Conference Paper

Vertical Distribution of Radar Reflectivity Factor in Intense Convective Clouds over Indonesia

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Abstract

Vertical distribution of intense convective clouds over Indonesia has been studied using radar reflectivity factor (dBZ) data gathered from the latest 2A25 TRMM–Precipitation Radar (PR) product over a 10-year (1998–2007). The vertical distribution of dBZ at the PR pixel scale has been classified into two type of convective cells, i.e., cumulonimbus tower (CbT) and intense convective clouds (ICC) following the classification proposed by some previous studies. The CbT contains Z threshold 20 dBZ at 12 km altitude with at least 9 km deep and the ICC contains Z threshold 30 and 41 dBZ at 8 and 3 km, respectively. It is found that intense convective cloud is more frequently observed over land such as Sumatra, Kalimantan and Jawa than over ocean areas. Downward increasing (DI) pattern of dBZ toward the surface found in CbT over coastal area of Sumatra and Indian ocean. ICC8 and ICC3 shows downward decreasing (DD) pattern for all locations.

Keywords: radar reflectivity, intense convective clouds, Indonesia, TRMM-PR 2A25

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1. Introduction

Knowledge on the distribution of intense convective precipitation is useful for mitigation of natural disaster caused by precipitation. An increase of natural disasters due to intense convective precipitation for the past three decades has been reported [1]. The vertical distribution of intense convective precipitation can be investigated through the presence of convective clouds such as cumulonimbus (Cb) clouds. Such vertical structure or distribution is inferred from radar reflectivity factor (dBZ) given by weather or precipitation radar (PR) such as Tropical Rainfall Measuring Mission (TRMM- PR) [2]. The use of TRMM-PR data to study vertical distribution of intense convective clouds has been reported for tropical areas [3]. It was found that average vertical profile of cumulonimbus tower (CbT) and Intense Convective Clouds (ICC) over ocean are similar for all locations, whereas they are different over land areas. However, Indonesia was categorized as oceanic intense convection in this study.

Indonesia is not a maritime or continental area because it consists of large landmass and ocean, so that it is commonly called “maritime-continent” area. Therefore, characteristics of intense convective cloud in Indonesia may be different from maritime and continental areas. Study on the vertical profile of intense convective in Indonesia is limited to Kototabang, west Sumatra [4-6]. Recently, a study was conducted to study seasonal and diurnal variations of vertical distribution of precipitation over Indonesia using the TRMM-PR data [7]. However, this study did not investigate the vertical profile of intense convective precipitation. Furthere advances in understanding must be made in order to improve our overall understanding of vertical distribution of intense convective clouds over Indonesia.

2. Materials and Methods

In this study the primary data are TRMM PR 2A25 attenuation correction Z (version 7), for a 10 year period (1998-2007). Data have vertical resolution of 250 m and total 80 levels in the vertical. Detail information about TRMM PR can be found in Kummerow et al. [8]. As in a previous study [7], we only used the TRMM profiles with scan angle of less than 7° on either sides of nadir.

Intense convective clouds is classified into two types of convective cells following the classification method of Bhat and Kumar [3], namely, Cumulonimbus Tower (CbT) and Intense Convective Cloud (ICC). The cloud is assumed as CbT when the Z profiles have 20 dBZ at the altitude of 12 km and this value lasts up to 3 km (9 km depth). Moreover, the ICC type has Z value of 30 and 41 dBZ at 8 and 3 km altitude, respectively. Occurence frequency of each cloud type is contured on 1° × 1° boxes and 15 locations are selected as region of interest. The regional differences in the vertical distribution of intense convective are depicted in the form of normalized frequency by altitude diagram (CFAD) [9].

3. Results

Fig. 1 shows the number of Z profiles for CbT, ICC8 and ICC3 over Indonesia with the grid of contour plot being 1° x 1°. It is found that intense convective cloud is frequently observed over large landmass such as Jawa, Sumatra, Kalimantan and Irian Jaya.

