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Hydrology and Earth System Sciences
Discussions

Interactive comment on "The possibility of rainfall estimation using R(Z,Z_{DR},K_{DP},A_H): A case study of heavy rainfall on 25 August 2014 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 "The possibility of rainfall estimation using R(Z,ZDR,KDP,AH): A case study of heavy rainfall on 25 August 2014 in Korea" that was submitted to Hydrology and Earth System Sciences. The manuscript has been revised as suggested. We would appreciate any feedback on the revisions. Response to review by Anonymous referee #1

General comments 1. The authors attempt to validate a dualpol rain rate estimator. This should be stated in the title. To use "possibility" is the wrong term.

Author's Response :

We changed the title to "The validation of polarimetric rainfall estimators using R(Z,ZDR) and R(Z,ZDR,KDP,AH) in Korea" as reviewer's comment.

2. The authors touch important aspects and have some interesting ideas: finding a correct rr estimator, addressing the sampling issues for dualpol data, but in my view none of the issues are analyzed to an extent that is needed. For example ZDR. A method to derive the ZDR bias from disdrometer data is suggested. But I cannot find a verification of this approach.

Author's Response :

Thank you for your comment. The reference of ZDR bias measured by vertical pointing scan was needed to verification of ZDR bias obtained by this approach. The scan strategy of the BSL radar operated by Ministry of Land, Infrastructure, Transportation is not included vertical pointing scan for their purpose (rapid update data). That is why we are trying to find out the method for calculation of good ZDR bias and qualified ZDR. Therefore, we tried to validate the approach using rainfall comparison of radar and gage. Of course, there are many uncertainty for the estimation of radar rainfall such as difference of gage height and radar beam height, accuracy of radar rainfall relations, etc..

3. Also, the paper needs to be restructured. As such, the ZDR aspects are spread throughout the paper. So everything related to data quality should be one section (especially with respect to ZDR). Once this is handled, one can focus on the rain rate estimator, where the proposed one is compared to the ones that are typically used. In the current form it is really hard to collect all the pieces of information.

Author's Response:

We re-organized the manuscript as reviewer's comment. In "3. Result", we divided it two parts "3.1 Data quality of ZDR" composed of "3.1.1 Improvement of ZDR data quality using moving average", "3.1.2 Absolute bias correction of ZDR and ZH", and "3.1.3 Improvement of ZDR data quality using disdrometer" and "3.2 Validations of rainfall relations" including "3.2.1 The performance of rainfall relations with different ZH and ZDR biases obtained from the observed ZDR and mZDR", "3.2.2 The performance of the relations using ZDR bias obtained by disdrometer", "3.2.3 The simulation of R(Z,ZDR,KDP,AH) using generated variables". We modified figure number and related descriptions accordingly.

4. The authors just state that there is no birdbath data available for this event. The way they write the paper, it appears that the system is capable doing so. Then it should be an easy task to assess the proposal with a different set of data. I think there is material for a paper but the current form is not sufficient for publication.

Author's Response:

Thanks to reviewer's comment, we could add two more cases in the manuscript. The three rainfall events occurred on 23 August 2012, 8 September 2012, and 25 August 2014, which were caused by indirect effect of Typhoon, low pressure accompanied with the front, and low pressure were included and summarized in Table 1. We added related figures and description in the manuscript and also modified the some mistakes

Specific comments

1. The authors suggest that ZDR from a disdrometer might be used for calibration. This implies that ZDR is constant with height, so that such an estimate can be related to the radar height. This might be true to some extent in an stratified rain situation, but the rain rates considered here are certainly beyond a stratiformed rain situation. In other words the argument here is missing a proof, at least a discussion of possible limitations is needed.

Author's Response:

We agree that there is some limitations of using disdrometer data especially for the

convective systems which have much fluctuation of DSD with height. There would be fluctuation of DSD with height in three cases we analyzed. Unfortunately, there was no way to find out the distribution. As reviewer's comment, we added the limitations in the Sect. 4. Conclusions of the manuscript as follows; "Using DSD data for the calculation of ZDR bias might give more accurate rainfall estimation with R(Z,ZDR), even it is limited to the homogeneous DSD at the layer between radar beam height and ground and not strong wind condition which could degrade the quality of ZDR calculation from disdrometer."

