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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Potential flood volume of Himalayan glacial lakes" *by* K. Fujita et al.

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We thank the reviewer for his valuable comments. We partly restructured similar comments and replied to them. Our replies are denoted by a header [Reply].

- The PFV is not the main factor to assess the hazard of a glacier lake. Although the PFV is already more suitable than only the lake area, other factors such as dam properties, slope of the downstream river leaving the lake, availability of loose sediments, etc. are (at least equally) important for assessing the hazard. This might also be a reason why many glacier lakes that previously have been reported as potentially dangerous are not considered to be critical with the presented approach (P21L1-4). - The term "likely risk" (e.g. P16L23 and P18L2) should be avoided. Fist, because "risk" is defined as the product of the probability of occurrence (or return period) and the vulnerability. In this study, vulnerability is not considered at all, thus "hazard" is a much more ap-

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propriate term. Here, “likely risk” could be replaced, for instance, by “probability” or “probability of occurrence”. P17L22: Rather “significant” amount of lake water? Here I think as well that overtopping of the dam (for instance for glacier lakes with a rock dam) could release a large amount of water (see events in the Andes). This also refers to the third point of the general comments. P19L17-18: Such a lake would not have a risk for a break of a moraine dam. But in case of a large mass falling into this lake, a displacement wave could anyway drain a considerable part of the lake water volume, even when having a solid rock dam.

[Reply] We understand that many aspects have to be considered for comprehensive risk assessment. However, we simultaneously suppose that there is no guideline how many aspects or indices are sufficient for the assessment. If dam-collapse gets started, high PFV lake will result in more serious consequence than small PFV lake. Therefore we think that the PFV index suggests a kind of risk. As we described in the manuscript, anyhow, we did not assert that the PFV was the perfect index which solely made risk assessment possible. We mentioned that the other aspects such as possible triggers or vulnerability along the downstream, which the PFV was unable to evaluate, had to be taken account for more comprehensive assessment. We emphasized that the PFV made prioritization possible for further detailed investigations. High PFV does not imply high probability of GLOF occurrence while the minimum distance (MD) may be related to probability of occurrence as we already discussed (P23L3-12). Although the PFV is not a sole risk index, which was repeatedly mentioned in the manuscript, this is a part of risk indices. We deleted ’occurring’ (P18L2) and use ’likely hazard’. In the revised manuscript, we will not omit the related descriptions of hazard assessment. We will mention that some of the other aspects require expertise to be assessed, and are unable to be evaluated by remote sensing techniques. We will also emphasize that previous assessments were rather subjective and showed no obvious criteria based on past events. And we will emphasize that the PFV make prioritization possible for further detailed investigations.

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- In my view it is problematic to only consider lakes with PFVs of more than 10 million m3 as potentially dangerous. There are events even in the Himalayas (e.g., Dig Tsho, as mentioned in the text), but also in other mountain regions of the world (South American Andes, European Alps) with much smaller flood volumes that caused heavy damages downstream. Hence, I think it is fine to further focus on lakes with PFVs of more than10 million m3, but I would not use this as a threshold for defining a lake as critical or not.

[Reply] We did not assert that lakes with smaller PFV are safe. We recognized the commented point so that we discussed the Dig Tsho Event in the manuscript (P23L16-22). On the other hand, it is impossible to prepare figures such as Fig. S1 for all lakes whose PFV is greater than zero ($\sim$1500 lakes). Instead, we will provide related information for all lakes as supplement if this manuscript is accepted. In order to avoid misunderstanding such as the critical PFV is 10 million m3, we changed the last part of abstract as bellow: The distribution follows a power-law function, and we identified 49 lakes with PFVs of over 10 millionm3. This PFV approach allows us to prioritize the Himalayan glacial lakes that require further detailed investigations.

- The approach is – as the authors state explicitly – not able to evaluate the dam material (i.e. moraine, rock, or potentially even ice). This, however, is a crucial aspect for the hazard assessment of glacier lakes. It would be interesting to compare the PFVs with estimated flood volumes from outburst events from rock-dammed glacier lakes. Of course the internal dam properties cannot be assessed in detailed in satellite imagery, but I think it is possible to identify moraine dams in many cases due to their typical shapes (cf. Figs. 4 and S1). Hence, I suggest mentioning explicitly in the text that this approach is designed for moraine-dammed lakes (which probably is the large majority of glacier lakes in the Himalayas), and that a rough guess of the dam material is possible by carefully looking at the imagery.

[Reply] We declared our approach was based on an assumption of succeeding collapse of moraine-dam (P17L20) and target lakes were confined to the moraine

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dammed lakes (P20L9-10). We suppose that some expertise is required to identify moraine-dam or rock-dam. As we wrote in the manuscript, one of merits of this approach is that less expertise is required. In addition, we cannot guarantee that moraine-dam is never misjudged as rock-dam though the opposed misjudgment (rock-dam as moraine-dam) may not cause serious consequence in hazard assessment aspect. In this study, therefore, we think that precise judgment whether rock-dam or moraine-dam is not important (this has to be conducted in further analysis if someone likes), and dam property is better not to be judged on remote sensing data with moderate resolution such as ASTER, which may cause any misjudgments. We do not change the related description.

Regarding the structure of the text, the following points should be addressed and improved: - Add a section or sub-section on data used. First, it is not clear to me if the inventory of the 2276 glacier lakes has been exclusively created for this study. If so, some more details of the underlying 146 ASTER scenes should be given, for instance the acquisition dates.

