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Conference Abstract

Cosmic-Ray Neutron Sensing as a multi-purpose technology in eLTER platforms

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Abstract

Cosmic-Ray Neutron Sensing (CRNS) has emerged among proximal sensors as a reliable technique for non-invasive Soil Moisture (SM) estimation at a scale much larger than the usual point-scale sensors and at sub-daily resolution (Bogena 2015). The CRNS method is now widely used by research institutions and agencies around the world and nation-wide CRNS soil moisture networks have been established (Andreasen 2017, Bogena 2022). A procedure for proper use and calibration has been published by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (IAEA 2017). CRNS is also mentioned as a method for the measurement of Soil Water Content (SOHYD_168 variable) in prime eLTER sites (Zacharias 2024). Another flourishing application of the same technology is the measurement of Snow Water Equivalent (SWE - equivalent amount of liquid water stored in the snowpack), with Électricité de France being the first to deploy a full network on the French Alps and the Pyrenees (Paquet and Laval 2007). A smaller but more dense network has been recently deployed on the mountains of Veneto, Italy, by the Regional Agency for Environmental Protection of Veneto (Valt et al. 2024).

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CRNS is based on detecting ambient neutrons close to the land surface, generated as a consequence of the flow of high-energy particles from space and strongly absorbed by water molecules. The rate of neutron count rate by a detector placed above ground is correlated to the SM within a volume spanning up to a dozen hectares extension and up to 50 cm depth. In the case of SWE, the neutron count rate by a detector placed at the ground and buried by the snow is correlated to the SWE in the snowpack. Finapp developed a light and safe detector based on a lithium-doped plastic scintillator material, suitable for CRNS applications on field (Gianessi 2024). We report ongoing measurements by Finapp CRNS probes integrated in eLTER monitoring sites in Austria (Landslide Observatory at Hofermühle), Spain (Doñana Biological Reserve - DBR) and Italy (Istituto Angelo Mosso).

Between Nov. 2022 and the end of 2023, Finapp probes were installed in the DBR, inside Doñana National Park (SE Spain), an LTSER Platform (eLTER), for a comparative monitoring of different habitats. Fig. 1 shows the measured SM dynamics in 3 different sites within the DBR during the period of co-existence of the 3 probes: Juniper (woodlands on top of stabilized sand dunes), Monte Negro (heathlands in the lowland mantle) and Monte Blanco (xeric shrubland on top of stabilized sand dunes). They show a coherent dynamical response to rain events, characteristic of very sandy soils where water quickly infiltrates towards inferior horizons and feeds the aquifer. The effect of the 2024 dry summer is clearly visible.

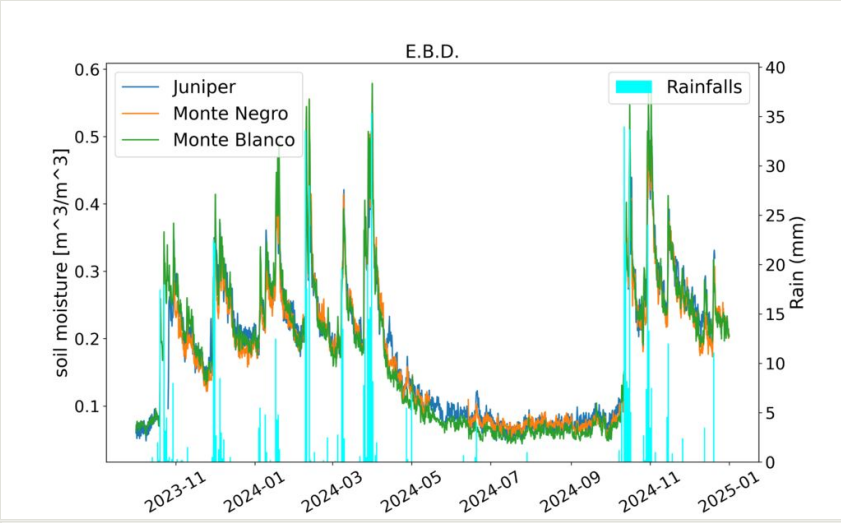


Figure 1. doi

SM dynamics measured by CRNS in 3 locations within the Doñana LTSER Platform, SE Spain, compared to daily accumulated rain registered by the "Meteo Palacio" weather station * [1] (Data: EBD-CSIC).

The region of Lower Austria is highly prone to landslides, therefore a long-term monitoring project on slow-moving landslides was established in 2014 at three different

sites (Landslide Observatories) to investigate surface and subsurface dynamics (Marr et al. 2023). This monitoring network is embedded in the Austrian LTSER Platform Eisenwurzen as LTER NoeSLIDE. A CRNS probe was installed in May 2023 at the Landslide Observatory at Hofermühle to investigate the role of SM as a triggering factor for landslides. On Feb. 20th 2024, a field sampling campaign of the SM within the sensor footprint was performed and used as a calibration point. Activities in this site included rover mapping campaigns, in which the probe was unmounted and moved to different points to the purpose of obtaining a mapping of the relative variation of SM across the site. Within the Histalp project precipitation time series, we identify the meteorological station of Waidhofen/Ybby as the most relevant to describe patterns at Hofermühle, which is about 7 km away*[2]. It shows a mean annual precipitation rate of 1197 mm/a (1896-2021) with the wettest months being June, July and August. Between Sept. 12th and 16th 2024, an exceptional atmospheric pattern led to long-lasting heavy rainfalls in many parts of Austria (BML 2024), which is also reflected in the data provided in Fig. 2.

