Development for better utilization of AMSR3 humidity sounding channels in JMA's global NWP system

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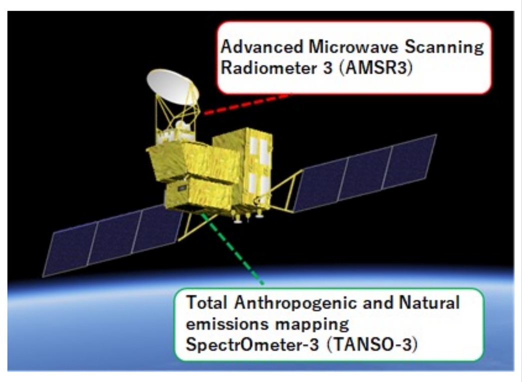
① Introduction

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. 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).

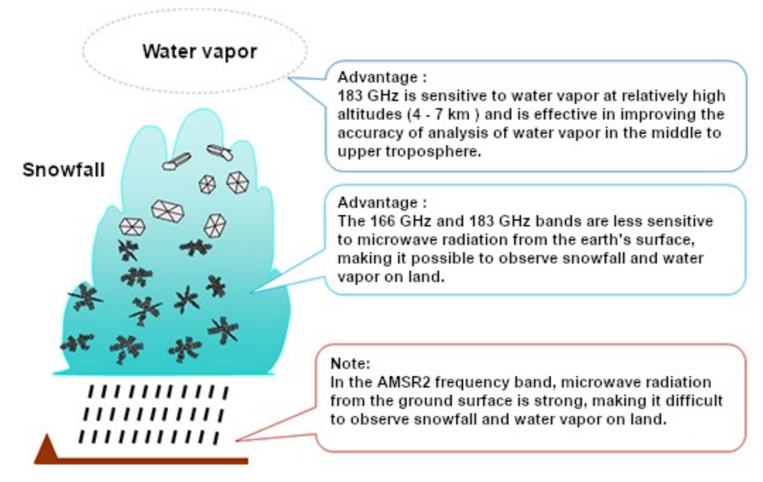


Satellite specification

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		JFY2025 (Apr. 2025 – Mar. 2026)

Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1σ)	Beam width (spatial resolution)
6.925 7.3	H/V	350	< 0.34 K < 0.43 K	1.8° (33km x 57km)
10.25	H/V	500	< 0.33 K	1.2° (22km x 38km)
10.65	H/V	100	< 0.70 K	1.2° (22km x 38km)
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° (6km 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



(https://www.eorc.jaxa.jp/AMSR/satellite/gosat-gw_en.html)

⑦ Summary & Future plan

Summary

- We attempted to apply DE retrieval method and superobservation to MW humidity sounder radiance and assessed each and combined impact on NWP skills.
  - Assimilating surface sensitive data using DE method improved accuracy of water vapor fields especially over Eurasian continent and sea ice area.
  - Assimilating superobbed radiance improved water vapors fields in the FG and analysis. Superobbing was more important when using data that was strongly affected by clouds.
  - The combined experiments yielded significant improvements in both the temperature and water vapor fields.

Future plan

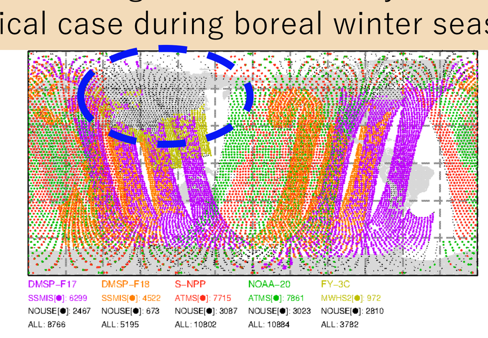
- We are currently conducting the final assessment along with other development items, aiming to implement them into JMA's global NWP system in Sep. 2025
- After the AMSR3 data becomes available, initial assessments of data quality and data assimilation experiments with these methods will be conducted.

