OVERVIEW OF THE FIRST SATELLITE OF THE GLOBAL CHANGE OBSERVATION MISSION - WATER (GCOM-W1)

Misako Kachi, Keiji Imaoka, Hideyuki Fujii, Daisaku Uesawa, Kazuhiro Naoki, Akira Shibata, Tamotsu Igarashi

, Earth Observation Research Center (EORC), Japan Aerospace Exploration Agency (JAXA), 2-1-1 Sengen, Tsukuba, Japan

Abstract

Japan Aerospace Exploration Agency (JAXA)'s Global Change Observation Mission (GCOM) is planned as the comprehensive observation system of the Earth System's essential variables of atmosphere, ocean, land, cryosphere, and ecosystem. GCOM consists of two satellite observing systems, GCOM-W (water) and GCOM-C (climate), and three generations to achieve global, comprehensive, and long-term Earth monitoring. The first satellite of the GCOM-W series will be GCOM-W1 with the Advanced Microwave Scanning Radiometer-2 (AMSR2) onboard. AMSR2 is a follow-on sensor of AMSR-E on NASA's EOS Aqua satellite, and contribute to the observations related to global water and energy circulation. Basic performance of AMSR2 will be similar to that of AMSR-E based on the minimum requirement of data continuity of AMSR-E, with several enhancements. Experiences through the AMSR-E research activities and the data themselves can be directly utilized in the AMSR2 algorithm development.

INTRODUCTION

JAXA currently operates and will launch several satellite missions targeting to monitor disasters and resources, and climate change including water cycle and greenhouse gases. Figure 1 shows current schedule of JAXA's operating and planned missions, including national and/or international cooperated missions.

To fulfill needs of continuous, homogeneous, and accurate observation of geophysical parameters, which construct the Earth environment, the Global Change Observation Mission (GCOM) is planned by the Japan Aerospace Exploration Agency (JAXA). Such observation is one of key issues for understanding and evaluating signals of climate change and variation. "GCOM" is not a name of single satellite mission, but consists of two medium-sized satellites, GCOM-W (water) and GCOM-C (climate), and three generations with one year overlap to ensure 10-15 years stable data records (Imaoka et al., 2010).

GCOM is a successor mission of the Advanced Earth Observing Satellite-II (ADEOS-II), launched on December 2002 but stopped its operation due to the satellite malfunction in 2003. JAXA developed two core sensors for ADEOS-II, the Advanced Microwave Scanning Radiometer (AMSR) and the Global Imager (GLI). AMSR for the EOS (called AMSR-E) was also provided to NASA's Aqua satellite launched on May 2002. AMSR-E is multi-frequency microwave radiometer with dual polarization capability, developed by JAXA. It has C-band channels for estimating Sea Surface Temperature (SST) and soil moisture. AMSR-E has high-spatial resolution compared to existing instruments by large size antenna of 1.6m. AMSR-E continued its operation for more than 9 years. Since the end of August 2011, however, the continuous increase of relatively large antenna rotation friction was detected twice, thus JAXA has been monitoring the condition. On October 4, 2011, the AMSR-E reached its limit to maintain the rotation speed necessary for regular observations (40 rotations per minute), and the radiometer automatically halted its observations and rotation. JAXA will continue to analyze this problem, and take necessary measures to correct the situation in cooperation with NASA.

JAXA will launch the successor of AMSR-E, the Advanced Microwave Scanning Radiometer-2 (AMSR2). AMSR2 will be installed on the first generation of GCOM-W (GCOM-W1), called “SHIZUKU”, whose meaning is “a drop of rain or dew” in Japanese.

