A Study on Convection over Sumatra and Its Relationship to Large-scale Disturbances Based on Coordinated Observations with the Equatorial Atmosphere Radar

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Convection and wind features over Sumatra and its relationship to large-scale disturbances were studied using both horizontal and vertical winds observed by the Equatorial Atmosphere Radar (EAR). Tropospheric observation over Sumatra was also carried out using other equipment such as a Boundary Layer Radar (BLR), an X-band Doppler weather radar (XDR), and radiosonde. Data obtained by these equipment were also used. Further, data provided by the Geostationary Meteorological Satellite (GMS), and National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis were used.

To investigate the relationship between convective activity over Sumatra and intraseasonal variation (ISV), a case study during June 2002 was carried out. In June 2002, convective activities over the Indian Ocean, Indonesia Maritime Continent (IMC), and the western Pacific were significantly modulated by ISV. Blackbody brightness temperature (TBB) observed by GMS showed that two super cloud clusters (SCCs) developed over the Indian Ocean (70 - 90°E) in the first half of June 2002, and propagated eastward from the Indian Ocean to the western Pacific without significant diminution. Zonal wind observed by EAR and surface pressure observed at the observation site suggested the existence of Kelvin-wavelike structure of ISV. From temporal variations of TBB, zonal wind at 850 hPa, and vertical shear of horizontal wind between 700 and 150 hPa, the observation periods were classified into the inactive phase (1-9 June), active phase (10-19 June), and postwesterly wind burst phase of ISV (20-26 June). During the inactive phase of ISV, convective activities caused by local circulation were prominent over Sumatra. Results of radar observations indicated the dominance of convective rainfall events over the mountainous area of Sumatra. During
active phase of the ISV, cloud clusters (CCs) which developed in the convective envelope of SCC with a period of 1-2 days mainly induced the formation of convective activities over Sumatra. Results of radar observations indicated that both of convective and stratiform rainfall events occurred over the mountainous area of Sumatra. In the postwesterly wind burst phase of ISV, convective activities were suppressed over Sumatra. Previous studies pointed out that local circulation induced by the Sumatra’s topography causes development of deep convection with a diurnal cycle. Further, this study points out that this deep convection with a diurnal cycle is dominant during the inactive phase of ISV, and is suppressed during the postwesterly wind burst phase.

The first observation campaign by the Coupling Processes of the Equatorial Atmosphere (CPEA) project (CPEA-I campaign) was carried out during March - May 2004. While other studies focused on convective events associated with rainfall, this study focused on westerly wind burst (WWB) event, when convective activity was suppressed. WWB occurred by eastward propagation of SCC moved from the Indian Ocean to the western Pacific. The convective envelope of the SCC reached Sumatra from the Indian Ocean on 5 May, then passed over Sumatra on 7 May. Intensification of the westerly wind occurred over Sumatra below 5.5-6.0 km as the SCC passed over it. On 7 May, the 2.5-4.0 km westerly wind at Kototabang (0.20°S, 100.32°E, 865 m MSL) was identified as a WWB. Precipitating clouds around Kototabang were suppressed after 7 May, as drier air (lower than 60% relative humidity) was transported by lower-tropospheric westerly wind from the Indian Ocean over Sumatra. Non-precipitation clouds were observed at 5-8 km by the lidar after 7 May.

After 7 May, the vertical wind at 2.5-5.5 km showed the oscillatory motion with a timescale of about 12 hours. Contrary to the radiosonde-derived downward wind with a horizontal scale of several hundred km, daily-averaged vertical wind at Kototabang showed upward motion of 0.07-0.08 m/s on 7 and 8 May, when westerly winds larger than 10 m/s prevailed at 2.5-4.0 km. The vertical wind oscillation was suppressed in the upper part of westerly wind region (above 3.0-5.5 km), where the Richardson number was smaller than 0.45 and westerly wind changed to easterly wind with large vertical shear (greater than 10 m/s/km). This fact implies that shear instability and horizontal wind change inhibited upward propagation of vertical wind oscillations. This study describes the detail of vertical wind motions over the mountain region of Sumatra during the WWB event for the first time. The observational results suggest that topography of Sumatra plays a
role in generating vertical wind motions, and that background horizontal wind is also important for modulation of vertical wind.

Many studies investigated large-scale wind and convective disturbances over the Indian Ocean, IMC, and the western Pacific using global objective reanalyses. However, routine upper-air soundings over IMC assimilated into global objective reanalyses are scarce. Therefore, evaluation of reanalysis wind by observed wind is necessary. In this study, lower-tropospheric horizontal wind reproduced by NCEP/NCAR reanalysis was evaluated using horizontal wind observed by EAR during 2001-2007. As a representative of lower-tropospheric wind, wind at 700 hPa was selected. First, it was shown that EAR wind and radiosonde wind at Padang (0.88° S, 100.35° E) agreed well and hence EAR wind is able to be used as representative of winds around (0° N, 100° E). This agreement also showed that radiosonde wind well represents large-scale wind. Next, NCEP/NCAR wind was compared with EAR wind. Though NCEP/NCAR-reanalysis wind was smaller than EAR wind, they showed good agreement. For zonal wind, correlation coefficient was 0.84 and slope of regression line was 0.74. For meridional wind, correlation coefficient was 0.69 and slope was 0.88.

At West Sumatra, radiosonde observations at Padang have been reported through Global Telecommunication System (GTS). Therefore they have chance to be assimilated into NCEP/NCAR reanalysis. The agreement between NCEP/NCAR and EAR winds improved in the group when radiosonde observations at Padang were reported through GTS (Group A) than when they were not reported (Group B). For zonal wind, all of correlation coefficients, standard deviation, and amplitude of NCAR/NCEP-reanalysis zonal wind improved. Correlation coefficient in Group A (0.90) was better than in Group B (0.79). Standard deviation in Group A (1.58 m/s) was better than in Group B (2.07 m/s). Slope of regression line in Group A (0.82) was also better than in Group B (0.66). For meridional wind, all of the correlation coefficients, standard deviation, and amplitude of NCEP/NCAR-reanalysis meridional winds also improved. Correlation coefficient in Group A (0.77) was better than in Group B (0.63). Standard deviation in Group A (1.25 m/s) was better than in Group B (1.62 m/s). Slope of regression line in Group A (0.96) was also better than in Group B (0.80). Number of radiosonde observations has increased since 2006 not only at Padang but also at other places in Indonesia (Medan, Jakarta, and Pangkal Pinang). Because the result of this study demonstrates that upper-air observations over IMC improve the quality of NCEP/NCAR reanalysis, efforts to maintain and extend upper-air observations in IMC are necessary for understanding and predicting large-scale disturbances in this region.