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Analytically based forward and inverse models of fluvial landscape evolution during temporally continuous climatic and tectonic variations

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Fluvial channels respond to changing tectonic and climatic conditions by adjusting their patterns of erosion and relief. It is therefore expected that by examining these patterns, we can infer the tectonic and climatic conditions that shaped the channels. However, the potential interference between climatic and tectonic signals complicates this inference. Within the framework of the stream power model that describes incision rate of mountainous bedrock rivers, climate variability has two effects: it influences the erosive power of the river, causing local slope change, and it changes the fluvial response time that controls the rate at which tectonically and climatically induced slope breaks are communicated upstream. Because of this dual role, the fluvial response time during continuous climate change has so far been elusive, which hinders our understanding of environmental signal propagation and preservation in the fluvial topography.

An analytic solution of the stream power model during general tectonic and climatic histories gives rise to a new definition of the fluvial response time. The analytic solution offers accurate predictions for landscape evolution that are hard to achieve with classical numerical schemes and thus can be used to validate and evaluate the accuracy of numerical landscape evolution models. The analytic solution together with the new definition of the fluvial response time allow inferring either the tectonic history or the climatic history from river long profiles by using simple linear inversion schemes.

Analytic study of landscape evolution during periodic climate change reveals that high frequency (10-100 kyr) climatic oscillations with respect to the response time, such as Milankovitch cycles, are not expected to leave significant fingerprints in the upstream reaches of fluvial channels.

Linear inversion schemes are applied to the Tinee river tributaries in the southern French Alps, where tributary long profiles are used to recover the incision rate history of the Tinee main trunk. Inversion results show periodic, high incision rate pulses, which are correlated with interglacial episodes. Similar incision rate histories are recovered for the past 100 kyr when assuming constant climatic conditions or periodic climatic oscillations, in agreement with theoretical predictions.