P13R.6 THE RAINDROP SIZE DISTRIBUTION CHARACTERISTICS AND ITS APPLICATIONS TO RADAR RAINFALL ESTIMATION IN TAIWAN AREA

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1. INTRODUCTION

It has been found that the drop size distributions (DSD) have great variation in different types of rainfall condition (Ulbrich and Atlas et al.1984). Through the integrated moments calculation from DSD, the coefficient No ($cm^{-1-\mu}m^{-3}$), m (dimensionless), Λ (cm^{-1}) of Gamma distribution: $N(D)=N_0D^{\mu}\exp(-\Lambda D)$ can be retrieved (Ulbrich 1983, Kozu and Nakamura 1991). The coefficient A and b of Z-R relations and the median volume diameter (D_0) can also be derived through the coefficient No, μ, Λ. With those coefficients, the DSD variation in different rainfall conditions can be studied and numerous Z-R relations can also be derived.

The difference between the disdrometer derived reflectivity and the radar observed reflectivity also had been investigated in a typhoon case. These reflectivity deviations could be due to the terrain blocking and the precipitation vertical micro-process.

In order to improve the accuracy of Z-R relation rainfall estimation, it is very important to understand the characteristics of DSD in Taiwan area which is located in subtropics and has unique topography.

2. Disdrometer data

The method suggested by Kozu and Nakamura (1991) was applied to calculate the coefficients of the Gamma distribution for each DSD data :

$$M_x = \int_0^{\infty} D^x N(D)dD \quad (1)$$

$$G = \frac{M_4^3}{M_3^2 M_6} \quad (2)$$

$$m = \frac{11G - 8 + [G(G+8)]^{1/2}}{2(1-G)} \quad (3)$$

$$\Lambda = \frac{(m+4)M_3}{M_4} \quad (4)$$

$$N_0 = \frac{\Lambda^{m+4} M_3}{\Gamma(m+4)} \quad (5)$$

The A and b of Z-R relation and the median volume diameter (D_0) can be derived by the coefficient No, μ, Λ (Ulbrich1983):

$$A = \frac{10^6 \Gamma(6+\mu+1) N_0^{1-b}}{[33.31\Gamma(3.67+\mu+1)]^b} \quad (6)$$

$$b = \frac{6+\mu+1}{3.67+\mu+1} \quad (7)$$

$$\Lambda D_0 = 3.67 + \mu \quad (8)$$

We had analyzed two years DSD data of 2d-video disdrometer in northern Taiwan area from year 2001 to 2002. Every dot in Fig.1 represented the derived Gamma coefficients μ versus rainfall rate from six minutes DSD data set. The result indicates that the μ and Λ decrease with increasing rainfall rate. (Fig.1 and Fig.2) That means the heavy rain is composed of many small and median rain drops rather than very large rain drops in Taiwan typhoon case. The variability of μ and Λ in light rain is more obvious; however the range of variation decreases with increasing rainfall rate and become more uniform in heavy rainfall.

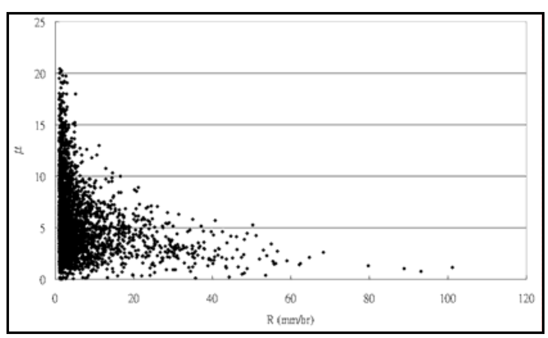

Fig.1: Scatter plot for Rainfall rate (mm/hr) vs μ for two years DSD data.

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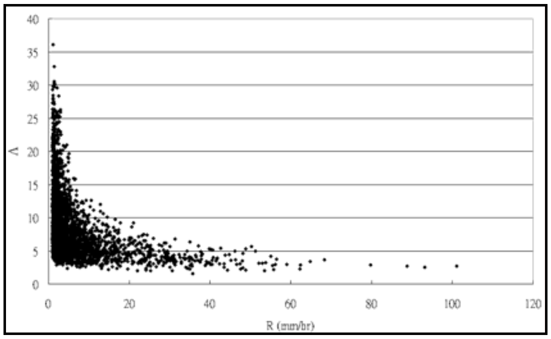

Fig.2: Scatter plot for Rainfall rate (mm/hr) vs Λ for two years DSD data.

