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Interactive
Comment

Interactive comment on "Thresholds in the sliding resistance of simulated basal ice" *by* L. F. Emerson and A. W. Rempel

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General comments

Emerson and Rempel describe laboratory experiments where disks of ice containing dispersed particles are slid on glass at room temperature. They measured the friction between the dirty ice and the glass as a function of sediment concentration and particule size. Their observations indicate that sliding occurs in two distinct regimes: "slippery" when sediment concentration is low and/or particle size is small and "sandy" (higher friction) when both sediment concentration is high and particle size is large.

The is a well-done set of experiments. The topic of sliding resistance caused by debris in ice is not often discussed and its importance is underrated so this publication is most

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welcomed. Results are clearly presented and interpreted with sound analyses. In the end, the paper reaches interesting conclusions and brings new data and interpretations to the topic of glacier sliding. I think experiments of this kind are really necessary to help formulate a more realistic basal boundary condition for glaciers and ice sheets (a poorly constrained aspect of numerical models) that takes into account realistic physics.

I agree with comments by referee A. Rathbun: the paper is both interesting and relevant to Cryosphere and I recommend publication with only minor revisions once issues discussed below have been addressed.

- In the experiments particle size ranges from 0.01 mm to 1.5 mm. Regelation ice has been observed to contain such small particle sizes but much of the surface area of the glacier bed where net melting occurs contains particles that are much larger (for an example, see Figure 3 of Cohen et al., 2005). Particles can be several millimeters to centimeters in size and these particles are the particles that will offer the highest frictional resistance (at least in the slow melt rate and slow sliding speed regime of glaciers). What would happen to the sliding regimes if experiments had been done with much larger particles? Would there still be a threshold?

- Emerson and Rempel's estimation of film thickness indicates that the film thickness is inversely proportional to the normal load (Equation 1). If this is the case, ice samples with small particles (say less than 100 microns) that initially displayed slippery behavior should eventually display the sandy-regime behavior once the normal load is increased sufficiently such that the water film thickness becomes smaller than the particle radius (or diameter, see specific comment # 3 below). If this is the case, then the friction coefficient is also a function of the normal load and not a constant for a given particle size and concentration. It would be interesting to test Equation 1 and this hypothesis by doing additional experiments with a given particle size and concentration and then increase the normal load. This may add another dimension to the flow regimes map.

Specific comments

1. Introduction, page 101 line 16. Hallet (1979) included both regelation and downward viscous flow around particles to determine the normal force between a particle and the bed.

2. Section 2: For the sake of completion, could the author specify what type of sediment (rock) particles were used in the experiment?

3. Section 4.1: I am wondering why the film thickness is compared to the particle radius and not to the particle diameter. I would think that particles with radii close to the film thickness could still be coupled to the ice and exert a frictional force on the glass plate. Clearly that depends on the balance of forces exerted by the ice and the water on the particle. The author should clarify why they choose the particle radius.

4. Also related to Equation 1, why choose $N = 1$ kPa in calculations for h? Why not 3 kPa (value with weigths of 2.25 kg) or 5.4 kPa (value with weigths of 4.5 kg). These values of N give $h = 28$ and 23 microns, respectively. These values depart further from observations. I understand the calculation is only meant as an approximation but if this is so why compare it so precisely with the particle radius.

5. Could the authors indicate the weight of ice holder so that the precise total weight on top of the ice sample can be calculated?

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Technical corrections

- page 108, line 20. Change 'roll' to 'role'

Reference

Cohen, D., N. R. Iverson, T. S. Hooyer, U. H. Fischer, M. Jackson, and P. L. Moore (2005), Debris-bed friction of hard-bedded glaciers, J. Geophys. Res., 110, F02007, doi:10.1029/2004JF000228.

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