SEASONAL, INTRA-SEASONAL AND DIURNAL VARIATIONS OF RAINDROP SIZE DISTRIBUTION AT KOTO TABANG, WEST SUMATRA

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1. INTRODUCTION

Rain Drop Size Distribution(DSD) is a key to relate integral rain parameters such as rain rate and *Z* factor. To reduce the uncertainty in radar rainfall measurement, it is important to know the DSD properties and develop DSD models appropriate to radar applications. Since it is difficult to directly obtain DSD information, it would be useful if we can relate DSD to measurable “macro-scale” rainfall properties such as rainfall type and wind conditions. It should be noted that such “macro-scale” properties are expected to show diurnal and seasonal dependence.

Seasonal variations in DSD have been reported in Brazil (L’Ecuyer et al., 2003) and in south India (Reddy and Kozu, 2003). Since the local convective activities should be related to diurnal cycle of rainfall, studies of both diurnal and seasonal variations of DSD may provide additional information to separate the effects of local and large-scale rainfall conditions.

We have been conducting comprehensive rainfall and atmospheric observations at Koto Tabang (KT), Sumatra including disdrometer observations (Mori *et al*. 2003; Kozu *et al*. 2004). In this presentation, we show temporal DSD variations derived from disdrometers in relation to local time, season and intra-seasonal oscillation (ISO), which will be connected to finding “macro-micro” relations in equatorial rainfall.

2. Observation sites and instruments

Table 1 lists the location and observation systems at KT. This site (S0.20°, E100.32°, H 850 m, ASL) is located in a mountainous region near Padang, west Sumatra, and affected both by local convective activities and monsoon. Rainfall observations at KT are mainly performed by the Equatorial Atmosphere Radar (EAR), and X-band rain radar, an BLR, and an Joss disdrometer, and an 2D video disdrometer.

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Table 1. Instruments at Koto Tabang.

Instruments	Description
EAR	
Frequency	47 MHz
Antenna aperture	110 m x 110 m
Antenna beamwidth	3.4 deg.
Transmit power	100 kW
Range resolution	150 m
Others	
X-band rain radar	JMA-177 (JRC)
Disdrometer,	2DVD, RD-69 (*1)
Rain gauge	ORG-815, MAWS (*1)
Water vapor profiling radiometer	WVP-1500
Micro-rain radar	MRR-2 (*2)

*1 Operated by FORSGC. *2 ILTS/Hokkaido University

3. DSD parameters studied

Considering that the most direct DSD parameter for radar remote sensing is the *Z*-*R* relation, we use ΔZ_{MP} (dB) define by

$$\Delta Z_{MP} = dBZ(\text{measured}) - 10\log_{10}(200R^{1.6}) \qquad (1)$$

where R is rain rate. The other two DSD parameters studied are the shape parameter G and the scaling parameter D_m. The former is defined as

$$G = M_4^3/(M_3^2 M_6) \qquad (2)$$

where M_x is the *x*th moment of DSD. When Gamma DSD model is assumed, G is related to μ:

$$\mu = \frac{11G - 8 + \sqrt{G(G+8)}}{2(1-G)} \qquad (3)$$

The latter, D_m, mass-weighted mean diameter is defined as:

$$D_m = M_4/M_3 \qquad (4)$$

The reason to use G and D_m are to investigate effects of micro-physical processes to the shape and the mean size of raindrops, respectively.

4. Seasonal-diurnal variation of DSD

Diurnal variation of precipitation would directly be related to local circulation, which is affected by large atmospheric conditions such as monsoon. Figure 1 shows seasonal-diurnal diagrams of ΔZ_{MP} and G derived from Joss-disdrometer data; the average of ΔZ_{MP} or G for a 2-week by 2-local hour box for the rain rate ranges from 1 to 3 mm/h and from 10 to 30 mm/h. Note that positive and negative values of ΔZ_{MP} indicate, respectively, broad and narrow DSDs, and that G = 0.81 and G = 0.71 correspond to μ = 10 and 4 respectively. In most cases G is greater than 0.71, and white region in (c) and (d) indicate no data (no rain).

