APPENDIX 8

OVERVIEW OF THE ADVANCED MICROWAVE SCANNING RADIOMETER 3 (AMSR3)

1. Introduction

JAXA has developed a series of the Advanced Microwave Scanning Radiometer (AMSR), which is a multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands from 6.9 to 89 GHz. Major objectives of the AMSR series are to produce global and comprehensive water-related products, such as sea surface temperature, soil moisture, precipitation, sea ice, etc., for climate and water cycle variation studies, and to apply them to operational utilizations, such as numerical weather prediction and fisheries. AMSR series is unique due to its large size antenna (1.6 – 2.0 m) that enables observation in high-spatial resolution and 6GHz channels for sea surface temperature and soil moisture observations.

The first generation of AMSR series is AMSR on board the Advanced Earth Observing Satellite-II (ADEOS-II) mission, and AMSR for EOS (AMSR-E) on board the NASA's Aqua satellite, which was launched in May 2002. AMSR has 7-frequency with 16-channel including 50-GHz, and AMSR-E has 6-frequency with 14 channels. While mission period of AMSR was only 10-month due to trouble in satellite bass, AMSR-E continues its scientific observation more than 9 years. AMSR-E halted its scientific observation in normal mode with 40 rpm (antenna rotation per minute) on October 4, 2011 but resumed its observation in slow rotation mode with 2 rpm on December 4, 2012 to provide overlap observation with its successor, AMSR2, for inter-calibration. AMSR-E has completed its mission on December 4, 2015 after providing 3-year overlap observation data. We are planning to integrate the water-related parameters derived from AMSR2 with those from AMSR-E to produce long-term continuous datasets for climate change studies.

The second generation of AMSR series, AMSR2 on board the Global Change Observation Mission – Water (GCOM-W or "SHIZUKU"), was launched in May 2012 to succeed the AMSR-E observation by joining the A-train orbit. AMSR2 has 6-frequency with 16-channel, which are almost equivalent channel set to AMSR-E except additional 7.3 GHz channels to reduce impacts of Radio Frequency Interferences (RFIs) to C-band. The GCOM-W satellite and AMSR2 have completed its designed mission life of 5-year in May 2017 and are currently in post-mission phase. Both satellite and instrument continue operation in the orbit. (see APPENDIX 1)

To continue and improve current capability of water cycle/climate monitoring by AMSR2, JAXA is currently developing the third generation of AMSR series, called AMSR3, to be installed on the Global Observation SATellite for Greenhouse-gases and Water cycle (GOSAT-GW). The GOSAT-GW satellite will carry two instruments, AMSR3 and the Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3). TANSO-3, led by Japanese Ministry of the Environment (MOE) and National Institute of Environment Studies (NIES), will improve observation capability of greenhouse gases from TANSO-2 on board the Greenhouse gases Observing SATellite-2 (GOSAT-2). Target launch of the GOSAT-GW satellite is Japanese Fiscal Tear (JFY) 2023.

This chapter presents an overview of the mission objectives, observing systems, and data products of AMSR3.

2. Mission Objectives

Major targets of the AMSR3 mission are to produce long-term continuous data record of AMSR series in order to contribute scientific studies on global/regional water cycle and climate variations, and to enhance operational utilization of near-real-time data for weather forecast including hurricane analysis, fishery in coastal area, and navigational assistance on arctic shipping route along with new geophysical parameter products, such as snowfall, multi-band sea surface temperature, high-resolution sea ice concentration, all-weather sea surface wind speed, etc..

The mission objectives of AMSR3 are as follows.

- Understanding and prediction of water cycle variation
    - Understanding water cycle variation related to climate change and utilizing prediction of impacts to societal life and its response

- Operational application and contribution to society
    - Weather: Operationally utilizing AMSR data forecast activities in meteorological agencies, and contributing to improvement of prediction accuracy of tropical cyclones and heavy rainfalls
    - Fishery: Providing sea surface temperature information, and contributing in search of fishery fields
    - Navigation support: Providing sea ice concentration and sea surface temperature information, and contributing to production of sea status and sea ice maps related to safety navigation of ships and selection of optimum shipping routes

3. Observing Systems

3.1. GOSAT-GW satellite

Figure 1 presents an overview of the GOSAT-GW satellite; its major characteristics are listed in Table 1. The GOSAT-GW satellite will carry AMSR3 and TANSO-3.

