

## CONCEPTS AND APPLICATIONS OF GCOM-W1 AND W2

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#### ABSTRACT:

The major sensor of the Water Series of Global Change Observation Mission (GCOM-W1) is The Advanced Microwave Scanning Radiometer-2 (AMSR2). AMSR2 is multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands. The instrument is a successor of AMSR on the Advanced Earth Observing Satellite-II (ADEOS-II) and AMSR for the Earth Observing System (AMSR-E) on NASA's Aqua satellite. Standard products of GCOM-W1 based on AMSR2 data are currently defined. All the eight standard products are: integrated water vapour, integrated cloud liquid water, sea surface temperature, sea surface wind speed, and sea ice concentration over ocean, snow depth and soil moisture content over land, and precipitation over the globe except for high latitude. Development of the GCOM-W1 system is going smoothly. Current target launch year of GCOM-W1 is in Japanese fiscal year 2011. Participation of GCOM-W1 in the A-Train constellation is now being coordinated. This is beneficial both to the inter-sensor calibration between AMSR-E and AMSR2, and synergistic use of the multiple instruments available in the A-Train. Offline simulation system of a land surface model has been developed at JAXA/EORC as for a pilot system of the future data assimilation products merging satellite data and model estimates, and shows promising results. The future possibility of installing a U.S. provided scatterometer on the second generation satellite of GCOM-W (GCOM-W2) is under discussion. Simultaneous active and passive microwave measurements will enhance the water cycle observation capability of the GCOM-W series.

### 1. INTRODUCTION

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. To contribute to those necessities and requirements, the Global Change Observation Mission (GCOM) is planned by the Japan Aerospace Exploration Agency (JAXA) for long-term continuous observation of the Earth's environment. GCOM is a successor mission of the Advanced Earth Observing Satellite-II (ADEOS-II), launched on December 2002 but terminated 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 Earth Observing System (AMSR-E) was also provided to NASA's Aqua satellite launched on May 2002, and is still continuing its operation for more than 8 years.

"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.

In this paper, we will present overview of science application of the GCOM-W1 with AMSR2, and its follow-on.

### 2. AMSR2 ON GCOM-W1

#### 2.1 AMSR2 Instrument

The major sensor of GCOM-W1 is the Advanced Microwave Scanning Radiometer-2 (AMSR2). AMSR2 is multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands. The instrument is a successor of AMSR on the ADEOS-II satellite and AMSR-E on the Aqua satellite. The frequency bands include 6.925, 7.3, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz. The 7.3-GHz channels were added to help mitigate RFI influences on the 6.925 channel based on limited observational evidence such as aircraft measurements, even though 6.925-GHz channels are kept since they have been successful and promising for retrieving sea surface temperature (SST) over the ocean. RFI identification methods will be investigated by comparing brightness temperatures from those two frequency bands. The instrument employs a conical scanning mechanism at a rotation speed of 40 rpm to observe the Earth's surface with a constant incidence angle of 55 degrees. Multiple feed horns are clustered to realize multi-frequency simultaneous observation. To compensate for gain variation, a two-point calibration is performed on every scan by using the high temperature noise source (HTS, temperature-controlled warm calibration target) and the cold-sky mirror (CSM) to introduce the deep space temperature. The 2.0m diameter antenna, which is larger than that of AMSR-E, provides better spatial resolution at the same orbital altitude of about 700km. Although we have had experience with the 2.0m-diameter dish itself for AMSR on ADEOS-II, a deployable antenna system with such a large aperture has been a new engineering development.

## 2.2 Standard Products

Standard products of GCOM-W1 based on AMSR2 data are currently defined (Table 1). All the eight geophysical standard products are: integrated water vapour, integrated cloud liquid water, sea surface temperature, sea surface wind speed, and sea ice concentration over ocean, snow depth and soil moisture content over land, and precipitation over the globe except for high latitude.

