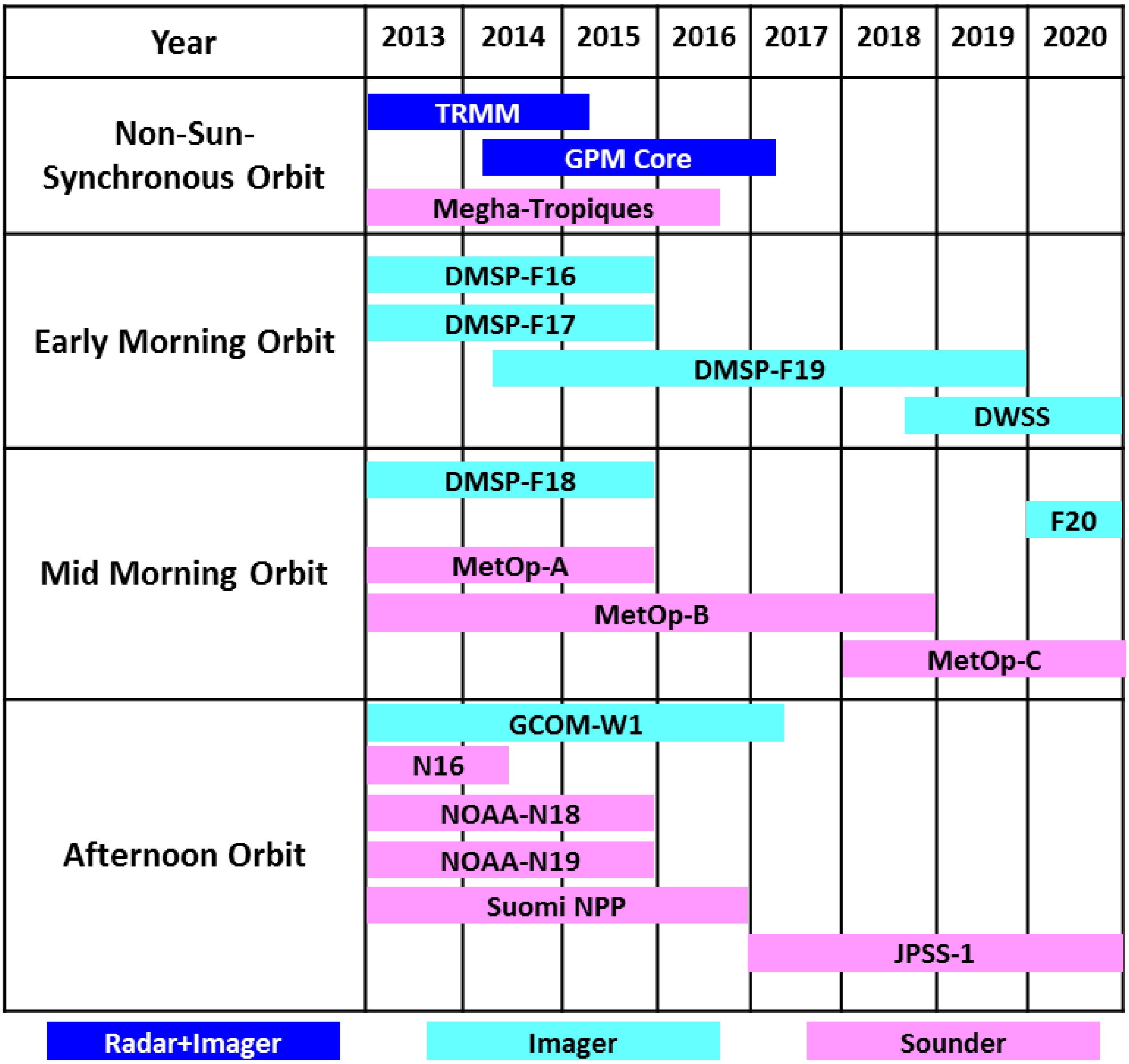

Figure 4 Worldwide Missions for Satellite Precipitation Observation (2013-2020) as of April 2015.

APPENDIX 3

OVERVIEW OF
THE EARTH CLOUD, AEROSOL AND RADIATION EXPLORER (EarthCARE) MISSION

1. Introduction

1.1 Cloud and Climate Change

Since the last report of IPCC (Third Report), the level of scientific understandings regarding the effect of aerosols and clouds, show a good progress. From the most recent report (Fourth Assessment Report; FAR), carbon dioxide is said to be the largest factor to the influence of the global warming. However, the effect of carbon dioxide to the global warming is considered to have been evaluated with a good accuracy. On the other hand, the radiative forcing of clouds and aerosols still remains as the dominant uncertainty in the prediction of the climate change in the future. It is reported that -0.5 W/m^2 for aerosol direct effect and -0.7 W/m^2 for cloud albedo effect, -1.2 W/m^2 as total aerosol, are counted for radiative forcing relating with aerosol/cloud. The figure is large enough comparing with the total anthropogenic radiative forcing; +1.6 W/m^2. We have to make a special attention to the fact that the uncertainty of the cloud albedo effect, i.e. interactions between aerosol and cloud, is very large; 2 W/m^2. This leads, without the correct understanding of the interaction between aerosol and cloud, climate change to remain uncertainties to predict future status with sufficient accuracy.
Furthermore, FAR suggests that the cloud life cycle process should be examined not just for cloud forming but also for the precipitation process or cloud termination process, which will affect global radiation budget through latent heat release and changing the radiative characteristics of the ground surface by such as snowing (IPCC, 2007).

1.2 EarthCARE mission and instruments

Japanese Aerospace Exploration Agency (JAXA), National Institute of Information and Communications Technology (NICT) and European Space Agency (ESA) are going to materialize a project named “Earth Cloud, Aerosol and Radiation Mission; EarthCARE”. EarthCARE is a challenging mission toward to solve the issues noted in the previous section. The observation scope of the EarthCARE is to observe globally such processes; the aerosol distribution, cloud forming with aerosol interaction and beginning of precipitation. To materialize such observation, four instruments were chosen, with their respective needs, to load on EarthCARE; LIDAR (light detection and ranging) and Doppler Radar for the aerosol/cloud profile observation, multi spectral imager (MSI) for aerosol/cloud lateral distribution observation and broadband radiometer (BBR) for Earth radiative flux observation. The observations by these instruments guarantee their synchronism and their uniformity in the observation region. In other word, more accurate synergy observations are preserved, by minimizing the differences in the condition of the observations between the instruments, resulted from such as the differences in the timing of the observation. The relationship between target geophysical parameters and instruments is shown in figure 1. The final goal of the mission is to reconstruct aerosol cloud structure with their physical characteristics with the accuracy of 10 W/m2 as radiative flux at top of atmosphere (ESA,2004, Gelsthorpe et.al., 2008).

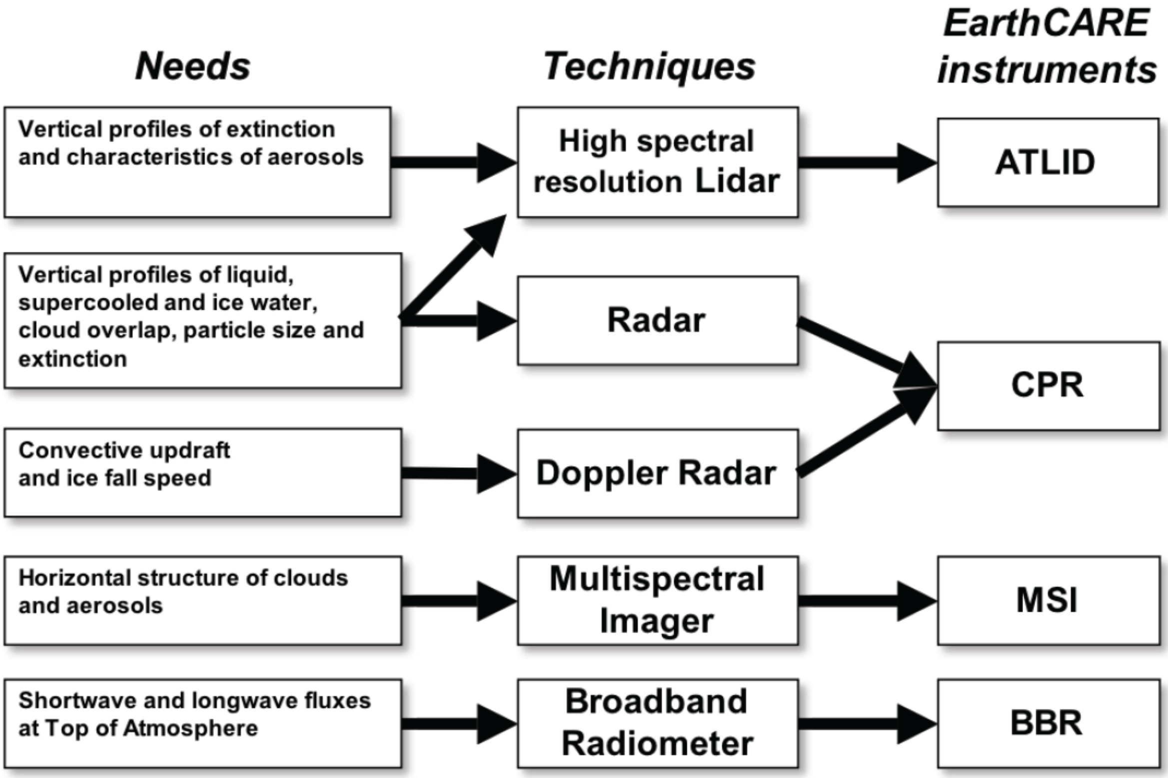

Figure 1 Relationship between target geophysical parameters and instruments

The outlook of EarthCARE satellite and CPR are shown in figure 2. A sun synchronous orbit was chosen as the observational orbit to cover all region of the Earth. Local time at equator of the orbit is 13:45 to 14:00 with consideration of cloud processes being active in the afternoon.
To get the accurate aerosol/cloud observation data, several unique points are implemented for instrumentation. The LIDAR is an Ultra Violet range single wavelength High Spectral Resolution LIDAR. The wavelength, 355 nm, has well sensitivity for the small aerosol particles that are missed by Radar, and make high transmit power possible for its eye safe character. It is possible for the LIDAR signals to be strongly attenuated when they meet dense regions composed by large particles such as clouds. High spectral resolution enables to receive Mie and Rayleigh scattering signals independently. In this way, the optical properties of aerosols can be retrieved directly, without an assumption of liar ratio. Through its polarization measurement, the depolarization ratio can be calculated to estimate the nonsphericity of the observed particle. Doppler W-band Radar penetrates thick cloud layers. Doppler measurement function distinguishes cumulus / convective cloud types and its particle status inside of cloud layer. Using Doppler value, we precisely know kinds of cloud particles. The detailed description of the Doppler Radar is noted in Section 2.1. The MSI has 7 channels with their central wavelengths to be 0.67, 0.865, 1.65, 2.21, 8.8, 10.8 and 12.0 μm, respectively. These channels will be used with split window method to get optical depth and effective radius of cloud and aerosols. Thermal infrared channel can be used to retrieve the cloud top height. The ground resolution of MSI is 500 m^2 and the swath width is 150 km. BBR design is a heritage of past Earth Radiation Mission, such as ERBE or CERES. BBR has two channels; one for the observing shortwave (0.25 ~ 4μm) and the other for longwave (4 ~ 50μm). Three angle radiometer will be used for flux determination considering its angular distribution. The effect of cloud forcing by the reflection of sunlight as well as by its emittance of longwave radiation are expected to be evaluated from the BBR observation. General characteristics for all four instruments are shown in Table 1.

