Dear Editors,

Dear Authors,

thank you for giving me the opportunity to review the manuscript nhess-2021-167 entitled "Glacial lake outburst flood hazard under current and future conditions: first insights from a transboundary Himalayan basin" by Simon K. Allen and co-authors. In this study, Allen et al. considered worst-case scenarios to model outbursts from three glacier lakes (among those one that might appear in the future) in the Poiqu basin, Chinese Himalaya. These simulations are thought to give guidance in decision and designing early warning systems to mitigate some of the impacts that GLOFs have repeatedly brought to the Poiqu basin in the past. Using the modelling software Hec-RAS, the authors found large differences in maximum flow depths and arrival times of the simulated flood waves at Nyalam, a rapidly growing settlement in close vicinity to the Nepalese border. These findings demonstrate the transboundary hazard that GLOFs may pose to mountain communities. The manuscript is well-written, offers good illustrations, and is (with few exceptions) clearly understandable, also to a broad audience.

Major comments

Allen et al. used a suite of well-established tools to assess possible trigger mechanisms of GLOFs, and to model hydro-mechanical characteristics and runouts of the flood waves. Unfortunately, the authors missed the opportunity to couple such triggers with the subsequent failure of moraine dams. Recent software such as r.avaflow have recently improved the understanding of GLOF processes[1–3], allowing for pseudo-probabilistic assessments of GLOF triggers and impacts under a range of adjustable and testable boundary conditions. However, given that the authors considered only three worst-case scenarios of moraine-dam failure, largely decoupled from the initial triggers, I see only limited progress in calculating the likelihood of observing a GLOF of a given magnitude, though this is repeatedly stated in the manuscript. Clearly, the authors present a thorough expert-based assessment of potential conditioning or triggering factors. Yet it remains unclear how this traditional, rather subjective procedure brings GLOF hazard and risk assessment forward with regards to the many previous case studies that we saw in the past years[4–13]. Thus, the authors' goal to estimate "the core hazard dimensions of GLOF magnitude and likelihood (or probability)" (L245-246) only remain partly fulfilled in my opinion. If this manuscript is intended to improve early warning and risk management, then the reader (at best a person involved in such tasks) might expect a more objective use of the terms hazard or probability, that is a numeric value between zero and one. A probability or return period might provide a robust baseline for decision makers compared to the current distinction between a 'high' or 'low' level of susceptibility or impact. Fortunately, most of the data (including high-resolution DEMs and satellite images) for such an extended appraisal already come with this manuscript. I thus would like to encourage the authors to revise their manuscript accordingly, considering a much wider range of scenarios in order to proceed towards a more objective assessment of current and future GLOF hazard in their study region.

More detailed and technical comments

In the following line-by-line comments, I wish to add more details to these issues. I also point at locations that could either deserve more attention or that could be shortened.

- L6: 'far reaching': in terms of run-out? Social consequences? Media coverage?

- L10: 'well-known dangerous': please consider avoiding subjective terms.
- L26-27: 'Based on … capacity building programs': Hardly mentioned in the text, consider revising or deleting.
- L39: 'rapidly in both size and number': how much? Consider using recently multi-temporal glacier lake inventories[14,15].
- L40: What is the frequency of GLOFs in the Himalaya? If I am not mistaken, most researchers deem GLOFs a low rate of occurrence.
- L47f: 'Such lakes can have volumes >100 m³', according to ref. [16]
- L69: 'within the eastern Himalayan region': why there?
- L75: 'are lacking': suggest to tone this a bit down, as it undermines previous appraisals[17–19].
- L79-82: Is this statement valid for all glaciated high mountains? Or only the Himalayas?
- L89-91: The last sentence could be deleted, if shortening is needed. The introduction ends well with a strong presentation of the research goals.
- L93: 'considering potential GLOF impacts'
- L97: 'mean annual air temperature'
- L99: are these precipitation rates (I think these are monthly?) the maximum or the average recorded in a given period?
- L105: 'GLOF danger': replace with 'GLOF hazard'?
- L107: 'losses of up to US$4 million': is this in today's currency?
- L111-112: 'a large and persistent threat, considered as one of the most dangerous lakes in Tibet': suggest to tone this down again. Given that previous appraisals used different criteria and thresholds, we may wish to avoid confusion what is now the 'most dangerous lake' in a given region.
- Figure 1: Please highlight the border between Nepal and China.
- L139: So estimating lake depth comes with zero uncertainty?
- L150: To my knowledge GlabTop models the glacier thickness in a bedrock topography. Did the authors add the moraine on top of this bedrock depression? How high / wide is this moraine? If not, how susceptible is a bedrock depression to overtopping? Did the authors consider sediment input from supraglacial debris into the lake?
- L155: Please consistently use Fig. / Fig / Figure (or any other option) throughout the manuscript. Sometimes the abbreviation is written with a dot, sometimes not.
- L154-164: the PFV approach may underestimate the amount of water that is generated from mass flows entering the lake and causing a splash wave. Given that the authors consider ice avalanches and landslides entering the lakes, how useful is it to use the PFV approach?
- L156: The PFV concept further seems to confuse mean and maximum depth. Why should the drain empty completely if the depth of the breach is equal to the mean depth of the lake? Again, the assumption of a fixed breach depth might simplify (or even underestimate) the worst-case scenario of GLOF volumes.
- L162-163: 'In comparison, … (Xu, 1988)': what is this comparison good for?
- L165: 'the DEM accuracy is unknown': what is the accuracy of the 1-m DEM then?
- L171-172: Again no uncertainties in these equations? Propagating estimates through Equations 1-4 might have already generated a substantial amount error that remains not completely untouched in the remainder of the manuscript. Also, why did the authors not choose a physical dam break model such as BASEMENT[20]?
- L180: What is the mechanism that causes overtopping? A splash wave? Or overflow by a (gradually) growing lake volume?
- L189: 'Uniformity of land cover and lack of vegetation': strong statements - please show this. Source for the chosen value of Manning's n?

