Response to Referee #3's Comments

The manuscript evaluates the downscaling of CCI soil moisture using the VTCI derived from MODIS and MSG SEVIRI, and comparing the results with in-situ observations from the Remedhus network. The authors nicely explain the downscaling methodology (which I was not familiar with) and also the background of the several remote sensing products used. The article is well structured and I enjoyed reading it. My only general remark is that the use of the English could be improved (e.g., articles are often missing, sometimes singular/plural is not used appropriately).

Response: We thank you for the considerable time that you devoted to this manuscript. And thank you for the positive comments and suggestions. The English of the manuscript also has been improved according to your comments. In the following, we provide an item-by-item response to your specific comments. Your comments are written in italic black color; our responses are shown in upright font blue color.

Specific comments:
P8507, line 4: "(e.g., Poporato et al., ...)"

Response: Thanks, this has been changed.

P8507, line 13: "dynamic forces distribution" - I don't understand this term, do you mean the meteorological forcing?

Response: To make it clear, this has been changed to "dynamic meteorological forcing".

P8510, line 1-3: "... like e.g., the as ..." - rephrase.

Response: Thanks. The sentence has been changed to "Normally the polar orbiting satellites such as Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Very High Resolution Radiometer (AVHRR) are in general used for downscaling microwave soil moisture, while the geostationary satellite data are rarely applied."

P8510, line 26: remove "can"

Response: It has been removed.

P8511, line 4: "products" is plural

Response: Corrected, thanks.

P8512, line 11-15: "Similarly, Zeng et al, ..." - this conclusion might be different for the region under investigation here, e.g., ERA-Land was shown to often have a better global performance than CCI soil moisture (e.g., Albergel et al. 2013). It's possibly better to refer here to some of the more comprehensive validations of CCI soil moisture (e.g., see also Dorigo et al. 2015).

Response: Thank you for pointing this out. The sentence has been changed to “Similarly, Albergel et al. (2013) provided an evaluation of CCI SM and two reanalysis soil moisture products using in-situ observations from five networks across the world. They concluded that the CCI SM product correlates well with in-situ observations with average R of 0.60.”

P8512, line 28: "modes" instead of "nodes"

Response: Corrected, thanks.

P8516, line 16: who were these settings chosen?

Response: The settings here are described in details in the followed sub-paragraph 1-4. Table 3 aimed to illustrate the labels of x-axis in Figure 3.

P8517, line 20: replace "would be" with "remain"

Response: Corrected, thanks.

P8518, line 5: "VTCI" instead of "VCTI"

Response: Corrected, thanks.

P8519, line 26: remove "that"

Response: Corrected, thanks.

P8521, line 1: "... that are required ..."

Response: Corrected, thanks.

P8521, line 3: "... soil moisture that is required ..."

Response: Corrected, thanks.

P8521, line 20/21: "... LAI ... can represent the status of soil moisture" - I don’t see why this is true for LAI, it has very low correlation with soil moisture. Please clarify.

Response: We tried to show that the LAI has similar seasonal trend as in situ measured soil moisture. But the LAT is less sensitive to soil moisture than the surface temperature. The text in the manuscript has been changed to “The results suggest that the surface temperature is more sensitive to soil moisture than the LAI.”

P8523, line 1: Mainly R seems to be better in the original CCI - do you have an idea why?

Response: It is a good question. The worse R of downscaled SM over some stations might be due to the uncertainties of VTCI. From the downscaling scheme itself, it can be seen that the accuracy of downscaled SM depends on original CCI SM and VTCI. In theory, if the VTCI can

perfectly represent the soil moisture, the accuracy of downscaled SM would be highly improved. That is reason why we conducted the sensitivity analysis of the VTCI to surface temperature, vegetation index, cloud, topography and land cover heterogeneity.

P8524, line 3: "of R, BISA, RMSD and ubRMSD" - Why are the numbers in Fig. 8 not consistent what you write in the first paragraph of Section 5.4?

Response: In this study, we used two comparison strategies. The first is validation at each station. The second is validation at network scale. The statistics presented in the first paragraph of Section 5.4 are the average values of R, BIAS, RMSD and ubRMSD that were calculated at each station. The statistics in line3 are the comparison results at network scale, which means the CCI SM and in-situ measurements are firstly averaged over the network, then the R, BIAS, RMSD and ubRMSD are calculated. The motivation of conducting the network comparison is to reduce the uncertainties introduced by scale differences between in-situ point and satellite pixel.

P8524, line 5: "overestimating soil moisture," - This does not seem to be consistent with Fig. 7, where the remote sensing soil moisture is rather underestimating compared to measured soil moisture?

