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Earth Surface Dynamics Discussions

Interactive comment on "Transport-limited fluvial erosion – simple formulation and efficient numerical treatment" *by* Stefan Hergarten

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Dear reviewer,

thanks for your encouraging comments and for the suggestions to improve the manuscript!

As the official discussion phase will end soon, I just write a few remarks on some points that might also be interesting for other readers and go more into detail when submitting the revised version.

Time-dependent problems: My statement "investigating the temporal behavior turned out to be quite complex" should not mean that I do not want to consider it. However, catching up with what has already been done for the detachment-limited case just

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Discussion paper

in one section of this paper is impossible. We know what solutions of the 1D diffusion equation look like, but the interesting aspect how disturbances propagate into tributaries where the diffusivity is lower than in the trunk stream. My recent Postdoc researcher has already started a study on the characteristic response time of catchments to changes in uplift or base level and which part the hillslopes play here. But this will be an own paper where I will not be first author.

Time-step size: You are right that the unlimited time-step size only refers to the situation with frozen flow directions. If a river enters a flat area, even weird aggradational ridges may occur and vanish after some time. Their size depends linearly on the time-step length, and we need very small time steps to avoid this problem if the river brings much sediments. In turn, I am actually running large simulations of permanently changing rivers in a foreland with zero uplift, and there it seems not be a problem at all. So it will even be a challenge to provide some rule of thumb.

Voronoi polygons: You are right that any finite-volume representation could be used. For the accuracy it is, of course, and advantage if the edge is in the middle of the nodes, and Voronoi polygons turn out to be useful if hillslope diffusion is considered additionally.

Equation (15): The linear dependence of all properties (height, flux) on base level is indeed the key to understanding the numerical scheme, so I agree that it should be described more thoroughly. I already prepared a figure where this is visible and where it can be recognized that it is not just a first-order Taylor approximation.

Tent-shaped uplift pattern: It would indeed be great to have analytical solutions (approximations) for the river profiles as you suggest. As far as I can see, your analytical solution is technically correct, but runs into problems with the contribution of tributaries for the transport-limited model. As an extreme example, all single-pixel catchments are located at the ridge and thus exposed to the maximum uplift in the 1D formulation using Hack's law. In the network, however, they are distributed over the entire catchment. So they are exposed to lower uplift on average and thus provide less sediment. I recently worked on a similar problem in the context of glacial erosion (Prasicek et al., EPSL, 2020, 0.1016/j.epsl.2020.116350), and it is more complicated that it seems first.

Extension by hillslope diffusion: This is indeed not very complicated and works quite well at least for triangular meshes. I will explain the implementation in the revised version.

Best regards,
Stefan Hergarten

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