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*Emerging risks from glacier vanishing and lake formation in cold mountain ranges**

Wilfried Haeberli
Geography Department, University of Zurich,
Switzerland

As a consequence of continued global warming, rapid and fundamental changes are taking place in high-mountain regions. Within decades only, many still existing glacier landscapes will probably transform into new and strongly different landscapes of bare bedrock, loose debris, numerous lakes and sparse vegetation. These new landscapes are then likely to persist for centuries if not millennia to come. During variable but mostly extended parts of this future time period, they will be characterized by pronounced disequilibria within their geo- and ecosystems. Intensive work on such aspects is presently carried out in Switzerland (cf. references).

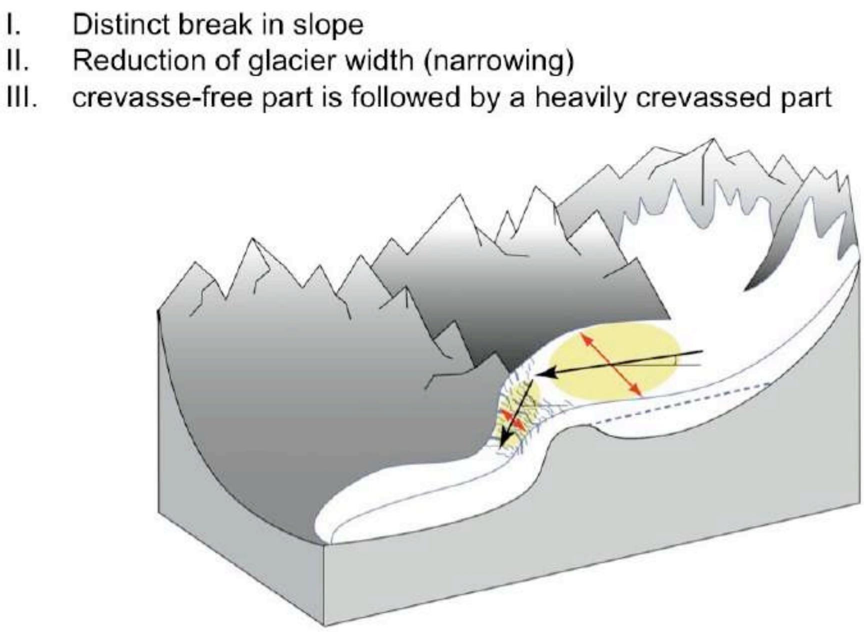

Figure 1: Morphological criteria to detect sites of probable overdeepenings (closed topographic depressions with an adverse slope in the flow direction) in glacier beds with potential lake formation as a consequence of continued future ice retreat and vanishing. The criteria especially apply to valley-type glaciers/glacier parts (where the largest new lakes are likely to form) and can easily be used in connection with Google Earth. Note that over-deepened bed topography is only

likely to occur where glacier surface inclination over larger areas is < 5°. A first and rapid approximation for detecting potential future lake sites is, therefore, simply to define glacier surfaces with slopes < 5°. From Frey et al. (2010,a).

The mentioned disequilibria include long-term stability reduction of steep/icy mountain slopes as a slow and delayed reaction to stress redistribution following de-buttressing by vanishing glaciers and to changes in strength and hydraulic permeability caused by permafrost warming and degradation (Haeberli 2013; Haeberli et al. 2013, a). With the formation of many new lakes in close neighborhood to, or even directly at the foot of, so-affected slopes, the probability of far-reaching flood waves from large rock falls into lakes is likely to increase for extended time periods. Quantitative information for anticipating possible developments exists in the European Alps (Haeberli et al. 2013,b). The present (2011) glacier cover is some 1800 km^2, the still existing total ice volume 80 ± 20 km^3 and the average loss rate about 2 km^3 ice per year. The permafrost area has recently been estimated (Böckli 2013) at some 3000 km^2 with a total subsurface ice volume of 25 ± 2 km^3; loss rates are hardly known but are certainly much smaller than for glaciers – probably by at least a factor of 10. Based on a detailed study for the Swiss Alps (Linsbauer et al. 2012), total future lake volume may be assumed to be a few percent of the presently remaining glacier volume, i.e. a few km^3 for the entire Alps. Forward projection of such numbers into the future indicates that glacier volumes tend to vanish much more rapidly than volumes of subsurface ice in permafrost, and lake volumes are likely to steadily increase. Already during the second half of the 21st century, more subsurface ice in permafrost may remain than surface ice in glaciers. Several hundreds of smaller and larger new lakes as anticipated and modeled in presently still glacierized areas (Figure 1; Frey et al. 2010, a and b; Linsbauer et al. 2012) are likely to form and then to coexist with, or even be surrounded by, largely de-glaciated/de-buttressed over-steepened slopes and mountain peaks with thermally

Figure 2: Fundamental changes in hazard conditions as related to the disappearance of glacier ice and the formation of lakes (cf. Haeberli et al. 2010). Due to the possible triggering of large impact waves and far-reaching flood waves by mass movements from the surrounding destabilizing slopes, lakes at the foot of steep icy mountain flanks are multipliers concerning the probability and reach of high-mountain hazards in inhabited down-valley regions.

