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Measuring wet-snow properties with ground-penetrating radar technology

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Snow stratigraphy and its interaction with percolating water play a vital role in determining periods with wet-snow instability. So far, research on wet-snow avalanches mostly focused on linking meteorological parameters with periods of avalanche activity, so that information on snowpack properties prior and during times of high avalanche activity is rare. Characteristics of percolating water within the snow cover were estimated by traditional snow pit observations or more recently measured with dielectric devices. Both methods are destructive and highly influence the snow stratigraphy and thereby the percolation behaviour. In the present study, we used an upward-looking ground-penetrating radar system (upGPR) to monitor snowpack evolution on a daily or whenever necessary hourly basis to obtain information on wet-snow properties without disturbing the snowpack above the antennae. We focused on (1) determining the volumetric liquid water content by calculating the relative permittivity of the wet snow above the radar antennae, and (2) on the advance of a wetting front and the wet-snow stratigraphy. Results were compared to in-situ measured permittivity, modelled wetting front advance and measured outflow at the bottom of the snowpack. The upGPR system allowed monitoring the advance of a wetting front and the arrival time at the bottom was similar to the time recorded with a nearby lysimeter. Potentially weak wet layers with a high liquid water content (>6%) were detected within the radar signals by multiple reflections. However, determining the exact amount of liquid water for each layer separately was not yet possible.