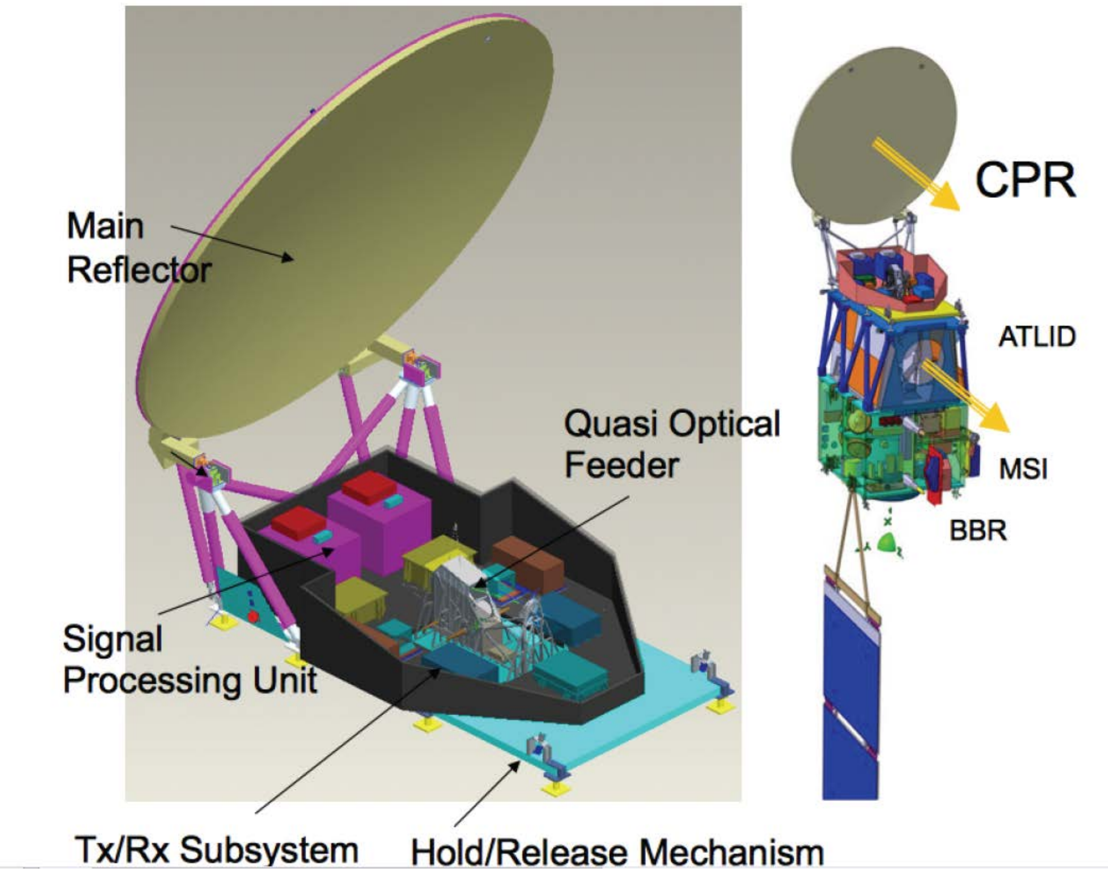

Figure 2. Outlook of CPR and EarthCARE satellite

Table 1 General characteristic of instruments

Instrument	Description
CPR	94 GHz Doppler Radar (see Table 2.)
ATLID	355 nm Hyper Spectral Resolution Lidar with three channels (Mie co-polar, Rayleigh, Mie cross-polar)
MSI	Push broom imager Resolution 500m, swath 150 km Seven channels (0.67, 0.865, 1.65, 2.21, 8.8, 10.8, 12.0 micron)
BBR	Three views radiometer Angle: Nadir, +- 55 deg Two channels; 0.2–4, 4–50 micron

4. Doppler Cloud profiling RADAR

The new space borne radar; Cloud Profiling Radar (CPR) is going to be developed in the cooperation between JAXA and NICT. From CPR observational requirements, we identified following design requirements. First point is the high sensitivity. This requirement is divided into large antenna size requirement, low noise figure of receiver requirement and high power of transmitter requirement. Second point is the Doppler capability. To materialize this function with satisfactory accuracy, large diameter of antenna with precise surface figure and high pulse repetition frequency (PRF) are required. To keep accuracy especially at boundary layer region, several other fine characteristics, such as side lobe characteristics of antenna, cross polarization characteristics and so on, are also required for CPR design.

As the result of design, we chose pulse pair scheme for Doppler measurement. In addition, the diameter of antenna was set as 2.5 m considering the limited diameter of launcher fairing. For transmitter, we employed improved Extended Interaction Klystron (EIK), of which original model is already employed for CloudSAT mission by NASA (Stephens et.al., 2002). The transmit power is 1.5 kW at end of three year mission. For PRF design, CPR has variable control capability of PRF with satellite altitude information. This is for maximizing frequency to keep good coherency between radar pulses, also good sensitivity by having much integration. Outlook of CPR is shown in Figure 2 and major specification of CPR is shown in Table 2.

However, the PRF is a factor of trade off between observational heights. Considering the natural cloud height distribution, the planned operation of CPR is to change observational height with latitude. As natural cloud height distribution, for low latitude region, the cloud height is rather high; in contrast, the polar region cloud height is rather low. The image of CPR operation is shown in Figure 3.

Table 2. General Specifications of CPR

Item	Specification
Radar Type	94 GHz Doppler Radar
Center frequency	94.05 GHz
Pulse width	3.3 micro second (equivalent to 500m vertical resolution)
Beam width	0.095 deg
Polarization	Circular
Transmit power	> 1.5 KW (Klystron spec.)
Height range	-0.5 ~ 20 km
Resolution	500 m (100 m sample); Vertical 500 m integration; Horizontal
Sensitivity*	-35 ~ +21 dBZ
Radiometric accuracy*	< 2.7 dB
Doppler range*	- 10 ~ +10 m/s
Doppler accuracy*	< 1 m/s
Pulse repetition frequency	Variable; 6100 ~ 7500 Hz
Pointing accuracy	< 0.015 degree

; at 10 km integration and 387 km orbit height

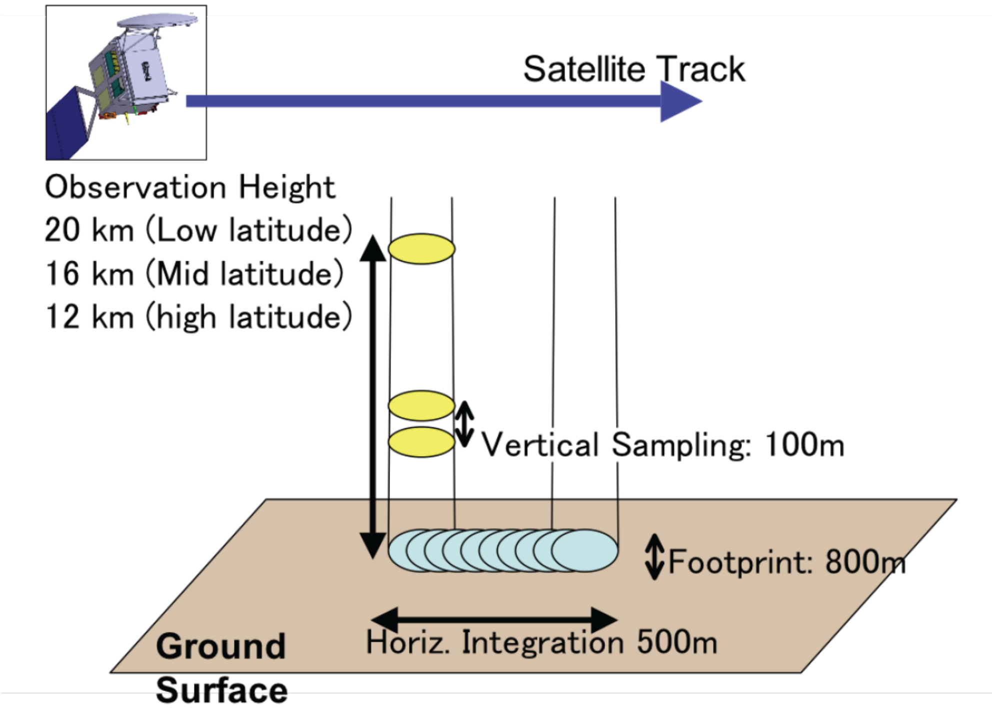

Figure 3. CPR Operation Image

5. Operation Planning

EarthCARE is planned to be launched in JFY2015. The calibrated engineering parameters (Level 1 data) and the retrieved physical parameters (Level 2 data) by all four sensors on EarthCARE will be stored and distributed from both JAXA and ESA. Data are planned to be used by research institutes and agencies in order to improve the accuracies of numerical weather/climate models. The data are also opened to researchers (after appropriate procedures), and are used in the analysis of radiation/aerosol/cloud/precipitation process.

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APPENDIX 4

OVERVIEW OF
THE ADVANCED LAND OBSERVING SATELLITE-2
(ALOS-2) MISSION

1. Introduction

The Advanced Land Observing Satellite-2 (ALOS-2) is succeeding to the radar mission of ALOS which had contributed to cartography, regional observation, disaster monitoring, and resources surveys.

ALOS-2 is equipped with a SAR antenna just under its body and with two solar array paddles at both sides, as shown in Figure 1. The observation data is transmitted directly to a ground station via X-band or through inter-satellite communication via Ka-band. The transmission speed is 800 Mbps maximum for X-band and 278 Mbps for Ka-band, respectively. Table 1 shows system specifications of ALOS-2. The local sun time of it orbit is at noon in order to complement other SAR satellites which are in dawn-dusk orbits.

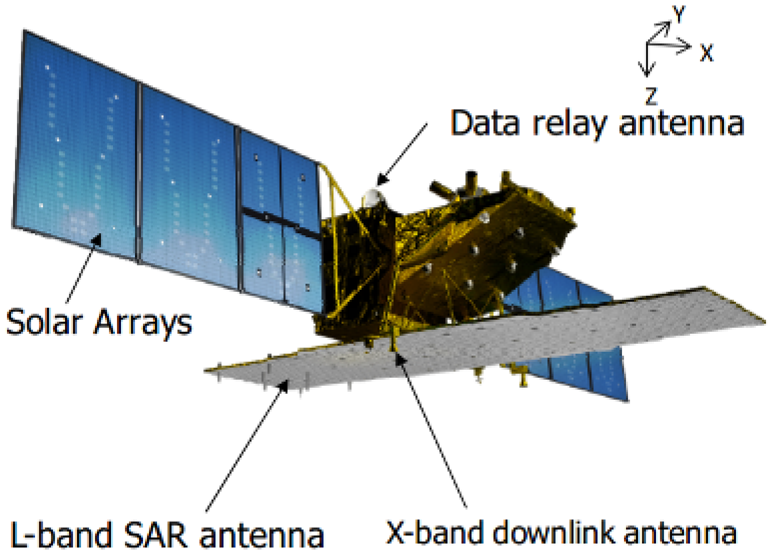

Fig. 1 ALOS-2 in-orbit configuration

Table 1 ALOS-2 specification

Observation mode	Stripmap: 3 to 10 m resolution, 50 to 70 km swath ScanSAR: 100 m/60 m resolution, 350 km/490 km swath Spotlight: 1×3m resolution, 25 km swath
Orbit	Sun-synchronous sub-recurrent orbit Altitude: 628 km Local sun time : 12:00 +/- 15 min Revisit: 14 days Orbit control: < +/-500 m
Launch	May 24, 2014 (JST), H-IIA launch vehicle
Life time	5 years (target: 7 years)
Satellite mass	Approx. 2 tons
Downlink	X-band: 800 Mbps (16QAM), 400/200 Mbps (QPSK) Ka-band: 278 Mbps (QPSK)

2. PALSAR-2 Characteristic

ALOS-2 carries the state-of-the-art L-band Synthetic Aperture Radar (SAR) called PALSAR-2. PALSAR-2 has a Spotlight mode (1×3m resolution in Az×Rg), a Stripmap mode (3 to 10 m resolution) and a ScanSAR mode. The Spotlight mode and a high resolution mode will allow providing users with more detailed data than ALOS/PALSAR. The ScanSAR mode will allow us to acquire a 350 to 490 km width (depends on number of scans) of SAR images at the expense of spatial resolution. The observation frequency of ALOS-2 will also be improved by greatly expanding the observable areas (2,320km). Right-and-left looking function by satellite maneuvering and electric beam steering using active phased array antenna establish the incidence angles from 8 to 70 degrees on both side of the satellite.

