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Comment on hess-2021-202

Anonymous Referee #3

Referee comment on "Towards disentangling heterogeneous soil moisture patterns in Cosmic-Ray Neutron Sensor footprints" by Daniel Rasche et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-202-RC3, 2021

There are three main result in the paper, (i) the simulations of footprints for thermal and epithermal neutrons, and how this feeds through to the measured neutron count for heterogeneous soil, (ii) measurements and simulation showing that the scatter plot of thermal and epithermal neutron counts can be used to characterise soil heterogeneity, and, (iii) the testing of different methods for calculating VWC. I found all these points interesting, relevant and suitably novel. Apart from clarification on Figure 6, I see no obvious problems - the rest of my points are suggestion or easily implemented clarifications.

Fig 6a: Why is there so little change in the R86 footprints in this figure (as measured by first soil contact) compared to Fig 3a? In the case of simulation set 3 (dashed lines Fig 6a) far field soil moisture drops from 0.7 to 0.2 which is very similar to the drop from 0.7 to 0.1 in Fig 3, but in Fig 6 we also have that the near field soil moisture is decreasing. Surely there should therefore be a larger change in the various footprints in Fig 6? In fact R86 actually decreases slightly in simulation set 2 between scenario 1 (wettest) and scenario 6 (driest)! Is there a mistake? Have missed something important?

Footprints: One question that remains in my mind is the practical relevance of simulated R86 and D86 footprints. This is especially the case for the thermal neutrons where the authors explicitly consider different definitions for the distance travelled by an individual neutron. But even for an epithermal neutron a choice is made to measure distance from the first interaction with the soil, rather than for example some weighted average of the distances from all interactions with the soil. This isn’t a criticism particular to this manuscript - it is a general practice when simulating R86 for epithermal energies.

One might hope that the R86 footprint would approximately have something like the following property,

$$N = 0.86*(p1*N1 + (1-p1)*N2) + 0.14*(p2*N1 + (1-p2)*N2)$$

where N is the counts detected at the detector, N1 and N2 are the counts that would be detected if the entire area was mineral soil or peat soil respectively (with their own VWC), and p1 and p2 are the proportion of the landscape from within or outside of the R86 distance respectively that is mineral soil. This kind of reasoning is already alluded to around lines 425. But perhaps this can be quantified maybe using something like the equation above? Perhaps p1 and p2 could be estimated? N1 and N1 could be added to Fig 4? Would similar hold for the both thermal and epithermal footprints? One could even envisage using the above equation as a definition for a footprint radius if a simplified circular geometry (p1=1,p2=0) was employed for the mineral soil. In any case extra discussion would be helpful.

Fig 3: Perhaps a comment on why R86 for thermal neutrons as measured from the first soil contact isn't in fact larger than R86 for the epithermal neutrons. I could imagine that as an epithermal neutron undergoes further collisions it will eventually reach thermal energies and will had further opportunity to travel from its initial soil contact – although I appreciate the picture is not be as simple as this.

Equation 6: This is an equally weighted normalised average of NT and NE. But its not clear at this point why this is done. It is explained that this combination makes the response have a "shallower slope" than NT, but one normally expects reduced sensitivity to be a bad thing! Perhaps the actual reason is a compromise between having a footprint more representative of the location in which the soil moisture sensors are installed (NT), and the better sensitivity of NE? There is additional explanation around line 545. Also, when using this "alternative approach 2" perhaps one needs to recalibrate the parameters a0, a1, a2, as I believe the original choice of these was made for the epithermal neutrons?

Minor corrections/suggestions:

Fig 3b: There's a problem with the legend.

Lines 16 and 84: "spatial discretization" is supposed to be "spatial disaggregation"? Also line 84 could be clearer.

Section 2.2.1: Some of the details in this section are general to all simulations (e.g. the detector radius, the energies of the thermal/epithermal neutrons) and would therefore be better in section 2.2.

Fig 5: I can't really see the reason to show both the blue lines and the green lines – they sum to 1.

Fig 6: Could be more easily understood if x-axis labelled by near field soil rather than scenario. This is especially because when reading the x-axis left to right it becomes drier which is the opposite way around compared to Fig3.

Fig 9: I can understand the authors might be pleased with this figure but why not simply add the simulation points to Fig 8a instead.

Line 433: Add reference to the Figure.

Line 272: I think the bandwidth should have time/frequency units? Partly I ask because, I think that if the smoothing is too intense your residual "noise" will actually contain some of the soil moisture signal. I therefore want a rough idea how much smoothing occurred.

Not that I think excess noise causes a problem, given the result stated on line 512. And I never doubted that the different approaches where significantly different.