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Interactive comment on "A conceptual model of cyclical glacier flow in overdeepenings" *by* J. B. Turrin and R. R. Forster

Anonymous Referee #1

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General comments

The paper presents some interesting data on short-term phases of ice acceleration and deceleration on a subset of Alaskan glaciers. However, I have a number of major concerns about the manuscript, which are as follows:

1) Velocity data from only one glacier is presented in the main paper, but the discussion is focused on broader scale patterns and controls on 'pulsing' behaviour. I would therefore like to see the data for the other glaciers in the main manuscript, even if it is just in summary form.

2) According to the table of imagery, data are available back to 1972, but results are only presented from the 1990s – 2013. These data should be incorporated and used

to identify whether the observed events change in characteristics over time and/or whether they are part of longer-term changes (e.g. build up to a full surge).

3) The basal topographic data are very limited (data are from two sites, one of which is a point measurement), yet the whole theoretical concept revolves around the presence of overdeepenings. There needs to be more detailed data to support the proposed link between basal overdeepnings and pulsing.

4) Leading on from this, it seems like the major difference between surging and pulsing suggested here is the role of the overdeepening. However, there are a large number of glaciers with overdeepenings were pulsing does not occur. Equally, evidence suggests that surging can occur via sediment deformation / changes in the basal hydrological system, without the need for an overdeepening, albeit on longer timescales in certain locations. I therefore think that the theory needs further calrification and development and needs to be supported by basal topography data.

5) The paper focuses strongly on the conceptalmodel, rather than the data, and only a limited portion of the results are presented (i.e. only for one glacier in detail and only for a portion of the time period). As a result, the theory has to make a series of assumptions from the initial dataset that are not fully backed up with further evidence (for example the limited ice thickness measurements). I think the paper has some interesting data, but this should be the focus, rather than a lengthy theoretical discussion.

Abstract

Line 4: Do you mean through to the 2000s or until the end of the 2000s? Also, it would be helpful to have a brief definition of a pulsing glacier in the abstract. It is defined below, but needed to here to clarify the distinction you are making between pulsing and surging glaciers.

Line 10: Clarify. Do you mean individual sections started to flow more rapidly than the surrounding ice or that large sections move as a single mass at once?

1. Introduction

P4464, Line 24: Can these pulses only occur via till deformation? Mini-surges have been observed (e.g. on Variegated Glacier) and linked to changes in subglacial hydrology, so is the distinction due to the mechanism?

P4465, Line 1: In which locations is this pulsing behaviour found? Just in Alaska? If so, why not elsewhere?

P4465, Line 6-22: This section needs more references. Where does the water come from to cause the till dilation? Surface inputs? Changes in thermal structure? Similarly, where does the water go at the termination of a pulse? With surges, it has been suggested that it is evacuated at the front, causing the slowdown, but how does this work if it only affects a portion of the glacier? How spatially extensive are these pulses (i.e. 10s of metres, 100s of metres)?

P4465, Line 23: Theory suggests that surging is also triggered by till deformation (e.g. Murray et al., 2003), but this section suggests that surging only occurs with changes in the hydrological system and pulsing relates to sediment deformation. It therefore contradicts your previous material.

2. Study area

P4466, Line 16: Again, helpful to say whether or not Alaska is unique in having this pulsing behaviour.

P4466, Line 20: Improve definition for identifying pulsing glaciers, particularly the meaning of' a significant portion of the ablation zone moving en masse'. Is this area defined in % or absolute terms and how quickly does it move?

P4466, Line 24: Why choose this glacier? Is it particularly representative? Please justify.

P4467, Line 4: Mixed discussion of surging and pulsing. Is the argument here that

Eldridge is a pulsing glacier?

P4467, Line 13: How thick is this debris cover? If it is thick (>3 cm), it could be insulating the glacier and reducing melt rates. This could also account for the slower velocities (e.g. compare to the Himalayan glaciers discussed in Quincey et al 2009 [J of Glaciology] and Luckman et al. 2007 [Remote Sensing of Environment]).

P4467, Line 18: Missing word.

P4467, Line 19: It is not clear from the figure which geology underlies the glaciers themselves, as the geological boundaries stop at the glacier edge. Presumably this was done for cartographic reasons, but it needs to be reconsidered so that the geology beneath the glaciers is also demonstrated.

3. Methods

P4467, Line 26: It would be helpful to add a brief description of the approach for those unfamiliar with feature tracking, e.g. that movement of features, such as crevasses, is tracked between sequential images and that time gaps of $\sim$ 1 year are needed to detect change and also to ensure similar surface characteristics, to facilitate the matching process.

P4469, Line 12: What was the original resolution?

P4469, Line 13: How is the location error estimated?

P4469, Line 16: As above, it is not clear from Fig. 2 what geology underlies the glaciers themselves.

4. Results

P4469, Line 20: What about the earlier data? Table 1 contains imagery back to 1972. This would allow you to investigate whether this pulsing happens on a regular basis and, if so, what the periodicity is. Similarly, the discussion covers dates that are not shown in Fig 3, which has only a subset of the data. I would not suggest showing

every interval, as this would result in a large number of graphs, but it should cover the full time range discussed (1996 to 2013) and should either have roughly regular time intervals or should illustrate key events (e.g. the acceleration / deceleration transition).

