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Progressive advance and runout hazard assessment of a low-angle valley glacier in East Kunlun Mountains from multi-sensor satellite imagery analysis

Wang et al.

General comments

The authors present a case-study of a low-angle valley glacier that has been advancing and is potentially destabilizing, and put this in the context of recent uptick of glacier detachment observations. The paper provides a valuable contribution to the ongoing discussion of the drivers, mechanics and possible consequences of glacier detachments. It is largely well written and easy to follow, and I believe that it should be published in NHESS after addressing the following points:

My first point of criticism is the hazard assessment, specifically the claim that the maximum runout distance of a potential glacier detachment is 1.3 km. The authors come to this conclusion using moderate friction parameters in a Voellmy-Salm model. However, a simple test using the mobility index Fahrböschung indicates that if KLP-37 were to detach in a manner similar to what has been observed at Aru, Flat Creek etc., the resulting mass flow could easily reach the railroad (Fahrböschung of 7-8°, based on my rough calculations). Kääb et al., 2020 show that Fahrböschung values for all known glacier detachments are between 5° and 10°.

Additionally, the hazard assessment was only carried out with one ice volume estimate that the authors state is likely conservative. I believe that the hazard assessment would benefit from being conducted with a range of starting volumes and upper boundaries. This, combined with a comparison of Fahrböschung values, would, I believe, paint a more honest picture of the hazard that glaciers like KLP-37 can pose, and therefore be of higher value to the scientific and hazard management community.

Finally, I was a bit surprised to find the entire hazard assessment in the Discussion section. I think it makes up a substantial enough part of the paper that it would deserve to be presented in the Methods and Results sections. Currently it comes as a bit of a surprise to the reader.

My second point of concern are the surface flow velocity measurements. There is a discrepancy of two orders of magnitude between the terminus advance velocity and the surface flow velocities. No physical explanation that I can think of can justify such a difference.

I suggest that this part of the analysis be redone, taking into account the uncertainties resulting from geolocation errors in the Planet data, and presented for the glacier and its surroundings.

Specific comments

Title: I suggest saying "Progressive advance and *detachment* hazard assessment …"

L50: "Specifically, increasing air temperatures, coupled with…" → Unclear whether you are intending this statement in a general sense or for specific cases (which ones?). Please clarify.

L53: Geometry changes were also documented on Flat Creek glacier, as well as several other instances (refer to Kääb et al., 2020).

L57: "Recent glacier collapse events on the QTP" → Have there been more than the two at Aru? If yes, please specify, otherwise maybe just refer to the Aru cases specifically.
L59+61: "glacier instabilities" → what kind of instabilities are you referring to here? Just glacier detachments or also ice avalanches, surges etc.? Maybe this can be formulated to be a bit more specific.
Figure 1: It would be nice to show the location of the weather station in this first Figure. The caption suggest that the figure shows something about the geology, when in fact only the topography and the faults ('seismic setting'?). That said, I think a geological overview would be well placed here since the authors later make a reference to fine grained rocks, but never describe the region's geology. Such a description should be added to the Study Site section. Lastly, I am not sure the yellow dots (ice avalanches triggered by the 2001 EQ) add much information here, since they are never mentioned again.
L104: please clarify what you mean by "pre-collapse" event
L106: since you just talked about both the east and the west branches in the previous sentence, it would be helpful to specify relative to which tongues the lakes are.
L108: "We can observe fine debris …" → how did you observe this? High resolution images are likely not enough to determine this adequately. If you have not had a chance to investigate in the field, a reference to the geology of the area (L110 "weak bedrock") would be helpful.
Figure 2: In this caption, as well as somewhere in the text, please note (and possibly show) the distance between the glacier and the railroad. Also, please label what the yellow polygon indicates.
L133ff: In this paragraph, it is not always clear which DEMs you made and which you just acquired. Did you generate any of the radar data based DEMs yourself (seems like they are all freely available products?). A little bit of clarification would be helpful here.
L155: define ∂t
L157: "which is set to zero because all the optical images used are orthorectified and georeferenced products" is not a satisfying reason for setting that value to zero. In my experience, orthorectified Planet images can exhibit a lot of jitter. Since you have your cross-correlation pipeline running in MicMac, you should be able to get an estimate of this value from the off-glacier cross correlation results.
Figure 3: The Nuth and Kääb approach for co-registering DEMs is pretty standard – the image could easily go into the supplementary material.
L194ff: I'm not sure that I agree with the authors approach to the applying single offsets here. In terms of snow penetration, if I had an estimate of penetration error with elevation, I think I would chose to correct it based on a fitting a curve to the data. The authors state that they are not interested in the high reaches of the glacier, but then show such results in Fig. 6. It would be interesting to see a bit more discussion of the effects of these error sources in the discussion. Do they significantly change the amount of thinning/thickening that we can see on the different parts of the glacier?
L215: I don't understand what you mean by "standard deviation of the mean elevation change of its elevation band"? Aren't you just using the standard deviation of each elevation band (as indicated in equation 3?).
L223: Please add a reference to the least-squares fit … isotropic variogram method, or describe in more detail.
L231: Why only three pairs? Processing all possible pairs would make your results more robust.
L251: It is not clear to me what "The snowpack downstream of the crevasses collapsed" means. Was there an avalanche? Or just different snow conditions over a crevassed area? Or a change to the actual glacier ice? Please clarify this point.

