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Mechanism of diurnal cycle of convective activity over Borneo Island

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1. INTRODUCTION

Convective activities occurring over the tropical Maritime Continent is one of major energy sources for driving global atmospheric circulation. Numerous attempts have been made to clarify mechanism on diurnal cycle around Maritime continent (Gray and Jacobson, 1977; Oki and Musiake, 1994; Liu and Moncrirff, 1998, etc.). Ohsawa et al. (2001) reveals the characteristics of convective activity over Maritime continent in summer using GMS (Geostationary Meteorological Satellite) -5 black-body temperature (TBB) data. Low TBB (active convection) area is often observed over inland area of Borneo Island during the nighttime. Nesbitt and Zisper (2001) and Mori et al. (2004) report that diurnal cycle and spatial distribution of convective activities using TRMM PR and TMI data. Especially over Borneo Island, precipitation is observed from nighttime to morning. Characteristics of convective activity over Borneo Island are clarified, but the mechanism is not still revealed. Recently, Ichikawa and Yasunari (2006) analyzed the detailed vertical structure of rain over Borneo Island using TRMM PR data and argues the mechanism of diurnal cycle due to the large-scale wind. But the mechanism of convective activity over Borneo island is not clarified so far.

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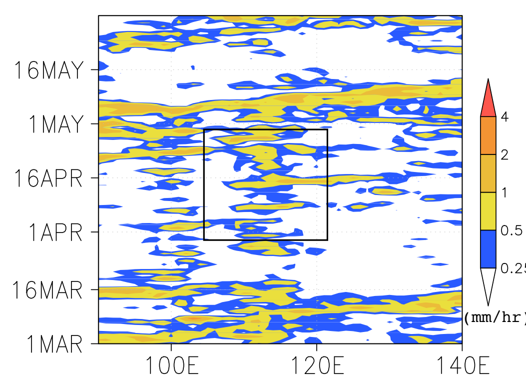
In this study, we conduct a cloud-resolved simulation using a regional climate model to clarify the mechanism of diurnal cycle of convective activity around Borneo Island.

2. DATA AND SIMULATION DESIGN

2.1. OBSERVATION DATA

Figure 1 shows longitude-time cross section of Global Precipitation Climatology Project (GPCP) daily precipitation averaged over 3S to 3N. In April, 2004 (box in Fig. 1), no tropical cyclone was observed over Borneo Island, and Madden Julian Oscillation (MJO) is inactive. In this period, additionally, diurnal cycle of convective activity is not disturbed by cyclones and synoptic scale disturbances and surface ambient wind over Borneo Island is weak, almost less than 5 m/s by NCEP global tropospheric data (not shown). We also use TRMM 3B42 version 6 3-hourly rain rate (TRMM-RR) data to compare with the simulation results.

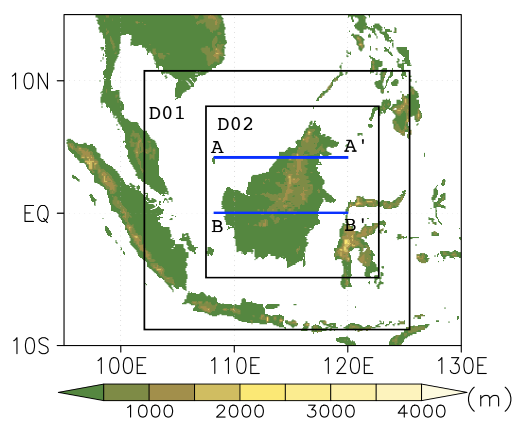
Figure 1. Longitude-time cross section of GPCP daily precipitation. The precipitation is averaged over 3S to 3N.



2.2 SIMULATION DESIGN

To analyze the mechanism of the diurnal cycle of convective activities, we conduct two-way nested cloud-resolved simulation using WRF (ARW-core) model version 2.1.2 with horizontal grid interval of 17.5 km (140x130 grid points) and 3.5 km (456x411 grid points). Figure 2 shows the domain of this simulation. Both domains have 31 vertical levels (surface to 50 hPa), and do not use convective parameterization not to influence the convective activities of inner domain. WRF Single-Moment 6-class graupel microphysics scheme and Yonsei University planetary boundary layer scheme are used in both domains. NCEP global tropospheric analyses data (6-hourly, 1x1 degree grids, 24 levels) is used as initial and boundary conditions. The simulation starts at 00Z 29 March 2004, and integrate for 32 days. We assume that the first two days of the simulation is in the spin up, so we analyze the simulation output in April.

