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Comment on hess-2021-25

Anonymous Referee #3

Referee comment on "Spatio-temporal soil moisture retrieval at the catchment scale using a dense network of cosmic-ray neutron sensors" by Maik Heistermann et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-25-RC4, 2021

Review of HESS 2021-25 "Spatio-temporal soil moisture retrieval at the catchment-scale using a dense network of cosmic-ray neutron sensors"

General comments:

This manuscript describes the first ever attempt to use multiple CRNS to estimate catchment-scale soil moisture, including temporal and spatial variations. The research conducted is of interest and importance to the research community, even if the findings are somewhat marginal in their advancement of practical application. While the paper is well-organized and written, it is excessively long and tedious to read. I understand that the authors wish to share the minutia of their novel methodology, but as written the paper is difficult to read and seems more akin to a grant proposal than a scientific manuscript.

I dislike the goal of the project to match the pattern rather than absolute values (stated in Line 434) and the general avoidance of quantifying differences or variability in the estimated and measured soil moisture values. I understand why the authors have chosen this approach, but I also think that the use of the absolute values of measured and estimated volumetric water content would be useful to present to the scientific community. Relative values only provide so much information.

For these reasons, I suggest the authors make major revisions to the manuscript before it can be accepted for publication.

Specific comments:

Section 2: The authors mention in passing the presence of very shallow groundwater, but do not mention how this likely has significant effects on their CRNS measurements. This issue should be addressed much more thoroughly.

Additionally, the authors should provide the textural and SOM information for samples taken near each CRNS (texture) and for each mixed sample (SOM). Providing an average catchment-scale value is not acceptable, and readers cannot be expected to read every cited paper to find this information, which could easily be incorporated into Table 2. Further, the estimated gravimetric water content values > 1.0 g/g shown in Figure 4b are unrealistic, unless you are considering a highly organic soil. However, based on the information presented, it is impossible to determine the soil type near CRNS 21 and 23.

Table 2: In addition to including information regarding soil texture and SOM for each site, the authors should include some indication of the variability of the values shown for each site. Also, bulk density values are incredibly low, less than 1 kg/L in most cases. Including the SOM content in this table would make those values look less suspect, if indeed the SOM content is extremely high. If not, the authors need to address the very low bulk density values reported.

Figure 5: How does the variability in θ_i^{obs} during Monte Carlo simulations compare to the variability observed in measured volumetric water content from thermo-gravimetric samples? Could the authors provide mean uncertainty values for Monte Carlo $\theta(N_i)$ and θ_i^{obs}? It is difficult to estimate these values from Figure 5 alone.

Line 525 and Figure 6a: Reference evapotranspiration is different than potential evapotranspiration, but the terms are used interchangeably in the text. Make sure all instances are changed to "reference."

Line 543: It would be good, again, if the authors would quantify this uncertainty.

Figure 9. The results shown in this figure are underwhelming. I expected that the highly concentrated CRNS sensors would be able to provide a closer match in spatial soil moisture distribution to the SoilNet measurements. The lack of spatial agreement with SoilNet soil moisture values, even with a high concentration of CRNS that is unlikely to replicated in practice, is surprising and a bit disappointing. If the CRNS are unable to provide useful spatially explicit information, what is the benefit of using these extremely expensive sensors rather than many cheaper in-situ sensors or downscaled remote sensing data? Also, I would be more interested in a time series figure showing the mean field-scale volumetric water content for each of the three scenarios- unconstrained, constrained, and SoilNet. I suspect that the constrained and unconstrained values would

be far more similar to one another than to the SoilNet values.

Line 595: While I agree that the current application of a large number of CRNS in a small area is interesting, I do not think it is economically feasible or sustainable. The authors should at least mention the cost prohibitive nature of this study.

Technical corrections:

Line 301: Should read "how the availability of sampling locations *affected* N_0 *calibrations*,

Line 725: Should read "from August 2019"