Dry Intrusion observed at Sumatera Island

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Abstract

A dry intrusion observed at 2–4 km MSL altitude at Kototabang (100.32°E, 0.20°S, 865m MSL), West Sumatera, Indonesia during 6–7 Oct., 1998, is described. The horizontal distribution of total precipitable water showed that the low precipitable water with narrow band was intruded from Central Indian Ocean to Sumatera Island. A back trajectory analysis supported that the dry air intruded from the central Indian Ocean. The different features from the dry intrusion in the western Pacific is two points: 1) the dry layer is ascent with time, and 2) the origin is not traced back to subtropical region but equatorial western–central Indian Ocean.

1. Introduction

During Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA-COARE) intensive observation period (Nov. 1992–Feb. 1993) extremely dry layers were sometimes observed in the lower–middle troposphere of equatorial western Pacific, where it had been thought to be always wet (Parsons et al., 1994). The air was incredibly too dry not to be explained by diabatic vertical motion. They were also found that the dry air event was visualized by distribution of total precipitable water, derived from special sensor microwave/imager (SSM/I). It was concluded that the extremely dry air intruded by lateral advection (e.g., Numaguti et al., 1995; Yoneyama and Fujitani, 1995; Mapes and Zuidema, 1996). These dry air events have been termed “dry intrusions”.

In general, convections in the warm pool region from the Indonesian maritime continent to equatorial western Pacific are the most active in the world, and they drive global-scale circulation. But, convective activities were strongly suppressed during the periods during dry intrusions. These dry events are sometimes expressed as drought periods (Brown and Zhang, 1997). Short-wave radiation into the ground increases under dry air events. Inversion layers are often observed at the lower part of dry layers. Mapes and Zuidema(1995) suggested that the inversion layers are formed by radiative heating of longwave radiation. It implies that budget of energy and water cycle must be different between dry air events and other conditions (Parsons et al., 2000).

Yoneyama (2003) analyzed rawinsonde observations based on nine-years research vessel journeys in the western Pacific since 1993, and reported many dry events. Yatagai and Sumi(1997) utilized NASA Water Vapor Project data and ECMWF data during 1988–1994, and reported some horizontal structures similar to dry intrusions observed during TOGA-COARE in the Pacific Ocean region and the Indian Ocean region. However, there are still few reports for dry intrusions except for the western Pacific. In this paper, dry intrusion observed by intensive rawinsonde observation in Sumatera Island is described.

2. Data Description

An intensive rawinsonde observation was conducted for comparison with a new boundary layer radar during 00UTC 29 Sep–06 UTC 7 Oct, 1998 (Renggono et al., 2001; Murata et al., 2002) at Kototabang, West Sumatera, Indonesia (100.32°E, 0.20°S, 865m MSL)(Fig. 1). The observation was conducted 4 times / day (0000,0600,1200,1800 UTC, LST = UTC + 7 hours). 4-times per daily NCEP/NCAR reanalysis data (Kalnay et al. 1996) were utilized to obtain horizontal structure of dynamical condition, and to do back trajectory analysis. The 0.05x0.05 GMS-5 black body temperature(T_{BB}) data were provided by Kochi University. The total precipitable water (TPW) was obtained from the dataset provided by JAXA retrieved from Tropical Rainfall Measurement Mission Microwave Imager (TRMM/TMI).

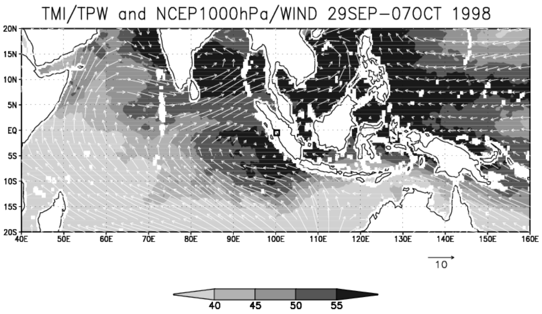

Figure 1: Horizontal distribution of total precipitable water (unit is mm) and NCEP 1000 hPa wind (unit is m/s) averaged for 29 Sep.–7Oct., 1998. The location of observation site is shown as a small square.

3. Synoptic condition

The average map of TPW and NCEP 1000 hPa wind during the campaign period is shown in Fig. 1. The period corresponded to the end of northern summer monsoon, but monsoon westerly still appear between 0–10°N. The amount of TPW is much different between south-western part and north-eastern part. Abundant moisture more than 50 mm of precipitable water exist over Bengal Bay, off the west coast of Sumatera and the western Pacific.

