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The Feasibility of Ground-Penetrating Radar as a Tool for Snowpack Monitoring

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Ground-penetrating radar systems (GPR) offer a wide field of applications. Especially in cryospheric implementations GPR proved to be an adequate tool to determine fast and non-destructively media transitions. In this study, we analyse the feasibility of impulse radar in recording internal snowpack transitions of density or moisture content. The utilized impulse radar systems for this research purpose are commercially available and the gathered data needs no calibration measurement for interpretation, which is a distinct advantage in comparison to frequency modulated continuous wave (FMCW) systems. Currently available methods monitoring seasonal snowpacks are either destructive as snow profiling or insufficient for measuring in slope areas or to determine snow stratigraphy as ultra-sonic sensors. Additionally, the risk exposure for the profiling teams is often a limiting factor for the data acquisition, especially in avalanche paths and ridge areas. In such regions an all-season monitoring system must be secured against being destroyed by avalanches. Thus, the implemented system operates from beneath the snowpack measuring in upward direction. The GPR system was tested in several varying snow conditions as cold dry snow and wet snowpacks. Furthermore, different frequencies, polarisations and two different radar systems were analysed on their applicability for the snowpack monitoring from beneath and the system was utilized in periods with various meteorological parameter. The results of these preliminary tests showed, that with a moved antenna it is possible to record snow layers in dry snow with adequate density steps and layer thickness, supplementary to the snow depth. A one meter-thick wet snowpack was penetrateable although the signal was very much attenuated. GPR systems with frequencies above 1 GHz provided insufficient pentration depth in late season snowpacks. Analysis of reflection phases allowed interpretation of their physical origin in terms of permittivity. The system set-up used is capable of improving information of spatial and temporal snow-pack characteristics especially in stratigraphy and snow depth and has the potential to be remotely operated.