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Interactive comment on "Incorporation of globally available datasets into the cosmic-ray neutron probe method for estimating field scale soil water content" *by* W. A. Avery et al.

Anonymous Referee #2

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General comments

The manuscript focuses on the mobile application of cosmic-ray neutron soil moisture probes (CRNP) and tests the reliability and accuracy of globally/continentally available data sets to provide information to support the calibration procedure. The relationship between CRNP measured low-energy neutron concentration and soil moisture can be strongly affected by changes in soil texture/soil type, surrounding vegetation, organic carbon content in the upper soil layer. Therefore, an operational procedure to provide information about CRNP calibration parameters for larger scales is of critical importance and relevance for the mobile application of CRNP.

The paper is generally well written and easy to follow. However, especially the overview

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of CRNP and its calibration in the method section (chapter 2.1 - 2.3.) require a deeper revision. In 2015, Köhli et al. revised the footprint characteristics for soil moisture monitoring with cosmic-ray neutrons substantially. Although the authors cite Köhli et al. (2015) several times, key insights of the Köhli paper are omitted or reported incorrectly. By improving the physical representativeness of the underlying neutron transport model, Köhli et al. (Ibid.) revealed the highly dynamic nature of the CRNP footprint (horizontal and vertical) and redefined the footprint radius to range from 130 to 240 m. Furthermore, Köhli et al. revealed the high sensitivity of the CRNP to soil moisture (and other affecting properties) in the first tens of meters around the probe resulting in the need for a dynamically weighted average of CRNP-affecting properties within the probe's footprint (very recently applied and successfully tested by Heidbüchel et al. (2016)). While the manuscript mentions results of "recent neutron transport modeling" (l 145-146), the only given number for the CRNP support volume is the outdated "circle of $\sim$300 m radius" (l 144). Although the authors mention the need for an adjustment of the sampling pattern for in-situ calibration ("in the light of recent modelling", l 217-219), the sampling scheme presented in detail in the paper is based on results from 2012. Also here it would be desirable to provide a more detailed discussion of the importance of a weighted sampling scheme. All these aspects impact the interpretation of the CRNP signal and are of critical relevance for mobile CRNP applications. Even though the aspects mentioned above did not affect directly the interpretation of the manuscript's main topic (evaluation of accuracy of globally available data sets for CRNP calibration), the reviewer recommends a more intense discussion of the current state of knowledge about the CRNP theory and its importance for the mobile CRNP application. More comments on this topic can be found in the "Specific comments" section of this review.

Despite these critical remarks, the manuscript is of high interest for the CRNP community and the manuscript's topic is well suited for the journal and the journal readers. I recommend a moderate revision before the article is considered for publication.

Specific comments

1. L 50-52: Delete “(∼36 km)” and “(e.g. ∼2-5 cm . . . Entekhabi et al., 2010)” since this is repeated and described again with the same citations in the following paragraph.

2. L 66: I assume that the footprint is given square kilometers.

3. L78-79: The authors mention here the footprint radius of “∼300 m” and underpin this by a citation of Köhli et al (2015). Since Köhli et al. revealed a reduced footprint radius (see also comments above) this is a wrong citation and should be corrected using the correct numbers.

4. L109: Since it is introduced for the first time (except from the abstract), “CONUS” should be written out here.

5. L132: The use of the term “energy levels” is unusual in unbound particle systems. Energies of free atmospheric neutrons can be approximated as a continuum throughout the elastic scattering spectrum. Better use “well-known energy spectrum” or “continuous energy spectrum”.

6. L135-136: “(i.e., the neutrons which are primarily measured by the moderated detector)” repeated information, compare line 130.

7. L 145-148: The authors mention new findings regarding the CRNP footprint and its dependency upon vegetation, soil moisture, atmospheric water vapor, elevation, surface heterogeneity. Since Köhli et al. (2015) investigated all of these aspects the citation should be placed at the end of the sentence. Furthermore, it would be highly desirable to discuss the impact of the dynamic nature of the CRNP footprint on the applicability for mobile surveys.

8. L173: The term “correction factor” has been used four times in the last 5 lines, please rephrase.

9. L217-L219: “In light of recent modelling . . . reduced footprint area”. How does this

recent finding affect the mobile application of CRNP?

10. L260: Delete ",and lattice water" since the test for lattice water relationships is described above.

11. L302-308: Excessive of the verb "use" - used six times within five consecutive sentences.

12. L323-324: I recommend to delete the sentence "Other than 1 outlier . . . " here, since this is repeated and discussed in section 4.1.

13. L330-333: Repetition of L 241-244

14: L350: Change to "Figure 4a and 4b".

15: L365: Instead of "MODIS product and derived equation" it might be better to write "MODIS product in combination with the derived equations".

16: L381: Change the title since it is the same like the title for chapter 2.6

17: L393-394: Why is this sentence given in italic letters? Furthermore, I find the formulation misleading. "Future sampling efforts" probably won't "minimize the range of bulk densities". But it can certainly increase the accuracy of bulk density estimation. Bulk density itself is affected by the land use and can be a very dynamic parameter (e.g. due to agricultural cultivation measures) and this dynamic nature it a further challenge for the mobile CRNP application. This issue should be mentioned. The incorporation of land use information can increase the accuracy of bulk density estimation.

18: L405-407: "This strong correlation is significant because large portions or the . . . regions are made up of mollisol soils". I did not understand this sentence. A "large portion" isn't an explanation for the significance, is it?

19: L477-479: ". . . given the relatively small change in BWE . . . in forests, we would expect small change in N0 through time". CRNP measurements in forest can be challenging for several other reasons. Bogena et al. (2013) revealed the importance of

the litter layer and its dynamic water content for CRNP calibration. Heidbüchel et al. (2016) found strong deviations in N0-calibrations for different times of the year and recommend a two-time calibration to catch seasonal variations in aboveground biomass. Furthermore, they found a considerable influence of root biomass on the CRNP signal.

20. L503: “minimum of 7” is a strong recommendation for a value which should be dependent on the individual site heterogeneity. Since there is no statistical proof for this statement, I suggest to avoid a concrete number.

21. L505: Why is N0 a correction factor? Please clarify to which function and which parameters you are referring to.

22. L507: The influence of road type has not been discussed in this work. Please explain the reasons for this recommendation.

23. L507: replace “in missing areas” by “data gaps”.

References: Bogena H.R., Huisman J.A., Baatz R., Franssen H.J.H., Vereecken H. (2013) Accuracy of the cosmic-ray soil water content probe in humid forest ecosystems: The worst case scenario. Water Resources Research 49:5778-5791. DOI: 10.1002/wrcr.20463.

Heidbüchel I., Güntner A., Blume T. (2016) Use of cosmic-ray neutron sensors for soil moisture monitoring in forests. Hydrol. Earth Syst. Sci. 20:1269-1288.

Köhli M., Schrön M., Zreda M., Schmidt U., Dietrich P., Zacharias S. (2015) Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons. Water Resour. Res. 51:5772-5790.

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