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Update on Global Change Observation Mission (GCOM)

The current status of JAXA's Global Change Observation Mission (GCOM) is updated. GCOM-W1 project has made a progress to start its Phase-C Study in JFY2007. GCOM-C1 project was started in October 2008. A progress of GCOM and NPOESS cooperation in the GEOSS context is also reported.

1 Introduction

As mentioned in the 4th 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 the natural variability, and also they are not necessary uniform over the Earth. Therefore, as is indicated before, the observing system of the climate variability should be stable, and should cover long-term period and entire Earth.

To respond to this necessity, Global Change Observation Mission (GCOM) will consist of two medium-size, polar orbiting satellite series and multiple generations (e.g., 3 generations) with one-year overlaps between consecutive generations for inter-calibration. Two satellite series are GCOM-W (Water) and GCOM-C (Climate). Two instruments were selected to cover 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 cover the observations related to the global water and energy cycle, while the SGLI will cover 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, 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

The first generation of GCOM-W (GCOM-W1) satellite will be a medium size platform that is smaller than that of ADEOS and ADEOS-II satellites. This is to reduce the risk associated with the large platform with valuable multiple observing instruments. Also, since the ADEOS-II problem was related to the solar paddle, it is being recommended for recent Japanese satellites to have dual solar paddles. One concern in the dual-paddle design was a possible influence to the field of view of the Cold Sky Mirror (CSM) that introduces cosmic background temperatures to feed horns. We have assessed the direct effect of solar paddles to CSM by simulating observed brightness temperatures by CSM. As a result, it was confirmed that the direct effect was small enough. Although some other indirect influences (e.g., influence in spillover portion between feed horns and CSM) may exist, this should be corrected in orbit. To avoid the shading to the solar paddles by large AMSR2 antenna and the effect to CSM mentioned above, the paddles were designed to have longer booms. Overview of the GCOM-W1 satellite is shown in Figure 4 and the major characteristics of the satellite in Table 1. The local time of ascending node will be 13:30 to keep consistency with the Aqua/AMSR-E observations.

The system Preliminary Design Review (PDR) of the GCOM-W1 satellite was over in March 2008. Also, the system critical design review (Part-1) of the AMSR2 instrument was finished in July 2008. The CDR (Part-2) will be held in November 2008 for data processing unit. In designing the instrument and the interface with spacecraft, one focused point was to improve the reliability to extend the design life from 3 to 5 years (i.e., design life of AMSR-E was 3 years). As a result, we decided to add redundant momentum wheel and interface board for two signal processor circuits.

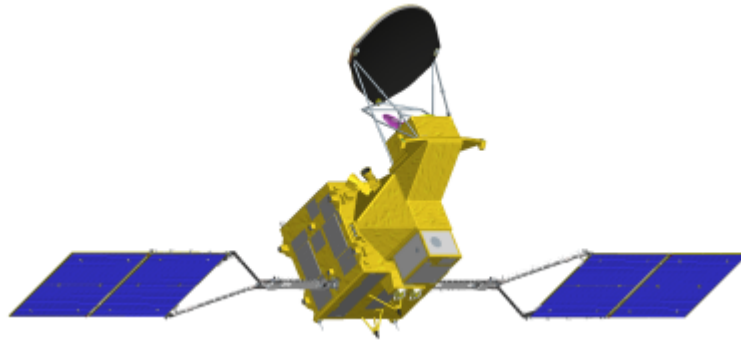


Figure 1: Overview of GCOM-W1 satellite

Table 1: Major Characteristics of GCOM-W1 satellite

Instrument	Advanced Microwave Scanning Radiometer-2
Orbit	Sun-synchronous orbit Altitude: 699.6km (over the equator) Inclination: 98.186 degrees Local time of descending node: 13:30
Size	5.1m (X) * 17.6m (Y) * 5.0m (Z) (on-orbit)
Mass	1940kg
Power	Over 4050W
Launch	JFY2011 (beginning of CY2012)
Design Life	5 years
Status	Phase-C study started in JFY2008

The overview of the AMSR2 instrument is shown in Figure 2 in two different conditions. Also, basic characteristics including center frequency, bandwidth, polarization, instantaneous FOV, and sampling interval are indicated in Table 2. Basic concept is almost identical to that of AMSR-E: conical scanning system with large-size 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 of the antenna, which is larger than that of AMSR-E, provides better spatial resolution under the same orbit altitude of around 700km. We have allowed possible little underlaps in the 89GHz scans due to the narrower beam size of AMSR2 with the same sampling interval of AMSR-E. We have an experience in developing the 2.0m diameter antenna for ADEOS-II AMSR except the deployable mechanism. Regarding the C-band receiver, we adopted the additional 7.3GHz channels for possible mitigation of radio-frequency interference (RFI). Incidence angle of 55 degrees (over the equator) was selected to keep 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.

