A new generalized approach for distribution normalization and implications for radar retrieval of raindrop size distributions

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A general rain drop size distribution (DSD) normalization method is formulated in terms of generalized power series relating any DSD moment to any number and combination of reference moments. This provides a consistent framework for comparing the variability of normalized DSD moments using different sets of reference moments, with no a priori assumptions about the DSD functional form. It also provides a method to derive any unknown moment plus an estimate of its uncertainty from one or more known moments, relevant to radar retrievals and rain microphysical models. The relationship to previous DSD normalization methods will be discussed, including previous one- and two-moment methods that also do not assume underlying DSD functional forms. It is shown that these earlier methods are particular cases of the generalized approach, but they apply additional explicit or implicit a priori constraints. Thus, the generalized approach helps to unify existing normalization methods. This approach is applied to a large, global dataset of disdrometer-observed and bin microphysics-modeled DSDs. As expected, the spread of normalized moments decreases as the number of reference moments is increased. Averaged for all combinations of reference moments and normalized moments of order zero through ten, 42.9%, 81.3%, 93.7%, and 96.9% of variability is accounted for by applying one-, two-, three-, and four-moment normalizations, respectively. Thus, DSDs can be well characterized overall using three reference moments, whereas adding a fourth reference moment contributes little independent information. The combination of particular reference moments leading to the smallest variability of various derived moments is also obtained. These results highlight the value of two-moment and especially three-moment normalizations. This is particularly evident when lower-order reference moments are combined with higher-order reference moments such as the sixth moment (proportional to radar reflectivity), with implications for rain DSD retrievals using radar plus additional instruments or sensors.

Keywords: Drop size distributions, Rain microphysics