Earth Surface Dynamics Discussions

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Comment on esurf-2022-30

Anonymous Referee #2

Referee comment on "Testing the sensitivity of the CAESAR-Lisflood Landscape Evolution Model to grid cell size" by Christopher J. Skinner and Thomas J. Coulthard, Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2022-30-RC2, 2022

This is a methodological paper exploring the impact of grid resolution on the CAESAR-Lisflood Landscape Evolution Model. The authors use an earlier developed global sensitivity analysis, referred to as the Morris Method to evaluate the impact of grid resolution compared to user-specified model parameters. They conclude that grid resolution does not change the modeled sediment output flux, but that resolution changes the frequency of events, with fewer big events producing the same output flux. This makes the authors conclude that changing the model resolution might give "the right answer for the wrong reasons".

The topic discussed in this manuscript is of interest to an increasing amount of people applying LEM's. Like the authors discuss, setting the resolution of a LEM is a choice with some implications which are, in some cases, overlooked. Re-applying the Morris exercise (a similar exercise was done for parameter sensitivity in Skinner et al 2018) to test the impact of resolution is useful. Yet, I feel the manuscript should be improved at several points to make it a contribution that adds to the existing literature on LEMs.

Some points not in order of importance:

- Almost no deposition is occurring in the shown simulations (erosion = 40-60k m3 versus deposition = 0.1-0.4k m3, this is a factor 100-200 difference!). This seems problematic for the goal of this paper since I would expect grid resolution to alter deposition. If almost no deposition occurs, I am not sure this is a proper catchment to test the impact of grid resolution. Given the narrow focus of this paper (only considering CAESAR-Lisflood), at least the full spectrum of erosion and deposition should be covered. I suppose this could be solved by comparing the results in-between smaller and larger catchments.
- Catchment size (related to previous comment): this is a very small catchment. At high resolution the topological network is strongly altered because of the limited catchment

area. In my opinion, a study focusing on one single LEM, should cover a larger domain of catchment areas to study the role of changing grid resolution. Using larger catchment sizes would also resolve the issue on deposition, I assume.

- From reading the title, I was expecting a study that would cover the impact of model resolution in general. However, this paper focuses on one particular model (CAESAR-Lisflood). It would have been more interesting to see a contribution spanning a wider range of models but focusing on one LEM is acceptable. However, it should be indicated as such in the title. Also, I would like to see a discussion on how these findings can be extrapolated to other LEM's. One more comment regarding the title: it is a little weird to use an abbreviation (DEM) in the title. Why not using 'spatial model resolution' or 'grid resolution' rather than DEM grid cell size? DEM resolution might be controlled by other factors such as the resolution of the source data the DEM was built from. When you say model grid resolution, you avoid this confusion.
- From the model description, it is unclear whether bedrock incision is simulated. How is sediment being produced? Is the full model domain supposed to be sediment (transport limited behavior versus detachment limited behavior?) or is there a conversion mechanism to transform bedrock into sediment (fluvial bedrock incision, landslides,…). Do you assume an initial soil cover where the sediment is derived from? This might be described in the original CAESAR publications but would be good to summarize here.
- Over what timescales do observations hold and how sensitive are they to the initial boundary condition (DEM). More broadly speaking, several LEMs are used to create synthetic landscapes to test specific scenarios. What happens if CAESAR-Lisflood is used to generate synthetic landscapes and how sensitive are these kinds of landscapes to changes in resolution (e.g. in terms of fluvial network).
- The introduction should be structured better. Now it reads as an enumeration of various studies, but I miss a good story line here. It would be helpful to provide an overviewing first paragraph where the authors summarize what they will discuss and for which types of models. Next discuss these points and clarify what is known from these studies and what the knowledge gaps are. From there move towards the final paragraph outlying what will be done in this paper. Also, this work builds on Skinner et al. It would be useful to provide a summary of their main findings and explain how this manuscript builds on those using various grid resolutions.
- Grid resolution is one thing, numerical methods another. The latter is not mentioned in the manuscript but is critically important regarding grid resolution: some numerical methods will be more sensitive to grid resolution than others. The paper would benefit from details on the numerical implementation of the model as well as details on the temporal properties of the simulations. Numerical methods determine the sensitivity of LEMs to grid resolution. Finite Difference Methods will respond differently to changing resolutions compared to Finite Volume Methods or Finite Element Methods. Moreover, I am wondering how the numerical model advances in time: is a forward difference scheme used or a more complex scheme (e.g. Runge Kutta,…)? Related to that: provide details on the timescale over which this model is run and the timesteps being used. In terms of model performance, as shown and as expected, models run faster at lower resolution. Should be good to discuss whether the model allows parallelization and how that alters performance for various grid sizes.
- Figure 1 is hard to interpret before reading the methods section. This figure comes directly from Skinner et al and I see little value in doing so. Rather provide the readers with a synthetic figure overviewing the method and move it to the methods section. One suggestion would be to replace this figure with a synthetic figure that describes 3-5 cases (dots on the graph). For every case, the authors can explain what a high mean versus standard deviation imply, and how it should be interpreted.
- Would be good to explain the different transport formulas and how they behave differently. It might be explained elsewhere but knowing how they work is critical to understand what is going on in this study so please summarize.
- Stream network analysis: it is obvious that you lose details when coarsening a DEM, no modelling is needed to show that. What would be an interesting exercise is to run a

synthetic LEM using a variable resolution and to check how the stream network comes out. Checking the order might be one metric to look at, but you could also consider evaluating the drainage density. This exercise could also be tested on drainage basins of various sizes (see before).

- Fewer yet more erosive events: is there a process-based explanation for this? Generally, with decreasing resolution, gradient decreases. Intuitively, I would expect this to result in decreasing erosion rates for single erosive events rather than increasing events. Some background on how erosion works in CAESAR-Lisflood might clarify this. Are there thresholds involved in the erosion mechanisms implemented?

Minor and line comments: see annotated PDF for details.

Please also note the supplement to this comment:
https://esurf.copernicus.org/preprints/esurf-2022-30/esurf-2022-30-RC2-supplement.pdf