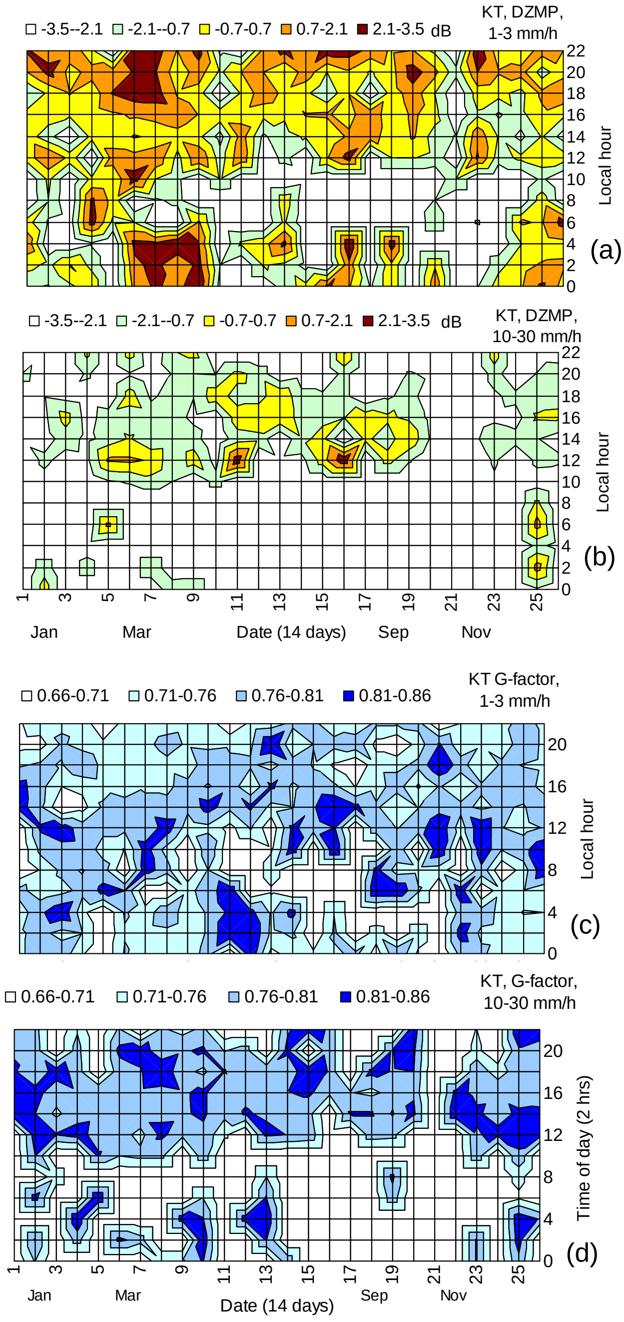

Fig.1. Seasonal-diurnal diagrams: (a) ΔZ_{MP} 1-3 mm/h, (b) ΔZ_{MP} 10-30 mm/h, (c) G 1-3 mm/h, (d) G 10-30 mm/h.

It is found that At 1-3 mm/h, ΔZ_{MP} increases slightly from early afternoon to late evening and midnight. On the other hand, early afternoon convections (12-14 LT, 10-30 mm/h) has clearly larger values than other local time. Similarly, the shape parameter G has smaller values in late evening to midnight for 1 - 3 mm/h, and in early afternoon for 10-30 mm/h. This suggests that Z-R relation should have diurnal variations, and that early afternoon rain (mainly local convection) and late afternoon rainfall (relatively organized rain system) have somewhat different micro-physical processes. It should also be noted that the above characteristics are less clear in north-east monsoon rainy season (November to December).

5. Intra-seasonal oscillation (ISO) and DSD

In addition to the diurnal and seasonal variations, there may be influences due to the intra-seasonal oscillation of large-scale cloud systems associated with Maddan Julian Oscillation (MJO). Morita (2004) found that lightning activities appear to be suppressed in active convection phase in MJO. Since lightning is generally associated with intense convection, this suggests that “active convection” actually occurs in “non-active” MJO phase.

In April to May 2004, a transition from non-active to active convection phases of MJO was observed around Sumatra (BMRC, 2004). This was clearly seen from the TBB from GOES-9 as shown in Fig.2(b) where abscissa and ordinate represent respectively date (April 11 to May 10) and longitude from 70E to 110°E. TBB data are averaged over 2°NS×0.5°WE box. The horizontal line at 100°E indicates the longitude of KT. As shown by four arrows, prior to the clear visit of active MJO phase (between April 27 and May 7), two pre-cursor cloud clusters visited KT (arrows (i) and (ii)). During the active MJO phase, two organized cloud clusters (arrows (iii) and (iv)) were observed.

Fig.2 (a) shows the trend of ΔZ_{MP} for 10-30 mm/h and 30-100 mm/h. In early to middle April, most of rainfall events were originated by local, small scale convection, and small clusters (i) visited KT around April 18-19. ΔZ_{MP} scatter widely but some systematic decrease can be seen in (i). This trend becomes more significant for rainfalls during the clusters (ii) to (iv). In particular, it should be noted that in active MJO phase April 28 to May 7 ΔZ_{MP}s are mostly negative.

