Estimation of Media Volume Diameter from three Tropical Convective Systems using C-POL radar

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Abstract

Since a differential reflectivity was proposed for rain estimation by Seliga and Bringi (1976), the polarimetric radar technique has attracted attention in radar meteorology. They showed that Z_{DR}, for an exponential rain drop size distribution (DSD), is directly related to the media volume diameter (D_0). The algorithm described by Gorgucci et al. (2000) can essentially be applied for a gamma DSD, and generalized to account for raindrop oscillations of the linear axial ratio model of raindrop. In this paper we applied Gorgucci et al. (2000) algorithm to BMRC/C-POL radar to estimate D_0, and compared with surface disdrometer. This single point comparison shows that radar is under estimated than the disdrometer. Also the radar is under estimation the D_0 sizes (slope 0.67), but the correlation coefficient is acceptable (0.84). It needs more research to overcome the problem of under estimation by C-Pol radar.

Key word: media volume diameter, C-POL

1. Introduction

Since a differential reflectivity was proposed for rain estimation by Seliga and Bringi (1976), the polarimetric radar technique has attracted attention in radar meteorology. They showed that Z_{DR} , for an exponential rain drop size distribution (DSD), is directly related to the media volume diameter (D_0). Polarization parameters such as radar reflectivity (Z_H), differential reflectivity(Z_{DR}), linear reflectivity difference (Z_{DP}), specific differential phase shift (K_{DP}), linear depolarization ratio (LDR), as well as the correlation coefficient (ρ_{HV}) have been successfully measured. These polarimetric measurements provide more information about precipitation and allow better characterization of hydrometeors. In general, Z_H, Z_{DR}, and K_{DP} are used to estimate rain rate and drop spectrum, since they depend mainly on drop size and shape. Careful intercomparisons between radar measurements of Z_{DR} and D_0 derived from surface disdrometers and airborne imaging probes have shown that D_0 can be estimated to an accuracy of about 10-15% (Aydin et al., 1987; Goddard et al., 1982; Bringi et al., 1998).

A general gamma distribution model was suggested by Ulbrich (1983) to characterize the natural variation of the DSD. The specific differential propagation phase (K_{DP}) is a forward scatter measurement whereas Z_{DR} is a backscatter measurement. The weighting of the DSD by Z_{DR} and K_{DP} is controlled by the variation of mean raindrop shape with size. A combination of the three radar measurements (Z_H, Z_{DR} and K_{DP}) can be utilized to estimate the DSD, specifically a parametric form of the DSD such as the gamma DSD.

This paper presents the algorithms proposed by Gorgucci et al. (2000) for the estimation of D_0 of a gamma DSD from polarimetric radar measurements at C-band frequency. Three cases of tropical convective system in Darwin Australia is tested. The D_0 estimation from BMRC/C-POL radar is compared with the D_0 derived from Joss and Waldvogel (1976) disdrometer on surface. The result shows that after attenuation and differential attenuation correction the C-band polarimetric radar can be used to estimate media volume diameter of gamma rain drop size distribution.

2. Raindrop size distribution data

Raindrop size distributions employed in this study were obtained from Joss and Waldvogel (1967) disdrometer data collected at Darwin, Australia during the period January – March 1999. Three convective system is selected to tested the D_0 estimation by C-POL radar. The continental and monsoonal rainfall systems is described by Keenan and Carbone (1992).

