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Atmospheric Measurement Techniques Discussions

Interactive comment on "Dual-polarization radar rainfall estimation in Korea according to raindrop shapes using a 2D Video Disdrometer" *by* H.-L. Kim et al.

Anonymous Referee #5

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General comments

The submitted paper talks about the development of a new axis-ratio relation with the 2DVD, wich is compared with other axis-ratio relations already known in the literature. The Authors applied also polarimetric rainfall algorithms to calculate the rain by utilizing as inputs polarimetric parameters, which are both measured by the radar and simulated by the disdrometer, according to the considered axis-ratio relations. Both radar and disdrometer rainfall estimates are then compared with rain gauges measurements. Another goal of the present work is to corrected horizontal reflectivity and differential reflectivity biases affecting radar estimates by comparing radar and 2DVD disdrometer polarimetric parameters. Gauge data are considered as truth. The topics of the paper

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Discussion paper

are ones of the most discussed in radar meteorology. Several past works, such as those cited by the Authors, have already dealt with the same problems giving valuable contributions in the assessment of radar estimates (see an additional reference list below for example). It's my opinion that the submitted work surely gives a contribution to the aforementioned topics. In fact, the element of originality is constituted by the fact the axis ratio relation proposed by the Authors can adapt to the particular weather conditions of the place in which it was developed, improving locally the radar estimates. So it's my opinion that some parts of the paper should be rewritten because poorly written (see specific comments and technical corrections). I also suggest to the Authors to submit the article after a revision concerning the English language. In conclusion, I believe that the manuscript it worth for publication after some major revisions.

Additional references

Lombardo, F., Napolitano, F., Russo, F., Scialanga, G., Baldini, L., and Gorgucci, E.: Rainfall estimation and ground clutter rejection with dual polarization weather radar, Adv. Geosci., 7, 127– 130, doi:10.5194/adgeo-7-127-2006, 2006b.

Sebastianelli, S., Russo, F., Napolitano, F., & Baldini, L. (2013). On precipitation measurements collected by a weather radar and a rain gauge network. Natural Hazards and Earth System Science, 13(3), 605-623, doi:10.5194/nhess-13-605-2013.

Zawadzki, I.: Factors affecting the precision of radar measurements of rain, in: Proceeding of the 22d Conf. Radar Meteorology, Zurich, Switzerland, 10–13 September 1984, Amer. Meteor. Soc., 251–256, 1984.

Villarini, G. and Krajewski,W. F.: Review of the different sources of uncertainty in single polarization radar-based estimates of rainfall, Surv. Geophys., 31, 107–129, 2010.

S. Spina, S. Sebastianelli, E. Ridolfi, F. Russo, L. Baldini, and L. Alfonso: Data selection to assess bias in rainfall radar estimates: An entropy-based method, AIP Conference Proceedings 1558, 1665 (2013); doi: 10.1063/1.4825849.

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Zhang, J. and Qi, Y.: A real-time algorithm for the correction of brightband effects in radar-derived QPE, J. Hydrometeorol., 11, 1157–1171, 2010.

Zhang, J., Langston, C., and Howard, K.: Brightband identification based on vertical profiles of reflectivity from the WSR-88D, J. Atmos. Ocean. Tech., 25, 1859–1872, 2008.

Gorgucci, E., Scarchilli, G., and Chandrasekar V.: Calibration of radars using polarimetric techniques, IEEE Trans. Geosci. Remote Sens., 30, 853-858, 1992.

Specific comments and technical corrections

P1, title: I would suggest: “Dual-polarization radar rainfall estimation in Korea according to raindrop shapes obtained by a 2D Video Disdrometer”.

P1, line 23: what did you mean with “a new axis ratio of raindrop relations”? It’s a relation between the raindrop axis ratio and the raindrop diameter? Please specify. It’s my opinion that you should better introduce this relation both in the abstract and in the introduction.

P1, lines 24-25: if you say: “polarimetric rainfall algorithms were derived using different axis ratio relations”, it seems that the polarimetric algorithm changes depending on the axis ratio relation you consider. But if we observe table 3 you applied each polarimetric rainfall relation with the same 4 axis ratio relations. Instead, the polarimetric parameter depend on the shape of raindrops you assumed, as it’s better specify at page 7 lines 28-29. So you should rephrase.

