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Interactive comment on "The impact of near-surface soil moisture assimilation at subseasonal, seasonal, and inter-annual time scales" *by* C. Draper and R. Reichle

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Anonymous Referee #2

- We appreciate the referee's comments on our manuscript, which have helped us to clarify several key points. These comments are reproduced below, with our response to each provided as a bullet point.

The authors analyze biases between AMSR-E, Catchment model, and in-situ SMs at three different time scales ' subseasonal (short), seasonal, and long term – and inves-

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tigates the impacts of assimilating rescaled AMSR-E SM into the Catchment model. SM-DA showed consistent improvement of SM at all time scales at four ARS sites. It is also shown that rescaling for one-year model-observation can result in updated SM worse than open loop SM.

This paper deals with an important emerging question in land data assimilation (multi-scale biases between different 'measurements') and how SM-DA affects individual time components when SM is scaled at a lumped time scale. The manuscript is well written and tables/figures concisely summarize results. I recommend that this manuscript should be accepted for publication after addressing comments listed below.

1. In the Introduction, the authors mention a possibility of model-observation biases varying at different time scales citing Su and Ryu (2015). It naturally leads to an expectation that the authors rescale sub-seasonal – long-term time components separately, but AMSR-E SM is rescaled for the lumped time scale in both control and treatment cases. It needs to be clarified in Introduction that the main focus this work is analyzing the effects of SM-DA with a lumped rescaling on updated SM at multiple time scales. It would also be good to add discussions about rescaling individual time components separately.

- The focus on rescaling with bulk statistics is now specified in the introduction: 'We have used this decomposition to examine i) the differences between remotely sensed and modeled soil moisture at each time scale, ii) how these difference affect observation rescaling using bulk statistics, and iii) how assimilating the bulk-rescaled remotely sensed observations impacts the model soil moisture at each time scale.'
- As noted below, Section 2.2 of the methods has been expanded to better introduce the assimilation experiments, and so this is specified here again.
- The possibility of rescaling at separate time scales is left for later work, however

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this possibility is now pointed out in the conclusions:
'This could perhaps be avoided by rescaling the observations separately at each time scale using the decomposed time series produced in this study, or using other methods that distinguish scaling characteristics at different time scales (e.g., Su and Ryu, 2015).'

2. It is written in Section 2.2 that a CDF-matching is used to rescale the observations, but it was later in the Result, Section 3.4, that I found that actually a linear model using mean and variance was used. The authors need to move this specific description to the Methods section because the use of mean-variance-based linear rescaling can influence the rescaling results discussed in the earlier sections.

- In response to Referee #1 & #2, Section 2.2, which introduces the data assimilation experiments has been expanded to more fully describe the assimilation experiments. This includes introducing the rescaling methods, and clarifying that all presented experiments used CDF-matching.
- It is later noted as a point of curiosity that the experiments were repeated with mean/variance rescaling, and very similar results were obtained:
'This suggests that for the particular examples in this study, the CDF-matching operator could be approximated by a linear rescaling, in which only the mean and variance of the model are matched, as in Scipal et al, 2008. To confirm this, the assimilation experiments were repeated using linear rescaling of the AMSR-E observations in place of CDF-matching. The results (not shown) were indeed very similar to the CDF-matching experiments, in terms of the rescaled observations and the assimilation output.'

3. The basis for using linear rescaling in place of CDF-matching is that variance distribution across time scales did not vary after CDF-matching. This argument should

be strengthened with more specific supports. For example, CDF-matching can be a more robust choice for non-stationary time series or when model and observation pdfs feature very different symmetry.

- All presented experiments used CDF-matching. See bullet above.

4. Was the mean perturbed ensemble (open loop) compared with the unperturbed single run? Please make sure the perturbation of soil moisture was done without unfairly penalizing the perturbed background predictions.

- This was done early in the experiments. The greatest deviation between a single unperturbed run and the mean of the model ensemble was at Walnut Gulch, during periods when the soil moisture nears the lower boundary (since the boundary limits the -ve ensemble deviation, the ensembles becomes biased). However, these deviations had a near-negligible effect on the evaluation statistics, and were deemed acceptable.

5. In Figure 6c, changes between M and Ac in SM_seas looks unrealistically substantial. With given AMSR-E SM pattern at LR shown in Figure 2, neither rescaling nor Kalman update would likely to make that large difference. Please double check the data to ensure the correctness.

- The plotted time series are correct. The evidence for them can be seen in Figure 1c. The AMSR-E observations have a consistent and sharp single peak in the seasonal cycle, while the Catchment model has annual maxima that occur at different times of year that are often maintained for longer. Hence, the assimilation reduced the maxima to one per year (while over-exaggerating its magnitude). The real issue here is likely that the notion of a mean seasonal cycle does not describe the model behavior very well.

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More specific comments - Page 7977, ‘due to very low observation counts over the study period at the other sites’: Please provide more information about the data scarcity in these sites (e.g., % of period the root-zone SM is available).

- There are no observations below the surface layer at Walnut Gulch and Reynolds Creek. At Little Washita, the 5-60 cm observations are available from 2007 onwards (giving too short a period to adequately sample inter-annual variations in this study). This information has been added into Section 2.1.

- Page 7984, ‘AMSR-E could be expected a prior to have a larger fraction of . . . in the remotely selected observations’: This a prior expectation (relatively large SMshort Var over SMseas Var) contradicts somehow ‘exaggerated seasonal cycle’ of AMSR-E at Little Washita and Little River. Need discussion on this contradiction.

- The point that we were attempting to make was that before looking at the data, we could expect AMSR-E to have large SMshort variance fraction, due to measurement noise but that this turns out not to be the case because of its very large seasonal cycle. Unfortunately, our use of ‘ a priori’ in the sentence was confusing, given it’s use in assimilation terminology. The relevant sentence has been edited to make this clearer:
  ‘One might expect AMSR-E to have a larger fraction of variance at SMshort, due to measurement noise from the remote sensor. However, ...’

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 7971, 2015.