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Validation of shared parameterisation for cosmic ray neutron sensors measuring snow water equivalent in the Italian Alps

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Seasonal snow cover plays a fundamental role in sustaining human activities in mountain communities. Runoff originating from the European Alps is a primary water source for millions of people. However, Alpine snow resources are increasingly threatened by rising temperatures and changes in precipitation patterns due to climate change. These factors underscore the need for accurate and widespread monitoring of the Alpine snow resources.

From a hydrological perspective, snow water equivalent (SWE) is crucial to assess the water amount stocked in the snowpack and, therefore, the water availability after snowmelt. The most historically widespread SWE measurement practices consist in the direct assessment of the snow bulk density through field campaigns involving vertical coring or snow pits. Although these methods are highly accurate, they provide limited temporal and spatial coverage due to the significant manpower required and the inaccessibility of many sites during the snow season.

In the last decades, the development of sensors based on cosmic ray neutron sensing (CRNS) allowed the measurement of continuous SWE data in already monitored sites, filling the gaps associated with manual measurements. However, applying CRNS to monitor snowpacks in inaccessible sites remains largely unexplored as the standard procedure to retrieve SWE from neutron counts relies on site-specific parameters derived from reference measurements.

This work presents a network of 26 CRNS sensors located across the Italian Alps. The network is

among the most extensive of its kind both in terms of both the number of probes and elevation range (1422 – 2901 m a.s.l.). Its broad coverage provides unprecedented insights into the possibility of retrieving SWE data independently of most of the site-specific features usually required. Notably, the parameterisation used to convert neutron counts into SWE is common to all probes in the network.

Manual SWE data from 13 sites within the network, collected during the 2023–2024 and 2024–2025 snow seasons, were used to calibrate and validate the network-wide parameterisation. The calibration process involved 35 direct SWE measurements performed at 6 sites during the first half of the 2023 – 2024 season. A total of 111 manual SWE data were used as the validation dataset.

The analysis shows that the application of a shared set of parameters results in a good representation of the snowpack characteristics. Moreover, the data from unmonitored sites of the network show high correlations with monitored sites at similar elevations. These results suggest that deploying CRNS probes can be used to overcome common limitations of snow monitoring, such as site accessibility issues, lack of manpower to perform manual measurements, and safety hazards linked to the harsh mountain environment.

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