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Analyzing point patterns on river networks – tools and applications in tectonic geomorphology

Wolfgang Schwanghart (1), Christian Molkenthin (2), Dirk Scherler (3,4)

(1) University of Potsdam, Institute of Earth and Environmental Science, Potsdam-Golm, Germany (w.schwanghart@geo.uni-potsdam.de), (2) University of Potsdam, Institute of Mathematics, Potsdam-Golm, (3) GFZ German Research Centre for Geosciences, Earth Surface Geochemistry, Potsdam, Germany, (4) Freie Universität Berlin, Institute for Geological Sciences, Berlin, Germany

Numerous natural phenomena such as landslides, tectonic faults and lithological contacts spatially intersect with rivers and such intersections form distinct geometric point patterns. The spatial arrangement of the points provides potentially important insights into the development of river networks and the underlying controls. However, a systematic approach towards analyzing the generated point patterns and comparing them to those simulated by a hypothesized process model was rarely considered.

We address this research gap by adopting methods from point pattern analysis, a branch in statistics that studies the spatial arrangement of points. Specifically, we employ methods of point pattern analysis on networks in three case studies. First, we investigate spatial patterns of landslides and their controls in the wake of the 2015 Gorkha Earthquake in Nepal. Second, we model the distribution of knickpoints and their headward retreat on the Roan Plateau, Colorado, and, third, we look at a dense array of knickpoints and their patterns in knickzones in the Big Tujunga river.

We implement a new class (PPS - Point Patterns on Stream networks) in the MATLAB-based digital terrain analysis software TopoToolbox and demonstrate how point pattern analysis provides a systematic approach to test hypothesized models of landslide susceptibility and knickpoint dynamics. Based on simulation envelopes using bootstrap techniques we quantify model uncertainties and identify potential controls based on statistical inference. Finally, the developed tools will not only be useful for studies in tectonic geomorphology but for applications of point patterns on directed networks in general.