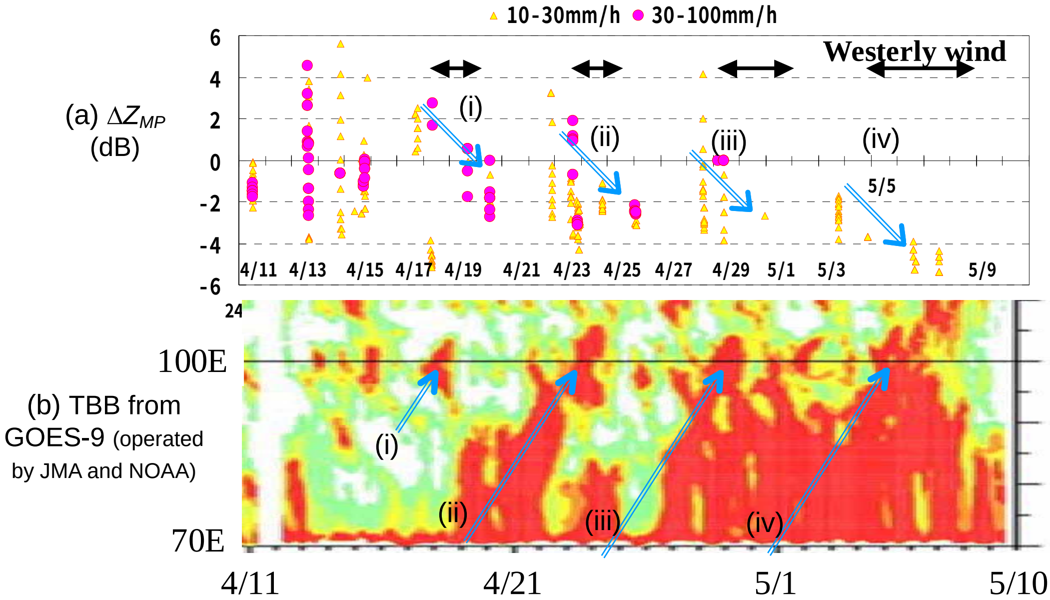

Fig.2. Comparison of at KT and time-longitude diagram of TBB from GOES-9 between April 11 to May 10, 2004.

Active convection around KT is generally associated with low-level westerly winds (Shibagaki et al. 2004). Short duration westerly wind field can also be seen in non-active MJO phase, and more systematic ones are observed with the visit of large scale cloud cluster. Such systematic westerly wind phases are also shown in Fig.2(a) as horizontal arrows. Local and large-scale wind interactions may be related to the intensity of convection and DSD.

Fig.3 shows *Z-R* relations during three rain events (a) April 17 (beginning of (i) in Fig.2), (b) April 28 (during (iii)), and May 5 (during (iv)). As shown in Fig.3, the May 5 rainfall (combined convective and stratiform) has much lower coefficient a in $Z = aR^b$ relation.

For closer look at the DSD characteristics during each event, temporal trends of rain rate, ΔZ_{MP} and G from the 2DVD are shown in Fig.4. In the April 17 event, ΔZ_{MP} and G have clear peaks in the initiation of convective rainfall on the ground. This suggests that big drops, generated aloft, first fall down on the ground. On the other hand, in the May 5 event, no such clear peaks are observed; ΔZ_{MP}s are almost stable around -3 to -4 dB.

In this paper, no description is given to the characteristics of D_m which are similar to those of ΔZ_{MP}.

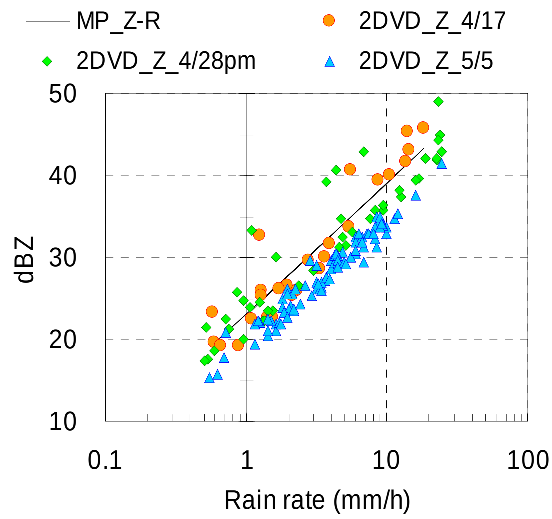

Fig.3. *Z-R* relations from 2DVD at KT for 3 rain events, April 17, April 28 and May 10, 2004.