From Fig. 1, we selected 15 locations for case study with more detailed analysis. Table 1 summaries the position of all locations. It is found that Jawa island (Jav) has the largest number of intense convective data, followed by Sumatra2 (SM2), Strait of Malacca

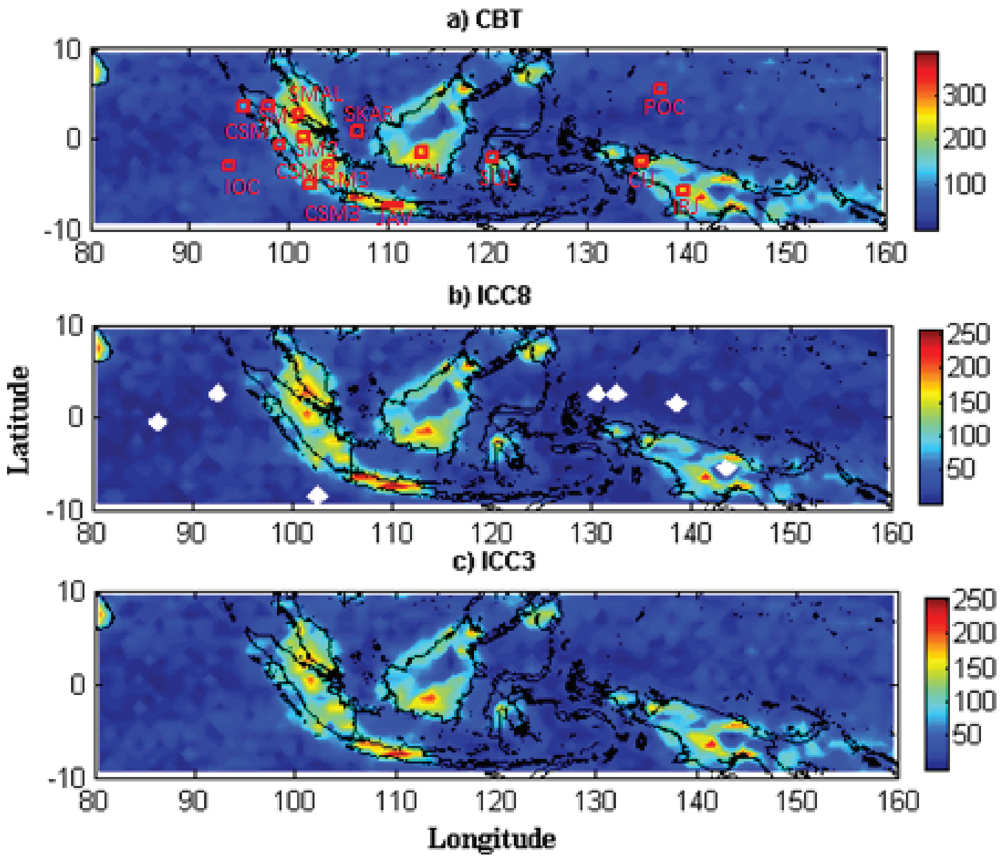

Figure 1: Spatial distribution of intense convective clouds over Indonesia. Red box in (a) denotes the region of interest.

Table 1: Locations of region of interest over Indonesia.

