

## ***Interactive comment on “Local land-use change based risk estimation for future glacier lake outburst flood” by S. Nussbaumer et al.***

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Interactive comment on “Local land-use change based risk estimation for future glacier lake outburst flood” by S. Nussbaumer et al.

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Reviewer: In addressing the comments of the reviewers please also take note of the additional comments below:

- I don't find the risk calculation approach used very convincing. You say you adapted the risk equation by Bründl et al. (2009), and calculate risk as  $R = I \cdot S \cdot V$ . As far as I can tell Bründl calculated risk as function of hazard probability, exposure (probability

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of an object being affected, value of the given object/element at risk, and its vulnerability – in my view quite different from your approach. Your conceptualisation reduces the first 2 terms to intensity, thus saying that you adapted their approach is somewhat questionable. Strictly speaking, risk indicates the expected losses due to a certain hazard type and magnitude for a defined time period (usually per year). Your risk concept includes nothing on the probability (and you state why) – explain this better. Also see my comment below on the exposure aspect (in the context of social vulnerability)

Author response: We aimed at bringing the widely applied risk-approach described by Bründl et al. (2009) into a form that fits to non-periodic events (which consequently cannot be assigned a return period as required by the Bründl et al. concept) and into a generalization degree which is feasible and practical for future conditions. These requirements inevitably point out the limits of this risk-concept. We appreciate your critical comments, as they show that we did not entirely achieve this aim and should spend more on discussing this fact. It is correct that explicitly the probability is missing in our adapted risk equation. Our approach is to ‘parameterize’ probability by using different hazard scenarios. In fact this is a common approach in hazard and risk assessments for non-stochastic processes (see e.g. Schneider et al., 2014, *Advances in Geoscience*). We recognize that we need to make this approach clearer and modify the text accordingly. Furthermore, as outlined in our response to the comments made by M. Mergili, we will modify the risk assessment using a matrix-approach as suggested by M. Mergili. This results in a strengthened risk framework. We add further explanation and arguments why and how we adapted the original risk approach proposed by Bründl et al. (2009) to the subject of future glacier lake outburst floods. In particular, we need to make clearer that in this case it is difficult to indicate probabilities of occurrence. A possibility is to assign qualitative probabilities to each flood scenario to get in line with the original risk concept (as mentioned above). Regarding the exposure aspect, please see our answer below.

– I think for people the exposure element could be included in the risk conceptualization

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(as you briefly discuss in the final section)

We are not entirely sure to what aspect of exposure this comment refers. Exposure of people in the sense of physical presence exposed to flood processes is included in our approach (the variable 'S' for people and buildings). If the comment refers to the probability of physical presence as originally foreseen in Bründl et al. (2009), then this aspect is not included in our approach. There is a number of reasons for which we think this would be barely feasible. Since we are dealing with future scenarios (decades ahead) different probabilities of exposure scenarios would be highly uncertain. Furthermore, different exposure scenarios according to different situations (day/night, summer/winter, etc) would have to be defined. As we plan to put one main focus of the revised paper on the importance of matrix definitions, involving even more scenarios with different exposure elements might make results confusing and we fear it would weaken our main points. Also, we aimed at elaborating a high-level of consistency in all dimensions at a coarse but reliable level of generalization. As the hazard part can only be roughly estimated, an overly detailed analysis of the damage potential would in our opinion bring an imbalance. We have always been aware of the limitations of our approach, as we also neglected other important elements, such as mortality. Consequently we never claimed our work a complete risk analysis, but risk estimation.

Nevertheless we fully recognize the need of adequate treatment of all important risk parameters. Therefore we plan to define which exposure situation the presented results could possibly refer to and to stronger outline the role of exposure in the risk conceptualization and in the discussion. We may also add that there is a large variety in literature how this aspect is handled. Gruber and Mergili (2013), for instance, implemented exposure only with the help of land-use.

