Development for all-sky assimilation of JAXA's future microwave sensor AMSR3 in the JMA's NWP systems

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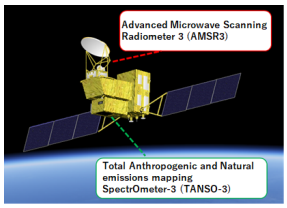
1. Introduction

JAXA's Advanced Microwave Scanning Radiometer 2 (AMSR2) has been operated on orbit since May 2012 and its microwave radiance data have been assimilated in the JMA's numerical weather prediction (NWP) systems. The assimilation of microwave radiance data has significantly improved NWP skills. In this context, JAXA plans to operate AMSR3 carried by the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW). JMA is preparing for assimilation of microwave radiance data from AMSR3.

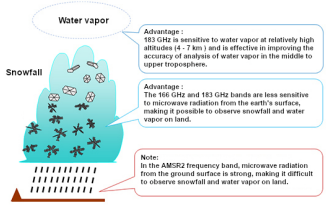
2. About AMSR3

- AMSR3 will be carried by the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW).
- AMSR3 will have all the frequency channels and polarization combinations of AMSR2 as well as additional three high-frequency channels (165.5 GHz, 183 ± 3 GHz and 183 ± 7 GHz, V-pol).



Satellite specification

Orbit	Type	Sun-synchronous, Sub-recurrent orbit
	Altitude	666km, recurrent cycle 3days (same as GOSAT)
	MLTAN	13:30±15min (same as GCOM-W)
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)
Target launch		JFY2024 (Apr. 2024 – Mar. 2025)



Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1σ)	Beam width (spatial resolution)
6.925 7.3	H/V	350	< 0.34 K	1.8° (34km x 58km)
10.25	**H/V**	**500**	**< 0.34 K**	**1.2° (22km x 39km)**
10.65	H/V	100	< 0.70 K	1.2° (22km x 39km)
18.7	H/V	200	< 0.70 K	0.65° (12km x 21km)
23.8	H/V	400	< 0.60 K	0.75° (14km x 24km)
36.42	H/V	**840***	< 0.70 K	0.35° (7km x 11km)
89.0 A/B	H/V	3000	< 1.20 K	0.15° (3km x 5km)
165.5	**V**	**4000**	**< 1.50 K**	**AZ=0.23° / EL=0.30° (4km x 9km)**
183.31±7	**V**	**2000 × 2**	**< 1.50 K**	**AZ=0.23° / EL=0.27° (4km x 8km)**
183.31±3	**V**	**2000 × 2**	**< 1.50 K**	**AZ=0.23° / EL=0.27° (4km x 8km)**

Red: Changes from AMSR2 including additional CHs

* Changed the specification of Ka-band passband to reduce the future risk of RF interference from 5-G mobile communication system

5. Summary & Future plan

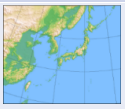
Summary

JMA is preparing for assimilation of microwave radiance data from AMSR3.

- AMSR3 will have additional three high-frequency channels (165.5 GHz, 183 ± 3 GHz and 183 ± 7 GHz, V-pol)
- Development for assimilating humidity sounding channels by using a dynamic emissivity retrieval.
  - DE method is effective over sea-ice area. The Impact on data assimilation is currently under investigation.
- Development for all-sky radiance assimilation in regional NWP
  - By using Individual hydrometer sub-grid fractions in RTTOV13, much realistic MW TB can be simulated.
  - We are not getting enough impact by all-sky assimilation in regional NWP. One possible reason is that estimated observation error based on cloud predictor is relatively high in regional NWP.

3. JMA's NWP system

Specifications of JMA's NWP system and assimilation method for microwave imagers as of Feb. 2023.

	Global analysis (GA)	Meso-scale analysis (MA)	Local analysis (LA)
Horizontal resolution	Outer: approx. 20 km Inner: approx. 55 km	Outer: 5 km Inner: 15 km	Outer: 2 km Inner: 5 km
Domain			
Assimilation method	All-sky radiance	Clear-sky radiance Retrieved precipitation	Clear-sky radiance

- GA: To use water vapor sounding channel over land and sea-ice more effectively, we attempt to introduce a dynamic emissivity retrieval method.
- MA,LA: To assimilate rain-affected radiance data more effectively, we are working on developing all-sky radiance assimilation in regional NWP

