Reviewer #4:

We thank reviewer #4 for taking the time to review our manuscript and their valuable suggestions regarding our manuscript. We are certain that these comments greatly improve our manuscript and they will be incorporated in a revised version of the manuscript. In the following section we will reply to all comments of reviewer #4 with R4-1 (i.e. reviewer 4, comment 1) and A4-1 (i.e. author response to R4-1), respectively.

R4-1: Fig 8 is powerful in demonstrating how this ratio between epithermal and thermal neutrons can change at sites with known heterogeneous soil moisture dynamics. I can see this being a useful metric to describe CRNS site heterogeneity in a simple way that can help a user understand possible site-specific impacts on soil moisture dynamics. I wonder if we should reconsider sensor footprint size once the Spearman rank correlation coefficient falls below a certain value?

A4-1: This is an interesting comment! We agree that the radial footprint size and anisotropy should be assessed in more detail if distinct differences of soil moisture patterns and dynamics occur within the expected measurement footprint (i.e. 200 m) as this will lead to deviations from existing footprint definitions which are based on neutron transport simulations with a homogeneous soil moisture distribution in the model domain. Defining a threshold value for the Spearman's rank correlation coefficient between the observed intensities of thermal and epithermal neutrons could be derived when several study sites are investigated. Here, it would be highly important that the detectors are shielded consistently (e.g. a polyethylene shielding only for the epithermal counter tube) and that the neutron intensities are always corrected in the same way for e.g. atmospheric pressure variations. A very important point is that the correlation between thermal and epithermal neutrons contains information on potential differences between the near-field and the far-field of the neutron detector but it remains unknown if this is a suitable approach when the soil moisture patterns are distributed differently. For instance, if the neutron detector is placed on the border between two soil moisture patterns with moist soils covering one half and dry soil covering the other half of the footprint, the relationship between the observed intensities in the two energy ranges is likely to be different. Thus, more research is certainly required!

R4-2: L55: The authors rightly point out here that there are methods using the ratio of epithermal and thermal neutrons to estimate biomass in the sensor footprint (e.g. Tian et al., 2016). The site description seems to suggest that there is a uniform (spatial) biomass at the test site, it would be better to explicitly state this if true. The literature has shown the ratio of thermal and epithermal neutrons can be influenced by biomass changes (although research tends to be looking at this temporally rather than spatially), so knowing that biomass is spatially uniform at the site would be beneficial. On this point I feel a bit more discussion on possible impacts of spatially diverse biomass would make the paper more robust, considering research has shown biomass to impact neutron ratios too. The limitations are touched upon (L586) but an expansion on this (hypothesis of influence, future research ideas?) would benefit the paper.

A4-2: This is correct. As it can be seen on the fig. 1, the very most fraction of the footprint is permanently covered with grassland. As we do not have information on the amount of biomass stored above ground, we assume it to be constant in time. This is reasonable as on permanent grassland no large agricultural management practices, except cattle grazing, and no large biomass changes due to cropping and harvest occurred.
We agree with the reviewer that the relationship between thermal and epithermal neutrons is likely to be influenced by distinct differences in vegetation patterns and dynamics. This influence then depends on the soil moisture contents and will be larger at observation sites with dry soils. Due to the moist conditions at our study site and most parts being covered with grassland, we expect no large influences for the present study. However, in future studies investigating the relationship between epithermal and thermal neutrons in greater detail using field data and neutron simulations should include the influence of hydrogen stored in vegetation. This would benefit both, deriving soil moisture and biomass from CRNS. We will add some information at appropriate locations in the manuscript.

R4-3: L141: Three simplifications in the model are outlined here. A brief expansion on the impact the authors predict this may have on the simulation would be a benefit to the reader.

A4-3: This was already mentioned by a previous reviewer regarding the definition of the detector in the model. We will add information for clarification.

R4-4: L60: Needs re-wording as it sounds a bit confusing currently: perhaps something like "However, the integration radius of thermal neutrons at the CRNS sensor can be expected to be much smaller (a footprint of approx. 35m)"

A4-4: We agree. We thank the reviewer for this suggestion and will replace the existing statement.

<u>Original:</u> "However, the average footprint size of CRNS, e.g., the integration radius of thermal neutrons
can be expected to be much smaller (approx. 35 m) compared to epithermal neutrons (200 m) (e.g. see, Bogena et al., 2020)."

<u>Adjustment:</u> "However, the integration radius of thermal neutrons at the CRNS sensor can be expected to be much smaller (a footprint of approx. 35m) compared to epithermal neutrons (200 m) (e.g. see, Bogena et al., 2020)."

R4-5: L109: Write the actual value for the material density of quartz next to the description.

A4-5: We will add the density of quartz used for calculating the porosities from soil samples taken in the field.