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Simulation of moisture in alpine rock walls during freeze-thaw events

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Rock moisture distribution during freeze-thaw events is the key to understanding frost weathering and subsequent rockfall. Data on moisture levels of natural rock walls are scarce and difficult to measure. An innovative and cheap way to avoid these problems is the use of simulation calculations. Although they are an abstraction of the real system they are widely used in natural science. A novel way to simulate moisture in natural rock walls is the use of the software WUFI which has been developed to understand the moisture behavior in building materials. However, the enormous know-how behind these commercial applications has not been exploited for geomorphological research to date. Necessary input data for the simulation are climate data in hourly resolution (temperature, rainfall, wind, irradiation) and material properties (porosity, sorption and diffusivity parameters) of the prevailing rock. Two different regions were analysed, the Gesäuse (Johnsbachtal: 700 m, limestone and dolomite) and the Sonnblick (3000 m, gneiss and granite). We aimed at comparing the two regions in terms of general susceptibility to frost weathering, as well as the influence of aspect, inclination and rock parameters and the possible impact of climate change.
The calculated 1D-moisture profiles and temporal progress of rock moisture – in combination with temperature data – allow to detect possible periods of active weathering and resulting rockfalls. These results were analyzed based on two different frost weathering theories, the "classical" frost shattering theory (requiring high number of freeze-thaw cycles and a pore saturation of 90%) and the segregation ice theory (requiring a long freezing period and a pore saturation threshold of approx. 60%). An additionally considered critical factor for both theories was the frost depth, namely the duration of the "frost cracking window" (between -3 and -10°C) at each site.
The results shows that in both areas, north-facing rocks are generally wetter than south-facing ones because of the lower irradiation. The rocks at Sonnblick are much drier than in Johnsbachtal because at high elevations, a high portion of precipitation is in solid form and does not contribute to rock moisture. Freeze-thaw events concurrent with pore saturations of > 90% are almost never observed. The time spent in the frost cracking window and paralleled by sufficient moisture (> 60 %) is particularly high at north-facing sites of the Johnsbachtal region and is generally higher in the interior of the rock (5-10 cm and deeper). In the annual cycle, particularly autumn and spring are pertinent for frost weathering (and consequently for primary rock fall) while in winter the rocks lack moisture and in summer, sufficient freezing events are missing.