The Characteristics of Raindrop Size Distribution and Drop Shape Relation in Typhoon Systems from 2D-Video Disdrometer and NCU C-Band Polarimetric

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Abstrract

The Drop Size Distribution (DSD) and Drop Shape Relation (DSR) characteristics of different precipitation systems have been investigated in numerous regions. However, the characteristics of DSDs and DSRs in typhoon systems are still poorly documented despite typhoons cause lots of damages all over the world. In this present research, authors focus on the DSDs and DSRs observed in typhoon systems in northern part of Taiwan in Western Pacific and compare with the DSDs retrieved from the polarimetric measurements. There were 13 typhoon cases DSD data were collected and analyzed. The time series of the vertical profile of reflectivity and the surface DSDs of two rainband cases were fully illustrated to understand the evolution of the DSDs and its relation with the vertical development of the reflectivity. The drop shape relation (DSR) in typhoon system was also derived and compared with the DSR in non-typhoon system. The result indicated that the raindrops in typhoon system were slightly more spherical than the non-typhoon condition. The DSDs retrieved from one typhoon case observed by NCU-C-band dual-polarization radar, together with another two disdrometer derived DSDs were compared with the DSDs of the continental and maritime convection systems. The results indicated that in the scatter diagram of the normalized intercepts and mass weighted diameters, the cluster from typhoon systems is uniquely located in between of the other two clusters from the continental and maritime systems.

Introduction

The drop size distribution (DSD) of rain can determine not only the different moment of rainfall integral parameters (e.g., rainfall rate; liquid water content; etc.) but also the measurements of dual-polarimetric radar (e.g., reflectivity; differential reflectivity; specific differential phase shift; etc.). However, it has been found that the DSDs have great variation in different types of rainfall condition (Ulbrich and Atlas et al. 1984). In this research, the DSDs from surface disdrometer and retrieval from NCU C-Pol radar were collected. The drop shape relation (DSR) was also been investigated and compared with Brandes el al. 2004 (hear after: B04).

DSD and DSR in typhoon system

The time evolution of DSDs and the corresponding vertical reflectivity profile of typhoon Haima 2004 in Fig.1 indicated that there were three different types of precipitation system could be reveled: the weak stratiform, stratiform and convection systems. Each of them have different characteristics of DSD: the weak stratiform systems had smallest maximum diameter (about 2.0 mm), the raindrops were concentrated in small raindrop and the systems were relatively shallow; the stratiform systems had bigger maximum diameter (about 3.8 mm) and the mass-weighted diameter could reach 1.9 mm; the convection systems had high concentration of raindrops in small to median diameter raindrop and the systems were much more deeper comparing to stratiform systems. The melting of snowflake or graupel from melting level may the reason caused bigger raindrops in stratiform system. For the convection systems, the balance between break-up and collision-coalescence might be responsible for the high concentration of small to median raindrops and bigger maximum diameter raindrop.

The axis ratio in typhoon systems was also examined by surface 2D-video disdrometer. In Fig. 2, the result indicate that the axis ratio of small raindrops (0.0 ~2.0 mm) were similar to B04. However, the raindrops were more spherical comparing to B04 in bigger raindrops (> 2.0 mm). The less oblate DSR was derived in 2nd order polynomial form as following:

$$\frac{b}{a} = -1.1301\times10^{-2} D^2 + 3.3913\times10^{-3} D + 0.99209$$

The result was consisted with Gorgucci et al. 2000: the DSR should tend to more spherical in stronger systems due to raindrop oscillations.

Estimating the DSDs from polarimetric radar measurements by constrain-gamma method (CGM) has been established by Zhang et al, 2001. The CGM using the advantage of the polarimetric measurement: differential reflectivity (Zdr) from polarimetric radar and an empirical constraining relationship between shape parameter (μ) and slope parameter (Λ) of DSDs. Combining new DSR and proper empirical μ-Λ relationship and the measurements of Zdr from NCU C-Pol, the DSDs of typhoon Saomai 2006 were obtained. In Fig. 3, the comparing of the retrieved DSD and the DSD observed by surface disdrometer from typhoon Nari 2001 and Haima 2004 showed that the typhoon systems were neither maritime type nor continental type convection systems.

