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Interactive Comment

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

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In this manuscript, the authors propose and test a simple calving "law" for ice shelves that equals some constant times the determinant of the 2D strain rate tensor (which is rotationally invariant). Although the proposed calving parameterization seems to work fairly well and produces some interesting results (namely, multiple steady states), the choice of parameterization should be better justified. Given the somewhat arbitrary choice of the parameterization, I would like to see the authors explore other possibilities.

Despite my concerns, with a bit of work I think this paper would be suitable for publication and would be of interest to a wide range of researchers. I would also like to thank the authors for submitting a well-polished manuscript – it made my job as reviewer a lot easier!

(1) The parameterization is hardly a law. This implies a degree of certainty/confidence that I don't see. For example, the proportionality constant is hardly a constant – it appears to vary by a factor of two between the two ice shelves that were considered in this study. I think its more fair to state that the authors were testing whether a calving law should/could depend on the determinant of the strain rate.

(2) Given the fact that K is not really a constant, how should we interpret it?

(3) I don't agree with the statement on page 2703 that K1+ has to vanish otherwise ice shelves would be unstable / not exist. That would be the case if the calving parameterization determined the terminus position based on the strain rates exceeding some threshold. If K1+ is not zero, then all that the parameterization is saying is that the calving rate would speed up as the shelf retreats toward the grounding line. Isn't that more or less what we observe for retreating shelves? Also, K1+ is likely not a constant (see point 1) and the strain rates near the grounding line will clearly not remain constant with time. And furthermore, what is meant by stable? Are ice shelves ever truly stable? Maybe this discussion just means that its difficult to grow an ice shelf outward from a grounding line (as opposed to forming one by thinning grounded ice).

(4) In light of point 3, what is the physical motivation behind choosing the determinant of the strain rate tensor? Why not choose the trace of the tensor, which is also rotationally invariant and is physically motivated by the fact that it appears in the steady-state calving relation (Amundson and Truffer, 2010)? (Isn't dilation rate the trace of the strain rate tensor?) There might be a good reason to choose one over the other, but I would like to know why. (Or maybe it would make sense to use both?)

(5) If this paper is truly building on previous work, then why ignore the potential dependence on ice thickness and thickness gradient (which depends on ice shelf width) (Alley et al., 2008; Amundson and Truffer, 2010)? Including these parameters may help to explain the differences in the proportionality constant from one ice shelf to the next...

Again, there may be good reason to do this, but I'd like to see some justification.

(6) There is an assumption in the paper that is somewhat hidden. At the top of p. 2703, the authors claim that the determinant of the strain rate tensor appears to be proportional to calving rate (as estimated by terminal velocity). This assumes that changes in glacier length are small compared to changes in velocity and calving rate. I don't have a problem with that assumption, per se, because it is consistent with observations – most of the time. I just think it needs to be stated more explicitly as an assumption.

A couple of minor points: (1) The first few sentences of the abstract are not really abstract material.

(2) Line 10 on p. 2702: "Perpendicular" compression also favors ice thickening; thick shelves seem to be more stable than thin shelves.

(3) Why was Equation 1 presented before Equation 2? A more natural order would be to first present Equation 2 and then use various arguments to reduce it to a simplified form.

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