Response to the review of hess-2018-0351

RC2: Responses to Anonymous Referee 2

The authors wish to thank the reviewer for his constructive comments and corrections to the discussion paper. In the following, we have responded to each of the comments from the reviewer for this manuscript. The comment from the reviewer (RC) is in italic font while the author comment (AC) and changes in the manuscript (CM) are in blue normal font.

General comments:

The authors apply the non-parametric k - nearest neighbour method (k-nn) to estimate radar precipitation from gridded surface observations of rainfall and temperature for the Oslo region in Norway. They show that utilising temperature as second predictor variable reduces the root mean squared error significantly compared to a k-nn model without temperature and compared to the original procedure using a constant Z-R relationship or separate snow/rain Z-R relationships.

The application of this method for radar rainfall estimation including temperature is novel and of interest not only for readers living in regions with colder climates. The research is done systematically and quite carefully. The paper is written well and clear in structure. However, there are three major points and some minor things which need attention before the paper can be published. One main point are the lengthy introduction and background sections which could be shortened. A second important point concerns the method to estimate the partial weights. It becomes not clear, that this method is really providing optimal weights. And, third, there seems to be an issue with the back-calculation of Z using the inverse Z-R relationship on a different time resolution as for the original forward calculation. Detailed information about this and the minor things are given below.

Detailed comments:

1. Sections 1 and 2: Both sections together cover almost 4 pages and represent the introduction with the state of the art. This is quite lengthy. The introduction is very general; the background is more focussed on the topic at hand. I would suggest to shorten these parts especially the introduction significantly and may be use the background as introduction.

AC / CM: We have merged the Introduction and background sections as suggested and updated the text to make the introduction more succinct.

2. Eq. 1: As predictor R(t) is used. Why not using Z(t) as predictor? For R(t) already a (wrong) Z-R-relationship has been applied, introducing great uncertainty. If a linear relationship is required a log-log transformation of Z(t) and Rest(t) could be applied beforehand. This needs at least to be discussed.

AC / CM: In the methodology presented in the paper, reflectivity (dBZ) could in principle be used instead of radar precipitation rate as shown by Hasan et al. (2016) for the univariate case. As we do not have access to the reflectivity (Z(t)) data from the Hurum radar for this study, we had to use the hourly radar precipitation rate which is available from the Norwegian Meteorological Institute. While the reflectivity can be back-calculated by inverting the algorithm that was used operationally, we feel this may add additional uncertainty and would not matter given the regression algorithm being used is nonparametric. Further, it can be noted that one key purpose of this work is to see how we can improve the radar precipitation rate data available to us as a finished product (hourly Surface Rainfall Intensity (SRI) product) from the meteorological institute.

The text is updated in the revised manuscript to clarify this.

3. Fig. 1: The units for observation length and elevation are missing. Also, the text of the legend is tiny and hard to read.
AC / CM: The units are added, and the font size of the text is increased in Fig.1.

4. Section 5.1: It is not clear if the estimation of the partial weights using partial information correlation (PIC) is really beneficial or even optimal. In order to prove the merit of PIC I would suggest to test two additional cases a) equal weights for P and T and b) using simple linear partial correlations. The performance for the latter two cases measured by RMSE should be worse than by PIC weighing.
AC / CM: The partial informational correlation (PIC) provides a generic measure of statistical dependence of predictors of a general linear or nonlinear system. Estimation of partial weight using PIC shows the partial dependence of radar precipitation estimation on air temperature.
Earlier papers have shown that the estimated PIC and weights collapse to what would be estimated using a linear regression model if the system is linear (Mehrotra and Sharma, 2006, Sharma and Mehrotra, 2014, Sharma et al., 2016). As the system here is nonlinear, our approach of using PIC to estimate partial weights appears more justified.
After receiving the reviewer's comment, we tested our approach using equal weights. We found that the gain in RMSE was not significant with the use of PIC based partial weight compared to equal weights, but the mean error was reduced when we used partial weight estimated using PIC.
The manuscript is updated to discuss this.

5. Fig. 4: This bar plot is not easy to read. I would suggest to use box-whisker plots instead.
AC: As the reviewer suggested we have plotted box and whiskers plot (refer Fig. I Appendix). However, bar plot presents the results at each gauge location compared to lumped box plot which we find interesting to report so we would like to retain the bar plot in the manuscript. We have attempted to improve the bar plot to make it more readable.

6. Page 16, line 1: The back-calculation of Z from R using a non-linear relationship on hourly data gives an estimated average Z value for each hour. This estimate can be quite different from the observed average Z value if the rainfall distribution within the hour is not unique. In the forward calculation the Z-R relationship is applied on 7.5 min Z values to calculate 7.5 minute rainfall intensities. Because of the non-linearity of the Z-R relationship a simple back calculation on a different time step than the one the original calculation was applied is not possible. For non-linear functions f is E[f(x)] < > f[E(x)].
AC / CM: We do agree with the reviewer that back calculated reflectivity on a different time step (hour) than the original calculation (7.5 minutes) is not same as the average value unless the precipitation is even within the hour and we fully acknowledge that this introduces uncertainties in the results. As mentioned above, we do not have access to reflectivity data (or 7.5 minutes precipitation rates). In order to compare our proposed nonparametric radar precipitation estimation with radar precipitation rates computed using separate equations for snow and rain, we decided to back calculate the reflectivity from the data available to us.
The manuscript is updated to discuss the uncertainty in the computation in more detail.

