Addition of microwave humidity sounder radiance data to all-sky assimilation in the JMA global NWP system

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1. Introduction

It is more effective for the numerical weather prediction (NWP) to assimilate satellite microwave radiance data in all-sky condition than those in clear-sky condition. Accordingly, all-sky assimilation for microwave imagers and some microwave humidity sounders was implemented in JMA's global NWP system in December 2019 (Shimizu et al. 2020), thereby improving mid- and lower-tropospheric humidity forecasts and tropical cyclone track forecasts. In this context, JMA newly applied the all-sky assimilation scheme to the radiances around 183 GHz from Suomi-NPP, NOAA20/ATMS, DMSP-F17, F18/SSMIS and Megha-Tropiques/SAPHIR. In addition, assimilation of radiances from FY-3C/MWHS-2 for all-sky conditions was also commenced. These developments were implemented into JMA's operational global NWP system in June 2021. This report summarizes these developments and their impacts on forecasting.

2. Quality control updates

Observation error assignment is based on the symmetric (average of observation and first guess (FG)) cloud amount (Geer and Bauer 2011). As a measure of this, an index depending on available channels for each sensor is derived as follows:

(1) If brightness temperatures (TB) at 90 GHz (TB_{90}) and 150 GHz (TB_{150}) are available (Suomi-NPP, NOAA-20/ATMS, DMSP-F17/SSMIS, and FY-3C/MWHS-2), a scattering index (SI) (Geer et al. 2014) is used, defined as

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

Here, the superscript *clr* indicates the calculated TB under the assumption of clear-sky conditions.

(2) If the TB of DMSP-F18/SSMIS at 150 GHz is unavailable due to malfunction, an alternative index defined as C_{37} (Geer and Bauer 2011) is used:

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

Here, TB_{37v} represents the vertically polarized TB at 37 GHz, and TB_{37h} represents the horizontally polarized value.

(3) For Megha-Tropiques/SAPHIR, which has none of the above channels, the index C_{183} using the TB at lowest peaking channel 6 (183 ± 11 GHz) (TB_{ch6}) is used (Chambon and Geer 2017):

$$C_{183} = TB_{ch6}^{clr} - TB_{ch6}$$

Minor changes are applied in the quality control update. To expand microwave humidity sounder coverage over land, radiances of DMSP-F17/SSMIS and Megha-Tropiques/SAPHIR are assimilated, when the radiances are less sensitive to the surface. Exclusive thinning between SSMIS and MHS is removed.

The addition of all-sky microwave humidity sounders and the above updates significantly increases the number of assimilated microwave humidity sounder data (Figure 1).

3. Impact evaluation: data assimilation experiments

The impact of adding all-sky microwave humidity sounders and quality control updates was evaluated in data assimilation experiments with JMA's global NWP system. The experiment period for boreal winter was from 10 December 2019 to 11 February 2020, and boreal summer was from 10 July to 11 September 2019. The CNTL experiment had the same configuration as JMA's operational global NWP system as of October 2020, and the TEST experiment was performed with the updates described in Section 2 in addition to the CNTL experiment conditions.

Figure 2 shows changes in the standard deviation of FG departures against CNTL. The FGs of TEST were closer to observations than those of CNTL for clear-sky radiance (CSR) data, which are sensitive to humidity in the mid- to upper-troposphere (Fig. 2a) and for radiosonde relative humidity (Fig. 2c). These results indicate that short-range forecasting of mid- to upper-tropospheric humidity fields was improved consistently against observations. The FGs of TEST were also closer to observations of the CrIS (Fig. 2b) and aircraft wind observations (not shown). These outcomes indicate that all-sky assimilation for humidity sounders also has positive impacts on temperature and wind fields due to the tracing effect of 4D-var (Geer et al. 2014). Figure 3 shows zonal mean improvement ratios in root mean square errors against ECMWF analysis for specific humidity and temperature. In the troposphere, humidity and temperature field were improved (Fig. 3), and this improvement was retained up to two forecast days (not shown).