P1, lines 25-26: what did you mean saying “radar-point one hour rain rate”? A radar estimates rain in a pixel not in a point. A rain gauge measures rain in a point. Could you specify if the pixel in question includes within it the rain-gauge location? Furthermore with “one-hour rain rate” did you mean the average rain rate in a hour? It would be better if you put the unit. I would suggest to write “the radar-pixel hourly mean rain rate”.

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P1, lines 24-27: you wrote: “Second, polarimetric rainfall algorithms were derived using different axis ratio relations, and estimated radar-point one hour rain rate for the differences in polarimetric rainfall algorithms were compared with the hourly rain rate measured by gauge.” The sentence is too long, please split it. Moreover, I suggest writing: “the estimated radar-pixel hourly mean rain rate obtained from the different polarimetric rainfall algorithms” instead of “estimated radar-point one hour rain rate for the differences in polarimetric rainfall algorithms”

P1, lines 27-28: I would change “in relation to calibration bias of reflectivity and differential reflectivity” into “to calibrate reflectivity and differential reflectivity biases”.

P1, lines 28-29: the sentence is poorly written, I suggest to write: “For D < 1.5 mm and for D > 5.5 mm the shape of raindrops obtained by the new axis-ratio relation developer by the 2DVD is more oblate than the shapes obtained by the existing relations”.

P2, lines 6-9: the sentence is poorly written, I would write “Zh and ZDR biases were calculated by comparing Zh and ZDR radar measurements with the same parameters simulated by the 2DVD. In order to produce more accurate rainfall estimation.” (it is redundant to say that a bias is used to correct a bias). In addition it’s my opinion that you should better specify what is the aim of your work. If I understood, you developed a new axis-ratio relation with the 2DVD. You developed also the polarimetric rainfall algorithms by using the same tool? Then, you applied polarimetric rainfall algorithms to calculate the rain by utilizing as inputs the polarimetric parameters, which are both measured by the radar and simulated by the disdrometer, according to 4 axis-ratio relations. You corrected also Zh and ZDR biases by comparing radar measurements of polarimetric parameter with the disdrometer simulations of the same parameters. Finally you validated the rainfall estimations obtained by both the radar and the disdrometer by a comparison with the rain gauges measurements considered as the ground truth. In many past works the rain gauge observations have been considered as the ground truth, for example in both Lombardo et al., 2006 and Sebastianelli et al., 2013 which I suggest the Authors to cite:

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- Lombardo, F., Napolitano, F., Russo, F., Scialanga, G., Baldini, L., and Gorgucci, E.: Rainfall estimation and ground clutter rejection with dual polarization weather radar, Adv. Geosci., 7, 127– 130, doi:10.5194/adgeo-7-127-2006, 2006b.

- Sebastianelli, S., Russo, F., Napolitano, F., & Baldini, L. (2013). On precipitation measurements collected by a weather radar and a rain gauge network. Natural Hazards and Earth System Science, 13(3), 605-623, doi:10.5194/nhess-13-605-2013.

In particular, the radar estimations reliability is assessed before and after the calibration to test the effectiveness of the calibration process. Could you better clarify this aspect in the text by briefly describing the methodology followed in your work?

P2, lines 13-16: I would write: “In particular, a dual polarization radar can estimate rainfall more accurately than a single polarization radar by providing reflectivity (ZH), differential reflectivity (ZDR), differential phase (ΦDP), specific differential phase (KDP), and cross-correlation coefficient (hv)”.

P2, line 17: what did you mean with backscatter? Perhaps you meant back-scattered signal?

P2, line 17: I would delete “of hydrometeors” because for me it is redundant.

P2, lines 16-21: I suggest to say: ”Dual-polarization radar provides characteristics of the precipitation such as precipitation type by means of . . . obtaining more informations about DSD (Cifelli et al., 2011), and reducing the impact of DSD variability on rainfall estimation. For these reasons rainfall estimates provided by polarimetric weather radar are better than that given by a single polarization weather radar.”.

