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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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The authors present a remote-sensing based approach to estimate the potential flood volume (PFV) of glacier lakes in the Himalayas. They developed a methodology, which is based on the depression angle between the flat lake surface and the surrounding terrain. Based on this angle, they (1) estimate if the lake has a potential for an outburst (which is the case if this angle is larger than 10°; this threshold was found by analyzing the pre-outburst conditions of five lakes that had a lake outburst in the past); and they use this depression angle to (2) determine the PFVs of the glacier lakes.

This approach is then applied to a dataset of more than 2200 glacier lakes in the entire Himalayan-Karakoram mountain ranges. Furthermore, an error evaluation considering the DEM accuracy and the influence of the threshold value for the depression angle is performed.



GENERAL COMMENTS

Given the large number of glacier lakes in this part of the world, most of them located in remote regions but nevertheless with potentially vulnerable infrastructure below, such an approach that relies purely remote sensing is very valuable. The performance of the index proofed to be in good agreement with reality (comparison of estimated PFVs with estimated flood volumes of real events). This methodology will thus become an important tool to easily, rapidly, and at low costs, determine the PFV of glacier lakes.

In my view, this is an important contribution to the scientific community. However, the methodology is limited to the determination of the PFVs, which can help to identify and prioritize future works; but it is not suitable to be included directly into hazard assessment procedures.

I have two general suggestions regarding this manuscript; one is to skip or at least rewrite the parts related to the identification of potentially dangerous lakes and other aspects of hazard assessments; the second addresses the structure of the manuscript.

Regarding hazard assessments the following points should be considered and adapted:

- 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).

- 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.

- 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.

- 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 appropriate term. Here, “likely risk” could be replaced, for instance, by “probability” or “probability of occurrence”.

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. 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. Second, a description of the DEM data used for the determination of the steep lookdown 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.

- 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.

SPECIFIC COMMENTS

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”.

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

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?

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.

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

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.

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.

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.

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

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

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

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.

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.

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”

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