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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Modeling the Glacial Lake Outburst Flood Process Chain in the Nepal Himalaya: Reassessing Imja Tsho's Hazard" *by* Jonathan M. Lala et al.

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Review of "Modeling the Glacial Lake Outburst Flood Process Chain in the Nepal Himalaya: Reassessing Imja Tsho's Hazard" (hess-2017-683) by Lala et al.

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Summary

Lala et al. present results from a modelling study that assesses the possible downstream impacts of a glacial lake outburst flood (GLOF) initiated by an ice avalanche into Imja Tsho, in the Nepal Himalaya. Imja Tsho has attracted a great deal of attention

because it is a large and growing lake surrounded by steep slopes, is bounded by an ice-cored moraine that could lose integrity over time, and because it is situated just a few km upstream from the village of Dingboche. Hence, if it were to burst, some have suggested that the impacts to Dingboche could be severe. Lala et al. critically examine this possibility and come to the conclusion that the risk to downstream communities is actually much lower than found in previous studies. Overall, I think this is a generally coherent and well-executed piece of work that will be of broad interest. I do, however, have a number of suggestions and questions that I think need to be addressed first before this manuscript could be published in full.

General comments

First, the authors have made a good case here for undertaking this study, and have outlined clearly how their modelling approach compares with previous efforts. This indicates novelty in their work. However, Imja Tsho made headlines in October 2016 when the Nepalese Army were deployed to undertake some engineering work to lower the lake, and thereby reduce GLOF hazard. Whilst the authors allude to this recent change briefly in the Introduction (P2 L23), it seems that this change (reported by the BBC to be a lowering of 3m) has not been considered in this study. For example, the bathymetric survey undertaken by the authors was completed in June 2016, several months before the lake lowering. Ultimately, my question here is: to what extent does the manual lake lowering affect the relevance of your results? For example, maybe the lake lowering by the army is insignificant in the grand scheme of things because the glacier will continue to recede (as you say in section 2.2), and occupy new overdeepenings, etc. But I think there should be more mention and consideration of this recent change in the size/volume of the lake.

Second, on p16 you mention something about the depth of erosion required to meet the ice core in the moraine, which got me thinking about ice-cored moraine degradation. From your results, it seems that the lake only really becomes a worry from 2045 because of the potential interaction with ice avalanches. Your model assumes that the

ice-cored moraine remains in a steady state (i.e. same elevation as today) over the period to 2045 and beyond. Or have I misunderstood? Is there any evidence that the moraine height and composition will change as the ice core degrades with climate amelioration? Is it right to assume that the moraine complex will stay the same to 2045? What implications does that have for your modelling? A quick google revealed this study, which may be instructive: Watanabe et al (1995) Mountain Research & Development, 15, 4, 293-300. I would like to see some discussion/consideration of how moraine lowering and progressive loss of internal ice might affect its susceptibility to being breached.

Third, you have focused on ice avalanche impact into the lake, and you make mention of some situations that you haven't modelled for (e.g. piping through the moraine), which is fine. But could the same steep slopes around the lake lead to rock avalanches or landslides into the lake, even in its current (smaller) configuration? Is the area prone to seismic shaking, which could weaken the dam or increase the potential for landslide impacts?

Fourth, in the abstract and elsewhere (e.g. Discussion), you mention how this study is reproducible with open access software, etc. But the RAMMS software costs money. Is it really fair to say that any stakeholder could access these bits of software and run the models?

Finally, the writing is generally good, but there are a lot of places where there is perhaps a lack of precision. I have listed these below in the minor comments section.

Minor comments

Abstract – I think you need to mention here that the lake was manually lowered. Seems to me to be a key part of the story that is missing from your summary.

P2 L2 – capitalise 'Earth'

P2 L3 – do H-K rivers really supply $\frac{1}{4}$ of the world's people with water? I note that the

reference you use is 10 years old – a time in which the global population has grown by $\sim$0.5 billion people.

P2 L9 – you should perhaps cite Quincey et al (2007) in Global & Planetary Change who examined influence of surface slope and velocity on lake formation. Indeed, you should mention velocity as a factor here.

P2 L10 – you need to say that it is through coalescence that these ponds grow to become lakes. You should perhaps also cite Benn et al (2001) in J Glac.

P2 L24 – can you say something about the amount of lake lowering by the army? Depth, volume, area changes? Needs quantitative information.

Figure 1 scale bar – seems odd to have labelled divisions of 1.25 and 2.5km, and the tick marks at 0.625km spacing. Simplify.

Figure 1 caption – you should perhaps state the source of the background image and ensure you have permissions to reproduce it. Likewise, it appears that the inset is from another paper, which is cited. But do you have permission to reproduce it here?

Figure 1 – how have you determined the dark blue areas of hanging ice? Steepness threshold from a DEM? Needs to be stated.

P4 L7 – to me, 'physically modelling' something would be a laboratory experiment, which is not what you are intending to do. I think you mean something along the lines of modelling a realistic process chain, but I'll leave the wording up to you. I don't think you mean physical modelling though.

P4 L13 – suggest you replace the word 'significant', which has specific statistical connotations.

P4 L25 – this aim confuses me. "This study seeks to assess a comprehensive set of models to evaluate. . .". This makes it sound as though you are testing the models themselves, AND evaluating the hazard. Is that possible? Is that what you're really

doing? Or is it that you are 'employing a comprehensive set of models to evaluate GLOF risk' (or words to that effect)? The last part of the sentence is also confusing – using easily replicable methods – surely the models ARE the methods? Would it be better here to split this into two sentences, the second saying, "This model chain represents an easily replicable method. . .".

P5 L3. Missing full stop.

P5 L4 – I think this statement is too general. Surely it's more relevant here to replace 'climate change' with 'glacier recession and thinning', or even 'risks associated with glacier recession' or similar. Fine to mention climate change, but the impacts are very broad indeed.

P5 L14 "an environmental flow software" – awkward wording

P5 L22-5 – is this how you have identified the blue shaded areas on Fig 1? If so, I think you need to refer to Fig 1 here somewhere.

P5 L30 –perhaps you need to present this as a full range of possible volumes.

P6 L13 – was the bathymetric survey done before or after the lake lowering work by the Nepalese Army?

P6 L24 – ok, but lake has been lowered by $\sim$3m by the army.

P8 L32 – data are plural

P10 L18 – "and an area was" doesn't make sense

P11 L7 – overdeepenings of the glacier BED, not the glacier itself.

Fig 4 inset – what do these graphs show exactly? This needs to be explained in the figure caption.

P12 L9 – what do you mean by "through 2045"? In the lake modelled for 2045 and forward in time from that point? Unclear.

P12 L10-11 – Here again some imprecision. Be careful. It reads to me as though the avalanche impacts the lake in 2025, but the resultant wave-induced erosion happens in 2045, which is clearly not what you mean to say! Reword.

Fig 8 caption – I think you need to say where these cross-sections are (i.e. in a channel) and that the locations of the transects is shown in Fig 6.

P19 L24 – in this paragraph you state that you have not modelled all scenarios of GLOF initiation, which is fair enough. But should rock avalanches or landslides be included in this list? What is the likelihood of a big slope failure into the lake, even in its current configuration? Is there significant seismic hazard here, which could enhance the possibility of slope failures?

P20 L18 – to a case study at Imja Tsho

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