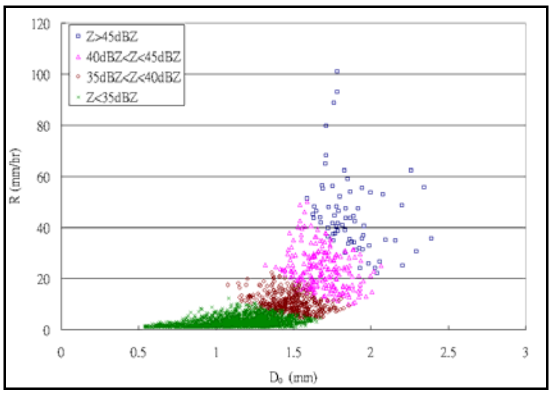

Fig.3: The median volume diameter (D_0) vs rainfall rate (mm/hr) in different reflectivity.

The analysis of median volume diameter indicated that the D_0 increases with increasing rainfall rate. However, the D_0 remains the value about 1.7 mm when the rainfall rate greater than 60 mm/hr. (Fig. 3) It also demostrated that the heavy rain event is composed of lots of median and small raindrops rather than giant raindrops. The microphysical process of collision and breakup may be the main reason for this unique D_0 value.

In order to show the contrast of DSD in the heavy rain cases, six DSD data sets with reflectivity near 50 dBZ were selected. Then these six sets were divided into two groups according to their rainfall rate. (Type A> 85mm/hr, type B< 65mm/hr). (Table 1)

The normalized gamma distribution suggested by Bringi and Chandrasekar (2001) was used to remove the inference of μ in No ($cm^{-1-\mu}m^{-3}$) and interpreted the characteristics of DSD in our analysis. The normalized intercept N_W ($mm^{-1}m^{-3}$) can reveal the concentration of DSD better than No ($cm^{-1-\mu}m^{-3}$), and the type A has more raindrops in higher N_W than type B in our research. Meanwhile, the type A has more small raindrops than type B, and the rainfall rate of type B are only half to type A.

$$N(D) = N_w f(\mu)\left(\frac{D}{D_0}\right)^{\mu} \exp\left[-(3.67+\mu)\frac{D}{D_0}\right] \quad (9)$$

$$N_w = \frac{(3.67)^4}{\pi \rho_w}\left(\frac{10^3 W}{D_0^4}\right) \quad (10)$$

$$f(\mu) = \frac{6}{(3.67)^4}\frac{(3.67+\mu)^{\mu+4}}{\Gamma(\mu+4)} \quad (11)$$

	dBZ	R	m	Λ	A	b	D0	Nw
	50.4	101.1	0.9	2.57	158.8	1.42	1.778	2.84E+04
A	49.7	88.8	0.691	2.51	152.7	1.43	1.738	2.74E+04
	50.2	93.2	0.48	2.35	147.9	1.45	1.765	2.66E+04
	50.8	55.8	1.39	2.11	435.2	1.38	2.401	4.03E+03
B	50.7	62.2	1.13	2.11	359.3	1.40	2.274	5.52E+03
	49.8	48.8	0.61	1.92	340.2	1.44	2.223	4.97E+03

Table1: The reflectivity, rainfall rate, No, μ, Λ, A, b, D_0 and N_W for type A and B.

3. Radar data

The radar data was collected from the WSR-88D radar of Central Weather Bureau of Taiwan during typhoon Nari in 2001. The radar is 60 km away in north-east direction from the disdrometer station. The lowest available data above the disdrometer station is about 1.75 km.

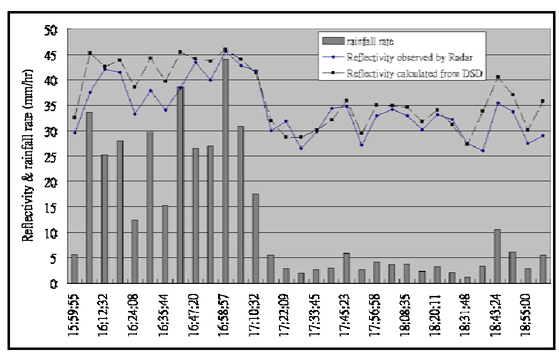

Fig.4: Time sequence of the disdrometer derived reflectivity (dash line), the radar observed reflectivity (solid line) and the rainfall rate in mm/hr (gray bar).

