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A new efficient, $O(n)$ and implicit method to solve the Stream Power Law taking into account sediment transport and deposition

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The Stream Power Law (SPL) has been widely used to represent incision by rivers, but it does not take into account the role played by sediment in modulating erosion rate and/or deposition. Several parameterizations have been proposed to improve the SPL, including a recent formulation proposed by Lague and Davy (2009). It assumes that the net rate of topographic change is the sum of the incision rate (controlled by the SPL) and deposition rate which is proportional to the local suspended sediment flux (estimated from the integrated net erosion rate) and inversely proportional to discharge (and thus drainage area). Here we present an efficient, i.e. $O(n)$ and implicit, method to solve the SPL that includes the role of sediment flux on landscape evolution using the Davy and Lague (2009)'s formulation.

We demonstrate its applicability by performing a range of simulations based on a simple setup composed of an uplifting region adjacent to a stable continental area on which a foreland basin is allowed to develop. At the outlet of the catchments that form in the uplifting region, small sedimentary fans develop that progressively coalesce into a larger one. As uplift and erosion progress, fan-apex elevation and fan slope increase with increased elevation of the uplifting region. The fan progrades to reach the edge of the model where sediment is allowed to leave the system. This yields to the formation of a steady state geometry both in the uplifting region and in the foreland basin.

Using the model we not only show how the stratigraphy of the foreland basin is controlled by the efficiency of river incision (through the SPL coefficient K_f) and the efficiency of rivers to transport sediment (through the dimensionless deposition coefficient G), but also show how it responds to variations in tectonic forcing, climatic events and is controlled by lithospheric flexure. Simulation results show that the value of the deposition coefficient G significantly controls the average elevation and slope of the uplifted region when G is ≥ 1. For smaller value of G, the control is much less important or negligible.

Because our method is optimally efficient (i.e., $O(n)$ and implicit), it is highly suitable to perform large numbers of simulations necessary for the inversion of field data. In the longer term, we plan on using our model to better constrain the nature and timing of erosional events on continents through an inversion of the stratigraphy of the adjacent foreland basins.

Davy, P. And Lague, D., 2009. Fluvial erosion/transport equation of landscape evolution models revisited. Journal of Geophysical Research: Earth Surface, 114, F03007, doi:10.1029/2008JF001146.