This study evaluates the impact of integrating satellite-derived land cover and vegetation characteristics into the HTESSEL land surface model. By incorporating inter-annually varying land cover, leaf area index, and effective vegetation cover parameterization, the model's representation of evaporation and soil moisture is significantly improved, particularly in regions with changing land cover and during dry seasons. It is an interesting study, making good use of the satellite products available - it is very thorough with a lot of figures and quantitative analysis. Nevertheless, I have a few comments that must be addressed before the manuscript can be published.

Introduction

The introduction needs to be expanded. The authors mention that the LSMs do not adequately represent the variability of vegetation, but which models and what do they do instead? The authors also talk about how satellite data has been used to derive ancillary maps, improve parameterisation and evaluate models but don't really talk about how these data are used in data assimilation, which is similar to what is done here. There are a number of studies assimilating LAI (e.g., direct insertion, Kalman filter etc) as well as other satellite products to constrain phenology. I think the study not only benefit from an expanded literature review but also discussing the results in context of other studies. Few examples below:

Albergel, C., Calvet, J.-C., Mahfouf, J.-F., Rüdiger, C., Barbu, A. L., Lafont, S., et al. (2010). Monitoring of water and carbon fluxes using a land data assimilation system: A case study for southwestern France. *Hydrol. Earth Syst. Sci. Discuss.* 14, 1109–1124. doi: 10.5194/hess-14-1109-2010

Kumar, S. V., Mocko, D. M., Wang, S., Peters-Lidard, C. D., & Borak, J. (2019). Assimilation of remotely sensed leaf area index into the Noah-MP land surface model: Impacts on water and carbon fluxes and states over the continental United States. *Journal of Hydrometeorology*, *20*(7), 1359-1377.

MacBean, N., Maignan, F., Peylin, P., Bacour, C., Bréon, F.-M., and Ciais, P.: Using satellite data to improve the leaf phenology of a global terrestrial biosphere model, Biogeosciences, 12, 7185-7208, doi: 10.5194/bg-12-7185-2015

Rahman, A., Zhang, X., Houser, P., Sauer, T., & Maggioni, V. (2022). Global Assimilation of Remotely Sensed Leaf Area Index: The Impact of Updating More State Variables Within a Land Surface Model. *Frontiers in Water*, *3*, 200.

Rahman, A., Zhang, X., Xue, Y., Houser, P., Sauer, T., Kumar, S., et al. (2020). A synthetic experiment to investigate the potential of assimilating LAI through direct insertion in a land surface model. *J. Hydrol. X* 9:100063. doi: 10.1016/j.hydroa.2020.100063

About ESA-CCI SM

Note that the ESA-CCI SM combined product uses the GLDAS-Noah model to rescale the different retrievals prior to merging. In theory, this preserves the dynamics and trends of the SSM retrievals but imposes on the combined product the absolute values and dynamic range of GLDAS-Noah (Lui et al., 2012). However, there are also some cases where the dynamics are

also impacted (e.g., Raoult et al., 2022). As such, the authors need to be more mindful when discussing the product in the text:

L231: It is not just the difference in representative soil layers which is an issue, but the construction of the product itself. The merging process uses the climatology and soil depth (10cm) of the GLDAS-Noah model, changing the absolute values.

L414: This needs to be rephrased since it is not strictly true. Although the ESA CCI SM combined product is only made up of remote sensing retrievals, the fact that it does use a land-surface model means that the end product contains information inherited from GLDAS-Noah. Calling it the “most trustworthy” is quite strong. It is a very good global product but deserves more caveating. In fact, I think more text about its limitations is needed in this paragraph.

Liu, Y. Y., Dorigo, W. A., Parinussa, R. M., de Jeu, R. A., Wagner, W., McCabe, M. F., ... & Van Dijk, A. I. J. M. (2012). Trend-preserving blending of passive and active microwave soil moisture retrievals. *Remote Sensing of Environment*, *123*, 280-297.

Raoult, N., Ruscica, R. C., Salvia, M. M., & Sörensson, A. A. (2022). Soil Moisture Drydown Detection Is Hindered by Model-Based Rescaling. *IEEE Geoscience and Remote Sensing Letters*, *19*, 1-5.

About *k*

More discussion about *k* would be interesting. I realise the values are listed in Figure 10, but maybe a table of the different values for each vegetation in the supplementary materials could be referenced on L180.

L276: Do these values of *k* make sense? Do we expect it to be lower for high vegetation than low vegetation? If is why?

General

Figures 2-4 and their discussion belong in the results selection. For example, Figure 4 is first introduced on L161 but with no supporting analysis. Maybe it could be moved to when it is discussed later in the text.

L149: this is not shown anywhere, should Fig 2c be changed to show this? Maybe a stacked bar chart to show the different contributions of vegetation type replacing each vegetation?

Figure 5 would benefit from an extra panel for DOLCEv3 E since it discussed in Section 3.1

Minor

I would personally avoid using the word “observations” when referring to retrievals but acknowledge that “observations” is widely used.

The “jet” colour scheme is also no longer recommended for figures

Section 2: add punctuation to the end of equations 10, 11
Section 2.1: rename since doesn't include evaluation sets which are still EO products

L61 : add citations
L80: I believe Earth System Model could be capitalised
L110: I believe it should be 7-189
L113: formatting issue
L212: please put the version number of ESA-CCI SM product used
L215: remind the reader what the model resolution is
L233: what models? Do you mean experiments?
L435: not sure that "obviously" is very sciency