L254: If it stayed unstable for four decades, does that mean it is actually stable? Clarify the point you are trying to make with this statement.
Figure 4: It is very hard to see much in this image, but there is a lot of empty space! I suggest rotating the image and making it 3x4 or 4x3 cells, so that it is easier to see something.
L267: Did you determine the uncertainties of the area in the same way that you did for the advance velocities, or some other method?
Figure 5: It would be really nice if each dot also had a horizontal bar that indicated over what time span the velocity was calculated.
L279: Clarify that you DON'T mean that the velocities were similar between 2009 – 2015 and 2015 – 2019, but instead were stable during those periods, but then jumped between 2015 and 2016.
Figure 6: Please make the colorbars a little bit larger and use the same scale for each image (in which case you can get away with just one colorbar for each line of plots). It is very hard to interpret the changes when the scales change.
L295: How much could this assessment be influenced by the radar penetration depths?
L298: over the whole east branch? Or another window? Please clarify.
L299: did the east branch only thin or also retreat?
L305: I'm not sure I agree with the term *bulging* for what is described here (and depicted in Figure 7b): Bulging implies that there was an upward motion of ice surface, but really there is just advance of ice. The DEM difference is mostly against previously un-glacierized terrain, so obviously this appears as thickening in the DEM difference, but it does not reflect thickening of ice in a place where the was ice previously. That said, I do see bulging Figure 6, but am having a hard time finding that in the cross-section.
L306: What makes it not a surge, but only surge-like? This could be an interesting topic to elaborate on in the discussion.
Figure 7: Can you indicate the years next to the different DEMs? That would help interpret the changes. Then, it would be nice if the colors were on a gradient scale along age, so that it is visually clear which way the changes progressed.
Figure 8: Because the x-axis runs from upglacier to downglacier in the previous plots, I think it would be beneficial to flip the x-axis in this plot (so that higher elevations are on the left and lower elevations are on the right).
L334: Over what area where these maximum velocities measured? Single points?
Figure 9: Please use colorbars that are not divergent (the blue to white to red implies that blue has an opposite signal to the red) but rather continuous, and use the same scale in each plot. Additionally, it would be very nice to see the velocities outside the glacier as well. Is there actually enough accuracy to distinguish the glacier from the surrounding landscape? Lastly, you keep referring to the 4800m elevation line, so it would be very nice to show that line in the plots.
L349: Your surface flow velocities and terminus advance velocity differ by two orders of magnitude. I don't see the explanations you offer as plausible, but suspect an error in the processing of the cross-correlation.
L370: How did you (or Wu et al?) determine the lower permafrost altitude in the field? It would also be good to take a look at the two global permafrost maps (Gruber et al., 2012, Obu et al., 2019), and reference those.
L374: If my memory serves me correctly, Leñas glacier was deemed temperate… but I think something similar was found at Flat Creek. Maybe double check the references?
L379: The statement that the ice-dammed lake exerts a hydrological influence on the glacier tongue needs to be backed up significantly. What kind of influence? This seems like it contradicts the cold-ice edge that is keeping the lake locked in. If the lake has not decreased in size, I don't see how it could influence the dynamics of the glacier in any substantial way.

