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Reply on RC2

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Author comment on "Soil moisture estimation in South Asia via assimilation of SMAP retrievals" by Jawairia A. Ahmad et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-460-AC1, 2021

Reviewer #2

Thank you for your comments. We have endeavored to reply to each and every point that was raised by the reviewer.

Major point

Comment: The comparison with in situ soil moisture measurements is the only direct and independent evaluation. However, the stations are not located in the regions with higher irrigation-equipped areas. These are the regions with higher impact, and with some indirect evaluation via the signal on evapotranspiration. While the results are consistent, the main conclusions are not fully supported by independent evaluation. Therefore, I suggest that this limitation is highlighted in the conclusions and abstract. For example, Line 473: "and improved the spatiotemporal soil moisture patterns (Figs. 3 and 7) and associated evapotranspiration (Fig. 8), particularly over irrigated areas." Since there are no direct observations of evapotranspiration and Soil moisture over the irrigated areas, I would recommend to say that the results "suggest improvements".

Response: Thank you for your comment. The evaluation is indeed limited by the unavailability of ground measurements across the irrigated areas in South Asia. To highlight this point, the following textual modifications have been implemented:

Lines 9 to 17

"Across the Tibetan Plateau, DA-NoCDF reduced the mean bias and RMSE by 8.4% and 9.4%, even though assimilation only occurred during less than 10% of the study period due to frozen (or partially frozen) soil conditions. The best goodness-of-fit statistics were achieved for the IMERG DA-NoCDF soil moisture experiment. The general lack of publicly available in-situ measurements across irrigated areas limited a domain-wide direct model validation. However, comparison with regional irrigation patterns suggested correction of biases associated with an unmodeled hydrologic phenomenon (i.e., anthropogenic influence via irrigation) as a result of SMAP soil moisture retrieval assimilation. The greatest sensitivity via assimilation was observed in cropland areas. Improvements in soil moisture potentially translate into improved spatiotemporal patterns of modeled evapotranspiration, although limited influence from soil moisture assimilation was observed on modeled processes within the carbon cycle such as gross primary production.”

Lines 472 to 473

“The results presented in Sect. 4 highlight that SMAP soil moisture assimilation decreased the magnitude of error (Table 2), and suggest improvements in the spatiotemporal soil moisture patterns (Figs. 3 and 7) and associated evapotranspiration (Fig. 8), particularly over irrigated areas.”

Line 476 to 477

“An important feature of SMAP retrieval assimilation observed in this study is the suggested correction of state estimation biases resulting from missing physics in the land surface model (unmodeled hydrologic process), i.e., irrigation.”

Comment: Also on this point, the title can be a bit misleading since there is no clear evidence of improved soil moisture across irrigated areas, but we see the impact of the assimilation across irrigated areas. Therefore, I also suggest a change in the title to clearly reflect the manuscript content.

Response: We have changed the title to be more reflective of the paper to:

“Soil moisture estimation across South Asia via SMAP retrieval assimilation”

Minor details

Comment: line 185 “ perturbations used by Kwon et al. (2019) (Table 2)” For completeness, I would recommend replicating Table 2 of Kwon 2019 (if there were no changes?) in the appendix for example.

Response: Thank you for the suggestion. The following table has been included in the appendix:

Table B1. Perturbation parameters applied to meteorological forcing fields for both the open loop and data assimilation simulations. M= multiplicative; A= additive.

Perturbed meteorological forcing	Perturbation type	Standard deviation	Cross-correlations with perturbations			
			P	SW	LW	Tair
Precipitation (P)	M	0.5	-	-0.8	0.5	-0.1
Shortwave radiation (SW)	M	0.3	-0.8	–	-0.5	0.3
Longwave radiation (LW)	A	50 W m⁻2	0.5	-0.5	-	0.6
Near surface air temperature (Tair)	A	1 K	-0.1	0.3	0.6	-

Comment: Figure 3: Please define acronyms in figure captions. E.g. “TPO” in red symbols are the observations ? SMAP-CDF are the colocated SMAP observations after CDF matching ? Also in Figure 10, e.g. panel c) FS GPP == FluxSat GPP ?

Response: Thank you for the recommendation. We have clarified the acronyms within the figure captions.

"Figure 3: Comparative timeseries of open loop (OL) and data assimilation (DA) estimated surface (top 5 cm) soil moisture. The solid line represents the ensemble mean whereas the shaded areas represent +/- 1 standard deviation () across the full ensemble. DA-CDF= assimilation with CDF-matching; DA-NoCDF= assimilation without CDF-matching; TPO= Tibetan Plateau Observatory measurements; SMAP-CDF= SMAP retrieval value after CDF-matching; SMAP-NoCDF= original SMAP retrieval value."

"Figure 10: Influence of SMAP soil moisture (SM) assimilation on an irrigated location is assessed through soil moisture of successive soil layers (L1 and L2), evapotranspiration (ET) and the corresponding behavior of the dynamic vegetation. ALEXI ET (Sect. 3.2.3), FluxSat gross primary production (FS GPP; Sect. 3.2.4), and GOME solar-induced chlorophyll fluorescence (SIF; Sect. 3.2.5) are used as evaluation datasets. (a) L1 = layer 1 near-surface SM and L2 = layer 2 root-zone SM. Noah-MP modeled ET exhibits similar temporal patterns as the near-surface SM (L1); however, root-zone (L2) SM and GPP are not correspondingly modulated. DA-CDF= assimilation with CDF-matching; DA-NoCDF= assimilation without CDF-matching."

"Figure 11: (a) Normalized information content (NIC) with respect to RMSE ($RMSE_{OL}$ versus $RMSE_{DA-NoCDF}$) is computed through comparison with FluxSat gross primary production (FS GPP). (b) Correlation with GOME solar-induced chlorophyll fluorescence (SIF) depicts the spatiotemporal consistency between the Noah-MP modeled GPP and GOME SIF. Data from the summer months of water years 2016-2019 were used to compute the metrics."

Comment: Lines 336-354: It's not clear what's the motivation of Figure 6. To link some potential impact of the DA as a function of soil texture ? While it was clear in Figure 5 for the land cover, I would recommend removing Figure 6, and just mention in the text that no clear link was found between soil moisture in OL vs DA-NoCDF for different soil textures.

Response: Similar to land cover type, Figure 6 was intended to examine the updates in the spatial patterns due to assimilation with respect to soil texture. The objective was to analyze if any meaningful conclusions could be drawn based on the different soil types. As was shown in Figure 6, there were no distinctive patterns with respect to varying soil compositions. According to Reviewer #1's suggestion, and in an effort to focus the discussion within the main text, Figure 6 has been moved to the appendix with the following text added to line 342:

"The OL and MERRA2-forced DA-NoCDF joint PDFs categorized with respect to soil texture types did not yield any distinctive patterns and are included in Appendix C for reference."

Comment: Line 47: please define PMW

Response: We have replaced the acronym with the full term, i.e., passive microwave.

Please also note the supplement to this comment:
https://hess.copernicus.org/preprints/hess-2021-460/hess-2021-460-AC1-supplement.pdf