Every 30 s the RD-69 disdrometer system recorded the number of raindrops in 20 size intervals or channels covering diameters in the range from 0.3 to 5.0 mm. System "dead" periods were corrected using the technique of Kinnell (1977). One-min DSD with R > 0.5 mm h^{-1} and containing more than 100 drops were considered for analysis. Distributions were discarded if zero counts in one or more consecutive channels were located between channels with nonzero counts. No correction for bin-sizing errors, as proposed by Sheppard (1990), was made. A gamma distribution of the form

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$

was fitted to the observed DSD, where N_0 (m^{-3} $cm^{-1-\mu}$), Λ(cm^{-1}), and μ are the three DSD parameters. A maximum likelihood estimator (MLE) approach was employed to fit the gamma distribution. The fit procedure extended from the first channel recording nonzero counts to the largest channel recording nonzero counts (D_{max}). The incomplete gamma functions were solved explicitly employing the Van Wijngaarden–Dekkerr–Brent Method (Press et al. 1992), obviating the need to assume D_{max}/D_0 is large in the calculation of D_0.

3. D_0 estimation by C-Pol radar

Seliga and Bringi (1976) showed that for an exponential distribution, the two parameters of the DSD, namely N_w and D_0, can be estimated using Z_{DR} and Z_H. They used a two step procedure where they estimated D_0 using an equilibrium raindrop shape model and subsequently used that in the expression for Z_H to estimate N_w. This procedure can essentially be applied for a gamma DSD, and generalized to account for raindrop oscillations using the linear model in the form

$$r = 1 - \beta D.$$

the r is axial ratio, D is equabilum diameter of raindrop, β is an constant. Gorgucci et al. (2000) using simulations to derived an estimator for D_0 as the following form ,

$$\hat{D}_0 = a_1 Z_H^{b_1} (Z_{DR})^{c_1}$$

These coefficients for C-band are

$a_1 = 0.59$, $b_1 = 0.064$, $c_1 = 0.024\beta^{-1.42}$

The procedure for estimating the gamma DSD parameters is as follows: First, correcting the attenuation and differential attenuation by the method of Bringi et al. (2001). Second, estimate β using the algorithm described by Gorgucci et al. (2000), and subsequently, estimate $\hat{D}_0$.

The radar data was collected from the Bureau of Meteorology Research Centre C-band (5.3 cm) dual-polarimetric radar (C-POL) which was located on Darwin Australia in 1999. For the C-POL radar specifications and definitions of all observed quantities, see Keenan et al. (1998). We focus on three tropical convective systems with heavy rain that occurred on 15 January, 1 and 17 March 1999.

4. results and conclusion

In order to evaluates the performance of the D_0 estimation by using C-band polarimetric radar. We analysis three tropical convective systems passing through the D-scale rain gauge network settle on Darwin Australia. The D_0 estimated by C-POL radar is compared with the D_0 estimated from the surface disdrometer in the rain gague network.

Figure 1 is the D_0 space distribution estimated by C-Pol radar on 0600UTC 15 January 1999. The contour lines represent the radar reflectivity factor. The different colors represent different D_0 sizes which estimated by C-POL radar. The reslut show that most large D_0 is in the front region of strong convection. This feature is same with the results by Maki et al. (2001). Which use the surface disdrometer data to analyze tropical continental squall line in Darwin, Australia.

Figure 2 shows the detail comparison of the disdrometer and radar estimated D_0. The radar data and disdrometer data is shifted in space and time lag by the help of surface rain gauge data. After the space and time lag shift adjustment the results improved greatly, the correlation coefficient increases from 0.71 to 0.84.

The D_0 estimation by C-band polarimetric radar was tested, and compared with surface disdrometer. The method proposed by Gorgucci et al. (2000) is applied for BMRC/C-POL radar which under estimates the D_0 sizes (slope 0.67), but the correlation coefficient is acceptable (correlation 0.84). It needs further research on the algorithm of D_0 estimation for C-band polarimetric radar to overcome the under estimation problem.

