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

C.-H. You et al.

youch@pknu.ac.kr

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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 3

General comments

1. Although the content of the paper is relevant to the meteorological community, there

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Discussion paper

are some concerns. The philosophical justification for each approach is not clear. The DPOL provide more accurate information than SPOL, but still suffers from errors. However, why should a source containing errors (DPOL) be used for correcting another source (SPOL). Even if the approach is justifiable, why should one correct a source where a better source of data exists. I mean, one can use directly DPOL data instead of taking the effort for correcting SPOL?

Author's Response: Thank you for your comment. As reviewer's comment, the best way is to use DPOL directly however, there is some cases SPOL and DPOL are operated at the same time. For example, KMA (Korea Meteorological Administration) is replacing 10 SPOLs to DPOL year by year. The time period when SPOL and DPOL are operated at the same time should be existed for a few years. There is no way to correct reflectivity biases of SPOL, however, we could correct the reflectivity biases of DPOL using self-consistency method. As mentioned in the manuscript, the reflectivity of SPOL was much underestimated. If we use the reflectivity to calculate radar rainfall, its accuracy would not be reliable. When we would like to calculate more accurate climatological radar (SPOL) rainfall, we have to correct the reflectivity errors using possible methods at first. And we would also use this technique in real time for estimating radar rainfall in case both SPOL and DPOL are operated at the same time.

2. Another point is that the DPOL device is an S-Band radar system. How about the other device? Because of the radar radius, I assume that the SPOL device should be an CBand system, (Figure 4, left)? We know that S-Band has unique problems. How do you give explanation for using two different devices for correction? If my guess is not valid, the authors must provide a better explanation of the two devices.

Author's Response: Thank you for your comment and we are sorry to make confused. Both radars are S-band radars. We added the frequency of PSN radar in the revised manuscript 15 line on page 3. "the frequency is 2.712 GHz"

3. When it comes to using disdrometer data and the equidistance method, it is not

clearly explained how it is extended to the rest of the area. A better description must be provided.

Author's Response: Thank you for your comment and we are sorry for the confusion. Once the reflectivity bias is calculated, the bias will be applied to all the pixels of SPOL coverage. Because all three approaches used in this study including disdrometer and the equidistance method is to obtain the bias of SPOL reflectivity. We added the following sentence from 23 to 25 line on page 7 in the revised manuscript for better understanding. "The reflectivity observed by BSL or PARSIVEL subtracted from that observed by PSN was taken as a Z_H bias and it will be applied to all pixels of PSN coverage."

4. In general, I suggest to compare the methods with a common correction method for a better conclusion and investigation of the techniques.

Author's Response: Thank you for your comments. Actually, we could not find the common correction method of SPOL reflectivity in the previous literatures. That is why we tried to propose three approaches to correct SPOL reflectivity. We think that three approaches used in this study would be possible way to correct SPOL reflectivity.

5. Furthermore, the validation must be more clear. What is the temporal resolution of the data being evaluated?

Author's Response: Thank you for your comments. We added the following sentences line 29 on page 7 and line 1 on page 8 and line 8 on page 8 in the revised manuscript for better understanding. Line 29 on page 7 and 1 on page 8 : "The rain gages were 0.5 mm tipping-bucket type. Time resolution of gages is 1 min and data quality control was done by KMA." Line 8 on page 8 : "total accumulated rainfall amounts for analyzed time period"

6. How do you explain comparing radar data with point data.

Author's Response: Thank you for your comments. As reviewer's comment, there

would be some errors on comparing areal data (radar) with point data (gage). We tried to reduce the error by taking small area data (1 km $\times$ 1°) from radar centered on the corresponding rain gauge. Most studies on validation of radar rainfall estimation, gage rainfall is used as a reference. Please understand this.

7. How do you justify using a constant parameter set for the Z-R relationship?

Author's Response: Thank you for your comments. As reviewer's comment, there are many uncertainties of radar rainfall estimation. The variability of Z-R relation is one of main source of these uncertainties. The Z-R relations are different from storm to storm, precipitation types, climatology, and so on. In this study, we would like to show that if the reflectivity is corrected adequately, rainfall estimation would be improved. Anyway we added the results of validations obtained by another Z-R relation, $Z=300R^{1.4}$ which is widely used for NEXRAD in the revised manuscript for better understanding.

