Response to the reviewers' comments

Reviewer 3

This manuscript estimates variability of Lamba-mu relations of the assumed gamma-function DSD in observed liquid precipitation. The results obtained in this study may be useful for better understanding of uncertainties in these relations. I recommend a major revision of the manuscript having in mind comments below.

Main comments.

* *The authors should clarify their retrieval method described in section 3.3. They describe how they estimate mu (steps 2 and 3). How the corresponding Lambda value is then obtained? They state that they impose a fixed Lambda – mu relation with fixed coefficients (i.e., relation (7)). If they use this fixed relation then how different prefactors and exponents (alpha and beta in Table 1) are obtained?*

Answer

Thank you for your comment. In Section 3.3 we describe how the DSD parameters were retrieved using a combination of radar observations and a fixed relationship between μ and Λ. However, in Table 1 we do not follow these steps since we deal with disdrometer data only, so μ and Λ are coming directly from the observations (no need for retrievals). We modified Section 3.3 accordingly in order to make that more clear to the reader.

* *Please provide a better description of the geometry of measurements. What are relative locations of the disdrometer and the radar? At what heights radar*

measurements are made? Is the disdrometer directly below the radar resolution volume? In other words, what are horizontal and vertical distance separations between the radar and disdrometer.

Answer

Thank for your comment. We added the following sentences in the text:
"The TARA radar was collocated with additional sensors. This included a Parsivel disdrometer (see Pfitzenmaier et al. 2018, Fig. 1) provided by the Leibniz Institute for Tropospheric Research (TROPOS). For this experiment, the radar antenna elevation angle of TARA was fixed at 45° with constant azimuth. The collected polarimetric radar observables included the reflectivity factor at horizontal polarization (Z_{hh}) and differential reflectivity (Z_{dr}) at 200 m height (corresponding to the minimum range of TARA)."

* *Are coefficients in (7) simple mean values or are they some kind of weighted mean values? (for example, weighted by event durations, etc.).*

Answer

They are simple mean values across the 7 selected events without any weights.

* *Equations (1) through (5) assume untruncated distributions. Do you have any estimates how truncation to Dmax in (9) and (10) would affect the results? I assume that this effect is mu-dependent.*

Answer

We did not explicitly investigate this issue because the drop diameters considered in this study were rather small. Therefore, it is reasonable to assume that the truncation with D_{max} does not substantially affect the results. Similarly, the choice of the actual value for D_{max} (e.g., 6 or 7 mm) is very unlikely to change the μ-Λ relationships and our conclusions.
In general, we are perfectly aware of the limitations of the Parsivel in terms of detection of small droplets which could lead to overestimated D_m and μ values, since the width of the distribution will be underestimated.

** Line 164: Eq.(3) from Unal (2015) shows only horizontal polarization backscatter cross section. Do you account for the elevation angle for the vertical polarization cross section? What were assumed drop orientations?*

Answer

Yes, we account for the elevation angle of 45^{o} to calculate the radar cross section at vertical polarization. For the raindrop canting angle distribution, a Fisher distribution symmetric around 0^{o} with a width parameterized by κ being 30 is used.

** What are your estimates of uncertainties in the Lambda-mu estimates? Given the retrieval/measurement uncertainties, are the results for different events shown in Fig.3 really statistically different?*

Answer

We did not estimate the uncertainty explicitly but it is quite clear that at such small time scales, uncertainties on μ and Λ can be substantial. There is no real need to calculate these uncertainties because, as we already highlighted in the text, apart from events 2 and 6, for which the overall relations are obviously different, the rest of the events had very similar μ-Λ relationships that were well within the expected uncertainty range for μ and Λ.

** The correlation coefficients of 0.12 - 0.24 for retrieved Nt (as mentioned in the abstract) actually indicate no reliable correlation.*

Answer

Thanks for your comment. We modified the sentence as follows:
"After careful data filtering and removal of problematic Z_{hh}/Z_{dr} pairs, the correlation coefficient for the retrieved N_T values remained low, only slightly increasing from 0.12 into 0.24."

** I suggest calculating a power-law correlation coefficient between Lambda and mu for each event and also RMSD between individual Lambda – mu points and the best fit. Showing these statistical metrics in in Table 1 would be beneficial.*

Answer

Thanks for your comment. We included the correlation coefficient and RMSD in Table 1.

** Why not to use lower elevation angle for radar measurements to increase ZDR?*

Answer

Indeed, a lower elevation angle would increase the value of Z_{dr}. However, during the ACCEPT campaign, only the 45° elevation was considered, which was the optimal choice in order to combine polarimetric and Doppler spectra information and perform other, microphysical studies.

Minor comments

** Since you use binned DSD information, you should probably use summations in (9) and (10) rather than integrals.*

Answer

Only the DSD data derived from the Parsivel are binned. Equations 9 and 10 are used for the DSD retrievals from the radar data, which are not binned. That is why an integral is the correct mathematical expression.

** Equations (7) and (11) are repetitive.*

Answer

Thank you for your comment. Since we moved section 3.4 before 3.3 to address another comment, we should keep both equations 7 and 8 in order to avoid any confusion for the reader.

* *The first line after (9): here capital Lambda size parameter and small lambda - wavelength are mixed up.*

Answer

Thanks for spotting this mistake! We made the necessary changes.

* *Add Zdr frame to Fig. 2.*

Answer

Thank you for the suggestion, but we do not think that this is necessary. The purpose of Figure 1 and Figure 2 is to help visualize the events and to compare some basic DSD moments such as radar equivalent reflectivity factor, rain rate etc. between the Parsivel and TARA.

* *Line 296 says: see Section 3a, but there is no section 3a in the paper. Is it 3.1 ? Also you are referring to section 3c in line 340 (and in other parts of the paper), but it probably should be section 3.3. Check the entire manuscript for consistency in referencing different sections.*

Answer

Done.

* *Are sigma' and sigma in lines 302-304 the same parameter?*

Answer

Yes. Actually σ' is the new σ (mass spectrum standard deviation).