Upgrade of the Radiation Process in the JMA Mesoscale Model

Ryoji Nagasawa
Numerical Prediction Division, Japan Meteorological Agency
1-3-4 Otemachi, Chiyoda-ku, Tokyo 100-8122, Japan
E-mail: r-nagasawa@naps.kishou.go.jp

In response to several issues regarding the radiation process, the three modifications outlined here were found effective for forecast improvement and were implemented into the JMA operational non-hydrostatic mesoscale model (MSM) with a horizontal resolution of 5 km, which has been in operation since March 2006.

Ⅰ. Mitigation of the dependence of longwave radiation calculation on the vertical resolution

In the longwave radiation calculation of the MSM, the effective cloud fraction (i.e., the product of cloud emissivity and the cloud fraction) has conventionally been used. However, Räisänen (1998) pointed out that this value depended on the vertical resolution. Accordingly, the dependence of longwave radiation calculation and the heating rate on the vertical resolution was mitigated by implementing the method of Räisänen (1998) in which longwave radiation is estimated from cloud emissivity and the cloud fraction recurrently. The panel on the left of Fig. 1 shows the difference in the upward longwave radiation flux at TOA (OLR) between 50 and 75 vertical layers MSM calculated using the former method. The cold colors indicate that OLR in the latter is relatively larger than that in the former. On the other hand, the panel on the right of Fig. 1 indicates that OLR has little dependence on the vertical resolution in the method of Räisänen (1998).

Ⅱ. Use of the monthly climatology for aerosol optical depth

The optical parameters (optical depth, single scattering albedo and the asymmetry factor) of various kinds of aerosol were previously parameterized in only two types – continent and marine (see the panel on the left of Fig. 2). Accordingly, more detailed monthly climatology for aerosol optical depth (vertically integrated) retrieved through satellite observation (January 2000 – December 2005) was introduced into the radiation calculation. In the center panel of Fig. 2, aerosol from the Chinese continent is shown arriving over the islands of Japan. This feature of aerosol distribution could not have been considered by the continent- and marine-type aerosol parameterization. However, using the monthly climatology of aerosol optical depth enables consideration of this feature in the radiation calculation of the MSM. Since there were no satellite observations of single scattering albedos and asymmetry factors, these parameters were set into two types (continent and marine) as before. In the panel on the right of Fig. 2, the downward shortwave radiation flux at the surface (clear sky) shows some decrease corresponding to the distribution of the value of the aerosol optical depth.

Ⅲ. Upgrade of the diagnostics method for the effective radius of cloud ice

In the radiation calculation of the MSM, the temperature and effective radius of cloud ice were previously related following Ou and Liou (1995) – a technique that was also used in the former JMA global NWP model (GSM). However, the relationship was optimized for the former GSM, which tended to overestimate the climatology of the effective radius for the MSM in terms of OLR. Accordingly, this relationship was replaced with that of Ou and Liou (1995) modified by McFarquhar et al. (2003).

The three modifications outlined here were included in the operational MSM from December 2008. In the future, upgrades of the diagnostic method for the effective radius of cloud water and modification of treatment regarding the maximum-random overlap in shortwave radiation calculation are planned.

References

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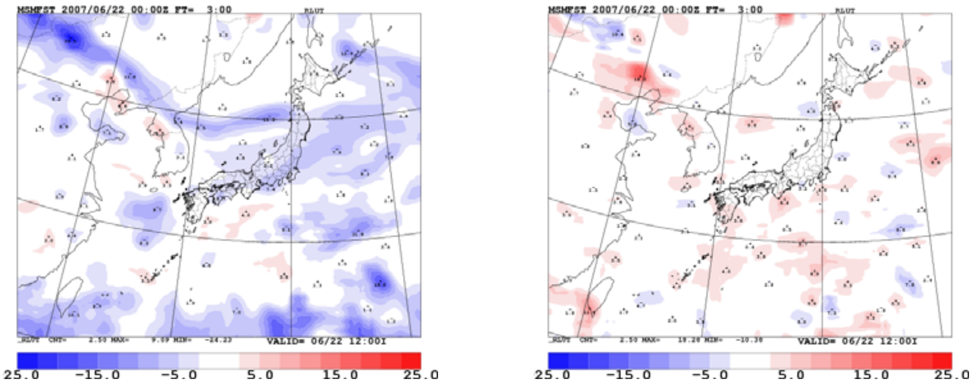

Fig. 1 The difference in the upward longwave radiation flux at TOA (50 vertical layers MSM minus 75 vertical layers MSM) (Wm^{-2}). Left panel: the former method. Right panel: the method of Räisänen (1998). The initial time is 00 UTC on 22 June 2007, and the forecast is for a three-hour period. The model tops are almost the same for 50 and 75 vertical layers.

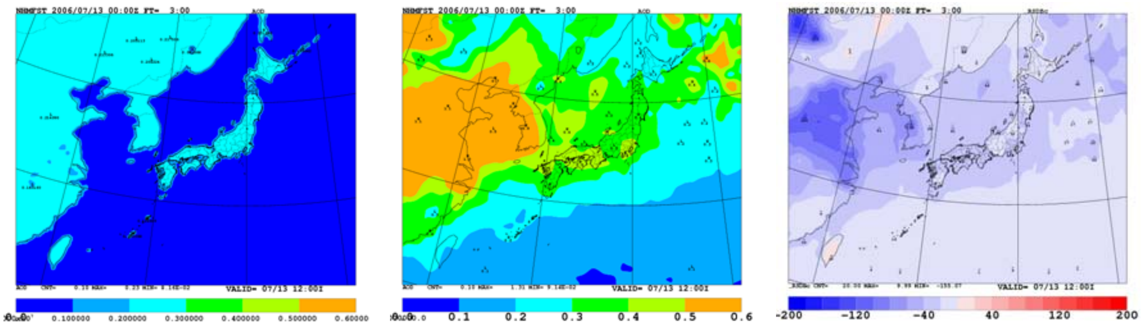

Fig. 2 Left panel: the former climatology for aerosol optical depth (vertical integrated) depended only on land and sea distribution. Center panel: the new monthly climatology for aerosol optical depth (July, vertically integrated). Right panel: the impact of the new climatology for aerosol on the downward shortwave radiation flux at the surface (clear sky) (Wm^{-2}). The initial time is 00 UTC on 13 July 2006, and the forecast is for a three-hour period.

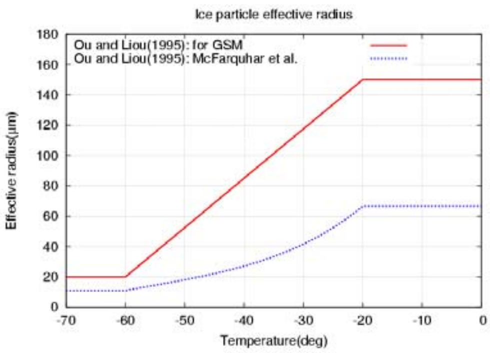

Fig. 3 Relationship between temperature (deg) and the effective radius (μm) of the cloud ice used in the radiation calculation. Red: relationship of Ou and Liou (1995) optimized for the former GSM. Blue: that of Ou and Liou (1995) modified by McFarquhar et al. (2003).