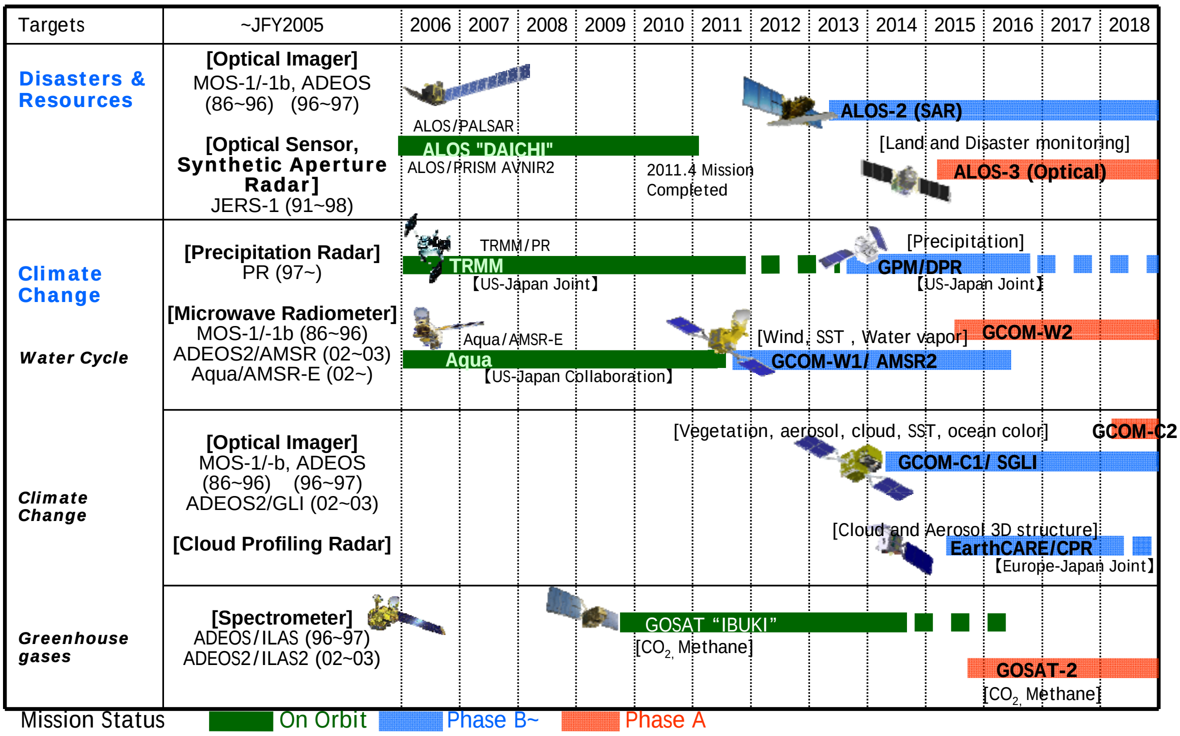

Figure 1: **Current schedule of JAXA’s operating and planned missions as of September 2011. Joint missions with national and international organizations are also included in this table.**

GLOBAL CLIMATE CHANGE OBSERVATION MISSION (GCOM):

Table 1 is major characteristics of GCOM-W1 and GCOM-C1 satellites. Global Change Observation Mission (GCOM) is planned as the comprehensive observation system of the Earth System’s essential variables of atmosphere, ocean, land, and cryosphere (Figure 2). Most of these observations are expected to provide data commonly useful to the climate research and the meteorology. Additionally, the mission is designed to find out the traces of human-induced environmental changes, such as deforestations, forest fires, air and water quality changes to distinguish the human-induced changes and the natural cyclic changes. GCOM consists of two medium size of satellites; GCOM-W1 will carry AMSR2; and GCOM-C1 will carry the Second Generation Global Imager (SGLI).

	GCOM-W1	GCOM-C1
Instrument	Advanced Microwave Scanning Radiometer-2	Second-generation Global Imager
Orbit	Sun Synchronous orbit Altitude：699.6km (on Equator) Inclination: 98.2 degrees Local sun time: 13:30+/-15 min	Sun Synchronous orbit Altitude：798km (on Equator) Inclination: 98.6 deg. Local sun time: 10:30+/- 15min
Satellite scale	5.1m (X) * 17.5m (Y) * 3.4m (Z) (on-orbit)	4.6m (X) * 16.3m (Y) * 2.8m (Z) (on-orbit)
Satellite mass	1991kg	2093kg
Launch	JFY 2011 by H-IIA Rocket	JFY 2014 by H-IIA Rocket
Mission life	5-years	5-years

Table 1: **Major characteristics of GCOM-W1 and GCOM-C1 satellites.**

As shown in Figure 3, three consecutive generations of GCOM satellites with one year overlap in orbit enables over 13 years observation in total. GCOM first generation satellites, GCOM-W1 and GCOM-C1, are planned to be launched in Japanese Fiscal Year (JFY) of 2011 and 2014, respectively.

