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Status of Global Change Observation Mission (GCOM)

This document reports on an overview and the status of JAXA's Global Change Observation Mission (GCOM)

1 Introduction

As described in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the climate system is an interactive system consisting of the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere and maintains its function by the complicated physical and biochemical interaction among all the components. In addition to the natural variability of the system such as the El Nino-Southern Oscillation (ENSO), various natural and anthropogenic external forcing bring additional changes. This results in not only the global change but also the local climate changes and frequency of the unusual weather. Therefore, satellite observations of climate change should cover wide range of targets including aerosol variation as the anthropogenic external forcing, changes of sea surface temperature (SST) and cryospheric states as the indicators of climate change, and changes of natural variability in water and energy cycle and weather. Also, long-term and continuous measurements at least for 10 to 20 years are indispensable for detecting slight climate change signals modulated by the natural variability. Since any climate change signals can be different at different part of the Earth, unbiased observations from satellites are the optimum method.

Global Change Observation Mission (GCOM) has been discussed to fulfil the above requirements to accomplish the climate change observation. It will consist of two series of medium size satellites: GCOM-W (Water) and GCOM-C (Climate, tentative). The reason we divide a large platform satellite such as Midori-II (ADEOS-II) into these two mid-sized satellites, is to increase the robustness and flexibility of system. The new system should be enough reliable, flexible for development. Three consecutive generations of satellites with one year overlap will result in over 13 years observing period in total. The GCOM-W satellite will mainly contribute to the observations related to the global water and energy circulation, while the GCOM-C to the surface and atmospheric measurements related to the carbon cycle and radiation budget.

2 GCOM-W

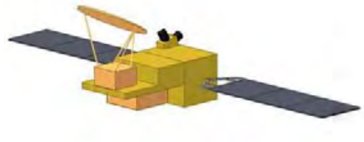
2.1 Mission Objectives

GCOM-W mission will take charge of long-term observations related to global water and energy circulation including over polar areas. To achieve the measurements, multi-channel microwave radiometers are suitable via the capability of performing global, frequent, and quantitative measurement. They provide quantitative measurements of surface parameters through non-precipitating clouds (through light precipitating clouds in some cases) and vertically integrated layer information via the interaction of microwave radiation with intercepting media (e.g., rain drops and snow grain). By these capabilities, the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the GCOM-W satellite will observe the changes in cryosphere including sea ice, ice sheets, and snow cover in which the global warming signal may instantaneously and significantly appear. Changes in sea surface temperature (SST), precipitation, cloud water, and water vapor will also be monitored in association with the air-sea interaction such as the El-Nino events. In addition, surface soil moisture will be observed to help quantitatively determine the water and energy balance between land and atmosphere.

2.2 System Overview

From the concept study in Japanese Fiscal Year (JFY) 2004, overview of the GCOM-W is shown in Table 1.

Table 1: Overview of GCOM-W

Orbit	**Type**: Sun-synchronous, sub-recurrent **Altitude**: 699.6km **Inclination**: 98.19 degrees **Local time of ascending node**: 13:30
Satellite overview	
Mission life	5 years
Launch vehicle	H2A launch vehicle
Instruments	AMSR2
Target launch year	JFY 2010

We have been trying to install a microwave scatterometer simultaneously with the AMSR2. However, we have decided not to carry the scatterometer for the first generation of the GCOM-W based on the discussions with international partners. Although advantages of the simultaneous observation by radiometer and scatterometer are still desired, we prioritize the continuity of the AMSR-E data at this time. Afternoon orbit (13:30 of local time of ascending node) was selected to continue the AMSR-E observation. Detailed configuration of the spacecraft will be designed in the next phase. For example, two solar paddle system is much better for risk reduction but may influence the calibration accuracy of the AMSR2 due to the field of view interference to the cold sky mirror that introduces the deep space temperature. This type of trade-off analysis is currently being made.

Overview of the AMSR2 is shown in Figure 1. Basic design is almost identical to that of AMSR-E: conical scanning mechanism with large-size offset parabolic antenna, feed horn clusters to realize multi-frequency observation, external calibration using two-point temperature calibration sources, total-power radiometer systems, and so forth. Basic characteristics including center frequency, bandwidth, polarization, instantaneous field of view (IFOV), and sampling interval are indicated in Table 2. Regarding the 6.925GHz channels, there will be a possibility to change the frequency configuration to mitigate radio frequency interference (RFI) problem in the frequency bands. More details will be explained later in this paper. Sizes of the IFOV were calculated by assuming the orbit altitude of approximately 700km and the main reflector size of 2m. Incidence angle of 55 degrees was selected to keep consistency with AMSR and AMSR-E observations. The swath width will be approximately 1450km. Through this orbit and swath width, entire Earth's surface can be almost covered within 2-days independently for ascending and descending observations.