The time sequence of the disdrometer derived reflectivity and the radar observed reflectivity indicated that the radar underestimated the reflectivity about 3.0dBZ in heavy rain period. (Fig. 4) The value is similar to the Ulbrich (1998) which shows that the WSR-88D radar will underestimate the reflectivity about 3.5 dBZ. During the weak rainfall period there was very small difference between disdrometer and radar. The reason for this discrepancy could be complex, it will need more research.

4. Z-R relation

The A and b of Z-R relation calculated from the gamma distribution coefficient (No, μ, Λ) of the DSD data indicates the variations between different rainfall conditions. It shows that the A decreases and b increases with increasing rainfall rate. (Table 2) The variation is due to the variety of DSD in different rainfall condition.

R (mm/hr)	A	b	Amounts
0~10	**294.8**	**1.2669**	**347**
10~30	**287.1**	**1.2940**	**127**
30~60	**262.9**	**1.3386**	**39**
60~	**164.5**	**1.4178**	**3**

Table2: The averaged Z-R relations in different rainfall rate in typhoon season.

In order to improve the accuracy of the Z-R relation rainfall rate estimation, the classified Z-R relations derived from disdrometer was applied to estimate the rainfall rate from the radar reflectivity. Before this calculation, the statistical difference between the disdrometer derived reflectivity and the radar observed reflectivity was considered. All radar observed reflectivity was added by 3.0 dBZ, and the classified Z-R relation was selected according to the surface rainfall rate observations. Then the one hour precipitation accumulation was calculated by each PPI scan with corresponding Z-R relation. (Fig. 5)

The area rainfall accumulation is quite satisfactory by using the disdrometer derived Z-R relation and corrected radar reflectivity, especially in the heavy rainfall area. The $Z=300R^{1.4}$ usually underestimates the rainfall rate in Taiwan. With the corrected Z-R relation and reflectivity, the rainfall rate estimation by radar is much better.

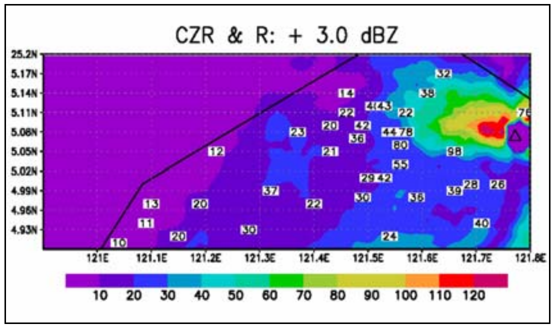

Fig.5: The one hour precipitation accumulation derived from corrected Z-R and corrected reflectivity (color shaded), and the surface rainfall rate observation (digital numbers).

5. Summary

By analyzing two years DSD data from 2d-video disdrometer in northern Taiwan area, we can see the great variation of rain drop size distribution. It shows that the heavy rain events are mostly composed of small and median raindrops rather than big raindrops. And the median volume diameter increases with increasing rainfall rate, but the median volume diameter remains about 1.7 mm when the rainfall rate greater than 60 mm/hr. The microphysics process of collision and breakup may be the main reason for this unique D_0 value.

The comparison between the reflectivity observed by WSR-88D radar and calculated from DSD was made. The average deviation between them were about 3.0 dBZ, it is similar to the result of Ulbrich (1998) . The precipitation vertical micro-process and the attenuation may cause the underestimation. During the weak rainfall period there was very small difference between disdrometer and radar.

Then the A and b of Z-R relation calculated from DSD data also varied with the variation of the coefficients of gamma function which have been analyzed before. The results suggest that the A and b of Z-R relations should be varied in different rainfall conditions. The A decreases and the b increases with increasing rainfall rate, and the modified Z-R relations were applied to the corrected reflectivity to improve the Z-R relation rainfall estimations. The area rainfall accumulation is quite satisfactory by using the disdrometer derived Z-R relation and corrected radar reflectivity.

In the future, we will utilize the polarimetric parameters from the National Central University C-Band dual-polarimetric radar which just been upgraded from Dppoler radar in November 2004 and combine the disdrometer data to investigate the precipitation micro-process in Taiwan area.

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