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A new method to determine channel slopes as a proxy for erosion rates

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Major parts of quantitative tectonic geomorphology are based on the stream-power law. It states that the fluvial erosion rate is a function of SA^{θ} where S is the channel slope, A the catchment size, and $\theta \approx 0.5$ the so-called concavity index. Therefore, deriving channel slopes at given catchment size from DEMs is a key to determining erosion rates from topography. However, computing slopes directly from differences in elevation of neighboring nodes introduces a considerable statistical variation due to the limited accuracy of the DEM, so that smoothing is required.

In this study we present a novel method to determine representative slopes at a given catchment size A involving a large set of DEM points significantly reducing the statistical uncertainty. In a first step, all catchments of a given size $A_{\max}$ (e.g., $4A$) are delineated, and only those DEM points with catchment sizes above a value $A_{\min}$ (e.g., $\frac{A}{4}$) are considered. Then, local fluvial equilibrium topography according to the stream-power law is fitted to the elevations in each catchment, allowing for the computation of the representative channel slope at each catchment size $A \in [A_{\min}, A_{\max}]$. Two approaches to take into account non-fluvial processes at small catchment sizes have also been implemented. One of them allows that θ varies from catchment to catchment, and the other one assumes that the erosion rate is proportional to $S\,(A^{\theta} + o)$ with a variable offset o.

The method was tested for several mountain belts and two DEMs (SRTM3 and ASTER GDEM). For the 3 arc second DEM (SRTM3) the new way to determine representative slopes reduces the variance of slopes over the entire orogen roughly by a factor of 4 compared to computing the slopes directly from the DEM. This means that about three quarters of the overall variation in slope arises either from the limited resolution or accuracy of the DEM or from temporal variations. The effect is slightly smaller for the 1 arc second DEM (ASTER GDEM), but is remarkably similar for the considered mountain belts. In particular, there seems to be no clear correlation between the goodness of the approximation by local fluvial equilibrium topographies and the degree of glaciation in the past.