Authors' response letter (hess-2023-304)

The following is a point-to-point response to comments by reviewer #2

Dear Reviewer #2,

We thank you very much for your constructive comments and suggestions. The comments are very useful to improve the quality of our paper. All concerns and suggestions raised are addressed accordingly. Please find below your comments and our responses. Note that the authors' responses are highlighted in red.

P2L7

Comment #1: 'also thermal conductivity/diffusivity etc.'

Response #1: Thanks for the suggestion. This will be edited accordingly.

P2L26-28

Comment #2: 'A study on Tibetan Plateau shows that five soil databases are all different from the in-situ soil samples in terms of soil texture, bulk density, etc.'

Zhao, H., et al.: Analysis of soil hydraulic and thermal properties for land surface modeling over the Tibetan Plateau, Earth Syst. Sci. Data, 10, 1031–1061, https://doi.org/10.5194/essd-10-1031-2018, 2018

Response #2: Many thanks for sharing this useful and insightful material.

P8L1-2

Comment #3: There are many 1km soil moisture product available, perhaps interesting to add other 1km SM product to the comparison.

Han, Q., Zeng, Y., Zhang, L. et al. Global long term daily 1 km surface soil moisture dataset with physics informed machine learning. Sci Data 10, 101 (2023). https://doi.org/10.1038/s41597-023-02011-7

Zheng, C., Jia, L. & Zhao, T. A 21-year dataset (2000–2020) of gap-free global daily surface soil moisture at 1-km grid resolution. Sci Data 10, 139 (2023). https://doi.org/10.1038/s41597-023-01991-w

Zhang, Y., Liang, S., Ma, H., He, T., Wang, Q., Li, B., Xu, J., Zhang, G., Liu, X., and Xiong, C.: Generation of global 1 km daily soil moisture product from 2000 to 2020 using ensemble learning, Earth Syst. Sci. Data, 15, 2055–2079, https://doi.org/10.5194/essd-15-2055-2023, 2023

Response #3: Many thanks for sharing these important materials. We have independently evaluated and compared the 1 km GSSM soil moisture, 25 km ESACCI SSM products and 1 km ASCAT SWI against the station observations. Our results (as demonstrated in Figures 1 below) suggest that ASCAT yields better performance than ESACCI SSM and GSSM 1 km products, though the latter products show higher temporal dynamics as shown by the higher temporal correlations with the ground observations. The increasing and decreasing trends are also better captured by ASCAT. While the uncertainty in GSSM products is likely linked to lack of training data from Ireland, the biases in ESACCI SSM may be attributed to its native grid resolution which is too coarse to effectively represent the soil heterogeneity, and/or differences in soil depths. We have therefore carefully chosen ASCAT as the reference.

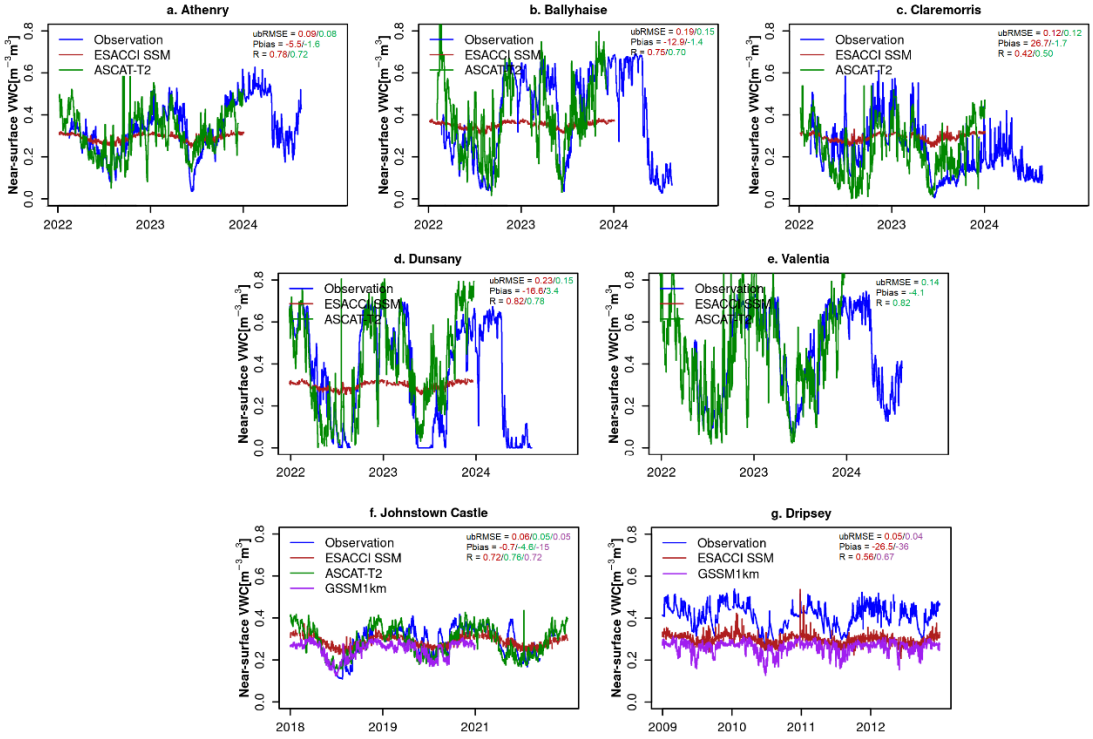

Figure 1. Evaluation of satellite-derived 1 km ASCAT-T2 (0-10 cm), 1 km GSSM (0-5 cm) and 25 km ESACCI near-surface soil moisture against the station observations. No available ESACCI SSM grid values for Valentia, and due to ASCAT later year of operation in 2015, no available ASCAT values also for Dripsey.

