Regular Observation by Global Change Observation Mission 1st-Water GCOM-W1 (SHIZUKU)

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Abstract

The Global Change Observation Mission 1st-Water GCOM-W1 (Japanese name SHIZUKU) is the first satellite in the two series of the Global Change Observation Mission (GCOM), a project to clarify the mechanisms of water cycle and climate change by observing the atmosphere, oceans, land, snow and ice over the entire globe over long periods (10 to 15 years). GCOM-W1 was launched from Tanegashima Space Center on May 18, 2012 with a mission to observe the mechanisms of the global water cycle. This paper introduces the GCOM-W1 satellite, the fields in which its observation data is applied and how this data is useful.

Keywords

GCOM-W1 Global Change Observation Mission 1st-Water, international cooperative observation, advanced microwave scanning radiometer 2, global observation standard bus, A-Train, GCOM

1. Introduction

The recently increasing severity of global environmental issues has stimulated worldwide interest in efforts toward their solution. Identifying the causes of global environmental issues is important to solving them, and long-term observation at the global scale using satellites provides very effective data for this identification. Japan Aerospace Exploration Agency (JAXA) is conducting the Global Change Observation Mission (GCOM) for clarifying the mechanisms of water cycle and climate change. The Global Change Observation Mission 1st-Water GCOM-W1 is the first satellite in two series for these observations. At NEC, we acted as the main contractor for the development of GCOM-W1, which was launched successfully from Tanegashima Space Center using the H-IIA launch vehicle on May 18, 2012. After initial function checks in orbit, the satellite began providing brightness temperature product data in January 2013 and geophysical quantity product data in May 2013.

2. Outline of GCOM-W1

2.1 On-orbit Satellite Configuration and Main Characteristics

Fig. 1 shows the on-orbit configuration and the **Table** shows its main characteristics.

2.2 Advanced Microwave Scanning Radiometer 2 (AMSR2)

The advanced microwave scanning radiometer 2 (AMSR2) is the successor to the advanced microwave scanning radiometer (AMSR) on board the ADEOS II satellite (Japanese name MIDORI 2) and the advanced microwave scanning radiometer for EOS (AMSR-E) on borad Aqua. AMSR2, at an altitude of 700 kilometers, detects weak microwaves that are radiated naturally from ground surfaces, ocean surfaces and the atmo-

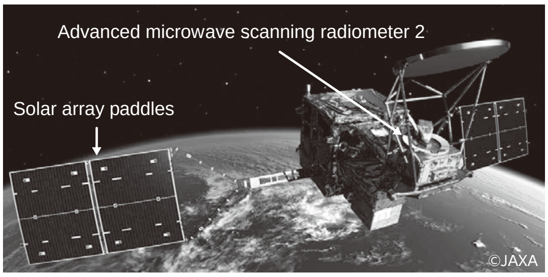

Fig. 1 On-orbit configuration of GCOM-W1.

Table Main characteristics.

Operational orbit	
Orbit type	Sun-synchronous sub-recurrent orbit
Altitude (at equator)	699.6 km
Orbital inclination	98.186º
Local sun time at ascending node	13:30 +/-15 min.
Reliability and service life	
Design life	5 years or more after launch
Reliability	Satellite bus: 0.8 or more (5 years after launch)
Launch	
Date	May 18, 2012
Launch vehicle	H-IIA
Mass	
Mass at launch	Approx. 2 tons (including propellant)
Electrical power	
Paddle system	2 paddles
Generated power	3,880 W or more (at worst EOL)
Battery capacity	200 Ah

sphere and measures their intensity with very high accuracy.

AMSR2's microwave-receiving antenna scans the earth's surface conically once every 1.5 seconds, with a range of about 1,450 km per scan. This scanning method allows AMSR2 to observe more than 99% of the globe once in the daytime and once at night every two days.

2.3 Mid-sized Observation Satellite Standard Bus

A typical satellite consists of a mission module such as earth observation sensor and a bus module for satellite power management attitude and orbit control and transmission of observation data.

The bus module should be standardized as much as possible between satellites to provide customers with products at low prices with fast delivery times and high quality. In our development of GCOM-W1, we fulfilled this need by applying as extensively as possible the results of the development of past satellites whose design and/or manufacturing were commissioned to us.

The most of the design of the GCOM-W1 bus module is applied in the development of the climate change observation satellite GCOM-C1, which also belongs to the GCOM series of satellites.

2.4 Efforts for High Reliability

GCOM-W1 is required to maintain high reliability so that it can continue uninterrupted observation over a long term. We made various development efforts to meet this requirement.