4. Plan and development for assimilating AMSR3's data

Plan for all-sky assimilation

- We will assimilate 18.7V, 23.8V, 36.4V, 183 ± 3V, 183 ± 7V (GHz) channels with all-sky approach.
- Observation error is assigned based on a symmetric (average of observation and model) cloud amount.
  - 2 types of cloud amount will be used.
    - polarization difference of 37GHz (C37) (Geer and Bauer 2011) will be used for low frequency channels(18 ~ 36.4 GHz)

$$C37 = 1 - \frac{TB_{37v} - TB_{37h}}{TB_{37v}^{clr} - TB_{37h}^{clr}}$$

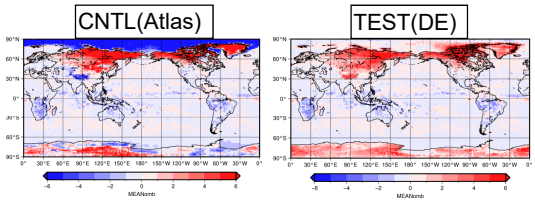
    - Scattering Index (SI) (Geer et al. 2014) will be used for high frequency channels (183 GHz)

$$SI = (TB_{90} - TB_{150}) - (TB_{90}^{clr} - TB_{150}^{clr})$$

Development for assimilating humidity sounding channel by using a dynamic emissivity retrieval method

- To obtain accurate surface emissivity over land and sea-ice, we attempt to apply a dynamic emissivity retrieval method (Karbou et al., 2005, Baordo and Geer, 2016) to the humidity-sounding sensors(ATMS, SSMIS, MHS, GMI, MWHS-2)

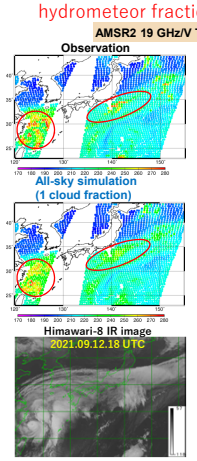
Mean of O-B for ATMS ch19 (183±4.5 GHz) over December 2022.

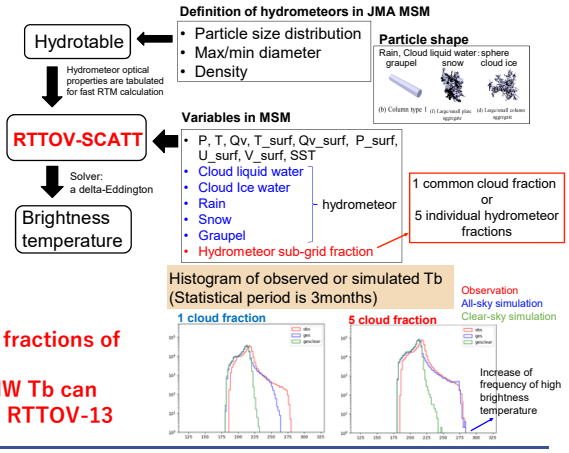


The DE method reduces O-B bias in high latitude, especially over sea ice.
The impact on data assimilation will be investigated.
89 GHz (over land) and 165 GHz (over sea ice) channels will be used for emissivity retrieval of AMSR3.

Development toward all-sky assimilation in the regional NWP

- Comparison of AMSR2 brightness temperature between observation and simulation
  - RTTOV13 is used as radiative transfer model
  - Comparison of the use of common cloud fraction to each hydrometeor and the use of individual hydrometeor fraction for RTM



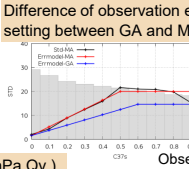


By using sub-grid fractions of 5 hydrometeors, a more realistic MW Tb can be simulated with RTTOV-13

Impact evaluation of the all-sky assimilation in the regional NWP

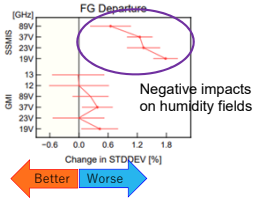
- The data assimilation experiments were conducted.
  - CNTL: Clear-sky radiance and retrieved precipitation of AMSR2 were assimilated (Same as operational meso-scale NWP as of May 2021)
  - TEST: Same as CNTL but, only AMSR2 was transferred to all-sky assimilation (retrieved precipitation was not assimilated)
  - Experimental period : 26 June - 23 July 2020

Difference of observation error setting between GA and MA

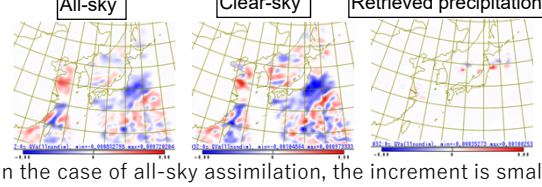


Observation error is relatively high in MA

Changes of STD of FG departure against CNTL



Comparison of increment for AMSR2 data (850hPa Qv)



In the case of all-sky assimilation, the increment is smaller than clear-sky assimilation even in clear-sky area. The increment for rain-affected observation is also small.