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Hydrology and Earth System Sciences Discussions

Interactive comment on "Radar subpixel-scale rainfall variability and uncertainty: a lesson learned from observations of a dense rain-gauge network" *by* N. Peleg et al.

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This paper describes a study of small-scale rainfall variation and its effect on estimating area-average rainfall from rain gauges, that is then used to determine the uncertainties in radar rainfall estimation. The paper is well-referenced and well-written. However, the authors need to make very clear what the novel contribution of this paper is. There are several issues with the analyses that need to be addressed, particularly those related to the sampling of tipping bucket rain gauges at short time scales. Finally, I think that the authors should devote more time to drawing conclusions from the results (instead of just presenting a summary in the last section. I have several specific comments that

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are given below.

Specific comments:

1. On p. 2, line 11, I suggest noting here that the distance to the radar is 63 km.
2. On p. 2, line 20, the authors note that the "radar-to-true rainfall ratio decreased with increasing time scale". The fact that the ratio decreases could mean an improvement in case of radar overestimation, but can be a degradation in case of radar underestimation. I think the authors should make clear whether this is an improvement.
3. In the Introduction, I think the authors should make very clear here what the novel contribution of this paper is. What sets this paper apart from the literature that is cited in this section?
4. In the first paragraph of p. 3, the authors could consider mentioning the importance of spatial rainfall variation for hydrology in urban areas (see e.g. Berne et al., 2004, Journal of Hydrology 299, 166-179 or Smith et al., 2002, Journal of Hydrometeorology 3, 267-282).
5. On p. 7, lines 16-25 the authors describe the QC procedures that were applied to the rain gauge data. It is not clear to me how this quality control is carried out. What were the criteria to remove data? Was this done by hand, or were there objective criteria?
6. On p. 8, line 7, the authors indicate that the mean radar beam height at the location of the gauges is 710 m. What are typical wind speeds and directions occurring in rainfall events? This is important because rain may be blown away from directly under the respective radar pixel. Another issue is that there is some time between measurement by the radar and the arrival of the raindrops at the

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gauge (on the ground). Especially at short time scales this can have a significant effect (Leijnse et al., 2010, Journal of Hydrometeorology 11, 1322-1329).

7. On p. 8, lines 16-24, the authors state that they use different $Z - R$ relations for all radar pixels under consideration, each of which has been optimized using gauge data. This results in a huge (factor of 2.4) variation in optimal $Z - R$ relations within a 4.6 km $\times$ 4 km area. But even if this variation would have been limited, the use of different $Z - R$ relations over such a small area does not make sense to me. The fact that there are such great differences should be thoroughly investigated. It seems to be related to the first two digits (possibly azimuth; could this be partial beam blockage?) in the radar ID given in Table 2 ($a \approx 60$ for ID=10xxx, $a \approx 90$ for ID=11xxx, and $a \approx 125$ for ID=12xxx). In any case, I find the use of such wildly varying $Z - R$ relations over such a small area unacceptable.

8. On p. 9, line 2, the authors refer to "the problem mentioned in the previous section". I think this problem should be stated here explicitly.

9. On p. 9, lines 19-21, the results of the correlation analyses are presented. I think that, especially for the shorter time scales considered here, the fact that the rain gauges are tipping bucket gauges can play a significant role. For example, on a 1-minute time scale, the minimum rainfall intensity recorded by a rain gauge is 6 mm h^{-1}, given a tip volume of 0.1 mm. And there will often be minutes with zero rainfall if the intensity is less than 6 mm h^{-1}. This issue should be discussed here.

10. On p. 9, line 21, I think there is a typing mistake: "toward the daily scale" should be "toward 1 on the daily scale".

11. On p. 9-10, Section 3, the authors compare parameters of fitted correlation functions to those presented in the literature. I think that the authors should explicitly

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note here that these parameters need not be similar to those presented in literature because of different rainfall climatologies.

12. On p. 10-12, Section 4.1, the authors discuss the variance reduction factor. I agree with them that a detailed discussion of the VRF is not necessary here, but the reader should be able to understand what VRF means. For this it is essential to clearly define both $\sigma^2_{\overline{R}_s}$ and $\sigma^2_{R_s}$. What is meant by "variance" here? For example, is $\sigma^2_{R_s}$ the uncertainty in gauge measurements, the spatial variation in point rainfall within a given area, or something else?

13. On p. 11, line 14, I think there is a typing mistake: "and is a Boolean" should be "and $\delta(i,j)$ is a Boolean".

14. I don't understand the sentence starting on p. 11, line 24 ("The VRF is very close to..."). Why does the fact that the VRF is close to zero imply that the mean square of the point variance is also close to zero? And what is meant by the "mean square of the point variance"? How should I interpret this?

15. On p. 13, line 5 the authors say that a percentage is plotted in Fig. 6b, and the label of the x-axis of that graph also reads "percentage". However, what is plotted are fractions (i.e. a factor 100 smaller values). I suggest either changing the x-axis of Fig. 6b or changing the wording from "percentage" to "fraction".

16. On p. 14, lines 9-10, the assumption "we assume that there is no bias between the rainfall measured by the rain gauges and the rainfall measured by the weather radar" is valid, but not necessary if var$\{R_r - R_g\}$ is not computed based on Eq. (4) but by just taking the variance of the differences between R_r and R_g.

17. On p. 14, there is a typing error: "reduce" should be "reduced".

18. On p. 15, the statistics CSI, POD, and FAR for the detection of precipitation by radar are evaluated. These statistics tell us something about the ability of the

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radar for determining the difference between dry weather and precipitation (no matter how intense). I don't think these statistics are very relevant for hydrological applications.

19. On p. 15, line 9, the authors mention that a "zero threshold was used to mark the occurrence of rain". However, for both radar and rain gauges it is unclear what this means. For radar, there is always a signal (noise). I think that if the authors decide to keep the analysis of these statistics, it is essential to discuss how "zero" is defined for radar rainfall estimation (is this anything below the noise level?). For tipping-bucket rain gauges, "zero" rainfall is also ill-defined, so it should also be made very clear what is meant by "zero" rainfall for gauge measurements as well.

20. On p. 15, line 19, the authors note that "an improvement was detected", but I'm don't understand what caused this improvement.

21. On p. 15-16, the ratio of radar rainfall estimated to true rainfall is discussed. Were all radar pixels used separately, or were these averaged?

22. On p. 16-17, Section 6, I think it would be better to have a section called "Conclusions", where conclusions are drawn about what we can learn from this study. I don't think the current Section 6 (Summary) adds much to the paper.

23. On p. 24, Fig. 1, would it be possible to also show the location of the radar in the inset map of Israel?

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 1, 2013.