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The Cryosphere Discussions

Interactive comment on "High sensitivity of tidewater outlet glacier dynamics to shape" *by* E. M. Enderlin et al.

A. Aschwanden (Referee)

aaschwanden@alaska.edu

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In "High sensitivity of tidewater outlet glacier dynamics to shape" Enderlin et al. study the sensitivity of outlet glacier behavior to glacier width and bed elevation using a numerical ice flow model. A stress perturbation at the calving front is applied to a set of width and bed elevation profiles that reflect the shape of prominent Greenland outlet glaciers. The study concludes that glaciers which are closer to flotation are more likely to exhibit unstable retreat following the perturbation. Unstably-retreating glaciers show varying lag times (the time between perturbation and onset of unstable retreat), and the authors suggest that this may explain some of the inter-regional variability in outlet glacier dynamics. The study suggests a high sensitivity to variations in bed elevation, that is, the depths of troughs and shoal. Because the response to the applied pertur-

bation depends on ice thickness relative to flotation, ice thickness must be known with high fidelity to assess the stability of an outlet glacier. Differences in ice thickness on the order of 10's of meters (which is within the accuracy of ground penetrating radar measurements) decide whether a glacier will show unstable retreat or not. Therefore, the authors suggest that prediction of outlet glacier behavior must be complemented by detailed sensitivity studies.

The manuscript is well conceived and written. An obvious criticism would be that the authors tackle a 3D problem using a flow-line model with parametrized variation in width. However, I understand that higher-order or Stokes 3D models with a moving grounding line which are computationally cheap enough to perform sensitivity studies are not readily available. At least not yet. When such models become available, future studies will provide further insight, exploring the consequences of such a simplification a simplified view. The authors address the limitations of their approach in Section 2 sufficiently.

I have a few suggestions:

Section 2 Model description

A short paragraph describing model initialization is needed. Include information such as run length of the initialization and definition of steady-state (e.g. volume change less than $x\,\%$ over y years). Please add the run length of the individual experiments. From Figure 2 and 3, one would assume that the experiments were run for 15 years. If this is the case, please state so in the manuscript. I wonder if 15 years are sufficiently long. Unstable retreat for the combination (shoal,trough)=(425,620) m doesn't occur until year 14 year. I think we need some assurance that unstable retreat does not occur for other combinations after 15 years.

Section 3 Model results

In this section, both thinning rates and ice thickness are mentioned on several occa-

sions. I suggest adding a plot showing them. I find it difficult to connect the manuscript text with the figures. I suggest to clearly point out in which sub-plot the information given in the text can be found. For example: "Raising the bed within the depression increases the ice surface above flotation and reduces thinning rates by up to $\sim 5\,\mathrm{m\,yr^{-1}}$ in the depression (Fig. 3h) , so that unstable retreat does not occur. Raising the elevation of the shoal without raising the depression reduces thinning rates by up to 4 m yr-1 but does not cause thickening within the depression (Fig. 3g), quadrupling the lag time. . . ".

Figures:

In general the figures are illustrative and carefully crafted, but are quite small for the amount of information they contain. This is especially true for Figure 2. This might be a consequence of the unique format of the The Cryosphere Discussion; are the figures in the final version going to be larger? Maybe the readability of the figures could be increased by a different choice of color scheme. Here is a (mere) suggestion: How about visually grouping the experiments by color? One could use two shades of three colors; e.g. blues for widening, greens for uniform, reds for narrowing. http://colorbrewer2.org/ is an excellent resource for color combinations suitable for different applications.

Technical comments:

p. 554, l. 7-13: Awfully long sentence, maybe split into two.

p. 555, l. 7: "$\pm$35 m uncertainty": provide a reference

p. 556, l. 2: "surface mass balance": If you intend to be consistent with the Glossary of Glacier Mass Balance and Related Terms, I think this would be called "climatic-basal balance" (Table 1).

p. 560, l. 8: Only the sensitivity tests that exhibit unstable behavior show a significant lag time.

p. 561, l. 8: The statement that large scale ice sheet models have a spatial resolution

greater than 1 km is incorrect (i.e. outdated). Recently, century-scale simulations with element sizes of 1 km in outlet glaciers have been performed with ELMER, ISSM, and PISM; e.g. F. Gillet-Chaulet et al. (2012, The Cryosphere): Greenland ice sheet contribution to sea-level rise from a new-generation ice-sheet model. Also, it might worth citing Durand et al. (2011, GRL): Impact of bedrock description on modeling ice sheet dynamics.

Interactive comment on The Cryosphere Discuss., 7, 551, 2013.