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Interactive comment on "Calibration of a non-invasive cosmic-ray probe for wide area snow water equivalent measurement" *by* M. J. P. Sigouin and B. C. Si

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General comments

This study concerns the application of the cosmic-ray neutron method to monitor snow water equivalent. The authors performed neutron count measurements over two winters (2013/2014 and 2014/2015) in an agricultural field in Saskatoon (Canada). Based on this data, they developed an empirical equation to provide estimates of average SWE which were compared with continuous snow depth measurements.

This paper is an interesting presentation of a snow application of the cosmic-ray neutron method. It is also well written and fits well to the scope of Cryosphere Journal.

However, some methodological improvements need to be undertaken as outlined in my specific comments. In addition, I am not convinced that the presented method is able to provide quantitative estimates of SWE that are more accurate than the traditional snow depth measurements. Thus, the study should be more critical and should better discuss the potential drawbacks of the method.

Unfortunately, the study suffers from the limited experimental setup. For instance, the temporal dynamics of snow depth and soil moisture within the CRP footprint should have been continuously monitored in a distributed way. In addition, the sampling design assumes a CRP footprint that is too large. Finally, the CRP used in this study shows a relatively high noise in neutron count rates. Thus, for future applications a CRP with a large detector tubes (e.g. CRS-2000/B) is preferable. These limitations and recommendations for future studies need to be discussed in greater detail.

Specific comments (manuscript version)

L56: "Canada" instead of "CAN"

L114: According to a recent study the footprint is considerably smaller and not constant in time, see Köhli et al. (2015)

L152-154: You should make some rough calculations how much the additional snow accumulation in the CRP footprint could have influenced the SWE estimates by the CRP. If the effect is in the sub-millimeter range it could be considered to be negligible.

L175: More details on the local soil properties need to be given (e.g. bulk density, porosity, soil texture, etc.).

L178-179: This is a very rough estimate and very likely prone to overestimation since vertical water transport into deeper soil region is neglected.

L184: The value of 4.53 cm suggests that the soil porosity must be at least 0.453. This is extremely high, e.g. sandy soils have typically porosities in the range of 0.30-0.35 (Nimmo, 2004). Thus, this value is may be overestimated (see comment above).

L225-229: Such scaling is unnecessary in the case of this study. Scaling would be necessary in case absolute neutron count rates would be important, e.g. in case neutron count measurements from different locations would be compared among each other. However, in this study the neutron counts are converted to snow water equivalents, which is inherently a sort of scaling.

L240: This spacing is not appropriate (see comment L114). Add a discussion on the consequences.

L256-259: How did your snow height and SWE data compare with predictions of this equation?

L296: You should also present scatter-plots of the correlations (without the soil water storage adjustment).

L321-324: This is very unlikely, since modelling of neutron transport of non-homogenous environmental conditions have shown that only extreme cases, e.g. discrete objects like tree trunks, may have an influence on neutron intensity (e.g. Franz et al., 2015). In any case, such assumptions would need to be substantiated by a dedicated neutron transport modelling study.

L353: See earlier comments.

L364: How do these error estimated compare with traditional SWE measurement methods?

L348: Fig. 5 clearly shows that the 7-hourly averaged neutron count rates are still strongly fluctuating. The reason for the strong fluctuations is the decreased sensitivity of the CRP due to the high hydrogen content in the CRP footprint. The sensitivity of the CRP can be easily increased by increasing the aggregation period, see Bogena et al. (2013) for a detailed analysis. I suggest using at least daily averaging to reduce the effect of CRP noise on the regression analysis.

L377-378: Any snow melt water, especially above the soil surface, will lead to overes-

timation of SWE.

L387: “Comparison of. . .”

L396: “estimated” instead of “modeled”

L401: “SWE dynamics”

L408: See comment L152-154. In addition, this would only explain the overestimation of the first period.

L412-413: Although the distance between the RCS and Airport sites is far larger than the distance between the RCS and CRP sites, the point measurements at the RCS and Airport sites seems to compare better. Also the point measurements seems to better compare with the manually measured SWE (please provide RMSE). This is even more notable, given the typically large spatial heterogeneity of snow covers. This suggests to me that the presented method less accurate as the point measurements, although the CRP method integrates over a larger area.

Figures

Figure 1: A small-scale map should be included showing the location of the test site. The actual CRP footprint is smaller (see Köhli et al., 2015).

Figure 2: The accumulated precipitation of the lower graphic is not correct (starts too late)

Figure 5: See comment above. I suggest to remove the accumulated precipitation for the sake of better clarity.

Literature

Bogena, H., Huisman, S., Baatz, R., Hendricks Franssen, H.-J. & 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.

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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 Resources Research, 51, doi: 10.1002/2015WR017169.

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