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Monitoring temporal changes within the snowpack utilizing upward-looking radar systems

Lino Schmid[1], Christoph Mitterer[1], Jürg Schweizer[1], Achim Heilig[2, 3, 4], Olaf Eisen[3, 4], Robert Okorn[5]

[1] *WSL Institute for Snow and Avalanche Research SLF, Flüelastrasse 11, Davos Dorf, Switzerland (schmidl@slf.ch).*
[2] *Department of Geosciences CGISS, Boise State University, Boise (ID), USA*
[3] *Institute of Environmental Physics, University of Heidelberg, Heidelberg, Germany*
[4] *Alfred Wegener Institute for Polar and Marine Research, Bremehaven, Germany*
[5] *Electronic & Technology Management (ETM) FH JOANNEUM, Kapfenberg, Austria*

As the seasonal snow cover exists close to its melting point, the snow structure is constantly changing. Furthermore, the snowpack is spatially variable. Therefore, the evolution of snow stratigraphy can only be followed if using a non-destructive, continuously operating sensor system. Such systems should provide information on snow layering, snow settling, i.e. strain rates for specific layers after recent loading by precipitation, or the propagation of a wetting front.

For this study, two different upward-looking radar systems buried in the ground recorded continuous data of snow stratigraphy during the winter season 2010-2011. Under dry-snow conditions every three hours a measurement was performed; as soon as parts of the snowpack were wet, the sampling rate was changed to two measurements per hour. In addition to a previously installed and tested upward-looking impulse radar system (upGPR) a low-cost self-assembled frequency modulated continuous wave system (upFMCW) in a similar frequency range was buried in the ground. We compare the radar signals gathered with two different frequencies (600, 1600 MHz) with the upGPR to the signals recorded with the upFMCW in the frequency range of 1 - 2 GHz. Under dry-snow conditions, the radar offers the unique possibility to follow the evolution of internal snow layers, in particular to monitor settling rates of single layers. Under wet-snow conditions, the occurrence of strong multiple reflections as well as the daily increase in two-way travel time of reflection horizons allow one to determine the absolute amount of liquid water, the depth of a wetting front, the timing of the daily peak in volumetric liquid water content and its decreasing due to refreezing during the night.