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Interactive comment

Interactive comment on "Validation of SMAP L2 passive-only soil moisture products using *in situ* measurements collected in Twente, The Netherlands" *by* Rogier van der Velde et al.

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The authors would like to thank the referee for carefully reading our manuscript and providing constructive criticisms. In our response below we reply to the individual concerns.

Referee 2 comment 1: I believe the authors should explain better why they used a model for root-zone soil moisture (40 cm depth) to represent the 5 cm depth soil moisture (both in situ and SMAP estimates).

Authors' response: The model used in this study is the Dutch national hydrological

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model (LHM). This is a modelling framework that couples physically-based modelling approaches for groundwater, unsaturated soil and surface water flow. Particularly the combination of groundwater and unsaturated soil water flow is advantageous for a region with shallow groundwater tables, such as the Netherlands. Another advantage of using LHM is that it makes use of best possible boundary conditions and atmospheric forcings, e.g. 100 m resolution subsurface information, 500 m resolution soil maps and coupled soil physical characteristics, 5 m resolution Digital Terrain Model, 25 m resolution land use map, 1 km resolution daily rainfall and reference evapotranspiration.

We agree with the reviewer that for this research a model with a shallower top soil layer would have been better, but that would have been impossible with the set of boundary conditions and atmospheric forcings available for the LHM. Therefore, we have chosen to use the root zone soil moisture simulated by the LHM and transform this towards the statistical moments of the 5 cm in situ measurements as is presented in section 5.1. We justify the validity of this approach based on the findings of Caranza et al. (2018). They found strong linear relationships between the 5 cm and 40 cm in situ measured soil moisture by the Twente monitoring network suggesting that the surface soil moisture can be used proxy for the root zone soil moisture and vice versa. Pezij et al. (2019) have previously adopted this assumption successfully for the assimilation of the SMAP L3 product into the LHM. Here we used it to develop upscaling functions to translate the spatial mean of point measurements to the domain of the SMAP reference pixels.

Section 5.1 is fully devoted to the justification for using the simulated root zone soil moisture as proxy of the in situ measured soil moisture at 5 cm depth. A discussion on this topic in the context of Carranza et al. (2018) and Pezij et al. (2019) can be found on P10L5-L10. In revised manuscript we will referred to this discussion when we introduce the use of the LHM root zone soil moisture simulations around P6L20. Further it should also be noted that the soil moisture states in process models are defined at the mid-point of the soil layer, 20 cm, and the 5TM probe installed 5 cm below the soil surface has an approximate 4 cm influence zone and measures over a 1-9 cm soil layer. This information can be partly found on P9L14-L16. We will update the text with the fact that the model states are defined at the mid-point of the root zone layer, e.g. 20 cm.

References: Carranza, C. D. U., van der Ploeg, M. J., and Torfs, P. J. J. F.: Using lagged dependence to identify (de)coupled surface and subsurface soil moisture values, Hydrol. Earth Syst. Sci., 22, 2255-2267, doi:10.5194/hess-22-2255-2018, 2018.

Pezij, M., Augustijn, D.C.M., Hendriks, D.M.D., Weerts, A.H., Hummel, S., van der Velde, R., and Hulscher, S.J.M.H.: State updating of root zone soil moisture estimates of an unsaturated zone metamodel for operational water resources management, J. Hydrol. X, 4, 100040, doi: 10.1016/j.hydroa.2019.100040, 2019

Referee 2 comment 2: Figures 5 and 6 shows that the match between model and measurements is not very good and I was wondering if the authors tried to get a relationship between the 5 cm and the 40 cm soil moisture values.

Authors' response: Indeed the 1:1 match between the measurements and the model simulations has imperfections, but we can also note that both respond in a similar fashion to rainfall inputs as is supported by the high correlation coefficients (> 0.88). In the manuscript in section 5.1 we attribute the difference between the 5 cm in situ measured soil moisture and the root zone soil moisture simulations to discrepancies in soil properties, in soil depth over which information is provided and the decoupling of the surface and subsurface soil moisture when the groundwater retreats under dry conditions.

For this manuscript, we have made use of the complete matchup set as well as the part of the set, for which a linear relationship is found, to develop the upscaling function. We have not included a comparison between the root zone soil moisture simulations and the subsurface in-situ measurements because we do not find this relevant for the objectives of this research.

