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A reduced complexity numerical method for flow accumulation and sediment transport under both convergent and divergent flow conditions

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Many methods currently used to model the mobilisation and depositions of sediment in natural environments on medium to long timescales are numerically inefficient. This is in part a function of the complexity of the underlying flow physics, and in part a function of similar complexity in the physics of sediment transport. Here, we derive a new approach to calculate both flow accumulation and resulting sediment transport across a grid by adopting a novel, simplified, vectorised scheme to describe the flow of water over terrain. The method for calculating local discharge assumes that the energy gradient of the flow is adequately represented by the bed gradient (removing flow dependence on the acceleration or momentum of the flow), then enforces only: 1. conservation of water mass, and 2. that flow is always perpendicular to slope. Sediment transport can be added to the scheme by introducing a pair of additional assumptions: 3. that sediment mass is conserved (i.e. the Exner equation), and 4. that volume flux of sediment is some defined function of local discharge and bed gradient. The method is equivalent to solving for a “flow potential” vector field across the grid, which is always follows with the local bed gradient. The resulting matrix solution is order n and highly efficient, both for flow routing alone and also when calculating the resulting sediment transport. Here, the model is demonstrated as part of the Landlab modelling framework, but it would be equally well suited to integration into any other gridded surface process model. The method is validated by comparison to results from physical experiments describing fan and delta top evolution performed at the National Center for Earth Surface Dynamics.