Impact of a Revised Parameterization of Cloud Radiative Forcings on Earth's Radiation Budgets Simulation

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It is widely recognized that the earth's radiation budget strongly depends on cloud parameters such as fractional coverage, vertical overlapping and radiative properties. Therefore, a good parameterization of the cloud radiative forcings (CRFs) is fundamental to realistically represent the earth's radiations in numerical models. A revised parameterization scheme is proposed for the accurate description of cloud-radiation processes, and its impact on the simulation of earth's radiation budgets is investigated using the JMA operational global NWP model (GSM0103). The revisions include

- The maximum-random cloud overlap assumption proposed by Geleyn and Hollingsworth (1979) is applied to the radiation computations both for longwave (LW) and for shortwave (SW).
- To eliminate the underestimation of LW CRF depending on model's vertical resolution, LW cloud emissivity is evaluated by the sophisticated method suggested by Räisänen (1998).
- SW multiple reflection between layers partially covered by clouds is properly computed by accounting for a vertical overlapping of clouds. This procedure of SW computations is perfectly consistent with the treatment of overlapping clouds in LW computations.
- Following Sun and Rikus (1999), effective radii of ice cloud particles are parameterized as a function of the ice water content and the cloud temperature.

The top of the atmosphere (TOA) radiation fields produced by the model are compared with the Earth Radiation Budget Experiment (ERBE) data. Fig.1 shows the errors in TOA outgoing longwave radiation (OLR) derived from one-month model integrations using the original and revised parameterizations. OLR is very sensitive to the radiative forcing of optically-thin high-level clouds such as cirrus clouds. The sophisticated treatment of cloud emissivity in the revised scheme is able to more precisely evaluate the radiative effect of semi-transparent clouds than the method in the original scheme. Moreover, the new parameterization for effective radii of ice particles increases LW optical depth of ice clouds all over the globe. As a consequence of them, the revised parameterization scheme alleviates the underestimation of LW CRF and somewhat reduces the positive OLR bias.

Fig.2 shows the errors in TOA absorbed solar radiation (net downward SW radiation) simulated by using the original and revised parameterizations. In SW computations, the original scheme assumes the random cloud overlap within a cloudy fraction of model's grid for computational efficiency. However, this approach may lead to too much SW reflection over the convective regions where clouds tend to overlap maximally in the vertical. Over the maritime continent and the ITCZ, the revised scheme substantially suppresses excessive SW cloud forcings and gives a better agreement of TOA SW fluxes with the observation. While the model-produced SW reflectivity in mid- and high-latitudes still remains to be underestimated in spite of the revisions to SW scheme. The deficiency probably results from the insufficient representation of low-level clouds in the model.

References

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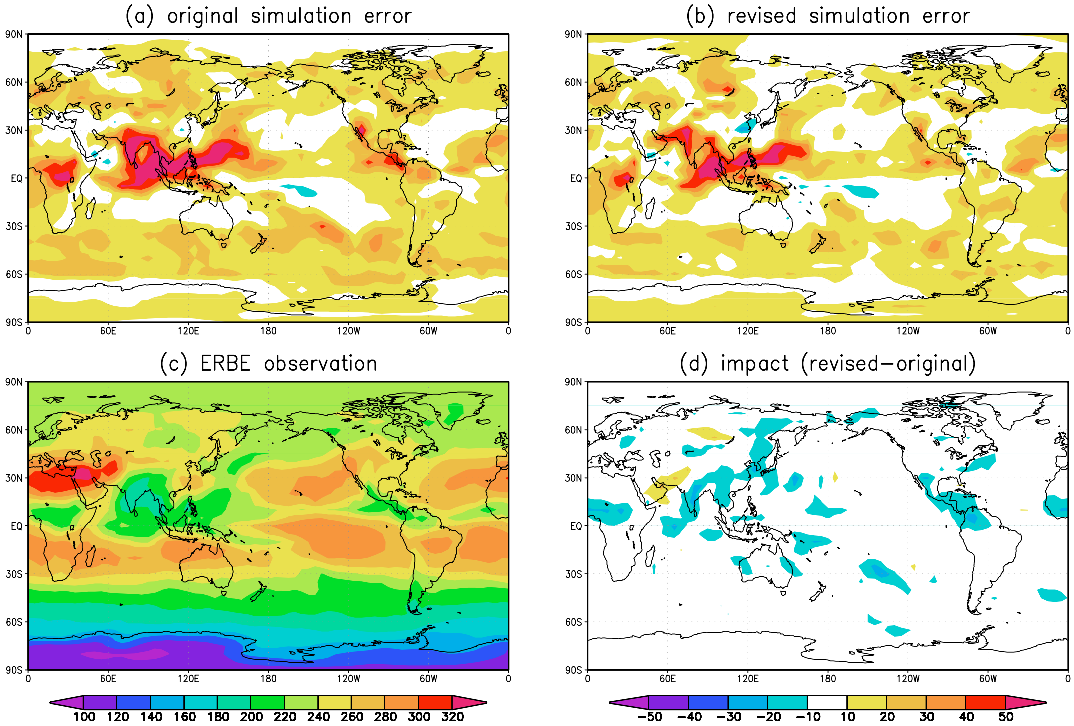

