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Problem of Cloud Overlap in Radiation Process in JMA Global NWP Model

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1. Introduction

The JMA global NWP model (JMA-GSM) tends to be optically thicker (thinner) in the tropics (extratropics) for the shortwave radiation compared with observations (Fig. 1). One of the causes is an insufficient treatment of a cloud overlap in the shortwave radiation calculation. To improve the treatment, the problem and solution is studied.

2. Problem of current cloud overlap in shortwave radiation calculation

In a shortwave radiation scheme of JMA-GSM, total cloud fraction is calculated by assuming a maximum-random overlap treating a column area as clear sky and cloudy areas separately. In the cloudy area of the column, a random overlap is always adopted to treat cloud multiple scattering effects. In the longwave radiation calculation, maximum-random overlap is adopted (NPD/JMA 2007).

In a case that a fraction of optically thin high level clouds (anvil) is large and a fraction of tower-shaped cumulus is small, which is often observed in the tropics, cloud optical thickness is overestimated in the shortwave radiation calculation (Fig. 2).

3. The solution

An Independent Column Approximation (ICA, *e.g.*, Cahalan *et al.* 1994) can take the cloud multiple scattering effects into account in shortwave radiation calculation (Fig. 3). This makes it possible to improve the aforementioned problem and to adopt maximum-random overlap both in the shortwave and longwave radiation

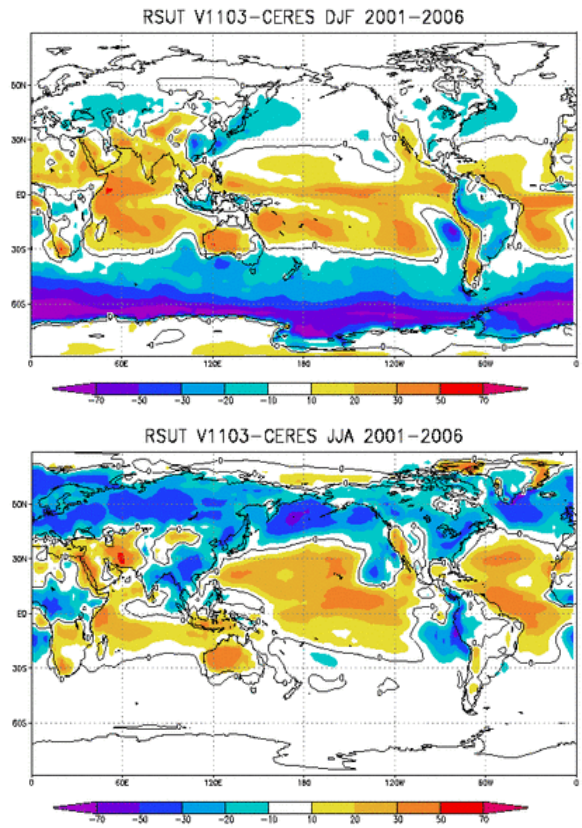

Fig. 1 Upward shortwave radiation flux at TOA (JMA-GSM - CERES) (Wm^{-2}). Left: JJA, right: DJF. 2001-2006 year average is shown.

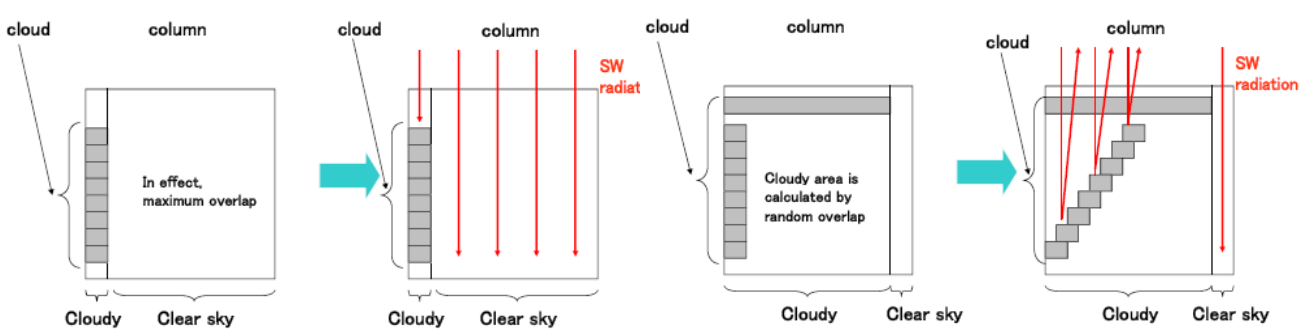

Fig. 2 Pattern diagrams of the case that cloud optical thickness is overestimated by current cloud overlap in shortwave radiation scheme. Left: Without anvil, Right: With anvil.

