The Second Reviewer

Soil moisture memory (SMM) is a key characteristic describing land-atmosphere interactions. The authors used the latest version of NOAH-MP with several parameterization schemes to simulate the SMM and compared it with the SMM derived from SMAP and ISMN observations. The manuscript is well organized and written. I have only a few minor concerns as follows.

1. The authors used the SOM modeled by NOAH-MP to estimate the Marcropore Volume Fraction (MVF). What about the reality and accuracy of these SOM maps? And then, how is the error in the SOM estimate transferred to the MVF? And finally, what is the impact of uncertainty on the MVF results?

   R: A good questions. Instead of using a spatially-constant MVF, we tried to link MVF with SOM to use spatially-varying MVF. However, this representation of the MVF in the real world apparently not enough, because it reflects only the biotic factors not other abiotic factors, e.g., MVF formed during freezing-thawing cycles (especially in the seasonal frozen ground and thawing permafrost regions) and cracks formed during wetting-drying clays. To represent these processes is even more challenging. We have also tested machine-learning based, 1 km, global datasets of hydraulic parameters (should contain macropore information) but it does not show significant differences from other macropore simulations.

   Introducing MVF reduces the numbers of parameters that need to be calibrated. In practice, we can calibrate MVF, one parameter, instead of Ksat and other water retention curve parameters. Future studies should learn this important parameter from soil moisture profile or streamflow, e.g., using differential modeling.

   From the indications as stated in the paper, a larger value of MVF can substantially enhance drainage of soil water (while reducing the water retention) to deeper soils and aquifers (increase recharge) and thus reducing both short-term and long-term memories.

2. For the SMM observed by the ISMN stations, the authors show the results of the root zone layers. What about the results in the surface layer? It is better to show the SMAP, NOAH-MP, and ISMN results at the same time.

   R: We acknowledge the suggestion to include surface layer results for ISMN stations alongside SMAP and Noah-MP data. However, there are two key reasons why ISMN data was not used for the surface layer in our analysis. First, the spatial scale of ISMN observations is at the point level, which is significantly smaller than the 1/8-degree grid scale of Noah-MP and SMAP, making direct comparisons challenging due to potential scale mismatch. Additionally, the limited number of ISMN stations across the U.S. further complicates the ability to represent spatial patterns at a regional or national scale.

   In contrast, SMAP provides continuous surface soil moisture data across the entire U.S. with a resolution that is much closer to that of Noah-MP, allowing for a more consistent comparison. Furthermore, SMAP has been widely used in previous studies as a benchmark for model validation, enabling us to compare our results with those established in the literature. For these reasons, we focused on SMAP and Noah-MP for surface layer analysis while using ISMN data primarily for root zone validation, where its limitations are less critical.

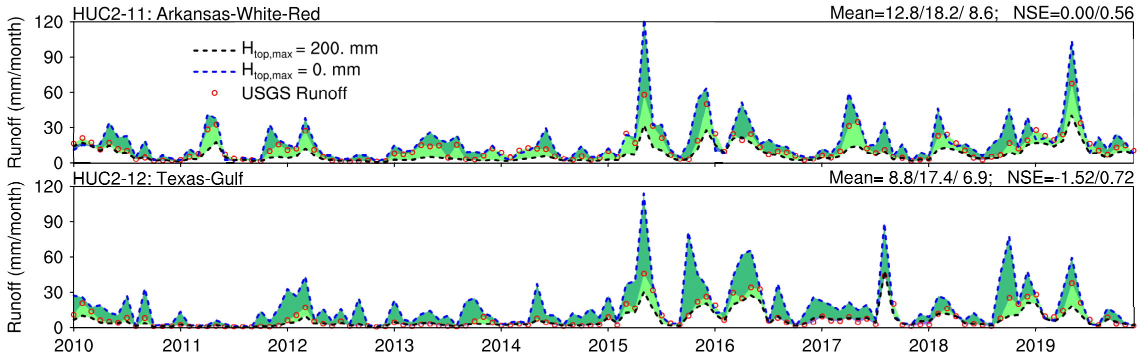
The following part in the paper is modified to reflect your concern: "Some sources of uncertainty may affect our results in this study, including uncertainties in input data, and models. The SMAP L-band penetration depth can indeed be shallower than 5 cm, especially over wetter regions like the eastern CONUS, which may introduce a mismatch when comparing SMAP observations with the Noah-MP 5 cm layer. SMAP reliability is affected by plant water storage change (in the eastern part and some mountainous sites), introducing uncertainties into SMM values for the benchmark. While SMAP observations may be less reliable over these densely vegetated areas, they still support our objective of enhancing our understanding of the physical processes in soil hydrology. Furthermore, the SMM patterns captured from SMAP can be insightful in understanding regional variabilities in SMM.

Another concern is the influence of ISMN spatial representation on SMM analysis. ISMN stations are point-based, and it is assumed that one point represents a 1/8-degree grid area. It is possible that the point measurements cannot fully capture the spatial variability within the Noah-MP grid cells, leading to discrepancies in the representation of values and spatial patterns. The limited number of stations may further amplify this issue. One potential solution to address the scale mismatch between point-based observations and grid-scale simulations is the use of high-resolution or hyper-resolution models. These models can provide finer spatial detail, allowing for a more direct comparison between observational data and model outputs, thereby improving the accuracy of the analysis and reducing scale-induced biases. Incorporating such approaches in future studies would help mitigate the limitations posed by the current scale differences."

3. What physical situation in reality corresponds to a water pond of several tens to two hundred millimeters thick on a grid of 0.125 degrees in the model? How long does it last? Is it physically realistic?

   R: Surface ponded water results from the exceedance of precipitation rate over infiltration rate. It occurs over regions where the soil's permeability is low (clay soil and frozen ground) during severe storms or spring snowmelt. About a quarter of the severe floods in the US in the 20th century were directly linked to surface ponded water from spring snowmelt.

   The ponding threshold highly depends on the hydrological connectivity of surface ponded water in local depressions that are further dependent on micro-scale topography. In the beginning when we design this model, we do not have any idea about its value or range. After testing against streamflow observations, we know this value can be up to ~100 mm.



200 mm is to make sure there is no runoff of surface ponded water (infiltration excess runoff); 0 mm means all excessive water runs off.

4. In the caption of Figure 1, the last sentence, Theta_w is missing.
   R: Paper is revised

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