Reply to reviewer 2

Overview

Zhang and co-authors present a numerical model to represent glacier detachment, a rapid process that is not typically represented in physical glacier models – and a process that I believe many in the glaciology community are not likely familiar with. The novelty of this study is that it provides a framework for coupling the rapid evolution of internal stresses with basal friction, with great potential for applicability to improve hazard prediction in High Mountain Asia and other glacierized regions.

We thank the reviewer for the thorough review and also all of these great comments and suggestions! They significantly help in improving the manuscript!

General comments

In general, the manuscript is well written and organized, with clear descriptions of the mathematical equations. The authors openly acknowledge the missing processes from this model that are also involved in glacier detachments, and justify their focus on internal stresses and basal sliding.

We thank the reviewer for this positive comment.

The paper includes links to a GitHub repository of model code and a Zenodo repository of data. The links are valid, but the repositories themselves need a bit of work to make them more usable. The Zenodo archive lacks a description of the files included, with no description of the variables saved in the MATLAB file or even a description of which simulation those results correspond to (out of several sensitivity simulations presented in the paper). In the GitHub repository, the README file does not provide any practical instructions for using the model scripts or descriptions of the different files included in the repository. I am also not sure if GitHub qualifies as a suitable repository for this journal or not.

We now modify the code and data availability sections. We put a version of the code for simulating Sedongpu Glacier detachment at https://zenodo.org/records/15831881. By this we hope people can freely try running the code. In the code folder, we put a readme document for a guide of using PoLIM. At the same location, we put velocity and glacier boundary data for Sedongpu Glacier.

Please see below for specific comments and questions that should be addressed to further strengthen this manuscript. Given the novelty of this topic and modeling approach, I recommend this paper for publication with some minor revisions. I enjoyed reading this paper, and I feel that it will make a great contribution to the glaciological literature, serving as a foundation for improved understanding and representation of dramatic detachment events in more complex glacier models.

We thank the reviewer for this positive comment and endorsement!

Specific comments

Figure 1b,c – It would be helpful to draw on the broader map (Fig. 1a) the boundary of the DEMs to get properly oriented. You might consider including only one of the DEMs here, since they look so similar, but I can also understand the reasoning for including both. It's great that the caption points toward the difference DEM in a later figure.

We have indicated the approximate range of the DEMs (a) and also included the elevation difference (d) from 2015 to 2018 in Figure 1.

Line 70 and Table 1: It would be helpful to provide a citation to justify the value chosen for A (10^-16), as it is several orders of magnitude higher than the values according to Cuffey/Paterson (10^-24).

The 10^{-16} value is with the unit of Pa^{-3} yr^{-1}. We now change it to the unit of Pa^{-3} s^{-1} (3.17e-24). This value is for ice temperature around 0 degree C according to Cuffey and Paterson (2010). See the table below. The citation is added.

Table 3.3: Measured and inferred values of creep parameter A at different temperatures, for $n = 3$.

T (°C)	A ($10^{-25}\,s^{-1}\,Pa^{-3}$)	Method	Reference
0	24	Mean of 5 calibrated models	See below†
	38	Mean of 5 borehole tilt values°	Raymond 1980
	55	Closure of tunnels	Nye 1953
0	24	**Recommended base value**	
	93	Various lab tests	Budd and Jacka 1989
-2	27	Various lab tests	Budd and Jacka 1989
-10	3.9	Ice shelf spreading	Jezek et al. 1985
	5.3	Ice shelf spreading	Thomas 1973b
	2.5–4.3	Ross Ice Shelf flow‡	MacAyeal et al. 1996
	1.8–3.2	Filchner-Ronne Ice Shelf flow‡	MacAyeal et al. 1998
-10	7.6	Borehole tilting	Fisher and Koerner 1986
	6.7	Flow-line with borehole	Reeh and Paterson 1988
	8.7	Borehole tilting	Dahl-Jensen and Gundestrup 1987
-10	3.8	Mean of ice shelf values	
	7.7	Mean of simple shear values	
-10	3.5	Various lab tests	Budd and Jacka 1989
	3.5	**Recommended base value**	

† Hubbard et al. 1998; Gudmundsson 1999; Adalgeirsdottir et al. 2000; Albrecht et al. 2000; Truffer et al. 2001.
° We have calculated A for $n = 3$ using $AR^{8} = A_o \tau_o^n$, where A_o, τ_o, and n are values given by original authors, and R is Raymond's corrected stress value. Stresses are for the greatest depth of reported measurements.
‡ Calibrated model for flow of entire ice shelf (Ross) or part of ice shelf (Filchner-Ronne). Low and high values are for effective temperatures of −15 and −20 °C, respectively.

