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Discussions

Interactive comment on "The Impact of Climate on Surging at Donjek Glacier, Yukon, Canada" *by* William Kochtitzky et al.

Anonymous Referee #2

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This paper addresses an interesting glaciological problem and presents a wealth of data on Donjek Glacier and its climatic setting. However, it is frustratingly inconclusive, and sheds little light on surging processes at the site. This reflects a systemic problem with the paper, particularly a disconnection between the research aims and what the data sets are capable of showing. The data do point the way to some interesting possibilities, but these require further investigation before their potential can be fully realized.

A major issue is the question of whether the timing of surge onset is related to cumulative snow accumulation, as has been demonstrated at Variegated Glacier by Eisen et al. (2001). A large proportion of the paper (pp. 133-200, 287-319, 417-444) is devoted to this question, using firn- and ice-core data to construct time series of annual

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accumulation and comparing them to the intervals between surge events. However, as the authors point out, at Donjek Glacier the surge reservoir zone is in the ablation area, ~15 km downstream of the snowline. Thus elevation changes are driven not by snow accumulation, but by the flux divergence minus surface ablation rates. It is clear that the flux divergence term is dominant in this case. During surge build-up, the ice thickens due to convergent flow (which more than offsets melt), while during the surge phase the ice thins faster than the melt rate due to divergent flow. There is no reason to expect that dynamic thickness changes in the ablation zone during surge build-up are correlated with annual accumulation rates some 30 km upstream, even when the latter are adjusted to account for transport time. Ice is not delivered to the reservoir zone one annual increment of snowfall at a time. The integrated mass balance upglacier of km21 will determine the balance flux, but the distances involved mean that the balance flux will be insensitive to annual variations in accumulation.

Unfortunately, this means that all the careful work with cores to determine annual variations in snow accumulation is to no avail. The correlation between cumulative accumulation and surge period has no direct physical meaning, and Figure 4 does not show the same thing as Eisen's data. I think the authors get it right when they concede that "it is possible that the consistent net accumulation observed at Eclipse Icefield between surge events simply reflects consistent average accumulation over each of the ~12-year surge intervals" (432-435).

A more fruitful line of inquiry would be to examine time-series of elevation changes in the reservoir zone itself, and to relate these to dynamic cycles. At present, there is no discussion of the important observations by Abe et al. (2016), which revealed consistent velocity patterns over the last two surge cycles. What are the causal relationships between ice dynamics and elevation changes, and how do they evolve over the surge cycle? How & when do the dynamics influence elevation change (e.g. through cycles of divergent vs. convergent flow), and how & when do elevation changes influence the dynamics (e.g. via changing shear stresses or other factors)? The ice surface elevation change data presented in the paper are obviously too sparse to examine these issues in detail, but a good starting point would be to look at the trends in ice elevation shown in Fig 5 alongside the dynamic patterns revealed in Abe et al's velocity records (their Fig 1c and d). In particular, note how the patterns of elevation change correspond to the spatial patterns of velocity during quiescence (and, importantly, the variations in glacier width, particularly the 1/3 reduction in glacier width between km22 and km18). The narrowing of the glacier indicates that the glacier needs to speed up below km20 to satisfy continuity, but it either undershoots (quiescence) or overshoots (surge) the required value. Why should this be?

In a throwaway statement on line 510, we read that the upper extent of surge behavior is "coincident with a change in bedrock lithology". The fact that the dynamic instability occurs at both a topographic and geologic transition deserves to be investigated and reported in detail. What exactly is the lithological change? How does this relate to valley morphology? How might this affect the ability of the glacier to evacuate basal meltwater? If they hope to understand the surging behavior of Donjek Glacier, the authors need to give serious consideration to the idea that the instability relates to topography and/or geology and how it interacts with the dynamics. Knowledge of the subglacial topography would add a great deal of value in this respect, but the current sampling shown in Fig. 8 is far too sparse to allow any useful analysis.

Of course, the topic of the paper is the impact of climate on surging, and the fact that recent climate changes have had no discernable impact on the length of the surge cycle is clearly of interest. But the significance of this can really only be understood when considered alongside the causes of the dynamic instability, and the question of why the instability should be resilient to the observed climate change.

The subject of surge onset and weather shows promise, but this too will require more work. The authors state "three of the top ten rainiest months appear to coincide with surge onsets" (410). This of course means that the other seven rainiest months do not, but there could be something in this and it should be investigated in more detail.

Perhaps rain events do have an influence, but only if the glacier is 'primed', or close to a critical state (i.e. if the surge front is close to the terminus, or some other condition is met). Can a particularly rainy month trigger a surge a year or two sooner than average? Conversely, can a dry summer delay surge onset causing the period to be longer than average? Detailed figures showing monthly precipitation totals relative to surge onsets would help shed light on this (resolution of the monthly precipitation record in Fig 7d is currently too low to convey useful information).

At present, the paper's shortcomings and 'red herrings' mean that it does not advance our understanding of the timing of surges with regard to environmental controls, or yield new insights into surge mechanisms at the site. This is a pity, because clearly a great deal of work has gone into the data collection, analysis and presentation. There is potential for something of value here, especially with regard to the possible topographic and geological controls on the instability in the ablation zone of Donjek Glacier, and the timing of surge onset relative to enhanced inputs of surface water. My recommendation is that the authors set the paper aside until they have explored these issues, and got closer to the heart of the intriguing problem of Donjek's unusual surging behavior.

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