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First multi-year cosmic-ray neutron sensing cluster: insights from three years of soil water storage observations across depths and scales at an agricultural research site in North-East Germany

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Cosmic ray neutron sensing (CRNS) allows for the estimation of root-zone soil water storage at the hectare scale. Therefore, CRNS can be valuable assets of long-term hydrological observatories aimed at unravelling key hydrological processes beyond the point scale. One such observatory is the cluster established within the *Cosmic Sense* project, situated within the ATB research site in Marquardt, NE Germany, and probably the best-equipped CRNS field laboratory so far. Here we present an overview of datasets which uniquely combined three years of observations (2019-2022) from a dense CRNS cluster with a wealth and variety of supplementary measurements. The long-term operating CRNS cluster (8 permanently installed sensors) was complemented with (i) short-term measurements of additional stationary CRNS, expanding the cluster footprint, (ii) rover CRNS campaigns as well as (iii) a dedicated irrigation experiment which was monitored by a cross-scale combination of sensors, including UAV and CRNS roving. Alongside the CRNS, insights on soil water storage states and fluxes were gained by long-term measurements of profile soil moisture (at 27 locations, up to 105 cm depth), soil water tension (up to 200 cm depth), groundwater and surface water levels (3 locations along the hillslope) and GNSS-R (Global Navigation Satellite Systems reflectometry). Snapshot information of near-surface water storage dynamics were obtained by UAV-based remote sensing. Furthermore, Electrical Resistivity Tomography profiles along the hillslope supplied a 3D view of water storage distribution in depth. Ground truthing campaigns, ancillary measurements of biomass and soil properties helped capture the spatial distribution of these properties and made the interpretation of the soil water content data more robust. Overall, the Marquardt cluster is unique in its combination of a dense CRNS cluster along with the long ongoing operational period of more than three years and the wealth of additional hydrometerological data. Additionally, the 3-year data-set captures a wide range of wetness conditions, from prolonged dry spells to heavy rainfall events and snow episodes. Therefore, such a comprehensive dataset, combining innovative techniques with traditional hydrometeorological measurements gives the opportunity to investigate a range of research questions. Those could be related, but not limited to, the study of dominant flow paths and hydrological connectivity during heavy rainfall; the suitability of sensor combinations to best study water storage dynamics in a heterogeneous landscape and the retrieval of spatial soil water storage patterns using a CRNS

cluster and ancillary data.

Cosmic Sense Official University of Potsdam Webpage https://www.uni-potsdam.de/en/cosmicsense/