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Exploring Cosmic Ray Sensor data to evaluate large scale water storage dynamics in humid mixed landscapes

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Catchment-scale storage dynamics strongly influence runoff generation processes and regulate vegetation water use and agricultural production. Knowledge about the amount and distribution of water storage is also important for constraining and evaluating hydrological models. However, soil water storage is characterized by marked spatial heterogeneity (driven by variations in soil and land use properties) which causes difficulties in extrapolation from point measurements to the catchment scale. In humid northern environments, such as in Scotland, short-term dynamic storage changes occur predominantly near the surface. Under these circumstances, novel Cosmic Ray Sensor (CRS) soil moisture data can potentially provide more representative water storage data at relatively larger scales (>20 ha). In the past, CRS applications have shown that variations in other hydrogen sources near the soil surface (e.g. water vapour, biomass, mineral water) can influence the CRS signal. In particular, changes in vegetation biomass can be significant in annual agricultural crops such as those observed in northern UK. Questions remain regarding the information CRS signals may provide in humid and temporarily variable mixed landscapes (including different soil types and agricultural land uses).

Here, we aim to explore the key steps involved in using CRS data to evaluate field-scale soil moisture dynamics in a humid mixed agricultural catchment in NE Scotland. This is the first CRS analysis in Scotland in a location which captures the main catchment soil types and land uses within its footprint but with mixed rotating crops. Two years of data are further complemented by a range of point-scale soil moisture data and hydrometric monitoring. The use of CRS is also analysed for the first time against stable water isotope tracers, which provide independent information on large scale storage dynamics. We evaluated the time-variable contribution of different soil-vegetation units to the CRS footprint and how this relates to catchment storage dynamics. Factors such as relative contribution of spatial and temporal biomass change to the CRS signal were also considered.

Preliminary results show that inferred soil water dynamics from the CRS are comparable to point measurements within the footprint in terms of relative change. However, absolute values of integrated soil moisture from CRS and point-scale data vary in scale and magnitude. Furthermore, our findings suggest that vegetation water content during the growing season is comparable to the spatial heterogeneity in soil moisture within the footprint. In this case, temporal changes in vegetation (both seasonally [crop growth] and yearly [distinct crop cycles]) need to be considered as part of the CRS calibration procedure. So far, our study highlights that multi-method approaches (i.e. CRS, point-scale measurements and isotope tracers) capturing spatial and temporal variability are important to deliver relevant information on soil water storage. This combined approach is ultimately aimed at exploring spatio-temporal patterns in water storage and flow dynamics in mixed agricultural, northern UK catchments.