References

Hasan, M. M., Sharma, A., Johnson, F., Mariethoz, G. & Seed, A. 2016. Merging radar and in situ rainfall measurements: An assessment of different combination algorithms. *Water Resources Research,* 52**,** 8384-8398.

Mehrotra, R. & Sharma, A. 2006. Conditional resampling of hydrologic time series using multiple predictor variables: A K-nearest neighbour approach. *Advances in water resources,* 29**,** 987-999.

Sharma, A. & Mehrotra, R. 2014. An information theoretic alternative to model a natural system using observational information alone. *Water Resources Research,* 50**,** 650-660.

Sharma, A., Mehrotra, R., Li, J. & Jha, S. 2016. A programming tool for nonparametric system prediction using Partial Informational Correlation and Partial Weights. *Environmental Modelling & Software,* 83**,** 271-275.

Appendix

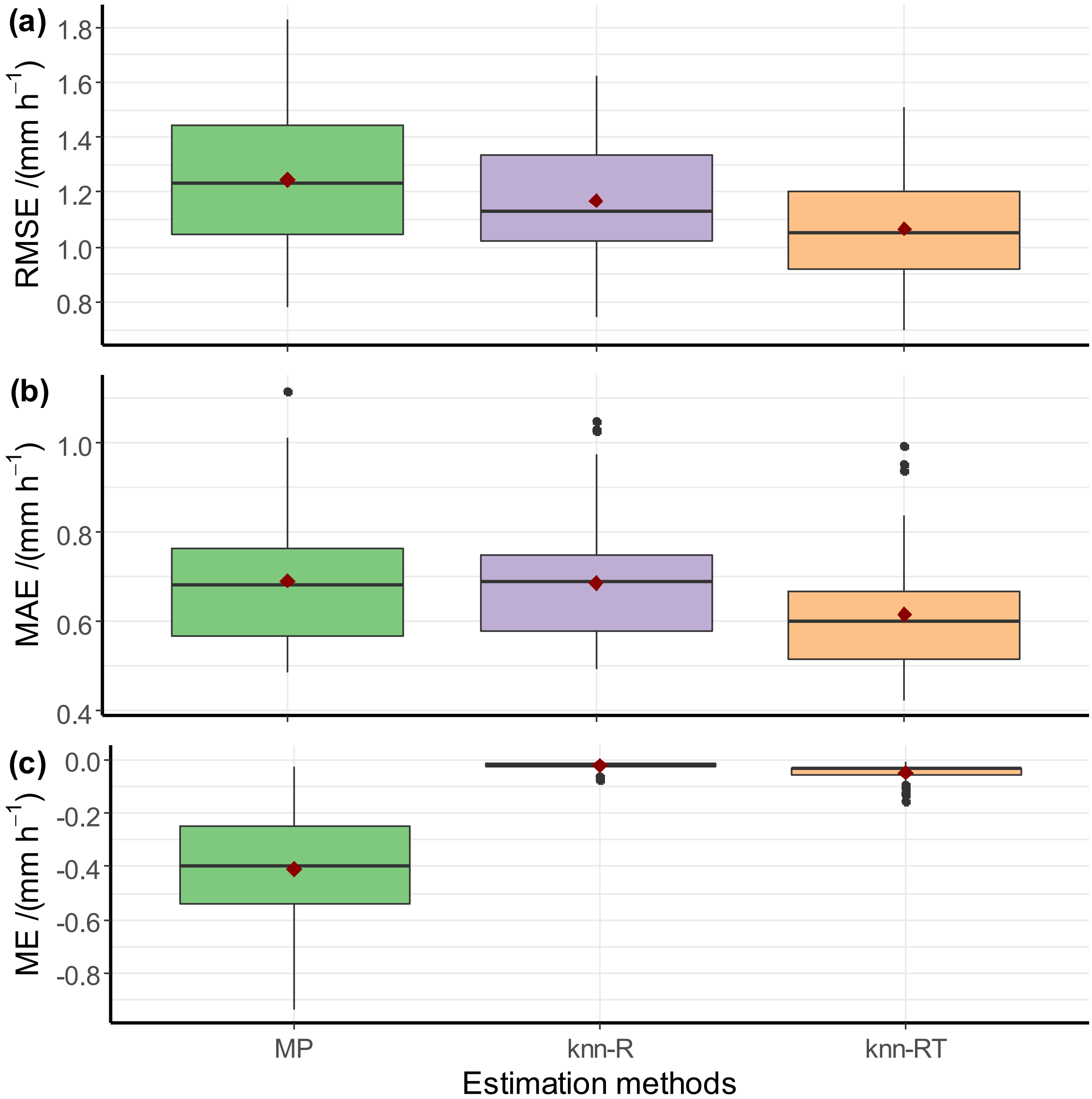

Figure I: Box plot representing three quality metrics (RMSE, MAE and ME) at gauge locations for the original data (MP) and for the two nonparametric models (knn-R and knn-RT). Mean value of quality metrics for each model by red diamond point. Here, knn-R denotes the nonparametric model with radar precipitation rate as a single predictor, while knn-RT denotes the nonparametric model with radar precipitation rate and air temperature as two predictors with fixed partial weight of (0.68, 0.32).