Review of *Assessing rainfall radar errors with an inverse stochastic modelling framework* by Green et al. (2024)

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1 Introduction

The presented work makes use of the rainfall simulator presented in Green et al. (2023). Using the generated rainfall fields as ground truth it works backwards taking into account multiple error sources to generate the equivalent radar reflectivity that would be observed by a C-band radar. From this radar reflectivity another corrected 'best guess' rainfall field is obtained. The ground truth is then compared with this best-guess and the results are used to assess the uncertainties in radar QPE. Validating a QPE method is challenging as the ground truth is typically only available very locally at rain gauges or integrated in time over watersheds. Therefore, this work proposes an interesting approach which could be promising. Unfortunately I found the methodology to be difficult to understand as some key explanations are missing (in particular how the best-guess rainfall field is estimated and how beam-broadening/radar-sampling is taken into account) and the work could benefit from an in-depth review of a weather radar expert (preferably from the MetOffice), as I feel that it could be really beneficial to the quality of the work. In the end, I think that the work is worth publishing but the following points would need to be addressed.

2 Major points

1. l140: Unfortunately several lines are missing which makes it very difficult to properly understand this paragraph. Moreover I find that some clarifications and derivations are missing (in particular for Equ9). This makes this subsection really difficult to follow, which is unfortunate given how important it is in the methodology. I would suggest to rewrite this section entirely. Figure 4 also needs significant improvements as its relation with Eq 8 and 9 is not clear at all. A height discretization is briefly mentioned without any details. This discretization should be thoroughly explained and described as well in Figure 4.

2. I'm not sure how the corrected rainfall field (last plot in Fig 6 for example) is obtained and it is not clear in the text. There is a missing explanation on how to go from the ensemble of attenuated reflectivities (last panel of Fig 5.) to this corrected rainfall field. Is it the same QPE used in Green et al. (2023)? Even in your rainfall simulator paper, the QPE method is not described in detail. In the conclusion it is written *a standard radar rainfall estimation process*, however that does not mean much to me as QPE methods are typically quite specific and are often fine-tuned by the weather service that operates them. Additional explanations are needed in particular as it is the main output of the whole method!

3. Sec 3.3: you have some very low values of reflectivity in the histogram of reflectivity (< -20dBZ). I suspect that you considered raw radar data, without any significant noise filtering to derive this statistic. However, in practice every standard weather radar processing routine will remove these values by applying a minimum SNR. As such, I don't feel like your approach is representative of a real use case. I would suggest to use the same type of noise thresholding used at the MetOffice on your radar data and fit a model only to the remaining unfiltered noise. I suspect that in the current situation the resulting binary precipitation field (precip/no-precip) will look very unrealistic due to not filtering any noise (see next point).

4. Choice of colormaps: the choice of a default colormap for all variables (viridis) is not really appropriate. Typically precipitation intensity and reflectivity are displayed with variations of the Rainbow colormap, which makes it easier to detect regions of large precipitation. Other variables which are bounded (for example proportional error) should rather be shown with a sequential colormap. I would suggest to check the pyart library for relevant colormaps for reflectivity and precipitation. Another important thing is that you should separate no-precip (dry) from low precip to improve visibility. The values of zero precip should be left white in my opinion.

5. Equ 11: Fig. 20 shows that the effect of attenuation is maximal if R is large and the distance d to the radar is small, but $MR(t)$ is largest if the distance is large and R large. As such, why is it used as an indicator for the effect shown in Fig 20. Shouldn't we choose an indicator that is inversely proportional to d ?

6. Fig16 and 17: these figures show empty plots, without any explanation why!

7. Fig21 and 22: : I don't get the difference between the two figures. It is not clear at all in the text. Is the second image for precipitation > 0.1 mmh^{-1} only?

3 Minor points

1. l.21:I think you should also include the beam-broadening effect with non-uniform beam filling in the major error sources for QPE

2. l.52: Missing reference, should be Section 3

3. l.61: Since the study focuses on a single radar, it would be good to provide some info on this radar for people who are not familiar with the Met Office radar network (e.g. coordinates, frequency, PRF, pulse width)

4. Equ3: please introduce the precipitation intensity variable $R(t)$ properly

5. Fig3: please indicate clearly in the caption that the blue histogram is empirical from radar data.

6. L133 eq8: c is not defined

7. l.160: what is pixel variability? I imagine it is the variability between ensembles at pixel level. But this is defined and explained nowhere. The proportional error is also not defined explicitly.

8. Fig5: Please provide proper coordinates for your radar image, both in X and Y directions (-100 to 100 km). Do it at least in one image, you can then potentially indicate that, since the coordinates are always the same, you drop them from your figures. I saw that on Fig 7. 10 and 13, you indicated the coordinates, but starting from the top-left of your domain which is not standard. Please make everything more homogeneous.

9. Fig12: the area of high precipitation is not visible in the image because the color scale of the rainfall field is not adequate. If the area is too small, use at least an arrow or a circle to show it. Also I wonder to which extent a precipitation field with such a tiny region of extremely high precipitation surrounded by almost zero everywhere else is realistic in a real world case (and is not caused by unfiltered clutter).

10. l.228: I don't understand *proportion of rainfall in an images with the image RMSE*, shouldn't it be proportion of heavy rainfall as in the plot y-label. And if yes, how is "heavy rainfall" defined? Is it the same as the significant rainfall from the PRS (1mmh^{-1}), because in this case heavy is maybe a bit exaggerated?

11. l.277: "imageS" (wrong capital S)

12. Tab1: Please provide full name of ECDF here (empirical cumulative distribution function) as it the acronym is used before Fig23.

13. The addition of letters (a, b, c, ...) in the captions of multiple panel figures (e.g. Fig 11, 22,...) would make it much easier for the reader to immediately link the corresponding plot to the reference in the caption.