- Reduce number of citations – including nearly 100 citations is excessive for this type of paper; also ensure that all citations in the text are included in the bibliography

P6: “: : were identified based on a literature review (CIPRA, 2010; OcCC, 2007; Müller,

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2005; BUWAL, 2003; ARE and UVEK, 2005; IPCC, 2012; Voigt et al., 2010; de la Vega-Leinert and Schröter, 2004), and interviews with the local planning authorities and the government representative (oral statement Michlig, 2011; oral statement Holzer, 2011).”

We worked over all references and eliminated about 20 (see also the similar comment of Referee 2). We completed the missing references in the bibliography.

- L19: “on socio-economic scenario” should be scenarios

Ok, we replaced it.

- L25: “quantification in driving forces” should be “of driving forces”

Ok, we replaced it.

- Remove the many double periods at the end of sentences

We deleted all redundant double periods.

- P9: isexpected

We corrected that.

- Explain better what the 2 intensity scenarios mean. It's not just a matter of water height, but given the amount of water surely also one of flow/impact velocity. In that sense, can a GLOF with a water height <2 m be considered medium? Please make this clearer

We fully agree that not the entire process understanding is included in this classification. This is however the official classification for debris flow intensities given in Swiss guidelines. As we aimed at producing Swiss-relevant results, we stuck to this incomplete definition.

- P10, Vulnerability: Please rework the sentence: “The definition and use of vulnerability varies depending on the conceptual approach and its relation to risk (cf. ATEAM,

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2004; UNISDR, 2009; Dow, 1992; Cutter et al., 2009).” Vulnerability is understood to be the capacity for loss. Citing publications that use now outdated definitions is not very useful. Also define social vulnerability (e.g., “people’s differential incapacity to deal with hazards, based on the position of the groups and individuals within both the physical and social worlds”, Clark, GE, Moser S, Ratick S, Dow K, Meyer WB, Emani S, Jin W, Kasperson JX, Kasperson RE, Schwarz HE (1998) Assessing the vulnerability of coastal communities to extreme storms: the case of Revere, MA, USA. *Mitigation Adapt Strat Glob Change* 3(1):59–82.

We recognize that vulnerability is a complex concept, and especially, one that is used in a wide range of contexts, with different approaches and applications. We do not understand why the references given should be outdated as they are reflecting the diversity of modern concepts of vulnerability. UNISDR 2009 is certainly an authoritative reference and defines vulnerability as: “The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.” This publication also mentions the many aspects of vulnerability, including physical, social, economic or environmental factors. The IPCC Special Report on Extreme Events (SREX) published in 2012 is certainly another major reference we can add to the list. This publication defines vulnerability as “The propensity or predisposition to be adversely affected”. This quite general definition, by the way, is also maintained now in the IPCC 5th Assessment Report to be published in 2014. We think it is basically consistent with the comment and the reference defining vulnerability as ‘the capacity for loss’. The question is how to operationalize this concept, and the many aspects. We recognize that we need to further embed our vulnerability approach in the broader literature, at least we are interpreting this comment in this direction.

- In the discussion on social vulnerability it would be worth commenting on the time it takes between a GLOF occurring and expected impact in the various settlements, which allows an assessment of the possibility of early warning and possibly some evacuation/relocation measures. Even if there are only a few minutes before impact there

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might be enough time to flee to higher ground/higher floors in strong buildings. This will reduce the overall risk, and is interesting to be discussed in the context of social vulnerability (those poorer/foreign/disadvantaged people may have higher a SV). I also assume that by 2045 (if not long before then) some form of monitoring of the lakes will take place, allowing effective early warning (you only briefly touch on this point on P18). Elaborate on this point

