TORRENTIAL RAINS IN INDONESIAN CAPITAL CITY JAKARTA

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Abstract

Torrential rains that repeatedly occurred in Indonesian capital city Jakarta, in late January and early February 2007 caused widespread floods there. In the present study, the cause of this heavy rainfall event has been analyzed. Interactions between large-scale winter monsoon flow from Siberia and local-scale, diurnally driven circulation over Java Island is found to be the main cause for this heavy rainfall event. Real-time monitoring and prediction system for such severe rainfall are needed for mitigating the urban flood disaster. To monitor heavy rainfall, an X-band radar has been installed by the collaborative activity between BPPT, Indonesia and RIGC/JAMSTEC.

Key words: heavy rainfall, monsoon, local circulation

1. INTRODUCTION

Torrential rains repeatedly occurred over Java Island during the period from late January to early February 2007, resulting in one of the worst flooding events in recorded history in the Indonesian capital of Jakarta and surrounding areas, which paralyzed the capital city activities for more than a week. Prior analyses of the cold surges were focused mainly on the structure and evolution of the surges in different regions. How the trans-equatorial monsoon flow affects the occurrence of torrential rain over Java Island in the Southern Hemisphere has not been well understood, which may be a weak point for preventing flood damage in this capital city. Relevant phenomena include the Madden and Julian Oscillation (MJO), which significantly affects tropical weather, especially in the Indian and western Pacific Ocean regions. An active MJO can cause enhanced convection over the island for an extended period of time. However, the period during late January to early February 2007 when the torrential rains occurred over the island was not in a MJO active phase. In this study, we investigate the influence of the trans-equatorial monsoon flow on the formation of the repeated torrential rains over the island using QuikSCAT sea surface winds, GMS infrared images, radar observation and balloon sounding data for the period from late January to early February 2007.

2. LARGE-SCALE CONDITIONS

Figure 1 presents the large-scale sea surface wind vectors measured by NASA's Quick Scatterometer (QuikSCAT) on 1 February 2007 when heavy rainfall occurred in Jakarta. A strong northeasterly winter monsoon flow originated from Siberia with a wind speed greater than 10 $m\ s^{-1}$ was observed over the South China Sea. This wind system crossed the equator and passed over the Karimata Strait between Kalimantan and Sumatra Island in the Indonesian maritime continent and blew over the Java Sea, then reached Java Island in the Southern Hemisphere. This strong trans-equatorial monsoon flow persisted for more than a week in late January and early February 2007. In the south of Java Island, on the other hand, relatively weak southerly flow was observed to merge with this northerly wind over Java Island, indicating that large-scale ITCZ is just located over this island. This large-scale condition will be favorable for the occurrence of large-scale convergence.

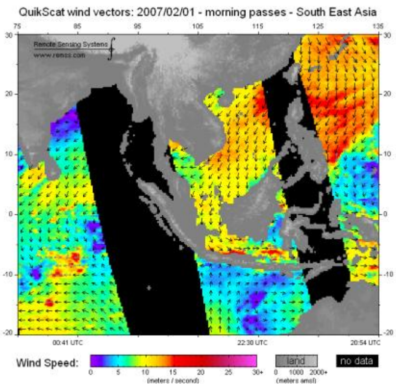

Fig. 1. Sea surface wind vectors measured by NASA's Quick Scatterometer for Februay 1, 2007.

3. LOCAL-SCALE CONDITINS

Figure 2 shows the hourly rainfall observed at Pondok Betung Meteorological Observatory, Jakarta in Java Island during 29 January to 3 February 2007. The four-day total rainfall during 30 January to 2 February reached 589.0 mm. It is noteworthy that the rainfall exhibits a pronounced diurnal cycle, which cannot be solely explained by the large-scale convergence mentioned in the previous section. The precipitation was regularly initiated in the night during 2000 to 2200 LT, and continued for 4–5 hours. The rains stopped falling in the early morning, occurred again after 3–4 hours and continued until around noon on 1 and 2 February 2007.

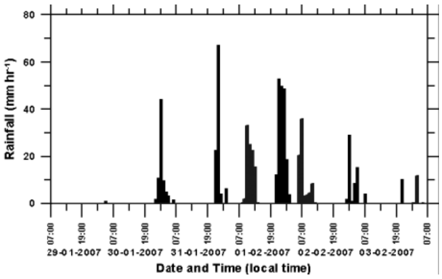

Fig. 2 Hourly rainfall observed at Pondok Betung Meteorological Observatory, Jakarta in Java Island during 29 January to 3 February 2007. (Wu et al., 2007)

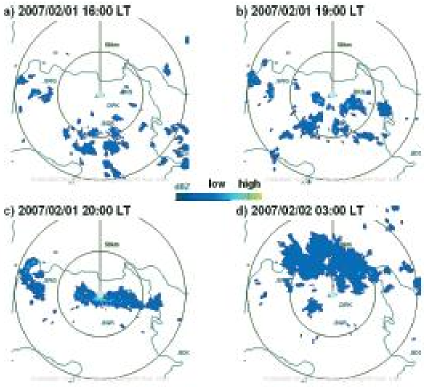

Fig. 3 The X band radar Plan Position Indicator (PPI) Reflectivity display at the 0.5-degree elevation angle obtain at Pondok Betung Meteorological Observatory, Jakarta (Wu et al., 2007)

