

TC-2022-237

3<sup>rd</sup> revision

**Brief Communication: Rapid ~335 10<sup>6</sup> m<sup>3</sup> bed erosion after detachment of the Sedongpu Glacier (Tibet)**

Andreas Kääh, Luc Girod

**3<sup>rd</sup> revisions, response to editor**

Editor comments in *blue italic*, author responses in normal font. (Combined font characters did unfortunately not translate correctly from the pdf of the editor comments into the below text).

*Thanks a lot for having responded to the new comments during the second round of revisions and for having updated the manuscript accordingly. When comparing the current manuscript to the version at the stage of initial submission (December 2022), I think it is fair to say that the manuscript has improved in clarity and that the additional details that you added make the story very interesting, also for those who are not directly in the field of glacier geomorphology/erosion/hazards (like me). I am convinced that this short, yet very clear story will be of interest to the readers of The Cryosphere. After reading the latest version of your manuscript, I have formulated a series of mostly minor and easy to incorporate suggestions that I hope you will find helpful. I invite you to consider these comments, after which we should normally be able to proceed to the final acceptance of your manuscript.*

We would like to thank the editor for the careful and detailed comments and suggestions on this version of the manuscript. Below are our point-by-point responses.

- *l.12: probably best to have a consistent use of m<sup>3</sup> or km<sup>3</sup> to make quantities directly comparable. Not only here, but throughout the manuscript.*

We put 0.6 km<sup>3</sup> in brackets after 600 10<sup>6</sup> m<sup>3</sup> for non-expert readers less familiar with millions of m<sup>3</sup>. This should have been the only km<sup>3</sup> unit in the manuscript.

- *l.15-16: this last sentence of the abstract was quite difficult to understand. Consider rewriting to something along the lines of: "...the Himalayas. This high-magnitude low-frequency event illustrates a potential for rapid post-glacial landscape evolution and associated hazards that have rarely been observed (at such high intensity) so far".*

Implemented

- *l.19: "...disappearance, these newly uncovered areas are..."*

Done

- *l.23: "...comparably slowly, over..."*

Done

- *l.26: not sure you need "respectively" here, since you do not refer to anything*

*menBoned before in a given order. Would suggest removing this here. Same for occurrence on l. 67.*

Done

- *l.29: "...indicaBon on the maximum..."*

Done

- *l.30: "...detachment, enBre..." (also other occurrences where a "," would be needed: e.g., in l. 53 "Obu et al. (2019), ..."), l.99 ("..study site, only very...")*

Done, and we rely on the proof reading to find other occasions.

- *l.36-38: hard to understand. Possibly change to: "We summarize key site informaBon on the 2018 glacier detachment, and quanBfy the glacier-bed volume changes and other landscape changes in the basin unBl 2022" (possibly even add unBl which month in 2022)*

Done

- *l.40: for the study site descripBon, in the current formulaBon, it seems like there is no glacier remaining at all? While in reality a part of the glacier survived / did not collapse? Would be good to specify this a bit more. Also, to frame it becer, maybe start the sentence with: "At the Bme of its detachment, the Sedongpu glacier was..."*

Clarified in section 2 and 4 that the tongue/lower glacier part detached. Reformulated as suggested.

- *l.40: elevaBon of about 3700 m: could you provide the elevaBon range of the glacier at the Bme of detachment? And possibly also for what is now remaining of the glacier?*

Included in sections 2 and 4, respectively.

- *l.42: "... The highest point"*

Done

- *l.43-44: extreme angles of the slopes: could you provide a quanBficaBon for this statement? What slope for the angles are we to expect here?*

Done (40-45 deg)

- *l.45: "...Tsangpo has an..."*

Done

- *l.52: "The wider study region..."*

Done

- *l.68: "...avalanches ran from the Gyala west flank over..."*

Done

- *l.72: "enBre tongue": so from this I tend to understand that the enBre glacier did not collapse? See related comment above. Would be good to have a quanBtaBve indicaBon about how much of the glacier was lost and e.g., the elevaBon range of the glacier before and aKer the collapse.*

Done

- *l.72: possibly reword to: "...detached, complemented by an addiBonal..."*

Done

- *l.82: yes, indeed quite high uncertainties for the ice thickness reconstruction. Aside from the change in velocity, the fact that relative errors are very large for velocities of slow-flowing glaciers also leads to a large (relative) error in the corresponding ice thickness reconstruction by Millan et al. (2022). Would be good to mention this in one or two additional sentences.*

Done

- *l.89: “unbl 2022” (add white space)*

Done

- *l.88-92: quite a long and fragmented sentence. Suggest splitting this up in two sentences, e.g., “and its surroundings, with maximum erosion depth of 360 m and an average of 135 m over an area of 2.5 km<sup>2</sup>, amounting to about 335±5 10<sup>6</sup> m<sup>3</sup>. This volume corresponds to about 2.5 times the detached glacier volume (Figs. 1-2...”*

Done

- *l.92: “...can be observed at limited...”*

Done

- *l.93: “...elevation changes from January...”*

Done

- *l.94: “...contribute by far to the largest...”*

Reformulated

- *l.110-111: “... (Yang et al., 2023). A new early...May 2022, and was then also...”*

Reformulated

- *l.118: glacier bed being “likely temperate”: is there any evidence for this statement? Measurements and/or modelling of glaciers in this region? Would be good to specify and provide additional info for this.*

We removed this statement. It was based on our interpretation of the climatology of the region, the regional permafrost limit, and the lack of continuous ice flow from the highest (= potentially coldest) parts of the catchment. (Nourishing of the glacier tongue is rather through avalanching). We prefer to remove the statement instead of adding a long discussion on the topic.