Specific comments

P1, L22 to L24: You talk about combining all the three methods. You must address a way how to combine them, and if you think it is better, you should add it to the paper as the fourth method.

Author's Response: Thank you for your comment. As reviewer's comment, the sentences are not connected to our result directly. We removed the lines in the revised manuscript as reviewer's comment.

P2, L6 to L8: How do you evaluate each method in these regards? Your reference data is uncertain!

Author's Response: Thank you for your comment. We put the sentences just to explain the difficulties on radar rainfall estimation in general not to evaluate all things in this study.

P3: why don't you separate the two sections of "Data" and "Methodology". Each method should be described separately in a subsection. A better description of data

must be provided.

Author's Response: Thank you for your comment. We divided "Data and Methodology" into two separated section and we described each method in a subsection in the revised manuscript as reviewer's comment. For better description of data, we added Figures 2, 3 and the following sentences to describe the rainfall cases from line 1 to 23 on page 4 in the revised manuscript." Figure 2 shows the time series of Z_H observed from BSL radar on 8 September in 2012 and 25 August in 2014. The precipitation within radar coverage on 8 September in 2012 was occurred by low pressure with the front located at northern part of Korea. The core of the precipitation systems was elongated from south to north and moved to eastward. The maximum reflectivity of the core was more than 45 dBZ and caused rainfall at the western part of radar center at 0300 LST (Fig. 2(a)), became more organized shape at the eastern part of radar center at 0400 LST (Fig. 2(c)), and moved to eastward and located out of land at 0500 LST (Fig. 2(e)) on 8 September in 2012. The precipitation system on 25 August in 2014 was caused by the low pressure located at southern part of Korea. The two strong rainfall within the radar coverage were located at south-western part of radar center with distance between 120 km and 150 km and southern part of radar center with distance between 30 km and 90 km, respectively at 1200 LST on 25 August in 2014 (Fig. 2(b)). The two convective cells moved to eastward, their strength were intensified and the area of rainfall was wider at 1300 LST (Fig. 2(d)). The two systems moved to eastward continuously, were merged together at 1400 LST (Fig. 2(f)). Figure 3 shows the time series of hourly rainfall and daily accumulation measured by a gage which recorded highest daily rainfall within radar coverage on 8 September in 2012 and 25 August in 2014. The highest daily accumulated rainfall was recorded from North Changwon (ID 255) and Geumjeong (ID 939) on each day, respectively. The daily accumulation of ID 255 was 150 mm, the maximum hourly rainfall was around 40 mm, and the duration of the rainfall was 7 hours (Fig. 3(a)). The daily accumulation of ID 939 was around 270 mm, the maximum hourly rainfall was more than 100 mm h-1. The rainfall amount for 3 hours (1000 LST, 1400 LST, and 1500 LST) were mainly contributed to the total rainfall

accumulation on 25 August in 2014 (Fig. 3(b))."

P3, L9 to L13: You start the paragraph with "Data". What are you referring to? The entire paragraph is a bit unclear.

Author's Response: Thank you for your kind comment. We modified "Data" to "Data observed from PARSIVEL".

P3, L14: What is PSN? What is BSL? Explain the location of each radar device and the abbreviations.

Author's Response: Thank you for your kind comment and we are sorry for confusion. We added the abbreviations line 9 and 10 on page 3 in the revised manuscript as follows; "PSN (Pusan radar) is located at coastal line and BSL (Bisalsan radar) is located 76.9 km away from PSN (Fig. 1),"

P3, L30: You must give reasons for taking the equidistance line for correction. How do you use the correction for the rest of the study area? How reliable is the approach?

Author's Response: Thank you for your comment. The comparison of both reflectivity observed from PSN and BSL which point same target was done in order to get more reliable results. That is why we tried to find out the equidistance line for both radars. And then the difference of reflectivity at the equidistance line would be considered as a systematic bias. Once the bias is obtained, the bias will be applied to all pixels of PSN coverage. As mentioned in the manuscript, the equidistance method would be used if the sample number is enough.

P5, L8: "reflectivity and Z_{DR}" - Either both symbols or both the entire word.

Author's Response: Thank you for your comment. We modified "reflectivity and Z_{DR}" to "Z_H and Z_{DR}" line 26 on page 4 in the revised manuscript.

P5, L9: What is the "systematic bias"

Author's Response: Thank you for your comment. The errors are composed of sys-

tematic bias and random error. We could correct systematic bias but not random error. We focused on the systematic bias. Anyway, for better understanding we modified "systematic bias" to "bias".