P9L30

Comment #4: There are descriptions on which soil datasets lead to better statistics, however, this reviewer is missing 'then what'. What readers can learn from this exercise in terms of improving either one soil databases? Or indicating model deficiency for future improvements?

Response #4: Thanks for the comment. In our conclusions, we highlight the shortcomings of global soil databases, and model deficiency due to uncertainty of soil hydro-physical parameters. Our study underscores the need to improve the PTFs used in Land surface models and/or development of detailed region-specific soil properties to enhance land surface model performance applied to highly heterogeneous and managed landscapes and improve our understanding of the role of soils in land surface processes.

P9L35

Comment #5: It is not clear what is the resolution of the model areal grid. Is it 9km (5 arcmin)?

Response #5: The model resolution is 1 km. This is highlighted in section 2.4 of the paper.

P10L22

Comment #6: For Athenry and Johnstown Castle, you can say that, for the rest, the simulations are way off the observations.

Response #6: We agree with your observations. We have mentioned these locations in the same statement, but we may rephrase the statement accordingly to avoid confusion.

P10L30-31

Comment #7: By 'reference' here, do you mean, in this case, due to the match of grid resolution, ASCAT satellite data is more comparable to the model simulation results?

Response #7: Yes, ASCAT is treated as the reference, as it performs better than ESA CCI SSM and 1km GSSM products (see Figure 1 above). It's also non-blended/non-modeled satellite products, 1 km spatial resolution matching the model grid and provides information that allows evaluation of surface and subsurface soil moisture.

P12L17-19

Comment #8: This reviewer think it is still making sense to compare with satellite LST data, for example, from ESA CCI LST. Such comparison with independent dataset may reveal some further insights.

Response #8: Thanks for your useful suggestion. We are aware of this and have previously incorporated satellite LST from MODIS to investigate the capability of a land surface model over Ireland (Ishola et al. 2022). The satellite LST allowed us to compare and demonstrate the patterns of change in temperature across the surface, however, the context of the current work is on the physics of soil moisture and soil temperature for which we now have actual measurements from a network of stations to evaluate our models across the country. We believe this is a fair judgement and therefore we have ruled out further investigations using satellite LST

Reference

Ishola, K. A., Mills, G., Fealy, R. M., Fealy, R.: A model framework to investigate the role of anomalous land surface processes in the amplification of summer drought across Ireland during 2018, I*nternational Journal of Climatology*, 43, 480 - 498. https://doi.org/10.1002/joc.7785 , 2022

P14L14-17

Comment #9: From the result, it is not clear how field capacity difference influences the differences in soil moisture simulations.

Response #9: Thanks for the comment. From basic knowledge of soil water, we understand that field capacity and wilting point are required to determine the available water, the model implements that within the diffusivity form of Richard's soil water representation shown below and in this work we have provided a demonstration of the importance of the soil datasets field capacity in driving the soil water conditions within the model.

As demonstrated at Dripsey site (see Figure 12 in the paper) for example, when we changed the field capacity to be representative of the actual value of the site, we obtained much better results for STATSGO, relative to SOILGRID. The SOILGRID with lower soil field capacity than STATSGO (see Figure 3 of the paper) allows water to drain more quickly, thereby retaining less water in the pore spaces and increasing dry conditions in the model. Our calculation of grid-scale Pearson correlation coefficients between mean difference (standard deviation difference) of soil moisture and difference in the field capacity yields approximately 0.65 (0.45), and -0.40 (-0.1) with the soil hydraulic conductivity difference. This suggests that the mean and variability of soil moisture difference between STATSGO and SOILGRIDS are significantly ($p < 0.05$) influenced by the soil parameter values. However, for robust understanding on whether the remaining errors in the simulations are still linked to soil parameter uncertainty, it would involve performing ensemble simulations based on ensemble of parameter values which is beyond the scope of this work.

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial \theta}{\partial z}\right) + \frac{\partial K}{\partial z} + S$$

P14L25-27

Comment #10: it is not clear from the result that there is a reference soil databases. So when the authors mentioned 'accurately represented', this reviewer is confused.

Response #10: The stations (Johnstown Castle and Dripsey) with extended period of measured data provide further information on soil properties (e.g. Kiely et al., 2018; Ishola et al., 2020), including the soil FC values which were contrasted against the model prescribed FC values before arriving at the phrase 'accurately represented'.

We will revise section 2.5 to include information on the available measured soil FC values from the two stations.

