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Atmospheric Measurement Techniques Discussions

Interactive comment on "Approaches to radar reflectivity bias correction to improve rainfall estimation in Korea" *by* C.-H. You et al.

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Response to review At first, thank you very much for referee's effort in reviewing our paper even your busy time. We revised the manuscript titled "Approached to radar reflectivity bias correction to improve rainfall estimation in Korea" that was submitted to Atmospheric Measurement Techniques. The manuscript has been revised as suggested by reviewer and we also corrected some mistakes. We would appreciate any feedback on the revisions.

Response to review by Anonymous referee 2 A. Major comments This paper discusses radar reflectivity bias correction to improve rainfall estimation in Korea. The paper content is relevant for its publication. However, for its publication, it needs some revisions as the followings;

1. 1. Introduction Line 28: rainfall rate → areal rainfall rate

Author's Response:

Thank you for your comment. We changed "rainfall rate" into "areal rainfall rate" at line 28 on page 1 in the revised manuscript.

2. 1. Introduction Line 29: This derivation -> this estimation

Author's Response:

Thank you for your comment. We changed "this derivation" to "this estimation" at line 29 on page 1 in the revised manuscript.

3. 1. Introduction, There does not be existed a unique R(Z) -> There is not existed a unique R(Z)

Author's Response:

Thank you for your comment. We changed the sentence accordingly at line 4 on page 2 in the revised manuscript as reviewer's suggestion.

4. Put the values of ranges in figure 1 with interval of 60 km.

Author's Response:

Thank you for your comment. We added the values of range with interval of 60 km on Figure 1 in the revised paper.

5. 2.2 Methodology Line 12: at similar heights -> at the almost same height(?)

Author's Response:

Thank you for your comment. We modified "at similar heights" to "at the almost same height" line 1 on page 6 in the revised manuscript.

6. The reflectivity was calculated from the DSD measurements at 1 min resolution -> The reflectivity was calculated from DSD at 1 min resolution

Author's Response:

Thank you for your kind comment. We modified the sentence as reviewer's comment from line 24 to 25 on page 6 in the revised manuscript.

7. 3.1 Equidistance line method, concerning Fig. 6, it shows average reflectivity difference between PSN and BSL. Which radar shows higher reflectivity? What is the reason on the dominant peak of the average value? It should be explained.

Author's Response:

Thank you for your comment. The negative bias means that the PSN reflectivity was underestimated comparing with BSL reflectivity. For better understanding, we added the following sentence from line 29 to 30 on page 6 in the revised manuscript. "The reflectivity observed by BSL or PARSIVEL subtracted from that observed by PSN was taken as a Z_H bias." And we also added the following description from line 26 to 27 on page 8 in the revised manuscript. "It means that the reflectivity observed by PSN was underestimated comparing with BSL." The dominant peak of the average value occurred from 1500 LT would be caused by the decreased sample number for the comparison of both reflectivities. Therefore, we added the following sentence from line 28 to 31 on page 8 in the revised manuscript. "The number of samples was generally above 60, but it was smaller than 60 after 1450 LST. The dominant peak of the averaged reflectivity difference occurred from 1500 LST would be caused by the decreased sample number for the comparison of reflectivity observed from both radars."

8. 3.1 Equidistance line method, comparing the average reflectivity differences between PSN and BSL in Fig. 6 and 7, most of the average values in Fig. 7 is less than 0 dB. However, most of the average values in Fig. 6 is higher than 0 dB. It should be explained in detail.

Author's Response:

Thank you for your comment. Figure 6 shows the time series of the average reflectivity

difference between PSN and BSL on 25 August in 2014 and Figure 7 is same as Fig. 6 but for on 8 September 2012. The rainfall system was different from each other. We expect that the difference came from two reasons, one is different precipitation system and the other is radar hardware calibration accuracy. Therefore, we added the following sentence from line 20 to 23 on page 11 in the revised manuscript. "It would be caused by the difference of total rainfall amount between two rainfall systems. The maximum total rainfall amount for both cases were around 250 mm for 25 August and 150 mm for 8 September 2012. Another reason of the fluctuation would be the difference of radar hardware calibration error for PSN between two events."

9. 3.2 Overlapping area method, concerning Fig. 10, it shows average reflectivity difference between PSN and BSL. Which radar shows higher reflectivity? What is the reason on the dominant peak of the average value around 03 LST? It should be explained.

Author's Response:

Thank you for your comment. The negative averaged reflectivity means that BSL reflectivity is higher than that of PSN because the difference is equal to the values which are BSL reflectivity subtracted from PSN reflectivity. The possible reason on the dominant peak of the average value around 03 LST is that the sudden change of microphysical characteristics of rainfall pass through the overlapping area. Therefore, we added the following sentence from line 20 to 22 on page 9 in the revised manuscript. "The fluctuation also would be caused by the sudden change of microphysical characteristics of rainfall pass through the overlapping area for both radars. It would reduce the accuracy of Z_H of BSL corrected by self-consistency"

10. 3.3 Disdrometer method, what are the daily rainfall amounts from the gauges and Parsivel on 8 Sept. 2012 ?

Author's Response:

Thank you for your comment. We added the daily rainfall amounts from both instruments from line 9 to 10 on page 10 in the revised manuscript as follows; “daily total rainfall amounts for PARSIVEL and the gauge were 54.4 and 55.0 mm, respectively.”

11. 3.3 Disdrometer method, explain the reason on the unstable behavior of reflectivity from Parsivel in Fig. 13. Is it reasonable to use Parsivel data as a reference in this study? Why is it sufficiently reliable to us as a reference in split of the unstable behavior.