2. The authors do not attempt to make an recommendation which rr to use now. Or is there further research needed? What about the "robustness" of the approach, s.th. the authors state in the introduction? This is not addressed.

Author's Response:

Thank you very much for your comments. The study is of course needed to obtain more and more accurate radar rainfall estimation. In this study, we found out that R(Z,ZDR) was better when the ZH bias and ZDR bias can be obtained accurately otherwise R(Z,ZDR,KDP,AH) had better comparing with both relations. We added the description in Sect. 4 of the manuscript as follows; "Using DSD data for the calculation of ZDR bias might give more accurate rainfall estimation with R(Z,ZDR), even it is limited to the homogeneous DSD at the layer between radar beam height and ground and not strong wind condition which could degrade the quality of ZDR calculation from disdrometer. Comparing the statistical scores between the most accurate R(Z,ZDR) and R(Z,ZDR,KDP,AH) in this study, R(Z,ZDR) had better performance than that of R(Z,ZDR,KDP,AH). However, R(Z,ZDR,KDP,AH) is expected to be less sensitive especially to ZH and ZDR errors in both observations and simulations. Therefore, R(Z,ZDR,KDP,AH) could be used as a representative rainfall relation in case ZDR bias was not calculated accurately in Korea."

3. What is the accuracy goals for the estimator. How did the rr estimator work for other

data sets? Anyone else is using it? What accuracy is achieved there?

Author's Response:

We think it is related to number 2 of reviewer's comment. We found out that R(Z,ZDR) was better when the ZH bias and ZDR bias can be obtained otherwise R(Z,ZDR,KDP,AH) would better in this study.

4. Ah(I assume the path integrated attenuation) is not introduced. How is it computed, quality control formula.

Author's Response:

Reviewer's is totally right. We used following method which was explained in You et al. (2015a) to calculate AH from polarimetric radar. We added the some descriptions for AH calculation in the Sect. 2.2 of manuscript like "AH was calculated from the radial profile of the attenuated reflectivity and two-way PIA (Path Integrated Attenuation) along the propagation path using observed ZH, differential phase shift from BSL radar. The more detailed description for AH calculation can be found in You et al. (2015a)." Please refer to supplement 1.

5. Also the rr estimators should be introduced in more detail. For some of the estimators recommendations can be found in literature. Why not using a R(Kdp) relationship?

Author's Response:

As reviewer may understand our purpose of this study, we would like to focus on the performance of polarimetric radar rainfall relations with respect to ZDR. That is why we compared two relations R(Z,ZDR) and R(Z,ZDR,KDP,AH) which are dependent on ZDR data. For reviewer's understanding, the results from R(KDP) were shown below.

Figure 1. Scatter plots of gage rainfall and R(KDP) on (left) Case 1, (middle) Case 2, (right) Case 3.

6. The rr estimators need to be introduced in the text (not just in a table) with refer-

ences.

Author's Response:

We added following sentences in Sect. 2.3 of the manuscript. Fig. 3 shows the scatter plot of rain rate obtained from disdrometer and polarimetric radar rainfall relations R(Z,ZDR) and R(Z,ZDR,KDP,AH). The CC and RMSE of R(Z,ZDR) (R(Z,ZDR,KDP,AH)) were 0.95 (0.99) and 3.5 mm h-1 (1.2 mm h-1) which are same relations used in You et al. (2015a). The rainfall relations for validation and simulation are summarized in Table 2.

7. Did the authors verify the result with another data set? Section 2.1.

Author's Response:

As reviewer's comments, we added two more cases in the manuscript as mentioned in above answer to the reviewer's comments related to data set.

8. Quality control of disdrometer: very crude. It is well known that wind effect can bias disdrometer measurements. Did authors check for this? If not, they should do this and figure out how the conclusions may change in their study.

