

Review of: "Investigating changes in basal conditions of Variegated Glacier prior and during its 1982-1983 surge" by Jay-Allemand et al.

General comments

This is a very interesting paper that applies the inverse method of Arthern and Gudmundsson (2010) to real data, with the objective of inferring the basal conditions of Variegated Glacier, Alaska, leading up to and during its 1982-1983 surge. The authors first use a linear friction law and infer the friction parameter β from surface elevation and velocity data for 25 datasets representing different stages of glacier evolution. They then use an effective-pressure-dependent friction law to infer the temporal evolution of basal water pressure for each dataset, given profiles of temporally fixed parameters A_s and C in the friction law. Prognostic simulations with the inferred friction parameter are used to model the evolution of the glacier surface profile leading up to and during the surge. The modelling results qualitatively exhibit several known features of the Variegated surge, including the development of a mass reservoir prior to the surge and the transfer of mass downstream during the surge. The authors use the results to interpret a significant and progressive evolution of basal conditions (here interpreted in terms of basal water pressure from the friction law) many years prior to the surge. This paper presents new and interesting results that will be useful to the community, both in terms of demonstrating the application of an inverse method to real data, and in terms of adding to our understanding of the surge cycle using one of the most comprehensive datasets collected on a surge-type glacier. I have no major criticisms of the paper, but several suggestions for how the structure and content of the paper could be improved with minor revisions, plus a few requests for clarification or elaboration of the results.

1. Structure and reorganization: I think the paper would be more clear if the long introduction were broken into a short introduction and separate sections describing the observations from Variegated Glacier (p. 1464, l. 26 – p. 1465, l.14) and the modelling approaches (end of intro). I would also recommend a clear separation of methods and results. These sections are currently interleaved, but I think it would make more sense to present the methods in their entirety (e.g. including the continuity equation for the prognostic simulations and the friction law) before launching into the results. An over-arching section entitled "Results" would be useful, as would a Discussion (see below).

2. Discussion content: One of the major conclusions of the paper is that Variegated experienced a progressive change in basal conditions taking place over years during the build up to the surge, and yet this conclusion is not really placed in the context of previous work (aside from a few references to previous studies of Variegated). I think the paper would benefit from added discussion/interpretation of these results in particular. The authors might consider how their findings relate to previous work by Frappe and Clarke (2007) and Sund et al. (2009) suggesting that the dramatic manifestation of surge-type behaviour may just be the final phase of a progressive acceleration. Other points of discussion that would be warranted include how the results would vary with different choices of model inputs. For example, what is the effect of allowing λ to vary with each dataset? How would the sensitivity of sliding speed to basal water pressure be different for different choices of C and A_s (see p. 1487, line 23)?

3. I think it is reasonable to attribute temporal changes in basal friction to some measure of changes in mean basal water pressure as is done in the paper (as opposed to evolution of the sliding parameter A_s or properties of the bedrock cavities). However, I think the authors should take care in their writing that this is an interpretation and not a definitive result. There are several places in the paper, including the abstract ("It confirms that dramatic changes took place in the subglacial drainage system..."), where the claims of this result are overstated. Some minor rewriting with phrases like "Our analysis supports...", "This is consistent with", etc. would largely alleviate this problem, along with making clear where statements apply to simulation results rather than being general truisms.

Specific comments (page.line):

1463.top: elaborate briefly on two-phase surge

1463.23: rather "has not been previously linked" than "cannot be easily linked".

1463.24: specify this surge description is for temperate glaciers

1464.3-10: This description sounds as though it might fit a regular seasonal cycle; make clear how the conditions for a surge differ from an ordinary seasonal cycle.

1466.13-15: It would be useful to be more precise about "very good agreement" and somehow quantify this for the reader's benefit.

1468.18-19: Why not choose exactly the text book value for temperate ice?

1471.19-23: Adding a few sentences of explanation here would be appreciated.

1472.5: Is this uniform layer of thin ice added because Elmer/Ice has to be implemented on a rectangular domain?