One such effort is the adoption of system engineering techniques. Since a satellite is a very large-scale system, we

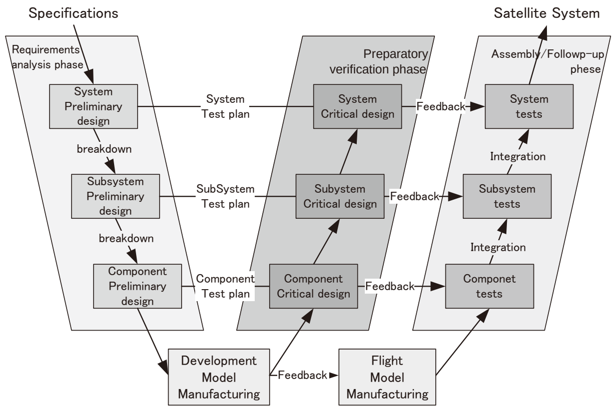

Fig. 2 V-Model in the development of GCOM-W1.

believe it is very effective to introduce system engineering techniques in order to confirm the packaging of functions and performance required for the satellite system.

One of the critical ideas in system engineering is the V-Model development process and we introduced it widely in the development process. **Fig. 2** shows the V-Model we applied in the development of GCOM-W1.

We advanced the development of GCOM-W1 by defining the preliminary design phases as requirement analysis phases and placing them on the left side of the V-Model, while placing the follow-up design phases on the right side. To improve verification reliability, we positioned the critical design phases as preparatory verification phases for confirming design validity, with verification through design analysis and development tests.

Another effort we made was to secure the traceability of the design specifications and test plans and the validity of tests/verification methods in the manufacturing and tests phases. Since it is not always possible to test each and every design specification requirement, it is necessary to fully consider the coverage of verification requirements. In the development of GCOM-W1, we secured high reliability by conducting sufficient reviews in the verification planning phases.

2.5 International Cooperative Observation by Participation in the A-Train

The A-Train is a constellation of earth observation satellites that orbit at an altitude of about 700 km at intervals of about 10 minutes. This satellite constellation is organized under the leadership of NASA (**Fig. 3**). It is called the A-Train because its orbit crosses the equator at around 1:30 in the "Afternoon" each day. This constellation provides a large variety of observation data acquired by various sensors on different satellites at the same time of day, enabling more knowledge to be obtained than through observation using a single satellite. The satellites currently participating in the A-Train are Aqua

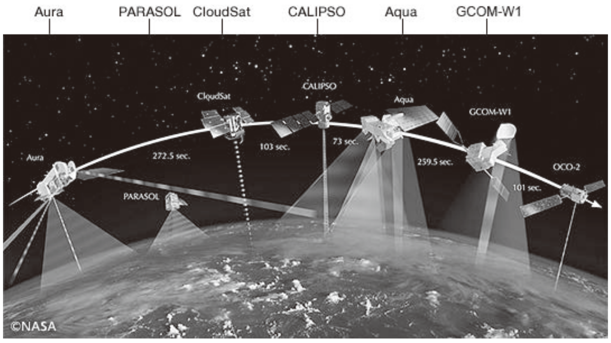

Fig. 3 Image of the A-Train satellite constellation.

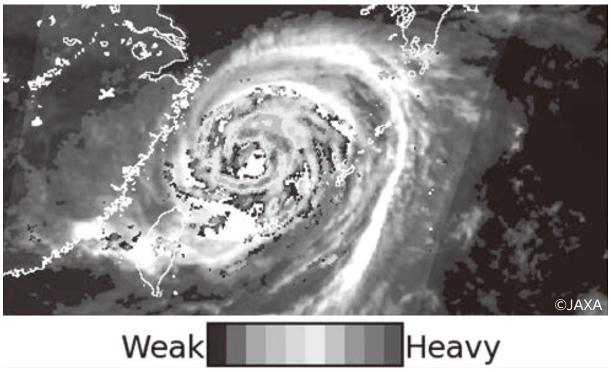

Fig. 4 Typhoon observation image.

(NASA, USA), CloudSat (NASA, USA), CALIPSO (NASA, USA/CNES, France) and Aura (NASA, USA). GCOM-W1 is the first Japanese satellite to join this project.

3. Utilization of Observation Data

The advanced microwave scanning radiometer 2 (AMSR2) mounted on GCOM-W1 is the successor to the advanced microwave scanning radiometer (AMSR) mounted on the ADEOS II satellite and the advanced microwave scanning radiometer for EOS (AMSR-E) mounted on the Aqua satellite. It takes over the observation activities of AMSR and AMSR-E and is expected to continue to provide more valuable data.

GCOM-W1 can observe eight geophysical parameters of the earth, including precipitation, integrated water vapor, sea surface temperature and soil moisture content. This data will be utilized by multiple fields, including meteorology, agriculture and fisheries.

3.1 Utilization for Meteorology

Weather forecasts are based on ground observation data obtained from observatories and weather radars in several locations as well as data sent from satellites such as GMS and MTSAT (both called HIMAWARI in Japanese). However, each observation method has its own advantages and disadvantages.

