The Cryosphere Discussions

The Cryosphere Discuss., referee comment RC1
https://doi.org/10.5194/tc-2021-96-RC1, 2021

Comment on tc-2021-96

Anonymous Referee #1

Referee comment on "Surge dynamics of Shisper Glacier revealed by time-series correlation of optical satellite images and their utility to substantiate a generalized sliding law" by Flavien Beaud et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-96-RC1, 2021

Review for:

"Generalized sliding law applied to the surge dynamics of Shisper Glacier and constrained by timeseries correlation of optical satellite images" *Beaud et al.*

Summary:

The authors present a study with the overall goal to use satellite observations of a surging glacier to constrain the form of a generalized sliding law. The manuscript is overall very well written, especially the first half, and the figures are informative and of high quality. The manuscript has three main parts: First, the authors derive a new generalized form the traction relationship which combines rate-strengthening with weakening applicable to both hard and deformable beds. The second part presents satellite velocity and elevation observations of a glacier surge captured on Shisper Glacier. Finally, the last part uses these observations to constrain parameters within their generalized sliding law presented in the first section.

The goal of the study is very worthy. We have much work to do to better understand basal physics and I am generally enthusiastic about the first two sections. I quite like the generalized relationship derived in the manuscript, especially when compared to less physically based generalized sliding laws. However, I still find little advantage for transient simulations where defining u_t still requires aprior knowledge of the bed conditions. For these sections, I include some suggestions to improve these sections detailed in the line-by-line.

However, I have fundamental concerns about the methods/data used to constrain the traction relationships presented in the last section.

- Investigating traction relationships require the traction and velocity to be very well constrained. In this regard, the basal shear stress is the biggest concern. The methods to invert for the topography presented by Farrinetti 2019 use simplified physics that assume all motion is derived from ice deformation. Given the observations presented in the paper and the hypothesis that the glacier responds to melt suggests that this is not the case. Thus, while the variations in topography derived from this method likely reflect variations in the bed topography, the actual thickness of the glacier in the paper is largely uncertain. On top of this is the fact that the glacier is surge type, so inverting for the bed topography will also have a large dependency on what velocity field or surface elevation data set is used for the topography inversion. The authors do not note what data they use for the inversion, although this is not the main issue here.

- Estimating the basal shear stress using the driving stress for a glacier undergoing large transient forcing is insufficient. In the case of a surging glacier, sharp and variable gradients observed in the velocity field indicate higher order stresses will undoubtedly play a role in the basal traction field. This requires more sophisticated inversion methods such as the SSA or Full Stokes which take into account higher-order stresses by using a more complete formulation of the momentum balance. However, these methods are only as good as the data that constrain the inversion, in which case there are still problems, one of which I have outlined above, another is knowing the ice rheology, and the last and probably the most important I will outline below.

- A basic feature of a surge is large is transient surface geometry changes (i.e. Kamb et al. 1985) which will have a significant impact on the stress field. Evidence of large surface geometry changes is presented in the paper, where 100s m ice thickness changes can be observed through the three elevation data sets presented. However, comparing the velocity field which represents a snapshot for a specific time period during a surge to an elevation dataset averaged overtime, we have no idea and really no way of determining whether the stress field is consistent with the velocity field at that point in time.

With the combined effect of these three sources of uncertainty for the traction field, all of which as presented are nearly impossible to assess, I do not see how conclusions regarding traction relationships can be made unless other high resolution elevation data sets could be found that match the time period of the observed velocity data and better inversion methods are used.

A revised manuscript would need to address this prior to be considered for publication. The challenges for the last section are considerable. However, the data and interpretation are interesting and in theory I do like the idea of trying to use surge behavior (with better data) to populate a traction curve (although there are a lot of things about surges (i.e. heavy crevassing) that make inverting for the traction field difficult.) A revised manuscript might want to focus on the surge behavior where a discussion on the potential for constraining traction relationships using surge glaciers would surely be interesting.

Specific Comments

Line 20:21: This generalization is not necessarily true. There are direct observations at several locations in Greenland rebuke this paradigm (i.e. Ryser 2014, Maier 2019 – measurements slow flow, Lüthi 2001, Doyle 2018 – measurements in fast flow).