Figure 2. Simulation domains and topography.



3. RESULTS

Figure 3 shows monthly averaged 6-hourly precipitation by TRMM 3B42 and the WRF simulation in April, 2004. In 12-17 LT (Fig. 3-b), precipitation area is observed over the island along coastline and central mountains. The precipitation that observed along the coastline immigrates to center of the island (Fig. 3-c) and the precipitation continues till next morning over center of the island (Fig. 3-d,a). The time evolution of simulated precipitation (Fig. 3-a,b,c,d) is similar to observation. The precipitation bands, which is formed along the coastline, move into inland area corresponding to the sea breeze front intrusion.

Figure 3. Monthly averaged 6-hourly precipitation by (a)-(d) TRMM 3B42 and (e)-(h) WRF simulation.

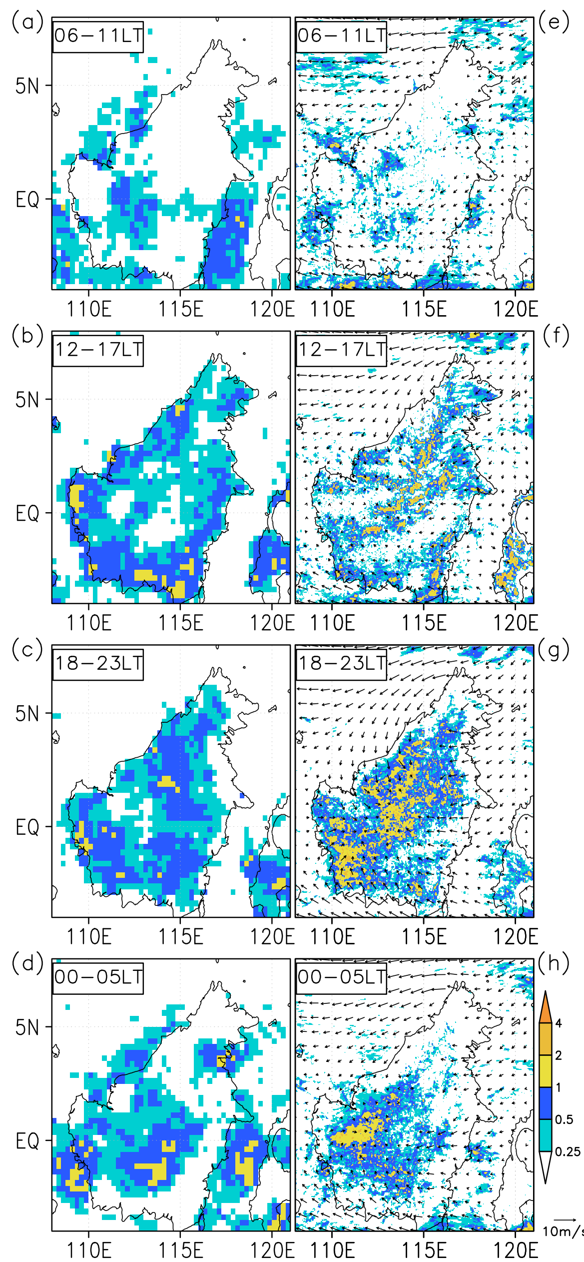


Figure 4 shows the vertical cross sections of monthly averaged wind perturbation from area averaged wind along 0.0 N (Fig. 1 A-A') at (a) 16 LT and (b) 00 LT. Distance from coastline to center of the island is about 1000 km along 0 N. Sea breeze develops along both side of the coastline and upslope wind develop around the central mountains at 16 LT. At 00 LT, the sea breeze fronts intrude to inland area and enhance the precipitation over the mountains (Fig. 3-h).