Line 73: Is the basal friction coefficient held constant through time using the value from the inversion? (Section 3.1.1) Please clarify.

Right. We set \beta constant in space before we simulate the detachment. We now add an additional sentence to make it more clear.

Figure 3b: The velocity looks very spotty, with alternating patterns of high and low velocity along the glacier center-line. This should be at least discussed, with some validation or justification for the pattern.

ImGRAFT's methodology primarily relies on feature point tracking for surface velocity estimation. However, due to drastic variations in surface morphology, posing substantial challenges for feature point tracking in this region. Consequently, the estimated velocity results exhibit considerable errors in certain areas and demonstrate pronounced spatial heterogeneity. Nevertheless, the current findings generally capture the overall surface velocity distribution pattern of this glacier.

Figure 4: Are the values of basal friction prescribed to be 1000 at both ends of the glacier? What is the sensitivity to this value? Especially at the terminus, it seems like physically the friction should continue to be very low to allow for free movement.

Very good point. We do prescribe an initial β = 1e3 Pa m^{-1} yr. At the glacier head and terminus, we use a Dirichlet boundary condition in the velocity solver, so β will not be updated during the initialization. Here I present three sensitivity plots for initial β = 1e2, 1e3 and 1e4 Pa m^{-1} yr. We can see clearly that the initial value has some impacts on grids close to the head and terminus, but the majority of glacier is not affected. To avoid confusion, we do not plot β for the head and terminus grids in the revised manuscript.