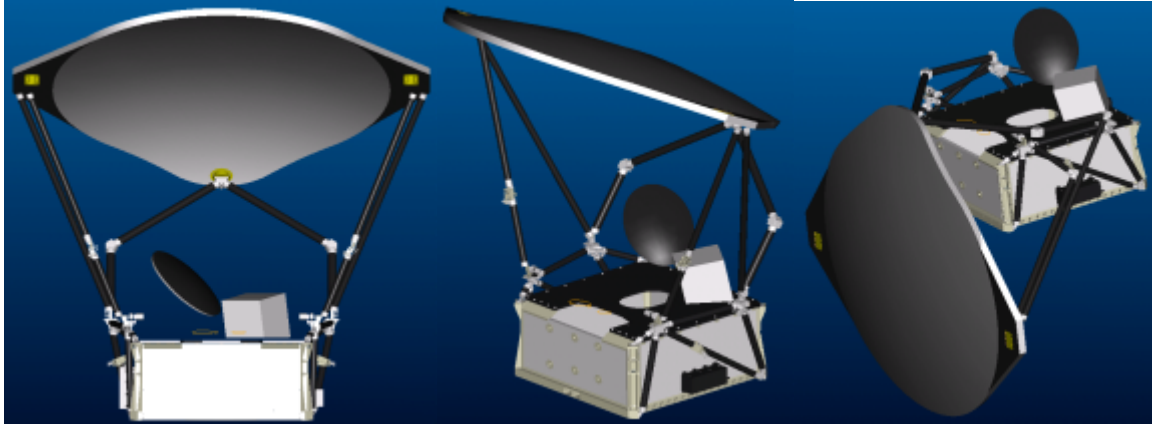


Figure 2. Overview of AMSR2 (sensor unit). Deployed (left and center figures) and stowed (right figure) conditions are shown.

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 / 7.3	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)	

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
<i>Brightness temperatures</i>		
Brightness temperatures	2.7-340K	Global, 6 frequency with dual polarizations
<i>Geophysical parameters</i>		
Integrated water vapour	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°C	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

Main physical parameters of four main region of globe, i.e. Atmosphere, Ocean, Land and Cryosphere were discussed 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 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 polarimetry, 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 primary production and 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.

The observation channel specification is shown in Table 4. 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 polarimetry, 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.

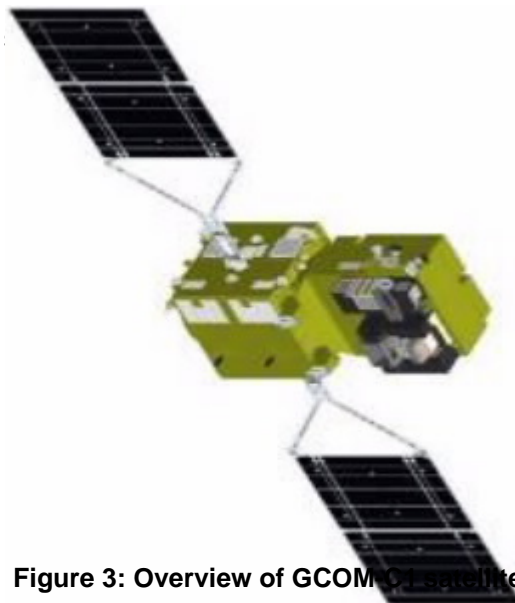
Table 4. SGLI Channel Specifications

Channel	Center wavelength	Band width	Std. Radiance	Max. Radiance	Ground resolution
	VN, P, SW: nm T: m		VN, P: W/m ² /sr/ T: Kelvin	m	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-C1



or characteristics in Table 5.

Figure 3: Overview of GCOM-C1 satellite

Table 5: Major Characteristics of GCOM-C1 satellite

Instrument	Second-generation Global Imager (SGLI)
Orbit	Sun-synchronous orbit Altitude: 798 (over the equator) Inclination: 98.6 degrees Local time of descending node: 10:30
Size	4.6m (X) * 16.3m (Y) * 2.8m (Z)
Mass	1950kg
Power	Over 4250W
Launch	JFY2013 (TBD)
Design Life	5 years
Status	Phase-A study in 2008

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-flight 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 4.