No.	Area/ Region	Position	Data number		
			CbT	ICC8	ICC3
1	Indian Ocean (Ioc)	2.5°-3.5 °S, 93.5 ° -94.5 °E	35	12	22
2	Sumatra1 (SM1)	3.19°-4.19 °N, 97.4° -98.4°E	91	61	68
3	Sumatra2 (SM2)	0.2° S-0.8°N, 101 ° -102 °E	290	224	216
4	Sumatra3 (SM3)	3.5°-2.5 °S, 103.5 ° -104.5 °E	273	193	183
5	Coastal Sumatra1 (CSm1)	3.1°-4.1°N, 94.9 ° -95.9 °E	124	72	94
6	Coastal Sumatra2 (CSm2)	1.15°-0.15 °S, 98.6 ° -99.6 °E	107	61	49
7	Coastal Sumatra3 (CSm3)	5.5°-4.5 °S, 101.7 ° -102.7 °E	203	122	124
8	Strait of Malacca (SMal)	2.3°-3.3 °N, 100.5 ° -101.5 °E	320	231	206
9	Jawa (Jav)	7.7°-7.2 °S, 109.5 ° -111.5 °E	347	245	240
10	Kalimantan (Kal)	2.01°-1.01 °S, 112.8 ° -113.8 °E	292	215	209
11	Sulawesi (Sul)	2.5°-1.5 °S, 120 ° -121°E	41	31	25
12	Strait of Karimata (SKar)	0.3°-1.3 °N, 106.5 ° -107.5 °E	21	13	11
13	Pacific Ocean (Poc)	5.01°-6.01 °S, 137 ° -138 °E	102	46	57
14	Coastal Irian Jaya (CIJ)	3.01°-2.01 °S, 135 ° -136 °E	318	156	174
15	Irian Jaya (Irj)	6.21° - 5.21° S, 139.2 - 140.2E	265	137	155

