Implementation of Rainwater and Cloud Water Budget in the Cloud Layer into the Cumulus Parameterization Scheme of the JMA Global Model

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The cumulus parameterization scheme implemented in the operational Global Spectral Model (GSM) at the Japan Meteorological Agency (JMA) follows the scheme proposed by Arakawa and Schubert (1974) with modifications by Moorthi and Suarez (1992), Randall and Pan (1993) and Pan and Randall (1998). In the scheme of GSM, condensed water in upward cloud mass flux is lifted to the cloud top. Some of this falls as rainwater, and the rest is detrained as cloud water. The ratio of rainwater is assumed to be proportional to the cloud depth. The cloud water is re-distributed to the layer above the freezing level to represent anvil cloud detrained from deep cumulus. This parameterization is quite economical, but may produce errors because of its simplicity.

Miyamoto and Komori (2008) showed that GSM tends to predict drier middle troposphere than radiosonde observation over Japan in the summer season and the NWP models of two other NWP centers (ECMWF and UKMO) in regions where deep convection is active. They concluded that the dry bias is due to deficiencies in the convection process of GSM.

To reduce the dry bias, we are currently developing a modification of the cumulus parameterization scheme. The following three processes are introduced into the modified scheme: (1) generation of rainwater in the updraft (e.g., Cheng and Arakawa 1997); (2) detrainment of rainwater from the updraft (Kuo and Raymond 1980); (3) detrainment of cloud water from the updraft between the cloud base and the cloud top. Cloud water is assumed to detrain at the same rate as rainwater. We also assume that only frozen water contents detrain below the cloud top to represent anvil cloud. The convective downdraft process is also upgraded to allow calculation of the downdraft ensemble corresponding to the updraft ensemble. In addition, the evaporation process of convective rain is revised to the version proposed by Kessler (1969).

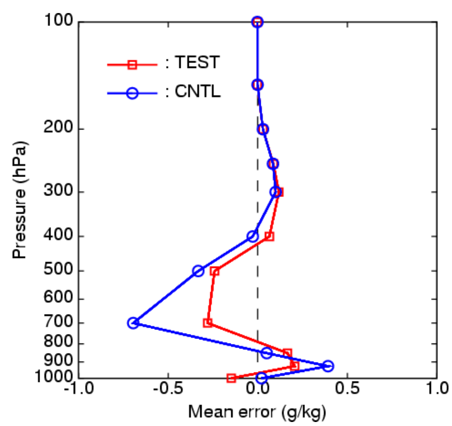

Fig. 1. ME of specific humidity in 48-hour forecasts against radiosonde observation over the tropics (20°N – 20°S) in August 2008 by TEST (red) and CNTL (blue).

In order to evaluate forecast skill, forecast/assimilation experiments using the operational GSM (CNTL) and the modified GSM (TEST) were conducted for August 2008. Figure 1 shows the averages of the mean errors (ME) of specific humidity in 48-hour forecasts against radiosonde observations over the tropics. It can be seen that the dry bias around 700 hPa seen in CNTL is reduced substantially in TEST. This reduction is caused by the

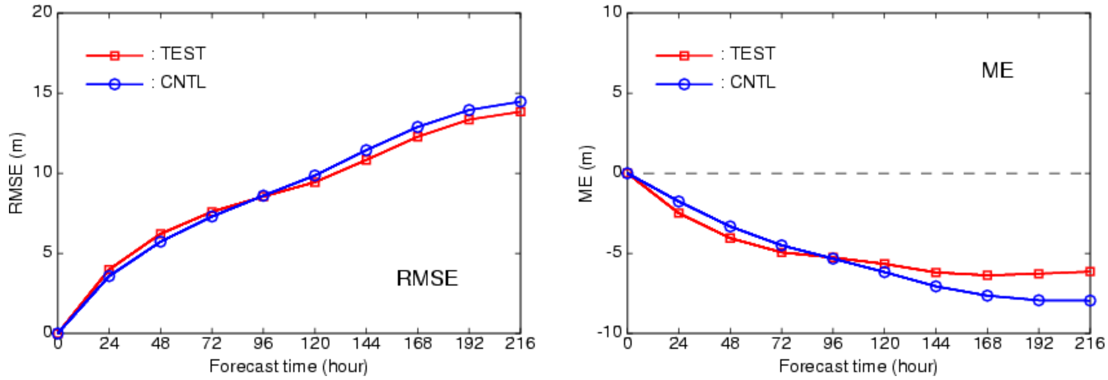

Fig. 2. RMSE (left) and ME (right) of 500 hPa geopotential height against the initial fields over the tropics in August 2008 by TEST (red) and CNTL (blue).

evaporation of detrained cloud water from the updraft in the cloud layer and increased evaporation of rain due to the modification of the parameterization scheme.

The root mean square errors (RMSE) and ME of 500 hPa geopotential height against the initial fields over the tropics are shown in Figure 2. The RMSE of TEST is larger in the early forecast hours and smaller in the later ones than that of CNTL. The ME shows a similar tendency except for its sign, which suggests a close relationship between the tendencies of RMSE and ME. It is likely that these tendencies of TEST in the early forecast hours are caused by the negative bias in temperature forecasts in the lower and middle troposphere, which is larger than that of CNTL (not shown). It is necessary to reduce these errors to enable implementation of the modification to the operational GSM.

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