Figure 2 shows time-height cross-sections of GMS T_{BB}, NCEP 700 hPa geopotential height anomaly and 700 hPa zonal wind anomaly during Sep. 1–Oct. 31, 1998. Active convections correspond to MJO active phase are present in 70–100°E during 10–25 Sep. The organized cloud system propagated eastward, but it was unclear in the maritime continent. The strong westerly (westerly burst) begins to occur in the lower troposphere of equatorial eastern Indian Ocean on around 15 Sep. The westerly varies with quasi-10-day periodicity in the westerly burst. Low pressures correspond to strong westerlies, and each pressure anomaly seems to propagate westward. A dry intrusion described in this paper is a part of this strong westerly periods during 6–7 Oct., 1998.

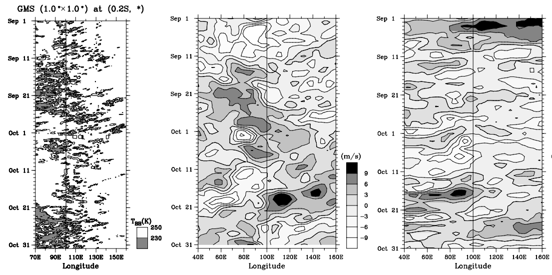

Figure 2: Longitude–time cross-section of GMS T_{BB} (left), 700 hPa zonal wind anomaly (center) and 700 hPa geopotential height anomaly (right) from 1 Sep.–31 Oct. 1998 average.

4. Observational results

Figure 3 is a vertical profile of temperature, and specific humidity on Oct. 6 of 18UTC (Oct. 7 of 01LST), 1998. The vertical axis is a height from the ground (865m MSL). There is a extremely dry layer around 2 km height (around 3 km above MSL). The weak inversion layers appear at the bottom and the upper dry layer (1.5 and 2.5 km above ground level). Figure 4 is time-height cross-sections of relative humidity and specific humidity. An extremely air with less than 60–70 % of relative humidity and less than 6–8 g/kg specific humidity appears at the altitude of 2–4 km MSL on Oct 6–7. The dry layer is ascent with time by about 500 m/day.

Figure 5(a) is the horizontal distribution of TPW retrieved from TRMM/TMI, and Fig.5(b) is distributions of NCEP 700 hPa geopotential height and horizontal wind. The difference of the TPW with Fig. 1 is the narrow band of low TPW along the equator between 80–100°E. The dynamical structure (Fig. 3b) at the level of dry layer represents that the almost symmetric two depressions to the equator located in the central Indian Ocean, and strong westerly blows between the depressions.

5. Discussion

The dry intrusion observed at Sumatera Island is compared with that observed during TOGA-COARE IOP. The dry layer is observed at the height of 3 km MSL with around 1 km thickness, and an inversion layer appears at the bottom of the dry layer. These thermodynamic structure is well similar to that observed during dry air events in the western Pacific. Numaguti et al.(1995) and Mapes

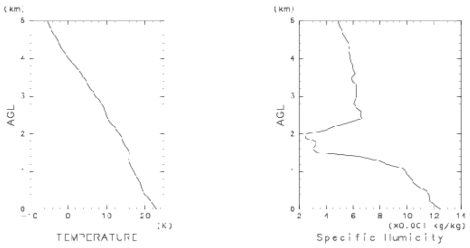

Figure 3: Vertical profiles of temperature and specific humidity on Oct 6 of 18UTC (Oct 7 of 01LST), 1998

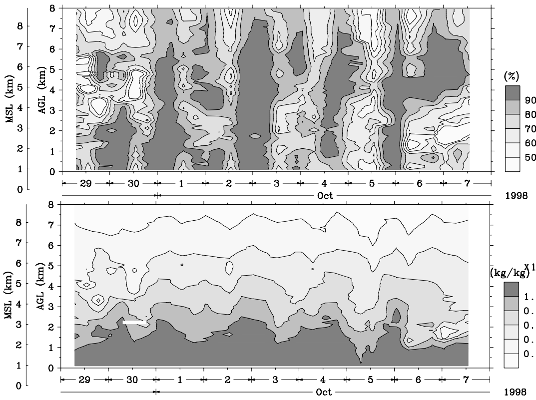

Figure 4: Time-height cross-section of (a)relative humidity and (b) specific humidity. The period is 29 September–07 October, 1998.

and Zuidema(1996) considered the effect of the inversion layers at the bottom of the dry layer as a cause of convectively suppressed condition.

The dry layer in the western Pacific tended to be descent with time. It was considered a result of atmospheric subsidence by radiative cooling. The dry layer observed at Sumatera is ascent with time. It is a different point from that observed in the western Pacific.

