The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2017-135-RC1, 2017

The Cryosphere Discussions

Interactive comment on "Brief Communication: The Khurdopin glacier surge revisited – extreme flow velocities and formation of a dammed lake in 2017" *by* Jakob F. Steiner et al.

V. Round (Referee)

vround@hotmail.com

Received and published: 21 August 2017

This brief communication describes the recent surge of the Khurdopin glacier through remotely-sensed observations of surface velocity and surface elevation, and highlights the extreme flow velocities and development of a potentially hazardous ice-dammed lake. The new velocity observations are consistent with previous surges of Khurdopin Glacier, for instance the 18 year period since the last surge, the pattern of acceleration before the surge and the season and magnitude of the peak surge velocities.

General comments:

The manuscript is well written and the methods sound, but aside from confirming similar behaviour to previous surges and alerting us to possible lake formation, more could be done to communicate what is new or novel about the results of this study. The following are the main points which I think have potential to be expanded upon to increase the value of the study.

1) The Planet satellite data used here has much higher temporal and spatial resolution than the Landsat data which has been used in previous studies. Does this provide any particular benefit for the analysis of the velocities over the course of the recent surge?

2) The DEM analysis nicely shows the expected patterns of mass displacement during quiescence and surging. This is new for specifically surge related studies of this glacier, but similar results have already been seen for Khurdopin glacier as part of mass balance studies by Gardelle et al. (2012) and Bolch et al. (2017). Do the results presented here provide any new insight into why or how the glacier surges?

3) The relationship between the surge and recent lake formation is explained and some projections of potential lake area and depth are made. I think that these projections could be communicated with a little more detail, for example what factors may affect the likelihood of the lake reaching the projected sizes or why this lake could be particularly relevant. Is the hazard expected to be greater than after the previous surges, for which there were no recorded damages according to Iturrizaga (2005)?

4) The hypothesis that the 'thermal switch' mechanism is responsible for the surge initiation doesn't seem to be backed significantly by the results, or if so the discussion of this assumption needs to be strengthened. If there isn't significant backing for either of the often cited 'thermal switch' or 'hydrological switch' initiation mechanisms, then I don't think it is necessary to classify the surge as either.

5) The 'Velocities during surge events' section gives a long description of the velocity changes in time and space, but it is difficult for the reader to build an overview picture. A visual summary of the temporal evolution would help greatly, especially given the

large amount of data available. I think this is important if you want to talk about the 'advance of the surge front' (P3,L3). Figure 1 shows the three extremes of the surge but not the evolution between.

Specific comments:

P1, L12: 'during a glacier surge in of' remove 'in'

P1, L14: Does the 'fastest rates globally' refers to peak rates for surging glaciers or to glaciers in general? The use of 'm/a' in '5000m/a' could suggest that rate to be an average rate over a year. Using "m/d" may avoid this confusion.

P1, L15-16: This sentence could do with some reworking. Firstly it isn't clear if the four year build up in velocity occurred over the whole glacier or just part of it. Also the term 'upper tongue' probably has little meaning to the reader at this stage.

P1, L19: The 'however' at the beginning of the sentence implies contradiction of the hypothesis in the sentence before. Does the crevassing and disappearance of supra glacial ponds contradict the thermal switch mechanism, or reduce certainty in your hypothesis? I think these observations indicate a factor which amplifies the surge regardless of the initiation mechanism.

P1, L27: I suggest a slight rewording of the two general driving mechanisms, because the 'build-up of ice mass during the quiescence phase. . .' applies to both mechanisms.

P2, Section 2: There could be a few more details in the methods section here instead of only in the supplement. I would like to see at least an indication of the temporal resolution/number of images from Landsat and Planet (this is also missing from the supplement). Perhaps also spatial resolution (what is meant by 'high resolution') and/or indication of error margins.

P2, L16: SRTM should be mentioned here too as it was also used for investigating mass changes.

P2, L23: Is this information about the source of the debris/medial moraine included because it is important to the glacier velocity?

P2-3, Section 3: I tended to get lost reading this section with its rather long chronological description of the three surges. One could present the results by describing the various phases of the three surges simultaneously. This could cut out some repetition and make similarities more apparent. Displaying this information about the temporal evolution of velocity as a figure would also allow the text here to be shortened and provide a very valuable summary and overview of the surges. Velocity over time could be shown for both the lower and upper parts of the tongue, as these show different behaviour, or better still for the whole length of the tongue.

P2-3, Section 3: Is the difference in peak velocities between the different surges, e.g 2000m/a in 1999 and 5000m/a in 2017, a real result or could it be an artefact of the temporal averaging period, where shorter periods are more likely to capture faster peak velocities?

P3, L3: The advance of the 'surge front' is not clear to me. Quincey et al. (2011) show a very distinctive surge front at Kunyang Glacier but not for the 1999 surge of Khurdopin Glacier. Citing the surge front observed by Quincey et al. (2011) implies a similar acceleration pattern to the Kunyang surge. Perhaps the term 'surge front' is a bit subjective in this case. This is where a visual representation of the temporal changes, with more than three times steps, would be really useful.