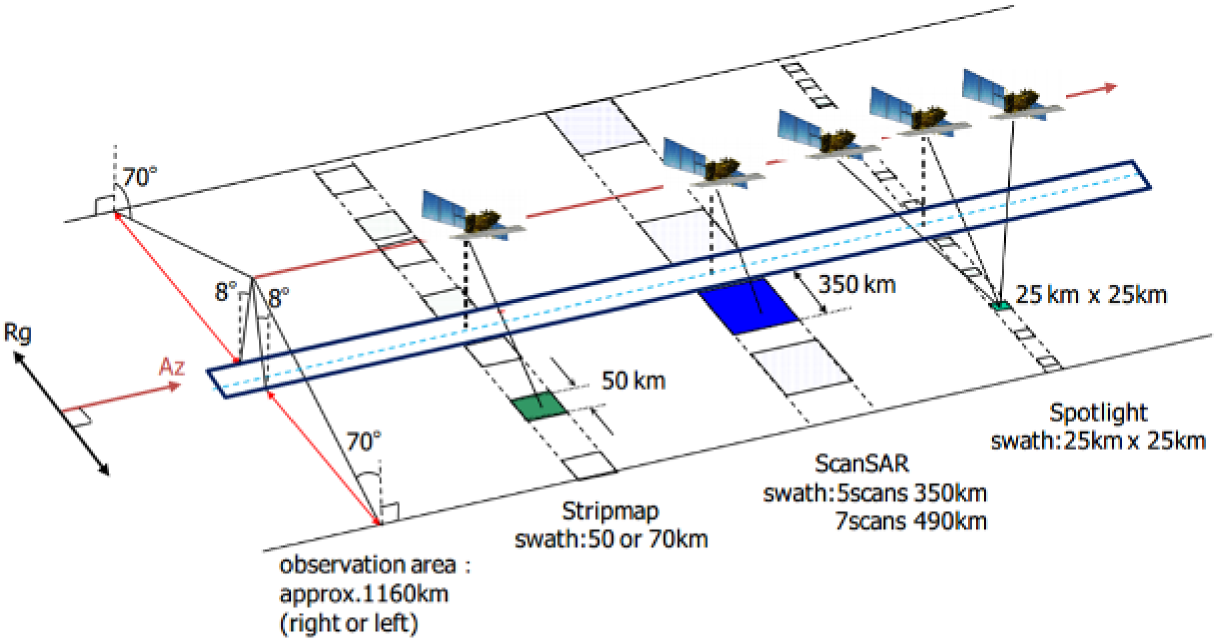

Fig. 2 PALSAR-2 observation modes

Table 2 PALSAR-2 specification

Observation mode		Spotlight	Stripmap			ScanSAR
			Ultra-Fine	High-Sensitive	Fine	
Incidence angle		8 to 70 degrees				
Band width		84 MHz	84 MHz	42 MHz	28 MHz	14 MHz/28 MHz*
Ground resolution		3 m x 1 m (Rg x Az)	3 m	6 m	10 m	100 m (60 m)
Swath		25 km	50 km	50 km	70 km	350 km (490 km)
Polarization		Single	Single/Dual	Single/Dual/ Full/Compact	Single/Dual/ Full/Compact	Single/Dual
NESZ		-24 dB	-24 dB	-28 dB	-26 dB	-26 dB/-23 dB
S/A	Rg	25 dB	25 dB	23 dB	25 dB	25 dB (20 dB)
	Az	20 dB	25 dB	20 dB	23 dB	20 dB

The parameters specified at 37degrees incidence angle above the equator.
* 28 MHz bandwidth in ScanSAR mode is used for only 350 km swath

PALSAR-2 is composed of two subsystems; Antenna subsystem (ANT) and Electric Unit (ELU). ANT is an active phased array antenna, which steers a beam both in elevation and azimuth direction (plus-minus 30 degrees in elevation and plus-minus 3.5 degrees in azimuth). Figure 3 shows the antenna configuration of PALSAR-2. The size of ANT is 10 m in azimuth and 3 m in elevation, and is composed of five electrical panels, which have 180 Transmit-Receive-Modules (TRMs) in total. The Spotlight mode and Ultra-Fine mode use the three of five panels to satisfy resolution requirement and the other modes use all panels. The transmitted power is 3950 W and 6120 W respectively.

Figure 4 shows the system diagram of PALSAR-2. Key components of the Electric Unit (ELU) are Exciter (EX), Transmitter (TX), Receiver (RX), Digital Processor (DP), and System controller (SC). As for RF signal, EX generates pulses, selects two chirp signals (up or down and phase modulation) with a selected center frequency either 1257.5, 1236.5 or 1278.5 MHz in order to avoid interference to Radio Navigation Satellite Services which use L-band, and stretches the signal to a selected bandwidth either 84 MHz, 42 MHz, 28 MHz or 14 MHz. Received radar echo signals are compressed by BAQ or DS-BAQ algorithm. Compression mode is selected from 4 bit, 2 bit, or no compression.

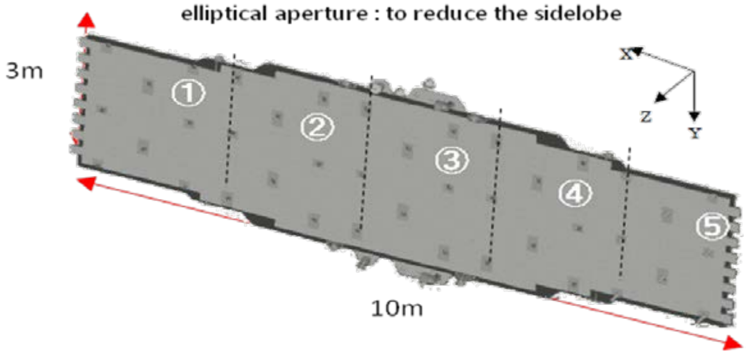

Fig. 3 PALSAR-2 antenna configuration

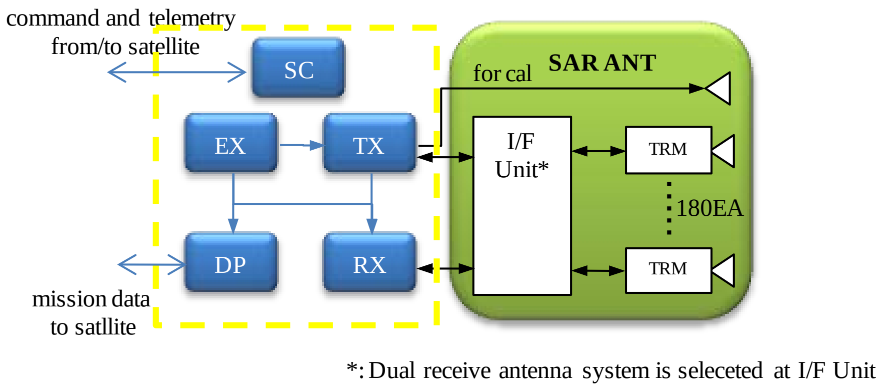

Fig. 4 PALSAR-2 system diagram

3. ALOS-2 Data Products

3.1 Definition of ALOS-2 Data Products

Two categories of data products are defined - level 1 product and higher level products.

3.1.1 Level 1

Level 1 is radiometrically and geometrically calibrated data and is a standard JAXA product for ALOS-2 users.

3.1.2 Higher-level data product

Products above level 2 are higher-level data products. Higher-level data products are made more sophisticated by processing with digital elevation models. This is provided by JAXA's EORC as soon as ready.

3.2 Standard Data Products

Table 3 PALSAR Standard data products

Level	Definition	Note
1.1	Range and azimuth compressed complex data on slant range. Full resolution	Beam modes: Full resolution mode, Low data rate mode, Polarimetric mode SLC: Single Look Complex Used for interferometry
1.5	Multi-look processed image projected to map coordinates. Option G: Systematically Geo-coded (No option: Geo-referenced)	Map projection Resampling Pixel spacing
2.1	Ortho-rectified and slope corrected products	Map projection Resampling Pixel spacing

4 ALOS-2 Operation Concept and Observation Strategy

ALOS-2 is operated based on the Basic Observation Scenario-2 (BOS-2) that is optimized as the background mission while the emergency observation is the highly prioterized operation for the disaster mitigations. The BOS-2 is open to the public through ALOS-2 i.e. *http://www.eorc.jaxa.jp/ALOS/en/top/obs_top.htm*

The BOS-2 is designed to achieve the Earth observation using the several modes of the PALSAR-2, i.e. high resolution strip mode (84 MHz-singe polarization), Dual polarization mode (42 MHz-Dual Polarization), Quad-mode (42 MHz-Full polarization), Dual Strip (28 MHz), and ScanSAR (14 MHz-Dual-350 Km /490 Km swath) for observing the solid earth (deformation study), biosperic study (forest monitoring, carbon estimation) and Cryospheric study (sea-ice, polarer monitoring), and map generation.

APPENDIX 5

課題分野研究概要

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2.2. 水循環・水資源管理 7
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2.4. インフラ変位モニタ 11
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2.6. 生態系 15
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1.　課題分野研究とは

「課題分野研究」とは、ひまわり8号等のJAXA以外の衛星のデータも含め、衛星データを複合的に用いて、あるいは、衛星データ解析技術以外のモデリング技術や同化技術など複数の技術分野を横断的に利用して、課題を解決しようとする利用研究です。

(1) 課題分野研究が目指す方向性

① 衛星データと地球環境モデリングの融合

地球観測衛星はこれまで災害監視や地球環境のモニタリングに大きく貢献してきましたが、今後はこれらに加えて、我々の社会にとって解決すべき地球温暖化や地球環境変化への対応としてグローバルな地球観測データの高度利用をさらに進めて行く必要があります。そのためには、地球環境全体として変化して行く過程を予測する必要があり、そのような過程をシミュレーションできる地球システム統合モデルや環境モデルの開発が各方面で進められていますが、その実施には様々な長期的な衛星観測データが不可欠となっています。また、科学技術イノベーション総合戦略2015においても、地球環境観測・予測技術を統合した情報プラットフォームの構築【総務省、文部科学省、国土交通省、環境省】が謳われています。

② 地球科学と社会利用の両輪としての地球観測

地球観測は、その本来の特性から、ひとつのミッションで地球科学と社会利用の両面に波及効果をもたらすものであります。従って、地球科学と社会利用のミッションを切り離して議論することは、地球観測が本来持っている両面性に鑑みて、極めて非効率な事態を生み出すと考えられます。むしろ、両者がシナジー効果を生み出しつつ発展することが戦略的に有効であります。従って、課題分野研究では、ゴールとして社会利用のみを追求するのではなく、同時に地球科学の発展も目指すものであります。

(2) 課題分野研究一覧

以下に、EORCで行う課題分野研究と利用する衛星データのマトリックスを示します。JAXAでは、各衛星ミッションと、地球観測研究センター（EORC）、衛星利用運用センター（SAOC）が連携して衛星地球観測とその活用を行っています。EORCが主に担当する部分を黄色で示しています。

研究分野 ＼ 衛星		ALOS-2	GPM/TRMM	Earth CARE	GCOM	GOSAT	ひまわり
防災利用		○					
海洋監視	① 船舶監視	○			○		
	② 環境監視		○		○		○
水循環・水資源管理			○		○		○
大気環境物質監視				○	○	○	○
インフラ変位モニタリング		○					
気候システム・放射過程			○	○	○	○	○
生態系		○	○		○	○	○
農業		○	○		○		○
公衆衛生		○	○		○		○

