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Temporal evolution of crack propagation in a weak snowpack layer of buried surface hoar: insights from high-resolution, high-speed photography

Bastian Bergfeld (1), Alec van Herwijnen (1), Jürg Dual (2), and Jürg Schweizer (1)

(1) WSL institute for Snow and Avalanche Research SLF, Avalanches and Prevention, Switzerland, (2) Institute for Mechanical Systems, ETH Zürich, Zürich, Switzerland

For a snow avalanche to release, a weak layer has to be buried below a more cohesive snow slab. While field measurements can readily be used to identify weak layers within the snowpack, it often remains difficult to determine if avalanches will release, in particular during the initial phases of weak layer burial when the slab above the weak layer is usually still soft and weak. This uncertainty challenges avalanche forecasting and requires a better understanding of snowpack properties contributing to crack propagation in weak layers. We therefore performed a series of PST experiments over two weeks in January 2019 to track a weak layer of surface hoar from its burial up to the time when PST experiments resulted in full propagation. Within these two weeks after weak layer burial the slab successively thickened due to snow accumulation. The total amount of new snow was more than 80 cm and initially very soft and weak. All PST experiments were filmed using a portable high-speed camera with a horizontal resolution of 1280 pixels at frame rates up to 14000 frames per second. By applying a high density speckling pattern on the entire PST column, we then used digital image correlation (DIC) to derive high-resolution displacement and strain fields in the slab, weak layer and substratum. These measurements allowed us to derive the critical cut length, crack propagation distance and speed, which were related to detailed snowpack measures obtained from manual profiles and high resolution digital cone penetration measurements (SMP). Our results show that the transition between partial to full propagation occurred at the tenth day after burial when the load induced by the slab increased from 55 kg/m2 to 71 kg/m2. Studying the transition between no, partial and full propagation is therefore only possible if detailed snowpack and crack propagation data are collected over a time span that includes both, no and full propagation. A layer of surface hoar that is additionally loaded almost daily requires extraordinary weather conditions, which we were fortunate to experience at the beginning of 2019. The weather conditions induced a rapid change of the snow slab whereas the weak layer did hardly change. Our dataset provides unique data to study snowpack properties related to sustained crack propagation vs. crack arrest and allows new insight into the dynamics of crack propagation associated with slab avalanche release.