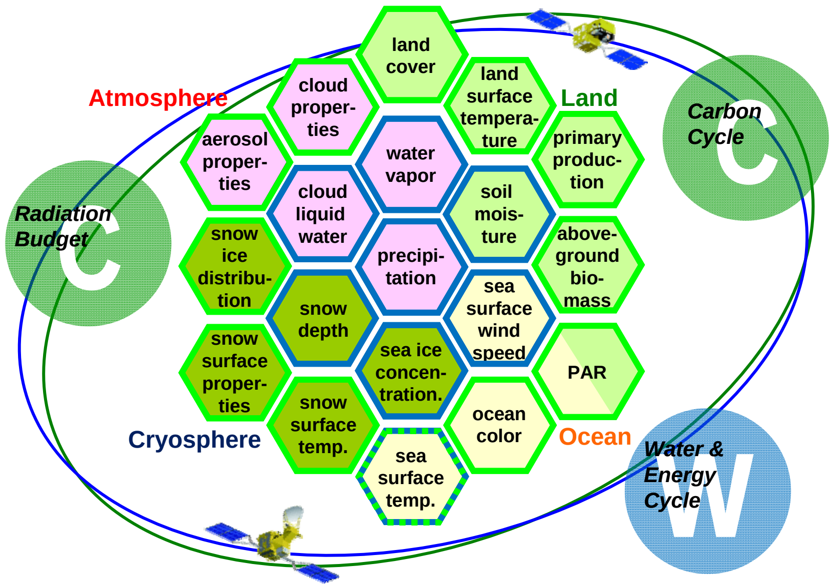

Figure 2: **GCOM geophysical parameters in four categories (atmosphere, land, ocean and cryosphese), which can be observed by GCOM-W (blue border) and GCOM-C (green border). Sea Surface Temperature is observed by both GCOM-W and GCOM-C, so its border is dotted line of blue and green.**

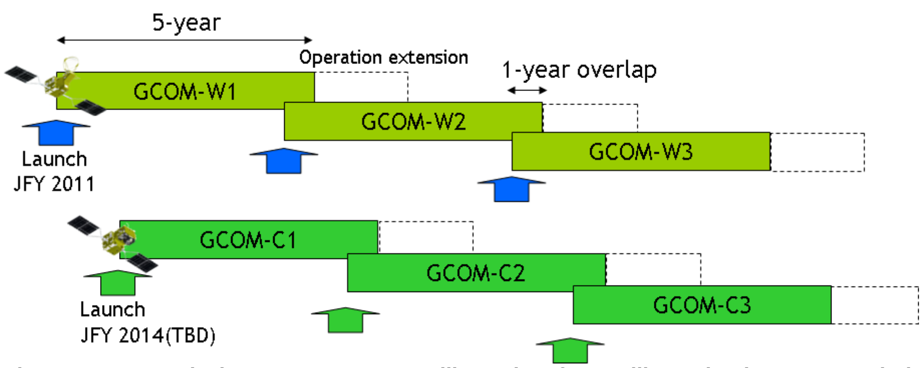

Figure 3: **GCOM mission concept. GCOM will consist of 2 satellite series (GCOM-W and C) spanning 3 generations in order to perform uniform and stable global observations for 13 years.**

GCOM-W1 SATELLITE:

AMSR2 instrument:

Targets of the GCOM-W1 satellite are water-energy cycle, and will carry the AMSR2. AMSR2 will continue AMSR-E observations of water vapor, cloud liquid water, precipitation, SST, sea surface wind speed, sea ice concentration, snow depth, and soil moisture (Table 2). Basic concept of AMSR2 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. Basic characteristics of the AMSR2 instrument are indicated in Table 3.