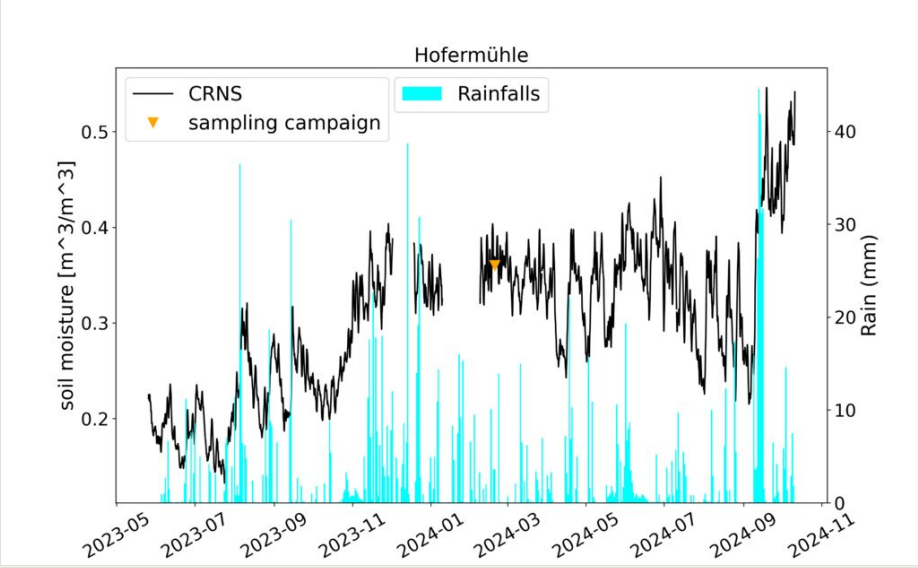


Figure 2. doi

CRNS-measured SM series at the Hofermühle site together with the daily aggregated rainfall* [2]. The site is part of LTER NoeSLIDE and LTSER Platform Eisenwurzen (Data: UNIVIE, ENGAGE working group).

The probe at the Istituto Mosso LTER site (NW Italian Alps, 2901 m a.s.l.) was installed in Dec. 2023 to continuously measure SWE during the snow-covered season 2023/2024. To assess the performance of the probe, the measured data were compared with SWE values collected during targeted field campaigns. Fig. 3 shows the variability of the continuous SWE during the analysed period and the SWE values measured in the field, highlighting the good accuracy of the probe. The probe is currently installed to measure the SWE during the snow-covered season 2024/2025, while more probes are planned to

be installed at the site with the goal to measure both SWE and SM (during the snow-free season).

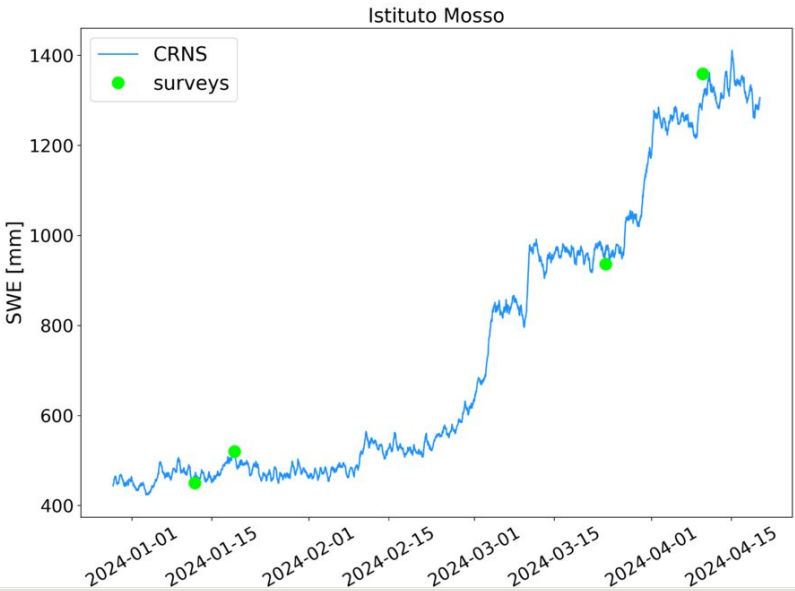


Figure 3. doi

SWE at the Istituto Angelo Mosso site, Italy. The trend continuosly measured by the CRNS probe is compared to a set of targeted field campaigns (Data: UNITO).

The same technology has been applied to notably different scenarios, highlighting the versatility and reliability of CRNS for monitoring the dynamics of water in different forms and under a variety of conditions. We suggest that the spreading use of CRNS probes in monitoring networks will improve the comparability across scales and environments.

Presenting author

Enrico Gazzola

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Conflicts of interest

The authors E. Gazzola and S. Gianessi are employers of the company manufacturing the CNRS probes used in this study.

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Endnotes

*1 Meteorological data from Meteo Palacio station, located in the DBR, are avalilable at: https://meteorologia-palacio.icts-donana.es/

*2 Long-term precipitation data (5 min average rainfalls) for the Waidhofen/Ybby station are provided by Histalp project: www.zamg.ac.at/histalp