Response to Referee#1 (Clemens Schannwell)

We would like to thank Clemens Schannwell for his willingness to review our manuscript, the helpful comments and the constructive suggestions to improve the manuscript. We are glad for the Referee's very positive assessment of our study and are happy to hear that he would support the publication in TC. We will prepare a revised version of the manuscript, addressing the points raised by the Referee. Please find below the *Referee's comments in italics* and our response in blue.

Sincerely,
Johannes Feldmann et al.

Referee #1 (Clemens Schannwell)

General comments:
The manuscript by Feldmann 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.
Will be done.

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?
Will be done. The temperature value, which is related to the ice softness via an Arrhenius law, will be provided.

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.
Will be included.

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(xgl). In its original form, it is written as a function of ice thickness h(xgl). Do you use the flotation condition to get from one form to the other? And if you do, shouldn't there be a factor ρo/ρi in front of B(xgl). I do not think, it affects your results, but this was unclear to me.

We are grateful for the Referee for discovering this inconsistency. Indeed, as assumed by the Referee, in our calculations we use the flotation criterion (factor -rho_o/rho_i) to translate between ice thickness and bed elevation at the grounding line. We simply forgot to include this constant when writing down the equations for the manuscript. We will correct this in the manuscript.

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.

We very much acknowledge this idea and are currently running simulations to investigate the influence of the length of the bed depression, the results of which we might present in the paper Appendix.

Technical corrections:

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

We understand the Referee's point here and are willing to follow the Referee's two following related suggestions (see next two comments). However, regarding the paper title we would be really in favor of using the term "instability-prone" as we are convinced that it describes the systems we model in an appropriate and concise way. It is important to us to state in the title that we simulate systems that represent not only marine outlet glaciers but those which are (theoretically) subject to the marine ice-sheet instabilty mechanism. Whilst using the the suggested term "marine outlet glaciers" alone would leave out an important part of information, adding more words like "resting on retrograde bed" would substantially lengthen the title and make it less readable. Since "instability-prone" involves all these details in one short term, we would like to refrain from removing this term from the title if the Editor is ok with it.

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"?
We will change the wording in the abstract according to the Referee's suggestion.

L5: successive – > step-wise?
Will be done.

L8: delete "from"
Will be done.

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.
Will be changed.

L25: Check correct spelling of MacAyeal citation
Will be done.

L29: Appreciate the citation, but it should really be the Schannwell et al. 2019 TC paper.
We apologize for mixing up the years here. Of course, it should be the paper from 2019 on ice-rise divide migration. Will be corrected.

L40–50: Somewhere here, a reference to this new paper by Miles & Bingham 2024 in Nature might be worth adding.
Thanks for the hint, we will include the reference!

L60: conceptual – > idealised?
Will be corrected.

L87 Eq. 2: How did you decide on the radius of you Gaussian bump? Any particular motivation?
The expression is adopted from Favier and Pattyn (2015). In fact, to keep things simple, we also adopted their value controlling the radius of the bump. We will mention this in the text.

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

L99: Here and throughout, I would prefer if you used "ice sheet-ice shelf system" instead of "ice sheet-shelf system".
Thanks for the suggestion! In this case we really appreciate the conciseness of the term "ice-sheet-shelf system" and would prefer it over "ice sheet-ice shelf system", which is a bit more lengthy. In the end, this seems to be a matter of taste and we would suggest to leave it to the Editor to decide here.

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

L108: subsequently – > repeatedly
Will be corrected.

L108: "The perturbation is then reversed" – > "The sign of the perturbation is then reversed"
Will be done.

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.
We are grateful for this hint and will add a statement to the manuscript according to the Referee's suggestion.

L128: "step-wise elevation" – > "step-wise rise in elevation"
Will be changed.

L153: "glacier tips" – > "glacier transitions"
Will be changed.

L154–155: This is confusing. Is the ice shelf now grounded on the topographic high or not? Please clarify.
Thanks for pointing this out. We will add more detail to clarify.

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

L210: Delete second "the"
Will be done.

L290: "it's" – > "its"
Will be done.

L302: "In real world" – > "In the real world"
Will be done.

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.
We will change "regrowth" to "re-growth" throughout the manuscript for consistency.

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.
Will be done.

Sincerely, Clemens Schannwell