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Snow fracture: From micro-cracking to global failure

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Slab avalanches are caused by a crack forming and propagating in a weak layer within the snow cover, which eventually causes the detachment of the overlying cohesive slab. The gradual damage process leading to the nucleation of the initial failure is still not entirely understood. Therefore, we studied the damage process preceding snow failure by analyzing the acoustic emissions (AE) generated by bond failure or micro-cracking. The AE allow studying the ongoing progressive failure in a non-destructive way. We performed fully load-controlled failure experiments on snow samples presenting a weak layer and recorded the generated AE.

The size and frequency of the generated AE increased before failure revealing an acceleration of the damage process with increased size and frequency of damage and/or microscopic cracks. The AE energy was power-law distributed and the exponent (b-value) decreased approaching failure. The waiting time followed an exponential distribution with increasing exponential coefficient λ before failure. The decrease of the b-value and the increase of λ correspond to a change in the event distribution statistics indicating a transition from homogeneously distributed uncorrelated damage producing mostly small AE to localized damage, which cause larger correlated events which leads to brittle failure.

We observed brittle failure for the fast experiment and a more ductile behavior for the slow experiments. This rate dependence was reflected also in the AE signature. In the slow experiments the b value and λ were almost constant, and the energy rate increase was moderate indicating that the damage process was in a stable state – suggesting the damage and healing processes to be balanced. On a shorter time scale, however, the AE parameters varied indicating that the damage process was not steady but consisted of a sum of small bursts. We assume that the bursts may have been generated by cascades of correlated micro-cracks caused by localization of stresses at a small scale. The healing process may then have prevented the self-organization of this small scale damage and, therefore, the total failure of the sample.