P2, line 25: I would remove “of the rain” because for me it is not necessary.

P2, line 27: please split the sentence into two sentences by replacing the word “and” by a mark.

P2, line 32: I would replace “with types of storms and stages of storm development”

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with “with both types and stages of storm development”.

P3, line 4: I would say “rainfall estimations by polarization radars are affected by errors due to different sources of uncertainties such as . . . Reviews of the different sources of uncertainties are made by different Authors in the past, for example by Zawadzki (1984), Villarini and Krajewski (2010), Sebastianelli et al., 2013, and Spina et al., 2013, which I suggest the Authors to cite:

- Zawadzki, I.: Factors affecting the precision of radar measurements of rain, in: Proceeding of the 22d Conf. Radar Meteorology, Zurich, Switzerland, 10–13 September 1984, Amer. Meteor. Soc., 251–256, 1984.

- Villarini, G. and Krajewski,W. F.: Review of the different sources of uncertainty in single polarization radar-based estimates of rainfall, Surv. Geophys., 31, 107–129, 2010.

- Sebastianelli, S., Russo, F., Napolitano, F., & Baldini, L. (2013). On precipitation measurements collected by a weather radar and a rain gauge network. Natural Hazards and Earth System Science, 13(3), 605-623, doi:10.5194/nhess-13-605-2013.

- S. Spina, S. Sebastianelli, E. Ridolfi, F. Russo, L. Baldini, and L. Alfonso: Data selection to assess bias in rainfall radar estimates: An entropy-based method, AIP Conference Proceedings 1558, 1665 (2013); doi: 10.1063/1.4825849.

P3, line 5: please delete “These measurement errors affect rainfall estimation.” Because for me it’s redundant.

P3, line 6: I would replace “accurate measurement and calibration of ZH and ZDR” with ZH and ZDR” measurements.

P3, line 7: I would change “accommodation” in “assessment”.

P3, line 9: I would replace “measured ZH and ZDR” in “ZH and ZDR measurements”.

P3, lines 10-11: I suggest to use the wording “vertical profile of reflectivity” instead of

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"measured ZH from the radar profiler (at vertical incidence)". See for example Sebastianelli et al., 2013.

P3, line 11: the disdrometer-inferred ZH.

P3, line 12: please change "by comparing reflectivity between radar and disdrometer" into "by comparison between radar and disdrometer reflectivity".

P3, line 19: the principle has been theorized by Gorgucci et al., 1992, please insert citation.

P3, lines 22-23: a mean axis ratio and a polarimetric rainfall algorithms.

P3, line 24: please remove "the" and change "after" in "hereafter".

P3, lines 25-26: please put into the brackets "and newly derived axis-ratio relation from 2DVD data".

P3, line 30: please remove "the" before "data".

P4, line 2: please replace "drawn" with "given".

P4, lines 6-9: please check the English grammar and rephrase. I would write "data were used to develop a mean raindrop axis ratio relation...", and "The disdrometer data used in this study were collected by a 2DVD from..."

P4, line 21: a frequency.

P4, line 23: I would write "Data are obtained by using six..."

P4, line 29: I would say "both for Zh and ZDR calibration".

P5, line 1: and for rainfall estimation.

P5, line 2: please replace "from" with "due to".

P5, line 7: please write "the 2DVD rainfall estimations" instead of "rainfall calculated from 2DVD data".

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P5, lines 19-20: please rephrase. I suggest to say “In Fig. 2b and 2c we compare the axis ratio-diameter relation of Pruppacher and Beard (1970) with that found by the disdrometer before and after the correction, respectively.

P6, lines 12-13: the sentence is poorly written, please rephrase. I suggest to write “We analyzed the rainfall cases occurred during the period . . . . Fig. 3 shows six of these cases.

P6, line 18: As the 2DVD. . .

P6, line 25: the error is with respect to rain-gauge data? Please specify.

P7, line 1: you wrote “in suit”. What did you mean? Perhaps you meant “on site”?