③ Challenges for better utilization of MW humidity sounder

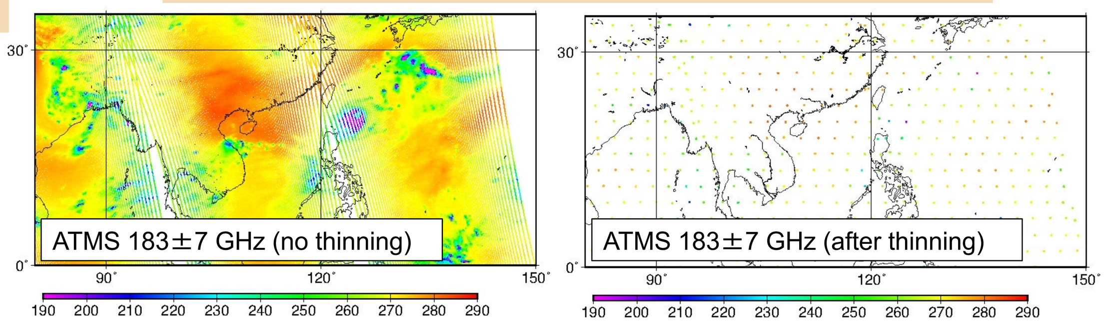
◎MW imagers & humidity sounders are assimilated with all-sky approach in the global NWP system, but following points remain challenges in the use of humidity sounders:

1. The data over land and sea-ice under dry atmospheric conditions, where the sufficiently precise surface emissivity is not used, are removed.
   ➢ Assimilating surface sensitive data using DE retrieval method.
2. Approx. 99 % of the data are not assimilated due to thinning.
3. The data strongly affected by clouds are not assimilated because of the discrepancies between observations and model simulations representation.
   ➢ Assimilating superobbed radiance and reducing the thinning distance

Data coverage of MW humidity sounder in a typical case during boreal winter season



Differences in data coverage with and without thinning



④ Impact of assimilating surface sensitive data using DE method

- To obtain accurate surface emissivity over land and sea ice, Dynamic Emissivity retrieval method (Karbou et al., 2005, Baordo and Geer 2016) was applied.

$$T_b(\nu,\theta) = T_s\varepsilon(\nu,\theta)\Gamma + \{1-\varepsilon(\nu,\theta)\}\,\Gamma\, T_d^{\downarrow}(\nu,\theta) + T_d^{\uparrow}(\nu,\theta)$$

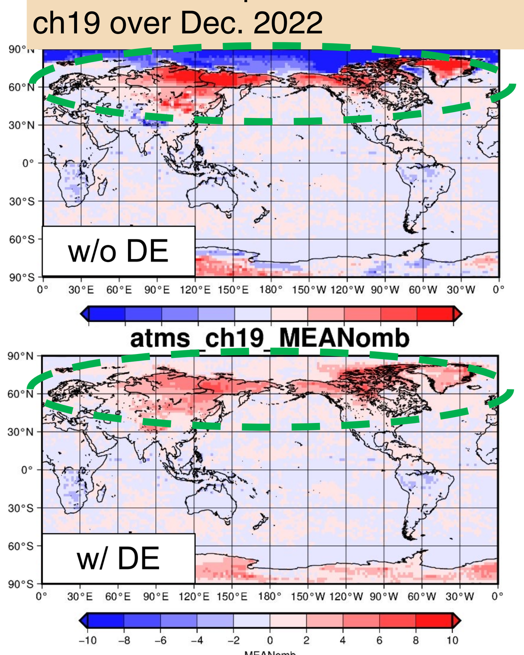
$$\varepsilon(\nu,\theta) = \frac{T_b(\nu,\theta) - T_d^{\downarrow}(\nu,\theta)\Gamma - T_d^{\uparrow}(\nu,\theta)}{(T_s - T_d^{\downarrow}(\nu,\theta))\Gamma}$$

$T_b(\nu,\theta)$: brightness temp.
ν: frequency, θ: zenith angle
T_s: land surface temp. (LST)
$T_d^{\downarrow}$: downwelling T_b
$T_d^{\uparrow}$: upwelling T_b
Γ: transmissivity

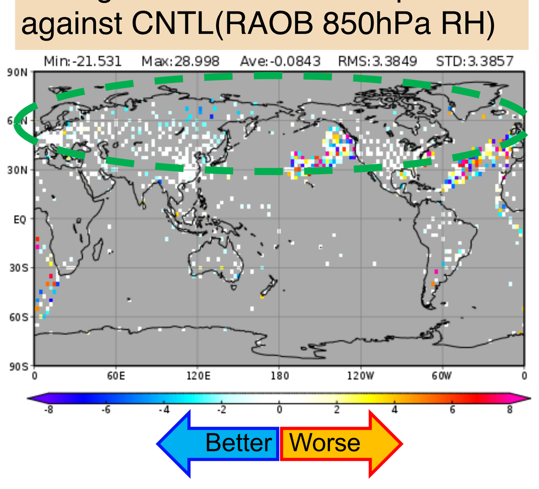
Actually, the equation in the RTTOV13 subroutine that accounts for cloud effects was used.