- *l.127: “contributed to the ice and sediment processes in the valley”: sounds a bit vague/mysterious here: can this be reformulated to be more specific? Or possibly remove this? (the sentence also works well without this)*

Reformulated

- *l.132: maybe reword to “...was able to transport most of the...”: i.e. omit “further”*

Done

- *l.136: “It would be interesting...”?*

Done

- *l.141: “In summary, between early 2017 and November 2022, around...”: and ideally, be even more specific for what early 2017 is (i.e., which month)*

Done

- *l.141: 659 +/- 7: this +/-7 remains a remarkably small error estimate (i.e., a mere 1% of the total volume)...*

Not really, 7 Mm<sup>3</sup> is quite a volume uncertainty and in itself equivalent to a huge event. It just appears small relative to the giant volume mobilized from Sedongpu. From the high-res satellite stereo data used such accuracy is well expected and not a surprise. The elevation accuracy does not scale with the lost volume, it remains largely constant.

- *l.141-143: suggest splitting up in two separate sentences: “...bedrock and sediments. About half of Bme volume (335 +/- 5 10<sup>6</sup> m<sup>3</sup>) is estimated to be eroded from the...”*

Done

- *l.144: “...in the lacer volume”: what is this exactly? Can you be more specific here?*

Clarified

- *l.151: “...could be particularly prone to erosion. This...” + on l.162: “...bed was much more prone to erosion than the...”*

Done

- *l.160: “...sediments, which are perhaps...”*

Done

- *l.169: very little precipitation. Has this been quantified, and could you provide a figure for these numbers? e.g., how this compared to other (standard) years, with this year having for instance X% less precipitation?*

We reformulated. This refers to the Suppl. Figures. The main point is that none of the datasets consulted gives an indication of strong precipitation that could have driven the erosion. Relative amounts compared to other years are less important in this context. And, given the uncertainties of all these datasets for the remote and extreme mountain topography of the study region, we prefer to not quantify precipitation amounts from these.

- *l.172: “...terrain gradients. Numerical modelling”: i.e., suggest removing the “though” here.*

Reformulated

- *l.174: other glacier detachments. Can you mention here how many detachments these are? e.g., “...detachments (X in total) listed in Kääh et al. (2021)”*

Done

- *l.175: suggest rewording to: “..., we do not find as important extreme erosion in these other cases compared to Sedongpu, but...”*

Done

- *l.178: “...potentially pronounced soft sediments...”*

Done

- *l.180: “...most glacierized mountains on Earth”: reference for this statement?*

Done

- *l.200: when calculating the size of the hypothetical catchment, you may want to refer to how*

*much larger this is than the actual catchment, e.g., "...catchment (X times more than actual size of the catchment)"*

Clarified that the 250,000 km<sup>2</sup> is actually the actual mountain catchment size of Brahmaputra, not a hypothetical size.

We also added one more sentence with another equivalent for the Sedongpu erosion volume, in late response to ref #2 who asked for long-term/large-scale perspectives of the Sedongpu volumes: *Multiplying the Sedongpu Glacier catchment area (50 km<sup>2</sup>) by vertical motion rates of 5 mm yr<sup>-1</sup> (Zhao et al., 2023) gives an uplifted volume of 250 10<sup>6</sup> m<sup>3</sup> 1000 yr<sup>-1</sup> indicating that the rock and sediment volumes recently eroded from Sedongpu are roughly equivalent to the volumes uplifted over 1–2 millennia for the entire catchment, neglecting density differences.*

- *l.211: unclear what signal is in change of GLOFs. Would be worth mentioning recent study in Nature by Veh et al. (2023), who suggest that GLOFs are reducing in frequency (<https://www.nature.com/articles/s41586-022-05642-9>). Eventually, in warm future climate, frequency will reduce if glaciers are very small to inexistent: if there's no glacier, it cannot produce a GLOF anymore... Although could indeed expect a rise at first with strongly changing glaciers and large amounts of melt: i.e., a bit like peak water concept for glaciers, but then instead for GLOFs.*

We prefer to leave the (vague, admitted) text as is in order to not discuss glacier lake outburst flood frequency over time (which time-scale?), as this is a complex issue that we don't want to rise at the very end of our brief communication. Veh et al (2023) refer to ice-dammed lakes. For moraine-dammed lakes, Harrison et al. (2017; <https://doi.org/10.5194/tc-12-1195-2018>) suggest a lagged increase in response to glacier shrinkage. This topic is currently debated in the community (e.g. also Veh et al. 2019; doi: 10.1038/s41558-019-0437-5). In response to a referee, we want here to just mention that the observed erosion volumes can also be seen in comparison to lake outbursts.

- *l.214-215: last sentence, in which you seem to directly make a link with climate change. But are we sure this is the case and that this event can (statistically) be attributed to climate change? It may be more likely due to climate change (from the limited evidence we have), but need to be careful to explicitly make this link. A bit in same line as collapse of Marmolada glacier last summer (e.g., EGU 2023 abstract by Gascoin and Berthier): could this event not have occurred without climate change? Difficult to make concluding statements about this without dedicated calculations and (many/detailed) field observations and measurements.*

Clarified that we refer to the disappearance of a glacier rather than directly to climate change. We believe our study shows an extreme case of what erosion volumes and speeds can develop after glacier loss.

*Thanks a lot for considering these comments. I look forward to receiving an updated (final?) version of your manuscript. And thank you once again for choosing 'The Cryosphere' for disseminate this interesting brief communication.*

Thank YOU!

**From the Copernicus team:**

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Done