

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

This study develops an imagery processing pipeline to improve coverage and quality of velocity observations (derived by combining Sentinel-2 and Landsat 8 imagery) of a surging glacier (Shisper Glacier in the Hunza Valley) and uses these detailed observations to 1) characterize the conditioning and trigger of the surge and 2) use the range of velocities observed during the surge cycle to validate a generalized sliding relationship. The velocity processing timeline appears robust, generating realistic velocity fields, and was certainly a large task in and of itself to achieve. The manuscript is well referenced and well-written, and I appreciate the detail taken to explore multiple facets of observed and/or inferred surge characteristics. Beyond the pipeline and interpretation of surge observations, the remainder of the manuscript is somewhat weaker, and could be improved if some of my comments below are addressed or considered. Mainly, discussion surrounding known uncertainties (ice thickness) is lacking, as are quantified evaluations of how well the relationship fits within bounds or as parameters/DEMs vary, which weakens the main argument that the generalized relationship works and is physically sound and useful for understanding surge dynamics. This work is important and can potentially offer the community new tools and insight into glacier sliding, but I think several points of clarification and additional statistics need to be included prior to meeting publication standards.

### **Major comments:**

The paper is quite long and does not read as three discreet parts as mentioned in the introduction (although the abstract describes the paper as having two parts). My impression is that much of the orthorectified imagery processing and velocity map development would be better suited for the supplement, with the main manuscript body focused on describing the surge and suspected drivers, and then applying those observations to test the generalized sliding relationship. However, the main tasks of the pipeline could be summarized in the methods with mention of how this pipeline has significantly improved velocity estimates. However, I will leave this up to the discretion of the authors and editor.

My main critique of the paper is that the uncertainties surrounding estimated driving stresses are not thoroughly evaluated (although they are mentioned), making it difficult to assess the accuracy/performance of the generalized sliding relationship. I think more quantitative metrics need to be used to illustrate the sensitivity of results to tuning parameters. Uncertainty in ice thickness stem from both (1) surface elevation uncertainty (DEMs) or (2) uncertainty in the bed topography.

-With regards to (1), excess velocity vs driving stress relationship is said to be mostly insensitive to DEM selected, with results for SRTM and 2019 DEM shown separately in the supplement. However, these comparisons are only qualitatively given. What % of observations fall outside the bounds during these cases compared to the SRTM/2019 DEM mixed assessment? Is a certain

quadrant of the glacier more prone to observations that fall outside of these bounds? Several statistics or quantitative values here would be useful.

-With regards to (2), the text on page 180 reads “*To constrain the bedrock topography of Shisper glacier, we used the three different bed elevation models proposed in Farinotti et al. (2019) and averaged the three results, as suggested by Farinotti et al. (2017).*”

More information here is warranted considering how large an impact the ice thickness imparts on driving stress. What was the range in modeled ice thicknesses compared to mean thickness? Which 3 models were used and why? Were the velocities used for the bed thickness inversion taken from before, after, or during the surge? I do think it is worth calculating changes in effective pressure vs velocity relationship using two end member modeled ice thickness fields in order to show (and quantify) the sensitivity of the relationship to unknown bed topography.

How were the upper and lower values of  $\sigma_{max}$  (maximum resistive stress) selected? The upper bound of 500 kPa falls well outside of previously published literature as per Table 3. It seems that this value was selected in order for the upper bound to “cap” the observations and encompass the majority of observed variability. However, how can results showing observations generally fall within curated bounds created using parameters tuned to fit the observations a robust way to validate the generalized relationship? Perhaps I am overlooking something, but this seems like circular reasoning to me, and some further clarification would also aid readers.

### **Minor comments**

#### Section 5.4 – mass balance of Mochowar glacier

The inclusion of this section is confusing without a companion section for Shisper glacier. The most important elements of this section can probably be integrated more seamlessly into sections 5.1 and 5.3.

I am interested in the lack of evident fall speed up in 2017 (based on Figure 5), preceding the onset of the surge in winter 2017. Can you comment on how its absence relates to the broader picture of hydrology-driven surging?

Table S1 – it seems that in 2016 and 2017, the time separation between pairs can be quite large, reducing the temporal resolution of summer to autumnal velocity measurements. How might this impact the ability to constrain the timing and magnitude of a “fall speed up”?

#### Section 6.2 Surge Trigger

I agree with the authors that there is sufficient evidence that surging at Shisper glacier is hydrology, rather than thermally, driven. However, I would like to see the manuscript comment on some reasons why the surge initiated *when* it did (as in, why specifically in late 2017, early 2018 rather than an earlier year). Is this simply due to increasing magnitudes of spring speed up in 2016 and 2017?

Line 240, regarding the data cube, D. I am having trouble following how images are grouped according to an image target date. Are all images that fall within a specific temporal window of the target date included in the stack?

Line 490 – correct spelling for “Greeland”

There are many incomplete/missing sections in the supplement. These will be filled in the next iteration of the manuscript?