Table 1. AMSR2 Standard Products

| Standard Products                                  | Target Area                  | Resolution |
|--|------------------------------|------------|
| Brightness Temperature (6-channel, 2-polarization) | Global                       | 5-50km     |
| Integrated Water Vapor                             | Global ocean                 | 15km       |
| Integrated Cloud Liquid Water                      | Global ocean                 | 15km       |
| Precipitation                                      | Global except high-latitudes | 15km       |
| Sea Surface Temperature                            | Global ocean                 | 50km       |
| Sea Surface Wind Speed                             | Global ocean                 | 15km       |
| Sea Ice Concentration                              | Ocean in high-latitudes      | 15km       |
| Snow Depth   | Land                         | 30km       |
| Soil Moisture Concentration                        | Land                         | 50km       |

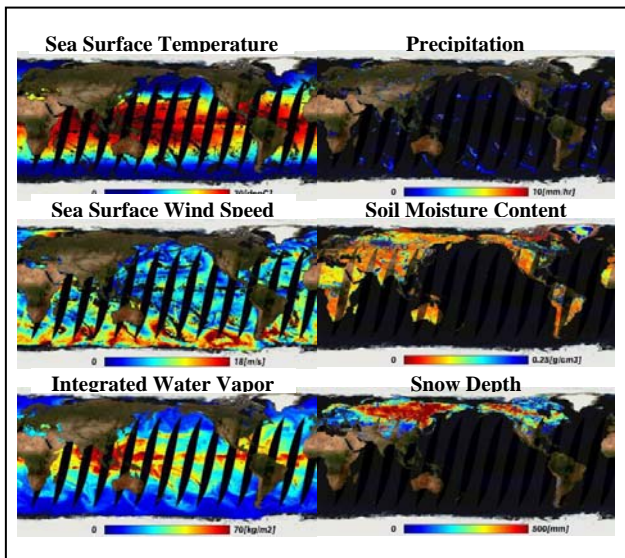


Figure 1. AMSR2 sample products in snap-shot (example produced by AMSR-E data).

The validities of these geophysical parameters have been proven by AMSR-E experience. However, there is a room for improvement in each geophysical parameter, particularly for land products. For example, the vegetation effect, which is one of the problems in the soil moisture retrieval using 6.925-GHz channels, should be more intensively assessed, and its error should be quantitatively identified. Cross validation and synergy with 1.4-GHz radiometer measurements, such as by the Soil Moisture and Ocean Salinity (SMOS) mission and the Soil Moisture Active and Passive (SMAP) mission, will be useful. Several research products are under discussion, including

integrated water vapour over land and sea ice, solid precipitation in cold latitudes, and sea ice thickness.

Table 2 Examination of possible utilization of satellite-based data in forcing data to LSM

| Input parameters (forcing data) to LSM   | Method in original Today's Earth system | Possible alternative data                                      |
|--|---|--|
| Surface Temperature, Surface Wind, Surface Pressure  | GPV forecast parameters                 | JRA-25 analysis data   |
| Surface Rainfall   | GPV forecast parameter                  | JRA-25 analysis data or GSMaP+ GPCP                            |
| Total Cloud Cover  | GPV forecast parameter                  | JRA-25 analysis data   |
| Surface Specific Humidity, Water Vapour Flux, Total Precipitable Water, Water Vapor Pressure | Calculate from GPV forecast parameters  | JRA-25 analysis data   |
| Downward Short Wave Radiation (Solar Radiation)  | Estimate from GPV parameters            | JRA-25 analysis data or MODIS and SeaWiFS Short Wave Radiation |
| Downward Long Wave Radiation   | Estimate from GPV parameters            | JRA-25 analysis data   |

## 3. APPLICATIONS

### 3.1 Assimilated Dataset

Data assimilation is being recognized as a powerful tool for interpolating intermittent satellite data. Assimilated results can be defined as research products. Data assimilation system under GCOM mission has not yet defined, however, JAXA/EORC established a research group on water cycle (W-RG) as one of the cross-cutting research groups over several satellite oriented missions under EORC, and the W-RG has started developing offline simulation system on water cycles over global land, which will be a basis for real-time data assimilation in the future. Current system does not have capability of data assimilation, but there are proposals to introduce the function in the system.