The distribution of total precipitable water on Oct. 7, 1998 indicates a narrow band of low precipitable water with several thousands km on longitude scale and several hundreds km on latitude scale along the equator, and it extends from central Indian Ocean to Sumatera Island. The horizontal scale of this dry intrusion is almost same as that observed in the equatorial western Pacific during TOGA-COARE.

This disturbance can be regarded as a part of the equatorial Rossby-wave disturbance emenated from

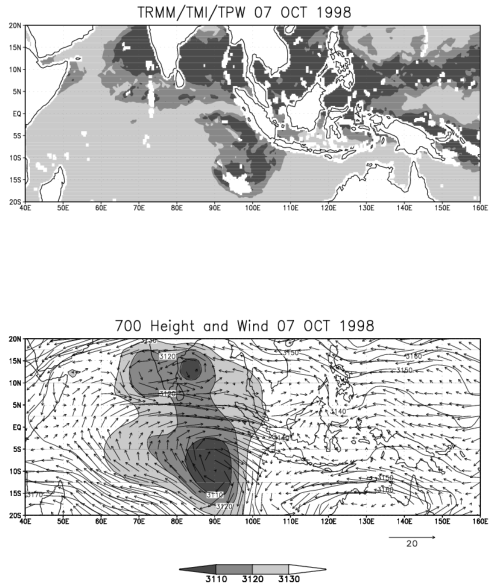

Figure 5: Horizontal distributions of total precipitable water and 700 hPa geopotential height and wind on Oct 7, 1998

equatorial convective disturbance (e.g., Kemball-Cook and Wang, 2001) concerning to Madden - Julian Oscillation (Madden and Julian, 1994) by the Rossby-wave response (Matsuno, 1966; Gill, 1980). Compared two figures (Figs. 3a and 3b), it looks that the dry air was intruded from the central Indian Ocean to Sumatera by strong westerly by Rossby-wave disturbance.

To confirm the origin of the dry air observed at Kototabang, back trajectory analysis (Fig. 4) is conducted. Each trajectories are calculated from (100°E, 0°) at 700 hPa, and the start times are 00UTC on 3 Oct (triangle), 00UTC on 4 Oct (square), 00UTC on 5 Oct (cross), 00UTC on 6 Oct (circle), and 00UTC 7 on Oct (plus). The trajectories of 3–4 Oct came from near sea level of south–southeastern part of Sumatera. The trajectories of 5–7 Oct was almost along 5°N and came from above 700 hPa level of the eastern Indian Ocean by strong westerlies. It indicates that the origin of 700 hPa level air above Kototanbang change on 5 Oct. The results of calculated back trajectories and the map of precipitable water during TOGA-COARE showed that the dry airs intruded from subtropics. In contrast, dry air above Kototabang comes from the equatorial central Indian Ocean. The precipitable water in the Indian Ocean is relatively low in the western side and high in the eastern side.

Therefore, it is considered that mid troposheric relatively dry air above the eastern Indian Ocean advected into Sumatera Island by strong westerlies.

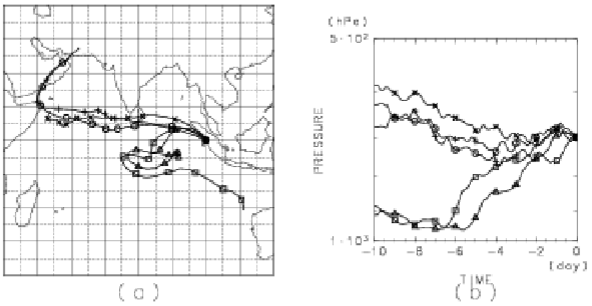

Figure 6: Results of a back trajectory analysis for (a) longitude–latitude and (b) time–pressure cross sections, calculated from 100.°E, 0°N, 700 hPa. Start times of each line are 00UTC of 3 Oct (triangle), 4 Oct (square), 5 Oct (cross), 6 Oct (circle) and 7 Oct (plus).

6. Summary

An extremely dry air was observed in 2–4 km MSL altitude at Kototabang (100.32°E, 0.20°S, 865m MSL), West Sumatera, Indonesia during 6–7 Oct, 1998. It occurred after the passage of active convections of MJO, and in the folloing westerly burst. The horizontal distribution of TPW showed that the low precipitable water with narrow band was intruded from the Central Indian Ocean to Sumatera Island. The strong westerly was caused between nearly symmetric two depressions to the equator. A back trajectory analysis supported that the dry air intruded from the central Indian Ocean. The different features from the dry intrusion in the western Pacific is two points: 1) the dry layer is ascent with time, and 2) the origin is traced back to equatorial western–central Indian Ocean.

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