However, we do find the question interesting and for the response to this referee comment, we have made the comparison between the LHM root zone soil moisture and 20 cm in situ measurements. Note that we have taken the 20 cm measurements because this is at the center of the 40 cm root zone layer in LHM and the model states are defined at the mid-point of the soil layer. The matchups are shown in the figure 1 and the metrics obtained are: a correlation coefficient of 0.95, a RMSE of 0.066 m3 m-3 and a bias of 0.067 m3 m-3. In general, the distribution of the data points in the plot are similar to those in figure 6 except that the spread of the data points is somewhat smaller and discontinuity is less sharp than in the comparison with the in situ soil moisture measured at a 5 cm depth.

Referee 2 comment 3: The validation is then carried out using the raw in situ measurements because it gives better results.

Authors' response: To be precise, we have carried out the validation with two references based on the native spatial mean derived from the in situ measurements and four references based on different versions of the upscaled spatial mean also derived from the in situ measurements. The results showed, however, that the best error metrics are obtained with the reference for which no upscaling has been performed.

In the discussion, section 7, we further analyse the error distribution and hydrometeorological circumstances under which large errors occur. We have chosen to only present the results with the native spatial mean for brevity. This has no influence on the findings in general because the upscaling is linear.

Referee 2 comment 4: The authors explain mismatches based on physical processes and the inability of SMAP to capture those processes. I would have liked to see more references when describing potential sources of error.

Authors' response: In the section 7.2 we refer to Colliander et al. (2017), Zheng et al. (2019) and Shellito et al. (2016) in the context of the dependence of the sampling depth on the soil moisture content. In the revised manuscript we will discuss the impact of standing water (floods) and frozen conditions also in the context of other investigations. For example, Brakenridge et al. (2007) have demonstrated the use of microwave radiometry for the estimating river discharge based on flood extent and Wegmüller (1990) described the behaviour of microwave signature under frozen and thaw soil conditions. Further, we will refer the SMAP and SMOS literature as the soil moisture products derived from both missions include flags for frozen soils and mitigation measures to account for permanent water bodies.

References: Brakenridge, G. R., Nghiem, S. V., Anderson, E., and Mic, R.: Orbital microwave measurement of river discharge and ice status, Water Resour. Res., 43, W04405, doi: 10.1029/2006WR005238, 2007.

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Shellito, P.J., Small, E.E., Colliander, A., Bindlish, R., Cosh, M.H., Berg, A.A., Bosch, D.D., Caldwell, T.G., Goodrich, D.C., McNairn, H., Prueger, J.H., Starks, P.J., van der Velde, R. and Walker, J.P.: SMAP soil moisture drying more rapid than observed in situ following rainfall events, Geophys. Res. Lett., 43. 9068-8075, doi: 10.1002/2016/GL069946, 2016.

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Zheng, D., Li, X., Wang, X., Wang, Z., Wen, J., van der Velde, R., Schwank, M., and Su, Z.: Sampling depth of L-band radiometer measurements of soil moisture and freeze-thaw dynamics on the Tibetan Plateau. Remote Sens. Environ., 226, 16-25, doi: 10.1016/j.rse.2019.03.029, 2019.

Referee 2 comment 5: The last paragraph does not seem to follow directly from the objectives of the paper or the results presented in the paper. It is also not clear to me how the mismatches can be used to help management.

Authors' response: We agree with the referee that the last paragraph does not follow directly from the results of the paper. We will remove this from the manuscript.

Referee 2 comment 6: My last point is regarding the abstract: even though the fact that the upscaling did not work is included in the conclusions, it has not been included in the abstract.

Authors' response: Our intention was to keep the abstract short with only the most relevant information for the readers. In the abstract we do mention around l16-17 the use of the Dutch national hydrological model for 'the development of upscaling functions to translate the spatial mean of point measurements to the domain of the SMAP reference pixels'. But indeed we do not follow up on the results obtained as we do in the conclusion with 'The upscaled in situ reference do not result in better metrics'. A similar statement we will include in the abstract.

Referee 2 comment 7: A minor point is that in the supplement, the tittle of the paper wrongly includes the word "upscale". Authors' response: Thank you, we will correct this.

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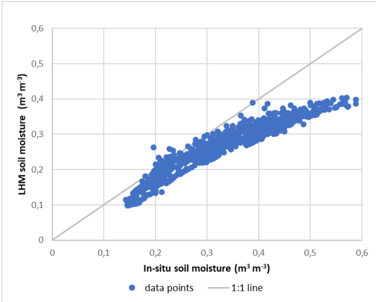

Figure 1. LHM root zone soil moisture against *in situ* measured soil moisture at a depth of 20 cm.

Fig. 1.

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