ANALYSIS OF THE MEAN RAINDROP SHAPE MODEL FOR DUAL POLARIZATION RADAR RAINFALL ESTIMATION

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Information about the shape of raindrops is critical for estimating rainfall rate with dual polarization radar. As described in the literature, the relation describing drop oblateness as a function of its equivolumetric diameter is nonlinear. There are several relations that express the shape-size dependence as nonlinear fourth-order polynomials that have five coefficients or five degrees of freedom. In fact, there is still no consensus regarding the most appropriate equation to use to describe the shape-size relation. However, while these non-linear equations are important for studying raindrop shape, it is not clear that they are needed to estimate an integral quantity such as rainfall rate.

An equivalent linear shape-size model with variable slope (β) was also proposed [1]. The slope parameter can be determined from an equation relating it to Z_h, Z_{dr}, and K_{dp} measurements. Two rain algorithms based on the use of Z_h, Z_{dr}, β and on K_{dp}, β, are examined. However, due to the better normalized standard error (NSE), the first algorithm (henceforth the β algorithm) was selected to be analyzed.

To test the performance of the proposed rain estimation procedure dealing all the implications rising from electromagnetic and microphysical aspects, realistic rain and radar measurement profiles reconstructed from real radar observations were used [2]. Starting from radar profiles collected by the NCAR S-POL dual polarization radar, two different sets of radar profiles were obtained for S-, C-, and X-band assuming the raindrop shape-size relations of Pruppacher and Beard [3] and Beard and Chuang [4] (henceforth PB and BC, respectively). The first model is linear, whereas the second is a non-linear one, expressed by a fourth order polynomial.

Using these profiles, the performance of the proposed rain algorithms based on β is compared with that of algorithms derived assuming two drop shape relations expressed by a fourth order polynomial proposed recently [5], [6] (henceforth BZV and THBRS, respectively). The simulation procedure allows the study of the influence of DSD variability as well as the effect of measurement errors on rain rate estimations.

In the absence of measurement errors, a common result for the three frequency bands is that the β algorithm meets the DSD variability requirements better than the BZV and THBRS algorithms. In the case of PB profiles, the NSE of the β algorithm is always lower than that of the BZV and THBRS algorithms (reduction varies from 6.5 % to 19%). For the BC profiles, the NSE of the β algorithm is of the same order or better of about few percent of the BZV and THBRS algorithms. Considering also the measurement errors, the β algorithm presents a decrease of performance even though its NSE remains comparable to or better than that of the other two algorithms. The interesting result is related to the normalized bias, for which the β algorithm demonstrates better results when compared to the BZV and THBRS algorithms.

In general, it is possible to conclude that the rain algorithm based on an equivalent linear shape-size model performs better than the THBRS and BZV algorithms, since in worst cases, the performance of the β algorithm is not too far from the performance of the standard rain algorithm obtained assuming the two non-linear shape size relations. It is important to note that this result has been verified with profiles following two shape-size models, one linear and one non-linear, the latter being quite close to the THBRS and BZV models used to derive the "standard" rain algorithms based on Z_h and Z_{dr}. This result can be considered as a general one, due to the ability of the β algorithm to minimize the error due to a wrong assumption regarding the drop-shape size model .

In summary, although the literature indicates that the relation between oblateness and diameter of raindrops can be appropriately described by a nonlinear relation, the exact knowledge of this relation is not necessary in the case of estimation of an integral quantity such as the rainfall rate. Is fact, using a simple equivalent linear shape-size model can be convenient to obtain reliable estimations.

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