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Climatic vs. tectonic control on glacial relief

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The limiting effect of a climatically-induced glacial buzz-saw on the height of mountain ranges has been extensively discussed in the geosciences. The buzz-saw concept assumes that solely climate controls the amount of topography present above the equilibrium line altitude (ELA), while the rock uplift rate plays no relevant role. This view is supported by analyses of hypsometric patterns in orogens worldwide. Furthermore, numerical landscape evolution models show that glacial erosion modifies the hypsometry and reduces the overall relief of mountain landscapes. However, such models often do not incorporate tectonic uplift and can only simulate glacial erosion over a limited amount of time, typically one or several glacial cycles. Constraints on glacial end-member landscapes from analytical, time-independent models are widely lacking.

Here we present a steady-state solution for a glacier equilibrium profile in an active orogen modified from the mathematical conception presented by Headley et al. (2012). Our approach combines a glacial erosion law with the shallow ice approximation, specifically the formulations of ice sliding and deformation velocities and ice flux, to calculate ice surface and bed topography from prescribed specific mass balance and rock uplift rate. This solution allows the application of both linear and non-linear erosion laws and can be iteratively fitted to a predefined gradient of specific mass balance with elevation. We tested the influence of climate (fixed rock uplift rate, different ELAs) and tectonic forcing (fixed ELA, different rock uplift rates) on steady-state relief. Our results show that, similar to fluvial orogens, both climate and rock uplift rate exert a strong influence on glacial relief and that the relation among rock uplift rate and relief is governed by the glacial erosion law. This finding can provide an explanation for the presence of high relief in high latitudes.

Headley, R.M., Roe, G., Hallet, B., 2012. Glacier longitudinal profiles in regions of active uplift. Earth and Planetary Science Letters, 317–318, 354-362.