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Mapping spatiotemporal soil moisture in highly heterogeneous agricultural landscapes using mobile dual-spectra cosmic-ray neutron probes

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The cosmic-ray neutron (CRN) probe has successfully been used to estimate soil moisture time series at various soil and land cover types across several climatic zones. Previous studies also demonstrate the value of mobile CRN campaigns (i.e. roving) for soil moisture mapping. However, the published study locations have mainly been homogeneous in terms of land cover and soil type. At such conditions, simple on-site calibration using small-scale soil samples can be sufficient. Nonetheless, soil sampling is typically time-consuming, is not always possible and/or is not necessarily representable of the true conditions. Furthermore, measured neutron intensities are dependent on all the hydrogen pools within the footprint, primarily soil moisture, but also litter layer and biomass. Thus, calibration using 100+ soil samples for each point along the survey route is necessary in highly heterogeneous agricultural landscapes. The requirement of such spatiotemporal calibration has hindered a full embracement of the CRN roving method. Neutron sensors with multiple energy sensitivities, here named dual-spectra CRN, can instead be combined to separate the influence of various hydrogen pools.

In this work, we used a dual-spectra CRN rover to collect data along a 34.5 Km NE-SW line in Denmark (approximately 176 line Km) at an average speed of 29 Km/h. The data was collected biweekly from December 2018 to May 2019 resulting in 12 campaigns in total. The dual-spectra averages of each campaign correlate to the SMAP soil moisture product, with a higher correlation for purer signals of thermal and epithermal neutron counts. Furthermore, the epithermal neutron intensity and thermal-to-epithermal ratio maps are dependent on the land cover type enabling the use of a simple and robust methodology to obtain spatiotemporal soil moisture maps using these multiple signals. The estimated spatiotemporal soil moisture values are within expected ranges and are not as the neutron signal dependent on land cover. Instead, the average soil moisture appears to be dependent on the estimated hydraulic conductivity map for the area.