Geoscientific Instrumentation Methods and Data Systems Discussions

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Comment on gi-2021-18

Anonymous Referee #1

Referee comment on "Assessing the feasibility of a directional cosmic-ray neutron sensing sensor for estimating soil moisture" by Till Francke et al., Geosci. Instrum. Method. Data Syst. Discuss., https://doi.org/10.5194/gi-2021-18-RC1, 2021

Review of manuscript titled “Assessing the feasibility of a directional CRNS-sensor for estimating soil moisture”. The idea is fantastic and very much needed. I think this is study that will gain the interest of the research community. The main limitations of the manuscript are:

- the assumption that readers are familiar with the cosmic-ray neutron sensing technology for measurement of soil moisture.

- The manuscript is dense and the logical arrangement of ideas together with some limitations in the English language makes this paper difficult to read. It starts by describing a previous directional sensor, but then it shifts the attention to simulation work, without interconnecting both. It seems to me that the manuscript could be much shorter and more straight to the point

At time it seems that this manuscript could have been partitioned in two different manuscripts parts: a more theoretical description of the error sources, propagation, and computation of directional neutron counts, and a second part about testing the quantitative reasoning with a modeling effort.

The “Limitations and Outlook” section contains valuable information for the research community. I suggest condensing this section into a fewer, but still relevant, number of points, or merging the points into a narrative. With so many bullet points I question the usefulness of the current layout. Even this section could be interpreted as a potential technical note or manuscript presenting and discussing limitations and opportunities of directional detectors.

Line 14. Define again the abbreviation for Cosmic Ray Neutron Sensing (CRNS) in the manuscript narrative.

Line 14-15: The first two sentences can probably be merged into one. Consider the following alternative: "Cosmic Ray Neutron Sensing (CRNS) has been widely adopted in the past decade to measure soil water content in environmental sciences" or this one "In the past decade, the adoption of Cosmic Ray Neutron Sensing (CRNS) has increased considerably to measure soil water content in hydrological, agricultural, and environmental research applications (Zreda et al., 2008)"

Line 15. Unclear statement "in both research and application". Research could be basic or applied, so its unclear whether the authors refer to applied research or applications beyond research (end user or consumer applications). Please clarify.

Line 17. Remove the first "or" so that "…, to support irrigation management…"

Line 22: Re-word to "a depth of a few decimeters" It may be good to provide a quantitative range. It seems that the typical sensing depth oscillates between 10 and 40 cm depending on the soil moisture conditions.

Line 25. This paragraph probably needs more context and depth. At this point it's not obvious that the CRNS is omnidirectional, so it may be good to state that this is the nature of current measurements and available instruments. I suggest briefly expanding more on the issue of instrument omnidirectionality (why is it this way?) and other factors such as soil spatial heterogeneity that can create soil moisture spatial patterns. I think this paragraph would be essential to understand the motivation of the study.

The "larger spatial support" compared to what measurement? point-level?

Line 30. Specify that the "energy level separation" is for the spectrum of cosmic-ray neutrons.

Line 33. Consider a better transition here. For instance: "An approach to reconstruct sub-footprint patterns in soil moisture consists of using a dense…. (Heistermann et al., 2021). Although…"

Line 39. Consider merging this paragraph with the previous since it's a continuation of the same argument.

Line 44. I would like to suggest the use of the following terms: "Directional neutron sensing" or "Cosmic-ray Directional Neutron Sensing"

Line 48. There seems to be a typo here: "and/and"

Line 50. Consider replacing "defense" with military applications

Line 51. There is an extra ")"

Line 55. This paragraph seems too short at only two sentences long. I suggest detailing the type or energy level of the incoming neutrons. It's unclear from the text whether the authors are referring to thermalized or epithermal neutrons. It will also be important to highlight that the term "directional" in the context of this paper mostly applies to the horizontal plane.

Line 59. Spell out "PE" (polyethylene?). Was this a high-density PE?

Line 61. How is N_{total} observed or computed? Is this the total considering the shielding or the total without it? I assume that for simultaneous collimation efficiency you need to two devices or alternatively the same device with and without the shielding over short periods of time.

