PDF Cloud Scheme and Prognostic Cloud Scheme in JMA Global Model

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1 Background

JMA (Japan Meteorological Agency)/MRI (Meteorological Research Institute) unified global model GSM (Global Spectral Model) is utilized not only for operations but also for climate researches including global warming simulations and will be used for operational ENSO predictions as a part of a coupled model in the near future. Therefore cloud scheme in GSM should represent large scale condensation precipitation appropriately, complicated cloud processes should be parameterised as properly as possible and the bias on radiation flux must be small for such a large variety of uses.

A PDF (Probability Distribution Function) cloud scheme (Sommeria and Deardorff 1977) is used in the current GSM. The PDF scheme in GSM is similar to Smith (1990), though so-called top hat type PDF is adopted in GSM. But some problems are recognized in PDF cloud schemes especially when these are utilized in large grid models such as global models. The most serious problem is discussed in Wood and Field (2000) and they showed that Smith (1990) scheme brings a large negative bias in cloud amount. This problem is significant also in GSM, particularly in the middle-high and high latitude.

2 Prognostic Scheme

Prognostic cloud scheme by Tiedtke (ECMWF 2004, Jakob 2000, Tiedtke 1993) has been implemented in GSM experimentally. In the scheme, time evolution of cloud water is determined by the formation and the evaporation terms which include processes of advection, heating and cooling by radiation and turbulence, heating and cooling by upward and downward motions of the air mass, detrainment from convection, evaporation by diffusion, conversion to precipitation, cloud ice fall, and so on.

Instead of a term of boundary layer cloud in Tiedtke (1993), a parameterization for subtropical marine stratocumulus (Kawai 2004, Kawai and Inoue 2006) is used in combination with Tiedtke cloud scheme on account of its effective reduction of radiation bias in such stratocumulus regions.

And cloud ice fall scheme by Kawai (2005) which enables to alleviate the time step dependence of cloud ice and represent the conversion from cloud ice to snow is also introduced in new scheme.

In the prognostic Arakawa Schubert convection scheme used in GSM, it is assumed that mass from convection is detrained only from each cloud top of the cloud ensemble on account of calculation cost. But when the scheme is used together with the Tiedtke cloud scheme without any modifications, the anvil cloud whose origin is convection is formed at too high altitude. Therefore the detrained cloud water and the cloud amount are redistributed in a variety of altitude from cloud top to cloud base, although the function of redistribution is determined just ad hoc.

3 Result

The total cloud amount is increased in new cloud scheme (bottom panel in Figure 1) from in current scheme (top panel). Figure 2 shows correspondent errors of total cloud amount of current (top panel) and new (bottom panel) cloud schemes in which ISCCP (International Satellite Cloud Climatology Project) observation data are used as climatology. The negative bias of total cloud amount is reduced.

The increase of cloud amount is prominent at middle level in troposphere (Figure 3). In current PDF scheme, cloud amount in middle level rarely exceed 50% even inside of extratropical cyclones because of its intrinsic problem. But in prognostic Tiedtke scheme, the cloud amount can be almost 100% in such cases. This is the reason why middle level cloud amount increases in Tiedtke scheme in middle-high latitude in Figure 3. Middle level cloud is increased in tropics too. In PDF scheme middle level cloud is difficult to be formed in such region because these regions are relatively dry and cloud water from convection is evaporated in one time step. In contrast, Tiedtke scheme can represent the time evolution of cloud water. Therefore the detrained cloud is evaporated gradually and middle level cloud can be kept to some extent even in very dry condition.

