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Fault activity and the distribution of river slopes and co-seismic knickpoint heights: statistical modelling and implications for river dynamics and paleo-seismology

Philippe Steer (1), Thomas Croissant (1,2), Edwin Baynes (1), and Dimitri Lague (1)

(1) Univ Rennes, CNRS, Géosciences Rennes - UMR 6118, F-35000 Rennes, France, (2) now at Department of Geography, Durham University, Durham, UK.

Most landscape evolution models adopt the paradigm of constant and uniform uplift. It results that the role of fault activity and earthquakes on landscape building is understood under simplistic boundary conditions. Here, we develop a statistical model generating earthquakes, including mainshocks and aftershocks, on a fault plane that respect the classical scaling laws observed for earthquakes. The distribution of seismic and aseismic slip can be partitioned following a spatial distribution of mainshocks along the fault plane. Slope patches, such as knickpoints, induced by fault slip are then migrated at a constant rate upstream a river crossing the fault. This new model produces co-seismic knickpoints with a uniform height distribution for a fully coupled fault, i.e. with only co-seismic slip. Increasing aseismic slip at shallow depths, and decreasing shallow seismicity, censors the range magnitude of earthquakes cutting the river towards large magnitudes and leads to less frequent but higher amplitude knickpoints, on average. Inter-knickpoint distance or time between successive knickpoints follows an exponential decay law. Using classical rates for fault slip, 15 mm.yr^{-1} and knickpoint retreat, 0.1 m.yr^{-1}, leads to high spatial densities of knickpoints requiring sub-metric spatial resolution to distinguish them. The correlation between the topographic profiles of successive parallel rivers cutting the fault remains positive for distance along the fault of less than half the maximum earthquake rupture length. Considering simple scenarios of fault burial by intermittent sediment cover, driven by climatic changes or linked to earthquake occurrence, leads to knickpoint distributions and river profiles markedly different from the case with no sediment cover. Our results suggest that river topography can be used for paleo-seismological analysis and to assess fault slip partitioning between aseismic and seismic slip.