Figure 1. Overview of AMSR2 (sensor unit). Deployed (left and center figures) and stowed (right figure) conditions are shown.

Table 2: Frequency Channels and Resolutions of AMSR2
(Orbit altitude of 700 km and main-reflector size of 2.0m are assumed)

Center frequency [GHz]	Band width [MHz]	Polarization	Beam width [deg.] (Ground resolution [km])	Sampling interval [km]
6.925	350	V and H	1.8 (35 x 62)	10
10.65	100		1.2 (24 x 42)	
18.7	200		0.65 (14 x 22)	
23.8	400		0.75 (15 x 26)	
36.5	1000		0.35 (7 x 12)	
89.0	3000		0.15 (3 x 5)	5

2.3 Data Products

GCOM-W data products will include Tb and geophysical parameters in swath form. Also, spatially and temporarily averaged global grid products will be generated. Since the Tb values are fed to retrieval algorithms to derive all the geophysical parameters and are directly used in the recent numerical data assimilation scheme, well-calibrated and stable Tb data are necessary. Eight geophysical parameters will be retrieved and processed as the standard products. In addition, research products will be identified and generated to enhance the GCOM-W capability. Currently, possible research products include cloud liquid water over land and ice, sea ice thickness, and all-weather sea surface wind speed by using lower frequency channels. Also, hydrological assimilated products are proposed to enhance land surface retrieval.

Current plan of the GCOM-W standard products is shown in Table 3. More high-level products combining the data from the AMSR2, SGLI on GCOM-C, and other satellite instrument will be considered.

Table 3: GCOM-W Standard Products

Product	Range	Comments
Brightness temperatures		
Brightness temperatures	2.7-340K	Global, 6 frequency with dual polarizations
Geophysical parameters		
Integrated water vapor	0 - 70kg/m^2	Over global ocean*, columnar integrated value
Integrated cloud liquid water	0 - 1.0kg/m^2	Over global ocean*, columnar integrated value
Precipitation	0 - 20mm/h	Global (except over ice and snow), surface rain rate
Sea surface temperature	-2 - 35℃	Global ocean*
Sea surface wind speed	0 - 30m/s	Global ocean*
Sea ice concentration	0 - 100%	High latitude ocean areas
Snow depth	0 - 100cm	Land surface (except dense forest regions)
Soil moisture	0 - 40%	Land surface (except ice sheet and dense forest regions)

* *Except sea ice and precipitating areas*

3 GCOM-C

3.1 Mission Objectives

First, we decided main physical parameters of four main region of globe, i.e. Atmosphere, Ocean, Land and Cryosphere. In each area, we discussed the parameters to be focused for climate change monitoring and the effect of human activities. For Atmosphere region, aerosol and cloud are focused. Especially to achieve ability to observe aerosol over land, three observation methods are employed for this sensor. They are ordinary split window method, near-UV method and multi angle polarimetry method. Observation of aerosol over land has difficulty for its weak signal with large background, which is caused by high reflectivity of land. However, some satellite sensors made this observation possible with their unique specifications. One is use of near-UV area, which is employed in TOMS. The other is multi angle polarlimetry, which is employed in POLDER. In both case, unique method aims to reduce background signal from land surface. For Ocean region, low polarization sensitivity for precise ocean color observation and 250 m resolution near coastal area, are requested. Because primary productivity is highly depends on coastal environment. For Land region, 250 m resolution and multi-angle observation are requested to estimate precise evaluation for vegetation and land use change, such as de-forestation. For Cryosphere, 250 m resolution is requested also to estimate precise loss of ice sheet and snow physical characteristics. Aerosol effect on snow is important issue to be counted. This 250 m resolution is requested on basis of the observational result of previous GLI sensor. The result showed us that 250 m resolution is suitable to materialize both global observation and regional human effect observation.

Finally, Table 4 shows the observation channel specifications. The total number of channels is reduced from previous sensor GLI by optimizing objectives of each area. Signal to Noise Ratio at standard radiance is over 200 for most of VNIR channels and NEdT lower than 0.2 K for TIR channels. For polarlimetry, requirements of observation angles and polarization direction are also shown in Table 4. These requirements are to aim estimate polarization state to reveal aerosols over land using theoretical characteristics of small particle scattering.

