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Geoscientific Model Development Discussions

Interactive comment on "Global Sensitivity Analysis of Parameter Uncertainty in Landscape Evolution Models" *by* Christopher J. Skinner et al.

Christopher J. Skinner et al.

c.skinner@hull.ac.uk

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Thank you very much for the comments Andy - We'd like to quickly respond to a few of your points on sediment transport laws/rules (as the journal format enables discussion) and we will provide a full response to all your points for the final paper response.

Firstly though - We are glad you appreciate the complexity of the task - there is a great deal of information in the paper and choosing what to highlight and discuss was a repeated issue in the papers formulation.

"âĂć The sediment transport formula was the dominant source of uncertainty, but I believe that this may in part be because these sediment transport formulas were not appropriate for Tin Camp Creek (Australia). – The grain size distributions for the rivers

displayed significance of sand in the UK and a dominance of sand in Australia. Both the Wilcock and Crowe (2003) and the Einstein (1940's-50's) formulas are tested with coarse sand as the smallest grain size class. In the Australian case, about 50% of the sand is finer the grain size used to produce the sediment transport formula. This is at the upper limit of the curve in Figure 6 of Wilcock and Crowe (2003), where their solution begins to bend more sharply but the data end. Therefore, there is great uncertainty and little constraint in the formulation."

There is a general point about sediment transport formulae and their applicability - that they generally perform well on the data they were generated from, but much less so when applied to other circumstances (e.g. Gomez and Church, 1989 and others since). So, in taking any sediment transport rule out of its 'comfort zone' we will encounter issues. Like the late George Box in saying "all models are wrong, but some are useful"

However, for the second point, looking at Wilcock and Crowe (2003) they use sand fractions from 0.0005 to 0.064m (Figures 1, 2 & 3 and P121) in their 48 flume experiments from which the formula was derived. For our first catchment (the Swale) there is a pretty good overlap between the sediment grainsizes used and the W&C ones. In the second catchment catchment - yes there are finer sands and a greater proportion of sand in those simulations than used in the formulae development.

However, we find the same sensitivity to sediment transport law in both basins - despite the different grainsize mixes. Sediment transport law has a much stronger impact than grainsize as shown in our Figure 3. The application to real basins - with representative grainsizes is a nice thing to have - but the real finding is the sensitivity to sediment formula choice in two quite different settings/basins. Therefore our argument would be that whilst the application of W&C to the Australian example may be outside the limits of the initial W&C development - it does not mean that the overall finding is incorrect. There is certainly scope for a study/paper on the role of sediment transport rules in LEM's (see later comment).

"The Australian example has a dominance of sand. Are there bedforms that appear in the river? If so, could you discuss the role of their form drag, which to my knowledge is not included in your model, and how it could affect sensitivity to choice of sediment transport formulations?"

To clarify, there are bedforms in the creek - and form drag is not included in the model. CAESAR-Lisflood will not generate realistic bedforms at this scale/resolution of application and these are not factored into the sediment transport equation.

" I find your discussion of sediment transport in section 4.3 to be unnecessarily vague. It is not unusual to see in the landscape evolution modeling literature a statement to the effect of "sediment transport formulas are problematic and it is a difficult thing so the error is probably there". Scientifically, this is unhelpful and in my opinion a little lazy. I think that here you have the opportunity to analyze why this is your major source of uncertainty, which is one way in which I hope this study can rise up above the others. Regardless of whether anyone trusts the form of your sediment transport formulations for the chosen grain size, form drag, etc., you have two mathematical formulations that must produce divergent outcomes for the set of provided hydrologic and topographic states. (I am presuming that over your 30-year time scales of interest, overall topography changes little.) Based on an analysis of these formulations, can you make a prediction of the factors that lead to this divergence?"

These are really good points, well made. This is something we can certainly improve in a revised discussion and I completely agree with you. There is further scope (in another study) to look at how different sediment transport equations respond (in the different settings) in this model that would be incredibly instructive to the LEM community and this is something we are working on (but first we need to look at how all the model parameters interact).

However, we would also like to emphasise that the primary purpose of this paper is as a methods paper, introducing a method in which the sensitivity and uncertainties of

LEMs can be assessed. Therefore, a detailed analysis of different sediment transport formulae is beyond the scope of this paper and also beyond the scope of GMD and better focused to a Earth Surface based journal. However, we agree that this would be incredibly valuable and a more in-depth test utilising more sediment transport formulae is planned. We see this paper as the introduction of a longer and larger set of experiments as part of the Landscape Evolution Model Sensitivity Investigation Project (LEMSIP) to which we would invite the community to contribute.

"âĂć Your premise is to test landscape evolution models, but the 30-year model run period is much shorter than most geomorphic models are used. Indeed, I wonder how much landscape evolution occurs, versus how much, over these time-scales, CAESAR can be thought of as a sediment-routing model with erosion or deposition being negligible (and therefore avoiding the nonlinearity in which changes in topography affect the long-term response of a LEM.) I think that this short time scale should be made explicit early in the paper. A discussion of how these results can (or cannot) be transferred to different time scales would be helpful as well."

Yes, this is a much shorter timescale than typically applied, but is the timescale that is relevant for decision making purposes – ie, for designing Natural Flood Management interventions, or landscape rehabilitation projects. The applications of LEMS for these purposes, at these timescales, was the motivation of the project as an understanding of uncertainties should be a crucial facet of any decisions made due to the modelling – as is the case for other modelling fields with operational uses, such as meteorology and hydrology. We had hoped this was clear from the Introduction, but will make this motivation more prominent.

Longer term simulations have been run for the Australian catchment, but at present it is not feasible to repeat this for the UK catchment as the individual simulations take too long to resolve.

Thank you again for your comments.

Chris Skinner and Tom Coulthard (on behalf of all authors).

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