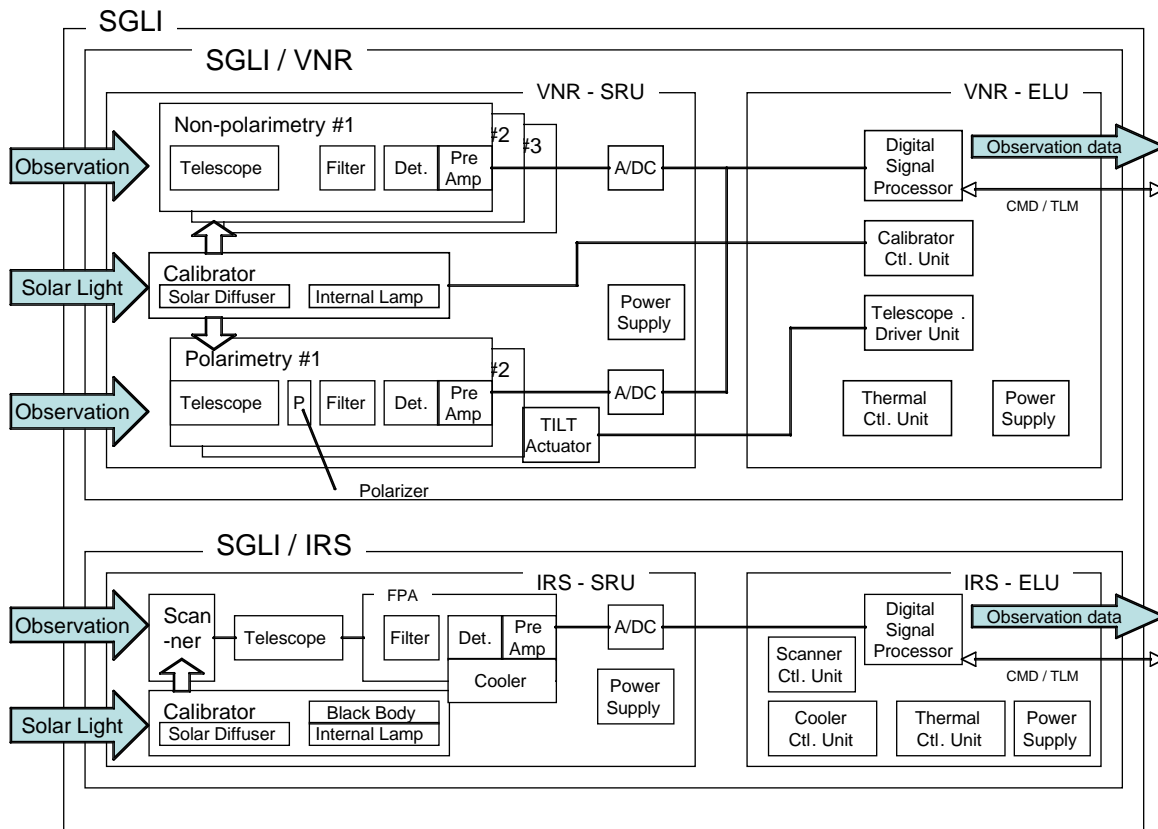


Figure 4. Block Diagram of SGLI

(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 polarimetry 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 moon 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-homignities.

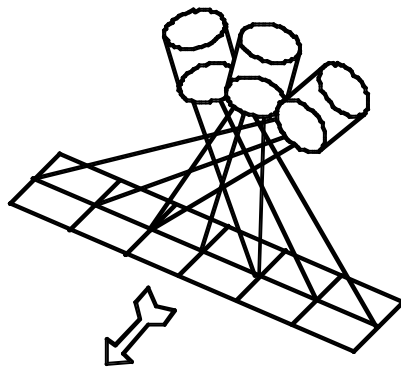


Figure 5 Non-Polarimetry part using three telescopes

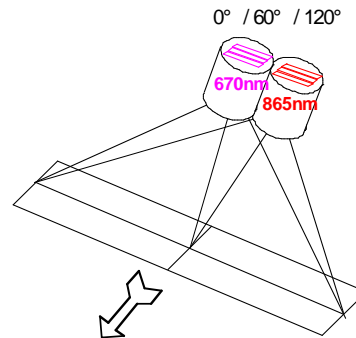


Figure 6. Polarimetry part using two telescopes

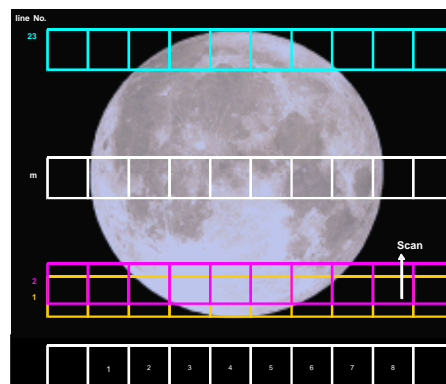


Figure 7. Moon mapping simulation with 1 km resolution channel of SGLI 23 samples are supposed to cover Moon image.

(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 GCOM and NPOESS cooperation in the GEOSS context

In November 2007, GCOM and the U.S. National Polar Orbiting Environmental Satellite System (NPOESS) cooperation has been reported to GEO as an early achievement of the Global Earth Observation System of Systems (GEOSS), and discussion between JAXA and NOAA has started. Specifically, both sides will benefit from data exchange and scientific collaboration, and GCOM measurements can be expected to meet key observational requirements for the period prior to the launch of the first NPOESS mission. In April 2008, NOAA and JAXA exchanged the Letter of Intent for preparing the Memorandum Of Understanding (MOU) for their cooperation.

NPOESS and GCOM will support the operational and research needs of the meteorological, oceanographic, environmental, climatic remote sensing programs and will provide global environmental support. In addition, data from these satellites will be made available to the meteorological and environmental organizations in the world in support of their weather forecasting and climate prediction capabilities. Through GEO, U.S. and Japan will cooperate in operating these two major satellite systems, sharing each others' data, and in conducting joint calibration and validation and cooperative science activities. In this manner, GEO is enabling the development of synergy between NPOESS and GCOM, filling observation gaps, and increasing the frequency and accuracy of observations. NPOESS/GCOM cooperation can benefit not only the U.S. and Japan, but also the whole world by disseminating key Earth observation data which are critical to the safety and security of all people.