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Erosion by an Alpine glacier

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Most mountain ranges on Earth owe their morphology to the action of glaciers and icecaps over the last few million years. Our current understanding of how glaciers have modified mountainous landforms has mainly been driven through landscape evolution models. These have included an array of erosion laws and mainly progressed through the implementation of various levels of sophistication regarding ice dynamics, subglacial hydrology or thermodynamics of water flow. However, the complex nature of the erosion processes involved and the difficulty of directly examining the ice-bedrock interface of contemporary glaciers has precluded the establishment of a prevailing erosion theory. Here we quantify the spatial variations in ice sliding velocity and erosion rate of a fast-flowing Alpine glacier in New Zealand during a 5-month period. By combining high resolution 3D measurements of surface velocity from optical satellite imagery with the quantification of both the production and provenance of sediments by the glacier, we show that erosion rates are proportional to sliding velocity raised to a power of about two. This result is consistent with abrasion theory. Given that the ice sliding velocity is a nonlinear function of ice thickness and ice surface slope, the response of glacial erosion to precipitation changes is highly nonlinear. Finally, our ability to constrain the glacial abrasion law present opportunities to further examine the interaction between glaciation and mountain evolution.