

Response to the comments from the reviewer 1

Responses to the general comments:

We would like to thank the reviewer for the constructive comments and corrections on the paper. The invaluable comments help improve our manuscript. Our responses are as follows.

In this document, for each comment (black font), we display an answer (blue font)

Responses to the specific comments:

Q1) Page 3, ll.28-29: “Thereafter, improvement of quantitative rainfall estimation was investigated by applying derived calibration bias.” This sentence is not clear. Please reformulate.

A1) The sentence has been revised as follows:

After

“Improvement of quantitative rainfall estimation was investigated by applying calculated Z_H and Z_{DR} calibration bias of radar.

Q2) Page 4, Section 2.1 (Disdrometer): It might be worth mentioning here that the 2DVD is considered one of the best and most reliable disdrometers on the market today.

A2) I also think that 2DVD is the most reliable disdrometer compared to other disdrometers. However each instrument has different advantage and disadvantage. So, we did not include the above sentence.

Q3) Page 5, Section 2.3 (Rain gauge): Please provide the brand/make and model number of the tipping bucket and specify if the data were quality controlled or not

A3) The manuscript has been revised as follows:

“The rain gauge used in this study is a RG3-M tipping bucket rain gauge from Onset Computer Corporation. Maximum rainfall rate of rain gauge is 12.7 cm (5 in) per hour, and operating temperature range is from 0° to 50°C. The bucket size of the rain gauge was 0.2 mm and time resolution was 0.5 s. The rain gauge is corrected to reduce instrumental uncertainty through field inter-comparison with reference gauge.”

Q4) Page 6, ll.10-11: Please explain why the rain rates from the 2DVD data are computed using the Brandes et al. (2002) velocity model while the older Atlas et al. (1973) velocity model is used to filter the 2DVD data.

A4) Atlas et al. (1973) fall velocity relation is derived as an exponential formula, and Brandes et al. (2002) fall velocity relation is computed as a polynomial function. For this reason, Brandes et al. (2002) relation is widely used for calculation of rain rates from the 2DVD data.

A number of hydrometeor fall velocity outliers measured by the 2DVD. Some particles have velocities well beyond the terminal velocity (≈ 12 m/s) of large raindrops (Kruger and Krajewski, 2002). So, we applied velocity-based filtering to reduce the effect of instrument errors. We use Atlas et al. (1973) fall velocity formula. This velocity relation has been widely used in many previous studies. In addition, the Atlas et al. (1973) velocity formula is used as a reference relation for comparison with measurement 2DVD data. Therefore, we use Atlas et al. (1973) velocity model to filter the 2DVD data.

Q5) Page 6, ll.24-25: “Therefore, the 2DVD data within 20% ~~percent~~ error were used in this study.” I’m not sure to fully understand what you mean by this. Are those 20% with respect to hourly accumulations or on an event basis?

A5) The manuscript has been revised as follows:

After

“Therefore, the rainfall differences between 2DVD and rain gauge used in this study are limited to a maximum of 20% error, and the 2DVD data were excluded from the analysis when rainfall difference between 2DVD and rain gauge was exceeding 20%.

Supplement

According to previous studies, rainfall differences between disdrometer and rain gauge were mostly from 10% to 20%. Therefore, the rainfall differences between 2DVD and rain gauge used in this study are limited to a maximum of 20% based on these previous studies.

First, after finding all of the quality control of 2DVD and rain gauge data, we calculated rainfall differences (= percent error) for each rainfall events. Second, the 2DVD data were excluded from the analysis when rainfall difference between 2DVD and rain gauge was exceeding 20%. Each accumulated rainfall of rainfall events were used for calculation rainfall difference (= percent error). The difference rainfall of selected rainfall events are listed in Table 2.

Q6) Page 7, ll.22-23: Here, it might be worth to say what you actually mean by “drop diameter” in this context. I assume you are referring to the diameter of a sphere with equal volume.

A6) The manuscript has been revised as follows:

Before

“D is the raindrop diameter in mm”

After

“D is the equivalent volume diameter of the particle in mm. Here, D is the diameter of a spherical drop of volume equal to the volume of the actual drop”

Q7) Page 7, ll.27-28: Please provide at least one good reference for the T-matrix method.

A7) I have attached two references of the T-matrix method.

Zhang, G., Vivekanandan, J., and Brandes, E.: A method for estimating rain rate and drop size distribution from polarimetric radar measurements, *IEEE Trans. Geosci. Remote Sens.*, 39, 830-841, 2001.

Jung, Y., Zhang G., and Xue, M.: Assimilation of simulated polarimetric radar data for a convective storm using ensemble kalman filter. Part I: Observation operators for reflectivity and polarimetric variable, *Mon. Wea. Rev.*, 136, 2228-2245, 2008.

Q8) Page 9, ll.1-2: “The polarimetric radar contains systematic bias of the radar itself.” Not sure what you mean by this. Please reformulate.

A8) The manuscript has been revised as follows:

Before

“The polarimetric radar contains systematic bias of the radar itself.”

After

“The radar measurements are affected by various observational errors, such as ground echoes, beam broadening and abnormal propagation echoes, etc. In addition, calibration biases of radar Z_H and Z_{DR} .”

Q9) Page 10, ll.5-6: *“This means that raindrops in South Korea are more oblate than the others.” This statement needs to be reformulated. There are many possible explanations for this and it would be premature to conclude that raindrops in South Korea are more oblate than in other places. The differences in axis-ratio might also be the result of instrumental effects, drop filtering and event selection. Please reformulate.*

A9) The manuscript has been revised as follows:

After

“These differences of raindrop shape can be caused by a variety of reasons, such as instrumental effects, fitting method, event selection, and different climatic regimes.

Q10) Page 10, ll.20: *“The correlation value of 0.10 mentioned in the text seems to be incorrect.*

A10) The manuscript has been revised as follows: 0.10 \Rightarrow 1.00

Q11) Page 11, Eq.(12) and (13): *There is no need to repeat the definition of the MAE and RMSE here.*

A11) First, we modified the Eq.(12) and Eq.(13) to Eq.(14) and Eq.(15).

R is the rain rate from observed one-minute 2DVD data in Eq (12) and (13) and, R is the averaged one-hour rain rate in Eq (14) and (15). So, we repeated the definition of MAE and RMSE to help readers understand better.

Q12) Page 12, ll, 6-7: *“In addition, the radar rainfall estimations from R(Kdp) and R(Kdp, Zdr) perform better than those of R(Zh, Zdr) for rain rates exceeding 5 mm/h”. This is not obvious from the graph. Please provide hard evidence to back up this statement (e.g., in the form of an additional table or RMSE values for R>5mm/hr)*

A12) We tried to explain the phenomena K_{DP} noise is reduced as rain rate increases (> 5 mm/hr), and combined polarimetric rainfall algorithm using K_{DP} better than $R(Z_H)$ and $R(Z_H, Z_{DR})$ for estimated rainfall at higher rain rates (> 15 mm/hr). However, as your comment, this statement is misleading it was excluded from the paper. Also, the manuscript has been revised.

Q13) Page 12, ll, 14-15: “Therefore, rainfall characteristics should be reflected in polarimetric rainfall relations.” This is too vague. Please reformulate.

A13) The manuscript has been revised as follows:

After

“Therefore, consideration of rainfall characteristics is necessary to improve the polarimetric rainfall algorithm.”

Q14) Page 20, Table 3: Please check if the low correlation values (0.10) are correct.

A14) we change 0.10 to 1.00, thank you very much.

Typos and English:

We would like to express our sincere thanks to the reviewer for the positive encouragement to our work.