The pilot system simulates energy and water balances over global domain using Iso-MATSIRO, an extended version of MATSIRO (Minimal Advanced Treatments of Surface Interaction and Runoff) land surface model (LSM) (Takata *et al.*, 2003), driven by atmospheric forcing from satellite observations and assimilated data products. In addition to water balance components such as evapotranspiration, runoff, and soil moisture, river discharge is also calculated using Total Runoff Integrating Pathways (TRIP) (Oki and Sud, 1998). Currently, the system is just an offline simulation, using forecast data from the Japan Meteorological Agency (JMA) and satellite data as

external forcing. The pilot system is based on the “Today’s Earth” from IIS, The Univ. of Tokyo (Yoshimura *et al.*, 2008), and the system is under improvement at EORC for combined use of satellite and Gridded Point Value (GPV) data, which includes objective analysis and forecasts by JMA’s operational Global-Scale Model.

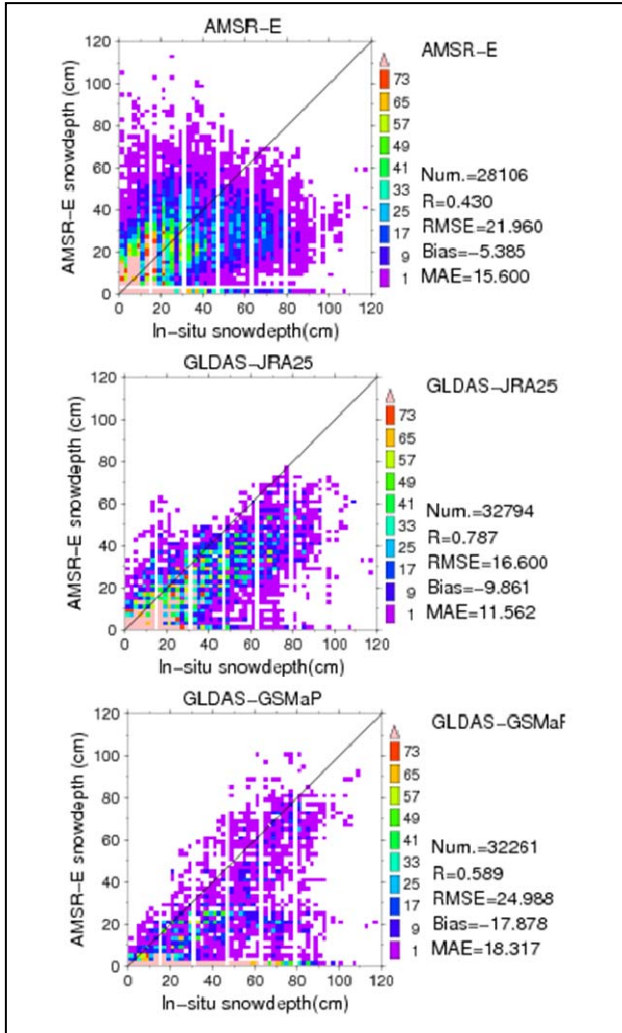


Figure 2. Upper: Daily mean comparison of in-situ measurement of snow depth and that retrieved from AMSR-E from 2003 to 2004. Middle: Same as upper panel but for snow depth calculated from Iso-MATSIRO using JRA-25 as input (GLDAS-JRA25). Bottom: Same as middle panel but replaced model rainfall to satellite-based rainfall (GLDAS-GSMaP).

