Review of Feldmann et al. "Hysteresis of idealized, instability-prone outlet glaciers under variation of pinning-point buttressing"

April 9, 2024

General comments:

The manuscript by Feldman et al. presents a suite of idealised simulations that investigates the potential of hysteretic behaviour in response to variations in pinning-point buttressing. They find that the depth of the bathymetric depression as well as the height and distance of the pinning-point from the ice divide strongly influence the evolution of the outlet glacier and demonstrate that these variables can induce hysteretic behaviour. Based on the results from their idealised simulations, they then infer qualitative implications for real-world geometries in Antarctica.

I enjoyed reading this well-written, clearly structured, and well-illustrated paper. By investigating pinning-point buttressing, the authors address in my view a sometimes somewhat underappreciated topic that fits well within the scope of the Cryosphere (TC). I commend the authors for managing to produce a steady-state geometry that includes an ice rise. Overall, I think the paper is already in pretty good shape and I deem my comments minor. Therefore, I am in full support for publication in TC. I am listing below my comments that I would like the authors to take into consideration. I hope the authors find my comments helpful.

Specific comments:

1. I recommend to slightly restructure the "Methods" section. For once, I would move information about the grid resolution into 2.1. Then I would add the info whether the model is thermomechanically coupled or not (I believe not). If it is not, what kind of ice temperature is assumed? In section 2.2., I think I would appreciate a short mentioning of the dimensions of the computational domain. Then I would introduce a new section heading "2.3 Forcing and Boundary conditions" after line 115. This would basically

contain the paragraph starting in line 116. It would then be good to add what kind of lateral boundary conditions you apply e.g. no-slip, fixed calving front etc.

2. In your analysis of the Schoof flux formula (Eq. 4), you write this as a function of bed elevation at the grounding line $B(x_{gl})$. In its original form, it is written as a function of ice thickness $h(x_{gl})$. Do you use the flotation condition to get from one form to the other? And if you do, shouldn't there be a factor ρ_o/ρ_i in front of $B(x_{gl})$. I do not think, it affects your results, but this was unclear to me.

3. I consider this comment interesting but rather optional. You have looked at the effect of the depth of the bathymetric depression and the size and position of the pinning point. I wonder how much the length of the bathymetric depression matters? My suspicion is that you could have a deeper bathymetric depression if the length of the depression is shorter than in your current setup without inducing hysteretic behaviour. If it is not too difficult or time-consuming to run, I would be interested in such additional simulations. Especially considering that in the real world the bedrock topography is never as smooth as we make them in our models.

Technical corrections:

Title: I am not the biggest fan of the "instability-prone" phrase. My suggestion would be just to say "marine outlet glaciers"

Abstract:
L4: What is an Antarctic-type outlet glacier? I would call it a marine outlet glacier.

L5: Again instability-prone. How about "marine outlet glacier resting on a retrograde bed"?

L5: successive $->$ step-wise?

L8: delete "from"

L9: Whenever I read "collapsed", I think the glacier has disappeared. But other than in your unconfined simulations, I would rather call it "a retreated state" as the ice stream is still present, just not as advanced as before. This pretty much applies throughout the manuscript.

L25: Check correct spelling of MacAyeal citation

L29: Appreciate the citation, but it should really be the Schannwell et al. 2019 TC paper.

L40–50: Somewhere here, a reference to this new paper by Miles & Bingham 2024 in Nature might be worth adding.

L60: conceptual − > idealised?

L87 Eq. 2: How did you decide on the radius of you Gaussian bump? Any particular motivation?

L92: Since you only have three categories, maybe rename your "moderate" scenario to "intermediate"?

L99: Here and throughout, I would prefer if you used "ice sheet-ice shelf system" instead of "ice sheet-shelf system".

L106: "until changes in the glacier volume become negligible". Can you be more precise what your stopping criterion is?

L108: subsequently − > repeatedly

L108: "The perturbation is then reversed" − > "The sign of the perturbation is then reversed"

L114: I think somewhere here, I would mention explicitly that in your approach you decrease pinning-point buttressing through the reduction in contact area between ice shelf and topographic high. Because other strategies would also be possible.

L128: "step-wise elevation" − > "step-wise rise in elevation"

L153: "glacier tips" − > "glacier transitions"

L154–155: This is confusing. Is the ice shelf now grounded on the topographic high or not? Please clarify.

L166–174: When you cut out your domain, what are you boundary conditions at the lateral walls? Parallel ice velocity? Please add.

L210: Delete second "the"

L290: "it's" − > "its"

L302: "In real world" − > "In the real world"

Comment hyphenation: I noticed that you for example write "regrowth" but "re-advance". I am myself unsure what TC's policy here is, but it is probably a good idea to do this type of hyphenation consistently.

Figures:

The Figures are well illustrated and of very good quality. I only have a single tiny comment.

> Fig. S4: Could you add the location of the topographic high to the plot as you did for Fig. S3 and Fig. S2.

Sincerely, Clemens Schannwell