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Interactive comment

Interactive comment on "Multi-source data assimilation for physically-based hydrological modeling of an experimental hillslope" *by* Anna Botto et al.

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Reply to Anonymous Referee 3

We would like to thank the reviewer for their careful and thorough reading of our manuscript and for the thoughtful comments and constructive suggestions, which will help us improve the quality of the paper. In the following, point-by-point replies will be provided.

1. Page 2, line 32. It would be good to elaborate on the trade-off problem in the introduction and refer to other studies that have investigated this problem, such as the recent studies by Zhang et al. (2016) and Zhang et al. (2018).

We thank the Reviewer for suggesting further interesting references about the topic, which we will certainly add to the manuscript, together with a brief discussion of the trade-off issue.

2. Page 3, line 25. Could you include a brief description or include a reference on the coefficient of uniformity used here.

Thank you for highlighting this aspect. We will provide a proper reference about the coefficient of uniformity (Lora, 2016).

3. Page 5, line 10. Use of dampening factor in the Kalman filter update is debatable. It is a factor that needs to be introduced to compensate for improper settings in the Kalman filter, including model and measurement uncertainty descriptions and ensemble approximations. Discussion of these issues should be included.

We thank the Referee for raising this good point. We will certainly try to clarify and highlight better this aspect in the revised manuscript, also with relevant references.

4. Section 4.2. It is not clear how the different model and measurement uncertainty parameters have been estimated. Are they based on preliminary sensitivity analyses?

We thank the Referee for highlighting this aspect. Measurement uncertainties have been estimated based on the accuracy of the sensors (tensiometers for the pressure head, water content reflectometers for the water content and tipping-bucket flow gauges for the outflow discharge) and plausible positioning errors. Uncertainties on model parameters and boundary conditions have been estimated mainly based on previous modelling experiences (Camporese et al., 2009a, 2009b) and prior characterization of the soils in the hillslope. In particular, for the Van Genuchten parameters some preliminary sensitivity analyses have also been performed. We will better clarify these aspects in the revised version of the paper.

5. Page 7, line 23-26. Why are the measurement error covariance matrix, anomalies and innovation vector normalized? There should be no need to normalize with the EnKF.

We thank the Reviewer for the question. In the paper, several scenarios have been carried out where different variables, i.e., pressure head, water content and outflow discharge, have been jointly assimilated. In this case, as the assimilated variables can differ from each other by orders of magnitude, the normalization of the measurements ensures that the covariance matrices in the Kalman gain are not ill-conditioned. Please see Evensen (2003) and Camporese et al. (2009b) for more details.

6. Page 8, line 13-14. Instead of the normalization of RMSE used, one could normalize *the RMSE by the Nash-Sutcliffe coefficient. That measure would be more appropriate for interpretation of the actual performance.*

We thank the Reviewer for highlighting this aspect. Please note that our objective here is not to assess how well the data are matched but rather to evaluate the benefits of different data assimilation scenarios in comparison to each other (and the open loops). To do so, we elected to use the RMSE as this index is traditionally applied in groundwater hydrology analyses, while the Nash-Sutcliffe efficiency is more popular in rainfall-runoff models.

7. Section 5.4. Would be good to discuss these results in relation to other observations of trade-offs reported in the literature, such as in Zhang et al. (2016) and Zhang et al. (2018).

We thank the Reviewer for the comment. As previously said (point 1), we will introduce the suggested references into the paper not only in the Introduction but also in the Results section where the different trade-offs are analyzed.

References

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