Geophysical Research Abstracts
Vol. 20, EGU2018-19633, 2018
EGU General Assembly 2018

Fiber bundle model with healing mechanisms: towards simulating progressive failure of snow

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Snow is a heterogeneous material with strain/load rate dependent strength. In particular, a transition from ductile to brittle failure behavior with increasing loading rate is observed. The rate dependent behavior can partly be explained with the existence of a unique healing mechanism in snow that stems from its high homologous temperature. As soon as broken elements in the ice matrix get in contact, they start sintering and the structure may re-gain strength. Moreover, the ice matrix is subjected to viscous deformation inducing a relaxation of local load concentrations and, therefore, further counteracting the damage process. Ideal tools to study the failure process of heterogeneous materials are the fiber bundle models (FBM), which allow investigating the effects of basic microstructural characteristics on the general macroscopic failure behavior. We present a new version of a FBM with two concurrent time-dependent healing mechanisms: sintering of broken fibers and relaxation of load inhomogeneities. Sintering compensates damage by creating additional intact, load-supporting fibers which lead to an increase of the bundle strength. However, the character of the failure is not changed by sintering alone. With combined sintering and load relaxation, load is distributed from old stronger fibers to new fibers that carry fewer load. In this case, the failure occurred suddenly without decrease of the order parameter and without divergence of the fiber failure rate; moreover, the b-value at failure converged to approximately 2, a value higher than the one of a classical FBM without healing (b=3/2). These results indicate that healing, as the combined effect of sintering and load relaxation, changes the type of the phase transition at failure. This must be considered when studying the failure (e.g. by monitoring acoustic emissions) of snow or other materials for which healing plays an important role.