1473.2-4: Aren't "no regularization" and " $\lambda=0$ " equivalent?

1473.10: "non-zero regularization term": these statements seem to apply to the non-zero values chosen, but surely not to any non-zero values. Please clarify this in the text.

1473: It would be useful to elaborate slightly on the L-curve analysis. Presumably one seeks the inflection point where only small increases in J_o produce large reductions in J_{reg} .

1475.5: Be clear that this is "in the simulation". The authors go on to explain how basal velocities should physically be able to exceed surface velocities. However, this seems more likely a result of the inversion.

1475.11-12: One can guess the representation is good from Figure 2b, but it would be nice to show this in a figure.

1477.4: Please comment on how the value $C=0.5$ was chosen.

1478.2: Since P_w is really backed out of the friction law, "associated with" seems more appropriate than "induced".

1478.9-24: The structure of this section seemed strange. It would make more sense to describe the results first and then interpret or explain them.

1478.26-28: "runoff"? Maybe "basal water pressure". Is this really a surprising result? Bedrock bumps should contribute to trapping water and raising basal water pressure.

1479.3-10: Here I would use more tentative language in relating these results to those of Lingle and Fatland (2003). It would help to walk through this argument with direct references to the figures so that the reader could follow the interpretation (see also comments on figures).

Eqn (19): What are the units here? Is this equation from Bindschadler (1982)?

1480.17: "modelled surge occurs in phase": this is presented like a result, but it seems to me that since β was inferred from the data that this is merely a result of the methodology.

1480.24: "validate" is probably too strong a word here, though it might be compelling if the authors showed a comparison with choosing a fixed β and allowing the surface to evolve forward in time.

1481.6: Because observations were not used directly to confirm that the inferred friction parameter profiles were correct, it seems too much to say "with a high accuracy". It would suffice to say "basal conditions consistent with surface elevation and velocity measurements".

1481.18: Perhaps "a significant step" rather than "the last step"!

Figure 9: Some further comment on the oscillations along the first 5km of the modelled flowpath is needed. I can understand why these values would be small or systematically low, but not fairly large and of both signs in this region.

Technical corrections:

General:

There are spelling errors throughout that a simple spell-check should detect.

"The Variegated Glacier": the authors should confirm with one of the Variegated insiders whether this glacier takes "the" before its name. It sounds incorrect to me.

In many places "such as" should be "such that", and "consists in" should be "consists of". Before some equations (e.g. Eqns 1, 14) "write" should be "is/are written". "allows" should often be "allows us" (e.g. 1471.11).

Remove redundancies in such phrases as "basal conditions below the glacier" throughout.

Specific (page.line):

Title and abstract: "prior" -> "prior to"

1465.23: Here and elsewhere in the text the word "inverted" is used when I think "inferred" is meant. Basal conditions were inferred by inverting surface data.

1470.18: "terminating" rather than "to stop"

1471.14: small lambda?

1472.5: "non-icy" -> "ice-free"

1472.13: I think I know what you mean, but I'm not sure this quantity would be called the median. It seems more like a weighted average where the weighting depends on the proximity in time.

1474.1-4: This needs to be rewritten for English.

1481.1-2: "easily" -> "likely"

Figure 2b: Hard to see crosses. Can these be enlarged?

Figures 4-5: Please clarify legend in the caption. Are some of these numbers indicating months?

Figures 6-7: It would help to combine these two figures so that they are stacked, and perhaps to plot $b(x)$ as well as $db/dx(x)$. Also please label "Time" in calendar years and annotate the time-space diagrams with dotted lines indicating the space-time progression of the surge.

References

Frappe, T.-P., and Clarke, G.K.C. 2007. Slow surge of Trapridge Glacier, Yukon Territory, Canada, *J. Geophys. Res.*, 112, F03S32, doi:10.1029/2006JF000607.

Sund, M., Eiken, T., Hagen, J.O., Kaab, A. 2009. Svalbard surge dynamics derived from geometric changes. *Ann. Glaciol.* 50(52), 50-60.