2. 各課題分野研究 概要

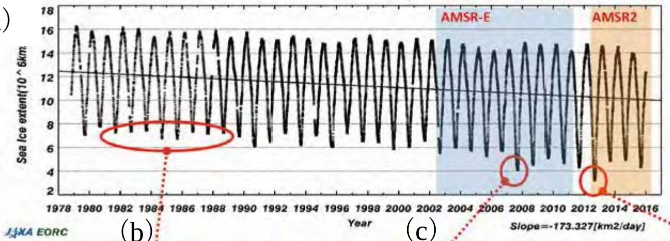
各課題分野研究の概要を次ページ以降に示します。

2.1. 海洋環境監視

海洋環境の変化は、日々の気象現象や漁場の変化のみならず、大規模な大気循環場や気候システム、海洋生態系にも影響を及ぼしています。さまざまな観測データから海面水温、海氷、クロロフィル a 濃度（植物プランクトンが持つ光合成色素）、光合成有効放射（植物の光合成に使われるのに有効な太陽光）などのプロダクトを開発し、データや画像を研究者や一般利用者に提供しています。海洋モデルとの連携により衛星観測の欠測を埋め、衛星から直接観測できない物理量を含めた、連続的な海洋環境データセットを作成し、気候研究や漁業などの現業利用の両面に貢献することを目指しています。

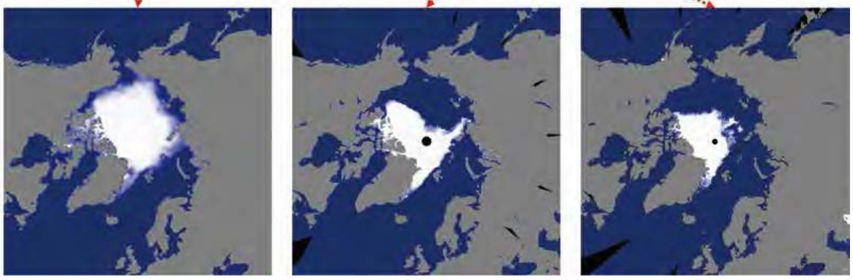
■ マイクロ波放射計による長期的な全天候観測 ―北極海海氷監視

(a)



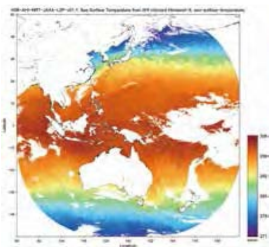
マイクロ波放射計による北極海における海氷面積変化（1978/11～2016/1）

(b) (c) (d)

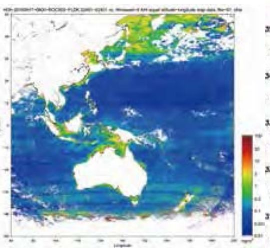


雲を透過して、その下の海氷分布や海面水温を観測可能なマイクロ波放射計は、1978 年以降複数センサで観測を継続することで、気候変動の影響把握に重要な情報を提供しています。北極海氷面積の長期間（1978/11～2016/1）の継続観測（a）により、2007 年 9 月に地球観測衛星「Aqua」の AMSR-E センサが観測史上 2 番目(c)、2012 年 9 月に水循環変動観測衛星「しずく」（GCOM-W）の AMSR2 センサが史上最小の面積（d）を観測しました。

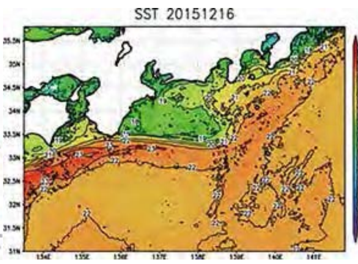
■ 静止衛星による高頻度観測



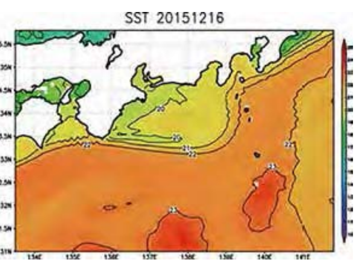
(e) ひまわり 8 号による海面水温の観測



(f) ひまわり 8 号によるクロロフィルの観測



(g) ひまわり 8 号が観測した海面水温を 3km 分解能日本南岸モデルにデータ同化した結果（2015 年 12 月 16 日）



(h) MODIS センサが観測した海面水温を 11km 分解能日本南岸モデルにデータ同化した結果（2015 年 12 月 16 日

2015 年 7 月に運用を開始した静止気象衛星「ひまわり 8 号」は、0.5～2km の空間分解能で、10 分毎にフルディスクの観測を行っています。JAXA では「ひまわり 8 号」から高頻度の海面水温（e）やクロロフィル a 濃度（f）のデータを作成し、さらに協力機関と共に高解像度の海洋モデルにこれらのデータを同化することで(g, h)、衛星とモデルを統合した、新たな海洋環境データセットの構築を目指しています。

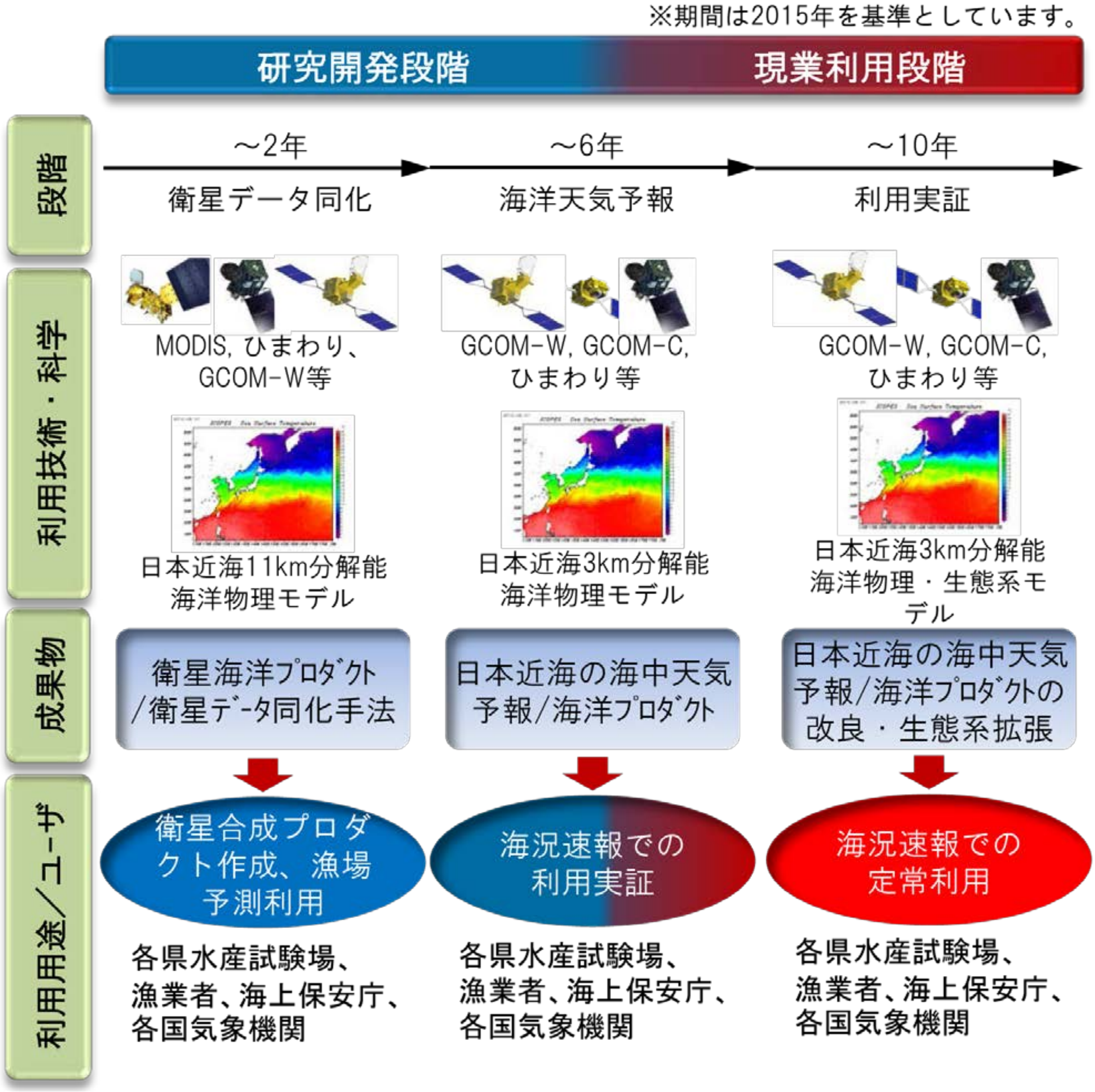
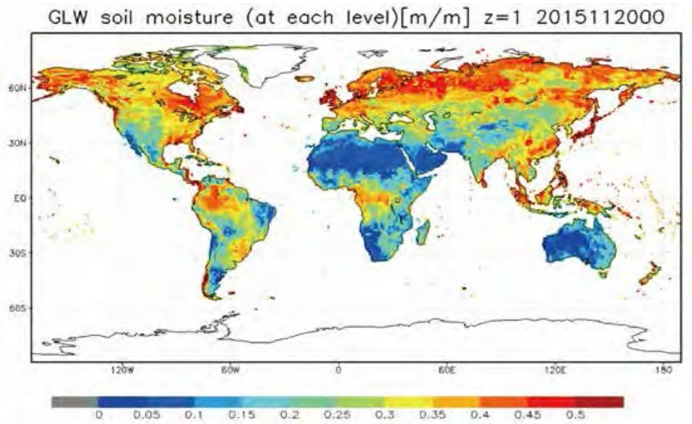


図 活動概要と利用のゴール

2.2. 水循環・水資源管理

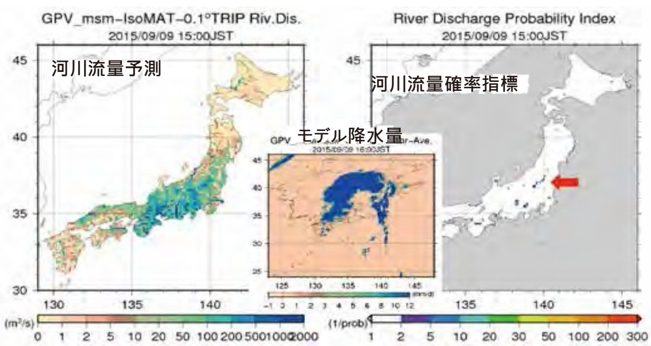
人々の活動がグローバル化する中､近年頻発している気象･気候の変動による洪水･干ばつ等は、局所的な事象ではなく、地球全体に影響を及ぼしています。地球規模で水循環のモニタリングを行い、衛星観測データと陸面の数値モデルを組み合わせて、水・食糧・災害等の問題への対応の鍵となる物理量（河川流量や土壌水分など）を推定し、危険指標などを利用しやすい情報（水循環データセット）として、提供しています。生態系情報と統合するなどの解析を進め、100 億人の水と食料需要を満たすための対策の提言を目指しています。

■ <u>全球 0.5 度格子陸面シミュレーションシステムの構築 ー土壌水分量</u>



これまで 1 度（約 100km）格子だったシステムを、陸面モデルについては 0.5 度（約 50km）、河川モデルについては 0.25 度（約 25km）格子に高解像度化しました。中規模河川の水災害把握に向けて、河川流量や氾濫面積割合の評価を進めています。

■ <u>日本域の高解像度陸面シミュレーションシステムの検討</u>
<u>ー2015 年 9 月 9 日 15 時時点の鬼怒川氾濫の河川流量予測</u>



空間解像度を 10km からより詳細な 1km にすることにより、 世界的にもまだ達成できていない、ローカルスケールの水災害把握が可能な陸域モデルを構築しました。国内一級河川の水災害把握に向けて、衛星と複合した水循環データセット及び危険指標の提供を進めています。

東京大学/芳村准教授提供。Today's Japan（10km 格子）でのシミュレーション結果

■ <u>全球合成降水マップ（GSMaP）just now version (GSMaP_NOW)」の開発と公開</u>

http://sharaku.eorc.jaxa.jp/GSMaP_NOW/index_j.htm

静止気象衛星「ひまわり」の観測範囲内で、観測から 30 分以内に利 用可能なマイクロ波放射計データ（主に、GMI センサ、日本付近の AMSR2 センサ、AMSU 直接受信データ）だけを利用して降雨分布を作成しました。さらに静止気象衛星から計算した雲移動ベクトルによる未来方向へ 30 分間の外挿を行うことで、毎時 0 分、30 分頃に、「実時間の」降雨分布を作成し、実利用ユーザから多かった、配信時間短縮への要望に対応しました。