- L201-2014: I found it somehow confusing to see first the paragraph on flood modelling, followed by a paragraph that describes potential causes for this flood. Again, it may sound a bit harsh, but considering these triggers decoupled from the flood routing models seems to represent not the state of the art in GLOF modelling. Determining the likelihood (again without a probability) for a rock or ice avalanche from a fixed angle of reach might be suitable for a large-scale assessment of GLOF susceptibility that pursue a rapid screening for sites that need more attention. Here, the authors have identified such sites, so there is (from my perspective) no need to rely still on the more traditional side of GLOF susceptibility appraisals. In other words, if there is a potential for rock to detach, what could be its size? How rapidly may this rock avalanche enter a lake? What would the displacement wave look like? It also remains unclear why the authors had chosen exactly those susceptibility factors in Table 3 (or 2). Suggest to add references to this table that showed if these susceptibility factors in deed had positive (+) relevance for triggering a GLOF.
- L205: There seems to be a referencing issue: The item Table 3 must be Table 2.
- L222: ‘cannot’: ‘may not’?
- L217-231: It’s good to know about historic changes in glacier velocity and elevation, but these insights seem to be decoupled from the future lake development. Please try to make this link clearer or consider deleting.
- L241: Please elaborate more on what you mean with ‘replicate’.
- L237-243: Do these scenarios also consider accelerated lake growth and glacier retreat, once the lake has formed?
- L246: ‘probability’: again, there is no probability involved in this study. ‘exposure of buildings’ has not been mentioned in the Methods. ‘A full hazard … assessment … is beyond the scope of this study’: why then calling this paper then a hazard assessment in the title?
- L250: Why did the simulations stop the border? Isn’t it one of the goals of this paper to show the transboundary hazard from GLOFs?
- L266: Why are the flow depths of 25m more realistic? Calls for some sensitivity analysis.
- L274-276: Again, very simplified assumption on sediment entrainment and aggradation.
- L285: ‘significant’: how much?
- L287: ‘high-impact low-probability’: How high is this impact and how low is this probability?
- L288: ‘requires more sophisticated modeling’: unclear why this has not been considered in this specific case study that offers the data to do this sort of modeling.
- L301: ‘likelihood or probability’: replace with ‘possibility’?
- L310: ‘low’: how low?
- L311: ‘can be effectively discounted’: why? And how efficient?
- L316: ‘large slope instabilities’: In-SAR might help to detect those?
- L326-347: Most of this section could be redundant or offer much more potential for discussion, if the authors considered a suite of lake impacts in this study.
- L343: ‘making this a high magnitude, but very low likelihood process chain’: how high is this magnitude and how low is the likelihood?
- L344-345: ‘active instabilities are clearly evident’: so, why not show these?
- L349-355: Similar to the comments above, it remains unclear, how the authors define the likelihood (or magnitude) of a GLOF.
- L360: ‘Con.’, ‘Trig.’, ‘Mag.’: please write out fully. ‘Catchment drainage density’: why is this important. ‘TP = 3280’: Unclear what this means, please explain. ‘Steep moraine slopes >500 m high’: really? A 500 m high moraine dam?
- L372: How complete is OSM in this region?

- L387: ‘While we did not simulate beyond the border owing to the limited coverage … ‘: needs to come earlier.
- L435: ‘applied these approaches for the first time’: really?
- L436: What is ‘complex’ in this topography?
- L444-447, and again L455ff: The artificial drainage of Jialongco somehow undermines parts of this paper, given that the simulations use the lake volume before the drainage, right? It would have been good to show how simulated flood magnitudes (flow depths, extent of the inundation, etc.) change because of the reduced flood volume, and if this in turn changes GLOF risk. In essence, if the probability of a given flood magnitude decreases (= hazard), then risk must also decrease, assuming constant values of exposure and vulnerability. It thus remains unclear why this insight has been held out from the introduction and all subsequent analysis.
- L458: ‘had only a minimal effect on the overall lake size’: Unclear conclusion with regards to Fig. 9.
- L463: ‘would reduce the threat to these buildings’: contradicts to what is written some sentences above?
- L470-483: largely repetitive from the Results, consider substantial shortening or deleting.
- L495-499: Content of these sentences unclear, even if formulated ‘in other words’. Please rephrase or shorten.
- L501: When talking about early warning, why not using the calculated flood arrival times to provide a solid basis for discussion? What do the authors suggest to implement in such an early warning system? How can people response to the warning?
- L503-504: ‘under the philosophy of preparing for the worst, while hoping for the best’: please avoid jargon.
- L504: ‘complex transboundary regions’: what is complex here and how can this study help to understand this complexity?
- L523-525: Not sure whether the increase in GLOF risk has been quantified in this study?
- L528-529: ‘Hard engineering strategies that address only the hazard source are a socially and environmentally less desirable option’: Not sure whether I can agree with this statement: If Hazard = 0 (because there is no lake), then Risk = 0. Consider revising or deleting this statement.

References

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