Implementation of all-sky microwave radiance assimilation into JMA’s global NWP system

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1. Introduction

Microwave radiance data from space-based observation contain a variety of information on geophysical parameters relating to the atmosphere and the earth’s surface (e.g., atmospheric temperature, water vapor, cloud, precipitation, surface wind and surface temperature). In this context, microwave radiance over ocean areas in clear-sky conditions has been assimilated in JMA’s global numerical weather prediction (NWP) system since May 2003 (Okamoto et al., 2005). As microwave radiance data relating to cloud and precipitation contain information on the presence of water/ice particles, assimilation of all-sky (including clear-sky, cloud and precipitation) microwave radiance contributes to better forecasting of atmospheric phenomena associated with severe weather conditions. The tracing effect of such assimilation based on 4D-Var also helps to improve dynamical initial conditions and supports improved forecasting (Geer et al. 2014).

JMA developed an all-sky microwave radiance assimilation scheme for microwave imagers and microwave water-vapor sounders (Kazumori and Kadowaki, 2017), including outer-loop iterations for trajectory updates in the 4D-Var minimization process for effective assimilation of cloud and precipitation. It was introduced into JMA’s operational global NWP system in December 2019. This report gives an overview of all-sky microwave radiance assimilation.

2. Data and Quality Control

The RTTOV-SCATT (Radiative Transfer for TOVS; Bauer et al., 2006) model enables multiple-scattering radiative transfer calculation for microwave frequencies as part of the RTTOV-10 package adopted as an observation operator for all-sky assimilation processing. Observation error assignment based on the symmetric (average of observation and first guess (FG)) cloud amount (Geer and Bauer, 2011) is applied to handle the non-Gaussian distribution of observation errors. Biased data such as those caused by insufficient cloud representation in JMA’s global forecast model (e.g., cold-sector bias) are removed, as the related observation error cannot be treated appropriately even if observation errors based on the symmetric cloud amount are considered. The all-sky assimilation scheme is applied to microwave imager (AMSR2/GCOM-W, GMI/GPM, SSMIS/DMSP F-17, F-18) and microwave water-vapor sounder (GMI/GPM, MHS/NOAA-19, Metop-A, -B) data previously assimilated under clear-sky conditions. Two additional microwave sensors (WindSat/Coriolis, MWRI/FY-3C) that had not been utilized in JMA's global NWP system were also included in all-sky assimilation.

3. Impact Evaluation: Data Assimilation Experiments

Data assimilation experiments were conducted using JMA’s global NWP system for the period from November 2017 to March 2018 (winter) and June to October 2018 (summer). The CNTL experiment had the same configuration as JMA’s operational global NWP system as of December 2018, and the TEST experiment represented all-sky assimilation for microwave imagers and microwave water-vapor sounders with two outer-loop iterations for trajectory updates in the 4D-Var minimization process.

Figure 1 shows differences in the standard deviations of FG departure statistics and the number of used data about SAPHIR/Megha-Tropiques (Sondeur Atmospherique du Profil d’Humidite Intertropicale par Radiometrie; only shown at 183.31±11 GHz; sensitive to lower-tropospheric water vapor) whose data are assimilated under clear-sky conditions for both experiments. The number of SAPHIR data used in TEST was higher, and the standard deviations for FG departure were lower. These results indicate improved FG water vapor fields in TEST for the lower troposphere in the tropics.

Figure 2 shows the improvement ratio for the root mean square error (RMSE) of geopotential height at 500 hPa verified against the experiments’ own analysis. Improvement was observed for most of the forecast range up to 120 hours in the summer and winter experiments, and other elements (e.g., sea level pressure and wind speed at 850 hPa) also exhibited improvement (not shown).

Figure 3 shows average TC track forecast errors and differences between TEST and CNTL for the summer and winter experiments. Errors in TEST decreased over the whole forecast range up to 96 hours with statistical significance for the forecast range up to 72 hours.

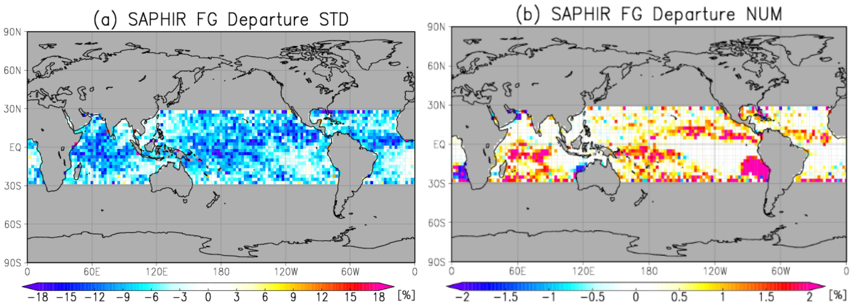

Figure 1: (a) Normalized changes for SAPHIR (brightness temperature [K] at 183.31±11 GHz) standard deviations of FG departures and (b) ratio of number of data used [%].

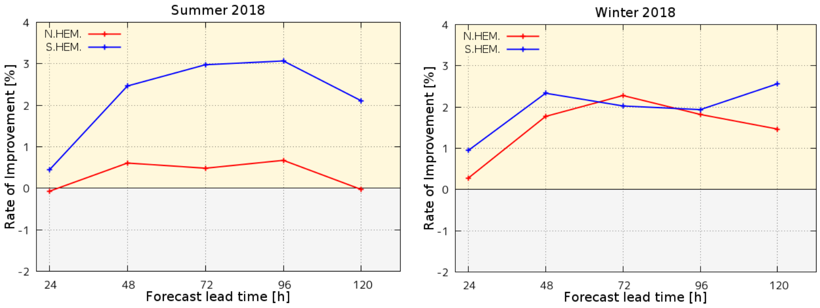

Figure 2: Improvement ratio ((CNTL − TEST) / CNTL [%]) for the RMSE of geopotential height at 500 hPa verified against the experiment's own analysis. Positive values indicate forecast error reductions of TEST against CNTL. The figures on the left and right show results for summer and winter 2018, respectively. The red and blue lines show verification results for the Northern Hemisphere (20 – 90°N) and the Southern Hemisphere (20 – 90°S), respectively.

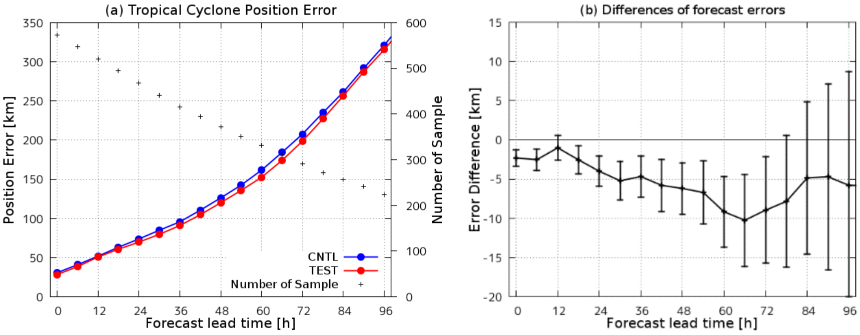

Figure 3: (a) Average TC track forecast errors for the summer and winter experiments. The red and blue lines are for TEST and CNTL, respectively, and dots represent sample data numbers. (b) Forecast error differences between TEST and CNTL. Error bars represent a 95% confidence interval.

References

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