

1. I am fine with proposing an approach more than a fully deeply tested method, but if observations at W band are used, they will come with a number of potential limitations (that are mentioned both by the reviewers and the authors - see sections 5.1 and 5.2 for instance) like calibration and attenuation to name two. It is relevant to list those limitations, but I think the authors should go further and investigate the sensitivity of the proposed retrieval to those uncertainties (simulating the effects on W-band reflectivity values and further down on the retrieved Dm and Nw). In this way, the potential of the approach could be more convincingly "established" (or not). For instance, if such an analysis shows that the W band must be calibrated at 1 dB to provide meaningful constraints, the applicability of the approach would be strongly supported. If 0.1 dB is required instead, this is another story...

Response:

We thank the reviewer for this constructive suggestion. We agree that quantifying the sensitivity of the retrieval to W-band calibration and attenuation uncertainties is essential to establish the practical potential of the proposed approach. Following it, we have added a quantitative sensitivity analysis (new Section 5.1 and new Figure 21) in which the W-band reflectivity is systematically perturbed and the perturbation is propagated through the full retrieval chain, $\text{DFR}(\text{Ka}, W) \rightarrow \text{Dm} \rightarrow \text{Nw}$. Below is the revised Section 5.1 (Sensitivity of the retrieval to W-band reflectivity uncertainties):

A critical question for the practical applicability of the proposed framework is the extent to which the retrieval tolerates uncertainties in the W-band reflectivity, given that no W-band radar observations are currently available and that the $\text{DFR}(\text{Ka}, W)$ constraint is invoked in the ambiguous zone of $\text{DFR}(X, \text{Ka})$, where the retrieval is most vulnerable. In this section, the tolerance is quantified through a controlled sensitivity experiment.

All uncertainty sources affecting the W-band measurement act exclusively through the reflectivity itself. In logarithmic units, the calibration bias (ΔZ_{cal}) and the attenuation-correction residual (ΔZ_{att}) are additive and can be combined into a single total error term, $\delta Z_W = \Delta Z_{\text{cal}} + \Delta Z_{\text{att}}$, such that the combined reflectivity is given by $Z_W + \delta Z_W$. Since $\text{DFR}(\text{Ka}, W) = \text{dBZ}(\text{Ka}) - \text{dBZ}(W)$, the net offset δZ_W translates into an equal and opposite shift in $\text{DFR}(\text{Ka}, W)$. The shifted ratio is then mapped onto Dm through the fitted $\text{DFR}(\text{Ka}, W)$ –Dm relationship (Eq. 19), and onto Nw through $\text{Nw} \propto \text{Dm}^{-4}$ (LWC being retrieved from Z_{Ka} and therefore unaffected). Consequently, a single sensitivity curve obtained by perturbing Z_W with a net offset δZ_W constitutes the complete response function of the retrieval to the combined effect of calibration errors and attenuation residuals.

The W-band reflectivities were perturbed with offsets ranging from -2 to $+2$ dB in steps of 0.1 dB, and the retrieval was re-run for all samples in the ambiguous zone of $\text{DFR}(X, \text{Ka})$. Among the ambiguous-zone samples, the fraction retaining a unique Dm solution decreases only gradually, from 80.5% at $\delta Z_W = 0$ to 72% at $|\delta Z_W| = 1$ dB (Fig. 21a). The Dm RMSE of the resolved samples increases from 0.08 mm at zero offset to 0.14 mm at $|\delta Z_W| \approx 1.1$ dB, remaining comparable to the best-performing conventional method (0.149 mm, Table 7); beyond ± 1.1 dB, the Dm RMSE exceeds that of the conventional methods, marking the point at which the advantage of the proposed framework is gradually lost (Fig. 21b). The RMSE of $\log_{10}(\text{Nw})$ increases consistently from 0.18 to 0.33 over the same range (Fig. 21c), yet it remains lower than that obtained with the conventional method (0.433, Table 7). The results indicate that the proposed framework tolerates a combined W-band reflectivity uncertainty of approximately ± 1 dB.