7. Concluding remarks

Diurnal, seasonal and intra-seasonal variations of DSD at Koto Tabang, Sumatra, have been investigated to study possible relationships between macro-scale rain properties and DSD. It is found that DSDs are affected by local convective activities, which is also dependent on monsoon related large-scale atmospheric environment. By comparing the behavior of ΔZ_{MP}s for light and intense rain rates, it is suggested that *Z-R* relations in early and late afternoon are different. Such diurnal variation of DSD is less clear in north-east monsoon season. In addition, it is found that DSD appears to show intra-seasonal variations in response to MJO. Further studies are needed to clarify this type of DSD variation is a general property. Nevertheless, this "multi-scale" variation structure of DSD observed at Koto Tabang can be a first step to develop an improved DSD and *Z-R* model for the radar measurement of equatorial rainfall.

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References

BMRC: www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/

Kozu, T., T. Shimomai, T. Okamoto, A. Zainul, S. Mori and H. Hashiguchi, 2004: Raindrop size distribution characteristics at Koto Tabang, Sumatra, from EAR and disdrometer measurements, *Spring meeting of Meteor. Soc. Japan*, Tokyo (in Japanese).

L'Ecuyer, T. S., C. Kummerow, H. Matsunaga, 2003: Relationships between the microphysics of precipitating cloud systems and their radar reflectivity patterns, P3A.1, *31st Conf. on Radar Meteorol.*, Seattle.

Mori, S., J. Hamada, I. T. Yudi, M. D. Yamanaka, N. Okamoto, F. Murata, N. Sakurai, H. Hashiguchi, T. Sribimawati, 2004: Diurnal land-sea rainfall peak migration over Sumatra Island, Indonesian maritime continent observed by TRMM satellite and intensive rawinsonde soundings, *Mon. Wea. Rev.*, **132**, in Press.

Morita, J., 2004: Analysis of rainfall characteristics of the Madden-Julian Oscillation using TRMM satellite data, Master's thesis submitted to University of Tokyo (in Japanese).

Reddy, K. K. and T. Kozu, 2003: Measurements of raindrop size distribution over Gadanki during south-west and north-east monsoon, *Indian J. of Radio & Space Physics*, **32**, 286-295.

Shibagaki, Y., T. Shimomai, T. Kozu, S. Mori, Y. Fujiyoshi, H. Hashiguchi, M. K. Yamamoto, S. Fukao, M. D. Yamanaka, 2004: Multi-scale convective systems associated with intra-seasonal oscillation over the Indonesian maritime continent. submitted to *Mon. Wea. Rev.*

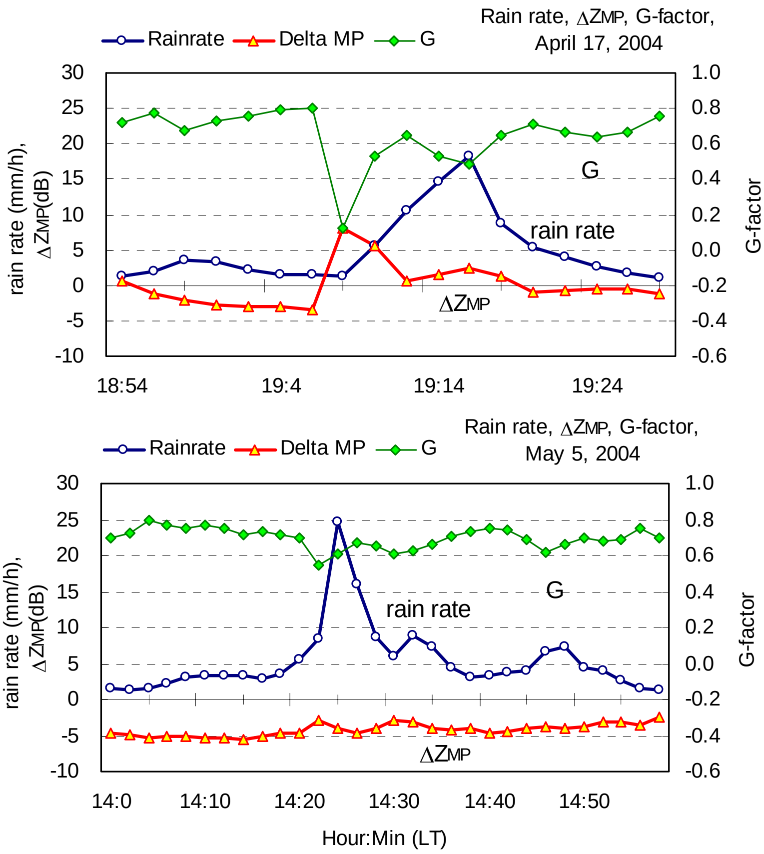

Fig.4. Time trends of rain rate, ΔZ_{MP} and G for two convective events on April 17 and May 5, 2004.