4. Summary

Addition of microwave humidity sounders (Suomi-NPP, NOAA20/ATMS, DMSP-F17, F18/SSMIS, Megha-Tropiques/SAPHIR, and FY-3C/MWHS-2) to all-sky assimilation was implemented into JMA's global NWP system in June 2021. Related experiments showed a positive impact on the accuracy of FGs for tropospheric humidity and temperature fields. The forecast fields of humidity and temperature were improved and these were retained up to two forecast days.

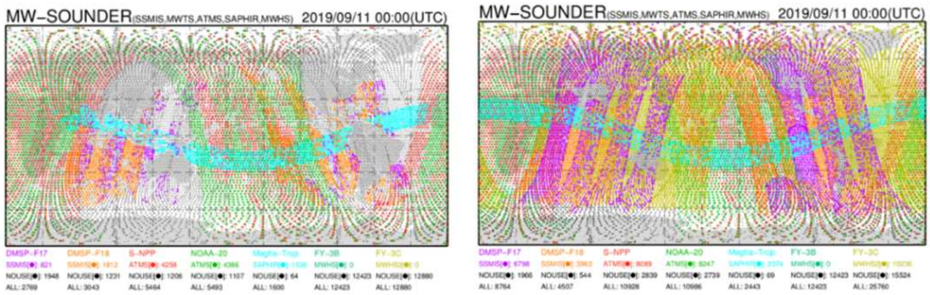

Figure 1: Coverage of microwave humidity sounder data assimilated during the 00 UTC time window on 11 September 2019. Left: before updates; right: after.

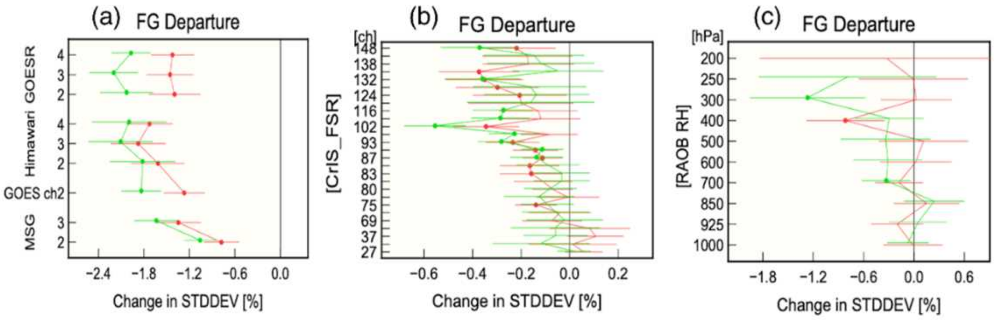

Figure 2: Normalized changes in standard deviation for FG departures in (a) CSR radiances from operational geostationary satellites, (b) CrIS radiances, and (c) radiosonde humidity. Horizontal lines show confidence levels of 95%. The validation periods are from 20 July to 11 September 2019 (red lines) and from 21 December 2019 to 11 February 2020 (green lines).

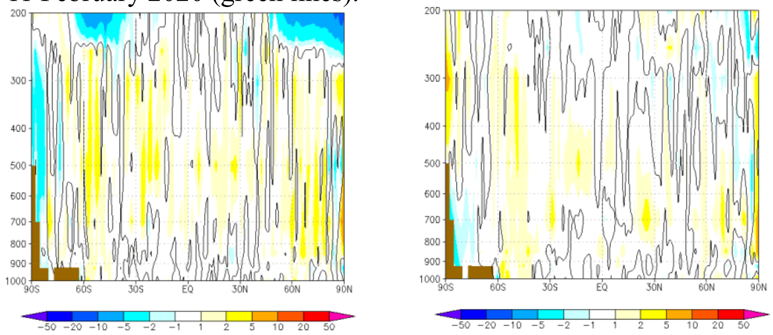

Figure 3: Zonal mean of relative improvement ratio [%] in root mean square errors against ECMWF analysis for day 1 forecasts of specific humidity (left) and temperature (right). Warm and cool colors represent improvement and degradation of TEST values, respectively. The verification period is 1 month (August 2020).

References

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