

Interactive comment on “Should radar precipitation depend on incident air temperature? A new estimation algorithm for cold climates” by Kuganesan Sivasubramaniam et al.

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The authors tackle an important problem of improving radar estimation of rain versus snow. Their work does provide some new insight, but there are some problems, including that the work needs to be brought back to hydrometeorology. At present it is a numerical exercise with limited explanation about the possible physical meaning of the results and their implications. There is no Discussion section in this paper, so it is difficult to know how the results compare to those in the literature. The meaning of β_P and β_T need to be better clarified; are used to determine the error in the radar-based precipitation estimate compared to the gauge estimate. The authors use the term

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“rain gauges” throughout. This is incorrect, as they are measuring precipitation. Please correct this accordingly.

The figures are reasonable, but the captions are too short and it is difficult for the reader to know exact content of the Figures. The improvement in RMSE (Figure 3-5) is somewhat unclear as the same colour ramp is used in Figure 2 that has a very different meaning. Also, the colour ramp is different in Figures 3-5; be consistent.

There is no mention of precipitation undercatch. See SPICE <<http://www.wmo.int/pages/prog/www/IMOP/intercomparisons/SPICE/SPICE.html>> among other references. This is crucial and without gauge undercatch (and other corrections), winter gauge precipitation estimation can be too low by a factor of up to 3. There are data from Haukelisetter, Norway that would be relevant.

Specific Comments

page 1, line 19: The term “raingauges” is often correct, as they are usually used. However, these specifically refer to those that designed to measure rain and not precipitation (snow and rain). It is suggested that attention be paid to this throughout the text to ensure that precipitation gauges are distinguished from rain gauges. The paper deals with snow and rain.

p1, l23-24: The sentence “[t]he backscattered energy is termed as reflectivity and used as the basis to quantify the associated precipitation.” is awkward. Its meaning can be understood, but the sentence should be more succinct. “The backscattered energy is measured as reflectivity which is used to estimate precipitation.”

p2, l3: The comments related to error are vague and some of the errors could be listed: “many sources of error. These errors”

p2, l7: “these uncertainties” is ambiguous

p2, l9: delete “being made”

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p2, l10: in the phrase “uncertainty during conversion from reflectivity to rain rate”, the words “during conversion” are unclear. Is this in the “computation of?”

p2, l10: As in my comment about p1 l19, be careful with the word “rain” as it is the computation of precipitation (rate), not just rain rate.

p2, l17-19: I do not agree with this statement. Most radar systems have used one Z-R relation for rain and another for snow, often calibrated in situ.

Figure 1. This caption is uninformative. Also, what are “greater” and “lower” rain gauges?

p3, first paragraph: the wording is confusing as to what was done here. The “linear regression analysis of observed hourly pairs of gauge precipitation and radar rain rate measurement” is difficult to understand. Later it is stated that “the raingauge locations with a greater regression slope for rain than snow are displayed with red open circles.” Is the regression slope the best approach? This may or may not be the same as the net quantity estimated from gauges versus radar. What is the length of record used in this analysis? The terms “pairs” is not clear. Is this pairs of stations?

p3, l18-21: Fassnacht et al. (1999) used weather radar from continuous (winter and summer) hydrological modeling.

p3, l25: The phrase “the rain drop is shaped by temperature” should be expanded to consider the snow crystal. This is mentioned in the next sentence, but seem to present a rain-centric approach.

p3, l31-32: “The probability of occurrence of snowfall versus temperature shows an approximately ‘S’ shaped structure in these studies.” This is not always true, as it can be linear (e.g., Fassnacht et al., 2013).

p4, l8-11: instead of telling us what is in the rest of the paper, give us some objectives or specifics about what research questions are asked.