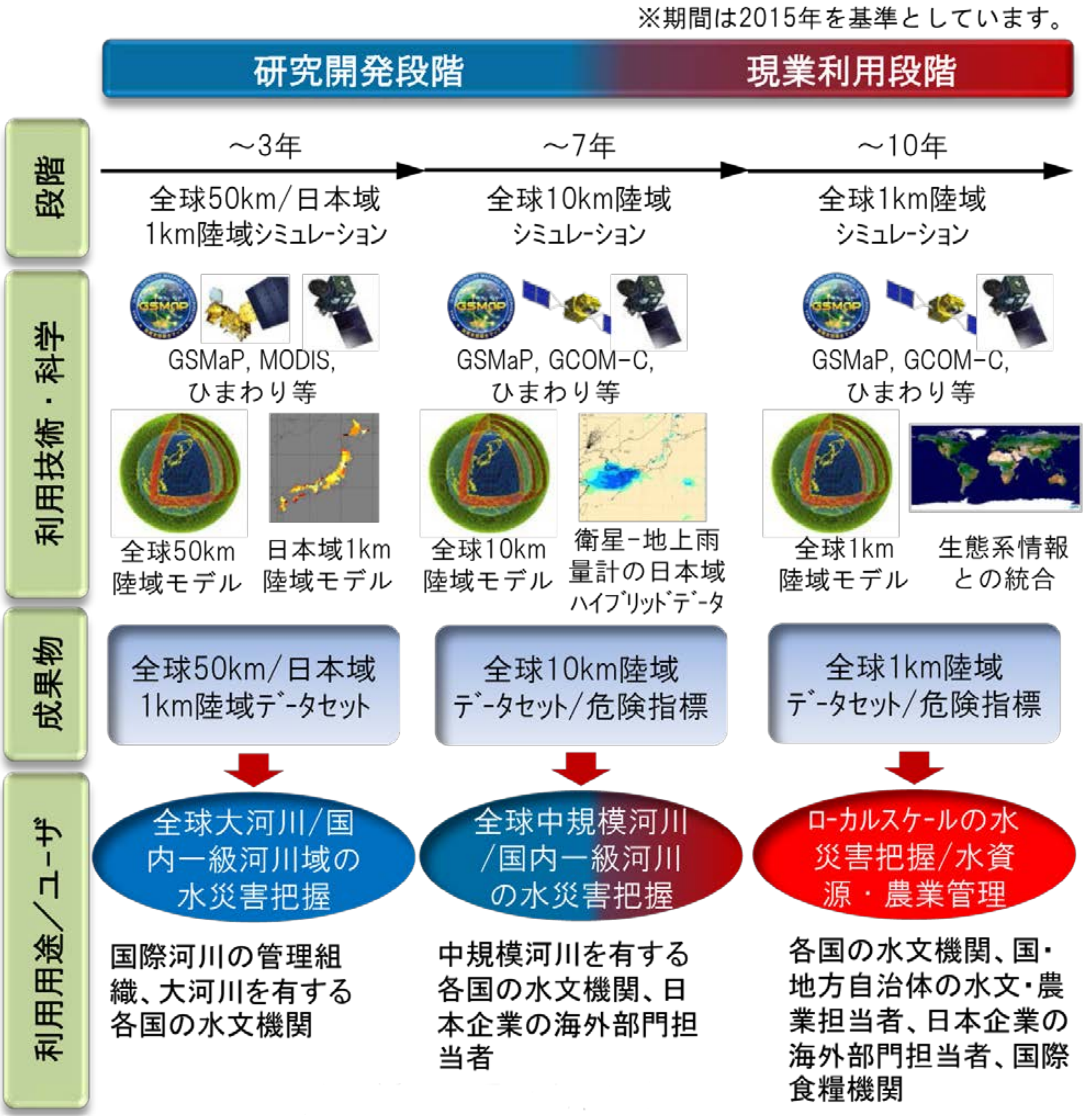


図　活動概要と利用のゴール

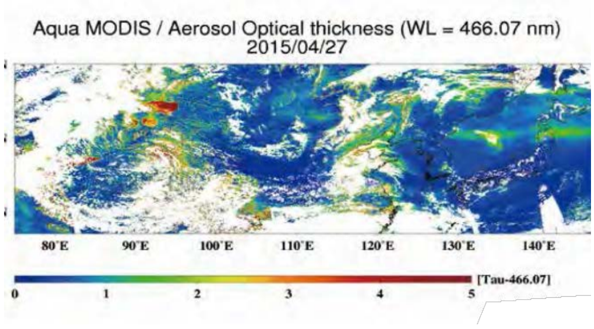
2.3. 大気環境物質監視

黄砂、PM2.5 等の大気汚染物質、火山灰、森林火災等によるエアロゾルは、視程の悪化、車や家屋、農作物への付着、健康被害など人々の生活環境に影響を及ぼしています。さまざまな衛星観測データからエアロゾルの光学的厚さ（どのくらい大気が濁っているか表す指標となる）やオングストローム指数（エアロゾル粒子サイズの指標となる）を推定し、データや画像を研究者や一般利用者に提供しています。外部機関と協力して衛星データをエアロゾル輸送モデルに組込むデータ同化システムを構築することにより、どこで発生したエアロゾルが、いつごろ、どこに、どのくらいの濃度で飛来するかを予測するシステムの構築を目指しています。また、大気環境物質監視課題では、エアロゾル発生源として重要な情報となる火災検知プロダクトの開発および雲の発達検知に向けた雲プロダクトの開発も行っています。

■ 人工衛星によるエアロゾルの観測

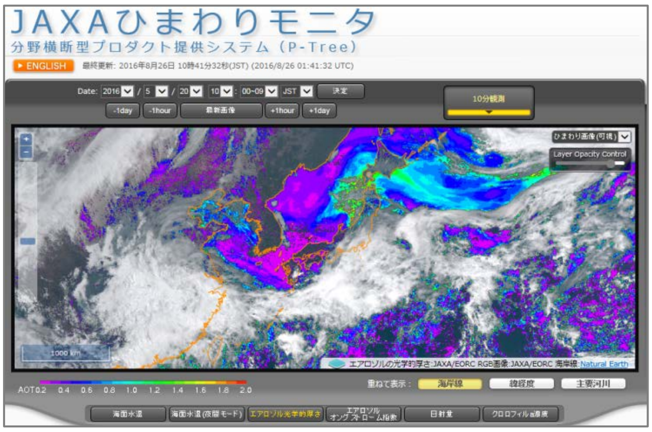
2015 年 11 月 17 日に温室効果ガス観測技術衛星「いぶき」（GOSAT）の TANSO-CAI センサが観測した阿蘇山噴火の様子です。

■ 自然環境や人間生活に影響を及ぼす大気微粒子エアロゾル



2015 年 4 月 27 日に地球観測衛星「Aqua」に搭載された MODIS センサが観測したエアロゾル光学的厚さ。中国大陸からの森林火災の煙が、東北地表上空を通過している様子がわかります。

■ JAXA ひまわりモニタからのプロダクト提供



大気環境物質監視課題で開発したプロダクトを定常的に処理し、JAXA ひまわりモニタ（http://www.eorc.jaxa.jp/ptree/index_j.html）からユーザへ提供するシステムを開発しています。

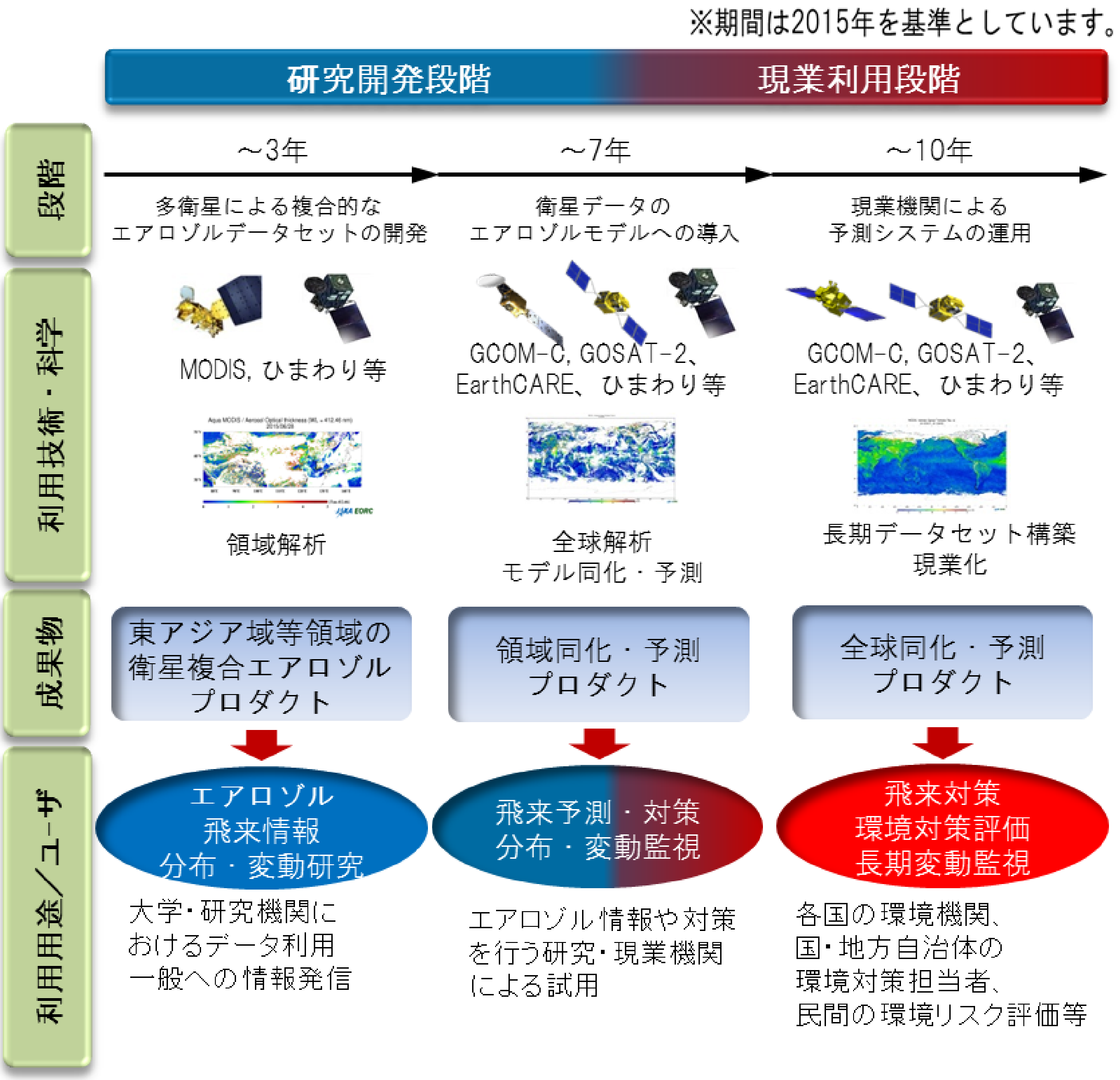
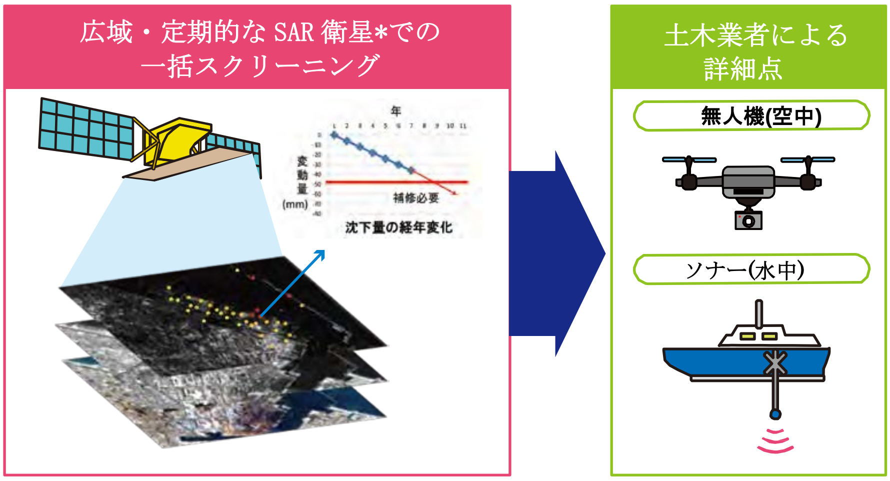


