Hydrol. Earth Syst. Sci. Discuss.,
doi:10.5194/hess-2015-515-AC2, 2016

Hydrology and Earth System Sciences
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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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Received and published: 2 March 2016

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,Z_{DR},K_{DP},A_H): 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 2

Overview

1. The aim of the authors is to find the optimum quantitative precipitation estimation

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method for the first dual-pol S-Band radar in Korea. To this end they search for the best method to remove biases in (horizontally polarized) reflectivity measurements (Z_h) and in differential reflectivity (Z_{DR}). They test mainly R(Z_h,Z_{DR}) and R(Z_h, Z_{DR}, K_{DP}, A_h), the later one proves to provide quite stable and reliable estimates of the rain intensity. A basic requirement for a publication is, that an (educated) reader is able to comprehend what was done and that she/he is able to repeat the investigation, based on the information of the publication. This goal is not met by this manuscript. I did not find a clear structure within the paper. It should be stated clearly, that different approaches to determine the biases in Z_h and Z_{DR} will be discussed in advance of describing the first approach.

Author's Response:

Thank you for your comment. We reorganized "2 Data and methodology and 3 Results" of the manuscript to help a reader understand what was done in the paper as follows; 2 Data and methodology; 2.1 Gage, disdrometer and radar data; 2.2 Calculation of polarimetric; 2.3 Z_{DR} data quality improvement; 2.4 Validation, 3 Results; 3.1 Data quality of Z_{DR}; 3.1.1 Improvement of Z_{DR} data quality using moving average; 3.1.2 Improvement of Z_{DR} data quality using disdrometer; 3.2 Validations of two rainfall relations; 3.2.1 The performance of rainfall relations with Z_H and Z_{DR} biases obtained by radar, 3.2.2 The performance of the relations using Z_{DR} bias obtained by disdrometer, 3.2.3 The simulation of R(Z,Z_{DR},K_{DP},A_H) using generated variables. We also changed the title of the paper as the first reviewer's suggestion "The validation of polarimetric rainfall estimates using R(Z,Z_{DR}) and R(Z,Z_{DR},K_{DP},A_H) in Korea".

2. The abstract does not describe what is done in this investigation.

Author's Response:

Thank you for your comment. We modified the abstract to describe what was done in this investigation more clearly as follows; "To improve the accuracy of polarimetric rainfall relations with different Z_{DR} bias calculations using 9 gate averaged Z_{DR} and a disdrometer, three rainfall cases were analysed and some methods were examined. The observed differential reflectivity (Z_{DR}) quality check was theoretically investigated using the relation between the standard deviation of differential reflectivity and cross correlation, and the light rain method for Z_{DR} bias was also applied to the rainfall estimation. The best performance for these heavy rainfall case was obtained when the moving average of Z_{DR} over a window size of 9 gates was applied to the rainfall estimation using horizontal reflectivity (Z_H) and Z_{DR} and to the calculation of Z_H bias. The differential reflectivity calculated by disdrometer data may be an alternative to the vertical pointing scan for calculating Z_{DR} bias. Comparing the statistical scores between $R(Z,Z_{DR})$ and $R(Z,Z_{DR},K_{DP},A_H)$ in this study, $R(Z,Z_{DR})$ had better performance than that of $R(Z,Z_{DR},K_{DP},A_H)$. However, $R(Z,Z_{DR},K_{DP},A_H)$ is expected to be less sensitive especially to Z_H and Z_{DR} errors in both observations and simulations. Therefore, $R(Z,Z_{DR},K_{DP},A_H)$ could be used as a representative rainfall relation in case Z_{DR} bias was not calculated accurately in Korea."

3. The paper contains a large amount of oversight, reducing the confidence in the care the authors took. The scientific innovation within this paper is quite limited. Known QPE approaches are tested and the results gathered during a strong precipitation event are presented. It is questionable if this is innovative enough to justify publication. Because of the limited quality in presentation I would reject the paper in the present form.

Author's Response:

Thank you for your comments. There are many researches on rainfall estimation using polarimetric variables. The researches were focused on $R(Z,Z_{DR})$, $R(K_{DP})$, $R(K_{DP},Z_{DR})$, $R(Z,Z_{DR},K_{DP})$. Recently, Ryzhkov et al. (2014) firstly found that the specific attenuation gives us more accurate rainfall estimates even for S-band polarimetric radar. After their study, A_H became one important variable for quantitative usage for S-band polarimetric radar. Most studies of rainfall estimation using AH, the performance of $R(A_H)$ was examined. The combined rainfall relations like $R(Z,Z_{DR},K_{DP},A_H)$ was rarely investigated until now. This study was focused on the performance of rainfall relations such as R(Z,ZDR) and R(Z,Z_{DR},K_{DP},A_H) with respect to Z_H and Z_{DR} bias and Z_{DR} data quality using observed data and generated data. We think these results obtained from this would be a possible topic for publication. We also added two more cases in the manuscript to make the paper more confident. 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 some mistakes.

