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Constraining the Stream Power Law: a novel approach combining a Landscape Evolution Model and an inversion method

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In the past few decades, many studies have been dedicated to our understanding of the interactions between tectonics and erosion. To predict river channel evolution, the Stream Power Law (SPL), which links erosion rate to drainage area and slope ($E = KA^mS^n$), remains the most widely used erosion model in the community. Despite its simple formulation, its power lies in its capacity to reproduce many of the characteristic features of natural systems (the concavity of river profile, the propagation of knickpoints, etc.). However, the three main coefficients that are needed to relate erosion rate to slope and drainage area in the SPL remain poorly constrained. In this study, we present a novel approach to constrain the SPL coefficients under the detachment limited mode by combining a highly efficient Landscape Evolution Model, FastScape and an inversion algorithm, the Neighborhood Algorithm. A misfit function is built by comparing topographic data of a reference landscape supposedly at steady state and the same landscape subject to both uplift and erosion over one time step. By applying the method to a synthetic landscape, we show that different landscape characteristics can be retrieved, such as the concavity of river profiles and the steepness index. When applied on a real catchment (in the Whataroa region of the South Island in New Zealand), this approach provides well resolved constraints on the concavity of river profiles and the distribution of uplift as a function of distance to the Alpine Fault, the main active structure in the area.