GCOM program is the first try for Japan to have continuous satellite observation over 13 years to reveal the relationship between climate system and human activity effects. Three series of satellite, of which life time is five years makes total 13 year observation with one year overlap. Prime mission requirement for this mission from program point of view, is to assure continuous observation.

Table 4. SGLI Channel Specifications

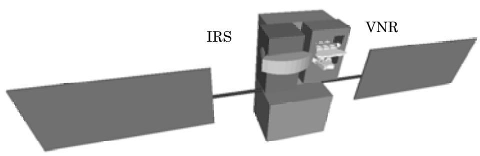
Channel	Center wavelength	Band width	Std. Radiance	Max. Radiance	Ground resolution
	VN, P, SW: nm T: µm		VN, P: $W/m^2/sr/\mu m$ T: Kelvin		m
VN1	380	10	60	210	250
VN2	412	10	75	250	250
VN3	443	10	64	400	250
VN4	490	10	53	120	250
VN5	530	20	41	350	250
VN6	565	20	33	90	250
VN7	670	10	23	62	250
VN8	670	20	25	210	250
VN9	763	8	40	350	1000
VN10	865	20	8	30	250
VN11	865	20	30	300	250
P1[*1]	670	20	25	250	1000
P2[*1]	865	20	30	300	1000
SW1	1050	20	57	248	1000
SW2	1380	20	8	103	1000
SW3	1640	200	3	50	250
SW4	2210	50	1.9	20	1000
T1	10.8	0.7	300	180~340	500
T2	12.0	0.7	300	180~340	500

*[*1]Polarization channels should have capability to observe at three polarization direction (0,60,120 deg.) and NADIR / Tilt view at +-45 deg.*

3.2 System Overview

Overview of the GCOM-C is shown in Table 5.

Table 5. Overview of GCOM-C

Orbit	**Type**: Sun-synchronous, sub-recurrent **Altitude**: 798 km **Inclination**: 98.6 degrees **Local time of descending node**: 10:30
Satellite overview	
Mission life	5 years
Launch vehicle	H2A launch vehicle
Instruments	SGLI
Target launch year	JFY 2011

To optimize broad spectral range requirement, we decided to split system into two sensors. For Visible and Near Infrared (NIR), we chose push bloom type sensor named VNR (Visible Near Infrared Radiometer) to realize multi angle polarimetry and non-polarimetry observation at once. To materialize this function with whisk bloom type, the requirements for tilt mechanism and low polarization sensitivity are difficult to design, because of its size and catroptic character. For non-polarimetry observation, it has three telescopes to cover wide swath. On the other hand, we have two telescopes for polarimetry observation to minimize parallax between three polarization direction channels. For Shortwave Infrared and Thermal Infrared, we chose whisk bloom type sensor named IRS (Infrared Scanner) to adopt heritage of GLI system. Each VNR and IRS has on-board calibrator to characterize in-fight change.

SGLI / VNR is requested to cover rather wide swath as a push bloom type sensor. At this point, observation orbit and swath design are crucial for characterize sensor system. We chose sun-synchronous orbit, of which height is approximately 800 km and revisit period is 34 day. Considering observation frequency requirement; every two day observation at mid latitude area, sensor swath should be wider than 1100 km. Because of employing push bloom type for VNR, swath is important parameter. Detector array size and total volume of optics highly depends on this parameter. For local time at descending node (LTDN), 10:30 AM is preferable, considering the cloud amount over land. However 1:30 AM is also acceptable as an option.

As the result, diagram of total system is shown in Figure 2.