For improvement of the system at EORC, possible utilization of satellite-based product and other data sources as forcing data (input to LSM) instead of GPV forecast is examined (Table 2). Rainfall by the Global Satellite Mapping for Precipitation (GSMaP) product, which is multi-satellite rainfall products based mainly on microwave imagers, will be replacement to model rainfall (Aonashi *et al.*, 2009; Ushio *et al.*, 2009). Downward surface short wave radiation product by MODIS and Monitoring for Environmental Studies (JASMES) website SeaWiFS data, which are distributed at JAXA Satellite Monitoring for Environmental Studies (JASMES) website (<http://kuroshio.eorc.jaxa.jp/JASMES/index.html>), can be also used as alternative input data (Frouin and Murakami, 2006).

Major advantage of utilization of JRA-25 analysis data (JMA’s 25-year Reanalysis dataset) as alternative to GPV is to enable model calculation for longer time period, since Total Cloud Cover in GPV forecast parameter is only available after November 2007.

Upper panel of Figure 2 shows daily comparison of snow depth for in-situ measurement and retrievals by AMSR-E from 2003 to 2004. Two experiments to use Iso-MATSIRO land surface model for the same period. One is an experiment using JRA-25 as input forcing parameters (here after refers as GLDAS-JRA25 experiment.) The other is same as GLDAS-JRA25 experiment but replace model rainfall to satellite-based rainfall (hereafter refers as GLDAS-GSMaP experiment.) Middle panel is same as upper one but in-situ observations are compared to output from GLDAS-JRA25 experiment and bottom panel to output from GLDAS-GSMaP experiment.

In-situ data is collected from the Global Summary of the Day (GSOD), and obtained from NOAA NCDC. 222 stations that meet the following conditions are selected and used for comparison; 1) The station is located in the northern hemisphere; 2) Water surface coverage within a 40km radius is less than 1%; 3) The difference between maximum and minimum height within a 40km radius is less than 300 meters; and 4) At least 100 records of snow depth data in the match-up dataset of AMSR-E are available. Correlation coefficient and root-mean-square error (RMSE) for GLDAS-JRA25 experiment show better accuracy than others. Replacement of model rainfall to satellite-based rainfall does not show positive effect because current rainfall retrieval algorithm for microwave radiometer cannot detect snowfalls.

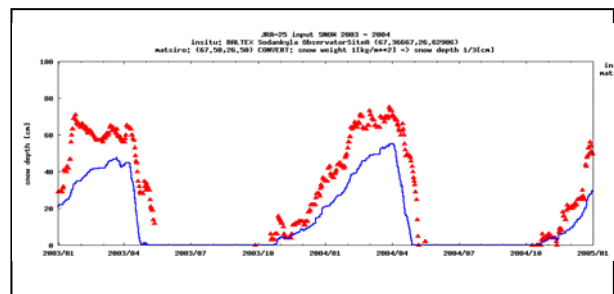


Figure 3. Temporal variation of snow depth by in-situ observation (red triangle) and by GLDAS-JRA25 experiment (blue line) from 2003 to 2004 at BALTEX Sodankyla, Finland (67.36667N, 26.62906E).

Figure 3 shows comparison of temporal variation of snow depth at BALTEX Sodankyla for the period of 2003 and 2004. Snow depth calculated by GLDAS-JRA25 experiment (blue line) shows good correspondence to in-situ measurement (red triangle) for seasonal cycle, but shows underestimate. Comparison to GLDAS-GSMaP experiment shows similar result to Figure 3 (not shown).

As next step, we plan to replace downward surface shortwave radiation to satellite-based product. Other plans to replace fixed database such as NDVI, and assimilation of forecast parameters such as soil moisture or snow depth are also discussed to improve the system.