P6, L16 to L19: The events must be described in the "Data" section. You should explain a bit the types of the two events.

Author's Response: Thank you for your comment. We moved the sentences in the "Data" section and added explanation of two events in the revised manuscript as mentioned in the author's response to the previous comment.

P6, L21: What are the "reflectivity biases"?

Author's Response: Thank you for your comments. I assume that reviewer means "reflectivity bias" at line 13 on page 6 in the original manuscript. The reflectivity bias means the difference reflectivity between PSN and BSL (PARSIVEL). We modified "reflectivity bias" to "the difference reflectivity between PSN and BSL (PARSIVEL)" line 28 and 29 on page 3 in the revised manuscript for better understanding.

P7, L9: What is the "precipitation system"?

Author's Response: Thank you for your comment. We modified the sentence to the following sentence line 16 to 18 on page 9 in the revised manuscript. "This result suggests that the rainfall observed from both BSL and PSN radar was not located enough over the equidistance line to get a reliable comparison until 0310 LST."

P8, S3.3: As already asked, it is not clear how you use this information for the rest of the study area. For example, for the points far away from the disdrometer.

Author's Response: Thank you for your comment. We added the following sentence from 23 to 25 line on page 7 in the revised manuscript for better understanding. "The reflectivity observed by BSL or PARSIVEL subtracted from that observed by PSN was taken as a Z_H bias and it will be applied to all pixels of PSN coverage."

P9, L1: Which one is “Fig. 16a)”?

Author’s Response: Thank you for your comment and we are sorry for confusion. We added (a) and (b) in Figure 18 (as Figure 16 in original) of revised manuscript.

P14: What are the circle? The legend must be provided including the scaling. What are BSL and PSN and AWAS? Those must be also described in the text.

Author’s Response: Thank you for your comment. We modified figure and captions in Figure 1.

P15: A similar question to the correction approach using disdrometer data. How do you use the information for the rest of the study area?

Author’s Response: Thank you for your comment. We added the following sentence from 23 to 25 line on page 7 in the revised manuscript for better understanding. “The reflectivity observed by BSL or PARSIVEL subtracted from that observed by PSN was taken as a Z_H bias and it will be applied to all pixels of PSN coverage.”

P17: What are the circles? The gray areas?

Author’s Response: Thank you for your comment. We added the following sentence in the caption of the Figure 4 in the revised manuscript. “The red (blue) dotted circle shows the maximum range of BSL (PSN) and gray shaded area show 200 km by 200 km extracted from each radar coverage in the left panel.”

P18: You are averaging over 3 km $\times$ 3°. How do you then take the spatial bias into consideration?

Author’s Response: Thank you for your comment. As mentioned previous reviewer’s comments, we would like to get systematic bias not random noise using equidistance line, overlapping area and disdrometer methods. We assumed the calculated difference between PSN and BSL (PARSIVEL) as a systematic bias. Once the bias is calculated, the bias will be then applied to all pixels of radar coverage.

P21: Following the y-intercept, the given equations are not going through the origin. How is it possible? Would it not result in a systematic error?

Author's Response: Thank you for your comment. The fitting line shows the relation between radar rainfall and aws rainfall. If both rainfall are completely same, the given equations are going through the origin. However, the rainfall from radar is not same as that from gage. We agreed with reviewer's comment. It would be caused by a systematic error.

P22, and P23: A complete description of the figure must be provided.

Author's Response: Thank you for your comment. We added complete description of the figure.

Technical corrections There are some parts with poor English. The ones I found: P1: The last sentence in the abstract.

Author's Response: Thank you for your comment. As reviewer's comment, we have already removed the sentence.

P2: L4-L5

Author's Response: Thank you for your comment. We modified the sentence to the following sentence in the revised manuscript. "There is no unique R(Z), since DSDs can be varied storm to storm and even within a single storm (Battan 1973; You et al., 2010)."

Additional revision according to other reviewers' comment 1. We added some sentences to describe the self consistency method from line 12 on page to line 4 on page in the revised manuscript.

2. We added some sentences in Sect. 5 from line 9 to 26 on page 12 in the revised manuscript.

3. And we also modified or added some sentences in the revised manuscript for better

understanding.

*** 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-AC3-supplement.pdf

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