Response: Thanks for the question. The “overestimation of soil moisture” is concluded from the network scale comparison. And from the station scale comparison (Fig 6), it can be seen that CCI SM seems to overestimate soil moisture at most stations with positive biases. And it is true that underestimation is observed in a few stations such as M13 that is shown in Fig 7.

P8524, line 7: "present more detailed spatial details" - Can you verify this by e.g., looking at the spatial variability of in-situ vs. remote sensing products?

Response: Thanks. It is really a good question. It is important and interesting to investigate if the downscaled soil moisture can represent the real spatial variability of soil moisture. The problem is the reference (spatial map of in-situ soil moisture) dataset is missing. We actually have tried to get this reference data through interpolating the REMEDHUS in-situ measurements. But we found that the interpolation scheme itself would incur uncertainties, as different interpolation schemes lead to different results. In our another study in China (Peng et al., 2016), we compared the spatial pattern of the downscaled soil moisture with high spatial resolution land cover map, and found that the downscaled soil moisture correspond well with the land cover map. Nevertheless, we fully agree with you, and we think the best solution for validating the spatial pattern of downscaled soil moisture is the availability of reference data. Therefore, the interpolation of intensive in-situ soil moisture to get real spatial soil moisture map should be focused in the future studies.

P8525, line 3/4: " better performance in summer and winter in terms of R, BIAS, RMSD and ubRMSD values" - Add "especially for MSG downscaled SM", as MODIS is sometimes worse than CCI.

Response: Done, thanks. “the downscaled soil moisture especially from SEVIRI”

P8525, line 11: "land use"

Response: Corrected, thanks.

P8525, line 14: What is meant by "similar"? Statistically not distinguishable? This is difficult to judge from the small number of stations within the categories. Please mention within what value bounds you consider the results as similar.

Response: Thanks for the questions. The “similar” term used here is concluded from the different performance of land uses in terms of R, ubRMSD, RMSD. For R value, the Forest-Pasture mainly has highest value than vineyard and rainfed. But it has highest ubRMSD values. For RMSD, the highest values are observed in Vineyard. To make it clear, we rephrase the sentences as “Figure 10 shows the performances of original CCI SM and downscaled SM over different land use categories. It can be seen that vineyard and rainfed have similar performance in terms of R and ubRMSD, while the forest-pasture presents relatively high R and ubRMSD that might be due to its limited number of stations.”

P8525, line 17: "MODIS and SERVIRI have similar performance" - However, the results presented above often showed slightly better results for SEVIRI, why this difference?

Response: Yes, slightly better performance for SEVIRI can be observed. It is due to the slightly better performances of SEVIRI over MODIS at each station, which is consistent with the results that are shown in Fig 6 and Fig 8.

P8525, line 17: "SEVIRI" instead of "SERVIRI"

Response: Corrected, thanks.

P8526, line 4/5: "has slightly better performance than 0.05◦ soil moisture in terms of mean R, RMSD, ubRMSD values" - Quite difficult to see in the avg,std bars, and within the error bars.

Response: Thanks for the comment. To support this statement, the statistic scores are add in the manuscript:

“Besides, the 1 km soil moisture has slightly better performance than 0.05° soil moisture in terms of mean R (0.465/0.44), RMSD (0.112/0.113 m^3/m^3), ubRMSD (0.055/0.058 m^3/m^3)”

P8527, line 3: change to "... method are its simplicity, the fewer required inputs and ..."

Response: Thanks for the comment. It is done already.

P8548, Fig. 9: Please add error bars to the bars (consistent with Fig. 6 right-hand bars).

Response: Thanks for the suggestion. The results here are based on the network averaged analysis. Therefore, we cannot add the error bars here.

References:

Albergel, C., Dorigo, W., Reichle, R. H., Balsamo, G., de Rosnay, P., Muñoz-Sabater, J., Isaksen, L., de Jeu, R., and Wagner, W. (2013). Skill and global trend analysis of soil moisture from reanalyses and microwave remote sensing. Journal of Hydromete- orology, 14(4):1259–1277.

Dorigo, W. A., Gruber, A., De Jeu, R. A. M., Wagner, W., Stacke, T., Loew, A., Albergel, C., Brocca, L., Chung, D., Parinussa, R. M., and Kidd, R. (2015). Evaluation of the ESA CCI soil moisture product using ground-based observations. Remote Sensing of Environment, 162:380–395.

Peng, J., Loew, A., Zhang, S., Wang, J., and Niesel, J.: Spatial Downscaling of Satellite Soil Moisture Data Using a Vegetation Temperature Condition Index, IEEE Transactions on Geoscience and Remote Sensing, 54, 558-566, 2016.