

Thank you for reviewing this manuscript and your comments and corrections are greatly appreciated. The following are our responses to your questions.

(1) It was assumed that the AMSR-E soil moisture retrieval is only representative of soil moisture in the top 5 cm soil (as stated in this paper, the AMSR-E sensor measures about 1–2 cm from the surface). To transfer the observation information from the surface to the deep layers, a mass-conservation data assimilation scheme was developed. In this study, however, the AMSR-E data were used to update the top two layers (10cm and 30cm respectively). Is it reasonable for this assimilation? What consequence will occur when only soil moisture of the top surface layer is updated using Eq. (5)?

Your concern is valid and is actually part of the reason the mass conservation scheme was developed. The conventional wisdom in the community is that the information at the surface can be passed to the lower soil layers through the error covariance matrix which, in the case of EnKF, is derived from ensemble members which are influenced by model physics as well as perturbation parameters. No convincing studies have shown that the surface soil moisture observations can be extended to the 2 m depth; in fact, several studies have shown that soil moisture assimilation led to degraded soil moisture updates in the lower layers as we discussed in the paper. This is why we developed the mass conservation scheme to avoid updating the lower layers using the conventional EnKF.

Soil moisture is spatially correlated within certain distances and so errors in the surface may be an indication that similar errors occur in the surrounding soil moisture field. Given this, updating the 2nd soil layer, which is the closest to the surface layer, is reasonable.

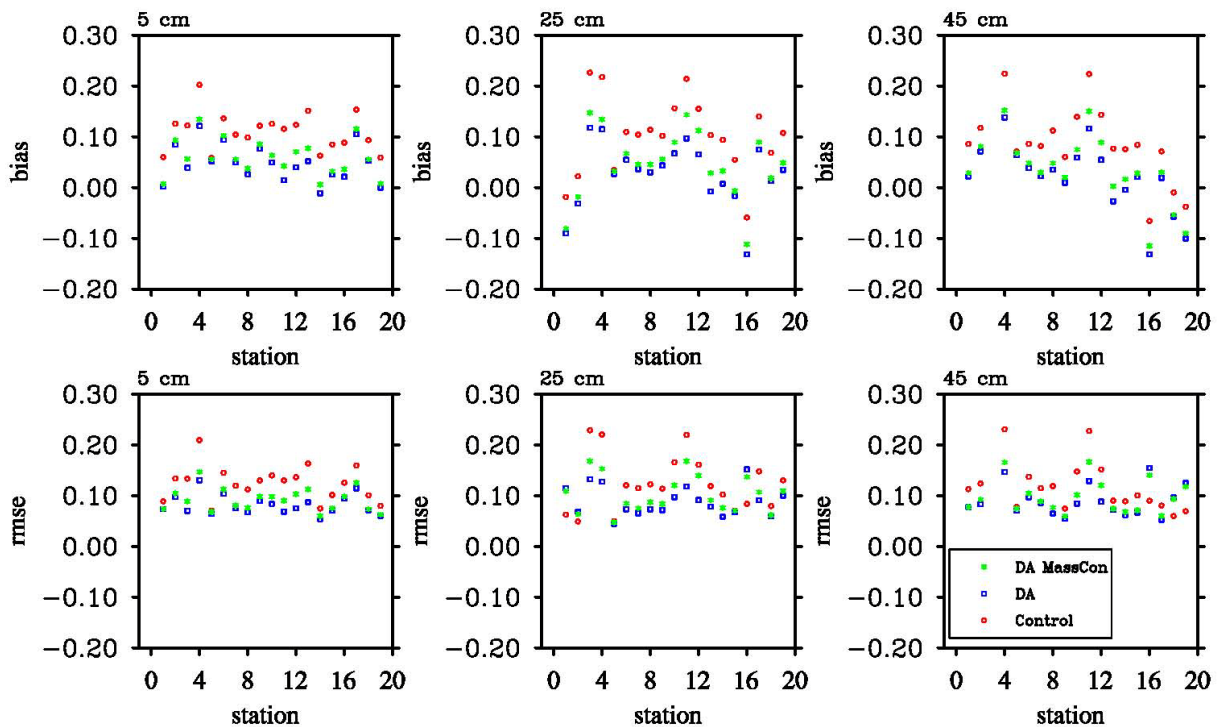
If only the surface layer is updated by AMSR-E retrievals, the impact on the soil moisture profile is very small. It exerts little influence on estimated ET and runoff which are evaluated using root zone soil moisture and/or profile soil moisture.