Orbit specification of the GOSAT-GW satellite was decided to satisfy requirements from both AMSR3 and TANSO-3 missions. Ascending orbit will be during daytime (same as GCOM-W), orbit altitude is same as GOSAT, and local sun time is same as GCOM-W. Orbiting number of one recurrent day is 44 and smaller compared to that of GCOM-W (233), so there are some differences in observation frequency. Unlike AMSR2, AMSR3 cannot cover global area within 2-day and small missing areas are remained in tropics. Observation frequency of AMSR3 is not homogeneous for every longitude due to fewer orbiting number compared to AMSR2, and there are fixed areas less than 1 observation/day.

Figure 1: **Overview of GOSAT-GW satellite**

Table 1: Major characteristics of GOSAT-GW satellite

Instrument	Advanced Microwave Scanning Radiometer 3 (AMSR3) Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3)
Orbit	Sun-synchronous orbit Altitude: 666 km (over the equator) Reccurent cycle: 3-day MLTAN: 13:30 +-15min
Mass	2.6 ton
Power	> 5.3kW
Launch	JFY2023 by H-IIA Rocket
Design Life	7 years
Mission data downlink rate	Direct transmission with X-band: 400 Mbps Direct transmission with S-band: 1 Mbps (Only for AMSR3)
Status	Development phase (Phase B) since Dec. 2019

3.2. AMSR3 instrument

AMSR3 has 8-frequency with 21-channel. Sensor characteristics and channel sets, including center frequency, bandwidth, polarization, instantaneous field of view (FOV) of AMSR3 are indicated in Table 2 and 3. The basic concept is almost eqlivalent to that of AMSR2; a conical scanning system with 2-m diameter offset parabolic antenna; feed horn cluster to realize multi-frequency observation; external calibration with two temperature standards; and total-power radiometer systems. Due to lower orbit altitude compared to the GCOM-W satellite, FOV of each channel is slightly smaller and swath width of the sensor is slighthly narrower.

To achieve targets in section 2, AMSR3 will have almost equivalent channels from 6.9 to 89 GHz with additional channels in 10.25 GHz H/V-polarization, 165.5 GHz V-polarization, 183.31+-3 GHz V-polarization, and 183.31+-7 GHz V-polarization to improve sensor capability as shown in Table 3. New 10.25 GHz channels will have wider bandwidth compared to original X-band (10.65 GHz) channels to improve NEDT to provide more robust SST retrievals in high spatial resolution. It will also contrinute to reduce missing areas due to Radio Frequency Interferences (RFIs) in 10 GHz channels. Three channels of high-frequency channels were selected to contribute snowfall retrievals and water vapor analysis in numerical weather prediction. There are some changes in specification of 36.0 GHz channels from that of AMSR2 by considering future possible risk of RFIs might be caused by the 5th Generation Mobile Communications System (5G).

Table 2: **AMSR3 Sensor Characteristics**

Sensor type	Conical scanning total power microwave radiometer
Antenna	Off-set parabolic antenna (φ2.0m aperture)
Swath width	**> 1530 km**
Quantization	12 bit
Incidence angle	55 deg. except 89G-B, **166G, 183G**
X-polarization	< -20dB
Beam efficiency	> 90%
Range	2.7 - 340 K
Sampling interval	10 km except 89G (5 km)
Data rate	87.4 kbps (average)
Designed Life	**7 years**

*** Bold indicates changes from AMSR2.**

Table 3: **AMSR3 Channel Set**

Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1σ)	Beam width (field of view)
6.925 / 7.3	H/V	350	< 0.34 K	1.8° (34 km x 58 km)
10.25	**H/V**	**500**	**< 0.34 K**	**1.2° (22 km x 39 km)**
10.65	H/V	100	< 0.70 K	1.2° (22 km x 39 km)
18.7	H/V	200	< 0.70 K	0.65° (12 km x 21 km)
23.8	H/V	400	< 0.60 K	0.75° (14 km x 24 km)
36.42	H/V	**840**	< 0.70 K **(TBD)**	0.35° (7 km x 11 km)
89.0 A/B	H/V	3000	< 1.20 K	0.15° (3 km x 5 km)
165.5	**V**	**4000**	**< 1.50 K**	**0.30° (4 km×9 km)**
183.31±7	**V**	**2000×2**	**< 1.50 K**	**0.27° (4 km×8 km)**
183.31±3	**V**	**2000×2**	**< 1.50 K**	**0.27° (4 km×8 km)**