Following improvements of AMSR2 instrument are planned based on experience in the AMSR-E mission; a) Deployable main reflector system with 2.0m diameter; b) Frequency channel set is identical to that of AMSR-E except additional 7.3GHz channel for radio frequency interference mitigation; and c) Two-point external calibration with the improved HTS. In addition, deep-space maneuver will be considered to check the consistency between main reflector and Cold Sky Mirror (CSM).

The GCOM-W1 satellite will join NASA's A-train, in front of the Aqua satellite, to keep continuity of AMSR-E observation at the same orbit. It will also provide synergy with the other A-Train instruments for new Earth science researches.

<table>
<tr><th colspan="2" rowspan="2">Products</th><th rowspan="2">Areas</th><th rowspan="2">Resolution</th><th colspan="3">Accuracy</th><th rowspan="2">Range</th></tr>
<tr><th>Release</th><th>Standard</th><th>Goal</th></tr>
<tr><td colspan="2">Brightness temperature</td><td>Global</td><td>5-50km</td><td>±1.5K</td><td>±1.5K</td><td>±1.0K (systematic) ±0.3K (random)</td><td>2.7 - 340K</td></tr>
<tr><td rowspan="8">GEO</td><td>Integrated water vapor</td><td>Global, over ocean</td><td>15km</td><td>±3.5kg/m²</td><td>±3.5kg/m²</td><td>±2.0kg/m²</td><td>0 - 70kg/m²</td></tr>
<tr><td>Integrated cloud liquid water</td><td>Global, over ocean</td><td>15km</td><td>±0.10kg/m²</td><td>±0.05kg/m²</td><td>±0.02kg/m²</td><td>0 - 1.0kg/m²</td></tr>
<tr><td>Precipitation</td><td>Global, except cold latitude</td><td>15km</td><td>Ocean ±50%
Land ±120%</td><td>Ocean ±50%
Land ±120%</td><td>Ocean ±20%
Land ±80%</td><td>0 - 20mm/h</td></tr>
<tr><td>Sea surface temperature</td><td>Global, over ocean</td><td>50km</td><td>±0.5℃</td><td>±0.5℃</td><td>±0.2℃</td><td>-2 - 35℃</td></tr>
<tr><td>Sea surface wind speed</td><td>Global, over ocean</td><td>15km</td><td>±1.5m/s</td><td>±1.0m/s</td><td>±1.0m/s</td><td>0 - 30m/s</td></tr>
<tr><td>Sea ice concentration</td><td>Polar region, over ocean</td><td>15km</td><td>±10%</td><td>±10%</td><td>±5%</td><td>0 - 100%</td></tr>
<tr><td>Snow depth</td><td>Land</td><td>30km</td><td>±20cm</td><td>±20cm</td><td>±10cm</td><td>0 - 100cm</td></tr>
<tr><td>Soil moisture</td><td>Land</td><td>50km</td><td>±10%</td><td>±10%</td><td>±5%</td><td>0 - 40%</td></tr>
</table>

Table 2: **List of AMSR2 standard products and its target accuracies.**

Center Freq. [GHz]	Band Width [MHz]	NE Δ T[K]	Polarization	Beam Width [deg.] (Ground resolution [km])	Sampling interval [km]
6.925 / 7.3	350	< 0.34/0.43	V and H	1.8 (35 x 62)	10
10.65	100	< 0.70		1.2 (24 x 42)	
18.7	200	< 0.70		0.65 (14 x 22)	
23.8	400	< 0.60		0.75 (15 x 26)	
36.5	1000	< 0.70		0.35 (7 x 12)	
89.0 A/B	3000	< 1.20/1.40		0.15 (3 x 5)	5

Table 3: **Frequency channels and resolutions of AMSR2 instrument**

Data Providing Service System:

To distribute AMSR2 standard products along with AMSR and AMSR-E standard products, GCOM-W1 Data Providing Service System (https://gcom-w1.jaxa.jp) has been in operation since August 2011. Currently, only AMSR and AMSR-E standard products are available from the system. AMSR2 standard products will be also distributed via the system after its data release. AMSR2 near-real-time products will be also available from the system to special users.

