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Constraining catchment-scale glacial erosion using a global inversion of detrital CRN data in the Himalayas of Central Nepal

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Glacial erosion is a first-order control for the evolution of high-elevation, glaciated, active orogens, where motion of glaciers over the bedrock has been proposed to be a highly efficient factor of landscape erosion. Understanding the mechanisms of glacial erosion and quantifying its magnitude is a central question for a number of studies in geomorphology, tectonics or climate sciences. It has, for example, been proposed that the glacial system could be imposing strict limits on the elevation of mountain ranges. If true, glaciers form a central piece in the complex puzzle of the climate-erosion-tectonics interactions.

Whereas a number of theoretical functional expressions for glacial erosion have been proposed, there are still very few effective quantifications of this process in steep and high mountain environments. This study aims at providing some insight on the magnitude of glacial erosion in the Marsyandi catchment of Central Nepal where abundant data are already available concerning the gradients in rock uplift, exhumation, fluvial erosion, and precipitation.

We collected and processed one of the densest dataset for detrital CRN in the Himalayas, with a total of 35 samples analysed for 10Be for the Marsyandi River and its major tributaries. The 10Be concentration along the Marsyandi displays a complex evolution pattern, with high concentrations in the highly productive upstream areas trending toward lower downstream concentrations due to the dilution of signal by the actively uplifting Higher Himalayas.

The method we use attempts to extract information on glacial erosion by assessing the magnitude of dilution induced by glacial sediments on the CRN signal at the catchment scale. We interpret the final CRN concentrations that we observe in our samples as a mixing between two contributions: (1) sediments derived from the fluvial domain, where we assume that erosion is proportional to stream power and (2) sediments derived from the glacial domain, that we assume to contain no CRN. We define a spatial structure for glacial erosion considering that it is constant at the sub-catchment scale. For each data point, we derive a relation expressing the local mass balance between the fluvial and glacial contributions. We merge this set of equations into a linear system that we invert to derive average glacial erosion rates for each sub-catchment and the erosion efficiency coefficient that relates stream power to fluvial erosion.

To our knowledge, this study is the first attempt for such near-field quantification of glacial erosion at the catchment scale. The inverted glacial erosion rates range from $\sim$3 to $\sim$10 mm/yr. They display a clear dependency with respect to the distribution of precipitation and predict that the most erosive catchments are located in the wet, southern flank of the range, whereas those located farther north in the rain shadow display relatively modest glacial erosion rates.