P7, lines 1-3: What’s the criteria you used to distinguish between the different rainfall event types? Any references? In Sebastianelli et al., 2013 you can find a description of the rainfall events types from the radar point of view. Look also the works cited in that paper about that, in particular Zhang et al., 2008, and Zhang and Qi, 2010 which define events consisting of a stratiform part and a convective one (in relation to your table 2). So I suggest to add the following references:

- Sebastianelli, S., Russo, F., Napolitano, F., & Baldini, L. (2013). On precipitation measurements collected by a weather radar and a rain gauge network. Natural Hazards and Earth System Science, 13(3), 605-623, doi:10.5194/nhess-13-605-2013.

- Zhang, J. and Qi, Y.: A real-time algorithm for the correction of brightband effects in radar-derived QPE, J. Hydrometeorol., 11, 1157–1171, 2010.

- Zhang, J., Langston, C., and Howard, K.: Brightband identification based on vertical profiles of reflectivity from the WSR-88D, J. Atmos. Ocean. Tech., 25, 1859–1872, 2008.

P7, line 3: precipitation type.

P7, line 4: what did you mean with “difference rainfall”? Maybe you refer to the differ-

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ence between disdrometer and rain gauge rainfall?

P7, line 7: I would change “larger” in “greater”.

P7, line 17: you would write “reach about”?.

P7, line 18: established within.

P7, line 22: major and minor axis.

P8, line 1: 10.7 cm wavelength.

P8, line 2: we calculated.

P8, line 2: relations which.

P8, lines 15-16: you wrote “Polarimetric rainfall relations between R and dual-polarimetric parameters are derived when rain rate is greater than 0.1 mm hr-1.”. Why? To avoid the smallest raindrop diameter and therefore the particles outliers? Please clarify.

P9, line 2: you wrote “The polarimetric radar contains systematic bias of the radar itself.” It would be appropriate to introduce a bias definition. You can find a bias definition in Spina et al., 2013. In this work the calibration bias error is defined as a systematic error affecting radar estimates of rainfall independently from both the instant of measurement and the location of the sampling volume.

P9, line 3: I would suggest to replace “accomodation” with “assessment”.

P9, line 4: I would suggest to write “the radar calibration” instead of “the calibration of the radar”; moreover, why the calibration was done only for light rainfall event? Maybe to avoid rain gauge error due to wind action which deflects the falling raindrops from the vertical, or it prevents the fall of the drops (updraft). So for the radar calibration you consider only stratiform cases? It is correct to say that?

P9, line 10: I would change “are point measurements” into “consist of point measure-

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ments".

P9, line 10: I would write "whereas radar data are measured in a sampling volume".

P9, line 18: I suggest the Authors to put into brackets "see Fig. 5".

P9, line 23: I suggest the Authors to write "…. Relation derived by measurements in the wind tunnel".

P9, lines 26-29: the sentence is too long and it is poorly written, please rephrase. I suggest to split it into two sentences. I suggest the Authors also to write "The Beard and Chuang (1987) polynomial relation (Eq. (9), black dashed line) is from 2.5 to 6.5 mm lower than the new mean axis-ratio relation values".

P10, lines 2-3: I would write "With the exception of this case, the new axis ratio was similar to Eq. (10) for diameters ranging from 3 to 5.5 mm".

P10, lines 5-6: please remove the sentence "This means that raindrops in South Korea are more oblate than the others"; it is my opinion that you can not assert this by comparing results of different models, which were obtained in different ways and with different data. To say something like that you should derive a mean axis-ratio relation with the same 2DVD in different part of the word.

P10, line 12: please change "from" in "by utilizing".

P10, line 13: I would write "and it was compared with R derived fron the 2DVD (Eq. (2))".

P10, line 14: the correlation coefficient. What correlation coefficient? Pearson correlation coefficient?

P10, line 15: I would write rain rate estimation as it is a disdrometer.

P10, line 19: observed rain rates.

P10, line 23: please check English grammar.

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P10, line 24: I would change “when compared” in “in comparison”.

P11, line 2: I would replace “from” with “measured by a”.

P11, line 9: with the hourly rain rate.

P11, line 14: obtained by the radar.

P11, line 15: measured by the rain gauge.

P11, line 16: I would write “2DVD rainfall estimation”.

P11, line 16: decide if you want to use showed or shown in the text.

P11, line 16: why good results. With respect to rain gauges? Please specify.