図 活動概要と利用のゴール

2.4. インフラ変位モニリング

陸域観測技術衛星「だいち」(ALOS)・陸域観測技術衛星 2 号「だいち 2 号」(ALOS-2)に搭載の L バンド合成開口レーダ(PALSAR-2)の観測データを用いて、広域かつ定期的に観測できる衛星 観測の特徴を活かした土木インフラの変位検出を行い、国や自治体が実施する土木インフラ管理の高度化・効率化に資するための研究を行っています(図 a)。JAXA では、基盤となる干渉 SAR 時系列解析アルゴリズム開発を含め、可視化が困難な変動量推定手法の開発・検証を行っており、これまでに、解析で検出した港湾施設の変状箇所確認(図 b)、河川堤防の沈下量の計測を行っています(図 c)。

■ インフラ変位モニタ

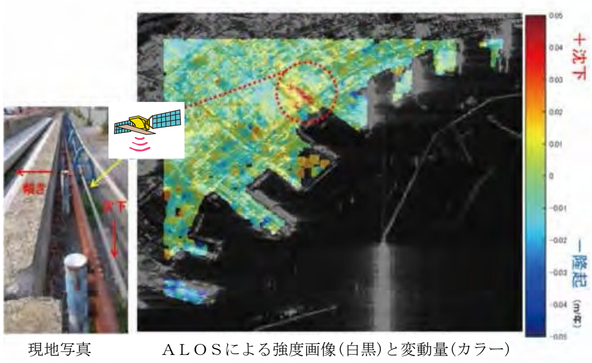


(図 a)

衛星で広域の観測を定期的に行うことで、要点検箇所となる変状 箇所(赤丸)を抽出することが可能 となり、実地で詳細点検を行う箇 所の絞込みが可能となります。

＊SAR 衛星：陸域観測技術衛星「だいち」(ALOS)・陸域観測技術衛星 2 号「だいち 2 号」(ALOS-2)

■ 港湾施設の変状把握



現地写真　ALOSによる強度画像(白黒)と変動量(カラー)

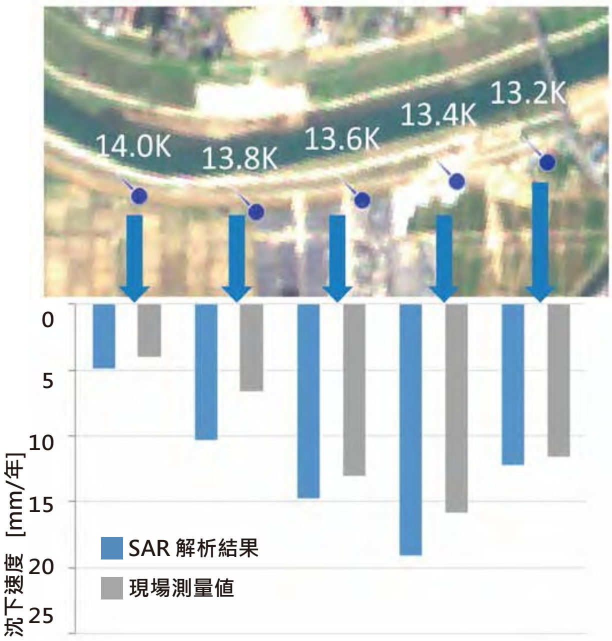
(図 b)

画像の赤丸が、経年微小変化の大きい箇所を抽出したもので、施設管理者より変状の可能性が指摘されていた箇所と一致しました。

■ 河川堤防の変状把握

衛星による干渉 SAR 時系列解析で沈下傾向を定期的に把握し、管理者に情報提供することで補修計画や点検計画の立案等の意思決定に役立ちます。干渉 SAR 時系列解析結果が現場測量データに近い精度を得ており、沈下傾向を把握するための高度化に向けた研究開発を実施しています。

(図 c)



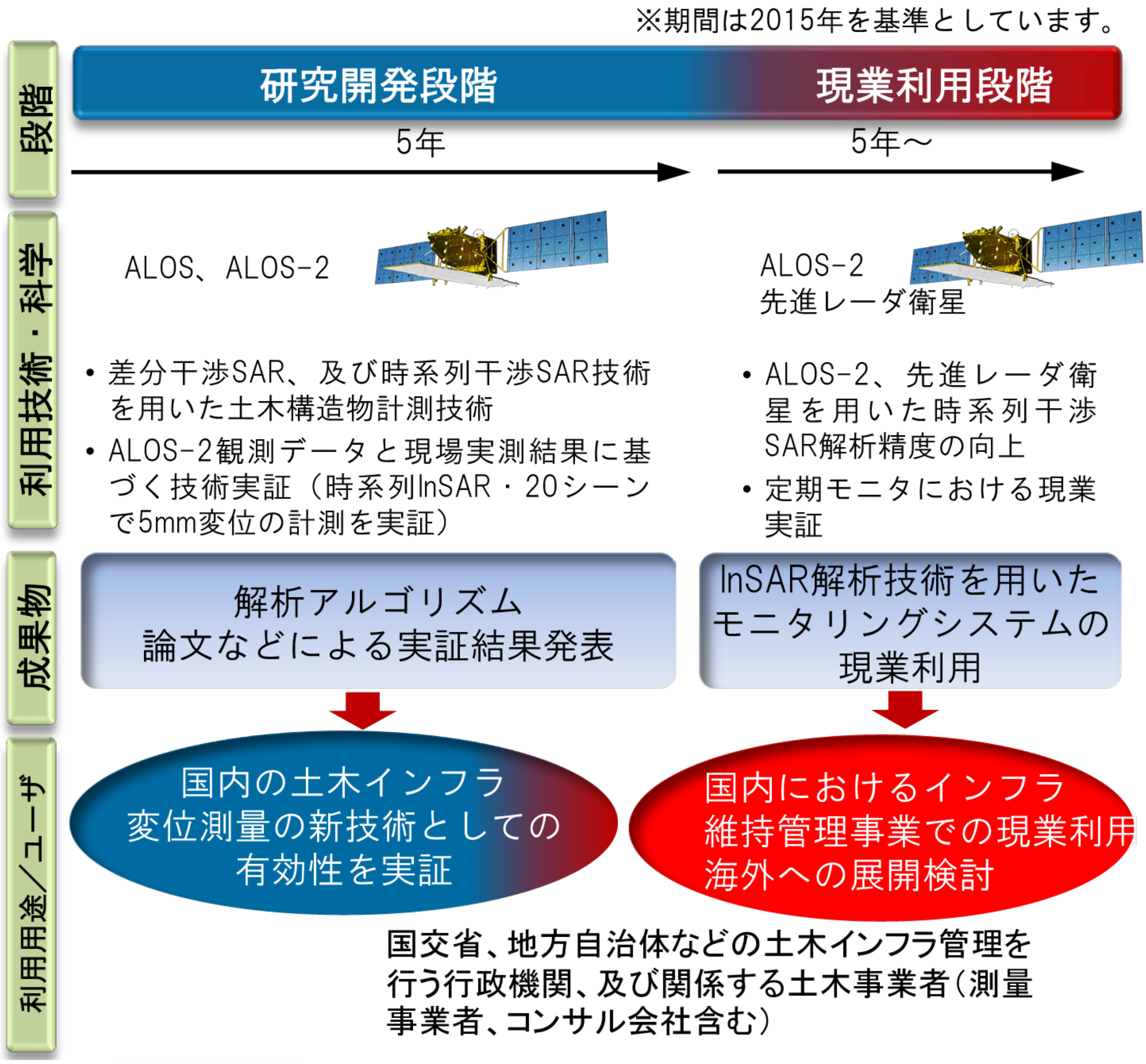


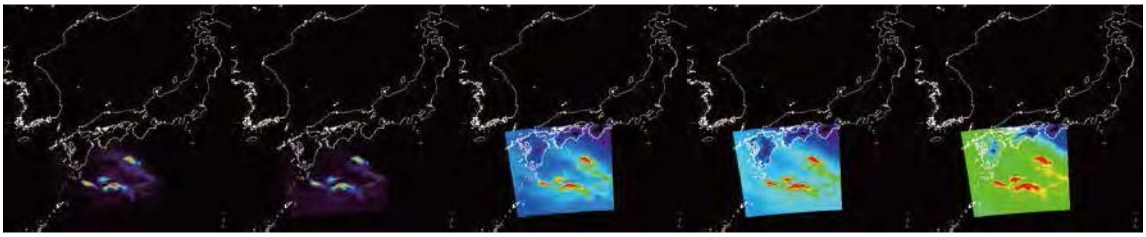
図 活動概要と利用のゴール

2.5. 気候システム・放射過程

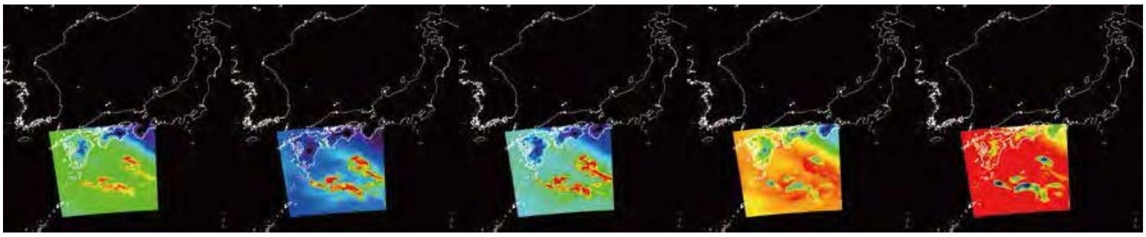
地球観測衛星の高度利用に必要なソフトウェア（放射伝達コード・衛星データシミュレータ）を基盤的に整備し、さらにそのソフトウェアを利用する研究を実施しています。例えば、雲・降水過程をより現実的に表現しながら地球大気をシミュレーションする世界最先端の全球雲解像数値大気モデル（NICAM）を、複数種類の衛星データを用いて検証する研究が進行しています。また、衛星雲・降水データを数値気象モデルに導入することで気象予報の精度向上に貢献する研究を進めています。

■ 日本周辺のマイクロ波放射計シミュレーション結果の例

10.65 GHz（H）　10.65 GHz（V）　19.35 GHz（H）　19.35 GHz（V）　21.30 GHz（H）



21.30 GHz（V）　37.00 GHz（H）　37.00 GHz（V）　85.50 GHz（H）　85.50 GHz（V）

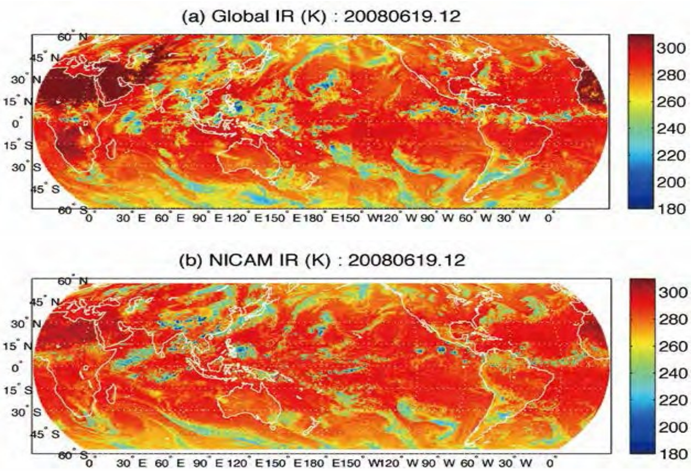


衛星データシミュレータ（Joint-Simulator）による、日本周辺の熱帯降雨観測衛星「TRMM」マイクロ波観測装置（TMI）シミュレーション結果。計算には、気象庁気象研究所より提供された、気象庁非静力学モデルによる大気データを使用しています。TMI の観測周波数、偏波に対応した輝度温度の違いがシミュレーションされていることがわかります。

