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The Cryosphere Discussions

Interactive comment on "Buoyant forces promote tidewater glacier iceberg calving through large basal stress concentrations" *by* Matt Trevers et al.

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This manuscript describes a set of flowline "full Stokes" simulations of notch induced buoyant calving with geometries analogous to Jakobshavn Isbrae, one of the largest outlet glaciers draining the Greenland Ice Sheet. The authors hypothesize that buoyant forces associated with the detachment of a block of ice above the waterline could trigger a buoyant calving event, similar to a multi-part calving event observed.

The idea behind buoyant calving events being triggered by subaerial block detachment is old and goes back (at least) as far as the early workshops on calving. Where this manuscript goes beyond previous research is in not only quantifying the stresses associated with block detachment using a model, but also probing the relationship of the

near terminus stress field with the choice of sliding law. Moreover, the authors attempt to further link the state-of-stress with variations in sub-glacial water pressure, which has been under explored to date.

In general I found the manuscript straightforward and easy to read. There are a couple of issues, however, that I do want to point out in addition to a few terminology suggestions. Most of them are relatively minor and should be easy to correct.

Major suggestions:

There is one major issue with the analysis, which is that the authors compare longitudinal deviatoric stress with a yield strength estimate from Vaughan (1993). The longitudinal deviatoric stress is problematic for two reasons. First, the various components of the deviatoric stress are not coordinate system invariant and have little physical meaning: a different coordinate system would result in different numbers. It is possible that the authors want to look at, say the components of the traction along the bed (which is well defined) or the largest principle deviatoric stress (which is also well defined). But this raises the more fundamental issue: it is the largest principle *Cauchy stress* and not the deviatoric stress that controls *tensile* fracture. And it is clear from the manuscript that the authors are fully focused on tensile basal crevasses. If the authors want to argue that the stresses are sufficient to trigger a *tensile* basal crevasse then they need to examine the largest principle *Cauchy* stress. Fortunately, this should be straightforward to compute from the full Stokes model. More problematically for the analysis performed here, for a kilometer thick glacier, the hydrostatic pressure is probably of the order of 10 MPa and may result in a negative (compressive) largest principle Cauchy stress. I should point that this is a common problem when dealing with failure of ice and especially basal crevasses. The most common solution to this problem is to (rather arbitrarily) superpose a hydrostatic pressure associated with water to the largest principle Cauchy stress to simulate the effect of water filled crevasses. This is commonly done and I think the authors could get away with it here if they want. Technically, you can't really do this and the right way to do it is to calculate the Cauchy stress after introducing an infinitely narrow test crack. Doing it the right way, usually results in a compressive stress when using the power-law creep rheology of ice. If the authors go the usual route of superposing a hydrostatic stress field, I do suggest showing the stress with and without water pressure to emphasize that the water pressure is (or is not) critical.

Another aspect of the analysis that is somewhat problematic is that the authors are comparing their stress metric to the yield strength estimated by Vaughan (1993). My understanding, however, is that Vaughan (1993) examined various yield strength envelopes, finding that the Von Mises stress envelope provided the best fit to the observations. The Von Mises yield criterion, however, is only equivalent to tensile failure in uniaxial loading, which is not the case for the model considered here. Recalling that the second deviatoric stress invariant invariant is proportional to the Von Mises stress, what I suggest is that in addition to the largest principle Cauchy stress, the authors also consider showing the second deviatoric stress invariant as an additional stress metric. This stress metric can be more directly compared with Vaughan's estimated yield strength. Note that in two dimensions, the second effective deviatoric stress invariant is equal to the maximum shear stress and thus the failure mechanism predicted by this envelope would be shear, rather than purely tensile failure and, if the authors go this route, the authors will need to be careful to point this out. Although we speculated that shear failure is important for tall calving cliff in Bassis and Walker (2012), I'm not aware of any strong observational evidence supporting shear failure in calving so the authors may want to take this suggestion under advisement as the broader community has doubts about the viability of shear failure.

Another minor point is that the authors convincingly argue that time scales they are interested are short compared to the time scales of flow and thus they can ignore the effect of ice flow on their experiments. However, if the time scale of interest is short compared to the time scale of flow, then this would seem to imply that an elastic rheology would be appropriate. This is surprising to most, but the elastic stress can

be quite different from the viscous stress and this is primarily a consequence of the non-linearity in the creep flow law used.

Minor comments. Page 3, near line 20: Technically, you can impose a boundary condition on the traction and not on the individual stress components.

What is a full School regime?

The authors should be a little bit careful when discussing sliding laws, water pressure and the stress regime because glaciers are actually three-dimensional with bumps in the bed. In three-dimensions, these bumps play a pretty big role in controlling the stress transmission upstream because portions of the calving front maybe well grounded whilst other portions are close to flotation.

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