P3, L9: The comment about not being able to discern length change is repeated in Section 4. I would expand upon it here and remove from section 4, or just remove it here.

P3, Section 4: DEM differences between 2000 and 2008 were calculated for Khurdopin glacier also by Gardelle et al. (2012), I think this paper is definitely worth consulting as they also focus on Khurdopin glacier for getting ablation rates. (Gardelle et al. 2012, Slight mass gain of Karakoram glaciers in the early twenty-first century, Nature

Geoscience Letters, DOI: 10.1038/NGEO1450).

P3, L22: Was the mass change over the whole glacier assessed between 2000 and 2011, or just 2011 and 2016? Is there enough confidence in the results to give us a number for these periods?

P3, L26-27: This sentence makes is seem like there have been considerable damages in recent decades, but Iturrizaga (2005) shows most damages in the early 1900s. Is there another source showing more recent damages, or is it possible that the floods have become less severe or the settlements less vulnerable?

P3, L29: The lake outbursts at Kyagar glacier discussed by Haemmig et al. (2014) were extremely rapid, jökulhlaup type events, not gradual as mentioned here.

P3, Section 5: The potential lake volumes might have more meaning for hazard assessment than the surface area. I imagine this could be quite easily calculated given the DEM of the lake basin.

P3, L36: I assume the 15 meter height increase at the fringe represents the upper bound on potential lake depth. Is there any indication that this height will increase or decrease in the next couple of years and what factors might affect the likelihood of the lake reaching these various levels? Additionally, the 80 meter increase at the centre doesn't seem relevant for the lake.

P3, L37: Do you mean the potentially large influx of subglacial sediments is into the potential lake basin? What effect would this have on the lake - decrease the potential volume of the lake?

P4, L2: Two surge periods is probably not sufficient to confirm 'a constant return period' especially over longer timescales, unless there are earlier indications of similar return period.

P4, L5: The observation of very different behaviour of the lower and upper parts of the tongue, separated by a steep part of bedrock at 12km, is interesting and has been

observed on other surging glaciers (Quincey et al. 2014, Round et al. 2017). Possible questions to discuss here are whether there is something about the lower part of the tongue that leads it to experience such extreme changes in behaviour, or what the significance of the steep section at 12km may be, or the significance of the avalanche mass deposits?

P4, L12-13: Couldn't the increased pressure and 'tipping point' reached at the end of the quiescence also initiate the surge through collapse of the subglacial drainage system or failure of subglacial till? Is it possible to distinguish between these processes with the available data, or is there some other indication leading to the conclusion of a switch from cold to temperate basal conditions?

P4, L12-13: Do you mean this switch from cold to temperate based applies to the upper part of the tongue with the gradual acceleration, or lower part of the tongue with the sudden surge acceleration? Is it feasible that the velocities during the assumed cold based phase be purely due to ice deformation?

P4, L14: Quincey and Luckman (2014) suggested both the 'thermal switch' or 'subglacial drainage' as possible controls and didn't seem to have enough evidence to conclude one way or the other.

P4, L20: Did the velocity results show a parabolic velocity profile across the tongue during the quiescence? This wasn't mentioned in section 3 but would be interesting..

P4, L21: The peak velocities of this surge are really incredibly high, as is the magnitude of the acceleration! A mention some of the feedback processes which could allow such extreme basal sliding velocities could be informative. Do you think subglacial till deformation plays much of a role?

P4, L26: I'm not sure how the increased resolution and overpass frequency of the Planet satellite data have led to better understanding of the surge. Is it the ability to resolve the peak velocity over shorter time frame or observation of more temporal

fluctuations or spatial patterns (e.g. transverse variation) in velocity? If so then this should be discussed somewhere.

Figures 1 and 2: The right hand panels show the inferred glacier bed elevation, however it would make sense to also show the observed glacier surface elevation. Showing the surface elevation from the 2011 and 2017 DEMs would provide an additional visualisation of the mass redistribution, and if shading or dashed lines are used the readability of the plot shouldn't be affected.

Figures 1 and 2: The maps should be in some way georeferenced.

Figure 3: Very nice to have some photos from the ground, but maybe indicate the date (month)

Figure 3, L3: The traced 'centreline' would more appropriately be referred to as 'former centreline' or 'former medial moraine'

Figure 3, L8: I would say the tongue below the dashed green line "showed no change during the surge" rather than "remained stable".

Supplement Table S1: How many images were used from each Satellite? It would be interesting to have this information about the potential temporal resolution of the data.

Supplement Table S1 (DEM data): This table should be labelled Table S2.

Supplement Table S2: The SRTM from 2000 should also be shown here as it was also used for the surface elevation analysis.

Supplement: The COSI-Corr model setup and potential error magnitude is explained clearly.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2017-135, 2017.