EGU21-11482
https://doi.org/10.5194/egusphere-egu21-11482
EGU General Assembly 2021

Micro-mechanical modeling using DEM to study the effect of mechanical properties on crack propagation for snow slab avalanches

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Dry-snow slab avalanche release is a multi-scale process starting with the formation of localized failure in a highly porous weak snow layer below a cohesive snow slab, which can be followed by rapid crack propagation within the weak layer. Finally, a tensile fracture through the slab leads to its detachment. About 15 years ago, the propagation saw test (PST) was developed. The PST is a fracture mechanical field test that provides information on crack propagation propensity in weak snowpack layers. It has become a valuable research tool to investigate the processes involved in crack propagation. While this has led to a better understanding of the onset of crack propagation, much less is known about the ensuing propagation dynamics. Here, we use the discrete element method to numerically simulate PSTs in 3D and analyze the fracture dynamics using a micro-mechanical approach. Our DEM model reproduced the observed PST behavior extracted from experimental analysis. We developed different indicators to define the crack tip that allowed deriving crack speed. Our results show that crack propagation in level terrain reaches a stationary speed if the snow column is long enough. Moreover, we define stress concentration sections. Their length evolution during crack propagation suggests the development of a steady-state stress regime. Slab and weak layer elastic modulus, as well as weak layer shear strength, are the key input parameters for modeling crack propagation; they affect stress concentrations, crack speed, and the critical length for the onset of crack propagation. The results of our sensitivity study highlight the effect of these mechanical parameters on the emergence of a steady-state propagation regime and consequences for dry-snow slab avalanche release. Our DEM approach opens the possibility for a comprehensive study on the influence of the snowpack mechanical properties on the fundamental processes for avalanche release.