Conclusion

The characteristics of DSD and DSR in typhoon system of Taiwan area have been well documented and the application on NCU C-Pol data also successfully retrieved DSD of typhoon Saomai 2006. Mainly, the composition of heavy precipitation in typhoon systems is high concentration of small to median diameter raindrops rather than lots big raindrops. The understanding of DSD can no only help reveal the microphysics process of precipitation systems but also improve the accuracy of quantitative precipitation estimation (QPE) from Doppler weather radar.

Reference

Brandes, E. A., G. Zhang, and J. Vivekanandan, 2004: Drop size distribution retrieval with polarimetric radar: Model and application. *J. Appl. Meteor*., **43,** 461_475.

Gorgucci, E., G. Scarchilli, V. Chandrasekar, and V. N. Bringi, 2000: Measurement of mean raindrop shape from polarimetric radar observations. J. Atmos. Sci., 57, 3406–3413

Ulbrich, C. W., and D. Atlas, 1984: Assessment of the contribution of differential polarization to improved rainfall measurements. *Radio Sci.,* **19**, 49-57

Zhang, G., J. Vivekanandan, and E. Brandes, 2001: A method for estimating rain rate and drop size distribution from polarimetric radar measurements. *IEEE Trans. Geosci. Remote Sens.,* **39,** 830–841.

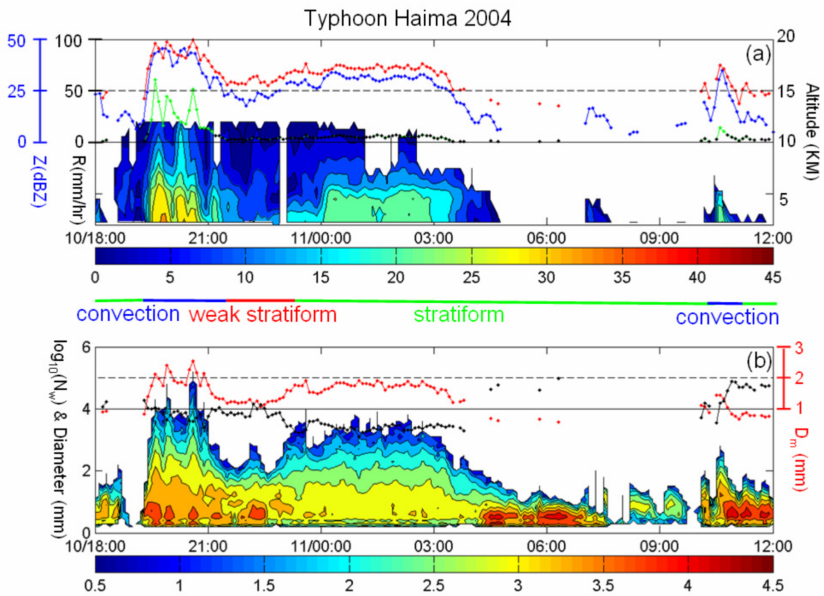

Fig. 1: The time series of the DSDs calculated from 2D-Video disdrometer and the reflectivity vertical profile observed by RCWF WSR-88D radar of Typhoon Haima 2004: from Sep. 10th 18 UTC to Sep. 11th 12 UTC 2004. In (a) The black (less than 10.0 mm/hr)-green (higher than 10.0 mm/hr) line represents the rainfall rate (mm/hr), red and blue lines represents the reflectivity (dBZ) calculated from the DSDs and the corresponding lowest reflectivity (dBZ) observed from RCWF WSR-88D radar, respectively. The color shaded represents the vertical reflectivity profile observed by RCWF WSR-88D. The left y-axis indicates the rainfall rate (mm/hr) and the reflectivity (dBZ). The right y-axis represents the altitude of the reflectivity vertical profile. In (b): the red and black lines represent the mass-weighted diameter (D_m) and

normalized intercept (N_w) in logarithmic scale, respectively. And the color shaded represents the DSDs in logarithmic of unit $mm^{-1}m^{-3}$. The left y-axis indicates the diameter of DSDs and the value of normalized intercept (N_w) in logarithmic. The x-axis in both (a) and (b) indicates the UTC time series. The different types of the system (weak stratiform, stratiform and convection system) are shown in the middle.

