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Assessing the potential of time-slicing in numerical models of landscape evolution

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Numerical models of landscape evolution have recently become a common tool in geomorphic research. At geological time scales such models are capable to simulate the spatio-temporal development of the drainage network and hillslopes. At their most basic form numerical models of landscape evolution solve two equations. The diffusion equation quantifies how landforms are smoothed over time, thus integrating various processes such as particle movement by rain splash, sheet wash and soil creep. The advection equation is used to calculate the effect of fluvial incision and is capable to simulate the upward migration of knickpoints along the drainage network.

Solving both equations for large and/or high resolution datasets, however, is not trivial since the relatively small time steps given by the Courant-Friedrichs-Lewy (CFL) condition limits the application on longer time scales. Various approaches such as implicit solvers have been proposed to relax the CFL condition. These solvers perform well as long as the investigated domain is characterized by parallel drainage patterns. In dendritic drainage networks, however, sharp spatial velocity gradients strongly decelerate such solvers.

Here we propose a different solver that involves a time-slicing scheme. The scheme involves the division of the spatial domain into different velocity classes and the allocation of computational effort to the different velocity regions that are evaluated explicitly at different time steps. The diffusion equation is solved implicitly.

First results of the simulations show that the computational time required to evaluate the development of dentritic networks is strongly reduced compared to a purely explicit solver. As such, the approach is suited to allow for fast computations of large datasets.