The system was designed with user friendly interfaces. After simple registration, users enable to search products by three ways; 1) choose by categories and/or geophysical parameters; 2) choose by looking explanation of products; and 3) choose by name of satellites and/or sensors. AMSR2 original data format will be HDF5, and those of AMSR and AMSR-E are HDF4, but some format transformations are available at the system when users request products; 1) from HDF5 or HDF4 to GeoTIFF or TIFF; 2) from HDF5 or HDF4 to netCDF (netCDF 4 classic model, CF-1.4); and 3) from HDF4 to HDF5. Registered users can also use sftp or http protocols to download data without searching.

Data release plan:

AMSR2 standard products will be distributed through GCOM-W1 Data Providing Service System. To research and/or operational organizations, who conduct joint study with JAXA, data will be distributed for calibration and validation purposes after completion of initial checkout phase. It might take three months after the launch. To general users, data will be distributed after completion of calibration and validation phase. It might take one year after the launch.

AMSR2 research products and browse images, validation results will be available from JAXA's Earth Observation Research Center (EORC) (http://sharaku.eorc.jaxa.jp/GCOM_W/). Development of browse website and calibration/validation monitoring pages are underway. EORC is also developing multi-radiometer processing system, which applies AMSR2 algorithms to other microwave imagers, such as AMSR-E, SSM/I and TMI, to produce long-term climate records for global change study.

Validation activities:

For validation of AMSR2 standard products and development of some research products, JAXA implements two types of activities in cooperation with other researchers. The first category is utilizing the existing observation networks maintained by operational agencies, such as;

- Radio-sondes and GPS networks provided by Japan Meteorological Agency (JMA);
- SST and sea surface wind speed provided from various buoy system operated;
- Ground-based precipitation radar networks provided by JMA; and
- Snow depth and other surface measurements by meteorological agencies, etc..

The other one is implementation of specific field campaigns and monitoring focusing on specific parameters in collaboration with other projects, such as;

- Soil moisture test sites, such as Mongolia, Thailand, and CEOP sites including Australia Murray-Darling Basin; and
- Snow depth test site in Yakutsuk.

Validation results will be shown in JAXA EORC's web site, and some comparison will be available in operational basis.

TOWARD ARCHIVING CLIMATE RECORDS:

Continuous, homogeneous, and accurate observation of geophysical parameters, which construct the Earth environment, is one of key issues for understanding and evaluating signals of climate change and variation. The GCOM mission is JAXA's first mission whose concept emphasizes importance of "long-term" observation by satellite. Through AMSR-E and AMSR2 on board three generation of GCOM-W, we can make continuous and homogeneous observation of water cycle variables more than 25 years. Furthermore, integration of those data with past microwave imager data will enable us to evaluate trends of water cycle variables for nearly 50-year, such as changes in sea ice extent. It is needless to say that information provides us substantial information to understand long-term climate variation.

Sea ice monitoring is one of the strong points of microwave radiometers, because of its capability to observe sea ice under cloud with no distinction of day and night. Figure 4 shows sea ice concentration in Arctic region in 3rd October 2011 observed by AMSR-E (left panel), and comparison of daily variation of Arctic sea ice extent from January to December from 2002 to 2011 (right panel). The minimum sea ice extent was observed in September 2007 since the satellite microwave observation was initiated, and record of 2011 is the second minimum.

JAXA is developing climate record of sea ice concentration from 1987 to present, using observation from AMSR-E and the Special Sensor Microwave Imager (SSM/I) on U.S. Defense Meteorological Satellite Program (DMSP) satellites. Algorithm developed for AMSR-E was applied to each SSM/I data. We have plan to extend this climate record toward past period by using the Scanning Multichannel Microwave Radiometer (SMMR) on board the Nimbus-7 Pathfinder satellite, and toward future period by using AMSR2 and its follow-on instruments, which will be on board second and third generation of GCOM-W series.