Specific notes

1. p2, l16: “different drop shape”, different from what?

Author’s Response:

We are sorry for the confusion. We added the descriptions to make it clearly from line 19 to line 21 on page 2 in the revised manuscript as follows; “1) equilibrium shapes defined by Beard and Chuang (1987), 2) oscillating raindrop shape from Bringi et al. (2003) and 3) shapes specified by Brandes et al. (2002).”

2. p2, l28: KMA installed an S-Band polarimetric radar in the fare northwest of Korea. Later in the next, the Bislsan radar was the first polarimetric radar in Korea. Bislsan is in the southeast of Korea. Is this a contradiction or are there at least two polarimetric radars in Korea?

Author’s Response:

We are sorry for making reviewer confused. We would like to describe the current status of polarimetric radar network in Korea. KMA (Korea Meteorological Administration) installed one S-band polarimetric radars in 2014 and KMA is replacing 10 single polarization radars into polarimetric radar. The replacement will be done until 2019. MoLIT (Ministry of Land, Infrastructure and Transportation) installed 5 S-band polarimetric radars since 2009 and will install one more radar soon. Ministry of National

Defence (NMD) has plan to replace 6 C-band single polarization radars into polarimetric radar. Anyway, because the description "The KMA installed an S-band polarimetric radar in the far northwest of Korea in 2014" was not important information we removed the sentence.

3. p3, l26: Fig. 1 show the location of all instruments? Where are the rain gages mentioned at the beginning of chapter 2.3?

Author's Response:

Thank you for your comment. We added the location of gages described in Section 2.3 of original manuscript in Figure 1 and added the following sentence line 3 to 5 on page 4 of revised manuscript. "The cross (ID 945, Daebyung site), triangle (ID 926, Jinbook site), and diamond (ID 255, North Changwon site) with plus sign show the location of gages which recorded the maximum daily rainfall accumulation in each rainfall events will be analysed in Sect. 2.4."

4. p4, l2: Radar Bislsan is (according to my digital elevation model) at a height of more than 1 km asl. The disdrometers are quite close to see level. In 82 km from radar the 0.5° beam is 1.1 km above radar height. There is nearly 2 km separation between radar and disdrometer measurements? Are these data comparable? You should at least discuss this problem.

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. 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 Z_{DR} bias might give more accurate rainfall estimation with R(Z,Z_{DR}), 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."

5. p3, l12: Drop numbers count only in the lower channels leads to an removal of the data. In the next step you remove drop size spectra with drop number counted only in the lower 5 channels? This is done twice.

Author's Response:

Thank you for your comment, As reviewer's comment, we removed the description.

6. p4, l25: The prefactor of D is 0.00057, not 0.5. . ..

Author's Response:

Thank you for your comment. We modified Equation (1) correctly.

7. p5, l24: What is N? N is the number of rain gages(121) or the number of hourly measurements (7 *121)?

Author's Response:

Thank you for your comment. N is the gage number multiplied by analysed hours. We modified the corresponding sentence as follows; "N is the number of radar rainfall (R_R) and gage rainfall (R_G) pairs, and and are the hourly rainfall amount in each rainfall event from the radar and gage, respectively."

8. p6, l20: There is no Bringi and Chandrasekar (2003). You assumable meant 2001, or did you mean Bringi et al. 2003?

Author's Response:

We are sorry for confusion. Bringi and Chandrasekar (2001) is correct. We modified it.

9. p6, l21: At least in Bringi and Chandrasekar (2001) I did not find this equation. Please give a more precise citation. What is ρ_{co}, what is ρ_{co}(l)? is ρ_{co}= ρ_{co}(0)? You call the correlation at different palces, ρ_{co}, ρ_{co}(l), ρ[n] and ρ_{hv}. Is it all the same thing? So please indicate what meant by which term.

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Author's Response:

Thank you for your comment. We unified all terms into hv. We also added the equation number of Bringi and Chandrasekar (2001) in the revised manuscript.

10. p7, l6: With equation 8, an L of over 3 (line 11) is reached by ρ_{hv}> 0.5 and an L of 1.7 (line 14) needs ρ_{hv}=.32. Probably the prefactor 10 is wrong in equation 8. Author's Response:

Thank you for your kind comment. We removed prefactor 10 in Eq. (8).