■ 静止気象衛星データと
シミュレーションデータの比較
（Hashino et al. 2013）

(a) 静止気象衛星データ（IR 10.8 μm）
(b) 全球雲解像大気モデル（NICAM）3.5km 分解能シミュレーションデータに衛星データシミュレータ Joint-Simulator を適用して作成した疑似衛星データ

(a)と(b)を比較することにより、NICAM 雲の水平分布をよく再現ができていることが分かります。




「気候システム・放射過程」解析フロー
衛星データシミュレータ・
放射コード：
架け橋的役割
数値気象・気候モデル
地球観測衛星
アルゴリズム処理による
地球物理量の算出
（リトリーバル）
疑似衛星観測値の計算
によるモデル検証・デー
タ同化利用等
Joint Simulator
for Satellite Sensors
Joint-Simulator
Rstar
局地モデル（LFM）
メソモデル（MSM）
MSMの地形
（水平格子間隔5km）
LFMの地形
（水平格子間隔2km）

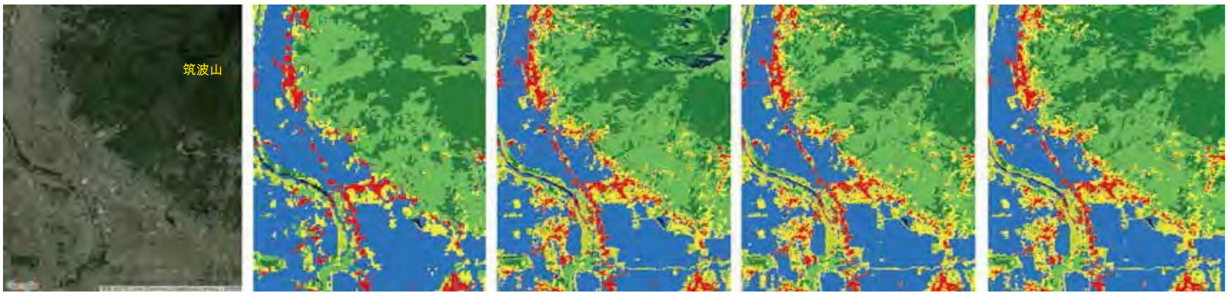
図 解析フロー

2.6. 生態系

森林破壊や都市化、災害等により土地被覆変化が近年加速し、時々刻々と進行する土地被覆の変化をキャッチアップできる土地被覆図が求められています。このために必要となる衛星高次補正プロダクト、教師・検証情報データベース、分類アルゴリズムを開発し、大学や研究機関などとの連携を通しての品質の向上に取り組んでいます。JAXAの過去・現在・将来の衛星データを活用し、光学・マイクロ波・能動・受動の多様なセンサを複合的に組み合わせた、世界初、総合的で高品質な土地被覆データセットを作成し、課題解決に貢献しています。

■ 高解像度土地被覆図の開発

土地被覆分類アルゴリズム v14.02 → 高解像度化（10m）→ 山影補正・除去 → 先験確率導入 v16.02



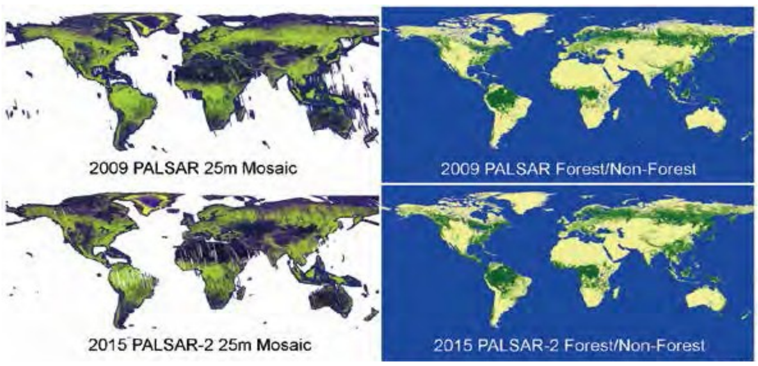
主に陸域観測技術衛星「だいち」（ALOS）の AVNIR-2 センサによる高次補正プロダクトを用いた高解像度土地被覆図の作成及び検証を実施し、動的な土地被覆変化を追うことで、これまでにない広域の 10m解像度土地被覆図を提供しています。農地の変化等の評価査定に活用されています。

■ 土地被覆分類リファレンスデータベースの整備（SACLAJ）

SACLAJ データベース

長期的な土地被覆変化の追跡するため、研究者や学生がウェブインタフェースから提供した地上情報踏査情報（現地写真など）と、衛星画像や空中写真、モニタリング情報などを集約したデータベースを構築しています。

■ 全球 25m 分解能 PALSAR-2/PALSAR モザイクおよび森林・非森林マップ



EORC で開発した高精度・高速大量処理の解析技術を、陸域観測技術衛星「だいち」（ALOS）および陸域観測技術衛星 2 号「だいち 2 号」（ALOS- 2）搭載の L バンド合成開口レーダ（PALSAR・PALSAR-2）による、全世界のデータに適用して作成したデータセットです。森林/非森林マップの分類精度は、現場写真や高分解能の光学衛星画像などから取得した 参照データとの比較により、84%以上であることを確認しています。

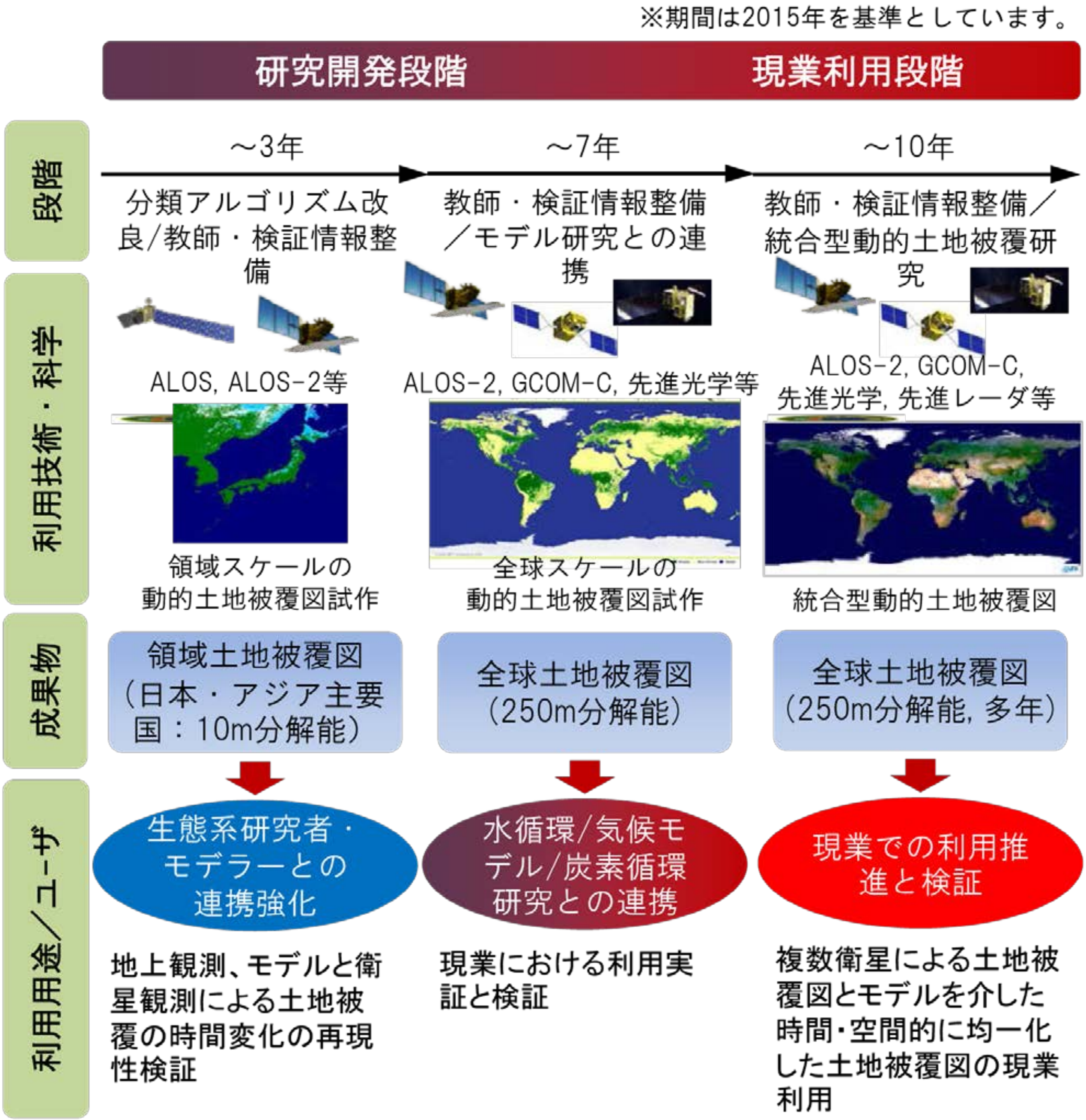
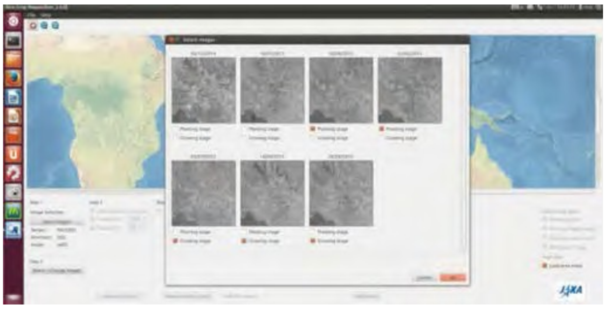


図 活動概要と利用のゴール

2.7. 農業

日本では食料の多くを輸入に依存しており、世界に目を向けると世界人口の約 1 割の８億人が栄養不足の状態です。このような食料問題に対して、地球観測を活用した科学的かつ客観的な作物の生育状況や収量予測情報に基づいて、各国政府や国際機関、民間企業などが 作物生産、輸出入、食糧援助などの意思決定を効果的かつ効率的にできる社会を目指しています。どこで作物が栽培されており、どのような生育状態で、いつどれくらいの収穫が見込めるかを常に監視･予測する研究開発を国内外の研究機関や政府機関等と連携して取り組んでいます。

■ 合成開口レーダを活用した水稲の作付面積の推定
――ソフトウェア「INAHOR（稲穂）」の開発



使用する合成開口データの選択

水稲作付け地域の推定結果（青色）

複数時期の陸域観測技術衛星 2 号「だいち 2 号」（ALOS-2）搭載の L バンド合成開口レーダ（PALSAR-2）の観測データから、水稲の作付面積を推定するソフトウェア「INAHOR（稲穂）」(International Asian Harvest mOnitoring system for Rice)を開発しました。東南アジアでは主に水稲が作付けされる雨季は雲に覆われていることが多いですが、合成開口レーダは雲の有無に関係なく作付け状況を把握することができます。インドネシアやベトナムなどの研究機関との共同研究のほか、各国の農業統計官が本ソフトウェアを活用して農業統計データをより効率的に収集することを目的としたプロジェクトをアジア開発銀行と実施しています。

■ 作物の作況判断のための農業気象情報提供システム「JASMIN」の構築

空間分布図：上段が現況下段が平年差

各農業気象の時間変動の一覧

作物の生育は光、温度、水環境などの農業気象要素と大きく関係しており、農業気象を広域かつタイムリーに把握することができれば、国スケールでの作物の作況判断に役立ちます。衛星観測による降水量、土壌水分量、日射量などの最新状況をウェブ上で閲覧できるシステム「JASMIN(JAXA's Satellite based MonItoring Network system for FAO AMIS outlook)」(http://suzaku.eorc.jaxa.jp/JASM/index.html)を構築しました。様々な農業気象情報について、現況や平年と比較してどれくらい異なるのかを俯瞰的に判断することができます。また、これらの情報と作物モデルを活用した主要穀物の短期収量予測手法の研究にも取り組んでいます。

