Review of “Drop Size Distribution Retrieval Using Dual Frequency Polarimetric Weather Radars”

The authors conducted a study to retrieve DSD parameters and subsequently compared them with disdrometer measurements. However, the methodology was not sufficiently elucidated in the text. The manuscript fails to address several uncertainties, which are neither considered nor discussed thoroughly when comparing retrieved and measured DSD. The study appears incomplete, requiring more comprehensive analysis and comparisons between the retrieved and measured DSD. Therefore, I suggest that this manuscript can be accepted only if the authors make major revisions. Please refer to the provided comments and suggestions for guidance.

General comments and suggestions:

1) The authors should consider and discuss height difference between radar gates selected for the DSD retrieval and the disdrometers. The height of the radars are quite high.

   Response: We acknowledge that the difference between radar volume and the disdrometer observation poses challenges in all radar-based retrieval algorithms. In our study, we have made concerted efforts to minimize the impact of this discrepancy. This was achieved by restricting our data collection to the lowest two radar elevation angles and confining the range of our retrievals to within 70 km.

   While these measures represent the best possible approach given the fixed positions of the equipment, we understand the importance of thoroughly discussing these inherent limitations. We will ensure that a comprehensive discussion of these height differences and their associated constraints is included in the revised version of our manuscript, providing a clear and honest assessment of the limitations of our study.

2) It is better to briefly introduce the synoptic scale weather conditions for the cases you selected, especially about wind direction and speed, temperature, and relative humility. Evaporation, collision-coalescence will affect the DSD measured at disdrometer station as the raindrops fall from the height of “terminal gate”.

   Response: Thank you for pointing this out. The majority of our samples were collected in June 2017, during the "Meiyu" rain season, a period characterized by varying weather conditions from light drizzle to thunderstorms. The ground temperature is around 25^{o} C, and normally no strong wind is associated with the rainfall during the Meiyu season. To simplify the model, no evaporation, collision-coalescence are considered in this work. We will convey this information in the revised manuscript.

3) I suggest performing the DSD retrieval at the terminal gate continuously for at least several radar scan to check robustness of the proposed method.

Response: Thank you for the suggestion. In the revision, multiple scans were used in the performance evaluation, although not continuously due to the different VCPs of the radar and our time synchronization requirements.

We quantitatively evaluated the performance of the proposed approach and look forward to including the results in the revised manuscript. In the quantitative evaluation, the rainfall rates were first estimated using three different approaches:

i.) using the retrieved DSD parameters following equation $R = \frac{\pi}{6}\int_0^{D_{max}} D^3 N(D) v(D) dD$ (Bringi 20002, Zhang 2001, etc);

ii) using the S-band radar reflectivity (*Z*) following the WSR-88D *R*-*Z* relationship, $Z = 300\, R^{1.4}$ (Ulbrich and Lee 1999);

iii) using the DSD observed by the Parsivel disdrometer following equation $R = \frac{6\,\pi \times 10^4}{\Delta t} \sum_{j=1}^{M} \frac{D_j^3}{S_j^2 DVD}$ (Raupach and Berne, 2015).

The rainfall rates from i and ii were then compared with the iii, which was treated as the ground truth. In the comparison, the relative absolute error (RAE) was calculated as.

$$\epsilon = \frac{|R_d - R|}{R_d}$$

where R_d are the rainfall rate estimated from the disdrometer as presented in approach iii, and *R* are the evaluating rainfall rate from approach i or ii, respectively.

Total 167 cases were used in the analysis. The criteria of cases selection are:

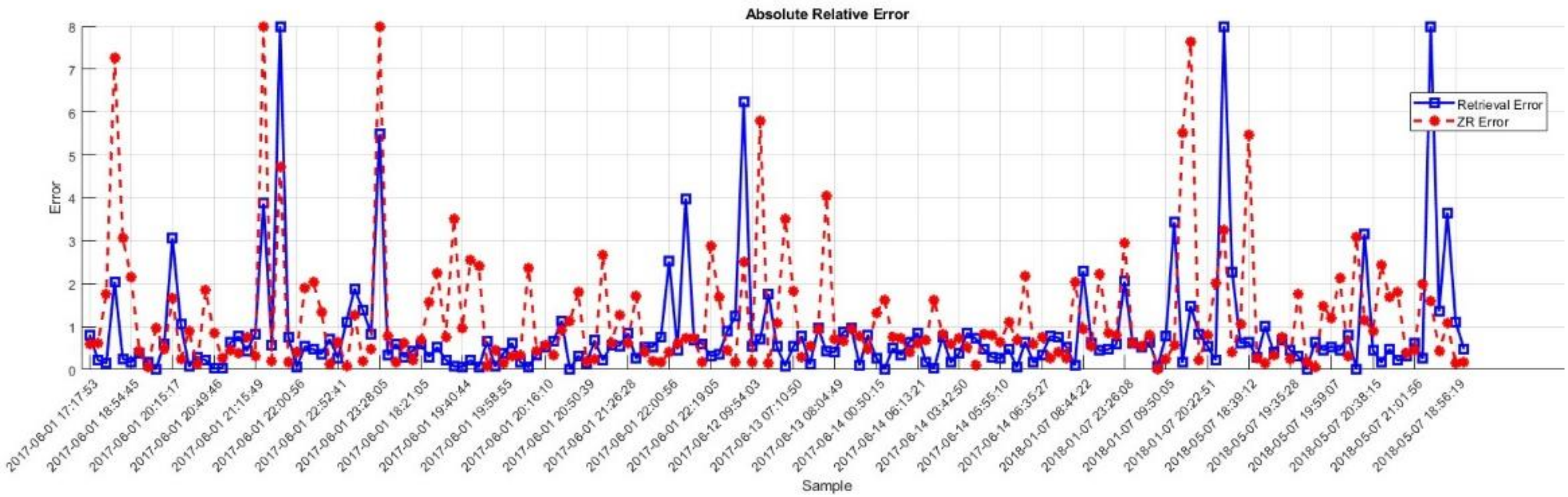
1.) time difference between S- and C- band scan is within 1 minutes

2.) only the lowest two elevation angle (0.5^{o} and 1.4^{o}) are used.

3.) reflectivity > 25 dBZ

4.) 25 km < disdrometer range < 70 km

The time series plot presented below illustrates the RAE results for two different approaches. Approach i, our proposed method, is represented by the blue line, while Approach ii, which employs the conventional *R*(*Z*) method, is indicated by the red line. The plot demonstrates that estimating rainfall rates using retrieved DSD parameters, as in our proposed approach, yields higher accuracy compared to the traditional *Z*-*R* relationship. Specifically, the median RAE for the *Z*-*R* approach stands at 0.72, which is notably reduced to 0.53 with our proposed method. This represents a significant improvement of 26.4% as observed in this study.



In the revision, the quantitative evaluation results and discussions will be added.

4) Unify the variable names such as ZSmeasured, KDP ,measured (Eq.9), ZS', KDPS' etc. in the text and figures.

Response: We will ensure all variables are properly defined and standardized in the revised manuscript.

Specific comments and suggestions:

Response: We greatly value your suggestions and agree that each one merits inclusion in our revised manuscript. In response to your specific comments, we have provided in-line responses, including the implementation of 'was-is' formatting where relevant. Thank you for your insightful contributions.

Line 5: What is the "assumptions of the collected data"? You should be more specific here.

We were referencing the mu-Lambda constraint which can vary depending on location and meteorological conditions. We will rewrite this to be explicit.

Line 37: Delete word "remotely".

Extensive research has been conducted to ~~remotely~~ estimate the drop size distribution (DSD), with many studies utilizing measurements taken at two frequencies.

Line 60: Is the "phase" differential phase?

This approach allows for the determination of DSD solutions that accurately represent the input reflectivity and specific differential phase information.

Line 61-71: The authors only depict the contents in section 2. What about section 3 and 4?

We will rectify this omission by including a brief synopsis of the additional two sections in the introductory material.

Line 74: Suggest changing the sentence to "the measurements of the two co-located polarimetric radars".

In the current work, the measurements of the two co-located polarimetric radars, RCWF (S-band) and RCMD (C-band), are used in the algorithm development and validation.

Line 93: Add year after "Jaffrain et al."

The findings of Jaffrain et al. (2011) demonstrated that sampling uncertainty

Line 98: Change "such and" to "such as".

Other factors, such as ~~and~~ the angle of the drop trajectory, coincidentally observed particles, and particles that intersect with only the edge will also lead to biases.

Line 104: The description of the range rings "two rings with ranges of 20 km and 70 km are shown in Figure 2" is different from the one the Fig.2. Please make sure they are consistent.

After checking the code to generate the plot, the range rings correspond to the ranges in the body of the text, and it is the “100 km” reference in the caption that is in error. Thank you for highlighting this. We will update it in the revised manuscript.

Line 152: What is “Z^S”? reflectivity of S-band? Change “dB” to “dBZ”.

Z^S > 25 dBZ

Line 155: What is “terminal gate”?

We later define terminal gate at line 230. We will move the definition (the gate at the disdrometer location) to line 155 where it is first used.

Line 154: Multiplier “2” is missed in front of K_{DP} in Eq.6. Please also check your algorithm if K_{DP} is multiplied by 2.