disturbed and degrading permafrost. Similar scenarios are likely to take place in many other cold mountain chains. Using integrated spatial information on glacier/permafrost evolution and lake formation together with models for rapid mass movements, impact waves and flood propagation in connection with vulnerability considerations related to settlements and infrastructure, hot spots of future hazards from flood waves caused by large rock falls into lakes can already now be recognized in possibly affected regions (Frey et al. 2010,b; Linsbauer et al. 2009, 2012; Künzler et al. 2010; Schaub et al.; in press). This enables in-time planning of risk reduction options, which may include adapted spatial planning, early-warning systems, improved preparedness of local people and institutions, artificial lake drainage or lake-level lowering, and flood retention optimally in connection with multipurpose structures for hydropower production (cf. Terrier et al. 2011) and/or irrigation.

Dealing with emerging risks from new lakes in immediate proximity of step icy mountain peaks means to deal with events of low probability but high damage potential. Over longer future time periods and with continued ice loss, the probability of disastrous events is steadily increasing. An illustrative recent case with minor damage but considerable remaining risk is the rock/ice avalanche from Nevado Hualcán into Laguna 513 in 2010 (Carey et al. 2012; Haeberli 2013)

References:

Böckli, L. (2013): Characterizing permafrost in the entire European Alps : Spatial distribution and ice content. PhD thesis, Geography Department, University of Zurich.

Carey, M., Huggel, C., Bury, J., Portocarrero, C. and Haeberli, W. (2012): An integrated socio-environmental framework for glacier hazard management and climate change adaptation: lessons from Lake 513, Cordillera Blanca, Peru. Climatic Change112, 3, 733-767.

Frey, H., Haeberli, W., Linsbauer, A., Huggel, C. and Paul, F. (2010, a): A multi level strategy for anticipating future glacier lake formation and associated hazard potentials. Natural Hazards and Earth System Science 10, 339-352.

Frey, H., Huggel, C., Paul, F. and Haeberli, W. (2010, b): Automated detection of glacier lakes based on remote sensing in view of assessing associated hazard potentials. 10th International Symposium on High Mountain Remote Sensing Cartography, Kathmandu. Grazer Schriften der Geographie und Raumforschung 45, 261-272.

Haeberli, W. (2013): Mountain permafrost — research frontiers and a special long-term challenge. Cold Regions Science and Technology (2013). http://dx.doi.org/10.1016/j.coldregions.2013.02.004

Haeberli, W., Clague, J.J., Huggel, C. and Kääb, A. (2010): Hazards from lakes in high-mountain glacier and permafrost regions: Climate change effects and process interactions. Avances de la Geomorphología en España, 2008-2010, XI Reunión Nacional de Geomorphología, Solsona, 439-446.

Haeberli, W., Paul, F. and Zemp, M. (2013, a): Vanishing glaciers in the European Alps. In: Fate of Mountain Glaciers in the Anthropocene. Pontifical Academy of Sciences, Scripta Varia 118.

Haeberli, W., Schaub, Y., Huggel, C. and Boeckli, L. (2013, b): Vanishing glaciers, degrading permafrost, new lakes and increasing probability of extreme floods from impact waves – a need for long-term risk reduction concerning high-mountain regions. Geophysical Research Abstract, Vol. 15, EGU2013-3273.

Künzler, M., Huggel, C., Linsbauer, A. and Haeberli, W. (2010): Emerging risks related to new lakes in deglaciating areas of the Alps. In: J.-P. Malet, T. Glade, N. Casagli (eds) Mountain Risks: Bringing Science to Society. Proceedings of the 'Mountain Risk' International Conference, 24-26 November 2010, Firenze, Italy, CERG Editions, Strasbourg, France, 453-458.

Linsbauer, A., Paul, F. and Haeberli, W. (2012): Modeling glacier thickness distribution and bed topography over entire mountain ranges with GlabTop: Application of a fast and robust approach. Journal of Geophysical Research 117, F03007, doi:10.1029/2011JF002313

Linsbauer, A., Paul, F, Hoelzle, M., Frey, H. and Haeberli, W. (2009): The Swiss Alps without glaciers – a GIS-based modelling approach for reconstruction of glacier beds. Proceedings of Geomorphometry 2009. Zurich, Switzerland, 243-247.

Schaub, Y., Haeberli, W., Huggel, C., Künzler, M., Bründl, M., in press. Landslides and new lakes in deglaciating areas: a risk management framework. Proceedings of the Second World Landslide Forum, 3.-7. October 2011, Rome.

Terrier, S., Jordan, F., Schleiss, A.J., Haeberli, W., Huggel, C. and Künzler, M. (2011): Optimized and adapted hydropower management considering glacier shrinkage scenarios in the Swiss Alps. Proceedings of the International Symposium on Dams and Reservoirs under Changing Challenges - 79th Annual Meeting of ICOLD, Swiss Committee on Dams, Lucerne, Switzerland (Schleiss, A. & Boes, R.M., Eds), Taylor & Francis Group, London, 497 - 508.

* *= this text is a modified version of Haeberli et al. (2013)*