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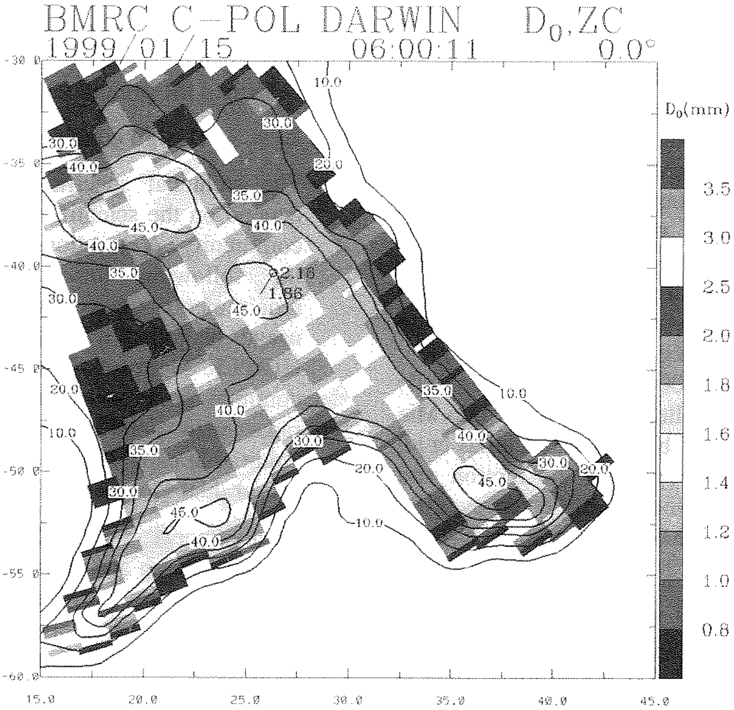

Fig 1 Space distribution of the D_0 estimated by C-Pol radar.

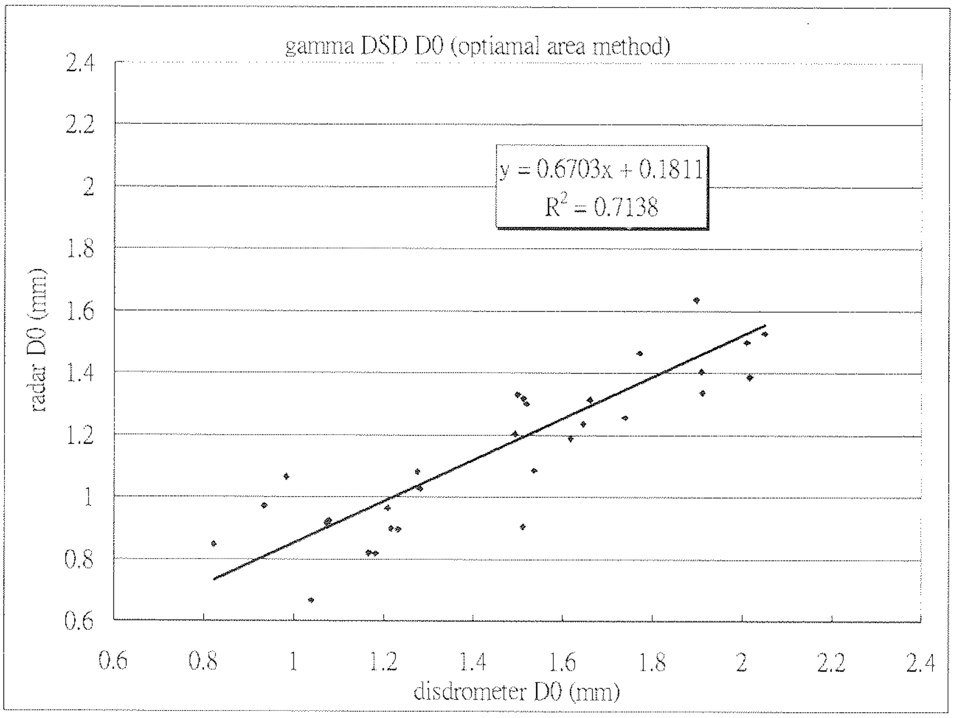

Fig 2 Scatter plot of the D_0 estimated by C-POL radar and RD-69 disdrometer.