EFFECTS OF LOW CLOUDS AND LOW-LEVEL WATER VAPOR IN SHORT-TIME VARIATIONS OF TROPICAL CONVECTION

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1 INTRODUCTION

Low clouds are important elements of the global-scale atmosphere, which affects the energy and water cycle of the climate system. Their effect in radiative budget due to high reflectivity is well known. This effect is most significant over the subtropical ocean, where low clouds exist at the top of the mixed layer under the clear subsiding atmosphere. In the tropical regions, however, the existence and the role of low cloud are not well known. In these regions, there are strong convective activity and high cloud cover, and they mask the low cloud from the conventional satellite view. In this paper, we will examine the possible role of low clouds in the dynamics of tropical atmosphere, focusing on short-time variations of cloud activity.

2 TWO-DAY VARIATION

In the equatorial Pacific, variation of convective cloud activity of about two-day period is apparent and is coupled with circulations of equatorial gravity waves (Takayabu *et al.*, 1996).

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By using a simplified two-dimensional atmospheric model, the two-day period cloud disturbances are simulated and their dynamics is explained in terms of interaction between cloud activity and gravity waves (Numaguti and Hayashi, 2000).

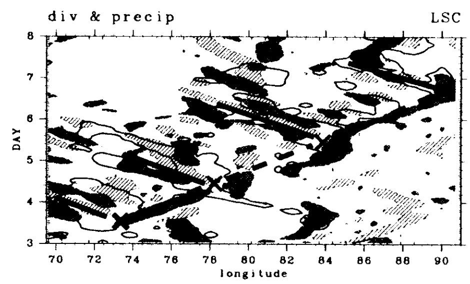

Figure 1. Longitude-time distributions of precipitation (contours), 900hPa convergence (dense shading) and 680hPa convergence (light shading) for 2-dimensional experiment.

Figure 1 shows the model result, indicating that the westward-moving convective clouds (shown as thick contours for precipitation) appear almost periodically with about two-day period. The structure is shown to be very similar to the observed one. In Figure 1, it is seen that the clouds are associated with westward- and eastward-propagating gravity waves (shown as shadings for convergence). The clouds and gravity waves show life-cycle behavior as shown schematically in Figure 2. It starts from low-level shallow cloud (a), grows into deep convection (b), decays from lower levels and excite shallow circulation cell (c), and begin westward movement of upper level cloud and generation of low-level cloud to the east (d). For this final generation of low-level cloud, eastward-propagated shallow gravity-wave cell plays important role. The upward motion by this cell brings low-level moistening and thus onset of cloud activity. In this life-cycle of cloud activity, these interaction between the low-level cloud and gravity-wave circulation is shown to be very important.

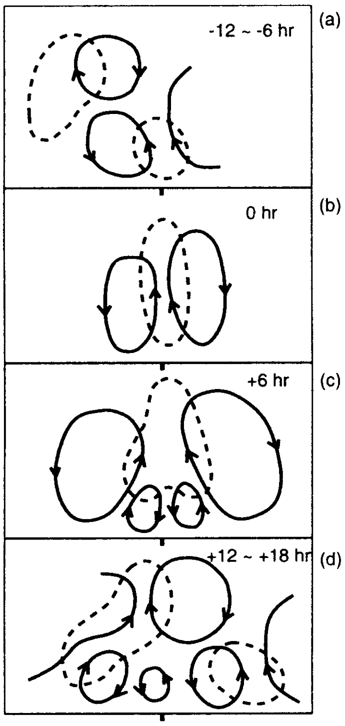

Figure 2. Schematic illustration of Circulations (solid curves with arrows) and cloud areas (dotted contours).

3 DIURNAL VARIATION

Another well-known short-time variation of tropical convective activity is its diurnal variation. Over the ocean, the maximum precipitation tend to occur from midnight to early morning. From the analysis of observation, it is shown that the convective activity is generally shallow in the evening and it grows during the night (Sui *et al.*, 1997).

The diurnal of tropical convective clouds is simulated by a meso-scale cloud model of two-dimensional domain (Kubota, 1999). The model used is the CSU-RAMS with an improved radiation code. The standard experiment (Figure 3) shows clear diurnal cycle of precipitation with early-morning maximum. In this case, there is a large radiative cooling at the top of the mixed layer, due to the existence of low-level cloud there.

