Exploring the combined use of SMAP and Sentinel-1 data for downscaling soil moisture beyond the 1 km scale

The authors test the possibility of downscaling SMAP coarse soil moisture to the sub-kilometer resolution using Sentinel-1 SAR data. This paper is interesting and the topic is suitable to HESS. However, I have several major comments the authors should seriously consider.

Major comments:

1. This paper directly disaggregates the SMAP coarse soil moisture at 9 km to high resolution using Sentinel-1 SAR backscattering coefficients. It should be noted that the method tested in this paper is based on the assumption of a near-linear relationship between radar backscatter σ^0_{pp} and soil moisture θ at different scales. In order to estimate the parameter β, a time regression is performed under the assumption that the soil roughness and vegetation conditions do not change greatly over a specified temporal window. Meanwhile, the parameter β is NOT invariant in time and space and it depends on vegetation cover and type as well as surface roughness. Therefore, a moving window of β estimation should be adopted when applying this downscaling algorithm to a long time period and the length of time window should be carefully determined. In this study, about 377 images of synchronized SMAP and Sentinel-1 were obtained during the period of January 1, 2017 to May 31, 2019. However, this paper did not describe how to determine the parameter β. In Page 15 Line 445, a temporal window of 40 data points was used to derive seasonal Γ. To derive β?

2. Page 14 Line 425-426: The soil moisture derived by CRNS shows a good linear correlation with Sentinel-1 VV and VH backscatter at a resolution of 100 m and 200 m at the agricultural and heathland site.
A good linear correlation between radar backscatter and soil moisture was observed in this study, which is the foundation of the downscaling algorithms. However, this good correlation may be caused by seasonal vegetation variations as indicated in Line 427-429. Please do more analyses to prove that the good correlation between radar backscatter and soil moisture was not induced by vegetation changes.

3. Page 15 Table 5: This table lists eight types of β and Γ combinations. However, the reviewer cannot follow how the β and Γ were estimated and the differences between different experiments. Please make more explanations.

4. Page 15 Table 4: This study estimated cluster dependent parameters β and Γ. The parameter of β was obtained from linear regression of soil moisture θ_{coarse} at coarse resolution and averaged backscatter within this coarse pixel. However, the soil moisture θ_{coarse} represents the average soil moisture condition. How can the θ_{coarse} be related to backscatters of different land cover types? Please clarify it and make more explanations.

Other comments:

1. Table 1 and Figure 3 can be merged, with R^2, bias and RMSE putting in the scatter plots.

2. Page 5 Line 210-211: The Ahlergaarde catchment is covered by 21 SMAP pixels. Please indicate the 21 SMAP pixels in Figure 1 with grids. Are the SMAP pixels in resolution of 9 km by 9 km or 36 km by 36 km?

3. Page 6 Line 230-233: For a deeper investigation of the spatial pattern information content of the Sentinel-1 data, an unsupervised data driven k-means cluster analysis is performed based on four parameters, the mean and the standard deviation of both the VV and the VH backscatter.
How were the mean and the standard deviation values calculated, over temporal variations or spatial variations of radar backscatter? Please clarify.

4. Page 11 Line 375: Heath in Table 2 should be Heathland.