RETRIEVAL OF RAINDROP SHAPE-SIZE RELATION USING DUAL POLARIZATION RADAR MEASUREMENTS

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1. INTRODUCTION

Dual polarization radar measurements of rainfall rate and other meteorological parameters are based on the assumption that the mean shape-size relationship of raindrops is well understood. In radar meteorology raindrops are modelled as oblate spheroids with eccentricity defined by an axial ratio b/a as a function of the drop diameter D. The raindrop oblateness increases with larger diameters and is more pronounced at the bottom. Moving from the description of a single raindrop to a population of raindrops described by the drop size distribution (DSD) as observed in a large radar volume, one needs to consider that large drops, as they fall, reach a higher terminal velocity than smaller droplets; therefore, collisions take place. A collision produces oscillations in the newly coalesced drops and in the fragments generated by the drop break-up. The result is that oscillating drops in a free atmosphere tend to be, in the mean, more spherical and the relationship between size and axial ratio may be altered. Thus, the estimation of the mean shape of raindrops in a radar volume is critical to extending the validity of ground-based results to the rain volume aloft.

This paper focuses on retrieving and interpreting the mean raindrop shape-size relation from polarimetric radar observations. A procedure to retrieve the drop shape-size relation that governs the polarimetric radar observations of reflectivity (Z_h,) differential reflectivity (Z_{dr}) and specific differential propagation phase (K_{dp}) is presented. The mean drop shape-size relations retrieved are analyzed to explore whether the natural raindrop shape-size relation can be described by a unique model.

2. RETRIEVAL PROCEDURE

The polarimetric radar measurements Z_h, Z_{dr}, and K_{dp} are all influenced by the DSD variability and by the raindrop shape-size relation. It has been shown [1] that representing radar measurements onto a two-dimensional space space defined by the two variables K_{dp}/Z_h and Z_{dr}, the influence of DSD is nullified so that any variation in this domain comes predominantly from the drop shape variability allowing the same to be observed.. The ratio between K_{dp} and Z_h will be henceforth referred as $\chi_{pp}=10\log_{10}(K_{dp}/Z_h)$ with K_{dp} in deg km^{-1} and Z_h in m^3 mm^{-6} and the space defined by χ_{pp} and Z_{dr} (in dB) is called the "Radar Drop Shape-Size Domain" (RDSSD) since the the position of a (χ_{pp}, Z_{dr}) pair in the RDSSD is determined by the prevailing shape-size of the drops in the radar measurement volume. Given a fixed shape-size model expressing *b*/*a* as a function of *D*, its representation in the RDSSD can be obtained by simulating radar measurements, say, at at S-band, for widely varying DSDs, using the following conditions: i) gamma DSD parameters varying in the ranges $0.5<D_0<3.5$ mm; $3<\log_{10}N_w<5$; $-1<\mu<5$; ii) $10\log_{10}Z_h<55$ dBZ iii) rain rate less than 300 mm h^{-1}; iv) drops canted with the mean and standard deviation equal to 0° and 10°, respectively. It is easy to see that the obtained (χ_{pp}, Z_{dr}) is close to mean curve that can be used as the representation of the shape-size model in the RDSSD. This property is used to devise procedure to determine a fourth order polynomial than can approximate the drop shape-size relation underlying a given dataset. The procedure is based on minimizing the error between the measured values of observables in the RDSSD domain and the mean curve representing a shape size relation in the RDSSD [2].

3. RESULTS

The procedure is applied to three different polarimetric radar data sets collected at S-band by the NCAR S-POL radar during campaigns conducted in Florida (Teflun B), Brazil (LBA) and Italy (MAP), two of which were part of the validation program of the Tropical Rainfall Measuring Mission (TRMM). Profiles of Z_h, Z_{dr}, and Φ_{dp} used in the study refer to rain paths of over 100 consecutive 0.15-km range bins. The drop shape-size relations obtained for each campaign are reported and compared with commonly used relations reported in the literature [3] [4] [5] [6] (hereinafter PB, BC, BZV, THBRS) in Fig. 1.

