Impact of a Parameterization for Subtropical Marine Stratocumulus

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1. Background

It is very difficult to represent a subtropical marine stratocumulus off the west coasts of the continents in General Circulation Models (GCMs) because of its complicated physical interactions in and around the clouds and a lack of vertical resolution of GCM. Therefore a lot of efforts have been devoted to simulate the clouds by model researchers. Those clouds have not been represented in Global Spectral Model (GSM) in JMA either where the prognostic cloud scheme by Sommeria and Deadorff (1977) is adopted.

2. Parameterization for Subtropical Marine Stratocumulus

Instead of detail consideration of total water and temperature fluctuation in the prognostic cloud scheme, the simple and classical parameterization by Slingo (1980, 1987) is implemented with some minor modifications. This is an exception of the prognostic cloud scheme.

The stratocumulus is formed in areas and layers where all following conditions are met.

- $-\frac{\partial J}{\partial P} > 0.07$ [K/hPa] (just above the layer)
- $-\frac{\partial J}{\partial P} < 0.01$ [K/hPa] (near the surface)
- the height of the layer is below 940 [hPa]

where q is potential temperature and P is pressure. The first condition guarantees the existence of strong inversion at the cloud top, the second one is to prevent the pseudo formation of stratocumulus in strong stable layer, for example, above land or sea ice in the nighttime and the last one is to intercept the fictious development of stratocumulus in shallow convection area, where the altitude of inversion is higher.

The cloud amount C_L and cloud water content in cloud q_{cl} are determined as below.

$$C_L = 12.0(-\frac{\partial J}{\partial P} - 0.07)$$

$$q_{cl} = 0.03 q_{sat}$$

where q_{sat} represents saturation specific humidity. Note that water vapor is reduced by cloud water content to conserve total water.

An important process concerning stratocumulus is a cloud top entrainment (CTE) process. GSM uses local turbulence closure model by Mellor and Yamada (1982). But local turbulence scheme causes concentration of moisture and consequent excessive production of boundary layer cloud at the top of boundary layer because of the large difference of vertical diffusivity between above and below the top of boundary layer almost all over the oceans. To prevent this problem, some value of vertical diffusivity is added even at strong inversion layer. Namely it works like CTE. Therefore this treatment is made invalid if three conditions described above are met.

3. Result

The results of one-month integration for July 2001 are shown at Figure 1 and Figure 2. Figure 1 shows the cloud amounts of without (left) and with (right) a stratocumulus parameterization. Low cloud amount is remarkably and selectively increased in off California, off Peru, off Mauritania, off Namibia regions. Figure 2 shows correspondent errors of upward shortwave radiation at the top of the atmosphere in which ERBE (Earth

Radiation Budget Experiment) observation data are used as climatology. The serious negative biases caused by a lack of reflection due to stratocumulus in these regions are reduced. The positive bias in downward shortwave radiation on the surface and negative bias of downward longwave radiation on the surface are also improved (not shown). Figure 3 shows the comparisons of seasonal variation of stratocumulus for 1992 off California, off Peru, off Mauritania and off Namibia regions. The parameterization represents the observational variations of stratocumulus (Klein and Hartmann 1993) well. Diurnal variation of cloud amount and total cloud water content of the cloud are also consistent with observations (not shown).

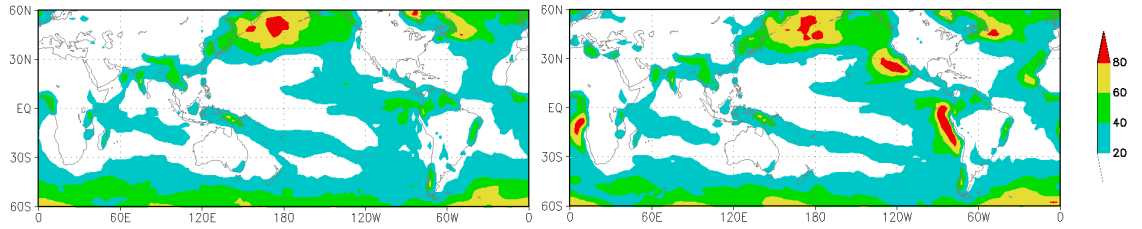

Fig. 1: Low cloud amounts in unit of [%] using T106 for July 2001 calculated left) without and right) with a stratocumulus parameterization.

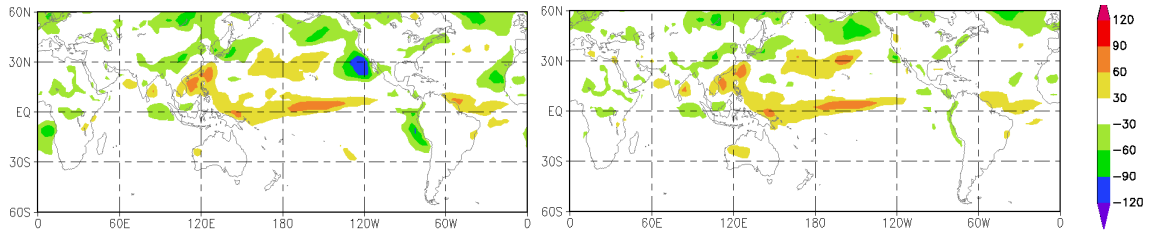

Fig. 2: As in Fig.1 but for errors of upward shortwave radiation at the top of the atmosphere [W/m^2]. Errors are calculated based on ERBE observation data.

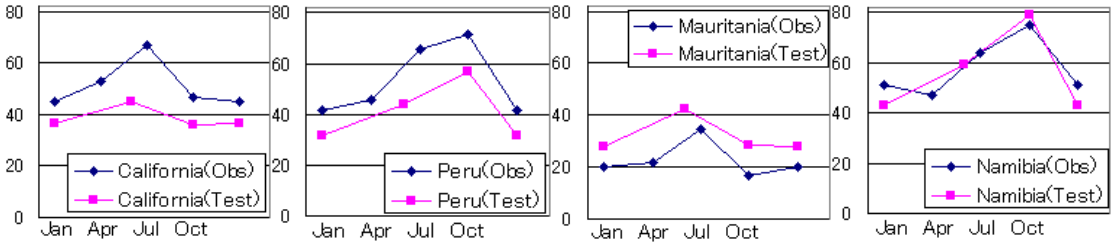

Fig. 3: Seasonal variations of stratocumulus cloud amount [%] using T63 for 1992 off California, off Peru, off Mauritania and off Namibia regions from left side. Observation data are from Klein and Hartmann (1993).

References

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