Author's Response:

Thank you for your comments. It is true that wind effect can give bias disdrometer measurements. Actually, we did not consider wind effect for this study. We did quality control algorithm using the equation suggested by Jaffrain and Berne (2011) to reduce the wind effect. |ãĂŰv(D)ãĂŮ_meas-ãĂŰv(D)ãĂŮ_Beard |≤0.6ãĂŰv(D)ãĂŮ_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. However, to know the accuracy of disdrometer, 10 mins rainfall amount measured from disdrometer and gage were compared. We found out that rain rate obtained from disdrometer was correlated to that of gage as shown in Fig. 7 in the manuscript. 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 thought that the disdrometer data can be used for the analysis. Anyway, we added the limitations in the Sect. 3.2.2 of the manuscript as follows; "However, these results would be changed when the drop size distribution of the rainfall system was fluctuated with height, especially at the layer between radar beam and ground. And the wind effect is another limitation of this results."

Figure 2. Time series of the 10min. maximum wind speed in one hour from Automatic Weather System located nearby PARSIVEL for three cases

References: Jaffrain, J., Berne, A.: Experimental quantification of the sampling uncertainty associated with measurements from PARSIVEL disdrometers, J. Hydrometeor., 12, 352-270, 2011. Friedrich, K., Higgings S.: Articulating and stationary PARSIVEL disdrometer measurements in conditions with strong winds and heavy rainfall, J. Atmos. Ocean. Technol., 30, 2063-2080.

Section 3.1 SD(ZDR): here terms accuracy and bias seem not properly separated. What a bias/uncertainty is should clearly separated.

Author's Response:

We changed "accuracy" into "performance" in the manuscript.

Error propagation (4.2): Not really introduced here. How are the distributions used? Independently (like a Monte-Carlo simulation). Here, suddenly other estimators are discussed here(R(Kdp) for example). For the real world comparison, these are not discussed. Why? If you want focus on R(Z,ZDR) and the proposed one here, you focus on these here as well. Or you say s.th about the performance (statistically) in section 3.3.

Author's Response:

In this section, we would like to show effect of the multi-cor-linearity for R(Z,ZDR,KDP,AH) because ZH and KDP are highly correlated as shown below Table 1. This can reduce the accuracy of relation for some cases but not all cases. To understand the robustness of the relation, we generated polarimetric variables just assuming Gaussian distribution as mentioned in the manuscript. The simulation and observation showed the ZH and KDP could interact in the direction of reducing an error of the relation from the simulation.

Table 1. The correlation coefficients of variables measured by POSS disdrometer. (Kang, 2016) : please Fig. 3 of attaches.

P 12/l. 12 ff: So if you have a HMC, you will abandon your proposed rain estimator? Really? So you implicitly state here, that it is not the best choice. What is a better choice?

Author's Response:

Thank you for your comments. We just would like to mention that both relations used in this study is not adequate for the solid precipitation like snow, hail. Anyway, we changed the sentences in the Sect. 4 as follows; "R(Z,ZDR,KDP,AH) is expected to be less sensitive especially to ZH and ZDR errors in both observations and simulations. Therefore, R(Z,ZDR,KDP,AH) could be used as a representative rainfall relation in case ZDR bias was not calculated accurately in Korea."

*** 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.hydrol-earth-syst-sci-discuss.net/hess-2015-515/hess-2015-515-AC1-supplement.zip

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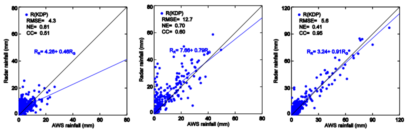

Figure 1. Scatter plots of gage rainfall and R(K_{DP}) on (left) Case 1, (middle) Case 2, (right) Case 3.

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Fig. 1.

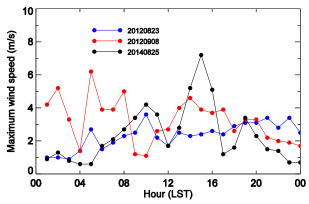

Figure 2. Time series of the 10min. maximum wind speed in one hour from Automatic Weather System located nearby PARSIVEL for three cases.

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Fig. 2.

Table 1. The correlation coefficients of variables measured by POSS disdrometer. (Kang, 2016)

Variables	ZH	ZDR	KDP	AH
ZH	1	0.31	0.98	0.69
ZDR	0.31	1	0.28	0.16
KDP	0.98	0.28	1	0.69
AH	0.69	0.16	0.69	1

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Fig. 3.