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# The influence of glacier ice temperature on the long-term evolution of longitudinal valley profiles: Can a landscape escape from the "glacial buzzsaw"?

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The long-term pattern of glacial erosion in alpine valleys leads to characteristic longitudinal valley profiles. While landscape evolution models commonly take glacier sliding velocity to be the dominant control on erosion, the influence of spatial and temporal variations in glacier ice temperature on the efficiency of erosion over long timescales (>1 Ma) remains largely unexplored. Yet, the thermal field of a glacier can strongly influence the pattern of sliding. Temperate glaciers, with basal temperatures at the pressure melting point (PMP), slide whenever and wherever the glacial hydrology produces high water pressures. In contrast, in polythermal glaciers, erosion efficiency is strongly linked to basal ice temperature; when and where basal ice temperatures are below the PMP sliding, and hence erosion, are limited.

We present results from numerical models in which we explore the influence of variations in glacier ice temperature on long-term glacial erosion processes in alpine valleys. These simulations are motivated by the persistent appeal of geomorphologists to polar glacial conditions to explain sites of unusually low glacial erosion rates.

We employ a transient 1D (flowline) ice flow model that numerically solves the continuity equation for ice, and includes a depth-averaged approximation for longitudinal coupling stress. We prescribe separate winter and summer surface mass balance profiles: a capped elevation-dependent snowfall pattern in winter, and we capture both daily and seasonal oscillations in ablation using a positive degree day algorithm in summer. The steady-state ice temperature within the glacier is calculated using the conventional 2D (cross-sectional) heat equation (i.e. diffusion, advection and production terms) at a prescribed interval. The ice temperature model uses the surface temperature at the end of each melt season as the surface boundary condition, and a prescribed geothermal gradient as the basal boundary condition. Basal sliding is limited to sites where the basal ice is at the PMP. Glacial erosion rate is parameterized as a function of sliding velocity, which in turn depends upon a flotation fraction that is parameterized to account for annual variations in the glacial hydrologic system.

We explore the long-term glacial erosion pattern when the landscape is subjected to different rock uplift rates, and to climates ranging from continental to maritime. Of specific interest to us are conditions that favor polythermal glaciers in which the basal ice at high elevations becomes cold. In such cases, rock uplift can outpace limited glacial erosion, allowing high peaks to escape from the "glacial buzzsaw" while basal ice at lower elevations remains at the PMP, allowing sliding and erosion. These simulations also allow a more formal assessment of the conditions under which cold basal ice can be invoked to explain low glacial erosion rates, and the conditions under which variations in rock erodibility may instead be invoked as the major control on erosion.