Author’s Response:

Thank you for your comments. We expect that the unstable behavior of reflectivity from Parsivel from 1400 LST to 1500 LST in Fig. 13 of original manuscript was caused by the sudden change of rainfall at that time period. We also should consider the threshold of reflectivity value observed from both PSN and PSRSIVEL to get more reliable Z_H bias. The bias would be obtained more accurately when the reflectivity values observed from both instruments were higher than 15 dBZ in this event. Therefore, we added the following sentence from line 17 to 21 on page 10 in the revised manuscript. “The sudden change of rainfall would cause the unstable reflectivity difference from 1340 LST to 1500 LST. The threshold of reflectivity value observed from both PSN and PSRSIVEL should be considered for the comparison to get more reliable Z_H bias. The bias would be obtained more accurately when the reflectivity values observed from both instruments were higher than 15 dBZ in this event.” Regarding with the possibility of PARSIVEL usage for getting Z_H bias, there are two main uncertainties come from the wind effect and the difference height between both instruments. To know the accuracy of disdrometer, 10 mins rainfall amount measured from disdrometer and gage were compared. We found out that rainfall amount obtained from disdrometer was correlated to that of gage as mentioned in the manuscript. We did quality control algorithm using the equation suggested by Jaffrain and Berne (2011) to reduce the wind effect. $|v(D)_{meas}\text{-}v(D)_{Beard}| \leq 0.6v(D)_{Beard}$

Where, $v(D)_{meas}$ is the velocity measured by PARSIVEL, $v(D)_{Beard}$ is the velocity for a

drop diameter D according to Beard’s model. We checked the maximum wind speed for all cases were less than 8 ms^{-1}. Friedrich and Higgings (2013) found out that once the wind speed exceeded a critical value, approximately 15-20 ms^{-1} based on the observations during Hurricane Ike and VORTEX2, the PARSIVEL continuously observed unrealistically large slow-falling drops as seen during Hurricane Ike. Therefore, we think that the disdrometer data can be used for the analysis. Anyway, we added the limitations from line 28 to 30 on page 11 in the revised manuscript as follows; “It is worth to noting that the result would be changed when the drop size distributions was fluctuated with height especially at the layer between radar beam and ground in case of disdrometer method.”

12. 4 Conclusion, the authors should include comparison of three methods using some statistical parameter.

Author’s Response:

Thank you for your comment. We added the following sentences from line 9 to 26 on page 12 in the revised manuscript “The rainfall estimation using $Z = 200R^{1.6}$ and $Z=300R^{1.4}$ and gauge rainfall were examined for 25 August 2014 and 8 September 2012 to investigate the accuracy of each method. The RMSE, NE, and CC of rainfall pairs for $Z = 200R^{1.6}$ ($Z=300R^{1.4}$) on 25 August 2014 in case of using equidistance method were improved from 65.7 (66.1) to 32.6 (27.0) mm, from 0.79 (0.81) to 0.36 (0.31), and from 0.88 (0.87) to 0.89 (0.88), respectively. On 8 September 2012, the RMSE, NE, and CC for $Z = 200R^{1.6}$ ($Z=300R^{1.4}$) changed from 30.0 (28.5) to 22.5 (20.0) mm, from 0.58 (0.56) to 0.41 (0.36), and from 0.81 (0.8) to 0.78 (0.76), respectively. The RMSE and NE of rainfall pairs for $Z = 200R^{1.6}$ ($Z=300R^{1.4}$) on 25 August 2014 in case of using overlapping method were improved from 65.7 (66.1) to 29.7 (25.8) mm and from 0.79 (0.81) to 0.31 (0.28), respectively. On 8 September 2012, RMSE and NE for $Z = 200R^{1.6}$ ($Z=300R^{1.4}$) were improved from 30.0 (28.5) to 21.8 (19.1) mm and from 0.58 (0.56) to 0.40 (0.34), respectively, by the use of bias correction, while CC for $Z=200R^{1.6}$ was unchanged at 0.81 and that of $Z=300R^{1.4}$ were

changed 0.8 to 0.79. The RMSE and NE of rainfall pairs for Z = $200R^{1.6}$ (Z=$300R^{1.4}$) on 25 August 2014 in case of using disdrometer method were improved from 65.7 (66.1) mm to 42.0 (61.4) mm and from 0.79 (0.81) to 0.40 (0.53), respectively. On 8 September 2012, RMSE and NE for Z = $200R^{1.6}$ (Z=$300R^{1.4}$) decreased from 30.1 (28.6) to 24.6 (23.9) mm, and from 0.58 (0.56) to 0.46 (0.44), respectively, while CC for Z = $200R^{1.6}$ (Z=$300R^{1.4}$) decreased from 0.81 (0.8) to 0.65 (0.59)."

B. Reviewer's recommendation

1. This paper shows radar reflectivity bias correction using three methods to get more accurate rainfall from single polarization radar. The approaches and results are considered as reasonable. Therefore, this paper is recommended for its publication with corrections as suggested in the major comments.

Author's Response:

Thank you for your kind comments. We revised the manuscript according to the reviewer's all comments. We also described the self-consistency method for ZH bias correction using BSL radar, added the hourly reflectivity distribution for both rain events used for the analysis, and added the results from rainfall estimation using Z=$300R^{1.4}$ to follow the reviewer 1's comments. We also modified some mistakes like misspelling.

*** Thank you very much again for your deep review and it will be of much help for better our manuscript quality.***

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/amt-2015-392/amt-2015-392-AC2-supplement.pdf

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