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The Cryosphere Discussions

Interactive comment on "Kinematic first-order calving law implies potential for abrupt ice-shelf retreat" *by* A. Levermann et al.

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General Comments:

This manuscript proposes a two-dimensional generalization to a calving law recently proposed by Alley and others (2007). The authors further argue that the one of the implications of the calving law is that some ice shelves, such as the Larsen B and Ross ice shelves, have the potential for rapid collapse. Thus the calving law can potentially explain the observed rapid retreat of the Larsen B and predicts the Ross Ice Shelf could be subject to a similar catastrophic collapse scenario.

In general the manuscript presents an interesting and novel idea that merits publication. It would be nice to see the manuscript expanded to provide a more robust comparison

between observations and model predictions. For example, why not also include data from the Ross Ice Shelf and other ice shelves in Figure 1b. (I believe velocities for all of the Antarctic ice shelves are now available courtesy of E. Rignot so this should be possible.) If more data is included is there a single constant that can fit all of the ice shelves in Antarctica and how much scatter is there in this type of plot? I also have some questions about the calving model, described in more detail below. Other than these, relatively minor concerns this manuscript will be of interest to the wider glaciological community.

Specific Comments:

1. There are a couple of confusing factors associated with the calving model (Equation 2) proposed in the text. First, I'm not sure I understand the logic behind the proposed expansion. The expansion appears to rest on the assumption that the principle strain rates are small so that higher order products in the expansion can be neglected. Perhaps I've missed something here. However, I would expect that fracturing and hence calving is most vigorous at large strain rates. The authors should explain this puzzling conundrum. Alternatively, Equation (2) should be motivated as the natural two-dimensional isotropic generalization of the empirical calving law proposed by Alley and others (2007)?

2. Second, it is unclear where Equation (2) applies. I suspect that the authors intend to apply it solely at the calving front as a type of boundary condition. However, if this is the case it is unclear physically why it is only the strain rate near the calving front that determines calving. This is especially puzzling since observations indicate that the large tabular calving events observed from ice shelves tend to initiate from rifts that develop far upstream of the calving front. Hence, I believe that the authors need to add the additional assumption that calving is solely controlled by processes that are local to the calving front?

3. Because Equation (2) only applies at the calving front, how dependent are the

results on the model resolution?

4. The implication of the chosen form of the calving law is that ice shelves are only stable if they exist within confined embayments. While this is true, there are also numerous unconfined floating ice tongues that appear to be stable. How can these features be reconciled with the calving law proposed?

5. Given the fact that we know that the sporadic detachment of large tabular bergs occasionally perturb the ice front position. Does the model predict that the calving front of ice shelves that are known to be stable are indeed stable in the face of these perturbations? Also, would the authors care to speculate on how they would introduce rifts prognostically into their simulation so that disintegration of ice shelves could be predicted?

Technical Comments:

Section 2, after line 10: I'm not sure that dilation, i.e., sum of the components on the diagonal of the strain tensor is the appropriate term. I think the authors actually mean rate of dilation since they are dealing with the strain rate tensor. However, many glaciologists may also argue that the dilation rate is close to zero because ice is to a good approximation incompressible. In two dimensions, of course, this implies that the dynamic thinning rate is related to the 2 horizontal principle strain rates. Perhaps dynamic thinning rate is a more appropriate term?

page 2703: Is Hughes (2002) the correct reference to cite for tabular bergs from ice shelves? I thought this paper was concerned with slab calving events from partially grounded tidewater glaciers.

Fig 6. (and a few other figures) show the present calving front position of the Ross Ice Shelf and compare it to the simulation prediction. However, the calving front position of the Ross Ice Shelf is continuously evolving as it advances and occasionally bits break off. It may be more useful to show the mean position or provide some measure of the

variation in the calving front position to let readers better assess how well the model agrees with the observations.

Interactive comment on The Cryosphere Discuss., 5, 2699, 2011.