*** Bold indicates changes from AMSR2.**

4. Products

List of AMSR3 standard products are shown in Table 4. A “standard” product is defined as a product with proven accuracy that is to be operationally processed and distributed. In contrast, a “research” product is a prototype for a standard product and is processed on a research basis. Both tables indicate standard products with shading. Several products that are research product in AMSR2 are upgraded to standard product in AMSR3. Tables 5-7 indicates a list of research products for AMSR3. Table 5 shows products that can be obtained from AMSR3 onlt, while Tables 6 and 7 are multi-satellite products. In AMSR3, we plan to produce Climate Data Record (CDR) from the AMSR series and other sensors to provide long-term water cycle datasets (Table 7).

Table 4: **Standard Geophysical Products of AMSR3**

Product Name (ID)	Stored Parameter	Area	Spatial Resolution	Range	Release Accuracy	Standard Accuracy	Note
Brightness Temperature (L1B)	Brightness Temperature (6-89GHz)	Global	5-50 km	2.7-340 K	±1.5 K	±0.3 K	TB differences between Asc. and Dsc. orbits after removing bias based on AMSR2 or TB estimate from numerical prediction model over ocean & in clear sky condition. Requirements for high-frequency channels (center frequency, band width etc.) is equal to that of GMI.
	High-frequency Brightness Temperature (166,183GHz)	Global	10 km	2.7-340 K	±1.5 K	±1.0 K	
Resampled Brightness Temperature (L1R)	Brightness Temperature (6-89GHz)	Global	5-50 km	2.7-340 K	±1.5 K	±0.3 K	
	High-frequency Brightness Temperature (166,183GHz)	Global	10 km	2.7-340 K	±1.5 K	±1.0 K	
Total Precipitable Water (TPW)	Total Precipitable Water over ocean	Global Ocean	15 km	0-70 kg/m^2	3.5 kg/m^2	3.0 kg/m^2	RMSE to GPS and/or sonde observation.
	Total Precipitable Water over Land	Global Land*	15 km	0-70 kg/m^2	6.5 kg/m^2	3.5 kg/m^2	RMSE to GPS and/or sonde observation. * Sparse vegetation area

Table 4: **Standard Geophysical Products of AMSR3 (cont.)**

Product Name (ID)	Stored Parameter	Area	Spatial Resolution	Range	Release Accuracy	Standard Accuracy	Note
Integrated Cloud Liquid Water Content (CLW)	Integrated Cloud Liquid Water Content	Global Ocean	15 km	0-1.0 kg/m^2	0.10 kg/m^2	0.05 kg/m^2	RMSE to optical imager observation.
Precipitation (PRC)	Liquid Precipitation	Global	15 km	0-20 mm/h	Ocean :50 % Land:120 %	Ocean:50 % Land:120 %	Relative error to GPM/DPR and/or ground radar network in 0.5-degree equivalent grid.
	Solid Precipitation	Global	10 km	0-4 mm/h	Ocean :130%* Land:200%*	Ocean:130%* Land:200%*	Relative error to GPM/DPR and/or EarthCARE/CPR in 0.5-degree equivalent grid. * Evaluate with monthly precipitation more than 1mm/month.
Sea Surface Temperature (SST)	6.9GHz Sea Surface Temperature	Global Ocean	50 km (6GHz)	-2 -35 ℃	0.8 ℃	0.5 ℃	RMSE to buoys observation.
	Multi-band Sea Surface Temperature		30 km (6+7+10GHz)			0.6 ℃	
Sea Surface Wind Speed (SSW)	Sea Surface Wind Speed	Global Ocean	15 km	0-30 m/s	1.5 m/s	1.0 m/s	RMSE to buoys observation.
All-weather Sea Surface Wind Speed (ASW)	All-weather Sea Surface Wind Speed	Global Ocean in high-wind	50 km	0-70 m/s	7 m/s	5 m/s	RMSE to dropsonde observation (winds speed more than 15 m/s).
Sea Ice Concentration (SIC)	Sea Ice Concentration	Polar Ocean	15 km	0-100 %	10 %	10 %	RMSE to optical imager observation.
High-resolution Sea Ice Concentration (HSI)	High-resolution Sea Ice Concentration	Polar Ocean	5 km	0-100 %	15 %	15 %	RMSE to optical imager observation.
Soil Moisture Content (SMC)	Soil Moisture Content	Global Land	50 km	0-40 %	10 %	5 %	MAE to ground-based observation.
Snow Depth (SND)	Snow Depth (Snow Water Equivalent)	Global land	30 km	0-100 cm	20 cm	20 cm	MAE to ground-based observation.