We fully agree, that an early warning system is one important risk reduction option. It is, however, not the only feasible measure and it primarily prevents from loss of lives. Possible measures in this context are also e.g. retention dams, which would prevent or reduce damage to properties. In our understanding of risk management, the procedure is to first assess the situation as it is without any risk reduction measures taken (expect of already existing measures), and then carrying out further risk analyses for all feasible mitigation measure separately. This analysis indicates the risk reduction introduced by every measure and helps decision makers to estimate the cost-benefit ratio for every possible mitigation measure. Our analysis aims at fulfilling to the first objective, while your suggestions targets at the second step. For the purpose of our paper (discussion of the relevance of the matter and presentation of the assessment approach), we suggest staying with our original analysis, mainly because we don’t have the necessary details that would be required to implement the time and evacuation aspect in the social vulnerability. We will, however, certainly elaborate in the discussion section more on these aspects brought forward by the comment in relation to risk reduction measures and highlight the importance of early warning systems with the help of currently installed systems (such as, Grindelwald lake (Switzerland) or Laguna 513 (Peru).

- P15: the sentence “Very high physical vulnerability, however, is predominantly present at the marginal areas of the case study area, as it mostly belongs to agricultural and unproductive areas.” makes little sense to me: vulnerability must always be assessed with respect to a given hazard type and

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hazard magnitude. In Fig 1 you show that the GLOF scenarios predominantly affect the southern part of the study area, close to the blue runout line. What is really the expected hazard event magnitude along the northern edge that is marked as high physical vulnerability? It also is not clear why forest and unproductive lands (fallow/unused land?) have very high vulnerability, while built-up areas/residential areas exposed to higher GLOF intensities have lower vulnerability (again, recall that vulnerability is capacity for loss due to a certain hazard type and magnitude – hard to see what losses you expect for categories such as unproductive land). Explain better

Under physical vulnerability we understand the degree of impairment experienced by an object under an impact of a process with a certain intensity (Bründl, 2009). In that sense an unprotected area (for example forest) can be more vulnerable than e.g. concrete buildings, even when the quantitative loss would be higher. This is in line with official government guidelines in Switzerland, i.e. the platform economy (BAFU, 2011a) of which we extracted the values for physical vulnerability. However, we agree that there is a certain potential for confusion, as the comment indicates, and will therefore add further explanation in the text, elaborating in more detail on the assumptions taken on vulnerability (as much for physical as for social).

- P15: “Contrary to the value for physical vulnerability, marginal areas featured low social vulnerability.” I think the discussion of variable social vulnerability only makes sense if you discuss it in the context of exposure and early warning/evacuation. If you have a situation where the GLOF catches the entire community by surprise the vulnerability will only be a function of hazard intensity (and perhaps physical vulnerability of the building the people happen to be in), but social vulnerability will be identical. It only becomes relevant in a situation such as early warning messages that may not be received or understood by everyone, or evaluation that is hampered by large family sizes, lack of transport or similar indicators for people with high SV. Discuss better

We understand the argument of this comment. Actually, it depends on the risk approach that is applied to what degree variable social vulnerability is relevant. In strict

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terms, risk is the probability of a negative outcome or loss (e.g. UNISDR, 2009 and several other publications). If we ‘stop thinking’ at the point of destruction of assets and loss of (or harm to) life, then the comments made may be adequate. In many vulnerability and risk assessments, however, aspects of social vulnerability (e.g. poverty, level of education and information, etc.) are taken into account because they influence the ability of people to take preventive measures, to appropriately evacuate, or the ability to recover from loss. We would like to include these aspects in the concept of social vulnerability but we recognize that we need to provide additional explanation to make these issues clearer to the readership.

Regarding the comments of the reviewers:

- Use of “Cf.” in principle seems ok to me, but check if it’s also ways appropriate (in that it stands for “see also”/ “compare with”)

Ok, we checked all literature in the course of the reduction of references. Where a change was necessary we replaced it.

- Reviewer 1 already correctly remarked that multiplying your ordinal category values is not meaningful – this is a critical issue that must be carefully addressed This comment has been elaborated and discussed carefully. An appropriate solution has been found and implemented (see comment of Referee Mergili).

We appreciate the constructive and very helpful comments by the editor Norman Kerle.

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 4349, 2013.

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