The X band radar Plan Position Indicator (PPI) reflectivity display at the 0.5-degree elevation angle obtained at Pondok Betung Meteorological Observatory, Jakarta for 1600, 1900, 2000 LT on 1 February and 0300 LT on 2 February 2007 is shown in Fig. 3. Initially, in the afternoon (1600 LT) the rains were predominantly over the mountainous areas of Java Island, approximately 40–70 km south of the Pondok Betung radar site. By 1900 LT the rains over the mountains are decreasing, and a broken line of convections initiated over the northern plains near the mountain foot. By 2000 LT the rains over the mountains disappeared, and convections over the plains had solidified into a line orientated west-east, extending for about 100 km. The precipitation system was tracked within ∼10 km south and approaching the Pondok Betung radar site. Very heavy rainfall with intensities of 53.0, 50.0 and 49.0 mm h^{-1} was measured on the ground at the Pondok Betung radar site at 2200, 2300 and 0000 LT, respectively. Subsequently, the reflectivity pattern continuously showed a line of storms, migrating northward to the Java Sea during the nighttime. The propagation speed of the precipitation system was close to ∼3 m s^{-1}, much slower than the speed observed in typical mid-latitude squall lines. In addition to the example shown above in this section, a similar result of the regular occurrence of afternoon rains over the mountainous areas of Java Island, night and morning rains over the plains were also observed on 31 January 2007 (not shown).

A wind blows up the slope of a hill or mountain due to solar heating of the land during daytime. An upslope wind forms because the air over a mountain becomes warmer than the surrounding atmosphere at the same levels. The upslope wind produces a wind convergence, which in turn induces an enhancement of moisture and rising atmospheric motion, causing the formation of cloud over the mountain in the late afternoon. As shown in Fig. 3, a number of convections developed over the southern mountain areas of Java Island in the late afternoon. This afternoon convection over the mountains may result from the enhancement of moisture by thermally induced local circulations, similar to that which occurred over Sumatra Island (Wu et al. 2003)

4. VERTICAL STRUCTURE

Balloon soundings were performed twice a day at Soekarno-Hatta International Airport, Jakarta in Java Island. The Skew-T Log-P diagrams for 1200 UTC (1900LT) on 31 January and 1 February 2007 are shown in Fig. 4. The 1200 UTC soundings on 31 January and 1 February indicated the Convective Available Potential Energy (CAPE) values of 1651.0 and 2202.8 J kg^{-1}, respectively. The high CAPE represents the potential for a high maximum speed of updraft leading to the strong convections. Both the two dew point profiles indicated the existence of a distinct dry layer at the mid-level of ∼600–300 hPa. The existence of the mid-level dry layer represents a strong convective instability over the island. Meanwhile, the wind profiles indicated that while southeasterly wind prevailed in the upper atmosphere (higher than about 700 hPa), there was a layer of northwest winds in the levels lower than about 800 hPa. The wind directions at the altitudes of 900 and 700 hPa are almost in the opposite directions, with a large vertical wind shear of 15 m s^{-1} through the 900–700 hPa layers. The low-level northwesterly winds were a result of the strong trans-equatorial monsoon flow from the Northern Hemisphere.

Low-level wind shear is a favorable and necessary condition for convection maintained by downdraft. Usually, during the boreal winter the vertical shear of wind over Java Island is relatively weak in the absence of a trans-equatorial monsoon flow from the Northern Hemisphere. However, as shown in Fig. 4, results from balloon soundings obtained at Jakarta indicated a strong vertical wind shear in the low-levels on 31 January and 1

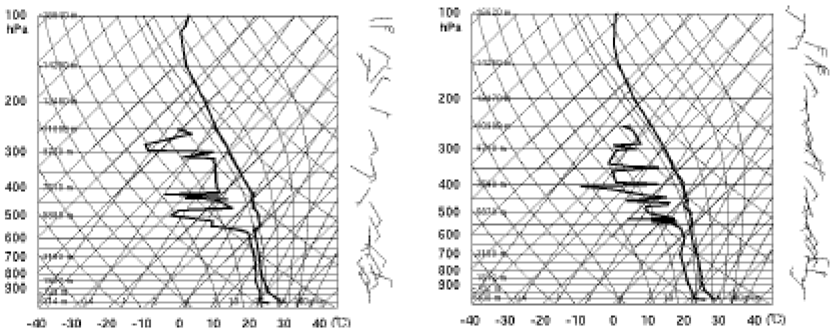

Fig. 4 The Skew-T Log-P diagrams obtained at Jakarta for 1200 UTC (1900 LT) on (upper) 31 January and (lower) 1 February 2007. The right line in each of the plots is the temperature profile, and the left line is the dewpoint profile. The winds are plotted as wind barbs with height on the right edge of the plots. (Wu et al., 2007)

February 2007. As described previously, the strong trans-equatorial monsoon flow caused the low-level northwesterly winds over the island. This strong and persistent trans-equatorial monsoon flow induced an intensive low-level wind convergence along its leading edge over the island. Simultaneously, the low-level northwesterly flow with the upper southeasterly wind produced a strong low-level vertical shear of wind over the island for days. Theses conditions allow the convections to be organized and to sustain for an extended period of time. As a result, the torrential rains occurred repeatedly for several days over the island, which resulted in the widespread floods over Jakarta and surrounding areas in late January and early February 2007.