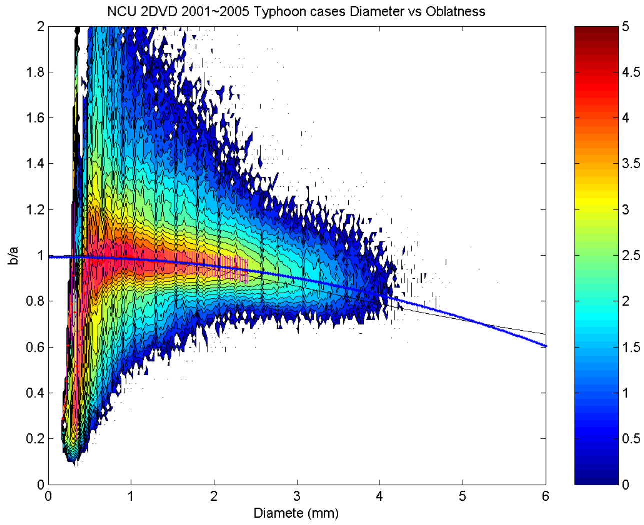

Fig. 2: (a) $\log_{10}$ [N(D_e, b/a)], where N(D_e, b/a) is the number of drops with each corresponding equivalent diameter D_e and axis ratio b/a in typhoon cases. The black solid line represents the DSR from Brandes et al. 2002 and the blue solid line represents the 2nd order fitting of DSR from typhoon systems. The pink bars represent the standard derivation of the average oblateness for each corresponding equivalent diameter.

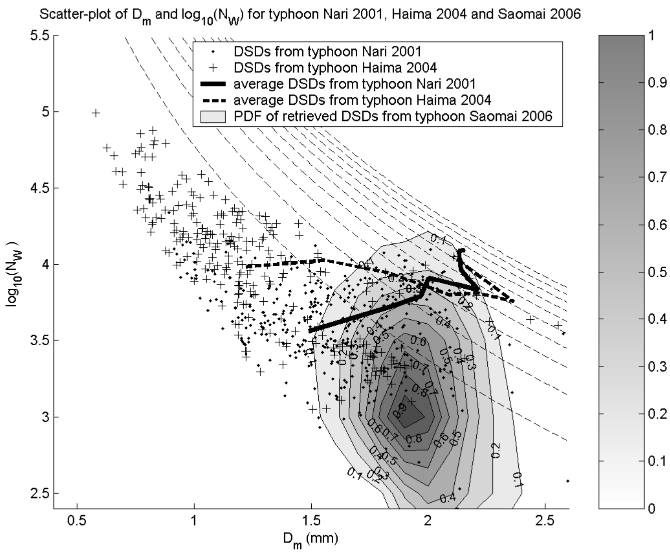

Fig. 3: The scatter-plot of mass-weighted diameter D_m (in mm) and the normalized intercept coefficient N_w (in $mm^{-1}m^{-3}$). The thin dashed lines indicate the rainfall rate from 10 mm/hr to 100 mm/hr. (The lowest one represents 10.0 mm/hr and the top one represents 100.0 mm/hr, the interval is 10.0 mm/r) The dots represent the DSDs data from typhoon Nari 2001 and the crosses represent the data from typhoon Haima 2004. The thick solid and dash lines represent the average D_m and $\log_{10}(N_w)$ for every 10.0 mm/hr rainfall rate (0.0 ~ 100.0 mm/hr) from typhoon Nari 2001 and Haima 2004, respectively. The gray shaded represents the D_m and $\log_{10}(N_w)$ of retrieved DSDs from

NCU C-Pol in typhoon Saomai 2006.