11. p8, l2: Ryzhkov et al. (2005a)

Author's Response: Thank you for your comment. We modified it in the revised manuscript.

12. p8, l19: Why do you have problems to detect the melting layer by a 6 elevation volume scan? There are approaches to determine the melting layer from an individual elevation.

Author's Response:

Thank you for your comment. In summer of Korea, the brightband is usually occurred at the layer between 4 and 5 km. Considering the maximum elevation and range of BSL are 1.6 degree and 150 km, the bright band may be located at the range of around 130 km even we consider the height of BSL. And dry aggregated snowflakes are commonly presented in the first two kilometres above the melting layer. It would be considered that it is very difficult to use dry aggregated snow method. That is why we described that the scan strategy with six elevation angles not to detect the melting layer. For reader's understand, we modified the description as follows in the revised manuscript; "The scan strategy of BSL with six elevation angles (-0.5, 0, 0.5, 0.8,1.2,1.6 degree) is not allowed to use dry aggregated snow method to calculate Z_{DR} bias."

13. p10, l24: Table 3 contains the results from chapter 3.3. The results from chapter

4.1 are not given.

Author's Response:

Thank you for your kind comment. We added Table 5 and Table 6 to summarize the results of Chapter 3.2.2 in the revised manuscript.

14. p11, l5: As far as I got it, you never introduced Ah, although that term is already used in the title. I assume, A_h is the path integrated attenuation for the horizontally polarized wave. This should be measured in dB/km but not in degrees/km.

Author's Response:

Thank you for your comment and we are very sorry for confusion. We modified A_H unit from degrees/km to dB/km and also described the following sentence about the AH in the revised manuscript. And we attached the supplement which includes more detail description about A_H calculation. "A_H was calculated from the radial profile of the attenuated reflectivity and two-way PIA (Path Integrated Attenuation) along the propagation path using observed Z_H, differential phase shift from BSL radar. The more detailed description for A_H calculation can be found in You et al. (2015a)."

15. p11, l18: What is an error step? You do not describe what you really did. I reconstruct, you increased added errors in Z_h, Z_{DR}, K_{DP}, and A_h simultaneously. How did you control the error covariances? How did you distribute the errors?

Author's Response:

Thank you for your comment and we are sorry for confusion. The errors of Z, Z_{DR}, and K_{DP} ingested to simulated data were distributed 0 to 5 dBZ with interval 0.25 dBZ, 0 to 0.6 dB with interval 0.03 dB, and 0 to 0.2 degree/km with interval 0.01 degree/km, respectively as mentioned in the manuscript. The errors were ingested to the simulation with 21 steps. For example, the errors of Z_H, Z_{DR}, K_{DP} were ingested to the simulation as much as 0.25 dBZ, 0.03 dB, 0.001 degree/km$innumber1ofx-axisontheFigure14.Atthesameway,theerrorswereincreasedwithintervalofeachvariableasthenumberofx-$

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$axisincreases.Wedidnotconsidertheerrorcovariancesinthisstudybecausewewouldliketosimulateundertheworstsituationa$
is relatively weakly affected by errors in each polarimetric variable even though the error co-variances were not considered in the simulation."

16. p13, l3, and l14: No "

Author's Response:

Thank you for your comment. We guess that No means Journal number. According to the Copernicus Publications Reference Types, we do not have to describe the Journal number.

17. p14, l28: Malte Diederich

Author's Response:

Thank you for your comments. We modified it in the revised manuscript.

18. p17, table 1: Give citations for the applied relations.

Author's Response:

Thank you for your comment. We added citations in Table 2 of revised manuscript and also added Figure 3 as the first reviewer's comment.

19. p17, table3: The exponent of Z_{DR} is in the wrong line.

Author's Response:

Thank you for your comment. We modified the Table 3.

20. p20, figure3c: Average of ρ, not $STDZ_{DR}$.

Author's Response:

Thank you for your kind comment. We modified the Figure.

21. p22, figure 5c: (same error)

Author’s Response:

Thank you for your kind comment. We modified the Figure.

22. figure 6, 10, 11: Most data are plotted in the lower left corner. I propose to use double logarithmic scales or to add an enlarged version additionally to show the data up to 20 mm rainfall.

Author’s Response:

Thank you for your comments. We added enlarged version additionally to show the scatters up to 20 mm h^{-1}.

23. figur9: It should be “range” not “Gate”

Author’s Response:

Thank you for your comment. We modified Figure 9.

24. figure 12: Specific attenuation in dB/km, not degrees/km

Author’s Response:

Thank you for your comment. We modified the unit of Specific attenuation.

*** 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-AC2-supplement.zip

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2015-515, 2016.