Possible Mechanisms for Glacial Earthquakes

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The large glacial earthquakes reported on by Ekstrom et al. (2003, 2006) and Tsai and Ekstrom (2007) have previously been evaluated in terms of their seismic characteristics. Here we take constraints such as known glacial ice properties, outlet glacier size, calving style, and meltwater variability to construct a self-consistent physical model of the glacial earthquake process. We find two classes of models are able to satisfy most observational constraints, one caused by lost basal resistance coupled to viscoelastic deformation and one caused by non-equilibrium calving, such as having large icebergs capsize into the glacier front. The non-equilibrium calving model currently has much stronger support and we present a mechanical model for how such iceberg capsizing could occur.
This model builds upon the equilibrium model of MacAyeal et al. (2003), allowing for hydrostatic pressure from the surrounding water, a contact force of the iceberg against the glacier front, and an optional second contact force on the opposite side to account for a mechanically competent iceberg melange or other added mass effects. In contrast to the MacAyeal model, we allow for accelerations and solve the dynamical system of equations given various initial conditions. With proper choice of parameters such as iceberg dimensions and initial conditions, these models reproduce all available glacial earthquake observational constraints, including earthquake amplitudes and timescales and recent visual observations.