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calculation. Although full ICA requires more computational cost than the current scheme, an efficient method was proposed by Collins (2001) without degrading accuracy of the radiation computation (Practical ICA: PICA). Essence of PICA is to ignore radiation calculation in sub-column whose contribution (width) is small (narrow).

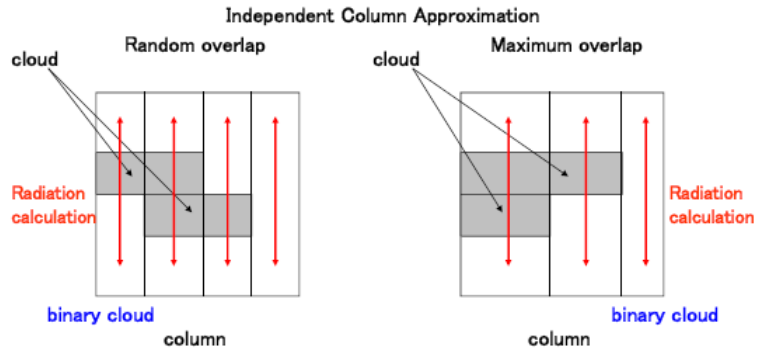

Fig. 3 Pattern diagrams of ICA (Independent Column Approximation) that only two clouds overlaps vertically. Left: in case of random overlap, Right: in case of maximum overlap.

4. Results

Fig. 4 and Fig. 5 show impacts of PICA with maximum-random overlap on JMA-GSM and simulated cloud distribution. Initial time of experiment is 12UTC on 10 Aug 2009 and 24 hour forecast was executed. Horizontal gird spacing and number of vertical layer of JMA-GSM are about 200 km and 60 respectively.

PICA with maximum-random overlap decreases cloud optical thickness around tropics and mid-latitude (Fig. 4). In addition PICA decreases shortwave heating in middle troposphere and increases that in lower