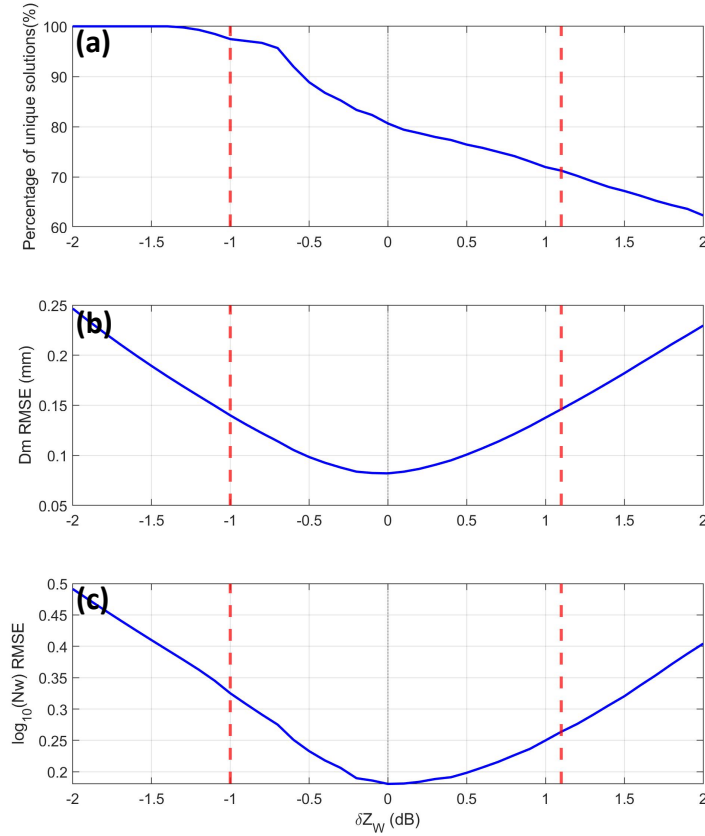


Figure 21. Sensitivity of the DSD retrieval to the combined W-band reflectivity uncertainty δZ_W , evaluated over the ambiguous-zone samples ($\text{DFR}(X, K_a) \leq 0$). (a) Percentage of samples retaining a unique Dm solution, (b) Dm RMSE of the resolved samples, (c) RMSE of $\log_{10}(N_w)$. The vertical red lines in all panels indicate the threshold offsets beyond which the Dm RMSE exceeds that of the conventional methods.

Because Section 5.1 already discusses the influence of radar calibration and attenuation-correction errors on the accuracy of DSD retrievals, which partially overlaps with the content of Section 5.2, the original Section 5.2 (Radar Calibration and DFR Uncertainty) has been removed.

Add the following statement in Section 6 :

The results of the sensitivity experiments demonstrate that a W-band reflectivity accuracy of approximately 1 dB is required, and that such accuracy can be achieved using current ground-based W-band radar calibration practice together with standard attenuation correction.

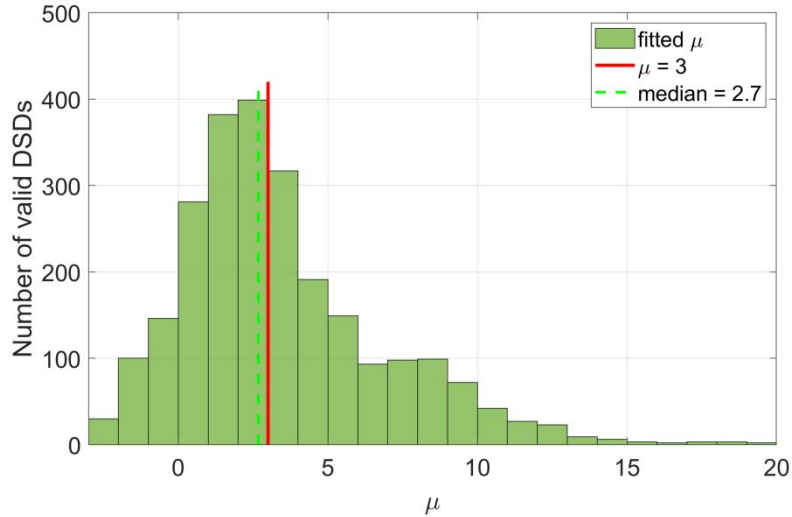
2. The choice of a fixed value for μ is also discussed in the reviews. The authors added a more "objective" way to select this value for μ . I have an issue though with the way μ , Dm and Nw are considered in this work: the fitted values of Dm and Nw on DSD spectra measured by the 2DVD are not independent of the fitted μ values (in that they are fitted all 3 at the same time, and a change in the fitted μ likely results in a change in the fitted Dm and Nw). But the optimization of the fixed μ value using the cost function defined in eq.18, minimizing the error on Dm and Nw, ignores this "link" between μ and Dm and Nw. To be fully consistent, the values of Dm and Nw used as reference in eq.18 should be refitted for all the tested values of μ . In addition, the selected μ value (3) could be compared to the distribution of the μ values fitted on the DSD measured at the ground, to further evaluate the

consistency. And the authors should explain how the DSD model is fitted to the 2DVD measurements (in section 3.1 for instance).

Response:

We thank the reviewer for this careful comment. In our implementation, the reference ("true") values of D_m and N_w that enter the cost function in Eq. (18) and the normalized gamma distribution (Eq. 6) are not obtained by fitting the three-parameter normalized gamma model to the 2DVD spectra. **They are computed directly from the measured spectra by the method of moments (Eqs. 2–5): $D_m = M_1/M_3$, and N_w is derived from LWC and D_m .** These quantities depend only on the moments M_3 and M_4 of the measured DSDs and are therefore independent of any assumed value of μ . The normalized gamma model with $\mu=3$ is used only at the final reconstruction step (Step 8) of the retrieval.

Using the least-squares method, the ground-based disdrometer measurements are fitted to the standard gamma DSD. The fitted μ values ranged from -3 to 20 , with a median of 2.7 (the following picture). The fixed value of $\mu = 3$, determined through the cost-function optimization, is very close to this median, indicating that the choice of μ is reasonable.



Since Section 3.1 is primarily dedicated to the description of the instrumentation, we feel that it may not be the most appropriate place for the discussion of the DSD retrieval. As the retrieval procedure is described in detail in Section 2.2, we have therefore chosen to move this explanation there, where we believe it fits more naturally. The following statement has been added at the end of Section 2.2:

“ It should be emphasized that no fitting of the normalized gamma distribution to the measured DSD is involved in deriving the reference DSD parameters. The D_m , LWC, and N_w are computed directly from M_3 and M_4 via Eqs. (3)–(5), and are therefore independent of μ . The normalized gamma distribution (Eq. 6) with $\mu = 3$ is used only at the final step of the retrieval (Step 8) to retrieve DSD from D_m -est and N_w -est.”