Reply on RC4
Martin Schrön et al.

Author comment on "Signal contribution of distant areas to cosmic-ray neutron sensors – implications on footprint and sensitivity" by Martin Schrön et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-219-AC4, 2022

Dear Reviewer 4,

thank you very much for your positive review and the specific comments in the PDF. We will briefly comment on your concerns in the spirit of the interactive discussion and we will also respond to some key comments from the annotated PDF. (RC=reviewer comment, AR=author response)

# General comments

> RC4.1: "The results have some practical implications for where to install (or avoid installing) cosmic-ray neutron detectors in heterogeneous environments, depending on the intended purpose of the measurements. The manuscript would be strengthened if the text focused more on explaining those practical implications [...] The focus should be on choosing installation sites that minimize heterogeneity in the footprint. The results here could help inform such choices."

AR: We agree that the method can help to inform the choice of installation sites, which is one of the key results. Often enough, choosing fully homogeneous installation sites is not possible, particularly in complex terrain. In those cases, the method can help to better understand the observed neutron-soil moisture relationship, to assess the systematic uncertainties produced by inhomogeneities, and to help to better identify specific events, such as remote irrigation. This is another key outcome. But understanding signal contributions is not only useful for stationary sensors: mobile CRNS is often bound to accessible roads, where sensor placement is less important than the understanding of the signal.

Hence, the implication on sensor placement is only one of many interesting aspects of this study. We will consider improving the discussion on these practical implications in the revised manuscript.

> RC4.2: "[…] and less on framing the distances calculated here as "a new practical footprint definition" for this type of detector."

AR: We agree that the footprint definition should not be the main focus of the study, that
is why we allocated only one of the five subsections in the Results to this topic. As discussed also with Reviewer 1, we do not intend to suggest a replacement of the conventional footprint with this new definition, but rather to suggest this new footprint concept for some specific scenarios where it could be more informative than symmetrical footprints. We will clarify this more clearly in the revision.

> RC4.3: "Because the detectors are strongly biased toward areas of dry soil, users need to understand that they do not inherently provide an accurate areal average of heterogenous footprints, as the results here show."

AR: Thank you for pointing this out again in a concise way. This is a take-home message of our study and we might consider using it as an inspiration to clarify the conclusions.

# Specific comments (excerpt)

- Eq 5: "Explain how this \([N(\theta_i)]\) is being estimated and the assumptions involved. It seems that the local neutron "production" rate for a portion of the landscape could likely be a different function than the functions often used for relating the "effective neutron intensity" to the soil moisture in the sensor's footprint (e.g. the Desilets 2010 function or similar). Please elaborate and justify any assumptions being made."

AR: We agree that this assumption is not trivial, but one of the outcomes of this study is that it seems to work out. The assumption that the "effective neutron intensity" of a completely homogeneous footprint behaves similar to the neutron production of a portion of the landscape seems natural, though. We tried to indicate that this is just an assumption in L105 ("We propose that ..."), but we agree that this topic needs clarification, which will done in the revised manuscript.

- L129: "Explain what \(W_r\) and \(r\) mean exactly in the context of a grid cell. Are you making any assumptions about the size of the grid cell relative to the size of the inhomogeneous areas or to the size of the total footprint?"

AR: Thanks for asking, \(r\) is the distance to the center of a grid cell and \(W_r\) is the radial intensity at this distance. As for all numerical approximations, the size of the grid cell should be small compared to relevant structures in the footprint. Although this concept and the details already go back to Schrön et al. 2017, we agree that it deserves better explanation and we will elaborate on it more clearly in the revised text.

- L178: "Why so large? That encompasses the majority of the sensitive zone as shown in Fig. 1."

AR: We chose 9 m radius for the detector to speed up simulations, as a reduction of the radius of the detector would drastically decrease the area of exposure to the neutrons and thus increase the simulation time. This is a standard procedure in detector simulations. If no structures were to be present below 9 m radius, the results would equally well emulate a smaller detector. For this reason, we used heterogeneous structures in our examples only beyond 9 meters. This limitation has also been discussed in L180-182. It is true that this model setup would be insufficient for the scenario in Figure 1, but this is only an illustrative plot which has not been simulated in our study. Nevertheless, we will add a note to the revised manuscript to clarify this.

- L267: "I think most of the text in this section [3.3] above this point should be moved to the Methods section."

AR: The reshaping procedure is one of the results of this study and has therefore been placed in the results section. This is similar to the footprint functions in section 3.5. We believe that both these aspects are *implications* or *consequences* of the methodological concept, rather than the concept itself. So we would like to keep them outside the methods section.
Table 1: "The chosen 5% difference in soil water content here is comparable to the magnitude of spatial variability that is commonly observed in "homogenous" fields. I think a table like this for a 10% difference in soil water content would be more instructive/educational. Differences of 10% would indicate to me an important but plausible level of inhomogeneity."

AR: Thanks for sharing your opinion about typical soil moisture changes. The results for 10% difference are already visible in the supplement tables. We will consider also showing them in the main manuscript as suggested.

Appendix A: "I tried running the code in Binder on Google Chrome. The code seemed to run without errors, but the figures shown below were not produced or not displayed. The sliders were visible, but not the actual figures."

AR: Thanks for testing the online notebook! The figures appear as soon as the sliders are used/moved. Can you please retry and feed back whether it worked on your system?