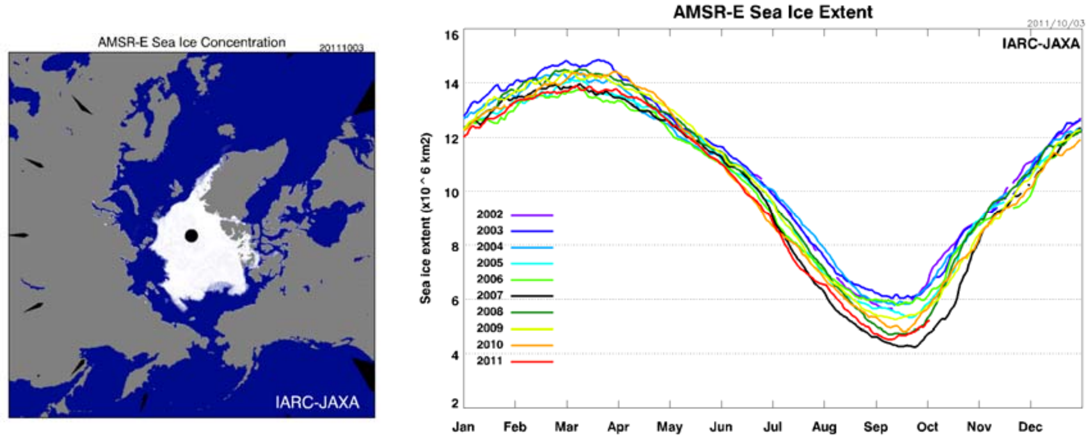

Figure 4: **Sea ice concentration extension observed by AMSR-E as of 3 October 2011. Left: Sea ice concentration of Arctic Sea. Right: Yearly variation of AMSR-E sea ice extent over the Arctic Sea. Images available at IARC-JAXA website (http://www.ijis.iarc.uaf.edu/cgi-bin/seaice-monitor.cgi?lang=e).**

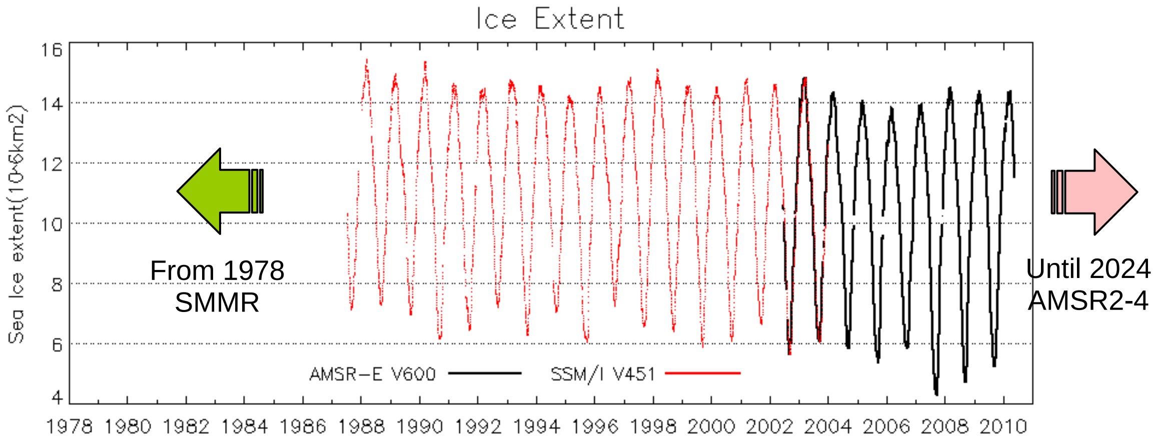

Figure 5: **Example of climate record of Arctic sea ice extent by SSM/I and AMSR-E. Record will be expanded to the past by using SMMR, and to the future by AMSR2 and follow-on instruments.**

REFERENCES

Imaoka, K., Kachi, M., Fujii, H., Murakami, H., Hori, M., Ono, A., Igarashi, T., Nakagawa, K., Oki, T., Honda, Y., Shimoda, H. (2010) Global Change Observation Mission (GCOM) for monitoring carbon, water cycles, and climate change. Proc. of the IEEE, **98**, pp 717-734.