Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2020-39-EC1, 2020

Earth Surface Dynamics Discussions

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

Jean Braun (Editor)

jean.braun@gfz-potsdam.de

Received and published: 24 July 2020

This is a very interesting contribution for those of us working on developing efficient and stable solutions to the basic equations governing surface erosion and sediment transport and deposition. It describes an $O(n)$ complexity and time-implicit method to solve the transport-limited equation (i.e., where change in surface height is equal to the divergence of sediment flux). It is a very important contribution that certainly highly suitable for publication in ESURF. Like in most previous studies, the expression used for the flux ($Q = KA^{m+1}S^n$) is chosen such that the steady-state topography obtained is identical to that obtained assuming the stream power incision model (SPIM) where erosion rate is given by KA^mS^n. The author rightly reminds us that the transient behaviour of a "divergence"-based approach is however different from that obtained by the SPIM. He also states that characterising this difference is not the purpose of this manuscript, and I agree with this.

The author also proposes to extent the method to solve another equation obtained by assuming that the rate of erosion/deposition, E, is the sum of an erosion term (assumed proportional to slope, S) plus a deposition term assumed proportional to sediment flux, Q ($E = \phi S + \psi Q$), which leads to a hybrid behaviour that can reproduce the observed transition between detachment-limited behaviour of the system when sediment flux is low to transport-limited behaviour when sediment flux increases (as proposed by Kooi and Beaumont in 1994 and Davy and Lague in 2009). This, I find, is the most interesting part of the manuscript.

The limitations of the method are well explained such as the first-order representation of the slope which tends to affect the sharpness of knickpoints. It is also limited to specific cases (i.e. $n = 1$ and $n = 2$). The author also mentions the problems caused by local depressions/minima without suggesting a potential solution.

I think the author could provide a more quantitative comparison between the results obtained with this new method and those obtained by solving the Davy and Lague (2009) approach directly (i.e. without using the flux divergence formulation) as done by Yuan et al (2019). I have rapidly coded the two approaches in 1D and easily showed that the improvement in speed is a strong function of G (for $G \geq 1$).

I found the paper well written and agree with the opinion expressed by reviewers (1 and 2) and with the minor modifications they suggest. Reviewer 3 makes more substantial and also very interesting suggestions for improvement to the paper. All agree that this is a very important contribution that should be published in ESurf.

Additionally to the suggestions made by the reviewers, I would like the author to provide a more structured explanation of the procedure used in the solution of what the author calls the “linear decline model". I note that the author’s implementation is based on equations [1]+[26] (I use square brackets to indicate equation numbers from the manuscript and parentheses to indicate equation numbers from this comment):

$$\frac{\partial H}{\partial t} = U - \phi S + \psi Q \tag{1}$$

and its discretised form [28]; but, of course, it also uses equation [17], which is equivalent to [16], itself a discretised form of equation:

$$\frac{\partial H}{\partial t} = U - \mathrm{div}\mathbf{q} \tag{2}$$

This leads me to conclude that the author uses two evolution equations simultaneously at every point of the landscape. Combining them also suggests that:

$$\mathrm{div}\mathbf{q} = \phi S - \psi Q \tag{3}$$

This may explain why the method is hybrid, depending on the value of the ψ parameter (purely advective if $\psi = 0$ and divergence based (or diffusive) for large values of psi), as pointed out by the author. However, it is not clear to me how to connect all these points together. I would appreciate if the authors could help me (and other readers) clarify this point with a more structured presentation of the basic partial differential equation(s?) that are solved in the "linear decline model" algorithm.

Interactive comment on Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2020-39, 2020.