Review of the paper:

Using satellite observations of precipitation and soil moisture to constrain the water budget of a land surface model

by Ewan Pinnington et al.

General comments

The paper describes a data assimilation exercise in which CCI satellite soil moisture observations derived from the active+passive product are ingested into the JULES land surface model. The 4D variational data assimilation approach is used for the adjustment of model parameters via the correction of the soil texture (i.e., the relative percentage of clay, sand and silt) through pedo-transfer functions. The authors show that after the ingestion the model soil moisture estimates are closer to CCI observations not only during the assimilation time period but also in the hindcast period. In addition, TAMSAT precipitation is used for driving the model suggesting that a better precipitation product is able to improve the soil moisture wetting up better than the assimilation of soil moisture does.

Evaluation

The paper is well written and clear and well fits the scope of the journal. I have four main MAJOR issues that the authors should clarify prior the paper can be considered adequate for a publication in HESS. I also have additional comments that should be addressed.

1) My main concern about this DA exercise relies upon the validation procedure. A fundamental assumption made by the authors (but never cited in the text) is that the CCI soil moisture product, being an observation, can be considered close to the truth. This is not explicitly said in the text but the numerous “RMSE reduction”, “bias reduction“ statements make think that we are reducing an error with something that is supposed to be very accurate and basically a close representation of the true soil moisture at the ground. However, satellite soil moisture products are far to be close to the truth, especially in areas with dense vegetation. Based on that, the exercise appears to me more a way to adjust the JULES soil moisture estimates to the CCI observations rather than an effective and real improvement of the model estimates. To this end, I suggest to:

- Demonstrate with independent observations (i.e., for instance derived from in situ stations) that the CCI is a relatively good product in Ghana and that the soil moisture estimates after assimilation are able to improve the JULES soil moisture estimates (and possibly the CCI itself which is the main task of any assimilation exercise). If independent observations are not available the authors can cross-validated the different soil moisture products by using them within an application.

- Change notation when compare JULES estimates with CCI as RMSE and BIAS refer to a product, i.e., the CCI, that is already uncertain itself and has its own bias and error with an unknown truth. I suggest to use root mean square differences (RMSD) and mean relative error.

2) A second issue is related to the performance scores used by the authors. That is RMSE and BIAS. From the figures it clearly appears that the main contribution of the DA is the correction of the bias. Therefore, the reduction in RMSE which contains information about both the correlation and the bias is mainly driven by the bias adjustment. That is, assuming CCI a good representation of the soil moisture at the ground, it is not clear if the DA is able to reduce the random error or only change the bias. If this is the case this could be simply achieved by a simple rescaling of the model estimates to the CCI observations. Therefore, I suggest the authors to use self-consistent scores like correlation, R^2 or fractional root mean squared differences (fRMSD, Draper et al. 2013).

   Draper, C., Reichle, R., de Jeu, R., Naeimi, V., Parinussa, R., & Wagner, W. (2013). Estimating root mean square errors in remotely sensed soil moisture over continental scale domains. *Remote Sensing of Environment*, *137*, 288-298.

3) A third issue, also highlighted by the authors but only at the end of the manuscript is the depth mismatch between ingested observations and model estimates. I think that the assumption of CCI soil moisture observations being representative of the first 10 cm is unrealistic. I suggest reformulating this assumption or providing more robust evidences for demonstrating it. In this respect, I have a suggestion. If the authors want to ingest CCI observations and solve the problem of the depth mismatch between CCI and JULES a simple and effective solution could be the use of the exponential filter (Albergel et al. 2008). Many studies of sequential DA into hydrological model use this solution (see Massari et al. 2015, Alvarez and Garreton 2016).
   In addition there is not mention about the effect of the ingested observations in the deeper layers. This should at least mentioned and discussed.

Albergel, C., Rüdiger, C., Pellarin, T., Calvet, J. C., Fritz, N., Froissard, F., ... & Martin, E. (2008). From near-surface to root-zone soil moisture using an exponential filter: an assessment of the method based on in-situ observations and model simulations. Hydrology and Earth System Sciences Discussions, 12, 1323-1337.

Massari, C., Brocca, L., Tarpanelli, A., & Moramarco, T. (2015). Data assimilation of satellite soil moisture into rainfall-runoff modelling: A complex recipe? Remote Sensing, 7(9), 11403-11433.

Alvarez-Garreton, C., Ryu, D., Western, A. W., Crow, W. T., Su, C. H., & Robertson, D. R. (2016). Dual assimilation of satellite soil moisture to improve stream flow prediction in data-scarce catchments. Water Resources Research, 52(7), 5357-5375.

4) Finally yet importantly, the changing of the soil texture after DA should somehow reflect the real ground texture more than the Harmonized database can do. This has to be demonstrated and

can constitute an additional proof for the DA exercise to be able to improve the model representation of the reality. Otherwise, DA becomes a simple fitting of the CCI observations.

I have also other additional comments that I will list below in order of appearance in the manuscript.

MODERATE. Section 2.2 Define here which are the differences between TAMSAT 2.0 and 3.0

MODERATE. Equation 1. Define *N*. Also $\boldsymbol{x}_i$ should not be $\boldsymbol{x}_o$? What does $\boldsymbol{x}_i$ represent?

MAJOR. Section 2.4. Describe here or later how the matrices ***B*** and ***R*** are estimated. This is totally missing in the text and is one of the most important topic in data assimilation.

Pag 12. Line 15. To retrieve hydraulic parameters… There is not proof in the paper that the DA scheme used is able to retrieve hydraulic parameters. Please clarify this aspect or remove.