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Measuring slope-scale crack propagation in weak snowpack layers

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For a snow avalanche to release, a weak layer has to be buried below a cohesive snow slab. The slab-weak layer configuration must not only allow failure initiation but also crack propagation across a slope. While in the past failure initiation was extensively studied, research focusing on the onset and dynamics of crack propagation only started with the introduction of the Propagation Saw Test (PST), a meter scale fracture mechanical field test. Since then, various studies used particle tracking analysis of high-speed video recordings of PST experiments to gain insight into crack propagation processes and to measure crack propagation speeds. At the slope scale, a few crack speed estimates have been obtained from seismic sensors, videos or visual observation. However, due to experimental limitations, these latter studies can only provide rather crude crack speed estimates and direct comparisons to PST measurements are still missing. Sure, performing experiments in avalanche terrain is challenging and limited for security reasons, but crack propagation occurs also in slopes not sufficiently steep to release an avalanche. This phenomena is called a whumpf. Since crack propagation in whumpfs is presumably similar to that in avalanches, we developed instrumentation to measure crack speeds on artificially triggered whumpfs. We designed small wireless time synchronized accelerometers with a sampling rate of 400 Hz that can be placed on the snowpack. These measure the downward acceleration of the slab when a crack in the weak layer below passes by. Though triggering whumpfs is difficult and unpredictable, we performed a successful experiment with seven sensors placed over a distance of 25 m. Our experiment revealed a crack speed around 50 ms^{-1}. In addition, we obtained very similar crack speed measurements from a 5.3 m long PST carried out close-by (42 ms^{-1}) and a video-based speed estimate of an avalanche triggered two days later (42 – 55 ms^{-1}). Our unique whumpf measurement is the first slope scale speed value that can be directly compared to results obtained with other speed measurement techniques. The similarity between the measured speeds suggests that the one-dimensional crack propagation in PSTs is also similar to the 2-dimensional crack propagation in Whumpfs and real avalanches. PSTs are therefore well suited to investigate crack propagation processes of dry snow slab avalanches.