[Reply] We will provide supplement table in which granule ID of ASTER data, acquisition date, longitude and latitude of the image center, and numbers of delineated and analyzed lakes.

Also the methodology for the mapping should be described in more detail. So far, only the Normalized Difference Water Index is mentioned, but nothing about if (or which) manual corrections have been applied.

[Reply] We added 'with manual corrections' after 'water index'.

Second, a description of the DEM data used for the determination of the steep look-down areas (SLA) for these 2276 glacier lakes is lacking completely; in only says in the abstract "the ASTER data". Did you use the ASTER Global DEM (GDEM)? (If so which version?) Or was this based on stereoscopic DEMS derived from the individual scenes? In any case some indications about the accuracy should be given.

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[Reply] Information of DEM (P18L14-21) and its accuracy (P21L19-22) were already described in the manuscript. We will change structure according to the comments from both reviewers and added short descriptions about this. But no significant change will be made.

- I suggest describing the methodology for the error assessment in or after the methods section instead of after the results. - The first part of the conclusions (from P23L14 to the middle of P24L8) is discussion rather than conclusions. This should be moved to the discussion section and the remaining short conclusions should be extended.

[Reply] We will change the structure and enrich the remaining conclusion.

P16L6: The description “depression angle from the lake shore” was not clear to me while reading this for the first time. I think here in the abstract it is appropriate to use a more descriptive formulation, e.g. “the angle between the outer dam front and the (flat) lake surface”.

[Reply] The suggested description "the outer dam front" is unclear for me. We only used "the flat lake surface" from your suggestion.

P16L9: I am not a native speaker, but I think “flooded” is more related to inundations thank outburst floods.

[Reply] This is corrected by native speaker but I inserted ’outburst’ before ’flooded’.

P16L16: Be more specific with “the ASTER data”: are these the scenes used to detect the glacier lakes or data used as DEM or for DEM generation?

[Reply] We used both data. I added ’visible band images and DEMs of’ before ’ASTER data’.

P19L5: Please give the source of the empirical relation given in Eq. 1.

[Reply] This is our own equation so that no reference is available. We deleted ’empirical’ and added ’obtained from several Himalayan glacial lakes’ before ’(Fig. 2)’.

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P20L13: Write “moraine-dam collapse”. An ice dam can also collapse; cases with extreme peak discharges are reported in the case of mechanical failures of ice dams caused by ice avalanches or surging glaciers.

[Reply] We corrected this.

P21L2-4: This sentence is hardly understandable to me. I understand this as “44 of the lakes that previously have been reported as potentially dangerous do not have a SLA”. If so, this is indeed an interesting finding which on the one hand challenges the previous hazard assessment; but on the other hand is could also confirm the concerns expressed in the general comments, i.e., that the PFV alone is not suitable to classify a glacier lake as potentially dangerous or not.

[Reply] As Dr. Margold pointed out, 23 out of 44 lakes, classified by Mool et al. (2001a, b) as potentially dangerous, are deemed safe by our criteria since these 23 lakes have no SLA. We will rewrite this part to avoid misunderstanding.

P21L26: What do you mean with “irregularly”? Pleas reword or rewrite.

[Reply] We separated the sentence into two as follow: Steep lakefront area (SLA) and associated potential flood volume (PFV) appeared (or disappeared) when the threshold angle has decreased (or increased). We found no regularity how large SLA or PFV appeared on which lake because the SLA depended on relative location among lakeshore and surrounding moraine, and the PFV depended on lowering lake level (related to the SLA) and lake area.

Figure captions in general: Placing the sub-figure letter (a, b, : : :) in front of the related descriptions eases the readability.

[Reply] We corrected the captions of Figs. 3, 6 and 7.

Table 1: Please give in the caption a link to Fig. 4 where these lakes are shown in more detail.

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[Reply] We added '(Fig. 4)' in the caption.

SUPPLEMENT Fig. S1: At least names of glacier lakes and the region where they are located, and maybe also Lat/Long and the image acquisition date should be included.

[Reply] We provide all information except for name and region in Table S2. We added "Details are listed in Table S2." in the figure caption. Only three formal names are available for us for the large PFV lakes (Tsho Rolpa (Rank 1), Thorthomi (Rank 11) and Shako Tsho (Rank 33) in Table S2) so that we excluded the name information. Instead, we will provide a set of files to access related information on Google Earth when the final paper is accepted. This will be helpful for readers to see individual glacial lakes in which the readers are interested.

Fig. S2, caption, second line: add "PFV = 0" to the parenthesis on the left and the PFV of this lake in 1975 to the parenthesis on the right.

[Reply] We added PFV information for both images.

TECHNICAL CORRECTIONS P16L16: Remove "the" before "ASTER data" P17L18: Write either "a debris fan" or "debris fans" P17L19: GLOF*s* P19L1: Delete either "ca." or "for instance" P20L15: Remove this sentence; it is a repetition of P19L23 P21L9: Place the reference to Table 2 directly into the parenthesis, after "10 million m3". At the current position it says that Table 2 gives an overview of major GLOFs, which is not the case P21L10: PFV*s* P22L2: Add "cumulative frequency" before "distributions" P22L26: Figure*s* 7a P23L4: I think this should be "Fig. 7c" instead of "3c"

[Reply] We corrected all points.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 15, 2013.