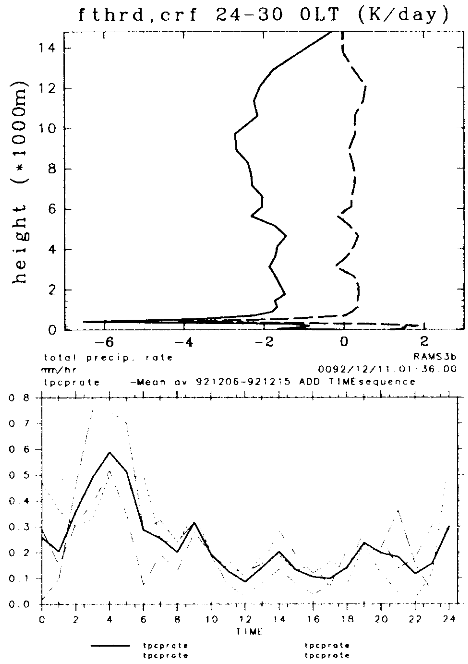

Figure 3. Radiative heating profile (upper) and composite diurnal cycle of precipitation for standard experiment

If the radiative effects of this low-level cloud is removed, the diurnal cycle (Figure 4) becomes very weak. These results indicate the importance of low-level cloud and its radiative effects for the diurnal cycle of the tropical convective clouds. In the noon-time, the low-level (boundary layer) cloud rarely occurs because it becomes unstable by solar heating. The boundary-layer cloud develops after sunset due to the dominance of radiative cooling effect in the night time, and then it moisten the low-level free troposphere due to its intensification effect of the turbulent transport of water vapor and heat. The development of deep convective cloud system is considered suppressed before the moistening of low-level free troposphere and can be effective only after the moistening.

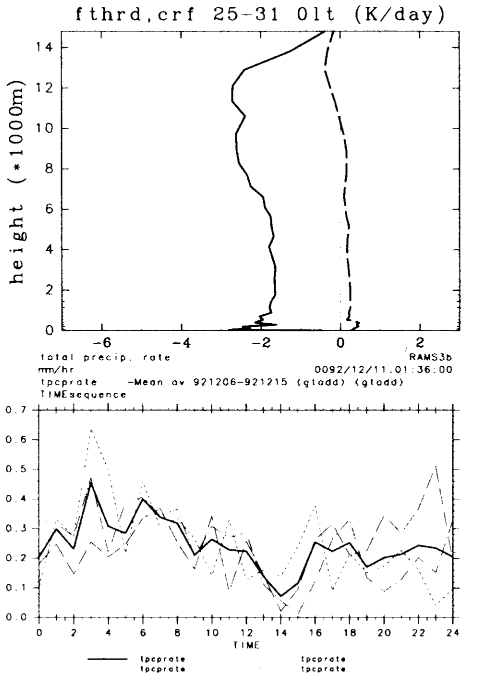

Figure 4. Radiative heating profile (upper) and composite diurnal cycle of precipitation for experiment without radiative effects of low cloud

4 DISCUSSION

In both type of short-time variation of cloud activity in the tropics, the low-level clouds play significant roles. The deep convective cloud systems develops from the low-level cloud, which have a moistening effect of low-level free troposphere. Thus to understand the variation of convective cloud activity, the examination of low-level cloud activity is considered necessary. However, the observational detection of the low-level cloud for the large scale ocean area is relatively difficult. The ships can observe the low-cloud but the observation frequency is limited. The detection by infrared channel satellite is difficult because of small temperature difference from SST. The visible channel can detect the cloud but it cannot sense the night-time cloud (which is important for diurnal cycle) and cloud under high-level clouds (frequently exist in the tropics). The discrimination of low- and high-level clouds is also difficult with microwave sensors. Thus the space-bone cloud profiling radar is one of the most useful sensor for detecting the large-scale behaviors of low-level cloud activity. Besides, the understanding of convective cloud systems and its coupling to large-scale circulation will be greatly improved if the three-dimensional behavior of meso-to-lager scale cloud systems, including its life cycle from initiation to decay, can be observed from the space.

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