Z-R RELATIONS OBTAINED FROM WIND PROFILER-DERIVED DSD FOR TRMM PR EVALUATION

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1. Introduction

Raindrop size distributions are crucial for understanding rain formation processes. The relations of reflectivity factor \( Z \) and rain rate \( R \) significantly change with DSD. Therefore, accurate estimates of rain rate from the precipitation radar (PR) onboard the Tropical Rainfall Measuring Mission (TRMM) needs statistics of DSD to determine typical Z-R relations. However, most studies have used disdrometers to measure DSD and have shown only surface measurements. Many processes affect raindrop size as drops fall, i.e., coalescence, nucleation, diffusion growth or evaporation, sedimentation, and breakup. Observations and numerical modeling results show significant changes in the DSD during rainfall (e.g., List and McFarquhar 1990; Kobayashi and Adachi, 2001). Continuous measurements of vertical profiles of DSD are needed both for the accurate measurements of the TRMM PR and improvement of our understanding of the rain process.

The present study uses an iterative retrieval method for arbitrary shaped raindrop size distribution (ITRAN) from wind profiler measurements; no particular DSD shape is assumed and the DSD is fully derived automatically (Kobayashi and Adachi, 2005, Rajopadhyaya et al. 1993).

2. Observations

We have derived many DSD from 400MHz band wind profilers at Tsukuba and Okinawa. Here we show results at Tsukuba. On 20 June 1997, typhoon 9707 moved over the Japan. Precipitation associated with typhoon rain bands was measured with a 404 MHz profiler at the Meteorological Research Institute in Tsukuba where is located about 100 km east of the typhoon center. The rain rate was ranging from 1 to 30 mm/h at the ground. In total 365 Doppler spectra of a distinct peak were selected and were applied to the ITRAN to derive DSD.

Figure 1 shows profiler-derived integral parameters (a) \( Z \), (b) total number of raindrops \( N_T \), (c) second moment \( S_a \), and (d) median volume diameter \( D_0 \) plotted versus the rain rate \( R \). Note that integrated rainfall parameters, except for \( D_0 \) are approximate values because the wind profiler was not accurately calibrated. Reflectivity factor correlates well with \( R \), which is in agreement with previous studies. However, the slope \( b \) in the Z-R relation of \( Z= R^b \) is 1.1. This value is smaller than that reported in previous studies.

The total number of raindrops increases as \( R \) increases (Fig. 7 b), which contrasts with previous studies that show a weak dependence of the intercept parameter on rain rate (Bringi et al., 2002, Testud et al., 2001). Although there is considerable variability, the rain rate can be determined from \( N_T \) in the present case. The second moment \( S_a \), depends strongly on \( R \) (Fig. 7c) and is also linearly related to \( N_T \) (not shown). Physically, \( S_a \) is related to the surface area of raindrops. The probability of drop collision is proportion to the square of the drop size. This may lead to the strong relation between \( R \) and \( S_a \).

Figure 7 (d) shows no apparent correlation between \( R \) and \( D_0 \), as in studies by Bringi et al. (2002). During fall of raindrops, small and
large drops, respectively, increase and decrease in number when collision-induced breakup occurs. These changes cause $D_0$ to decrease and $N_T$ to increase. The opposite also occurs through the collision-induced coalescence. Therefore, an inverse relation between $N_T$ and $D_0$ is expected. However, not even a weak relation between $R$ to $D_0$ is present in Fig. 7(d) despite the apparent relation between $R$ and $N_T$ present in Fig.7 (b).

Median volume diameter characterizes the shape of DSD but is mathematically independent on $N_T$. Similar values of $D_0$ are observed during precipitation events with similar DSD and different $R$.

Figure 2 shows vertical profiles of LWC, $D_0$ and $N_T$ at 13:09. Rain rate was 10 mm/h at the ground. The values of LWC and $N_T$ were normalized by the maximum values in the profile. The inverse relation between $D_0$ and $N_T$ is clear. Although most changes in LWC are in phase with change in $N_T$, there are some examples of inverse relationships between $N_T$ and LWC. For example, at 4 km, LWC increases but $N_T$ decreases. At this altitude, $D_0$ increases significantly, which leads to an increase in LWC.

3. Conclusions

The iterative method was applied to 365 spectra measured with a 404 MHz wind profiler, in precipitation associated with typhoon rain bands. Results show interesting relationships between LWC and integral rainfall parameters. We have also observed DSD derived from a wind profiler at the Okinawa Subtropical Environment Remote-Sensing Center of the National Institute of Information and Communications Technology in Okinawa. These studies will contribute the accurate measurements of the TRMM PR and the GPM.

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Fig.1 A scatterplot of the profiler derived parameters (a) $Z$, (b) $N_T$, (c) $S$, and (d) $D_0$ versus LWC
Fig. 2 Vertical profiles of LWC, D₀, and Nᵣ at 13:09. The values LWC and Nᵣ are normalized by the maximum values in the profile. The inverse relation between D₀ and Nᵣ is clearly seen.

References