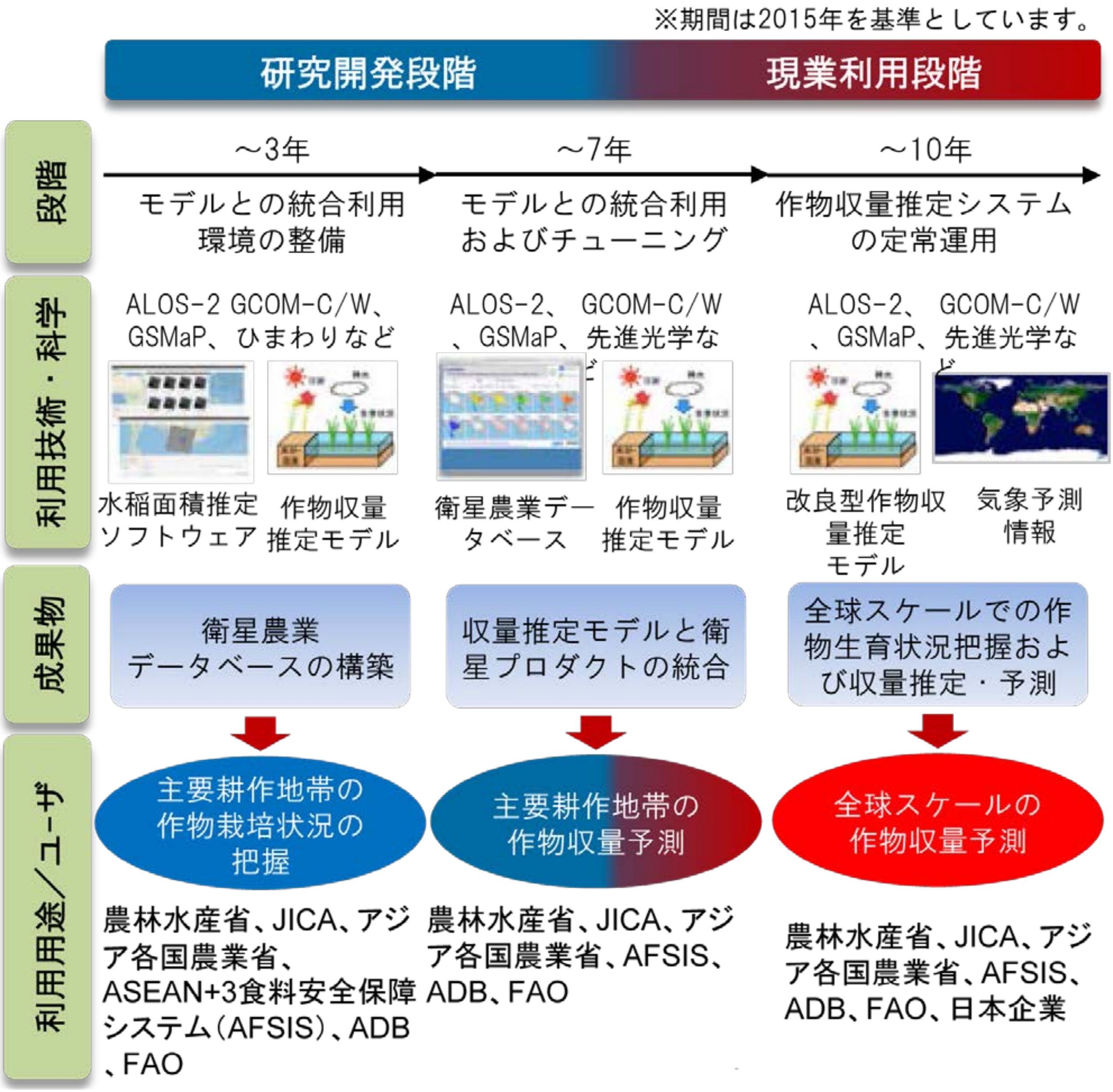
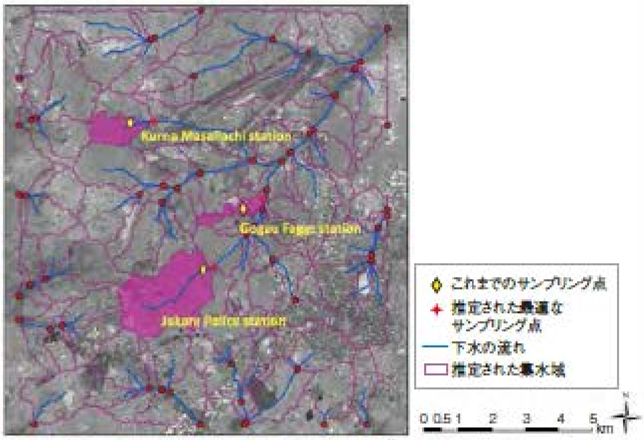


図 活動概要と利用のゴール

2.8. 公衆衛生

地球温暖化に伴う気温変化や降雨量などの環境変化は直接的（熱中症や循環器、呼吸器系疾患など）および、間接的（マラリア、コレラ、ポリオやその他感染症）に健康被害を与えることが懸念されています。これらの健康被害は、早期に流行を予測して事前に対策を取れないことが、被害拡大の一因となっています。降水量や温度、地形などの環境情報と健康被害の発生には関連性が指摘されていますが、途上国ではこれらの環境情報の監視体制が不十分な状況です。衛星観測による環境情報を活用して、感染症発生の早期警戒を行うための研究開発を大学などの研究機関や国際機関などと共同で取り組んでいます。

■ ポリオウィルス伝播状況の把握への数値標高モデル活用



ALOS数値標高モデルを活用した集水域の推定結果

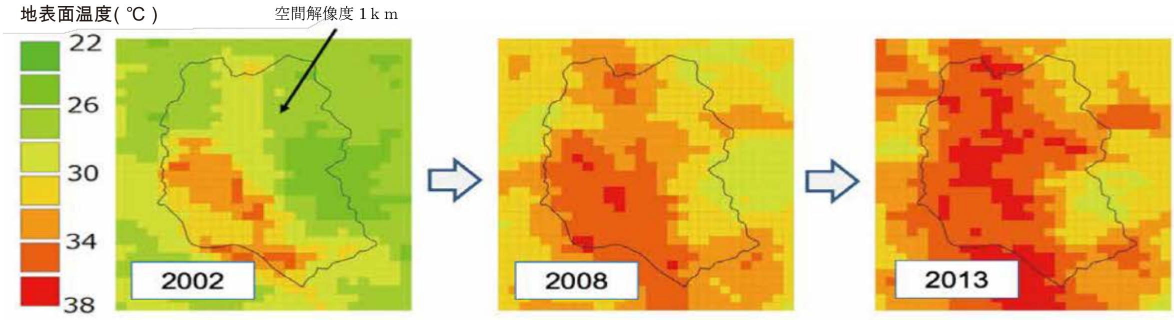
WHO（世界保健機関）では、定期的な下水サンプリングによるウィルス伝播の状況把握体制の構築を急務としており、そのためには下水の流れを考慮した効率的なサンプリング点の設定が重要です。ナイジェリアにおいて WHO と協力し、ALOS PRISM 数値標高モデル（AW3D）を用いて水文解析をすることで、集水域の特定（紫色）および下水サンプリング点（赤十字）選定を精緻化できることを示しました。

■ コレラ早期警戒のためのビクトリア湖の監視

ALOS AVNIR-2によるビクトリア湖周の画像

ビクトリア湖に生育する水草ホテイアオイはコレラ菌を媒介する可能性が指摘されており、陸域観測技術衛星「だいち」（ALOS）の AVNIR2 センサなどの衛星データからのホテイアオイの繁殖面積の拡大を推定することが期待されています。長崎大学熱帯医学研究所と共同で衛星から推定したホテイアオイの繁殖面積とコレラ患者数などの疫学的データとの関連性の研究を実施しています。

■ 下痢症発生リスク解析のための都市熱環境監視



バングラデシュ　ダッカの地表面温度の変化

急速な都市化により大都市のヒートアイランド化が進行し、都市の熱環境が大きく変化してきています。衛星観測による地表面温度から推定される暑熱暴露量は、下痢症などの感染症などの発生の指標となる可能性が指摘されており、東京大学医学系研究科と共同で両者の関連性の研究を実施しています。

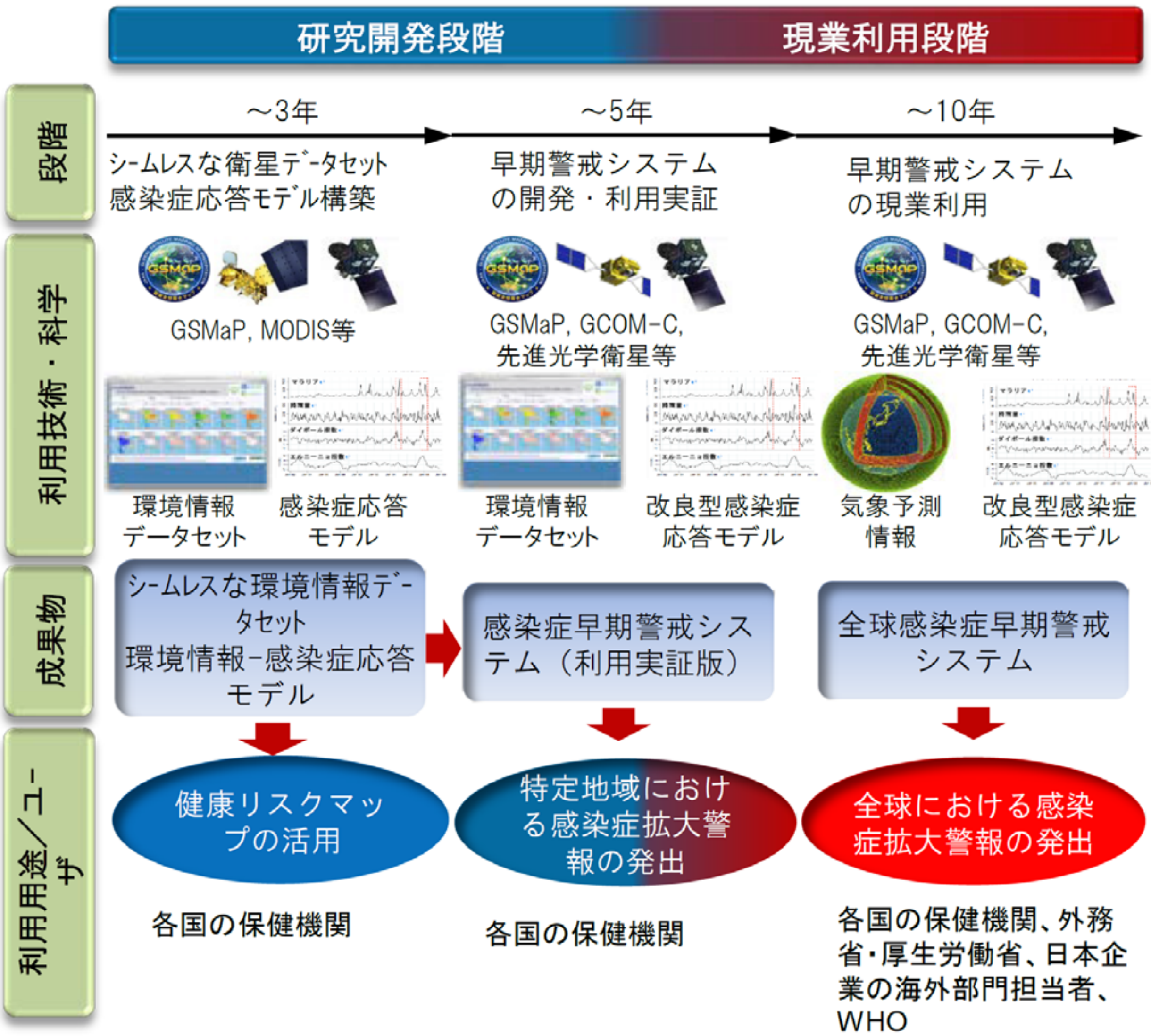


図 活動概要と利用のゴール