P11, line 17: I suggest the Authors to remove the sentence part “R(KDP, ZDR) > R(Zh, ZDR) > R(KDP) > R(Zh)”, and to describe the concept just in words because in this way it seems that R(KDP, ZDR) is greater than rainfall estimated by each other formula. What did you mean is that the R(KDP, ZDR) algorithm give the most reliable rainfall estimation, it’s right?

P11, lines 17-21: I would change “performed better” with “was more efficient”; it’s not clear what did you mean when you write “on DSD statistics”.

P12, line 2: I would replace “declined” with “worsen”.

P12, line 4: for lower rain rates.

P12, lines 3-6: please delete “the radar rainfall estimations from” because it is redundant.

P12, lines 5-6: rainfall measured by gauges.

P12, line 8: I would write “the uncertainty in radar estimates due to the use of KDP reduces itself”.

P12, line 18: ZH and ZDR biases were calculated separately for eight rainfall events.

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So you calculated eight ZH biases and eight ZDR biases?

P12, line 22: the BSL ZDR measurements.

P12, lines 22-23: ZDR value is simulated by the 2DVD?

P12, line 25: please add the word “respectively” at the end of the sentence.

P12, line 27: please replace the word “comparing” with the word “comparison”.

P12, line 30: I would write “. . . obtained before and after the bias correction, respectively, while . . .”.

P13, line 1: I would write “. . . obtained before and after the bias correction, respectively, while . . .”.

P13, lines 2-4: the sentence is not clear and poorly written. Please rephrase. Maybe you meant that before the bias correction the precipitation was 12.67 and after was 15.33? What’s the corresponding value of the gauge?

P13, lines 4-5: The comparison with the rain gauge rainfall shows that after the bias correction the rainfall radar estimates were improved by about 13.71%, it’s right?

P13, line 4: the rain gauge is the ground truth. You should say that also at the beginning of the paper (introduction and abstract).

P13, line 7: the sentence for me is poorly written, I would say “80.12 mm respectively for rain gauge, radar before bias correction, and radar after bias correction. The radar rainfall . . .”.

P13, lines 8-9: you calculated the bias for each event and then you performed a mean bias? It’s right?

P13, line 9: MAE passes from.

P13, line 10: decreased from.

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P13, line 10: please add “after the bias correction” at the end of the sentence.

P13, line 11: I would write “as well as MAE and RMSE values”.

P13, line 12: I would say “both MAE and RMSE values decrease after correcting bias, and this means that rainfall estimation tended to improve after bias correction”.

P13, lines 23-24: I would say “obtained through rainfall algorithms”.

P13, line 24: I would say “was assessed by comparing 2DVD and BSL radar data with rain gauge measurements”.

P13, line 25: I would change “was suited” into “is suitable”.

P13, line 25: what’s the meanings of “of the DSD statistics”? Maybe you intended “according to the DSD statistics”?

P13, line 26: please replace “had” with “have”.

P13, line 29: I would change “was weak” into “is noisy”. It’s right?

P13, line 32: I would say “radar rainfall estimations was close to rain gauges measurements”.

P14, line 1: I would say “different raindrops axis ratios”. Did you mean the shape of the raindrops detected by the disdrometer?

P14, line 2: I would say “. . . relations, which were assessed to derive point . . .”. P14, lines 3-4: I would say “obtained through rainfall algorithms”.

P14, lines 4-5: the sentence is too long and it is not clear, please rephrase. I suggest the Authors to write: “Polarimetric algorithms will be developed to obtain areal rainfall estimation. A classification of rain rate based on them will be also performed in a future work”.

P19, table 2: in the table caption please write “precipitation type” instead of “type of precipitation”.

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P19, table 2: what's represents PE[%]?

P22, table 5: I suggest the Authors to add two columns, the first one concerning the radar rainfall estimates, and the last one for rain gauge rainfall measurements.

P24, figure 2: you should clarify what represents the dotted line. Moreover you should specify that the red color correspond to the greater drop number density.

P26, figure 5: please add (b/a) at the y-label.

P31, figure 10: it's my opinion that it is better to replace the dotted lines with dashed lines.

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