The Japanese meteorological satellites GMS and MTSAT are capable of capturing both visible-light and IR images from a geostationary orbit. The visible-light images are identical to what human eyes would see, while the IR images are able to be captured even at night. They are basically the same as photographic images and therefore the observation of sea and ground surfaces is impossible if there are clouds above them. In addition, since each satellite is in a geostationary orbit, it can permanently capture images of half the globe but cannot observe the regions on the other side of the globe.

In contrast, GCOM-W1 is equipped with a sensor that captures the microwaves radiated from sea and ground surfaces, so it can observe the distribution of rain and water vapor and the ground and sea surface conditions through the clouds. Therefore GCOM-W1's sensor can identify, for example, the center of a typhoon more accurately even if it is covered with clouds, so that more accurate information on the scale and course of the typhoon can be provided. For example, when the data observed with GCOM-W is superimposed on the cloud distribution data observed with MTSAT as shown in **Fig. 4**, the presence of the eye of a typhoon, which cannot be identified so accurately from cloud distribution data alone, is located clearly with the AMSR of GCOM-W1.2)

As seen above, when the data observed by GCOM-W1 is combined with other observation data, it can contribute to further improvement of weather forecast accuracy and earlier transmission of public cautions/warnings related to natural disasters.

The fact that GCOM-W1 observes 99% of the globe's surface every two days means that it can also collect information on regions very distant from Japan. The resulting possibility of almost real-time collection of global-scale data is expected to contribute to the elucidation of the causes of abnormal weather.

3.2 Utilization for Agriculture/Fisheries

As GCOM-W1 is also capable of observing soil water content, it is useful for predicting droughts and agricultural product growing conditions.

The data provided by GCOM-W1 is also of vital use to fisheries. Information on the oceanic environment and fish distribution is important for efficient fisheries. Since each species of fish has a water temperature most suitable for it, the sea surface water temperature data over a broad area, which GCOM-W1 observes in real time, is very useful for finding effective fishing places for each species.

Previously, AMSR-E, mounted on the Aqua satellite, was in charge of providing information on sea surface temperature for

Average distribution at annual minimum in September in the 1980s (result of analysis by a microwave sensor mounted on a U.S. satellite)

Observation by AMSR2 on GCOM-W1 on September 16, 2012 [under verification] (smallest distribution on record)

Fig. 5 Change in sea ice coverage on the Arctic Ocean.

Japanese fishermen, but AMSR-E finished operation in October 2011. Consequently, anticipation is high for the information provided by GCOM-W1, which will mount its successor sensor.

3.3 Utilization for Global-scale Climate Change Research

Water on the earth plays a significant role in the redistribution of energy radiated from the sun. It is important to observe the water cycle over a broad area over a long term in order to elucidate the mechanisms of global-scale climate change.

Changes in the various water-related geophysical parameters observable by GCOM-W1 (integrated water vapor quantity, integrated cloud liquid water, sea ice concentration, snow depth, etc.) play significant roles in climate change research.

As an example, **Fig. 5** shows the sea ice extent in the Arctic Ocean observed by GCOM-W1 in September 2012 and that observed by a U.S. satellite in the month of September in the 1980s. The sea ice in the Arctic Ocean has been declining following the rise in temperature in the Northern Hemisphere since the 1980s. It is considered that this may be because the gradual decrease in sea ice thickness made it vulnerable to the influence of the atmosphere (temperature and wind) and sea surface temperature.

4. Future Efforts by NEC

We at NEC are presently developing GCOM-C1 (**Fig. 6**), another satellite for the Global Change Observation Mission (GCOM), as the main contractor.

GCOM-C1 will be in charge of climate change observation. Using the second-generation global imager to be mounted on it, it will be used in long-term observation of parameters related to radiation/heat balance and vegetation on a global scale.

GCOM-C1 is being developed with the aim of a launch in FY2016. After completing a critical design review to determine the start of satellite manufacturing in March 2013, it is currently in the manufacturing phase. We will develop a highly reliable satellite with maximum use of the design, manufacturing and testing methods established with GCOM-W1.

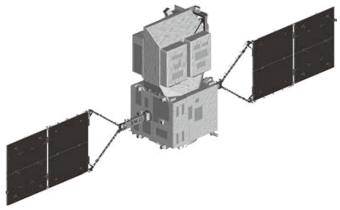

Fig. 6 On-orbit configuration of GCOM-C1.

5. Conclusion

After about a year since its launch, GCOM-W1 is currently in good condition, continually sending precious observation data to us. As it is important that observation data related to global environmental change be collected continually over a long term, JAXA is planning to launch the two satellite series of GCOM for three phases each, or six satellites in total, in their project.

The data obtained from global observation satellites such as GCOM-W1 is provided to many researchers and research organizations in Japan, as well as around the whole world, to contribute to protect people's daily lives. The technologies of NEC are expected to continue to play critical roles in this field.

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