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Interactive comment on "Short communication: Rivers as lines within the landscape" *by* John J. Armitage

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General comments:

Overview and challenge:

First off, I would like to apologize for the 9-days-late review! I had two EGU reviews on my calendar, and accidentally placed them on the same day – which in fact was yesterday, meaning that I really have no excuse.

I have high hopes for this submission despite the soon-to-be-apparent fact that I disagree with most of the reasoning. I challenge the authors with a counter-hypothesis that the most critical piece (and perhaps only critical piece) to grid-scale-independence

is multiple-direction flow routing because this parameterizes sub-grid topography and drainage systems.

While I have significant comments and disagreements with other parts of the paper, after completing my read-through of it and realizing your purpose, I think that this above comment is really the most critical towards your important and fundamental objective of removing the effect of grid size on LEM computations.

General comments:

The idea that rivers can be approximated as lines (with appropriate parameterized widths) should be appropriate for landscapes in which the significant lateral scales are $\gg$ river widths. This can often be the case in actively-uplifting mountain ranges, where uplift and incision work together to keep valleys narrow and V-shaped, and the lack of significant catchment area leads to small rivers, validating your assumptions – *in this setting*. Active orogens may well be the primary type of environment where LEMs are used, but either because of or in spite of this, I am concerned that such strong wording in this paper can lead to an echo chamber effect, in turn leading to the neglect of the broader range of landscapes on Earth. Therefore, I am writing a reminder that even in erosional landscapes, there can be rivers with km-scale widths. In the USA, the upper Mississippi, upper Missouri, Hudson, and Susquehanna have widths that are $\geq$ observed hillslope lengths; I am considering these widths in absence of control structures. This is similarly true for the Niger, the Irrawaddy, and probably many more. Furthermore, I am considering only the rivers themselves, and not their valleys, which can often be wider and are also not considered in most landscape-evolution models. (Langston and Tucker, 2018, offer a starting point to address this piece of reality.)

This is not to say that the foundation of the idea presented here is wrong. It is simply to say that it is not right all the time. Indeed, it is a reasonable assumption in mountain ranges, in which limited drainage area leads to narrow rivers. But I find it to be important to not make the places that one tends to model and think about become, in the scientific literature, the only landscapes that exist.

My second general point is on how well your model equations represent reality, which I note in the line-by-line comments and so will not restate here.

My third general point, and perhaps the most important, is my line-by-line comment, “fig. 3.”, below. As noted in the overview, I believe that multiple-flow-direction routing is the real answer to parameterizing sub-grid topographic and flow-routing complexity, and that the cell-centered vs. cell-edge routing is actually a separate issue. I suggest that you investigate multi-direction routing from cell to cell, as this will tell you whether the answer lies in using cells vs. edges or the SFD vs. MFD routing.

Line-by-line comments:

p1,l3. And as flow in the unsaturated zone; perhaps consider lumping all subsurface flow together

p1,l4. Typically, continent $>$ country $\sim$ mountain range, typically, so it might make more logical sense to reverse these. However, I am not sure why you include this, because LEMs are typically run at the mountain range or smaller scale.

p1,l12-18. Flow routing and river width are two processes that are about as separable as any become in Earth-surface processes. Flow routing occurs over the scale of a basin, is non-local, and is cumulative. River width responds to local conditions, e.g., shear stress, and is typically thought to tend towards an equilibrium – see Parker (1978), Phillips and Jerolmack (2016), and Pfeiffer et al. (2017) for some background on the latter. Therefore, I find it difficult to understand why you have gone from writing that parameterizing width is hard (yes, this is true, but also necessary if it is sub-grid) to writing that therefore we just focus on flow-routing? Mustn't we do both?

p1,l12. route $\rightarrow$ root

p1,l14. commas around "for example"

p1,l15. comma between "ideal" and "as"

p1,l20. "uphill" and "down hill" – consider being consistent with compound words

p1,l23. comma after "building on this question". I have ignored some more minor errors or non-standard English usage between lines 20 and 23, and there are enough of these that I will only point out really major ones (i.e. that affect the clarity) from here on out.

p2,l4. Could you describe the reality that this equation is portraying? Because there is a gradient in water flux (i.e., depth-integrated discharge), I presume that this is a transport-limited-style system. However, the situation in which rivers can be lines, based on your initial argument, is germane to steep mountains. Could you then explain either (a) how this equation is appropriate, or (b) how it might, even if not appropriate for the physical reality, create a mathematical setting that is useful for exploring your key concept?

p2,l14 (eq. 2). This equation works dimensionally, but I am not convinced that it represents reality. In a typical river system, one would accumulate flow over the full landscape [$\mathrm{m}^3\ \mathrm{s}^{-1}$]. Then, after partitioning groundwater and surface water and any losses due to ET (not so common in LEMs), one would assuming a rectangular channel with minimal wall friction for simplicity, and divide water discharge by the channel width to obtain a discharge per unit width (or “water flux”) with units of $\mathrm{m}^2\ \mathrm{s}^{-1}$. What you have effectively done is replaced the channel width by the distance between two cell centers. This means that the effective channel width in this case is a direct function of grid size. I think I am starting to understand why you combined flow-routing and channel width at the start of this paper, but I think that this is a distinct downgrade from actually considering channel width!

p2,l15. subscript on "s"

p3,l2. Calling cell edges "rivers" does not seem like a good idea – this terminology implies, regardless of your intent with it, that you have pre-determined the dimensions of hillslopes and the drainage density, and that rivers can meet across drainage divides.

p3,l3 (eq. 3). Here you are accumulating flow with l, which again implies that the geometric relationship between the edge length of an equilateral triangle and its area is proportional to any hydrologic lossiness and a realistic channel-width function. This certainly cannot be true. However, there is a linear proportionality between the cell-side length and the cell area, so this relationship – in spite of its dimensional consistency with water flux – retains a linear scaling with water discharge.

fig. 3. As I'm sure you're aware, and I'm hoping you weren't dreading that a reviewer would ask, there is a fourth case here: cell-to-cell multi-flow-direction routing. It seems to me that the multiple flow directions, rather than a single flow direction, could well be the key component here, because it provides a mechanism to redistribute water at a sub-grid level. This is a major point, as it could completely change your conclusions – though I hope you agree with me that it validates the importance of your work in identifying grid-scale dependence, which is a first-order numerical modeling issue that is worth solving properly!

p6,l8. Why are you mentioning avulsions? These are typically features of depositional rivers, but in these cases, river dimensions are often not well represented by lines.

p6,l9. I do not think that terraces, in general, represent changes in river flow paths, at least on the scale of a landscape. They can represent that it takes time for a river to modify its full valley, and sometimes moves across all of it, and sometimes does not. But in your initial premise of rivers being lines, all of this complexity (terraces, valleys, rivers) would be lumped together. Perhaps I am taking your initial statement too literally – but I am finding it hard now to follow a consistent thread of thoughts in terms of what is considered to be important for your story and what is not.

p6,l13. While I know this is just a test case, it would be useful for my curiosity to know how you know that the Ebro's valleys were filled during the late Pleistocene, when sea-level was low. I presume that either there has been rapid progressive incision, or that

colluvial (or other) processes may have filled the valleys with classic material (in which case the same LEM rule would be applied to both intact rock and loose material), or ...?

Code availability: excellent that you have made it available!

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