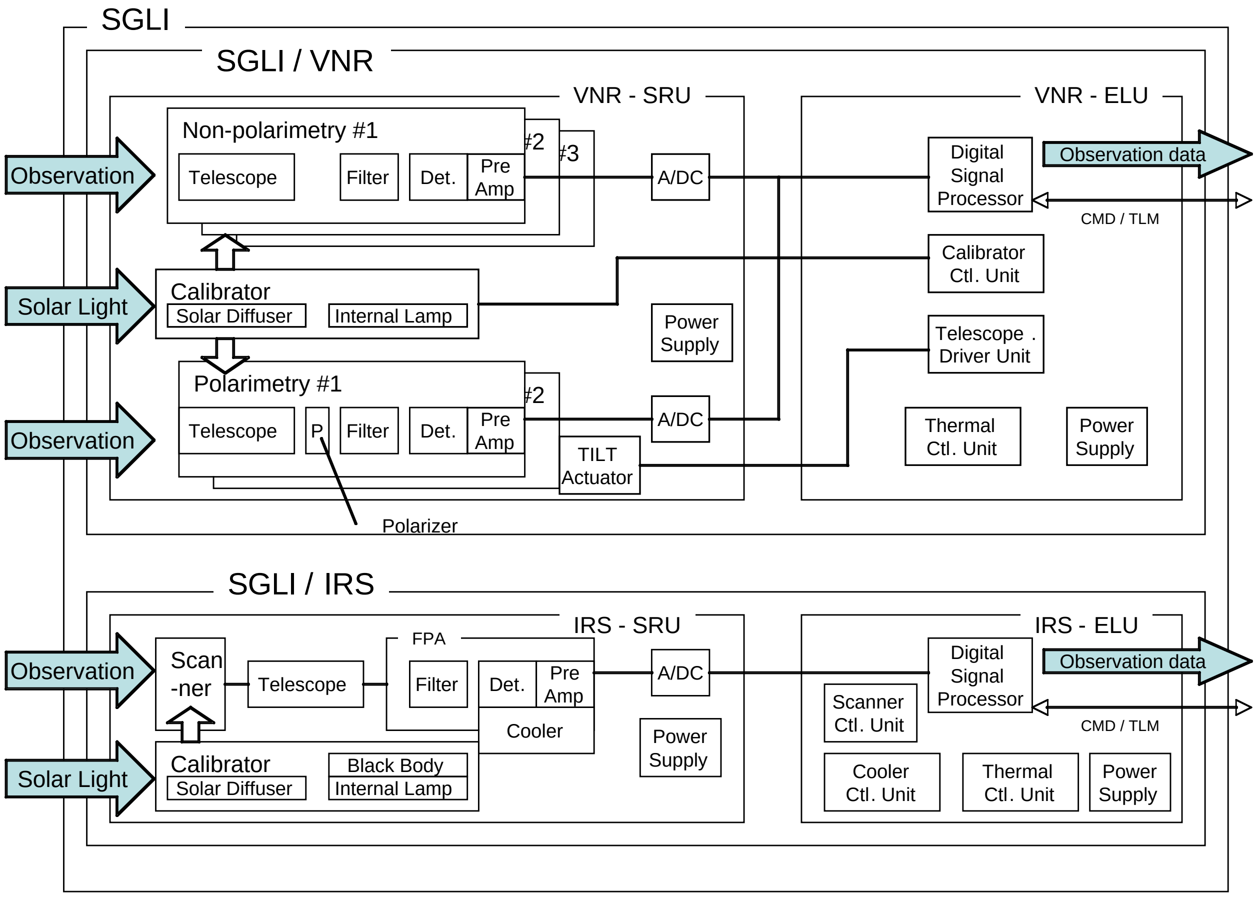


Figure 2. Block Diagram of SGLI

(1) VNR

VNR consists of non-polarimetry part, polarimetry part, on-board calibrator and electrical component. For non-polarimetry part, which has 11 channels, it has three telescopes for the wide swath as shown in Figure 3. To separate channels, we decided not to use dichroic filter to avoid any polarization sensitivities by optics. Instead of using filters, we decided to use along track direction for spectral channels, though it has some parallax. Keeping low incident angle in optical design, this sensor has very low polarization sensitivities; lower than 2.5 %.

For polarimetry part, which has two channels, we employed two telescopes for two wavelengths. Because polarimetery part is designed for tilt observation, swath can be covered with one telescope, contrastively. The reason why we use two telescopes is to minimize parallax between three polarization direction sub-channels, as shown in Figure 4. For polarimetry, *Corning Polarcor* is employed as polarizer after some trade off with prism, dichroic filter and film polarizer. Three polarization direction sub-channels located in one telescope. With three polarization direction observation at 0, 60, 120 degree, we can determine storks vector; (I, U, Q, V), of observed light, where element V is negligible in natural light. The tilt observation geometry is requested for poralimetry part. The signal from aerosol exceeds in forward scattering direction. Thus, observation direction must be forward tilted in north hemisphere, and backward tilted in southern hemisphere. In one orbit, the sensor tilts forward and backward each once. The designed scatter angle of aerosols to be measured is between 60 to 120 degrees.

