The Problem of Cloud Overlap in the Radiation Process of JMA's Global NWP Model

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1. Introduction

JMA's global NWP model (JMA-GSM) tends to produce optically thicker (thinner) values in the tropics (extratropics) for shortwave radiation compared with observed values (Fig. 1). One cause of this is insufficient treatment of cloud overlap in shortwave radiation calculation. Against this background, the problem was studied with the aim of improving the treatment.

2. The problem of current cloud overlap in shortwave radiation calculation

In the shortwave radiation scheme of JMA-GSM, the total cloud fraction is calculated with the assumption of a maximum-random overlap with a column area as clear sky and cloudy areas treated separately. In the cloudy area of the column, a random overlap is always adopted to account for cloud multiple scattering effects. In longwave radiation calculation, a maximum-random overlap is adopted (NPD/JMA 2007). If the fraction of optically thin high-level clouds (anvil) is large and that of tower-shaped cumulus clouds is small, which is often observed in the tropics, cloud optical thickness is overestimated in shortwave radiation calculation.

3. The solution

Independent column approximation (ICA, e.g., Cahalan et al. 1994) allows cloud multiple scattering effects to be taken into account in shortwave radiation calculation. This makes it possible to mitigate the aforementioned problem and adopt maximum-random overlap in both shortwave and longwave radiation calculation. Full ICA involves greater computational cost than the current scheme, but Collins (2001) proposed an efficient method called practical ICA (PICA) that involves less accuracy degradation in radiation computation. Essence of the PICA is to ignore radiation calculation in sub-columns whose contribution is small (i.e., narrow columns).

4. Results

Figures 2 and 3 show the impacts of PICA with maximum-random overlap on JMA-GSM and simulated cloud distribution. The approach reduces cloud optical thickness around the tropics and the mid-latitudes (Fig. 2), lowers shortwave heating in the middle troposphere and increases that in the lower troposphere (Fig. 3). The reduced excess shortwave radiation flux reflection in the middle troposphere induces an increase in the downward shortwave radiation flux to the lower troposphere and shortwave radiation absorption by cloud and water vapor below 900 hPa. The PICA method needs to be tested with a variety of cases, and appropriate parameters need to be fixed in consideration of computational cost and accuracy.

References

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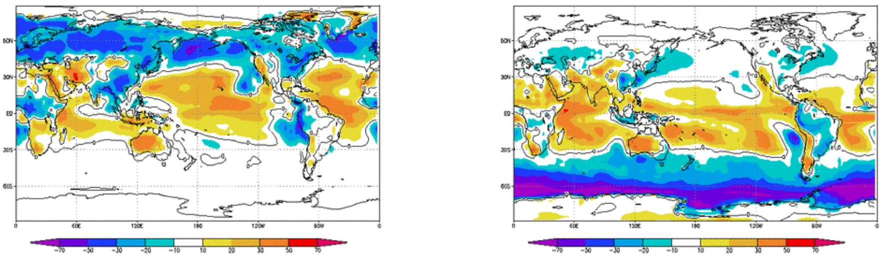

Fig. 1 Upward shortwave radiation flux at TOA (JMA-GSM – CERES) (Wm^{-2}). Left: JJA; right: DJF. The 2001 – 2006 average is shown.

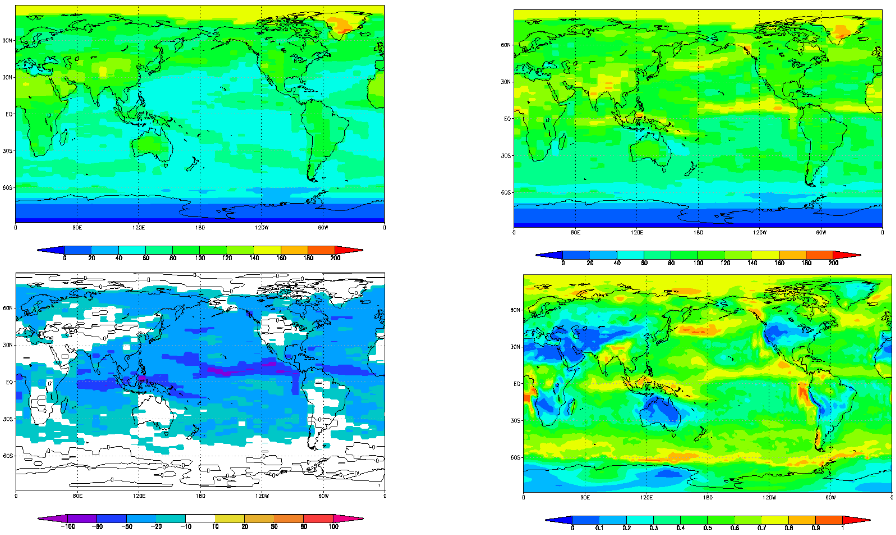

Fig. 2 Impact of difference in cloud overlap assumption for upward shortwave radiation flux at TOA (Wm^{-2}). Upper left: TEST; upper right: CNTL; lower left: TEST – CNTL; lower right: total cloud fraction. The initial time is 12 UTC on 10 August, 2009. The one-month forecast average is shown.

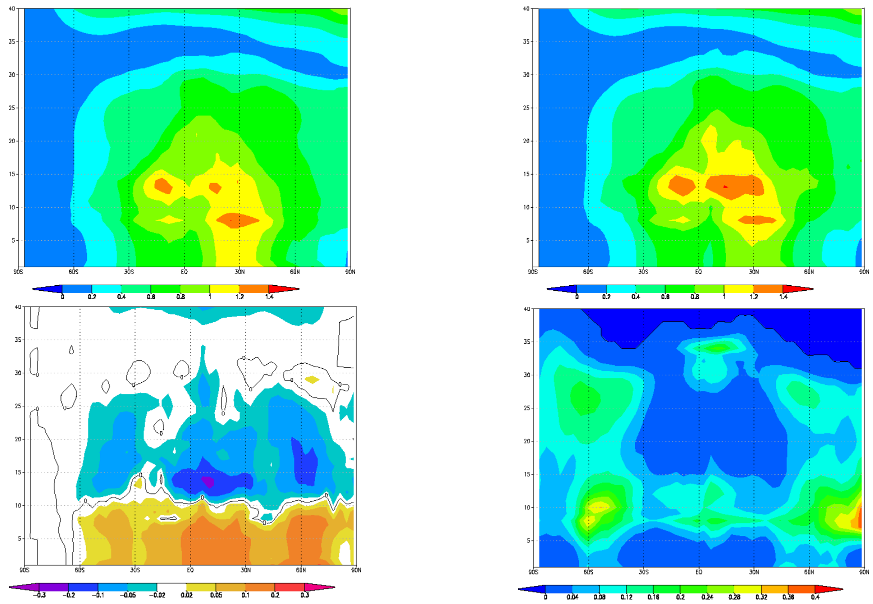

Fig.3 Impact of difference in cloud overlap assumption for the shortwave radiation heating rate (K/day). Upper left: TEST; upper right: CNTL; lower left: TEST – CNTL; lower right: cloud fraction. The initial time is 12 UTC on 10 August, 2009. The zonal mean and the one-month forecast average are shown.