Line 28-30: This is not likely generalizable everywhere. See (Maier 2021) for traction analysis that suggests some fast flowing regions generally obey rate-strengthening.

Line 31: Strange phrasing here.

Line 111-114: This description is a bit confusing. I am pretty sure skin friction is the same as viscous drag for a non-turbulent boundary layer. This needs to be much better defined. Right now I think you are actually referring to solid friction (i.e. generated from debris-bed interactions)? You need make it clear that this is what you are referring to, as this is the only thing that makes sense for the bottom panel of the hard bed figures in Figure 1.

Also while the could the case is made that there is a physical transition regime for till beds, can the same be made for hard beds? Based on your plots on Figure 1 the transition regime seems arbitrarily drawn after rate-weakening begins.

I would think the transition regime occurs between the start of cavitation and Iken’s bound.

Line 100: There is probably a more direct way to say this. Also see Helanow et al 2021 for the latest on numerically derived sliding laws over realistic beds. This might help your case that there is no need to explicitly model rate-weakening.

Figure 1: Ok the skin friction here is much better defined in a conceptual sense, but you are talking about solid friction, and this is not included in the sliding law of Gagliardini 2007. Iverson 2003 provides some of the only direct measurements of solid friction, however, it has not been incorporated nicely into sliding laws nicely yet in a theoretical sense. Some nice experimental work on solid friction was also done recently by Thompson et al. 2020. These papers might help better formulate your “hard bed skin friction” regime.

135: I like the concept of the generalized law you propose Eq 6., but the utility for me is somewhat lost. To model transients you still need to know the effective pressure and thus all the bed specific parameters in Eq 5 right? I think explaining the benefit of your generalization would be a nice thing to add here.

177-181: What is the uncertainty on the bed and thickness? This is fundamentally important to estimating the basal shear stress.

236-240: Using a PCA to reconstruct a timeseries needs much more explanation. Why do you do need to do this? What is the advantage? Is the data really noisy?

Figure 4: Interesting figure. I would possibly try to regroup this to show surge and non-surge behavior to make it to really emphasize the difference between the two states. If there is any way to consolidate into less panels this might help make things clearer. Maybe bold font for the inset text boxes? Really hard to read.

270-275: Fall speed up is quite interesting. Any idea why? Stress increase from snowfall?

283: You can also define based on propagating surge bulge seen in the strain field? To me the surge is hard to identify as a propagating velocity wave in Fig. 4 or 5.

Fig 5: Also an interesting figure. What is your reference for along flow distance (i.e. what side is the terminus?)? It would also be cool if you put your interpretation of the ‘surge front’ at different locations here (maybe with some accompanied interpretive text). It isn’t super obvious where this is from your velocity maps, and also might make for interesting discussion (maybe near lines 297-300).

311: Did you visually check for artifacts?

315: Can you indicate the location of these regions on Fig. 5?

345: Can the fact that these glaciers were recently connected explain some of the changes in geometry?

358-360: Sentence unclear.

367: So surge here is inferred to only happen in conjunction with melt forcing?

386-387: As stated without additional evidence this is highly speculative.

412-419: It would be interesting to know when the lake reaches flotation, as this could also induce unstable behavior similar to a surge.

Remainder of manuscript: I have commented enough on the remainder of the manuscript at the beginning of the review. In short, it is hard to do this analysis if the traction field is not confidently known. While I suspect that some of your conclusions, i.e. there could be a wide range of traction parameters in a small spatial domain, could be true, but its hard to see how you could differentiate a wide parameter space from errors. A few remaining comments:

Table 3: Gillet-Chaulet 2016, De Rydt 2016, and Maier 2021 all have parameters that you can add to this list.

Figure 8: Excess velocity is difficult to understand and conceptualize how it relates to a traction relationship. Can you populate a traction curve by just looking at changes in velocity with out regards to the original velocity? I think this would need an illustration of some sort.I

What sort of area does each dot represent? This is important when determining how independent each grid cell is.

485: The plots presented are also mostly examining spatial variations.

Appendix: This is really difficult to understand.