### 3.2 Ocean Flux Dataset

Over the ocean, the evaporation and then the latent heat flux are estimated from microwave radiometer data, and the Japanese Ocean Flux data sets with Use of Remote sensing Observations (J-OFURO) is one of the activities conducted to compile the momentum flux and the four components of heat flux derived from remote-sensing observations. Although the use of multiple datasets from various satellites is indispensable, the importance of the instantaneous measurement of geophysical parameters was reported to compute accurate latent heat flux. AMSR2 will simultaneously provide SST, scalar sea surface wind speed, and columnar water vapour content, all of which are necessary to compute the latent heat flux. Recent studies have proposed the cross validation of the fresh water flux using both geophysical parameters from microwave radiometer and microwave scatterometer ocean vector winds. Although GCOM-W1 will not be capable of observing ocean surface vector winds, the future possibility of installing a scatterometer on the next generation satellite is under discussion. Simultaneous active and passive microwave measurements will enhance the water cycle observation capability of the GCOM-W series.

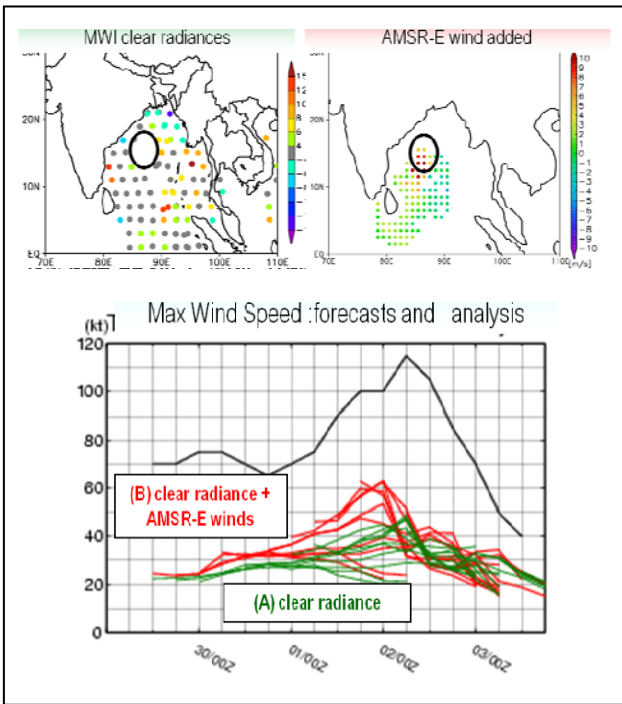


Figure 4. Example of improvement in maximum wind speed forecast by using AMSR-E all-weather wind speed for the case of Cyclone Nargis passing over the Indian Ocean in May 2008. Upper-left and -right panels show microwave radiances under clear sky, which is usually used for forecasting, and AMSR-E all-weather wind speed. Lower panel shows analysis (black), forecast just using clear microwave radiance (green), and forecast using AMSR-E winds in addition (Kazumori, 2009).

### 3.3 Weather Forecast

Japan Meteorological Agency (JMA) is currently using microwave radiometer data including AMSR-E for the meso-scale numerical prediction model (used for small-scale weather forecasting around Japan) and the global numerical prediction model (e.g., used for better forecasting of typhoon movement). In April 2008, JMA started to use the maximum wind speed

from microwave radiometers including AMSR-E for typhoon analysis (Kazumori, 2009).

The maximum wind speed from microwave radiometers are being used to help correcting the analysis based on infrared measurement from geostationary satellite. We are continuing the development of an all-weather wind-speed algorithm that uses the AMSR-E low-frequency channels of 6.9 and 10.65 GHz bands. The RSMC Tokyo - Typhoon Center of JMA is testing the product for their operational applications. Also, the Numerical Prediction Division of JMA performed a research to use the product for complementing the lack of assimilation data under cloudy conditions. Figure 4 shows the improvement of maximum wind speed forecast by using the AMSR-E all-weather wind speed as the information under cloudy conditions. The all-weather sea surface wind speed product is now also available from the WindSat brightness temperatures.

### 3.4 Integrated Utilization of Land Parameters

Land surface temperature observation by microwave imagers have big advantage in estimation under the clouds compared to optical imagers. Current soil moisture estimation algorithm for AMSR-E used fixed value for land surface temperature. Simultaneous estimation of land surface temperature with soil moisture will enable us not only to improve accuracy of soil moisture retrievals but also to obtain new product; Effective Near-surface Temperature (ENT) (Fujii *et al.*, 2010).