P4469, Line 20: I'm not sure I agree with this idea that the ice accelerates / decelerates en masse. Looking at Figs. 3 and 4, it seems like the area of maximum velocity propagates down glacier over time. Also, the resolution of the data is annual, meaning that the acceleration is only recorded by three data points (2002-2004) and likewise for the deceleration (2004-2006). It is therefore possible that the detailed temporal evolution is being missed if it is occurring at sub-annual timescales. This relates back to my earlier comments about the definition of a 'pulse' as opposed to a mini surge. This states that the pulse is 'characterized by a multi-year acceleration phase in which the glacier progressively increases its velocity due to deformation of a subglacial till, immediately followed by a multi-year deceleration phase during which the glacier progressively slows as the till consolidates.' However, I would argue that the acceleration was actually quite rapid (two years for an approx. 4 fold increase) and so was the deceleration, which showed a sharp reduction between 2005 and 2006 and was non-uniform across the glacier. Given the rapidity of the change, this could relate to a change in the hydrological system, potentially in combination with till deformation. It would be very interesting to see if the characteristics of this 'pulse' are similar over time (using the earlier Landsat data), or whether there is any kind of increase in magnitude that might be a precursor to a full surge. Similarly, surface elevation change data would help to determine whether these pulse are just cyclical events or part of a longer term surge cycle.

P4470, Line 4: The velocity field on the Rohn does appear to change with time from your maps. To support this point, velocity profiles for the Rohn should be presented as they are for the Nizina.

5. Discussion

P4470, Line 15: Remove this section.

P4470, Line 20: The results from the other glaciers are not presented in the results section, but are discussed here and used to build an argument. I am not against the idea of focusing on one particular glacier in more detail but it needs to be made clear why that glacier was selected and how representative it is. At least some data on the other glaciers should be presented in the main paper, even if it is more general, summary data, as this is forms an important part of the discussion.

P4471, Line 15: Needs a reference. Also, discuss their modern contribution, rather than general comment about past glacial periods, as this is much more relevant to the contemporary behaviour.

P4471, Line 20: Needs a reference.

P4472, Line 6-20: This is quite general and could be trimmed substantially.

P4472, Line 21: Needs a reference and/or supporting evidence.

P4472, Line 24: This conclusion is a big jump. Just because pulses occur in areas with similar characteristics as those associated with overdeepenings, does not necessarily mean that pulses occur where there are overdeepenings. Conversely, there are many locations where overdeepenings occur and pulsing behaviour does not, so the presence of one does not guarantee the presence of the other. Some evidence is provided below, but it is sparse and only for particular locations. The presence of overdeepenings is important to the overall conceptual model, but there is limited evidence. Are there no other basal data available here?

P4472, Line 24: This does not necessarily suggest that the gorge is overdeepened, simply that the bed at the terminus is the same elevation 0as at this point inland. What if the bed is just flat? We can't make any real conclusions from just one ice thickness measurement.

P4475, Line 7: If the water pressure is high, then this could increase the basal sliding

(which is greatest with high water pressure) and this could actually increase erosion in these areas. The sediment could then be removed by the glacial ice, e.g. through entrainment. Also, if this were the case and overdeepenings become the site of deposition, they would fill in over longer time frames, which geomorphological evidence suggests is not the case.

P4475, Line 13: As discussed above, this increase in water pressure can also cause accelerated flow due to increased basal sliding, so does not necessarily need to effect the till. One important point is whether the study glaciers are underlain by a hard bed or by substantial amounts of till, as this will determine which mechanism is more dominant. Do you have any information on this?

P4477, Line 16: Why does supercooling begin at this point? It relates to glacier thickness (and the depression of the melting point due to pressure), so surely there would need to be an increase in ice thickness for super cooling to begin? Looking at Figure 6, thickening seems to be represented as an effect of accelerated flow, rather than a cause.

P4478, Line 18: This is an interesting theory, but is there any evidence to support it, e.g. basal water pressure data, information on subglacial sediment? Also, it seems to be very similar to previous theories on the causes of surging, just that an overdeepening is involved. However, previous studies on surge-type glaciers suggest that a similar mechanism could operate without the overdeepening. Is the overdeepening necessary?

P4479, Line 1-13: No references in this entire section.

P4481, Line 1: Are these other glaciers underlain by deformable till or hard bed rock? This could explain the lack of surging behaviour, rather than the configuration of the overdeepening.

P4481, Line 13: Mark these glaciers on the map.

P4482, Line 17: As identified in the final sentences of this section, this relationship is limited (e.g. we have pulsing occurring when there is no PDD peak).

P4482, Line 21: Mark the meteorological station location on Fig 1. How representative are these temperature data of conditions in a different mountain range / at different elevations?

Figures

Figure 1: Add extent boxes/ polygons for the different ranges and dots for the individual glaciers. Define all abbreviations in the caption. If using colour, why not have the ocean in blue. Label Canada and Alaska for completeness.

Figure 2: As discussed above, the geology below the glaciers needs to be shown. The green font is hard to read. Add more than one tick mark for lat/ lot.

Figure 3: See comments above regarding time intervals. Why scale up to 350 m a-1 when it appears that there are no values in the upper end of the range? This makes it harder to see the velocity patterns.

Figure 4: As the data points are actually ranges (e.g. velocity for the period 2002-2003), think about how these are displayed and make it clear in the caption. At the moment, it is unclear whether a data point is placed at the start or the end of the velocity period (e.g. is the data point for 2002-2003, placed at 2002 or 2003 on the x axis). One simple solution is to place the data point in the middle of the range.

Interactive comment on The Cryosphere Discuss., 8, 4463, 2014.