- DE method reduced biases of FG departure for MW humidity sounder data. Assimilating surface sensitive data of MW humidity sounder data using DE method improved accuracy of water vapor field in the short-range forecast.

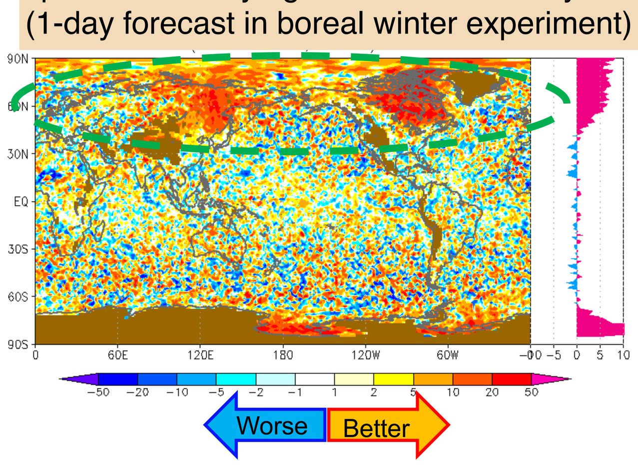
Mean of FG departure for ATMS ch19 over Dec. 2022



Change in RMSE of FG departure against CNTL(RAOB 850hPa RH)



Improvement rate of RMSE for 850hPa specific humidity against ECMWF analysis (1-day forecast in boreal winter experiment)

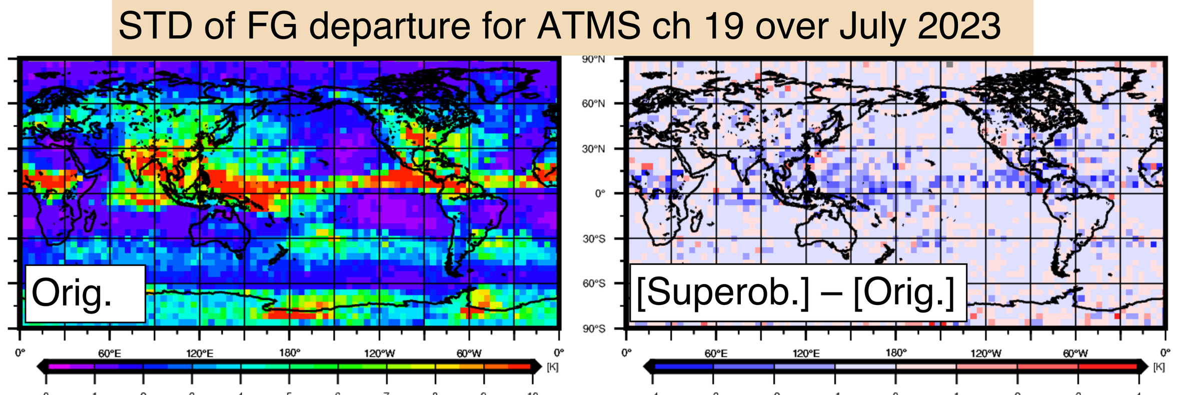


Water vapor fields were significantly improved over the area like snow covered land and sea ice.

⑤ Impact of assimilating superobbed radiance

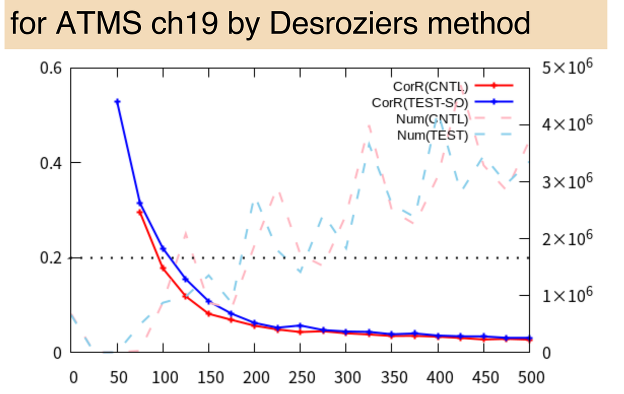
- Superobservation (Average radiances with 4D-Var inner model grid spacing (approx. 55 km), which is currently applied to MW imager only) reduced the representativeness error, which in turn reduced the STD of FG departure for MW humidity sounders.
- Assimilating superobbed radiance slightly improved water vapor fields in the FG and analysis. Superobbing was more important when using data that was strongly affected by clouds.
- Reducing the thinning distance (250-180 km → 150 km) further improved water vapor field in the FG and analysis

