Initial Results of a Direct Radiance Assimilation Experiment in the JMA Mesoscale 4D-Var data assimilation system

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Background

JMA operates the Mesoscale Model (MSM) and the 4D-Var data assimilation system [1] to provide disaster prevention information for Japan and its surrounding areas. Various observational data (surface, ship, buoy, radiosonde observation, wind profiler, ground-based radar data (rain and wind), Total Precipitable Water (TPW) and rain rate from microwave imagers, temperature profiles from satellite sounding instruments, atmospheric motion vectors derived from MTSAT images and ground-based GPS TPW) are used in operational analysis. Remote sensing from polar-orbit/geostationary satellites is important in obtaining information on rapidly changing atmospheric states over a wide area.

Meanwhile, variational data assimilation schemes allow observations to be different from analysis variables, and direct radiance assimilations make observation errors easier to define and less correlated than retrievals. Direct radiance assimilation in JMA's global data assimilation system has shown large positive impacts on analysis and forecast since 2004. Accordingly, direct radiance assimilation in the MSM is expected to provide improvements in analysis and forecast. Additionally, raw-level satellite data (level 1b/1c brightness temperature) will generally become available sooner than retrieved data after the launch of a satellite. The direct use of radiance is therefore important not only for forecast improvement itself but also for the early utilization of satellite data, and is indispensable for the future use of cloud- and rain-affected radiance in the JMA system.

In this study, RTTOV-9 [2] was implemented as an observation operator for radiative transfer calculation in the JMA Mesoscale 4D-Var data assimilation system. This is the same radiative transfer model used in the JMA global 4D-Var analysis [3]. The initial study focused on the impacts of directly using AMSU-A radiances from the NOAA-series, Metop and Aqua satellites.

Experimental design

JMA performs MSM analysis eight times a day. Early provision of MSM forecast outputs for Japanese forecasters requires a short cut-off time for observational data reception to enable the start of analysis. The current cut-off time is 50 min. after the analysis time, so data directly received from Japanese local stations are suitable for this system. NOAA satellite, MTSAT and Aqua/AMSR-E data are currently available through direct reception in JMA. In the experiment, AMSU-A radiances of the NOAA series, Metop and Aqua were used instead of retrieved temperature profiles. The experimental results were compared with the current retrieval assimilation results. Other radiance data, such as moisture channels from MHS/AMSU-B, Clear Sky Radiance (CSR) from MTSAT and radiances from microwave imagers, were not used in either experiment. The operational cut-off time was applied for the AMSU-A data set to estimate the real impact in JMA's operational system. The data-thinning distance was set as 40 km (the MSM inner-model resolution is 15 km), and available AMSU-A tropospheric channels (channel 4 to 8) were selected for the assimilation. Higher peaking channels were not used due to the limitation of the model-top height in JMA's MSM (about 22 km). Atmospheric profiles over the model's top height were extrapolated with the temperature lapse rate of US standard atmospheric profiles for radiative transfer calculation. The bias correction and observation error assignment for brightness temperatures were the same as those for the JMA global analysis. The period from

July 7 to 26, 2009 was selected to study cases of heavy rain in Japan.

Results and summary

The results showed better fits to radiosonde observations (RAOB) for three-hour forecasts in terms of geopotential height, temperature and wind (Fig. 1). Although there was no significant impact on the forecast of precipitation amounts, some improved cases of rain forecasts associated with cold fronts were found (Fig. 2). The predicted location of the rainfall band showed good agreement with the observed rainfall location in the direct radiance assimilation. It is presumed that the direct radiance assimilation of temperature sounding brought realistic atmospheric stability in the analysis and forecast field, which led to the improved forecast location of the rainfall band. The direct radiance assimilation of temperature sounding data showed a moderate and indirect impact on precipitation. In order to produce a larger impact on moisture field and precipitation forecast, moisture sensitive channels from MHS/AMSU-B and CSR would need to be incorporated simultaneously. In this initial experiment, successful implementation of RTTOV-9 as the radiative transfer model into JMA's mesoscale analysis and the advantages of direct radiance assimilation over the retrievals were confirmed. To implement the operational use of various radiance data in the JMA system, further studies regarding the impact of radiance assimilation on moisture sensitive channels are planned.

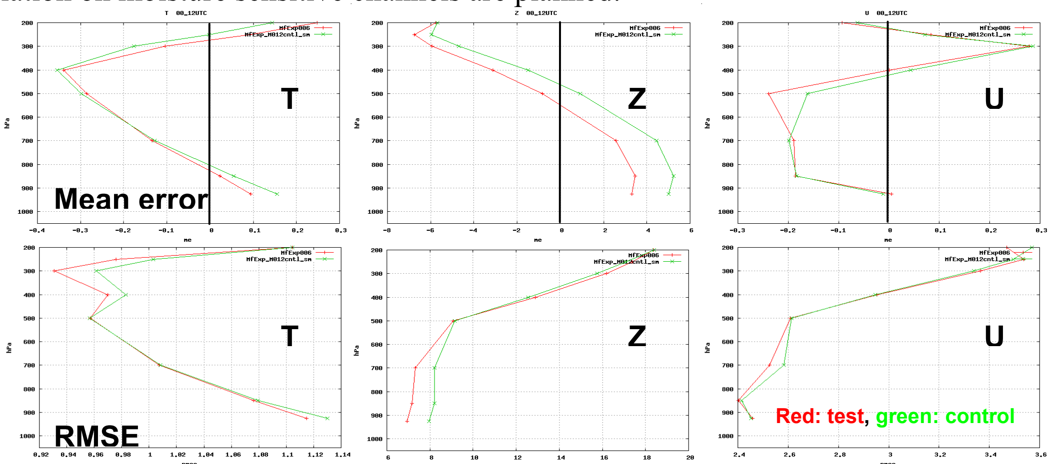

Fig. 1 Fits to RAOB for temperature, geopotential height and wind for three-hour forecasts. The upper panels are for mean errors, and the lower panels are for RMSE. The red lines show Test (radiance) and the green lines show Control (retrieval).

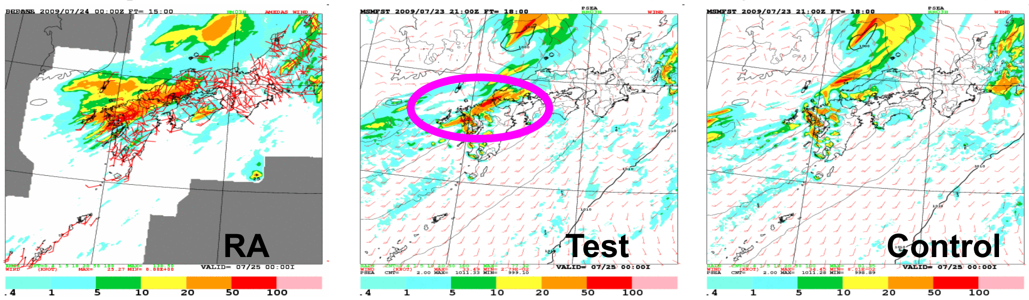

Fig. 2 Three-hourly accumulated precipitation of 18-hour forecasts from 23 Jul. 2009 at an initial time of 21 UTC. From the left, analyzed precipitation, the forecast of Test (radiance assimilation) and that of Control (retrieval assimilation) are shown.

References

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