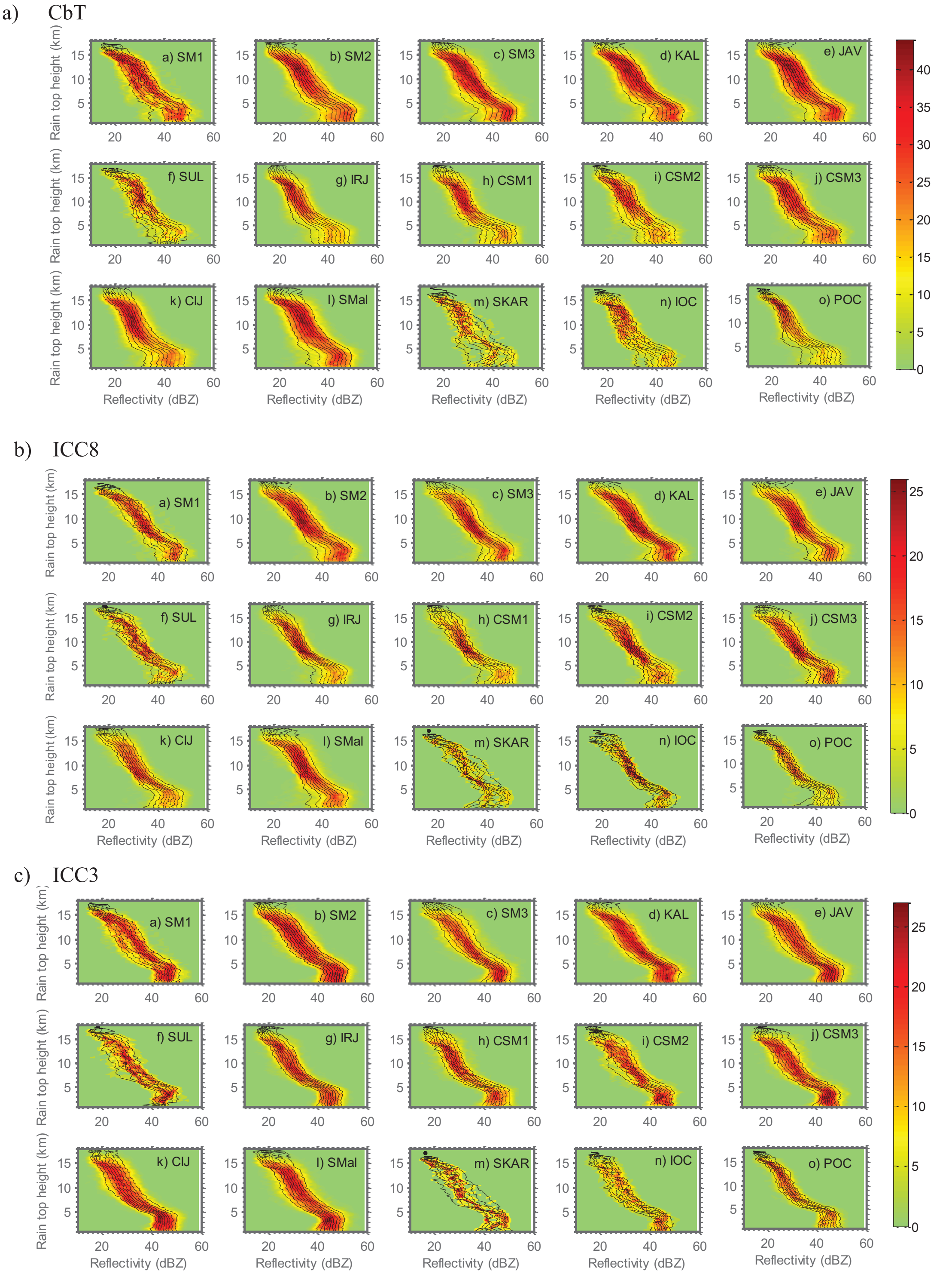

Figure 2: Countoured frequency by altitude diagram in different areas of convective cells, a) CbT, b) ICC8, c) ICC3 and the color bar on right refers to the relative frequency.

(SMal), Kalimantan (Kal), Coastal Irian Jaya (CIJ) and Irian Jaya (Irj). On the other hand, small number of intense convective clouds data is observed in Indian Ocean, Sulawesi and Strait of Karimata. This finding reinforces previous study about the role of large

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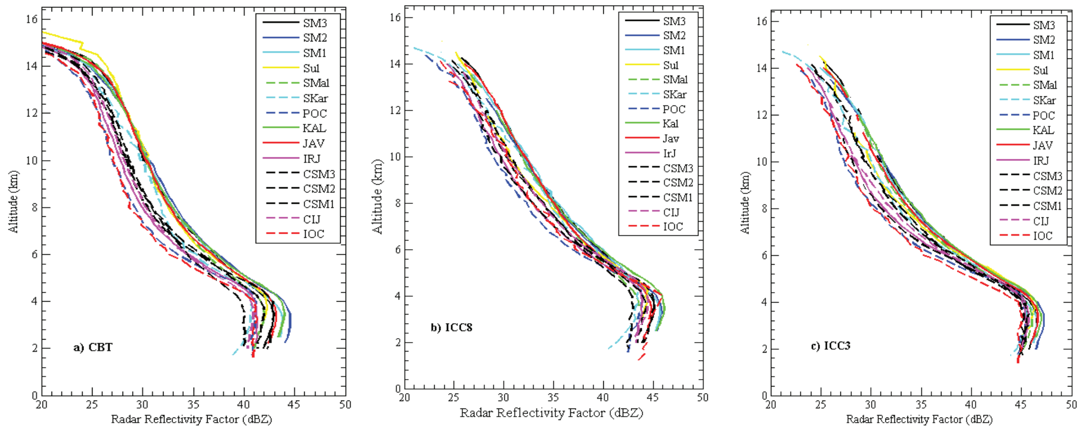

Figure 3: Mean vertical profile of Z for a) CbT, b) ICC8, c) ICC3. Land profiles are shown in thick solid and coastal and oceanic are shown in dashed lines.

landmass in initiating the intense convective clouds in Indonesia [7]. Number of CbT cloud is always larger than that of ICC8 and ICC3. However, number of ICC8 and ICC3 fluctuates; ICC8 number is larger than ICC3 at one location but it can be smaller at other locations.

Fig. 2 shows the CFAD (countoured frequency by altitude diagram) of CbT and ICCs. The lines in CFAD indicate percentiles of 10% to 90% and thick lines indicate 50% percentile which is mean value of data. Below the melting layer (< 4 km), CbT radar reflectivity shows downward increasing (DI) pattern over coastal areas of Sumatra (CSm1, CSm2, CSm3) and Indian Ocean (Ioc), whereas downward decreasing pattern are osberved in other areas. The DI pattern indicated a significant raindrop growth at below the melting layer (< 4 km). On the other hand, ICC8 and ICC3 radar reflectivity over all locations show downward decreasing (DD) toward the surface.

