Results of ASTEX and Composite model intercomparison cases using two versions of JMA-GSM SCM

Hideaki Kawai

Meteorological Research Institute, Japan Meteorological Agency
(e-mail: h-kawai@mri-jma.go.jp)

1. Introduction

In recent years, two model intercomparison cases have been developed to understand the transition of marine boundary layer clouds from stratocumulus (Sc) to shallow cumulus: the ASTEX Lagrangian case by Stephan de Roode, and the Composite Transition case by Irina Sandu, which is based on Sandu et al. (2010).

The cloud scheme of the operational global model of JMA (Japan Meteorological Agency), GSM (Global Spectral Model), is a PDF(Probability Density Function)-based cloud scheme (Smith 1990) and GSM also incorporates a simple Sc scheme to specifically represent Sc (Kawai and Inoue 2006). Another simple treatment for Sc is under trial to improve the vertical structure of boundary layer clouds, and solve some problems in the current operational scheme. In order to check the performance of these two versions in representing the transition of Sc to shallow cumulus, two versions of the SCM (Single Column Model) of the JMA-GSM were tested, and the results were submitted to the two intercomparison cases.

2. Two versions of JMA-GSM SCM
2.1. Sc scheme Version 1

Version 1 is the operational Sc scheme (Kawai and Inoue 2006) that was originally developed to represent Sc in models with relatively coarse vertical resolution.

The model conditions necessary to produce Sc are: (1) a strong inversion just above the layer, (2) not stable layer near the surface (to guarantee the existence of a mixed layer), and (3) application of the scheme only below 940 hPa.

When these three conditions are met, the following procedures are applied: (1) cloud cover of Sc is determined as a function of inversion strength; (2) in-cloud CWC (Cloud Water Content) is determined, as it is proportional to saturation specific humidity: $q_{c\,cld} = \beta \cdot q_{sat}$; and (3) mixing at the top of the cloud layer is suppressed.

2.2. Sc scheme Version 2

Version 2 is a simpler scheme, but it performs reasonably well in the current GSM because of the recent increase in vertical resolution. In Version 2, the conditions needed to produce Sc are: (1) $\theta_{700} - \theta_{surf} > 20$ [K] (based on Klein and Hartmann (1993)), and (2) not stable layer near the surface. When these two conditions are met, mixing at the top of the cloud layer is completely suppressed to prevent an entrainment of dry air in free atmosphere; Additional mixing at the top of the mixed layer, which has been used in the operational model for a long time to prevent the unrealistic formation of boundary layer clouds at the top of the boundary layer, is not applied, and the lower limit of vertical diffusivity is made to be almost zero at the top of the cloud layer.
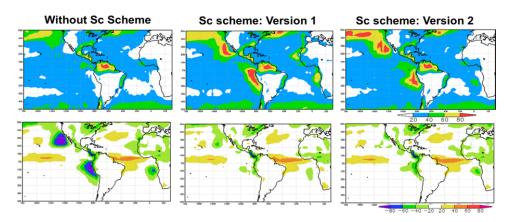

Fig. 1: Top panels: Low cloud cover (%). Lower panels: Error of TOA upward shortwave flux (W/m^2). The observation data are ERBE. Using TL159 for July calculated without an Sc scheme (left panels), with the Sc scheme version 1 (middle), and with the Sc scheme version 2 (right).

2.3. Performance of model climatology

Version 2 can produce almost the same amount of low cloud cover as Version 1, and the TOA shortwave bias of both versions is comparably small (Fig. 1), although the subtropical Sc clouds in Version 2 are slightly underestimated in areas adjacent to continents.

3. Results of the intercomparison cases
3.1. ASTEX case

In the ASTEX case, the forcing evolves from Sc circumstance into shallow cumulus circumstance. The ASTEX intercomparison case requests the calculation using a higher assigned vertical resolution, in addition to the operational resolution run. Whereas the operational GSM L60 has 13 layers lower than 2000 m, the assigned L80 resolution has 24 layers for the same range.
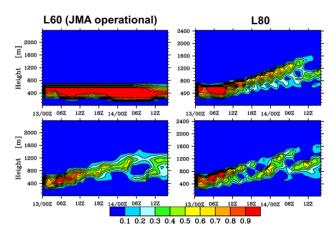

Fig. 2: Time evolution of cloud cover in the ASTEX case. Top panels correspond to Version 1 and bottom panels to Version 2, using vertical layers of the operational L60 (left), and the assigned L80 (right).

In the case of Version 1 and L60, the conditions required to produce Sc in the scheme are met throughout the simulation period, and the cloud layer remains unrealistically at the same altitude (Fig. 2). For the case of the fine resolution L80, the conditions for producing Sc are broken after several hours from the initial time. The cloud is produced by the Smith PDF scheme and the height of the cloud layer gradually increases (Fig. 2). The L80 case using Version 1 and the results using Version 2 are more consistent with observations, though the cloud cover might be not enough.

3.2. Composite case

The Composite case also gives the forcing evolving from Sc environment into shallow convection environment. Three different forcings are used in this case, which give differing speeds of the transition.

In reference forcing and fast forcing, the simulated cloud cover is too small using Version 1, because the conditions of the Sc scheme are not met (Fig. 3). On the other hand, using Version 2, the conditions are met for almost two days (Fig. 3), and the significant cloud cover for this period is similar to the LES results of many participants in this comparison. However, even when cloud amount of Sc is well represented in Version 2, the simulated height of the cloud layer is much lower than that in the LES results.

References

Kawai, H., and T. Inoue, 2006: A simple parameterization scheme for subtropical marine stratocumulus. *SOLA*, **2**, 17–20.

Klein, S. A., and D. L. Hartmann, 1993: The seasonal cycle of low stratiform clouds. *J. Climate*, **6**, 1587–1606.

Sandu, I., B. Stevens and R. Pincus, 2010: On the transitions in marine boundary layer cloudiness. *Atmos. Chem. Phys.*, **10**, 2377–2391.

Smith, R. N. B., 1990: A scheme for predicting layer clouds and their water content in a general circulation model. *Quart. J. Roy. Meteor. Soc.*, **116**, 435–460.
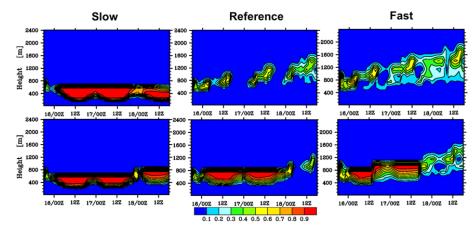
Fig. 3: Time evolution of cloud cover in the Composite case. Top panels correspond to Version 1 and bottom panels to Version 2 using slow (left), reference (middle), and fast (right) evolving forcing.