Figure 5 shows example of ENT obtained from AMSR-E for 1st June 2003 for descending (local time at 0130) and ascending (local time at 1330) orbits. SST from AMSR-E is also displayed. Diurnal variation of ENT over land is clearly seen especially over Sahara and India in Figure 4.

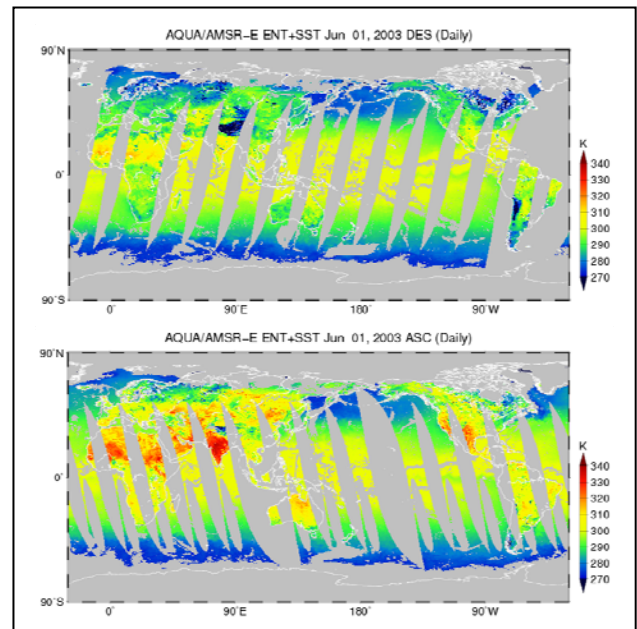


Figure 5. Example of ENT merged with SST, both retrieved from AMSR-E, for 1st June 2003 for descending (upper) and ascending (lower) orbits (Fujii *et al.*, 2010).

#### 4. FUTURE MISSION: GCOM-W2

Currently, discussion regarding the GCOM-W2 satellite is underway. In original concept of the GCOM mission, GCOM-W2 is to be launched 4-year after the launch of GCOM-W1 satellite, to achieve 1-year overlap to GCOM-W1/AMSR2 for calibration. AMSR2 improvement study for GCOM-W2 satellite recently has started. Discussion and study includes addition of high-frequency channels, c.f. 160GHz and/or 183GHz channels, to AMSR2. JAXA is also discussing with the National Oceanic and Atmospheric Administration (NOAA) and the Jet Propulsion Laboratory (JPL), the National Aeronautics and Space Administration (NASA) that U.S. provided scatterometer, a follow-on instrument to SeaWinds, will be installed on GCOM-W2. Sensor-level synergy for scatterometer is rain flag and correction in algorithm using AMSR2 data. That for AMSR2 is improvement of Brightness Temperature model as a function of wind vector. Other advantages in cross validation, and active and passive microwave synergy are highly expected.

#### 5. SUMMARY

Development of the GCOM-W1 system is going smoothly. Critical design review of AMSR2 was completed in January 2009, and flight model manufacturing is now underway. Thermal environment testing of the satellite system was over at the Tsukuba Space Center using the structural thermal model, and the critical design review of the satellite system was completed in July 2009. The additional review will be performed in early 2010 for remaining items. Participation of GCOM-W1 in the A-Train constellation is now being coordinated. This is beneficial both to the inter-sensor calibration between AMSR-E and AMSR2, and synergistic use of the multiple instruments available in the A-Train. Current target launch year of GCOM-W1 is in Japanese fiscal year 2011. Developing data assimilation system utilizing GCOM-W data for producing comprehensive hydrological cycle dataset is under consideration, and there is a possibility that will be implemented during the GCOM-W1 phase as a system to yield new research product.

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