The Cryosphere Discuss., 9, C1299–C1301, 2015
www.the-cryosphere-discuss.net/9/C1299/2015/

Interactive comment on "Microstructure-based modeling of snow mechanics: a discrete element approach" *by* P. Hagenmuller et al.

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Received and published: 26 July 2015

We thank Mark Hopkins for his interesting and constructive feedback that helped us to improve the paper.

This paper presents an interesting discrete element based dynamic microstructural snow model. The model snow microstructure was derived from muCT imagery and implemented by replacing each voxel of the muCT derived structure with a sphere whose diameter equals the width of the cubic voxel. Discrete elements or grains are defined by a preprocessing algorithm that delineates the location of necks or weak points in the structure. Only the surface spheres that cover the elements participate in interactions between neighboring grains. The spheres at grain boundaries are linked by an elastic constitutive model that supports both tension and compression in the normal direction and shear in the tangential direction. Once the tensile strength of the bond is exceeded in response to the stresses that arise when the sample is loaded the cohesive bond is broken. Once broken the grain/spheres interact through a model that supports elastic compression and frictional sliding. The DEM model is simple and avoids the complexity of a full polyhedral treatment. While this method creates some artificial roughness due to the inherent 'bumpiness' in grain-grain contacts, as the sphere radius $>$ 0 the bumpiness is diminished.

As an initial presentation of a new snow modeling technique this paper strikes a good balance between laying out the model details, exploring the sensitivity of the model to the grain-grain constitutive model, sphere diameter, sample size (RVE), and friction coefficient. Finally, results of large-strain uniaxial compression experiments on muCT derived samples having different densities and microstructures are presented. The comparison shows that sample density is a good proxy for a samples response to compression from initial elastic loading through failure. I am sure that the model can be used to study other loading states as well.

0.0.1 Comment 1

I have questions about the cohesive failure model. Does the failure occur in one time step? There appears to be no strain-softening? If not then the failure will send shock waves that radiate outward from the failure site. This is mitigated to some degree by the global damping that is imposed on the system. If this is the case then the problem is better addressed by the addition of strain-softening so that failure is attenuated over a number of time steps.

The failure of one sphere-sphere contact occurs in one time step. The failure of one grain-grain contact composed of multiple sphere-sphere contacts occurs generally in more than one time step. We effectively observed some elastic waves that radiate from the failure site. As explained l.8 p.1434, we used a numerical global damping to dissipate energy in the system. This damping also dissipates some of the elastic energy released from a failure site. The sensitivity analysis revealed a low sensitivity of the macroscopic behavior to the global damping which strongly affects these elastic waves. We therefore believe that these waves do not lead to extra bond failure and so do not affect the macroscopic behavior. Considering more advanced microscopic contact laws (e.g. including sintering) is an ongoing work.

0.0.2 Minor comments

P 1432 L 1: "The interactions between the members of two different clumps are frictional and cohesive, ..." Should mention elastic as well. Changed as suggested.

P 1436, L 10: "... and snow deforms ..." – "... and the snow sample deforms.". Changed as suggested.

P 1436, L 25: "compacity" I learn something new every day. Changed into "density".

Interactive comment on The Cryosphere Discuss., 9, 1425, 2015.