Fig. 3 shows mean vertical distribution of CbT, ICC8, and ICC3 over different locations. Intense convective of CbT (Fig. 3a) shows larger Z in Sumatra2 (SM2), followed by Kalimantan (Kal), Sumatra3 (SM3) and Jawa (JAV). For ICC8 (Fig. 3b) strong intense convective is observed in Sumatra (SM1, SM2, SM3), Jawa (Jav) and Kalimantan (Kal). Moreover, for ICC3 (Fig. 3c), strong intense convective is observed in Sumatra2 (SM2) and followed by Kalimantan (Kal), Sumatra (SM1, SM3) and Jawa (Jav). Intense convective clouds shows weaker or smaller Z in Indian Ocean (IOC) and Pacific Ocean (POC).

The mean vertical profile in Indonesia (Fig. 3) shows significant regional variation. This variation may be influenced by many factors such as topography, global and local atmospheric circulation [7].

4. Conclusions

Intense convective precipitation in Indonesia both CbT, ICC8 and ICC3 are dominant over large island such as Sumatra, Kalimantan, Jawa and Irian Jaya. Besides larger data number, intense convective clouds over large island is also much stronger than over open ocean and coastal areas. For CbT, below the melting layer (< 4 km), radar reflectivity over coastal areas of Sumatra and Indian Ocean shows downward increasing pattern while downward decreasing were observed over other locations. For ICC3 and ICC8, below the melting layer (< 4 km), radar reflectivity over all locations shows downward decreasing pattern.

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References

[1] Ye H, et al. (2017). Rapid decadal convective precipitation increase over eurasia during the last three decades of the 20th century, *J. Sci. Add,* **3**, 101-122, [doi: 10.1126]

[2] Yuan, T., and X. Qie. (2008). Study on ligthning activity and precipiation characteristics before and after the onset of the Shout China Sea summer monsoons, *J. Geophys. Res*, **113** D14101, [doi:10.1029/2007JD009382]

[3] Bhat, G. S., and Kumar, S. (2016). Vertical structure of radar reflectivity factor in intense convective clouds in Tropics, *J. Appl. Meteor*., **55,** 1277-1285 [doi:10.1175/JAMCD150110.1].

[4] Marzuki, et al. (2010).: Raindrop size distributions of convective rain over equatorial Indonesia during the first CPEA campaign, *Atmos. Res*., **96**, 645-655.

[5] Marzuki, et al. (2013) Raindrop axis ratios, fall velocities and size distribution over Sumatra from 2D-Video Disdrometer measurement, in: Michaelides, S. (Eds.) Advances in Precipitation Science, *Atmos. Res*., **119**, 23-37.

[6] Marzuki, et al. (2016) Precipitation Microstructure in Different Madden–Julian Oscillation Phases over Sumatra, *Atmos. Res*, **168**, pp. 121-138.

[7] Marzuki et al. (2018). Seasonal and diurnal variations of vertical profile of preciptation over Indonesian Maritime Continent, engineering and mathematical topics in rainfall. H. Thedore and P. Rao, *InTechOpen*. London, United Kingdom.

[8] Kummerow et al. (1998). The tropical rainfall measuring mission (TRMM) sensor package, *J. Atmos. Oceanic Technol*,**15**, 809-817.[doi: 10.1175/1520-0426(1998)015<0809:TTRMMT]

[9] Yuter, S. E., and Ra Houze Jr. (1995). Three-dimensional kinematic and microphysical evolution of Florida cumulonimbus: part ii. Frequency distribution of vertical velocity, reflectivity, and the different reflectivity, *J. Mon. Weather Rev,* **123**, 1941-1963.