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Towards disentangling heterogeneous soil moisture patterns in Cosmic-Ray Neutron Sensor footprints

Daniel Rasche[1], Markus Köhli[2,3], Martin Schrön[4], Theresa Blume[1], and Andreas Güntner[1,5]
[1]Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences, Geosystems, Section Hydrology, Potsdam, Germany (daniel.rasche@gfz-potsdam.de)
[2]Physikalisches Institut, Heidelberg University, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany
[3]Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany
[4]UFZ – Helmholtz Centre for Environmental Research GmbH, Dep. Monitoring and Exploration Technologies, Permoserstr. 15, 04318, Leipzig, Germany
[5]Institute of Environmental Science and Geography, University of Potsdam, Karl-Liebknecht-Straße 24–25, 14476 Potsdam, Germany

Cosmic-Ray Neutron Sensing (CRNS) has constantly advanced during the last decade as a modern technique for non-invasive soil moisture estimation at the field scale. Latest studies led to an improved understanding of the CRNS integration volume, weighting functions for reference soil moisture measurements and correction procedures of raw neutron counts.

It is common knowledge that soil moisture is highly variable in space. Nevertheless, the CRNS processing techniques currently assume that there is little structure to this variability within the 10 ha measurement footprint, i.e. no distinct difference in average moisture content between near and far field. In particular, with a single CRNS probe and the current knowledge it is not possible to separate different soil moisture conditions within the footprint.

Against this background, we investigated the effect of soil moisture patterns on the size of the measurement footprint and on the response of thermal and epithermal neutron intensities at a CRNS observation site in north-eastern Germany. The site exhibits pronounced differences in soil water content (and dynamics) in the near (0-60 m) and far field (> 60 m) of the neutron detector as the near field is dominated by mineral and the far field by organic peatland soils.

Neutron transport simulations with URANOS revealed that thermal neutrons have a smaller measurement footprint compared to epithermal neutrons. We show that thermal neutrons mainly originated from the mineral soils in the near field, while the larger epithermal footprint area also includes the peatland soils. However, the simulated thermal neutrons still seem to be influenced by peatland soil water variations.

With the support of the computer simulations, we were able to better interpret and identify patterns in the observed neutron count rates that represent different features of the heterogeneous field site. The study presents a new application for thermal detectors in concert with the standard epithermal detectors, and revealed opportunities for improving the calibration

against soil moisture reference measurements in the near field. We illustrate the potential of CRNS for estimating soil moisture time series at heterogeneous study sites and for disentangling different soil moisture conditions within the measurement footprint.