Glacier geometry and flow speed determine how Arctic marine-terminating glaciers respond to lubricated beds by Whyjay Zheng, 2022.

Overview

This study investigates the interannual impact of increased basal lubrication on glacier flow using a 1-D physical framework and tested on >100 glacier basins in Greenland and Austfonna Ice Cap Svalbard. Within the model framework, they determine that both the Péclet number over length (*Pe/l*) and a metric proportional to the product of speed and ice thickness gradient, termed J_o. J_o reflects the initial response to basal lubrication, and *Pe/l* reflects a general vulnerability to an elevation perturbation. The model results predict that glaciers are most sensitive to increased basal lubrication (that is, they will undergo greater acceleration given perturbed basal conditions) when J_o is relatively high and *Pe/l* is minimized or negative. Finally, these two quantities are calculated from observational data in 1996/1998 and compared to the acceleration observed along flowlines by comparing earlier speeds to those observed in 2018 from ITS_LIVE. They conclude that given a certain combination of glacier thickness, thickness gradient, and speeds are met, enhanced basal lubrication can destabilize and accelerate the full length of the glacier. This is an interesting approach aimed at identifying glaciers that are vulnerable to destabilization and provides useful information on how the baseline glacier geometry informs potential basal vulnerabilities. The manuscript is well-written and presents a creative approach to constraining a complex science question. The figures complementary to the text, and I appreciate the effort to document and archive model code and results through Github and interactive Jupyter notebooks. With some expanded motivation, and polished analysis and figures, this paper could make a valuable contribution to the cryosphere/glaciology community. Below, I've first listed my main comments/concerns, followed by minor comments.

Main Comments

1.) The premise of this work is centered on the concept of a potential *permanent* change to glacier basal conditions and constraining how the related effects on glacier dynamics (thinning and acceleration). It would be helpful to introduce the physical basis for such a change, rather than surge-type glaciers, including explicitly describing what such conditions would look like in reality. I understand that the spatially uniform increase in basal lubrication (reduction in basal friction, or K term) is not meant to imitate reality but is useful as a modeling tool. However, given the strong seasonality observed at Greenland glaciers in response to summertime meltwater and evolving subglacial conditions, what kind of environment meets the criteria of a "permanent change"? One with greater seasonal oscillations between efficient and inefficient drainage systems, one with continuous drainage and elevated basal water pressures throughout the year, or another scenario entirely? There seems to be a missing connection here that makes it somewhat challenging to contextualize how the findings of the paper inform our understanding of future climatic conditions on ice sheets/ice caps.

2.) The conclusions include some statements that extent beyond the results presented in the manuscript. do not seem entirely supported by the findings in the manuscript. For example, the phrase in the conclusion on line 239 states that: "The J_o–*Pe*/ℓ plot (Figs. 5–7) seems to capture the characteristics of glaciers vulnerable to basal lubrication. GrIS and Austonna glaciers with

more negative J_o and Pe/ℓ in 1996–1998 are more likely to speed up in the next 20 years." This argument can be made for the GIS glaciers based on the distributions shown in Figure 6, but it is far from obvious for Austfonna glaciers show in Figure 6. I think, with the limited sample of glaciers and subset that include surge types, there is not enough information to assert a distinction based on J_o and *Pe/l* alone. The conclusion should reflect this uncertainty. Even for the n=104 glaciers in Greenland, where distributions show a tendency for greater accelerations at basins with low/more negative J_o and *Pe/l*, the text should be careful to emphasize that this reflects results at a specific distance alone a glacier flow line and may not be representative of the entire glacier length.

3.) As addressed in the text, terminus retreat is also a common source of acceleration, especially at Greenland glaciers, and retreat impacts are indistinguishable from increased basal lubrication within the presented framework. I think it would be highly valuable to include net retreat when considering acceleration over the 1998-2018 period. For example, how does speed increases observed within subsets with low *Pe/l* /negative J_o and minimal retreat compare to acceleration observed at glaciers with low *Pe/l* /negative J_o but significant retreat? Showing that these variables are still applicable to acceleration in the absence of terminus retreat would strengthen the significance of the study.

It also may be worthwhile to evaluate the two groups of glaciers (here divided based on acceleration greater than or less than 300 m/yr) based on the percent increase in speed (such as > or <= 10%), rather than an absolute (300 m/yr) threshold.

Secondary/Minor Comments

Figures
-All axis labels and unit font sizes need to be enlarged.

-Please include lettered labels (a, b, c, etc.) on the subplots corresponding to the labels mentioned in the figure captions.

-Include a scale bar for zoomed inserts in Figure 1 and in Figure 2.

-Please also include legends for your figures. This includes a color bar for speed increases in Figure 5 and 7.

Figure 3
Køge Bugt (glacier 0207 in Figure 3) has retreat around 2 km between 1998 and 2018. This site also appears to have the greatest J_o values of the Greenland sample (shown in Figure 5), which would imply the most diminished sensitivity to respond to basal lubrication. This seems at odds with the statement on line 193, that states that Jo is a good predictor of glacier speed up at this basin.

Figure 6
Are the differences between the two groups' distributions statistically significant?

On the 3km flowline position analyses
Why is this position (3 km for 1998-2018 speed change and mean 3-5 km parameters) used for the majority of the analyses? Can you provide justification for why this distance from the terminus is most representative of glacier sensitivity to basal lubrication?

Line 232
The range in Jo should be to -1500 m/yr, not 1500, correct?