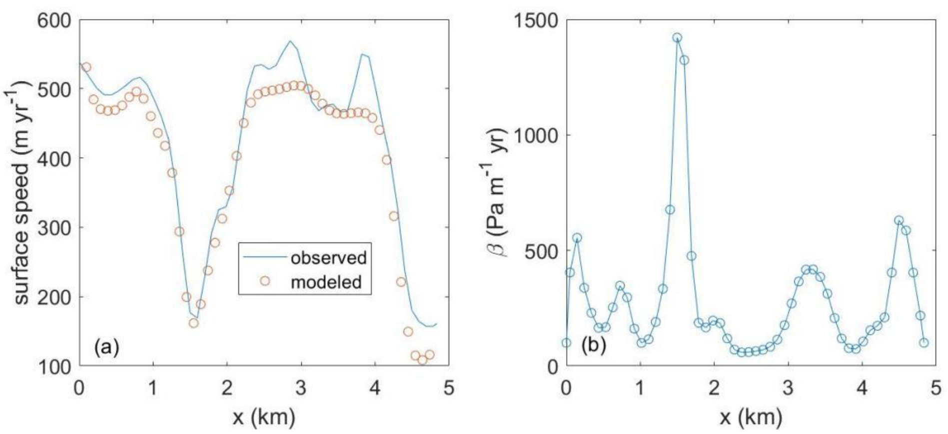


Figure 1: initial β = 100 Pa m^{-1} yr

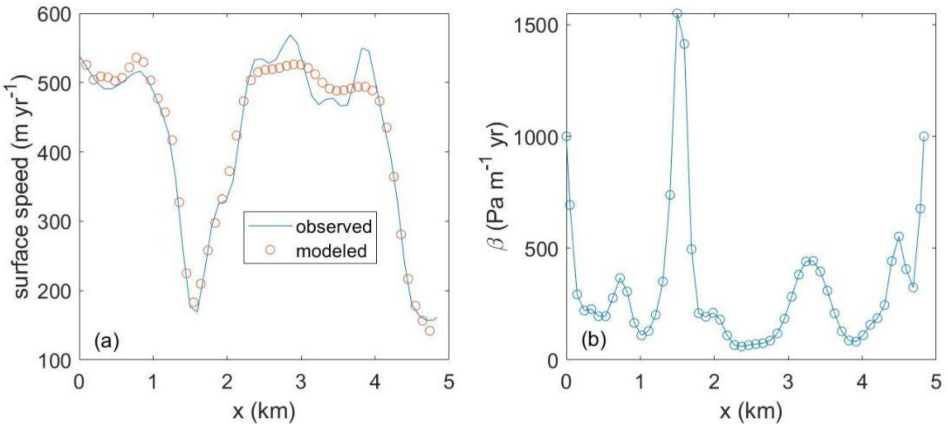


Figure 2: initial β = 1000 Pa m^{-1} yr

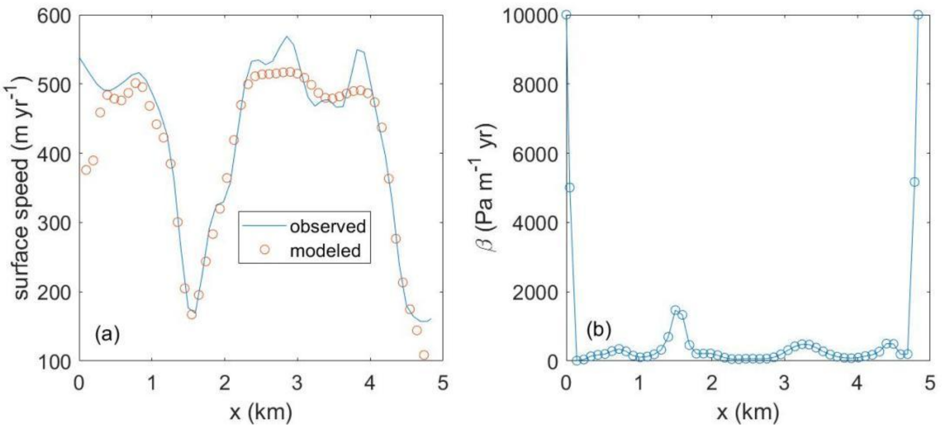
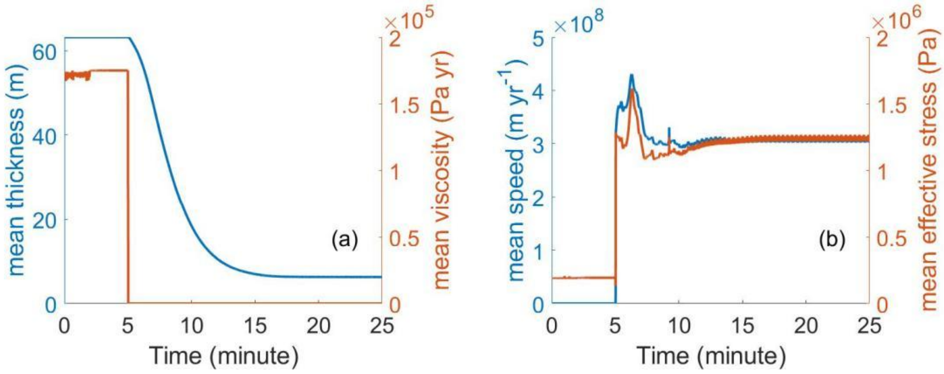


Figure 3: initial β = 10000 Pa m^{-1} yr

Figure 5: It looks like there are numerical oscillations in the initial ice viscosity (5a) and also in the new steady state of mean speed and mean effective stress following the detachment event (5b). While they appear to be stable oscillations, it would be good to discuss these numerical artefacts. Did you experiment with using a smaller time step to resolve this oscillation?

Thanks for this nice suggestion. We did several tests with smaller time steps (0.2s, 0.5s), and indeed, the oscillation can be greatly reduced by using a small time step. After some digging, it is probably due to some numerical instabilities raised by the basal sliding boundary condition we implemented in the model. We now use the figure below with a time step = 0.5 s for the consideration of computing time.



Line 209: If ice thickness is being evolved, why does the cross-sectional profile look the same across all time steps in Figure 7?

Right, those are forward runs and ice thickness is evolving. It is just because the time step is so small (1 second) that we can just barely see the changes within three time steps.

Editorial comments

I am not going to identify individual typos and grammatical errors, but there are several throughout the paper.

Thanks. We now carefully check the manuscript and correct all of the typos.

Figure 6a: Where is the black line in this plot? Make it visible by using dashes or symbols if it is perfectly aligned with one of the other lines.

Thanks for the suggestion. We now change the red solid curve to dashed in Figure 6 so that the black curve show up clearly.

Figure 7: I suggest using the same colormap for all three cases for better comparison.

Figure 7 is updated.