L384: I don't understand what you mean by "deflection region"
L386: It seems to me that the narrowing of the topography which kind of "pinches" the glacier tongue would help stabilize it, rather than making it unstable. Please clarify how you think this factor contributes to a destabilization.
Figure 11: Why are you only showing summer temperatures? At what elevation are these temperatures? The current graph does not support your claim that the area is in permafrost.
L395: I am a bit hesitant about this interpretation of the influence of temperature and precipitation on the flow speeds. Firstly, what exactly are you referring to by "flow velocity"? The advance of the glacier tongue or the mapped velocities on all of the tongue? This needs to be clarified. For the advance of the glacier tongue, the change really just happened between 2015 and 2016, but was likely the result of accumulation that happened further upstream in the years before. Please elaborate on these points.
Figure 12: Why are you only considering the tongue in you hazard assessment? The crevasses seem to be much higher on the glacier, and the situation at Aru showed that that was where the detachment initiated. At the very least, I believe that it would be valuable to run the model with the two endmember volumes.
L435: Can you get that much advance by just internal deformation? I don't know the answer, but feeling like there might have to be some sliding, at least in the fastest parts.
L458: I don't see how the current glacier flow velocities / basal friction parameters influence how far the mass flow resulting from a glacier detachment can travel. If the entire thing detaches, basal friction decreases to essentially nothing, and that is what determines the runout distance.
L461: I am not convinced by your justification for selecting the moderate friction parameters. I am not sure exactly what findings you are referring to with reference to the Allen 2009 paper, but until very recently, we had hardly heard about glacier detachments, and it is unlikely that a comprehensive assessment of basal friction values was published over 10 years ago. Furthermore, I am not aware of any findings that link the basal shear stress during regular glacier flow to the runout distances of glacier detachments, most certainly not for making a difference between surging and non-surging glaciers. Please clarify substantially.
L474: I don't understand what you mean by "experiencing ice-rock collapses"?
L475: I don't follow how Kääb 2020 suggest that any glacier advance is an indicator for a glacier instability (though I suppose this depends on how you define glacier instability – not all are hazardous).
L481: Please back up the statement of "the ice-dammed lake influencing the dynamics of the glacier tongue of the west branch". This is currently not supported by any of the data, nor has any relationship between the two been mentioned prior to this.
L487: Please back up the statement "was transported from the upper region by a historical seismic event". How did you determine this to be a logical possibility? Is there evidence of something like this elsewhere in the region? So far, we have not seen earthquakes causing detachments of low-angle valley glaciers… (not saying it's not possible though…).
L492: In addition to ground based InSAR, optical camera based systems are probably cheaper and similarly effective, if it's just for monitoring.
L494: I don't understand what you mean by saying "our simulations provide an alternative solution for assessing the hazard of an impending glacier collapse". Alternative to what? Is the glacier detachment impending, or just a possibility (I would argue that it is probably more likely that nothing will happen).

Technical corrections

Terminology: Over recent months, the term *glacier detachment* seems to have become the term of choice for describing the catastrophic detachment of low-angle valley glaciers. Rather than using the somewhat fuzzy term "collapse", which is frequently used for rock avalanches, slope failures etc., I recommend changing the terminology to glacier detachment throughout the manuscript. Example: Due to hazardous threats of glacier ~~collapse~~ detachments to … (Line 37).

Use of tenses: There are quite a few improper uses of past tenses. I have noted these below where I caught them, but am likely to have missed a few. In general, I suggest to put anything that the authors have done in the past tense. Example: We chose a set of parameters, we analyzed these images etc.

If your line numbers have changed, I also have these edits in a document (hand written). Please let me know via the editorial office if having this document would be helpful.

L26: *tripled* not trebled
L39: *glacier* not glacial
L40: *was* not have
L41: *was* not is
L46: *two* not twice
L46: remove *the lower parts* → the entire glacier was implicated in 2015
L53: *on* or *from* not in
L59: *mean global rate*, not global mean rate
L67: …identified the glacier, *which is* close to …
L68: intense *crevassing* on the glacier surface *raised* the question *whether* a hazardous ice avalanche *might be* imminent.
L71: *past* not recent
L75: *discuss* not discussed
L76: *estimate* not estimated
L77: *occurred* not occurs; *discuss* not discussed
L104: the west branch's *terminus lies about 220m lower* (Fig. 2a); remove "Particularly"
L112: *overlayed* not overlapped; *The* ice-dammed lake and supraglacial pond are also *shown.*
L118: Why are Table 1 and Table 2 shown at the end of the document? It would be much nicer to have them where they are referenced.
L121**:** I would say that glacier changes are *often* mapped on Landsat etc. images (partly bc for decades that is the best we had) and that they have a *resolution of 10-30m*.
L123: *used* (if you got it free) or *acquired* (if you bought the images) not "collected" (collected is used primarily for data collection that you do in the field). This comes up several times in the manuscript.
L127: Just say …*spy satellite to reconstruct the topography of KLP-37 in 1975.*
L161: *generate* DEM*s from* KH-9 stereo images
L177: *to* a spatial *posting* of; The DEM pairs *need* to be …
L185: *posting* or *resolution* not post
L196: odd use of while
L200: similar to ~~the~~ previous
L248: insert space after KH-9; *past* instead of recent
L249: *A time-lapse* of optical images …
L251: Remove "KH-9 image" since the crevassing didn't happen in the image, but rather in the world. The images just show it.
L262: *is* instead of were

L277: *the past* instead of recent
L278: *and* instead of while; *rose to more* instead of had been higher
L341: *tripled* not trebled
L350: remove one *not*
L360: *advanced continuously* instead of "had been progressively advancing"
L361: *accelerated* instead of was accelerating
L362: remove *temporal*
L363: …conditions of *the glacier,* topography …
L371: *terminus* instead of termini
L377: … crevasses *to reach the* sliding surface …
L403: *dense* is an odd choice of word here – what do you mean?
L403: *was* instead of "has been"; I don't understand what you mean by "within 40 days before"? 40 days prior? Or during the 40 days prior? Or up to 40 days prior?
L501: with *a total* advance instead of "with an accumulative distance"