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WESTWARD GENERATION OF EASTWARD-MOVING TROPICAL CONVECTIVE BANDS IN TOGA COARE

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1. INTRODUCTION

Some case studies reported westward generation of eastward-moving convective bands in TOGA COARE. For example, Halverson et al. (1999) reported that a convective band moved eastward and a new band formed to its west on 11 February 1993. Mechanisms responsible for the westward generation of eastward-moving convective bands are investigated using a cloud-resolving model.

2. NUMERICAL MODEL

A 2-D version of the Regional Atmospheric Modeling System (RAMS) is used. The model domain (950 km in the x direction and 27 km in the z direction) was translated at a constant speed (13.84 m s^{-1}). The wind profile was specified according to the wind sounding at 0600 UTC on 11 February 1993. Horizontal winds are westerlies at low to middle levels and easterlies aloft. A thermal was centered at 550 km from the left boundary (hereafter x = 0 km), and z = 1.6 km to initiate convection.

3. RESULTS AND DISCUSSIONS

Figure 1 shows an asymmetry of precipitating clouds between the primary band's western and eastern sides. On the western side of the primary band, precipitating clouds became organized into long-lived bands B2 and B3. New bands sequentially developed to the west of old bands. In contrast, none of the small precipitating clouds become organized into long-lived bands on the eastern side.

An expanded view of the rectangle in Fig. 1 is illustrated in Fig. 2. It is clear that the wave activity generated by the convective bands is biased to the western side. Disturbance D1 propagates westward with a phase speed of $\sim$ 15 m s^{-1} from band B1 and promotes the development of band B2. Disturbance D3 then propagates westward with a phase speed of $\sim$ 25 m s^{-1} from band B2 and promotes the development of band B3.

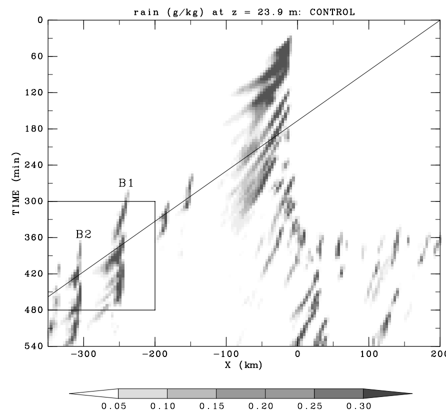

Figure 1: Time-zonal cross section of mixing ratio of rain (g kg^{-1}) at z = 23.9 m in CONTROL. The thin line indicates 0 m s^{-1} relative to the ground.

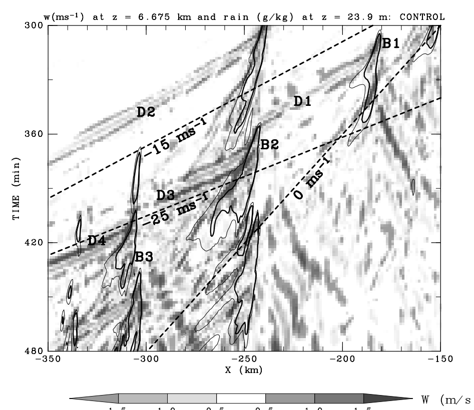

Figure 2: Time-zonal cross section of vertical velocity (m s^{-1}) at z = 6.675 km and rain mixing ratio (g kg^{-1}) at z = 23.9 m in the CONTROL case.

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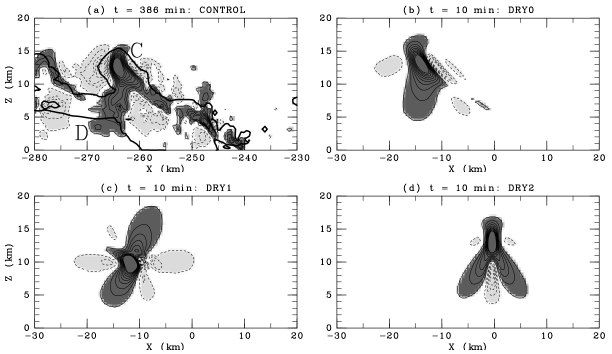

Figure 3: Vertical cross section of vertical velocity in (a) CONTROL (t = 386 min), (b) DRY0, (c) DRY1, and (d) DRY2. Updraft is heavily shaded, and downdraft is lightly shaded.

Figure 3a shows that westward-propagating disturbance D3 of upward motion is produced below cell “C”, separated from the leading edge of band B2 at x = –240 km. To investigate preferential excitation mechanisms of westward-propagating waves below the convective cell, we conducted a series of simulations in which gravity waves are excited by thermal forcing (“DRY”). In DRY0, with an ascending and westward-accelerated thermal, the pattern of updraft is similar to that in the CONTROL case (Fig. 3a). In DRY1, where the thermal forcing is fixed at a constant height but moves westward, the westward propagating disturbances with upward motion are produced upstream both below and above the forcing. In DRY2, where the thermal forcing is fixed in the x direction but ascends the same as in DRY0, upward motion is preferentially generated below the forcing. These simulations showed that preferential excitation of westward-propagating waves was due to westward motion of the cell, while preferential excitation of waves below the cell was due to ascension of the cell.

A local region having $Ri < 0.25$ at x = –280 to –275 km just above disturbance D3 is noticed around the critical levels where the horizontal wind (–25 m s^{-1}) is nearly equal to the phase speed of the disturbance D3 in Fig. 4. This region with $Ri < 0.25$ is remaining region R of convective cell C that excited disturbance D3 and dissipated near z = 14.5 km. Remaining region R is passively advected by the mean flow near the equilibrium level (z = 14.5 km). Thus, disturbance D3, with a horizontal phase speed that happens to match the mean flow near the equilibrium level, is trapped in the troposphere owing to remaining region R because the ducting conditions proposed by Lindzen and Tung (1976) are locally satisfied.

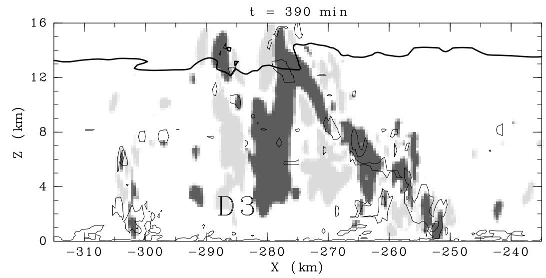

Figure 4: As in Fig. 3 but for regions having $Ri <$ 0.25 (contour) superposed on vertical velocity field at t = 390 min for the CONTROL case. A bold line indicates the critical levels of disturbance D3.

4. SUMMARY AND CONCLUDING REMARKS

The westward generation of new convective bands is explained by a gravity wave mechanism. Two westward-propagating modes excited below the convective cells moving westward relative to the convective bands appear to play an important role. A slow-propagating mode ($\sim$ 15 m s^{-1}) excited by a shallow convective band is ducted in the troposphere under an unstable layer of small Richardson number containing its critical level. A fast-propagating mode ($\sim$ 25 m s^{-1}) excited by a deep convective band is ducted in the troposphere under the remaining region of the convective cell containing its critical level. These two modes propagate horizontally to the west and promote the growth of shallow convection into long-lived convective bands. Refer to Shige and Satomura (2001) for the complete work summarized in this abstract.

Acknowledgement The simulations were made using the Regional Atmospheric Modeling System (RAMS) developed at Colorado State University.

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