Fig. 1 TOA outgoing longwave radiation (W/m^2) for July 1988. Errors in OLR simulated by using (a) the original scheme and (b) the revised scheme, and (c) the satellite observation (ERBE) and (d) impact of the revisions (revised simulation minus original simulation).

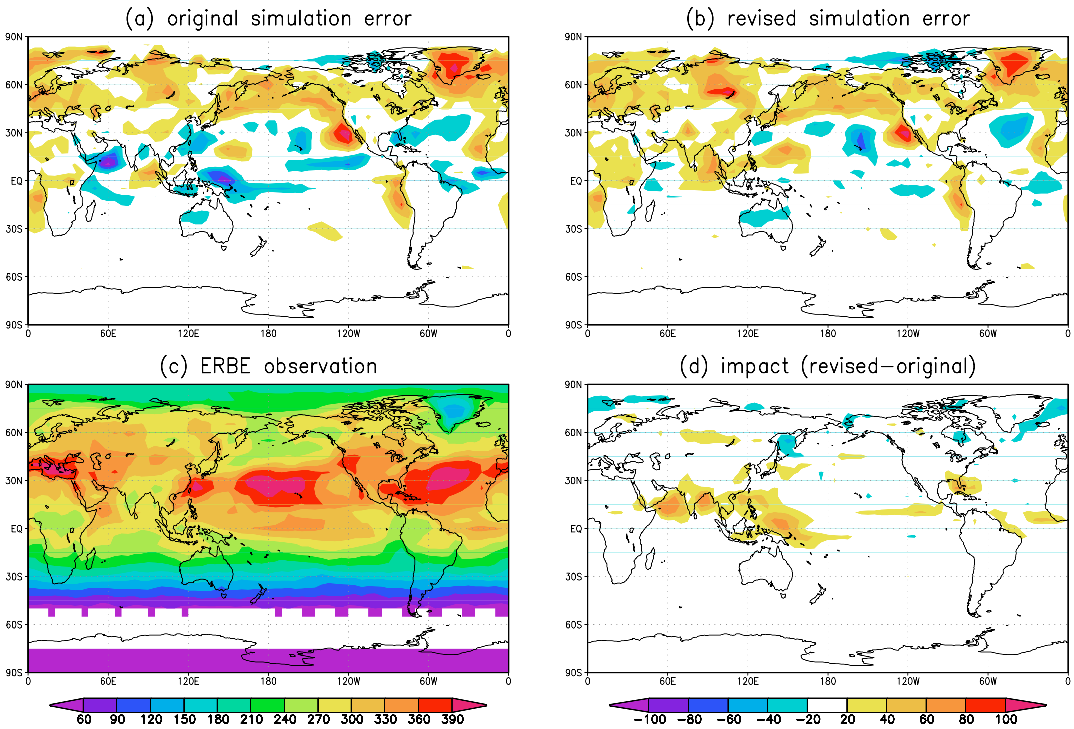

Fig. 2 Same as Fig.1 except for TOA absorbed solar radiation (net downward shortwave radiation).