Testing a novel sensor design to jointly measure cosmic-ray neutrons, muons and gamma rays for non-invasive soil moisture estimation by Gianessi et al. https://doi.org/10.5194/gi-2022-20

Author Response to Reviewer #1

RC: ***Reviewer Comment,*** *AR: Author Response*

RC: The authors present a novel set of experiments using a new sensor to simultaneously measure neutrons, muons, and gammas. The new sensor is compared to conventional sensors with satisfactory results for longer time periods of integration (i.e. 6 hrs for neutrons). The technology is lighter and potentially a lower cost, which will open up doors for more applications in science and in practical applications. The manuscript is well written and appropriate for the journal. I have a few suggestions that should be addressed prior to publication. Some instances of English grammar and word choice will need to be addressed.

AR: Thank you for the very quick and very positive feedback. All the comments and suggestions will be implemented in the new version of the manuscript as described in the point-by-point response below.

RC: L33: "Runoff generation"

AR: Thanks, it will be corrected in the new version of the manuscript

RC: L 40: "More recently, attention"

AR: Thanks, it will be corrected in the new version of the manuscript

RC: L 44: "has shown"

AR: Thanks, it will be corrected in the new version of the manuscript

RC: Figure 1: Are events outside of the blue and red ovals not included in the analysis?

AR: Figure 1 is only descriptive. The PSD vs. integrated charge plane is the simplest way to show where most of the neutrons and muons lie. In contrast, the actual selection of the events is based on the analysis of statistical outliers over different parameters. This information will be added into the new version of the manuscript.

RC: L165: For the gammas are there any corrections needed for pressure or air temperature/humidity variations?

AR: Based on current literature (Baldoncini et al., 2018, Serafini et al., 2021), gammas do not require corrections for pressure and air temperature and humidity. We agree that this has some advantages in comparison to neutrons and we will add this information in the new version of the manuscript.

RC: L247: I would use the SG filter on the neutron/gamma count time series, not the soil moisture time series that have been transformed by the calibration function.

AR: Thank you for the suggestion. We did not see relevant differences when applying the filter to the neutron/gamma time series or to the estimated soil moisture. But we acknowledge that the filter could be applied directly to the raw data. We will integrate this information into the new version of the manuscript.

RC: L 302-305: This sentence is confusing and long. Please rewrite.

AR: We have received from the Reviewer #2 and for Daniel Rasche (community comment) several comments and suggestions to improve the discussion about the use of muons for CRNS soil moisture estimation. Based on that, we will add in the new version of the manuscript much more details on the muon behavior and a comparison with neutron monitoring data base. The discussion of the result and this sentence will be rephrased accordingly.

RC: Figure 7. Will be interesting to compare the Muon detection with the correction factor being proposed by McJannet and Desilets using cutoff rigidity and atmospheric depth with the NMDB historical data. Unfortunately, that work is in the review process still.

AR: Thank you for sharing this ongoing study. We have searched for this publication, and we have seen that the paper has just now been accepted. Indeed, a comparison between that new proposed correction approach and the use of muons would be very interesting. As discussed also in the response to Reviewer #2, our current time series, however, are relatively short and do not capture strong incoming variability. For this reason, we consider this comparison beyond the scope of the present study. In contrast, we will stress that this new sensor design can provide in a longer term relevant data that can be used for testing different incoming correction approaches. We will integrate this discussion into the new version of the manuscript, and we will add the reference of McJannet and Desilets.

RC: Figure 8. So the soil moisture data is from FINAPP and not depth weighted following the Schron method? If you did have gravimetric surveys how would you depth weight them for the gamma sensitivity? From my understanding they would have a similar sensitivity with depth as the neutrons but be a little shallower (10-15cm?)?

AR: *Yes, the Reviewer is right: soil moisture data is from the neutrons from Finapp. This estimated soil moisture is compared to total gammas. We are not aware of analytic functions that have been published to weigh point-scale soil moisture data to correspond to gamma signal. However, current literature suggests exponential decreases in both vertical and horizonal direction* (Baldoncini et al., 2018). *So, we agree that gamma should have a similar sensitivity to neutrons but shallower depth and smaller footprint. We will add this information into the new manuscript to clarify how to better compare gamma signals to soil moisture series in future studies.*

RC: Table 1. Iwema et al. 2015 recommends 3 calibrations for estimating N0. From the variability here I would do at least 3 to estimate some uncertainty on N0. I agree additional gravimetric studies are needed, particularly for establishing the gamma to soil moisture

dependence, especially when used in cropping systems with significant temporal variations in vegetation biomass. Unfortunately, for CRNS and GRS studies all roads don't lead to Rome but to more gravimetric sampling :)

Iwema, J., Rosolem, R., Baatz, R., Wagener, T., & Bogena, H. (2015). Investigating temporal field sampling strategies for site-specific calibration of three soil moisture–neutron intensity parameterisation methods. HESS, 19, 3203–3216. https://doi.org/10.5194/hess-19-3203-2015

AR: *Thank you for the comment and for the reference. We agree that soil surveys still play an important role in assessing calibration functions and validating modelling results. We will integrate this comment and this reference in the new version of the manuscript.*

References

Baldoncini, M., Albéri, M., Bottardi, C., Chiarelli, E., Raptis, K.G.C., Strati, V., Mantovani, F., 2018. Investigating the potentialities of Monte Carlo simulation for assessing soil water content via proximal gamma-ray spectroscopy. Journal of Environmental Radioactivity 192, 105–116. https://doi.org/10.1016/j.jenvrad.2018.06.001