(2) To test the assimilation results from the three simulation runs (Control, conventional DA, DA MassCon), basin averaged daily series were evaluated for the soil moisture and flux. But the basin averaged values just provide a rough or coarse evidence of the assimilation capability due to the fact that they will mask the detailed spatial variations of these states. So, it is not necessarily convincing that DA MassCon is a capable scheme, if it only improves basin-averaged simulated soil moisture fields and fails to effectively ameliorate detailed soil moisture estimation. So I suggest the author make a comparison at the grid (0.01 degree for the Noah model resolution) or the point scale between the assimilated results and the ARS observations. That is, pick up the series of assimilated results from the grids corresponding to ARS measured points (about 20 points as shown in Figure 1), and calculate the correlations and errors of the paired series. Maybe a table is good enough to exhibit these results.

The large number of ARS stations ensures that statistics calculated from basin-averaged time series are consistent with those at individual locations. The following figure shows the bias and rmse of Noah soil moisture at 19 ARS stations. As can be seen, the statistics at individual sites are generally consistent with those of basin averaged time

series. At a couple of stations the opposite behavior was observed which is expected because AMSR-E retrievals represent spatially averaged soil moisture values. This is why we chose this site for the study because it provides enough in situ measurements to validate the assimilation results. On a related note, we realized that we accidentally included an ARS station in Figure 1 that was not used in the statistics calculation due to too many missing data. This will be corrected in the revised manuscript.

It is also important to note that improving basin-averaged soil moisture fields would have been, in and of itself, a solid measure of DA MassCon performance, as lumped models (still a crucial tool in the operational hydrological modeling community) depend on accurate basin-averaged soil moisture values to produce accurate hydrologic simulations.



Minor comments

(1) The area of Little Washita watershed is about 611 km², and the AMSR-E retrievals holds the resolution of 25 × 25 km. But the paper says on Page 8136, Line 13, “the experiment site contains about 5 to 6 AMSR-E pixels”. Is that right? Is the area of the experiment site not equal to the area of Little Washita watershed since $25 \times 25 = 625 \text{ km}^2 > 611 \text{ km}^2$?

Yes, we will add a note in the revision that the 5 to 6 pixels are for the rectangular domain that includes the watershed. The watershed area is smaller than a single pixel, but its irregular shape needs more than one pixels to cover the entire domain.

(2) Page 8137: Line 15: Is the Eq (2) right in which the subsurface runoff is equal to the hydrologic conductivity?

Yes. This is why it is called free drainage because the soil moisture flux (as given by Darcy's Law) is governed by gravity alone.

(3) Page 8139, Line 10, the symbol F in Eq(4) should be written as F_t to represent the time step.

Thanks for noting this which will be corrected in the revision.

(4) Page 8140, It is hard for me to understand the Eq. (6) for distributing the water increment to the layer 3 and layer 4. As the formation expressed, it can be rewritten as

$$\begin{pmatrix} Y_3 \\ Y_4 \end{pmatrix}_t^a = \begin{pmatrix} Y_3 \\ Y_4 \end{pmatrix}_t^f - \frac{1}{d_3 + d_4} (\Delta C_1 d_1 + \Delta C_2 d_2). \text{ But I don't think it is a right formation because } \Delta C_1$$

and ΔC_2 are variables of single values. Please check it and give an explanation for this equation.

This is a good point. The Y here should be lower case representing either θ_3 or θ_4 . The same increment is given to the 3rd and 4th soil layer. We will correct this in the revision.