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Interactive comment on "Sudden large-volume detachments of low-angle mountain glaciers – more frequent than thought" *by* Andreas Kääb et al.

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This manuscript addresses a glacier phenomenon that was until recently almost entirely unknown in the glaciological community. The authors make the case that the catastrophic disintegration of large parts of relatively low-sloped glaciers is perhaps not as uncommon as previously thought. The paper presents a collection of events, some of which are reported here for the first time. This paper is very important in that it provides a first base line for something that is glaciologically interesting, but that has very important implications in terms of natural hazard planning. While the glacier detachment events reported here are rare, they can be devastating, as shown by the Aru

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Discussion paper

events, and perhaps they also occur with sufficient warning to prevent the loss of human life, as shown by the second Aru event. The authors make a first assessment as to what conditions could lead to such detachments, and place the phenomenon as something between the better known occurrences of glacier surging and ice avalanching of hanging glaciers. The manuscript is also a testament to the power of modern remote sensing tools in reconstructing these events, in terms of just imagery, but also with repeat DEMs and feature tracking for volume and velocity evolution. The manuscript is well written and it can essentially be published as is. I am attaching a marked up copy with the very few editorial comments I have.

This manuscript is also thought provoking, and I would personally welcome some additions to the Discussion. This is more a matter of taste, so I would leave it to the authors/editors whether such an expansion is warranted. But in a second attachment I tried to line out some simple force balance considerations that could potentially be useful in helping explain the phenomenon. In most ways, they just expand on explanations already in the manuscript. In particular, a very simplified view of a glacier as a slab of rectangular cross section provides some insight: There is a maximum stress that can be imposed on the sides (which is reached when basal stress is zero), and if that maximum stress exceeds the failure strength of ice, then catastrophic failure must occur. This stress depends on the slope of the glacier and also on the half-width to depth ratio. In particular, it explains why low sloped glaciers cannot detach. Furthermore, this implies that relatively straight glaciers are more prone to large scale failures, because curvature along flow provides an additional mechanism to accommodate stress. Also, a quick calculation of the effect of rock falls on glaciers show that in most cases, the increase in driving stress is larger than the increase in effective pressure, which would imply that rock falls move a glacier closer to an instability. This is especially true, if basal water pressures can evolve into a direction to decrease effective pressure (which sees an initial increase due to the additional overburden). Finally, one thing that could be discussed in terms of the observation of fine grained sediments: Fine grained beds are (in my opinion) more likely to allow conditions where essentially zero effective stress can be attained over large areas, particularly with distributed sources of water supply (such as excess geothermal heat). On a solid bedrock, widespread high water pressure will lead to extensive bed separation, which eventually leads to channelized water flow and rapid de-watering of the bed. This can be more delayed on sediment beds, where much high-pressure water can be retained in the sediment structure.

It might be beyond the scope of this paper to add such considerations, but I find them interesting, which is why I added them here.

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Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2020-243/tc-2020-243-RC2-supplement.pdf

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Fig. 1.