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Increasing hazard from glacial lake outburst floods in ice-free Himalayas

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Sustainable development in the high mountains of Asia such as the Hindu Kush, Karakoram, Himalayas and the Nyainqentanglha will largely depend on how glaciers respond to atmospheric warming. Several thousand meltwater lakes dot the wider Himalayan mountain range today, and this number could nearly triple, if all glaciers melted eventually. These newly created depressions will trap water and sediment, and some might empty catastrophically. Such glacial lake outburst floods (GLOFs) are among the most publicised natural hazards, and widely expected to occur more frequently with ongoing glacier retreat and meltwater production. The released water volumes have often met downstream communities unprepared with fatal consequences for human lives and infrastructure, not least because objective and reproducible GLOF hazard appraisals focused on only a handful of glacial lakes.

We quantify GLOF hazard by predicting the 100-year flood discharge (Q_{p100}) for more than 5,500 present glacial lakes and nearly 9,500 depressions that glaciers may expose assuming they melt completely in the future. We used a Bayesian model to obtain 10^5-10^8 posterior estimates of peak discharge Q_p per lake, depending on its geometry and physically plausible breach rates. To estimate the contemporary Q_{p100} in the Himalayas, we finally coupled all predictions of Q_p from present lakes with an empirical annual GLOF rate of 1.26 in the past 30 years. We estimate a contemporary Q_{p100} of 11,000-15,000 m^3 s^{-1}, which is consistent with the largest reported Himalayan GLOF discharges in past decades. Our estimates highlight the Eastern Himalayas as the region with the highest present GLOF hazard, in line with the highest historical GLOF count in this region. First-order simulations of GLOF hazard from projected depressions show that future Q_{p100} could nearly double in an ice-free future, assuming that the GLOF rate will remain unchanged. The region of highest GLOF hazard may thus migrate into the Karakoram where the largest glaciers exist today.

While the average Himalayan river runoff is expected to increase by few percent within the 21^{st} century, we find that the peak GLOF discharges in our model may exceed hydrometeorological river discharge by orders of magnitude. Our predictions of GLOF discharges thus call for a practical implementation in building design codes, flood hydrology and hazard mitigation.