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Modeling snow failure and dynamic fracture with discrete elements

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Improving the prediction of snow avalanches requires a detailed understanding of the fracture behavior of snow as dry-snow slab avalanche release is a multi-scale fracture process. In principle, avalanches start with the formation of a localized failure in a highly porous weak snow layer underlying a cohesive snow slab, which can be followed by rapid crack propagation within the weak layer and finally a tensile fracture through the slab appears leading to its detachment. While the basic concepts of avalanche release are relatively well understood, performing fracture experiments in the lab or in the field can be difficult due to the fragile nature of weak snow layers. Numerical simulations are a valuable tool for the study of micro-mechanical processes which lead to fracture in snow. We use the discrete element method to simulate and analyze fracture processes. Using cohesive ballistic deposition, we numerically produce a highly porous and brittle weak layer covered by a dense cohesive slab. We tuned contact law parameters between the particles to obtain realistic macroscopic behavior of the slab and the weak layer consistent with laboratory and field experiments. To analyze the micro-mechanical behavior at the slope snowpack scale with an acceptable computational time, we define the particle size at a meso-scale between snow grain and snow layers. Numerical load-controlled failure experiments were performed on small samples and compared to load-controlled laboratory experiment data. Results show accordance of main mechanical behaviors: normal and shear stresses, strength, displacement over different loading angles between numerical simulations and laboratory experiments. This allows us to validate our approach of using meso-particle scale for simulations. Henceforth, we simulated snowpack slope scale propagation experiments by cutting the weak layer with a numerical snow saw, according to experiment procedures. The results of these numerical experiments reproduce the main dynamics of crack propagation observed in the field. Overall, our results show that the discrete element method in 3D can be used to realistically simulate snow failure and fracture processes and lay the foundation for a comprehensive study on the influence of the mechanical properties of the slab and weak layer on these fundamental processes for avalanche release.