The Cryosphere Discussions

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Reply on RC1

Thomas Frank et al.

Author comment on "Geometric Controls of Tidewater Glacier Dynamics" by Thomas Frank et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-81-AC1, 2021

We would like to thank the reviewer for taking the time to review our manuscript, and we appreciate the positive attitude towards it as well as the helpful comments to further improve it. We reply below by highlighting the reviewer's comments in italics above our answers.

My main comment is the discussion of bumps and no or slow retreat of the GL while the authorsuse SSA - plus no subglacial hydrology, and the Budd type friction law with a uniform friction coeffi-cient. I understand the choices for the experiment setup but would wish for a more detailed discussion how a higher order or full stokes simulation would affect the results on bumps and overdeepenings (e.g.SSA critised for a similar setup in Favier et al. (2012)). Furthermore, this concern is only raisedin sub-section 4.2. Before (Lines 217ff, 263, 367ff, . . .), it is only mentioned that the reason for no retreat at bumps is the shallowness of the fjord.

We acknowledge that the SSA is not a full representation of the complex stress regime near thegrounding line. For weak beds and fast-flowing outlet glaciers, as we aim to mimic in our synthetic setup, the SSA is however a reasonable approximation and widely used in the glaciological literature. In the study cited above (Favier et al., 2012), we do not see any criticism for using the SSA in a similar setup. The comparison of their results using a full-Stokes model to a setup using the SSA refers to a study by Goldberg et al. (2009), but, as is stated in Favier et al. (2012): ”The authors [Goldberg et al. (2009)] also observed a merge between both grounded areas with advance rates of the grounding line situated around 70 m a−1, whereas in our case the rates are lower and between 15 and 30 m a−1. This discrepancy is not surprising since both experiments were performed under different configurations and are hence not directly comparable. For example, the SSA experiments were conducted with a null velocity prescribed along the lateral walls, whereas we imposed free slip.” (Favier et al., 2012). We do not see how this statement, or any other made in Favier et al. (2012), discount the appropriateness of using the SSA in a setup similar to ours. On the contrary, we find that the results presented there using a full-Stokes model agree favorably well with our SSA results for bumps and overdeepenings. In Fig. 11 of Favier et al. (2012), longitudinal deviatoric stresses are plotted alongside along-flow profiles through the glacier. The stress distributions show the same characteristics as in our results (Fig. 5), with compression on the stoss side of a bed rise, and extension on the lee side. Furthermore, the along-flow profile show that on top of the pinning point in Favier et al. (2012), the glacier surface shows a bulge which is exactly the same feature that we observe in our setup (Fig. 3c.). Therefore, we believe that the study by Favier et al. (2012) rather supports our methodology in that it shows that a full-Stokes or higher-order model would likely yield similar results as the setup with SSA used here, and that the conclusions would remain.

With this said, we will expand on the discussion on the influence of the ice-flow approximation, following the discussion above. This will be done in 4.2 Study limitations, but also at appropriate places in the manuscript (e.g. line 217ff, 376ff, 435ff).

The special section 4.2 "Study limitations" makes sense in this manuscript and addresses the issue (only briefly) but should not be disconnected from the results and discussion. I highly recommend referring to section 4.2 throughout the text and/or change the strong conclusions (like L.369 "Therefore, it must be the shallowness of the fjord at this point (indicated by low S) which governs the dynamics here.") to more weaker expressions and elaborate a bit more on line 435ff.

Good point; we will make sure that the assumptions and limitations are more clearly articulated throughout the manuscript. Note, however, that the quote above is placed in context of comparing results of our artificial fjord settings where dS is the dominating control on retreat against settings where S is the governing factor. With this specific phrasing we therefore do not intend to draw any general conclusions about real-world glaciers, which would require a more detailed discussion on limitations, at this specific point in the text. We will clarify this distinction in a revised manuscript. Regarding line 435ff, we suggest to add a short explanation that not resolving vertical shear is less accurate where the bed slope is relatively steep, but that we do not expect our results to be hugely influenced as is pointed out in the comparison with a full-Stokes simulation above.

I assume you don't see any advance during your simulations since you set-up the experiment to grounding line retreat. However, I suggest including a comment (in section 4), how and if your finding could also capture/predict GL advance? If your relationship of GL retreat and wetted area (or velocity) is to be applied in real-life, those areas might also have seen GL advance.

These are good suggestions that we are happy to address in the revised manuscript. Indeed, we do not see any grounding line advance, but previous studies (Åkesson et al., 2018; Brinkerhoff et al., 2017) have shown that fjord geometry induces hysteresis in the retreat-advance cycle, where readvanceis inhibited if a fjord is widening or deepening ahead of a glacier. We expect this to hold for ourexperiments as well.

Specific comments

- L.6 Re-phrase, it is a bit confusing for an abstract: "We find that retreat in an upstream widening or deepening fjord does not necessarily promote retreat, but conversely, […]"

Rephrased as: "We find that retreat in an upstream widening or deepening fjord does not necessarily promote retreat, as suggested by previous studies. Conversely, ..."

- L.65 "larger suit of experiments" – why not mention you do 21 simulations?

Rephrase as: "Here, we use a numerical ice-flow model resolving two horizontal dimensions, we include a suite of 21 experiments and present a systematic approach..."

- L.143-154: The table 2 is very clear, but the text is partly confusing. For example: "we test 20 fjord geometries […] Additionally, we test […]" Clarify this paragraph in term of total numbers and subsets.

changed "additionally" to: "In the eight simulations outside our core experiments, we test asymmetric and longer perturbations to verify..."

- L.206 Define "very slowly" and "retreats quickly"

We define very slowly as <100 m $yr^{-1}$and quickly as >500 m yr^{-1}. This will be added in the next version of the manuscript.

- L.226: Please re-phrase for clarity: "However, in fjords that have a smaller S at xC than the reference fjord (bottlenecks and bumps), stable positions are also found where the fjord is narrow or shallow (small S). Therefore, S is also an important control on GL retreat."

Rephrase as: However, glaciers in narrower or shallower fjords than the reference fjord (bottlenecks and bumps) can also temporarily stabilize where S is small. This shows that the wetted area constitutes an additional important control on GL retreat.

- Fig. 8a: Maybe adjust present day glacier front line colour…

Done.

- Fig. A1 e&f: include line for bed topography (like in Fig. 3 c,d)

Done.

References:

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Goldberg D, Holland DM, Schoof C. 2009. Grounding line movement and ice shelf buttressing in marine ice sheets. Journal of Geophysical Research: Earth Surface 114. doi:10.1029/2008JF001227.