STD of FG departure for ATMS ch 19 over July 2023

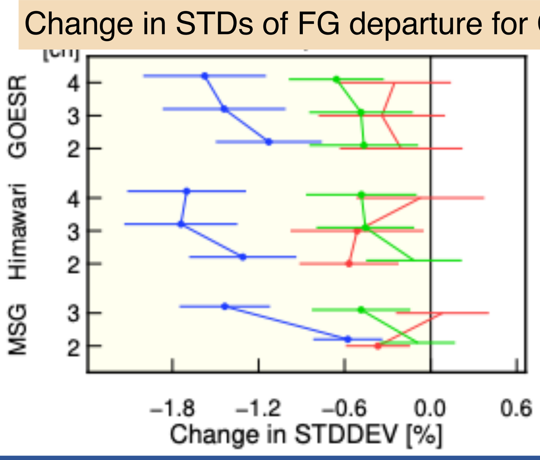


Superobservation reduced the STD of the FG departure, especially over tropical region

Horizontal correlation of observation error for ATMS ch19 by Desroziers method



Change in STDs of FG departure for CSR



Impact of ..
- Assimilating superobbed radiance data.
- Assimilating additional use of cloud affected data.
- Reducing the thinning distance

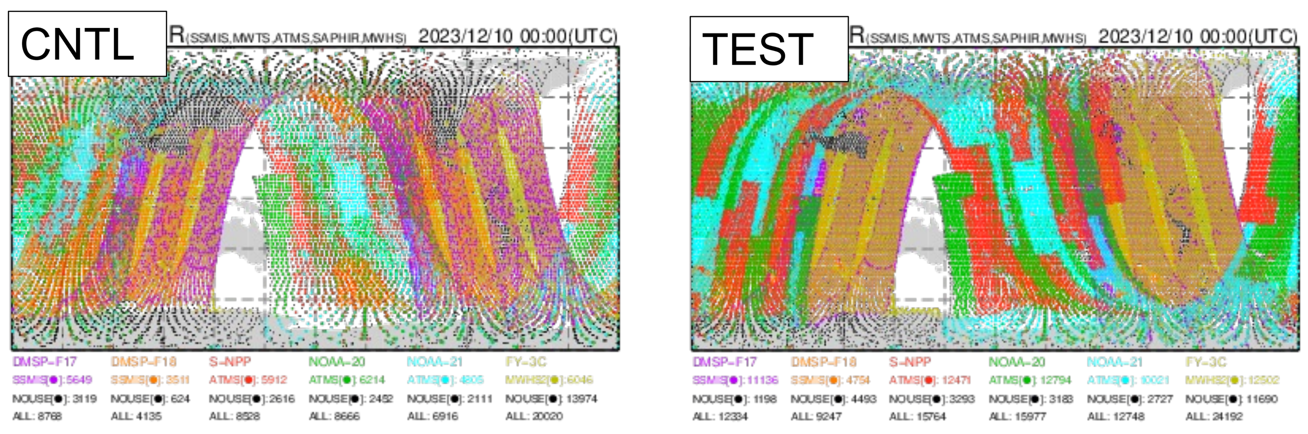
⑥ Combined impact of ④DE and ⑤superobservation

◎ Experimental settings

CNTL: Same as operational NWP as of July 2024.
TEST: Same as CNTL, but contents below were applied to all MW humidity sounder utilized in JMA (ATMS, SSMIS, GMI, MWHS-2, MHS)
- Assimilating surface sensitive data using DE method.
- Assimilating superobbed humidity sounder radiance and additional use of cloud affected data.
- Reducing the thinning distance(250-180 km → 150 km).