References

Kiely, G., Leahy, P., Lewis, C., Sottocornola, M., Laine, A., Koehler, A.-K.: GHG Fluxes from Terrestrial Ecosystems in Ireland. Research report No. 227.EPA Research Programme, Wexford. Available online at https://www.epa.ie/publications/research/climate-change/research-227.php, 2018

Ishola, K.A., Mills, G., Fealy, R.M., Ní, C.Ó. and Fealy, R.: Improving a land surface scheme for estimating sensible and latent heat fluxes above grassland with contrasting soil moisture zones. *Agricultural and Forest Meteorology*, 294,108151. https://doi.org/10.1016/j.agrformet.2020.108151 , 2020

P15L8-9

Comment #11: but this is also very much induced by how you preprocess SOILGRID data to your model grid?

Response #11: We agree with your observations. The lack of improvement in SOILGRID for this illustration is also linked to the preprocessing, particularly the empirical PTFs coefficients which are underpredicting the soil parameter values at the topsoil layer for Ireland's landscapes.

The statement will be revised accordingly.

P15L32-34

Comment #12: A latest paper explains some further challenges in terms of PTFs.

Weber, T. K. D., Weihermüller, L., Nemes, A., Bechtold, M., Degré, A., Diamantopoulos, E., Fatichi, S., Filipović, V., Gupta, S., Hohenbrink, T. L., Hirmas, D. R., Jackisch, C., de Jong van Lier, Q., Koestel, J., Lehmann, P., Marthews, T. R., Minasny, B., Pagel, H., van der Ploeg, M., Svane, S. F., Szabó, B., Vereecken, H., Verhoef, A., Young, M., Zeng, Y., Zhang, Y., and Bonetti, S.: Hydro-pedotransfer functions: A roadmap for future development, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1860, 2023.

Response #12: Many thanks for sharing this material with us. It's very relevant and information will be integrated into the statement made in the paper.

P17L11

Comment #13: you cannot tell from the results.

Response #13: We have made the judgement based on Athenry, Johnstown Castle and Dripsey stations, where the variances in simulated soil moisture are close to the observed values (see Figure 2 below). However, we will revise this section accordingly to properly describe the uncertainties in our results.

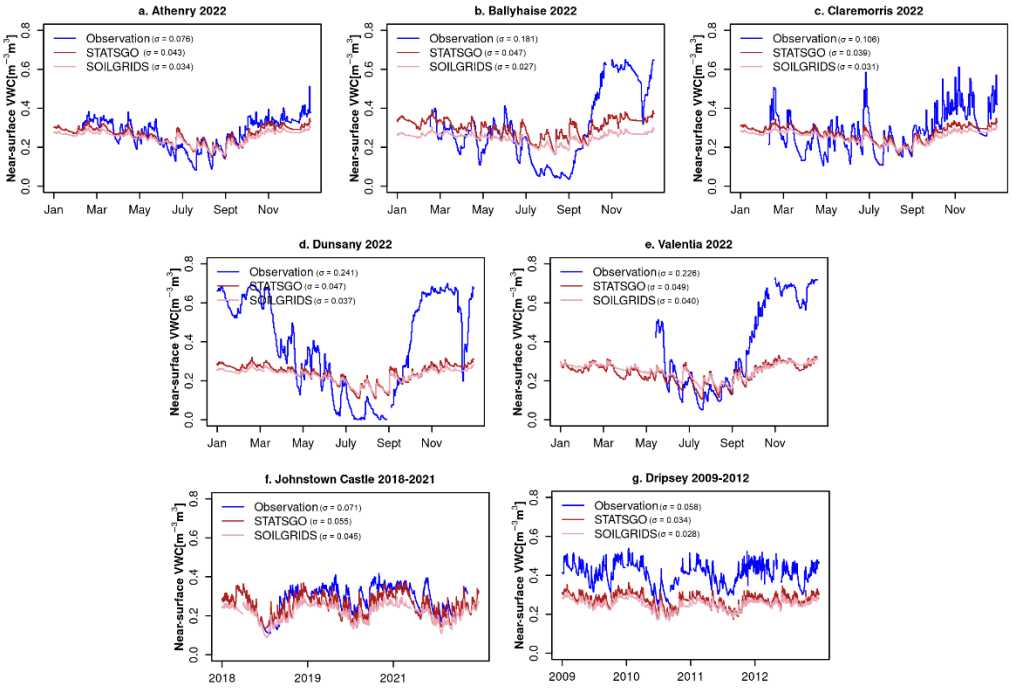

Figure 2. Temporal comparisons of near-surface volumetric water contents between observations at 5 cm depth and model simulations centered at 3.5 cm depth. The model simulations are contrasted with 20 cm depth due to unavailable near-surface observations for Johnstown Castle and Dripsey

P17L21-23

Comment #14: are you suggesting using ASCAT SWI is already enough, and there is no need of a LSM here then?

Response #14: We are suggesting based on the better performance of ASCAT SWI against station observations, relative to GSSM and ESACCI SSM (see Figure 1 above). The LSM is important to better understand the physics and complexity of soil moisture dynamics especially for Ireland where the landscapes are heavily managed and heterogeneous.