Table 5: **Research Products of AMSR3 (AMSR3 only product)**

Product Name (ID)	Area	Spatial Resolution	Range	Release Accuracy	Note
FOV-center Matched Brightness Temperature (L1C)	Global	5-50km	2.7-340 K	±1.5 K	TB differences between Asc. and Dsc. orbits after removing bias based on AMSR2 or TB estimate from numerical prediction model over ocean & in clear sky condition.
High-resolution Brightness Temperature (L1H)	Global	20-30 km	2.7-340 K	±1.5 K	6-89GHz only. TB differences between Asc. and Dsc. orbits after removing bias based on AMSR2 or TB estimate from numerical prediction model over ocean & in clear sky condition.
High-resolution Sea Surface Temperature (HST)	Global Ocean	20 km*	-2 -35 ℃	0.8 ℃	RMSE to buoys observation. *Input high-resolution brightness temperature
Land Surface Temperature (LST)	Global Land	15 km	0 - 50 ℃	Forest: 3 ℃ Non-dense vegetation: 4 ℃	MAE to ground-based observation.
Vegetation Water Content (VWC)	Global Land	10 km	0 - 4 kg/m^2	1.0 kg/m^2	RMSE to optical imager and/or ground-based observations.
Thin Ice Detection (TSI)	Polar Ocean	15 km	N/A	80 %	Right answer ratio to optical imager and/or ground-based observations.
Sea Ice Moving Vector (SIM)	Polar Ocean	50 km	0 – 40 cm	6 cm/s	Output zonal/meridional components.

Table 6: **Research Products of AMSR3 (merged product)**

Product Name (ID)	Area	Spatial Resolution	Range	Release Accuracy	Note
Soil Moisture and Vegetation Water Contents based on Land Surface Data Assimilation (LDA)	Africa, Australia (global in future)	25 km	Soil Moisture Content: 0 - 40 % Vegetation Water Content: 0 -2 kg/m^2	Soil Moisture Content: 8 % Vegetation Water Content: 1 kg/m^2	AMSR3 + Land model product. MAE to ground-based and/or optical imager observations. Need improvements in computer capability.

Table 7: **Research Products of AMSR3 (Climate Data Record (CDR))**

Product Name	Area	Spatial Resolution	Range	Release Accuracy	Period
Brightness Temperature CDR	Global	5-50 km	2.7-340 K	±1.5K	2002 - present
Total Precipitable Water CDR	Global Ocean	15 km	0-70 kg/m^2	3.5 kg/m^2	1987 - present
Integrated Cloud Liquid Water Content CDR	Global Ocean	15 km	0-1.0 kg/m^2	0.10 kg/m^2	1987 - present
Sea Surface Temperature CDR	Global Ocean	50 km	-2 -35 ℃	0.8 ℃	2002 - present
Sea Surface Wind Speed CDR	Global Ocean	15 km	0-30 m/s	1.5 m/s	1987 - present
All-weather Sea Surface Wind Speed CDR	Global Ocean	50 km	0-70 m/s	7 m/s	2002 - present
Sea Ice Concentration CDR	Polar Ocean	15 km	0-100 %	10 %	1978 - present
Snow Depth CDR	Global Land	30 km	0-100 cm	20 cm	2002 - present
Soil Moisture Content CDR	Global Land	50 km	0-40 %	10 %	2002 - present
Precipitation CDR (GSMaP Product)	Global	10 km	0-20 mm/h	Liquid Precipitation: Ocean:50%/Land:120 % Solid Precipitation: Ocean:80 %/Land:150 %	2000 - present