For both non-polarimetry and polarimetry we employed about 2000 element CCDs to cover 1000 km swath. Non-polarimetry part uses three CCDs. Whereas, Polarimetry part uses one CCD, because of its 1km resolution. CCD array might be specially designed and built for this sensor. To divide channels spectrally, we have a stripe color filter on each detector array. For polarimetry, we add a striped polarizer on a color filter. Then, observed signal is digitized with 12 bit Analog to Digital Converter. When satellite is not located on Land or coastal area, 250m resolution data will be integrated averaged on-board in 1 km resolution data for optimizing data size to be downloaded. The total daily data rate would be 70 GB including both VNR and IRS data.

For on-board calibration, we equipped solar diffuser and internal light as the heritage from GLI. Also we will try to use Moon as the stabilized natural light source. Figure 5 shows the simulation result for monn mapping with SGLI design and satellite orbit. And other observation modes for calibration are under study, such as satellite 90 degree Yaw maneuver to carry out in-flight calibration of detector in-homiginities.

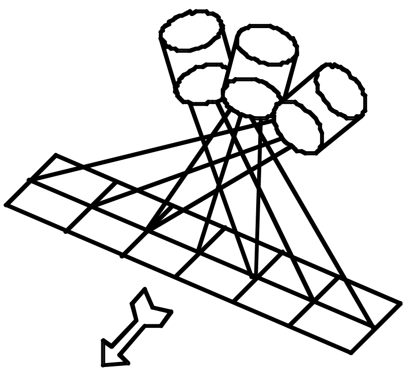


Figure 3 Non-Polarimetry part using three telescopes

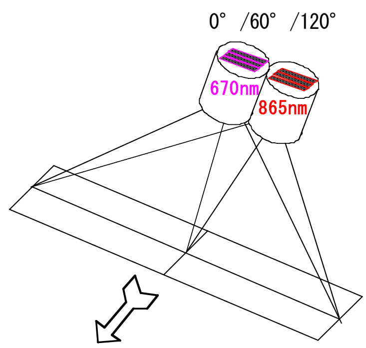


Figure 4. Polarimetry part using two telescopes

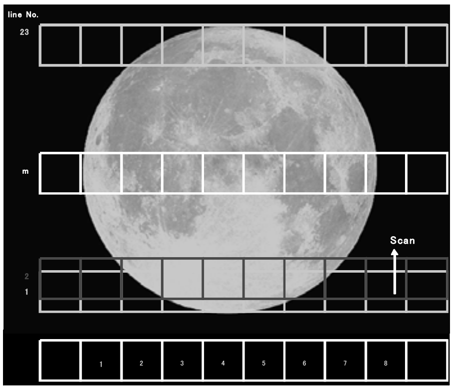


Figure 5. Moon mapping simulation with 1 km resolution channel of SGLI 23 samples are supposed to cover Moon image.

(2) IRS

Total system design of IRS uses the heritage from previous GLI on ADEOS-2 and Ocean Color and Temperature Scanner (OCTS) on ADEOS. IRS is full catroptic optical system with compact conical scanner, avoiding any color aberration. For detector array we chose PV-MCT type detectors for thermal infrared (TIR) channel, and PV-MCT or InGaAs detectors for shortwave infrared (SWIR) to simplify electronics and realize higher sensitivity / lower noise for than GLI. For cryo-cooler of TIR focal plane assembly, we employ staring cycle cooler system, which is well established in past GLI, ASTER-SWIR/TIR on EOS-Terra or other space programs in Japan. The required thermal environment for infrared detectors is about 70 K. For SWIR calibration will use solar calibration also and might have internal light; same as for VNR. For TIR, ambient black body will be used as a high level input source. Deep space view is used for both SWIR and TIR as zero level. For TIR band, resolution is set as 500 m. Whereas SWIR channel is set as 1 km except for one 250 m channel.

4 Conclusion

The importance of long-term, global, and continuous observation of the Earth including human activity effect on climate change was pointed out. To contribute to the isuue, a concept study of Earth observation satellites and sensors for climate change observation was done, and the new system, named GCOM is proposed.

The GCOM system consists of two mid-sized satellites: GCOM-W and GCOM-C. The set of satellites is planned to be launched every four years, three times to cover 13 years' continuous observation with 1 year overlapping. GCOM-W carries AMSR2. AMSR2 specification is almost same as AMSR and AMSR-E. GCOM-C carries newly developed SGLI, which is successor of GLI and has polarimetry and multi angle observation function. We are proposing to launch GCOM-W and –C, in JFY 2010 and 2011, respectively.