Period: Boreal Summer (10 July 2023 ~ 11 Sep. 2023)
Boreal Winter (10 Dec. 2023 ~ 11 Feb. 2024)

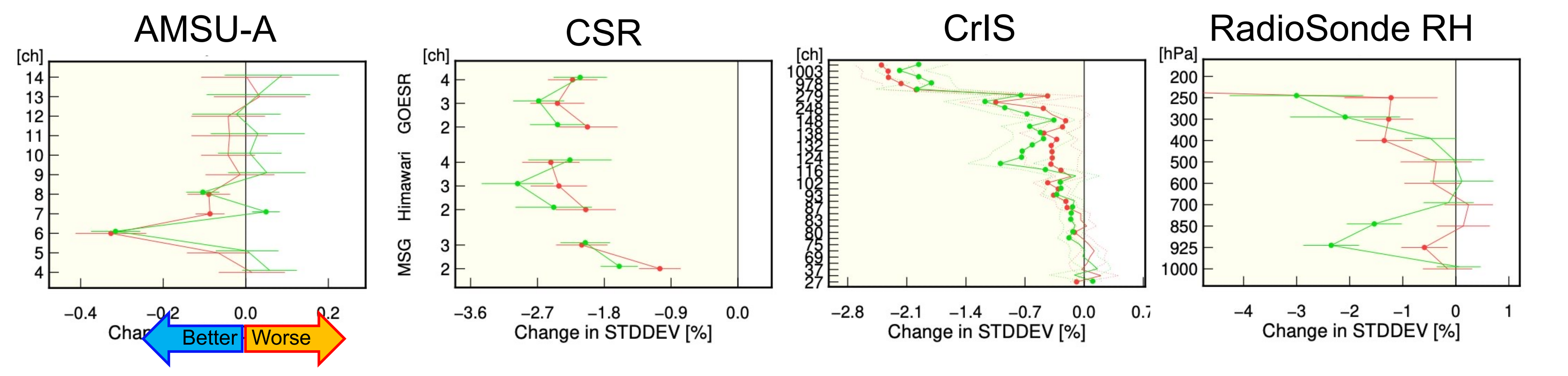
◎ Change of data coverage for MW humidity sounder



Number of assimilated MW humidity sounder data increased to approx. 210% (even more radiance data is included by superobbing)

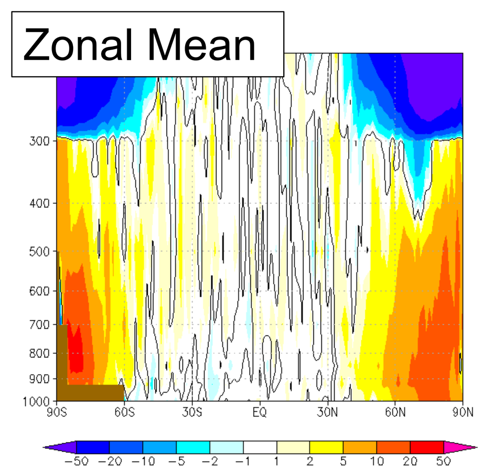
◎ Change in STDs of FG departure against CNTL

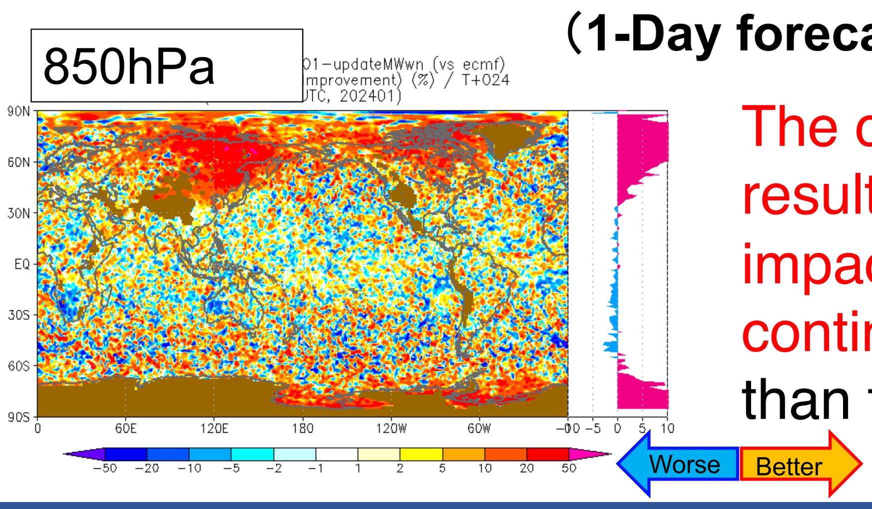
Green: Boreal Winter
Red: Boreal Summer



The STDs of FG departure were reduced for several independent observations against CNTL.
Temperature and water vapor fields in the FG were improved.

◎ Improvement rate of RMSE for specific humidity vs. ECMWF analysis (1-Day forecast in boreal winter)





The combined experiment resulted in larger positive impacts over the Eurasian continent and sea ice region than the ④only experiment.