Thank you for highlighting this error. You are correct, and we will update Eq. 6 to correctly include the two-way factor. The algorithm does account for attenuation in both directions.

Line 195: Delete word “minimum”.

the ~~minimum~~ system phi_dp

Line 203: Change to “converge to a solution”.

While it can quickly converge ~~on~~ to a solution,

Line 211: What is the coordinates? Please give more specific description about “The three coordinates”.

The three coordinates of the solution space are N_0, mu, and Lamda. We will rewrite this sentence to be more specific and make sure we haven’t made too far a leap in relating the DSD parameters to a coordinate space.

Line 207-220: I did not find the PSO method mentioned or applied in the referred article (Zhang et al., 2001). Please give more explanations on the word “particle” used in the PSO.

Zhang 2001 was referenced for the range of values used in the solution space (second half of the paragraph). We will find a general reference to include in the revised manuscript that can point the reader to an overview of PSO that is consistent with our application. We do want to refrain from misleading the reader that the use of PSO is a major innovation. We contend that many other optimization approaches would work similarly so long as they can overcome local convergence issues.

Line 215-222: Are the parameters alpha and beta the same in Eq. 7 and 8? What does index "i" stand for in Eq.8?

These parameters are different and we should have used different variables in our initial submission to avoid any possible confusion. They are used as weighting factors of the cost function in Eq. 7 and as local/global convergence factors in Eq. 8. We will update this in the revised manuscript.

"i" in Eq. 8 refers to one iteration of the optimization routine as applied to a single gate. We will more thoroughly describe these definitions in the revised manuscript.

Line 226-238: Based on my understanding, the parameters of DSD can be retrieved at each radar gate individually. If just used measured Z^S with less attenuation, k_{DP}^S, and k_{DP}^C at "terminal gate" to retrieve directly instead of the way described here, what difference will make on retrieved DSD?

We retrieved the DSDs for the gates between the radar and the terminal gate solely to more accurately calculate the attenuation factor (also a T-matrix calculation using the DSD) at each position and correct for the accumulated attenuation for the final retrieval. While this may not be as important at S-band, it does become a necessary step for the disdrometer at station 466950 which is located near our 70 km limit.

Line 246-251: Reorganize this part. Please also give the heights of radar "terminal gate" and the disdrometer stations and label them in Fig. 3.

We will reorganize these lines to properly reference Fig 8 before beginning to talk about it. For the radar and disdrometer heights we would prefer to construct an additional table that will include the data you are requesting. This may be a cleaner approach than including it in the Fig. 3.

Line 253-254: Rewrite this sentence.

~~First, the radar cross section, which depends on the physical cross section, is simply smaller and will therefore affect the reflectivity and phase inputs less than the larger drops.~~ First, the radar cross section, determined by the physical cross section, is inherently smaller for these drops, thereby exerting a lesser impact on both reflectivity and phase inputs compared to larger drops.

Line 278-284: The "blue/red circles" and "blue/red triangles" are not found in Fig. 10.

We had simplified the plot, but failed to update the manuscript body. Thank you for catching this. We will revise to reference the proper plot symbology.

Line 283-284: What is the “correction factor”? Please explain how do you “predict” what atmospheric effect.

We will rewrite this section to replace “correction factor” with “attenuation factor” or similar. As stated in response to your insightful comment on Line 226-238, the attenuation is calculated for the intermediate positions using their retrieved DSDs and the T-matrix method.

Fig. 2: Suggest change the sentence in the caption to “radii are drawn around the radar location.” In addition, delete “to indicate the data viability region.”

~~Figure 2. Taiwan - Instrument Locations. The radar site is shown by the solid black asterisk on the North. Circles with 25 km and 100 km radii are drawn around the location to indicate the data viability region. Measurement stations with disdrometers are shown in red. Terrain height is indicated in grayscale throughout the map for reference.~~

Figure 2. Taiwan - Instrument Locations. Radii (25 km and 70 km) are drawn around the radar location. Measurement stations with disdrometers are shown in red. Terrain height is indicated in grayscale throughout the map for reference.

Fig.3 and 4: At what elevation angle and time?

These all correspond to 0.5 degrees elevation. We will note this in the caption. The time is contained in the title of each subplot but may be missed. We will add “UTC” after each HHMMSS timetag to clarify.

Fig. 5: Please define the $Z^{S'}$, $A^{S'}$, etc. in the caption.

We will ensure all variables are clearly defined near their use when we edit the manuscript in response to your general comment 4.

Fig. 6: The Z^{S}_{h}, k^{S}_{DP}, etc. in the dash line box should calculated. Please do not mix up with measured Z^{S}_{h}, k^{S}_{DP}, etc. on the right side of figure.

We will revise the figure to explicitly state the values on the left side of the figures are calculated values and not the measured observed values.