Figure 4. Longitude-height cross section of monthly-averaged wind perturbation from area averaged wind at (a) 16 LT and (b) 00 LT along 0 N. Vertical component of wind is multiplied by 100. The lowest panel shows elevation (meter).

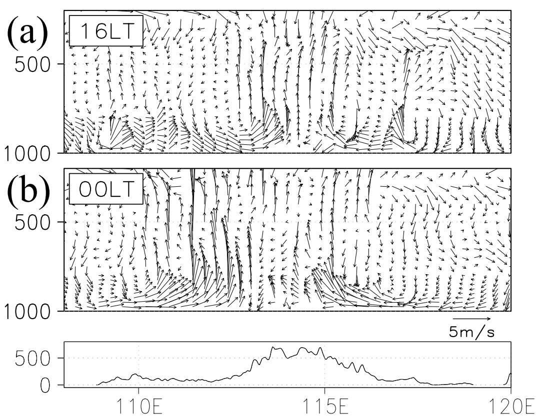


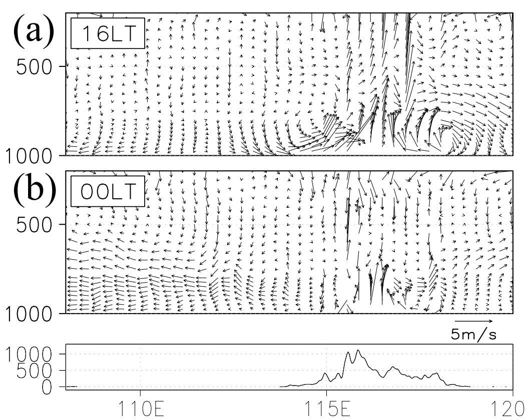
Figure 5 is same as Figure 4, but for 4 N (Fig. 1 B-B'). Distance from coastline to center of the island is about 400 km along 4 N. At 16 LT, upslope wind develops along both side of the mountains and the upslope wind converges over the mountains. The precipitation is getting small corresponded to the decline of the local circulation (Fig. 3-h) at 00 LT.

4. DISCUSSION

As Kimura and Kuwagata (1995) pointed out, feature of local circulation depends on horizontal scale of terrain. Over tropical islands such as Borneo island, diurnal cycle of convective activity provide large amount of precipitation, and local circulation triggers diurnal cycle of convective activity.

By Fig. 4 and Fig. 5, mechanism of diurnal cycle of convective activity over Borneo island seems to depend on distance from coastline to mountains. In cases where the distance more than about 500 kilo meter, sea breeze and upslope wind develop separately, precipitation band occurs along coast line and mountains in afternoon. In evening, sea breeze fronts and precipitation bands intrude into inland area and convection over mountains continue till next morning. On the other hands, in cases where the distance less than about 500 kilo meter, sea breeze and upslope wind develop and couple in the late afternoon. Convection occurs over mountains in early afternoon, and decays in evening.

Figure 5. Longitude-height cross section as for Fig. 4, except for along 4 N.



5. CONCLUSIONS

To elucidate mechanism of diurnal cycle of convective activity over Borneo Island, we performed one-month simulation during absent MJO season using WRF model. The spatial distribution and time evolution of simulated diurnal cycle of convection is in accordance with GMS and TRMM satellite data. In northern part of Borneo Island, distance from coast to central mountains is relatively narrow (about 100 km) ,on the other hands, the distance is relatively broad (about 500 km) in southern part of Borneo Island. Over the northern part of Borneo Island, land-sea breeze and upslope wind develop and convection initiated over only mountainous area. The convective activities over the mountain decay in evening. Over southern part of Borneo Island, sea breeze and upslope wind develop separately in afternoon, and convective activities occur over sea breeze front and mountain. Between the sea breeze front and mountain, convective activities are suppressed by compensational subsidence. In the evening, the sea breeze front penetrates into inland area and coupled with convection over mountainous area and the convective activities continue till next morning. The diurnal cycle of convective activity over Borneo island is maintained by sea breeze and upslope wind and it depends on distance from coast to central mountains. There is room for further investigation about the dependency of spatial scale and land-sea contrast for convective activity.

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