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Interactive comment on "How do modeling choices impact the representation of structural connectivity and the dynamics of suspended sediment fluxes in distributed soil erosion models?" *by* Magdalena Uber et al.

Peter Molnar

molnar@ifu.baug.ethz.ch

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The paper by Uber et al. presents an interesting analysis of sediment load variability by catchment-scale physically-based distributed PBD rainfall-runoff modelling. The authors demonstrate that the "actual location of sediment sources was more important than the choices made during discretization and parameterization of the model", where the analyzed modelling choices were the impact of contributing drainage area and Manning's roughness. Indeed, I agree that the location of major sediment sources is key for understanding sediment flux variability in any catchment, and that PBD mod-

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elling (such as that presented in this work) is an excellent way to represent the dynamic connectivity of catchments for sediment flux and better understand its sensitivities.

The Uber et al. paper closes with the wish that "further studies should focus on the influence of rainfall dynamics on modelled sediment fluxes in mesoscale catchments." (line 474). In fact, we conducted such an analysis and presented it in this journal recently (Battista et al., 2020a). Based on this work and other ongoing efforts I would like to share my perspective on three broad questions on catchment-scale combined hydrology-sediment modelling that came to my mind after reading Uber et al. I believe these are relevant challenges which we need to address and tackle in the future, and I would like to hear the authors (and others) opinion.

1. Structural or functional connectivity by hydrology-sediment modelling?

The notion of structural connectivity is useful to describe the fact that the landscape surface (watershed) is a collection of potential sediment sources and sinks connected by topographic pathways of sediment transport. Functional connectivity is the dynamic driver, where each individual event activates different sediment sources (and sinks) depending on where and when there is surface overland flow (produced by rain or snowmelt). PBD models in reality do (or should) represent both structural and functional connectivity.

The work of Uber et al. focuses only on structural connectivity – their PBD hydrodynamic surface flow solver is forced by a single (triangular) storm where rainfall is representing effective rainfall after infiltration (all rainfall runs off), the local erosion rate (in production areas) is a function of rain intensity, and all sediment is transported in suspension downstream (no deposition is allowed). Furthermore, rainfall is uniform in space, so only spatial signals coming from topography affect overland and channel flow. This effect together with mapped sediment sources allows them to quantify the contributions of different source areas.

In our work we instead focused on functional connectivity – our PBD hydrological-sediment flow solver is forced by a continuous time series of hourly climate (rainfall, cloud cover, temperature), and overland flow is produced locally by exfiltration if the soil is saturated or rainfall intensity when it exceeds infiltration capacity at the surface. Sediment can be produced at different rates from production areas. The variability in sediment fluxes comes from a combination of topographic (structural) and hydrological (functional) connectivity and is the result of integrating over many storms (Battista et al., 2020a). At the hillslope scale both models have the same spatial resolution (100m) in these applications, so in this sense they are comparable. Ours is however an application to a much larger catchment.

These two modelling studies lead me to ask: Is it necessary to understand structural connectivity separately from functional connectivity? What do we gain by this, as real basins never experience the kind of hypothetical climatic driving conditions studied by Uber et al., and runoff production in reality is heavily dependent on soil moisture that varies strongly in space and time? For example in Battista et al. (2002a) we showed that rainfall spatial variability had a significant effect on sediment load by increasing sediment production rates (increasing functional connectivity by locally high runoff production), while variability in surface erodibility had the opposite effect (decreasing functional-structural connectivity by magnifying sediment buffers close to streams). We concluded that it was futile to try to quantify the structural effects separately from that of functional effects, because they clearly act together in producing the sediment flux variability at the outlet. I am not convinced that event scale analyses and explorations of structural connectivity are helping us understand the processes better, unless we understand (and are able to model) why every event has a different hydrological, i.e. overland flow and therefore erosion, response across a catchment.

2. How do we validate the hydrology-sediment models we use?

Nevertheless, event based analysis did teach us something. In the same basin and with the same PBD model we studied the effects of moving storm events on flood peaks (Paschalis et al., 2014). This numerical experiment showed that event flood peaks (and thus high sediment transport rates) were affected more by temporal variability of rainfall at high resolution (within storm) than by spatial variability. But most importantly the soil moisture state at the onset of the events played a paramount role – because high soil moisture promoted clustering of saturated areas within a catchment leading to locally high overland flow production (and therefore erosion).

In the study of Battista et al. (2020a), and the paper by Uber et al., it is overland flow on hillslopes that erodes the soil and produces sediment to the fluvial network. This furthermore has to happen along overland flow paths that are continuous, otherwise sediment is deposited (not in Uber et al.) and does not reach the channels. In other words, any PBD model prediction of sediment fluxes at a catchment outlet relies on getting overland flow in the model right. In most cases it is not channel transport that matters.

This raises the questions: Are we sure we are predicting overland flow in our catchment scale models correctly? That means, does overland flow occur in the right place and at the right time during rainfall (snowmelt) events? The co-authors of Uber et al. have previously presented excellent work on such validation of PBD models at smaller scales with laboratory experiments (Cea et al.,2014), but at larger catchment scales this question of validating overland flow in PBD models remains open and deserving of attention. This may also affect the conclusions of Uber et al. (and any other modelling study of course). Any ideas in this direction would be very welcome.

3. Identifying and tracking sediment sources?

The highlight of the work of Uber et al. in my opinion is the simulation of the contributions of the different sediment sources to the outlets and the demonstration and discussion of the possible effects these have on the hysteretic loops of sediment versus water discharges in their two catchments. These results allow the authors to state that the actual location of sediment sources were more important than the modelling choices on the contributing drainage area and Manning's roughness. This is an impor-

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tant conclusion.

Combining the notions of functional hydrological-sediment connectivity raised in point 1, with the concern for correct simulation of local overland flow in point 2, brings me to this final challenge of using PBD hydrology-sediment models for the tracking of sediment origin. The results reported in Uber et al. give us some confidence that PBD models can be used for this purpose insofar some distinct sediment properties (mineralogy, geochemistry) of the source areas can be used as fingerprints. This is in my opinion a very worthwhile combination of hydrological modelling and geomorphological field data.

Using again our mesoscale study basin as an example, we have done this exercise with our PBD hydrology-sediment model in continuous simulation (13 yrs) at hourly timescales with two relevant conclusions (Battista et al., 2020b): (a) High peaks of suspended sediment concentrations observed at the catchment outlet could only be reproduced when we included an accurate geomorphological map of local sediment sources (landslides and incision reaches). Hillslope erosion by overland flow alone was not able to generate these high concentrations in our model. (b) Tracking sediment provenance in the model (similar to what Uber et al. do) with CRN 10Be isotopes showed us that our catchment can shift between channel-process and hillslope-process dominant behaviour in time depending on how we include our understanding of the local sediment production processes and rates into the model parameterization, and of course on the hydrological forcing. This means that the event scale partitioning of sediment flux to sources that Uber et al. find is indeed very relevant, but also time and parameterization dependent over longer timescales.

The integration over many events and longer hydrological forcing periods is in fact necessary to really identify individual sources (considering their production rate limitations) as main contributors to sediment flux at catchment scales. The use of sediment tracing techniques to validate PBD models in this regard, and in turn also to provide assistance to geomorphological interpretations of sediment provenance will be very helpful.

In conclusion, my comment serves to share some perspectives on the challenges we have had in combining PBD hydrology-sediment models in support of the work presented in Uber et al. It is my opinion there is much to gain from hydrological modelling combined with geomorphological process expertise in solving the sediment source-to-sink problem in a quantitative way, and the Uber et al. work is an interesting step in that direction.

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