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Cosmic rays on snow: A combined analysis of fractional snow cover derived from Sentinel-2, MODIS and Cosmic Ray Neutron Sensors across Europe

Nora Krebs[1], Paul Schattan[1], Sascha Oswald[2], Martin Schrön[3], Martin Rutzinger[1], and Johann Stötter[1]

[1]Institute of Geography, University of Innsbruck, Austria
[2]Institute of Environmental Science and Geography, University of Potsdam, Germany
[3]Department of Monitoring and Exploration Technologies, Helmholtz Centre for Environmental Research – UFZ Leipzig, Germany

Epithermal neutrons from cosmic ray showers are slowed by hydrogen atoms in snow. The drop in the fast neutron abundance in the atmosphere can be measured with above-ground Cosmic Ray Neutron Sensing (CRNS), allowing for an estimation of the Snow Water Equivalent (SWE). SWE is an important variable that has a substantial role in hydrological modelling and forecasts. However, up to now, SWE is conventionally measured at point-scale, which holds only little information about the average SWE in areas of heterogeneous terrain and where snow drift is a predominant process. CRNS offers the prospect of closing this gap by sensing neutrons within a footprint of 10–20 hectares. Currently, further investigations are needed to reduce the uncertainties in the signal conversion from neutron counts to SWE. In this study, we compare the daily signals of 65 CRNS stations across Europe with the corresponding Fractional Snow Cover (FSC) products from Sentinel-2 and MODIS (Moderate-resolution Imaging Spectroradiometer) with a 20 m and 500 m spatial resolution, respectively. By analysing the FSC products, we were able to identify characteristic ranges of neutron counts at snow presence (winter signals) and absence (summer signals). Comparing these ranges and their overlap among stations, we were able to distinguish typical signal properties of lowland, pre-Alpine and Alpine sites. We found that altitude-related properties, such as soil and vegetation characteristics govern the general neutron level at the study sites. Snowfall typically leads to a major drop in the neutron count rate that is superimposed on the summer neutron count level. High-altitude stations are generally characterized by low ranges of count rates in summer and by high ranges in winter, while low-altitude stations show a reversed trend. Our results demonstrate that the suitability of a station for SWE measurements with CRNS depends highly on the site-specific hydrogen pool fluctuations that can be linked to altitude. Especially in heterogeneous mountain terrain with low soil formation, the advantages of CRNS come into play and can provide a spatial average of SWE with low uncertainties.