Line 70. Please, clarify whether the unshielded side means less shielding to avoid confusion with a bare detector. For instance, the CRS 2000B already includes some shielding to attenuate neutrons. This means that the authors added an extra layer of shielding.

Line 73. Replace 2Pi by 360 degress. What do the authors mean with "flexible"? What is the integration time at each angle? or is it a continuous scanning? I think that a few more details will allow readers to reconstruct the idea and reproduce the study.

Line 99. Would this bycatch flux be similar regardless of the gas used in the detector (3He vs 10BF-3)?

Line 109. Emphasize that these settings are in the detector electronics. Can you add the model of the neutron pulse analyzer from Quaesta?

Lines 126. The wording in this sentence implies that there is an “unshielded side”, which most people will take as a bare detector, which I suspect is not the case here.

Figure 2. I like this figure. To make it a bit more explicit it will be good to add in the description the meaning of the shaded area. Are the arrows pointing in the “increasing” direction? Perhaps adding a “+
and “-“ symbols could help the reader. Will it be possible to add magnitudes to the axes and denote with a point the selected combination for this study?

Line 129. Unclear whether the authors are referring to the area in the FOV (i.e. area of the open side of the instrument) or the horizontal area part of the sensing footprint.

Line 141. While in situ experiments controlling the neutron flux are impractical, in situ validation of the approach is not. For instance, a field validation could be done by intensively measuring soil moisture. For this to work a field with a known directional variability may need to be selected. I just wanted to emphasize that in situ validation may not impractical (in terms of measuring soil moisture).

Line 149. I like the first question, but it may need to be formulated differently. As it stands now it will be more relative to the ability to regulate the rotary mechanism than the detector itself.

Line 150. The authors vaguely described what is meant with “contrast”. Perhaps a bit more background on this metric would be helpful. Most people are familiar with count rates and integration time, perhaps less familiar with signal contrast (unless the authors are referring to signal-to-noise ratio)

Line 151. What is a robust estimate? It would be nice to provide a more objective metric, perhaps in terms of error in volumetric water content (or the equivalent neutron count)

Line 165. Is the stretch of 600 m in all directions? or just in the horizontal direction?

Line 169. Please, adopt the term particle density which is more commonly used in the soil

science literature over “compound density”.

Line 172. This is what I meant earlier about “further” moderating the detector.

Line 181. The virtual detector is within a domain of 800 x 800 m, but the authors defined earlier that the domain was only 600 m. Please clarify.

Line 194. Is this FOV of 180 degrees something that would be possible with an actual instrument? From figure 1 it seems more like 90 degrees.

Line 195. In this section, are the authors referring to count rate based on raw neutron counts or on corrected counts by atmospheric conditions and incoming neutron flux?

Line 201. Remove word “Please”.

Line 202. Why not abbreviating gamma as “D” (directional) and “OD” (omnidirectional) or “uni” and “omni” for better readability across the manuscript.

Figure 4. Please indicate in the caption the assumption that R1total < R2total (I assume this since the bars for total counts are different for R1 and R2). Although I’m confused since in Line 215 it says that there is no fundamental different between A1 and A2.

Lines 290-300. These sections probably need to be merged into a single section and presented as separate paragraphs. The “Count rate” section is only one sentence long.

Line 319. How much higher is the reduction in count rate by adding the shield beta in wet conditions? Even a speculation would be fine here. Perhaps the authors can use soil saturated conditions as a reference. Do you need to add a reference to Table 3 in this statement?

Table 3. What is the integration time of these neutron counts? Are they corrected for atmospheric conditions? Is the “no shield” term referring to a bare detector or to the portion of the directional detector with “less” shielding? Please clarify.

Line 354. I’m starting to think that it is hard to remember what “worstcase” scenario means at this point. The definition of this term occurred several sections above and the name does not seem intuitive. I wonder if there is a better way of naming like and

Figure 9. Please specify for which sensor form factor this figure applies. Does this figure translates to other detector configurations?

Line 410. Larger planar shielding in what direction of the instrument. It will be good to provide a more explicit comment for other researchers that want to replicate or design their own directional detectors.

Line 396. How does this integration time relate to typical applications for soil moisture sensing in agricultural and hydrological scenarios? It will be good for the authors to expand on the practical applications/obstacles of the required time integrations and counts required to achieve a certain precision.