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The Cryosphere Discussions

Interactive comment on "The stability of grounding lines on retrograde slopes" *by* G. H. Gudmundsson et al.

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1 General statement

The manuscript "The stability of grounding lines on retrograde slopes" presents an example of a stable grounding line for which a section rests on a retrograde bed slope using three-dimensional and vertically integrated two-dimensional models. One-dimensional flow-line models showed that grounding lines are unconditionally unstable on retrograde bed slopes. Here, with two and three-dimensional models, the authors show that this statement does not hold as some configurations of stable grounding lines do exist on retrograde slope.

This manuscript could lead the community to reevaluate the West Antarctic Ice Sheet Instability that was based on the assumption that the grounding lines located on retrograde bed slopes were always unstable. While this statement is generally true, there might be some locations where the grounding line might actually be stable. The manuscript is generally clear and the methods well described, the figures and references appropriate. The methods and results are stated clearly in a well-written text. I therefore recommend this manuscript for publication after addressing the few changes described below.

2 Specific comments

In the Numerical models section, you mention several purely numerical aspects, such as using linear, quadratic or cubic elements for Úa or the importance of mesh resolution. However, these aspects are never discussed in the Results or Discussion sections. I would have liked to see a paragraph in which you discuss the numerical aspects of the model and answer questions like: What level of mesh resolution was required to avoid mesh dependency ? How long does it take to reach the steady-state ? What is the impact of element type (linear, quadratic, cubic) in Úa ? What is the influence of the initial conditions ?

In your simulations, as you mention in the text, only a section of the grounding line is located on retrograde slopes. Is it possible to have the entire grounding line on retrograde slope ? Do you think this stable grounding line on retrograde slope is something unusual due to the particular configuration with a deep trench in the middle of the bedrock and much higher bedrock on the sides ? Or do you think it could be something pretty common that was not noticed earlier as models were mainly relying on flow-line models ?

A last point I am a little bit concerned about is the grounding line break up shown in

Fig. 2. This pattern seems surprising and you mention that it is not a model or figure artifact. Do both models (Elmer and Úa) lead to this kind of break up ? Do you have the same pattern for other channel widths ? It seems to be caused by the very deep channel and the sudden variation in bedrock topography. Could you elaborate on this point ?

3 Technical comments

2HD and 1HD are not written consistently (dash position):“two horizontal dimensions” (page 2598 line 2), “two-horizontal dimensions” (page 2598 line 4), “one horizontal-dimension” (page 2598 line 3)

Page 2598 line 6: “maritime ice sheets” or “marine ice sheets” ?

Page 2598 line 12: Should be West Antarctic Ice Sheet

Page 2599 first paragraph: Could you mention the assumptions made in these studies ? I would also include results from Gomez et al. [2010] about the stabilizing effect of sea level rise on grounding line migration.

Page 2600 line 17: “does not excluded” -> “does not exclude”

Page 2600 line 20: “maritime” -> “marine”

Page 2602 line 9: I would have liked to see the vertically integrated model name and some references here before the equations instead of on page 2605.

Page 2602 line 8-18: I suggest making a clearer distinction between the physical, mathematical and numerical aspects: What ice flow approximation do you use ? How do you solve the equation ? These aspects should be clearly distinct.

Page 2602 line 20: Mention Einstein notation.

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Page 2603 line 2: I am confused by the notation σ_h as it is not exactly equivalent to the horizontal stress tensor that also contains $\rho g h \Delta_h s$. A different notation could avoid this problem, but I did not find a good one. Same for eq. (14).

Page 2603 line 9: It is surprising that you are using the action of the ice on the bedrock in eq. (8) as this is a boundary condition, and one generally focuses on the actions of external forces on the ice (traction vs friction). Therefore normal vectors in eq. (8) and eq. (13) are different, the first one pointing into the ice, the second one pointing outward, which is confusing.

Page 2604 line 22: I would have liked to see one additional sentence summarizing the treatment of the grounding line in Full-Stokes as you mentioned its treatment is different in both models.

Page 2604/2605: I suggest moving this paragraph at the beginning of the Numerical models section in order for the readers to figure out right away the approximations made in the vertically integrated model.

Page 2605 line 10: I would have liked to see more details on the remeshing part. Is automated remeshing used in both models ? What method is employed to remesh (mesh deformation or remeshing) ? How is element size determined ?

Page 2606 line 3: remove "both"

Page 2607 line 12: Does the initial geometry have an influence on the grounding line position ?

Page 2607 line 24-29: This part is not very clear and I am not entirely convinced that this is not a numerical artifact. Was this phenomenon observed with both models ? For several runs ?

Page 2616 Figure 2: Could you reduce the size of the figure ? It is quite large and this makes the pdf viewer slow. Also, in the caption, should be "listed in Table 1".

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Page 2617 Figure 3: Unfortunately, this figure is not very clear, the position of the grounding line in particular. I first thought that the grounding line was more advanced in the centerline than on the sides due to the higher surface elevation.

4 References

Gomez, N., J. X. Mitrovica, P. Huybers, and P. U. Clark, Sea level as a stabilizing factor for marine-ice-sheet grounding lines, Nat. Geosci., 3 (12), 850–853, doi:10.1038/ngeo1012, 2010

Interactive comment on The Cryosphere Discuss., 6, 2597, 2012.