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A fast, parallel algorithm to solve the basic fluvial erosion/transport equations

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Quantitative models of landform evolution are commonly based on the solution of a set of equations representing the processes of fluvial erosion, transport and deposition, which leads to predict the geometry of a river channel network and its evolution through time. The river network is often regarded as the backbone of any surface processes model (SPM) that might include other physical processes acting at a range of spatial and temporal scales along hill slopes. The basic laws of fluvial erosion requires the computation of local (slope) and non-local (drainage area) quantities at every point of a given landscape, a computationally expensive operation which limits the resolution of most SPMs.

I present here an algorithm to compute the various components required in the parameterization of fluvial erosion (and transport) and thus solve the basic fluvial geomorphic equation, that is very efficient because it is O(n) (the number of required arithmetic operations is linearly proportional to the number of nodes defining the landscape), and is fully parallelizable (the computation cost decreases in a direct inverse proportion to the number of processors used to solve the problem). The algorithm is ideally suited for use on latest multi-core processors.

Using this new technique, geomorphic problems can be solved at an unprecedented resolution (typically of the order of 10,000 X 10,000 nodes) while keeping the computational cost reasonable (order 1 sec per time step). Furthermore, I will show that the algorithm is applicable to any regular or irregular representation of the landform, and is such that the temporal evolution of the landform can be discretized by a fully implicit time-marching algorithm, making it unconditionally stable.

I will demonstrate that such an efficient algorithm is ideally suited to produce a fully predictive SPM that links observationally based parameterizations of small-scale processes to the evolution of large-scale features of the landscapes on geological time scales. It can also be used to model surface processes at the continental or planetary scale and be linked to lithospheric or mantle flow models to predict the potential interactions between tectonics driving surface uplift in orogenic areas, mantle flow producing dynamic topography on continental scales and surface processes.