Improvement of cloud treatment in radiation process of the JMA Non-Hydrostatic Model

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The Japan Meteorological Agency Non-hydrostatic Model (hereafter NHM) is an atmospheric regional meso-scale model for research and operational purposes. This model is used as an operational meso-scale NWP model since 1 September 2004. To improve the forecast accuracy of the model, the current radiation scheme has to be improved because the radiation scheme is somewhat old-fashioned. Therefore, we conducted an impact study on the cloud treatment in radiation process.

We execute the control run which uses the current radiation scheme of NHM (Sugi *et al*. 1990), hereafter OLDRAD, and execute the test run which uses the radiation scheme of the JMA global NWP model (NPD/JMA, 2002), hereafter NEWRAD. The latter scheme is more detailed than the former one in terms of the treatment of cloud optical properties. In OLDRAD, the cloud fraction diagnosed from the relative humidity is used for the radiation calculation. On the other hand, in NEWRAD, prognostic cloud liquid / ice water content is used for the radiation calculation, in which the cloud fraction is diagnosed by the method of Xu and Randall (1996). Major differences in the cloud treatment between both schemes are summarized in Table 1. The outline of the experiment is summarized in Table 2. Figure 1 shows the forecast domain for the experiments.

Figure 2 shows the vertical profiles of bias in the temperature predicted by a) OLDRAD and b) NEWRAD verified against sonde observations. In OLDRAD, the magnitude of negative bias in the temperature around 200hPa increases as time integration proceeds, while in NEWRAD, this cooling bias is well removed. The excessive cooling around 200hPa in OLDRAD may be caused by the black body cloud assumption that tends to cause emission of large long-wave radiation the cloud top. On the contrary, in NEWRAD, since the effect of optically thin high clouds is treated properly (to see Table 1), the upward long-wave radiation flux at the cloud top is smaller than that in OLDRAD. Therefore, there is no unnatural cooling around 200hPa.

Figure 3 shows a diurnal change of bias in the surface air temperature predicted by OLDRAD and NEWRAD verified against the surface observations over Japan. In OLDRAD, the bias is near 0K in the day-time and it is over 2K in the night-time. Therefore, the diurnal change of bias is very large. But in NEWRAD, it is smaller than that in OLDRAD in the night-time and it is about 1K all day long. This small diurnal change of surface air temperature bias implies that predicted surface air temperature is close to that of the surface observations on average. The reasons are as follows. In OLDRAD, the cloud fraction diagnosed from the relative humidity is a little large. Further, those clouds are treated as a black body and emit a large long-wave radiation flux toward the surface. But in NEWRAD, the effect of optically-thin high clouds can be treated properly and the diagnosed cloud fraction after Xu and Randall (1996) tends to be smaller than the cloud fraction diagnosed from the relative humidity. As a consequence, the downward long-wave radiation flux toward the surface in NEWRAD is smaller than that in OLDRAD and the surface air temperature falls in the night-time.

As mentioned above, the improved radiation scheme resolves excessive cooling around 200hPa and large diurnal change of predicted surface air temperature bias in current radiation scheme to some extent.

References

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Table 1 Major differences in cloud treatment between current and improved radiation schemes.

		Current radiation scheme	Improved radiation scheme
Cloud	Cloud fraction	Diagnosed from RH	Xu and Randall(1996)
	Cloud water	Not used	Used
Short-wave radiation	Optical property of cloud	τ : Product of constant, thickness and cloud fraction ω : diagnosed from τ g : 0.85	Diagnosed from cloud water path and effective radius Effective radius : Constant(for water) Function of T (for ice) Consider dependence of wavelength
Long-wave radiation	τ of cloud	Infinity(black body)	Same as left column
	Adjustment of cloud fraction	Not adopted	Adopted Effective cloud fraction : Product of cloud emissivity and cloud fraction Cloud emissivity : function of cloud water path Not consider dependence of wavelength

Table 2 Outline of the experiment

Experimental period	From 3 to 7 October 2004
Initial times	00, 06, 12, 18 UTC
Integration time	18 hours
Horizontal resolution	10km
Initial condition	Operational meso analysis
Lateral boundary condition	Forecasts of Regional Spectral Model

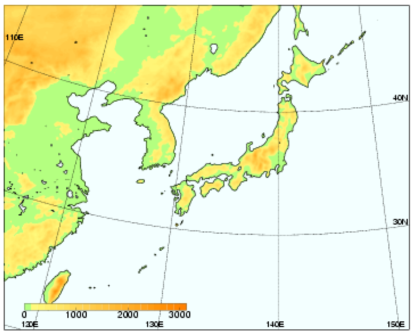

Fig. 1 Forecast domain for the experiment

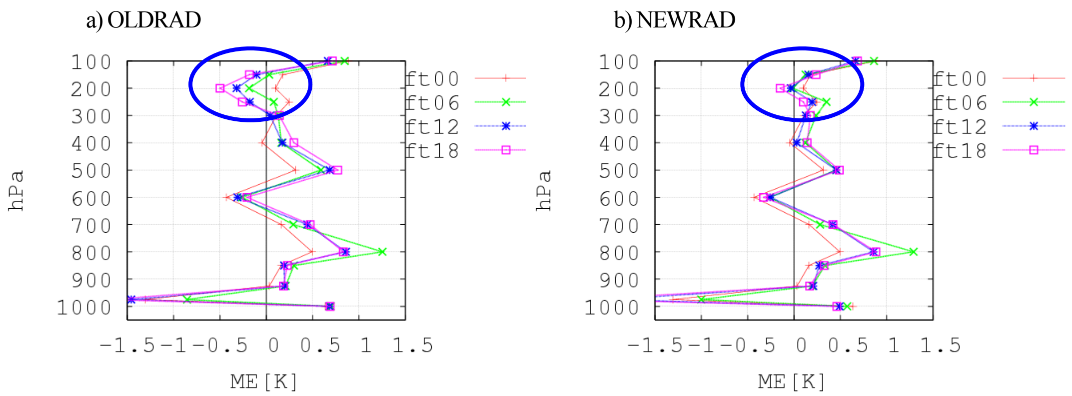

Fig. 2 Vertical profiles of bias in the temperature predicted by a) OLDRAD, b) NEWRAD verified against sonde observations. The data at 54 observational points included in the computational domain are used.

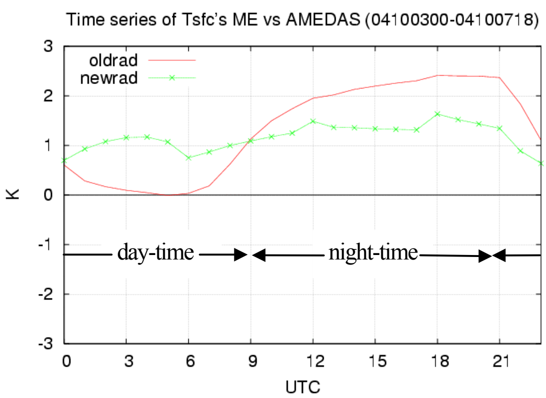

Fig. 3 Diurnal changes of bias in the surface air temperature predicted by OLDRAD and NEWRAD verified against the surface observations.