The bias on OLR (Outgoing Longwave Radiation) from ERBE (Earth Radiation Budget Experiment) observational climatology is shown in Figure 4. A positive bias on OLR in current scheme (top panel) is reduced in Tiedtke scheme (bottom panel). But a positive bias on upward short wave radiation at the top of the atmosphere in tropics and subtropics is deteriorated because of excessive cloud reflection (not shown). Evaporation rate of cloud water is increased 2.5 times larger than the value used in ECMWF to suppress the cloud amount in tropics and subtropics, but the cloud in such latitude is still excessive. A treatment of cloud overlap is maybe one of factors affecting the over-reflection, and another

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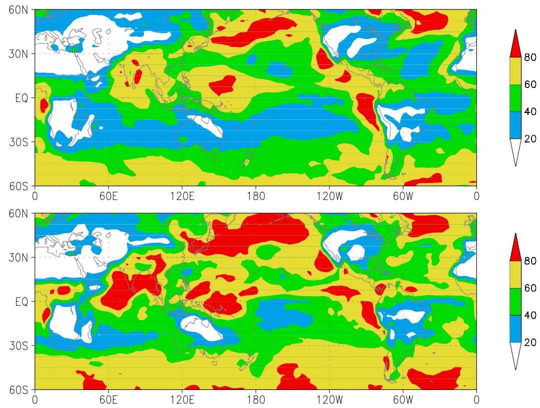

Figure 1. Total cloud amount [%] of the original (top) and the new schemes (bottom) using TL95L40. One month average from the initial time 12UTC 30 Jun 1990.

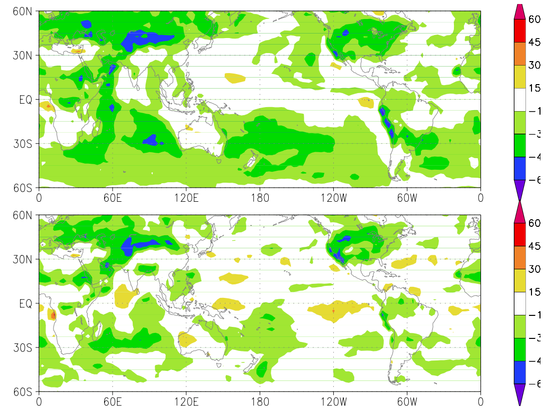

Figure 2. Same as Fig. 1 but for the error of total cloud amount based on ISCCP climatology [%].

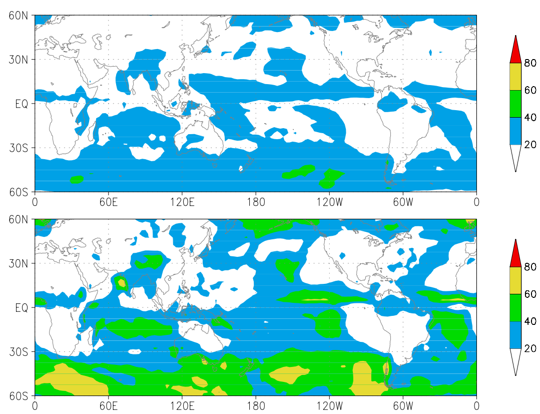

Figure 3. Same as Fig. 1 but for middle level cloud amount [%] (850hPa–500hPa).

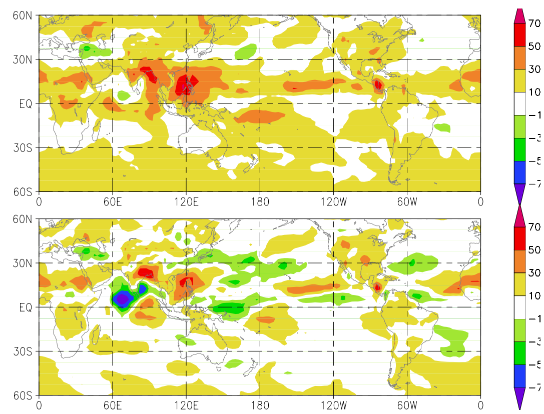

Figure 4. Same as Fig. 1 but for the error of outgoing longwave radiation [W/m^2] at the top of the atmosphere based on ERBE climatology.

factor is that shallow convection parameterization is not implemented in GSM yet.

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