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[Lecture]

Synergies of hydrology and space science: How cosmic-ray neutrons are used to detect water

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Abstract: Space weather observation with neutron monitors is based on the assumption that environmental conditions do not influence the local cosmic-ray signal. However, hydrogen in nearby snowpack or soils may be a nuisance even to highly shielded neutron detectors. This nuisance has been turned into a signal of major interest by scientists in hydrology and environmental research (Zreda et al., 2008).

Water in air, soil, snow, and vegetation determines the amount of ground-albedo neutrons from 1 to 10⁵ eV, which can be efficiently monitored by neutron detectors with a thin moderation shield. Dedicated Monte Carlo modeling revealed a signal footprint that extends decimeters deep into the soil and over 10 hectares area due to the long-range neutron diffusion in air. Thereby detectors can capture root-zone soil moisture relevant for irrigation or drought analysis. Hence, the technology has the potential to bridge the scale gap between point-scale and remote-sensing products. Due to their low maintenance and non-invasive nature, the technology has been established worldwide as a reliable and continuous measurement of soil moisture in agriculture or snow in alpine environments. Neutron detectors can also be used in mobile mode on cars, trains, or airships

to facilitate on-demand soil moisture mapping at the field-, regional, or even national scales.

However, these measurements are based on the assumption of a constant incoming cosmic-ray flux, which poses the challenge of real-time corrections using the neutron monitor database, for instance (Hertle et al., 2025). Since their network is sparse, joint efforts are required across disciplines to ensure sustainable observations of cosmic-ray variations continuously in space and time (Franz et al., 2025). The presentation will demonstrate how ground albedo neutrons from cosmic rays are used in hydrology and discuss the strong links and potential synergies with space weather research and adjacent disciplines.

Keywords: cosmic rays, neutron detectors, sensor networks, soil moisture, snow

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