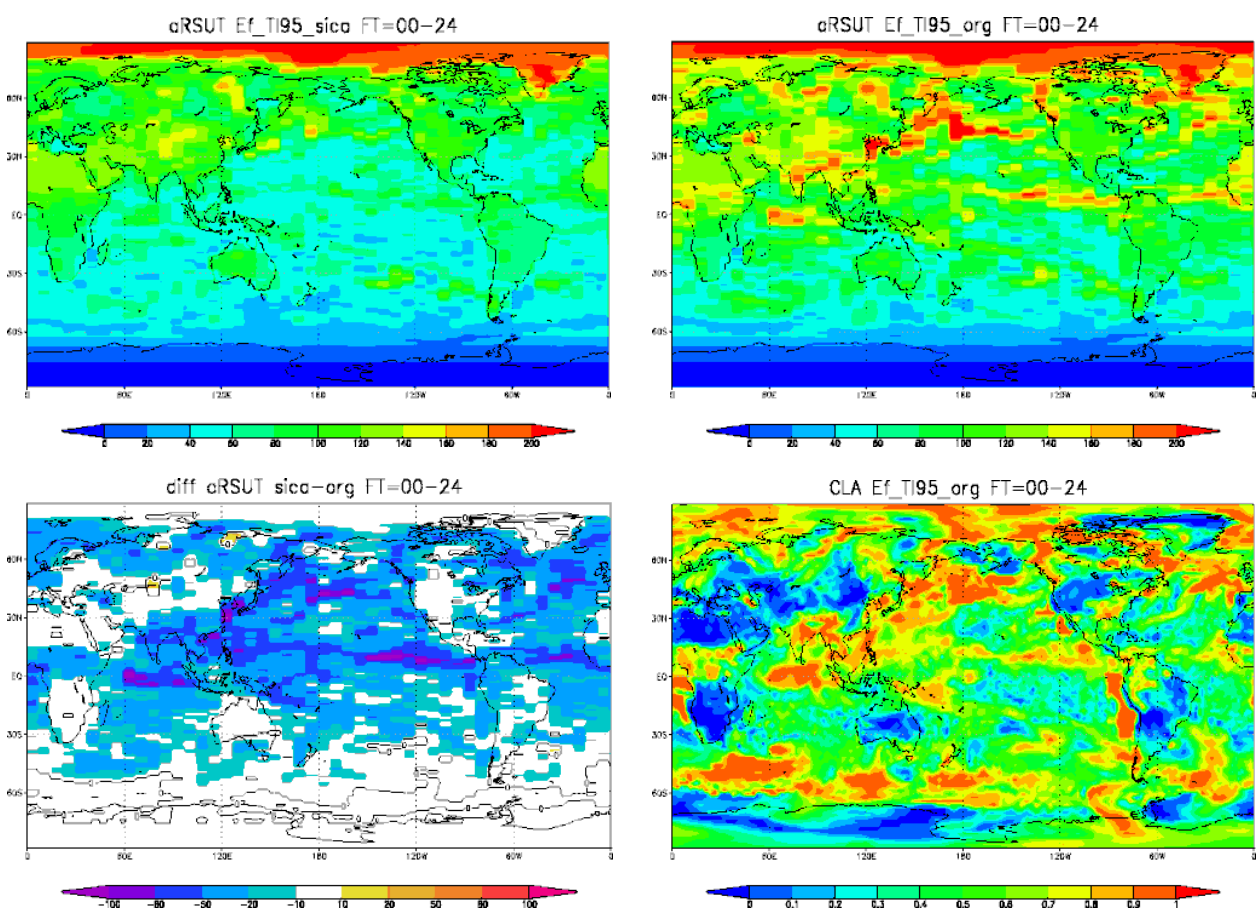

Fig.4 Impact of difference of cloud overlap assumption to upward shortwave radiation flux at TOA (Wm^{-2}). Upper left: TEST, upper right: CNTL, lower left: TEST – CNTL, lower right: total cloud fraction. Initial time is 12UTC on 10 Aug 2009. 24 hour forecast average is shown.

troposphere (Fig. 5). It is thought that decrease of excess shortwave radiation flux reflection in middle troposphere induces increase of downward shortwave radiation flux to lower troposphere and shortwave radiation absorption by cloud and water vapor below 900hPa.

5. Summary

JMA-GSM tends to be optically thicker (thinner) in the tropics (extratropics) for shortwave radiation flux compared with observation. One of the causes is an insufficient treatment of cloud overlap in the shortwave radiation calculation. Practical ICA, improved method to treat better cloud overlap in the shortwave radiation calculation with small computational cost is tested. The method with maximum-random overlap decreases cloud optical thickness extensively and increases (decrease) shortwave heating in middle (lower) troposphere. Practical ICA has to be tested in many cases and appropriate parameters have to be fixed considering computational cost and accuracy. And then description of cloud simulated by JMA GSM has to be improved.

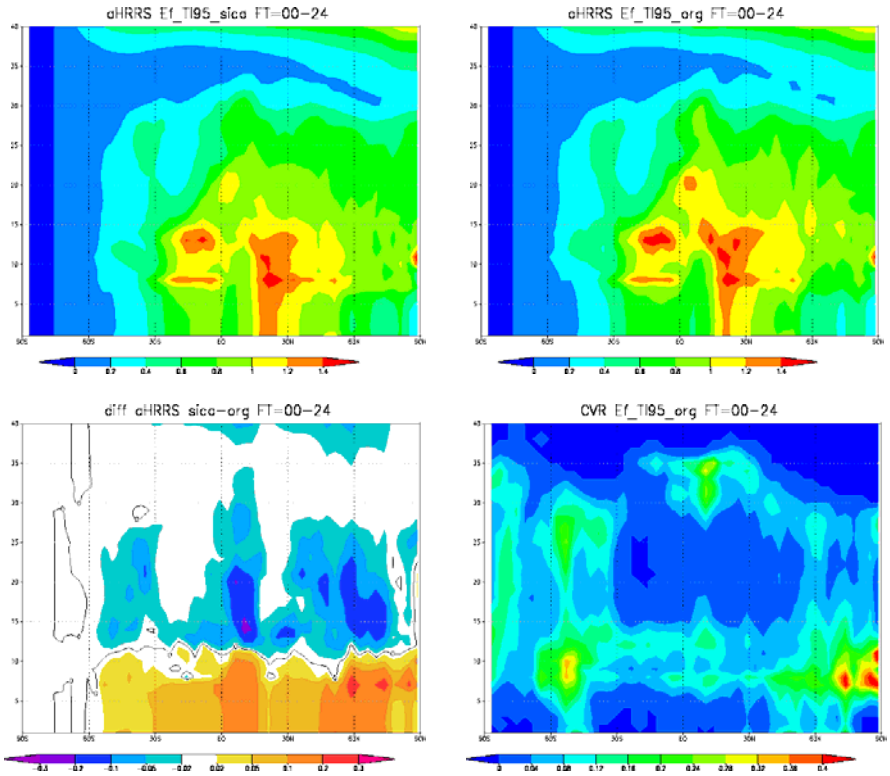

Fig. 5 Impact of difference of cloud overlap assumption to shortwave radiation heating rate (K/day). Upper left: TEST, upper right: CNTL, lower left: TEST – CNTL, lower right: cloud fraction. Initial time is 12UTC on 10 Aug 2009. Zonal mean and 24 hour forecast average are shown.

References

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