Earth Surface Dynamics Discussions

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Comment on esurf-2022-12

Jan-Christoph Otto (Referee)

Referee comment on "Volume, evolution, and sedimentation of future glacier lakes in Switzerland over the 21st century" by Tim Steffen et al., Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2022-12-RC2, 2022

The authors present a study on the future evolution of glacial lakes beneath glaciers in Switzerland. While this task has been previously performed for the same study area using a comparable approach, this study adds three significant new aspects to the procedure. The authors use an ice thickness model that is based on a large data set of GPR measurements for many glaciers (1). Even though the spatial assessment of the ice thickness is still based on models, the models used here have the potential to be more close to reality compared to the previous approaches that where based on glacier surface topographies only. Furthermore (2), the approach uses an established model to simulate the release of the potential overdeepenings by modelling glacier volume changes in relation to climate change for different climate scenarios. Finally, (3) the study for the first time accounts for the potential refilling of the exposed overdeepenings by generating a time- and space-dependent approximation of the sedimentation rate at various future stages of catchment and glacier evolution. This approach tackles the highly relevant uncertainty of the true lake evolution and potentially generates a more realistic picture of potential future lakes, despite other sources of uncertainty.

The study is well laid out and the manuscript has been produced with great diligence and logic. The methods applied uses data and approaches based on various previous studies published in the recent past. Therefore, methods description is focusing on references to existing papers. Solely the approach to quantify the sediment infill rate adds a new methodological step in this study. This approach is clearly presented, even though some issues arise (see below). However, the procedure presented is convincing and represent a logical way of assessing this critical parameter of lake sedimentation, where very little data is available so far. All results are clearly presented and visualized at good quality. The discussion states the relevant and critical aspects and implications of the approach and topic in general. The authors compare their results to two previous similar studies considering a good agreement with the approach by Linsbauer et al. (2012) and larger discrepancies to the other previous study.

I consider the manuscript a valuable contribution to the issue of future evolution of glacial lakes. Especially the accounting for sediment refill adds an important new dimension and the results in relation to future glacier and sediment dynamics present highly valuable new insights into the future of glacial and proglacial sedimentary systems, despite the rather simple approximation of glacial erosion and lake sedimentation. It therefore represents a significant improvement compared to previous studies and is worth publishing. I have only few comments and minor issues to consider.

Specific comment:

Section 3.3. – I have some concerns with the use of the variable α_{crit} in the estimation of the Sed_{in} components. For (1) abrasion, the variable makes sense as is. For (2), increase in deglaciarized area, and (3), glacial and periglacial erosion, I would suggest to reconsider your approach or the description of it. From my understanding α_{crit} represents the mean slope of all glaciers of the SGI2016 (L196 "α_{crit} are critical values for mean thickness and slope that correspond to an average Swiss glacier"). For parameter (1), it makes sense to me to use an overall mean for all glacier in the equation. Here you compare h and slope of individual glaciers with overall means across the SGI2016 dataset to generate an index of abrasion, which differs between glaciers due to size and topography. However, for parameter (2) and (3) I think it would make more sense to use α_{crit} as the mean slope of the individual glacier and not the overall mean. Since all other terms of the equation are referring to the individual glacier, I don't understand why slope does not. Maybe it's just a mistake in describing the equations. Please reconsider this issue.

Minor comments:

L63 add Otto et al. (2022) to the list for completeness

Otto, J.-C., Helfricht, K., Prasicek, G., Binder, D. & Keuschnig, M. (2022) Testing the performance of ice thickness models to estimate the formation of potential future glacial lakes in Austria. Earth Surface Processes and Landforms, 47(3), 723– 741. Available from: https://doi.org/10.1002/esp.5266

L147ff – Check the phrasing here with respect to the term "mean bedrock topography" . Previously you generated the bedrock topography from the ice thickness models, now you

go the other way…this does not make sense. I guess here you simply use the mean ice thickness model and not the bedrock topography. This would be in accordance to the Huss and Hock (2012) approach.

L154 – replace or with for

L188/189 – Erodibility is also affected by bedrock lithology. Sediment availability is equally important with respect to the tools required for abrasion. The former could probably not be accounted for here, while the latter is somehow represented by your consideration of headwall erosion. Please mentions these in the text.

L192 and L206ff – glacial and periglacial erosion….I would suggest to term this part solely periglacial or better headwall erosion (like you do in figure 5B), since you refer to the headwall area here only. Glacial erosion is represented by the approximation of abrasion in (1). Headwall erosion would include both processes, periglacial and feedbacks by glacial erosion.

206 – consider adding some more recent references like:

SANDERS, J. W., CUFFEY, K. M., MOORE, J. R., MACGREGOR, K. R. & KAVANAUGH, J. L. 2012. Periglacial weathering and headwall erosion in cirque glacier bergschrunds. Geology, 40, 779-782.

And/or

HARTMEYER, I., DELLESKE, R., KEUSCHNIG, M., KRAUTBLATTER, M., LANG, A., SCHROTT, L. & OTTO, J. C. 2020. Current glacier recession causes significant rockfall increase: the immediate paraglacial response of deglaciating cirque walls. Earth Surf. Dynam., 8, 729-751.

L386ff – In the methods section you described to quantify sediment infill rates in kg/m³ runoff. How do you relate these to erosion rates? (also relevant for figure 5B)

Figure 1 A: rename the legend items...it seems like you depict the total deglaciated area and not the total lake area as described in the figure caption. What does "1e6" represent at the upper left and lower right corners?