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p4, l14-15: “Theoretically, radar reflectivity measurement of rainfall and snowfall do not differ much.” I disagree. Justify this comment

p5, l2-3: yes, near surface air temperature can be used to estimate phase, but lapse rates including inversions must be considered.

p5, l12-13: This sentence comes out of nowhere. Provide a context for this statement

p5, l18-19: Is this for rain only or precipitation? Please clarify and be consistent.

p5, l32: state which “an additional covariate.” I assume that it is temperature.

p5, l2-4: delete these, we don’t need a foreshadowing of the next section

p6, l6: be careful with words like “prediction.” I think you mean “estimation”

p6, l12: you may want to include a location sub-script, such as i or i,j , if you think 2-D space is necessary.

p7, l18: state how many precipitation gauges in the “relatively dense network of rain-gauges.” Again, be careful with the word “rain” gauge.

p7, l13: the RSME equation has been published often enough. It does not need to reappear here. Remove equation 4.

p7, l21: specifically which wavelengths are used?

p8, l1, l14, etc.: the word “data” is plural.

p8, l1-2: Fix this sentence, “[t]he radar data [are] corrected for VPR that includes handling the bright band correction,” as the radar data are not corrected directly for VPR, but issues that appear in the VPR, such as bright band.

p8, l3: add an “s” to product’s”

p8, l10-11: so no snow Z-R coefficients are used, only rain (Marshall-Palmer) Z-R? Be more clear with this statement, as “[i]t can be noted that there are no seasonal

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variations in the Z-R relationship in any of the Norwegian radars” is vague.

p8, l12: so only some of the period 2010-2017 are used? Which period: “[a] subset of accumulated hourly radar rain rate.”

p8, l17-18: consider showing the hypsometric (elevation) distribution of the precipitation (and temperature) gauges. This could be included in Fig 1.

p8, l21: How many temperature gauges are there? Consider using a different symbol in Fig 1 to show which ones are precipitation only.

p8, l21-26: This section on temperature data should be a separate paragraph from the precipitation data. Also, provide more details on how the 1x1 km gridded temperature dataset is derived - how are these data interpolated? This is important, especially since there is some elevation change across the domain (Fig. 1).

p8, l28: are there locations with more than one precipitation gauge per 1 km²? Clarify if there are or are not.

p8, l30 and afterwards: define the term “timestamps” or use a different word.

p9, l1: reword this sentence to something like: “corresponding hourly gauge precipitation, radar precipitation rate estimate, and air temperature for ...”

Figure 2: define what the partial weights mean here, likely also referring back to equation 3. Add more in the caption, including that β_T is β_P minus 1. I would scale β_P from 0 to 1 (the true range), rather than 0.2 to 1.

p9, l13: “[n]early 70 % of the raingauge locations” what “were estimated with associated partial weight for air temperature timestamps.” Is this the precipitation adjustment?

p9, l14: I don’t see “the circles filled with brown tone colour.” I see orange and yellow

p10, l4-5: how does the regression slope in Fig 1 compare to the β_P in Fig 2? This could be an important comparison.

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p10, l8: I can’t see the “dark blue colour circles.”

p10, l7-10: As my comment on Figure 2 above, this paragraph does not make sense: is $\beta_P = 0$ for these four stations or equal to 0.2? If 0.2, then β_T is not equal to 1 and temperature is not the single predictor.

p10, l11: showing Table 1 (the summary statistics) in a figure (histogram) would be more informative, especially due to the discussion of non-parametric approaches in section 2.2

Figures 3, 4 and 5: add to the captions. It is unclear how these Figures are different.

p16, l8: the Beven (2012) citation is incomplete, see below.

References

Beven, K.: Data for Rainfall–Runoff Modelling, in Rainfall-Runoff Modelling: The Primer, Second Edition, John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781119951001.ch3, 2012

Fassnacht, S.R., E.D. Soulis, and N. Kouwen: Algorithm application to improve weather radar snowfall estimates for winter hydrologic modelling, Hydrological Processes, 13(18), 3017-3039, 1999.

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