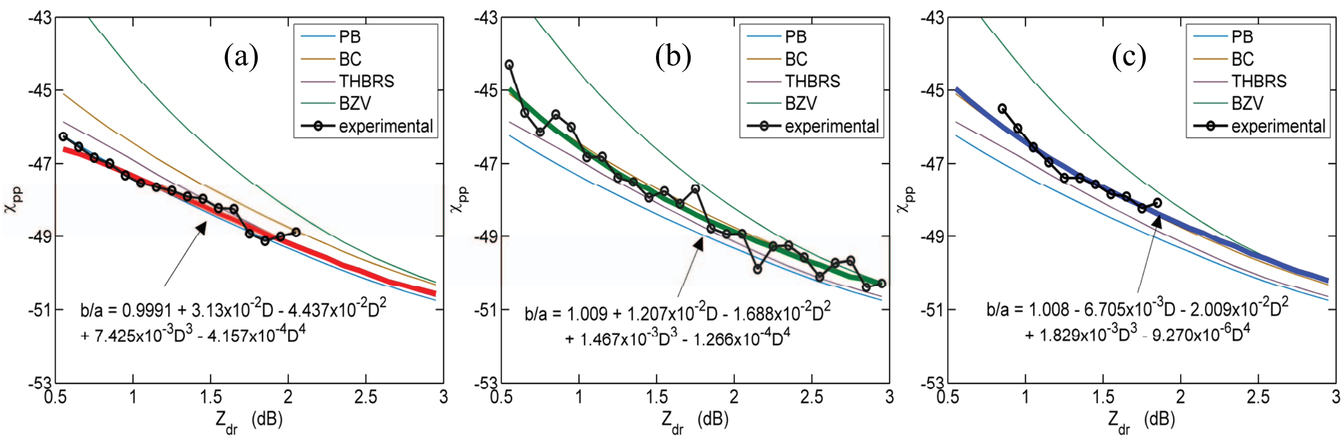

Figure 1: Reults for Teflun B (a), LBA (b), MAP (c). Each panel shows the experimental mean values of χ_{pp} computed for each Z_{dr} class of 0.1 dB (solid black line with dots) , and the representation in the RDSSD of the retrieved shape relation expressed by a fourth order polynomial (thick solid line). PB, BC, BZV, THBRS mean curves are reported as reference (thin solid lines).

The ability of each retrieved model to represent the experimental data is evaluated in terms of normalized standard error (NSE) and normalized bias (NB) computed between experimental mean χ_{pp} vs. Z_{dr} curve the curve representing the retrieved 4th order polynomial in the RDSSD. NB and NSE are normalized to the mean χ_{pp} radar data and are computed for each dataset as a function of Z_{dr} (Fig. 2). In Fig. 2, NB and NSE of PB, BZV, THBRS, BC for each dateset are also reported for reference.

In conclusion, the study documents the degree of change of the mean drop shape-size relation governing the natural rain. Specifically, for the cases considered in this study, the variability of the drop shape-size is between the values given by the BC and BZV models.

4. REFERENCES

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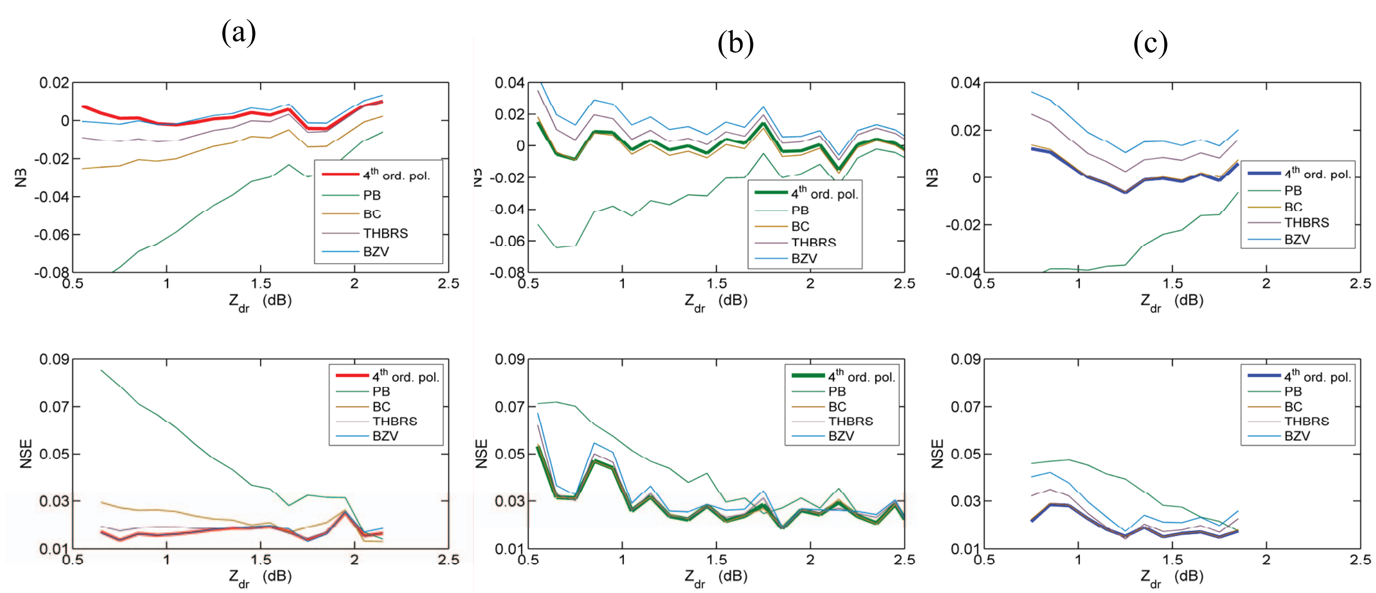

Figure 2: NB and NSE for Teflun B (a), LBA (b), and MAP (c) computed between experimental data in the RDSSD and mean curves corresponding to fixed shape size model. Solid thick lines correspond to the retrieved shape relation expressed by a fourth order polynomial. Thin solid lines refer to mean curves of PB, BC, BZV, THBRS.