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Clustering river networks in heterogeneous landscapes

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The structure and organization of river networks has been used for decades to investigate the influence of climate and tectonics on landscape form. The majority of these studies either analyze rivers in profile view by extracting channel steepness, or calculate planform channel metrics like drainage density or tributary junction angles. However, these techniques rely on the assumption of homogeneity: that both intrinsic and external factors are spatially or temporally invariant over the profile that is being measured. This assumption is violated for the majority of Earth's landscapes, where variations in uplift rate, rock strength, climate, and geomorphic process are almost ubiquitous.

We propose a new method for identifying and classifying river profiles into groups with similar morphology, with the aim of identifying parts of the landscape with similar climatic, tectonic, or lithological characteristics. Our method involves adapting hierarchical clustering algorithms developed for the analysis of one-dimensional time series data for use with river long profiles. We firstly test our clustering on two simple landscape evolution scenarios to explore the performance of the method where the prior uplift and erosion histories are constrained. We find that our method is successfully able to cluster regions with different erodibility, as well as isolating the effects of the transient response of a river network to a sudden base level fall event. By calculating k_s separately for each cluster, our method allows the extraction of more reliable channel steepness metrics than if these metrics are calculated for the landscape as a whole. We then test our method in two real landscapes with high-resolution topographic data: firstly in Bitterroot National Forest, Idaho, where we show that our clustering can distinguish between parts of the landscape above and below a transient incision wave when the lithology is relatively homogeneous. Our second test case is from Santa Cruz Island, California, which has a more complex tectonic history as well as lithological variation. In this site we find that lithology is the dominant control on river profile morphology despite the preservation of transient features such as knickpoints, hanging valleys, and marine terraces. These two examples demonstrate the ability of our method to disentangle fluvial morphology in complex lithological and tectonic settings.