5. REAL-TIME MONITORING

In order to reduce flood damages in the capital city, real-time monitoring, and if possible, prediction of the rainfall situations within the catchment area are needed. For these purposes, a C-band Doppler Radar (CDR) has been installed at Puspiptec Site, Serpong in the suburb of Jakarta in October 2007 and has been in operation since December 2008 by the collaborative activity between BPPT, Indonesia and JAMSTEC/RIGC under the JEPP (Japan EOS Promotion Program) project (Yamanaka et al., 2008). The real time radar image can be available via web-page (http://turbulence.ddo.jp/index.html). On March 26, 2009, another flood occurred in Jakarta due to the beak of the reservoir bank in the southern suburb of the city. Figure 5 presents the radar reflectivity image (right) and its composite with the cloud image obtained by MTSAT satellite (left) in that event. It can be seen that the rainfall was in the order of 50 mm h^{-1} but was lasting not very long (not shown). This kind of information is now available in a real-time basis, but only in the image. It will be more useful if such information is used for the flood prediction with the use of the hydrological prediction model in conjunction with the now-casting type rainfall prediction in future.

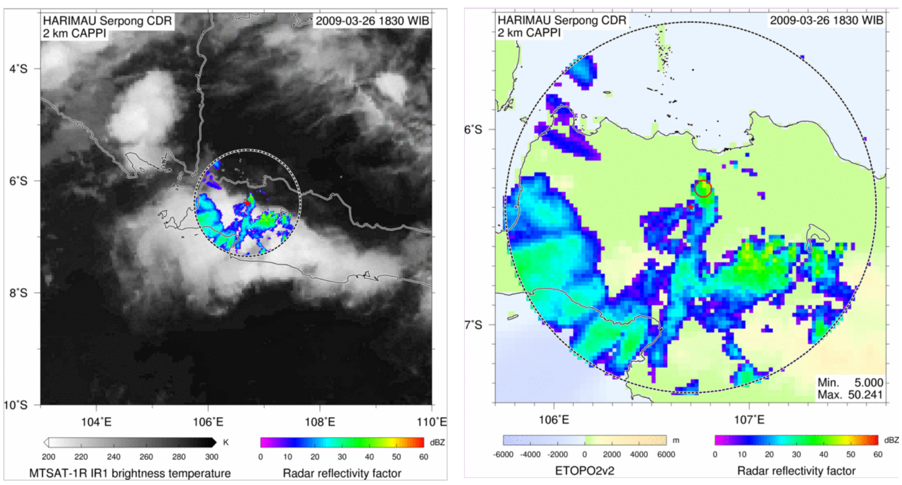

Fig. 5 CDR radar reflectivity at 2 km level at Serpong (right) and its composite with MTSAT IR1 cloud data (left: data from http://www.cr.chiba-u.jp/~4vl/) at 18:30 March 26, 2009. Red open circle in the right figure denotes the

location of the resovoir. Red point is the location of the CDR.

6. CONCLUSIONS

Torrential rains that repeatedly occurred over Java Island causing widespread floods during late January and early February 2007 coincided with a strong and persistent trans-equatorial monsoon flow from the Northern Hemisphere. The precipitation/convection over the island exhibits a pronounced diurnal cycle. While convections develop frequently over the island's mountainous areas in the afternoon, convections over the northern plains are active during the night and morning hours. The strong trans-equatorial monsoon flow and the upper southeasterly wind produce a strong low-level vertical shear of wind and a strong dry-air intrusion at the mid-level over the island. The strong low-level vertical shear of wind, wet lower and dry midlevel layer conditions allow the severe convections to occur repeatedly for days and to sustain for an extended period of time. The results suggest a possibility that the large-scale trans-equatorial monsoon flow interacts with thermally and convectively induced diurnal changes in the boundary-layer wind over the island, enhancing the convections over the mountains in the afternoon, and over the plains in the night and morning. The trans-equatorial monsoon flow plays a principal role in the formation of the repeated torrential rains over Java Island. Since Jakarta is located in the northern coastal region of Java Island, these interactions sometimes favor such heavy rainfall occurrences. To monitor and predict heavy rainfall event in the Indonesian capital city Jakarta, a C-band radar has been installed at Puspiptec Site, Serpong in the suburb of Jakarta by the collaborative activity between BPPT, Indonesia and JAMSTEC/RIGC under the JEPP (Japan EOS Promotion Program) project (Yamanaka et al., 2008). By utilizing the data obtained by this radar, more elaborated study on the heavy rainfall in Jakarta, in particular, its relationship with urban conditions will be conducted in future.

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