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 Uber et al.

Answer to Peter Molnar (Short Comment 1)

Thank you for your appreciation of our study and for sharing your ideas on our work and on hydro-sedimentary modeling in general. You are raising interesting questions and we agree that there is a high potential for future studies to apply physically based models with multiple sources to assess how structural and functional connectivity impact sediment dynamics at the outlet and to track sediment provenance.

Below, we give our thoughts to the points you raise. As you mentioned, the questions are interesting to the hydro-sedimentary modeling community in general. We don’t claim that our answers are universally valid but reply to your questions with regard to our study and the context of our study sites.

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

First of all, we agree that functional connectivity and especially spatial and temporal rainfall variability is at least equally important as structural connectivity as a driver of sediment flux variability. Indeed, we think that the question how spatial variability of rainfall forcing impacts model output is a major knowledge gap in hydro-sedimentary modeling. While it is an active research topic in hydrological modeling (e.g. Emmanuel et al., 2015; Lobligeois et al., 2014), the question has not yet been properly addressed in hydro-sedimentary modeling. In that sense, the work of Battista et al. (2020a,b) is very relevant.

We also worked on functional connectivity ourselves, but to date this work is only published in Magdalena Uber PhD thesis (Chapter 5 of Uber 2020). A major finding was that temporal rainfall variability is a driver of within event variability of sediment source contributions and spatial rainfall variability strongly influences between event sediment dynamics.

Nonetheless, we are convinced that the location of the sources is very important and that there also is much to gain from studying structural connectivity separately. In your comment you write that “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”. Here we slightly disagree. Of course the spatially uniform, synthetic triangular hyetograph that we apply is a simplification of reality, but it is not completely unrealistic. In both catchments some floods can be associated to widespread, stratiform precipitation (Hachani et al., 2017 for the OHMCV Observatory where the Claduègne catchment is located; Navratil et al., 2012 for the Galabre catchment) that is relatively uniform in space at the scale of our studied catchments (20 and 43 km^2). During these events occurring mainly in autumn and winter for which the exports of sediment are usually important, the rainfall amounts can be very high and spread over more than one day. As the soil moistures are high at these periods (e.g. Braud et al., 2014), the entire catchments are highly connected because overland flow occurs in widespread areas throughout the catchment. During such events the structural connectivity and particularly the location of the sources is very important as travel distance govern the sediment dynamics at the outlet.

However, we agree that structural and functional connectivity interact, particularly during more localized convective rainfall events, and one of our conclusions was that structural connectivity alone can only explain a part of the observed variability of the source contributions. In the approach we chose, we gradually increased model complexity by firstly focusing on model sensitivity and structural connectivity and then including rainfall variability while keeping other parameters constant (work in progress and beyond the scope of the submitted manuscript).

You further write that you are “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”. Here, we focused on the event scale because at our study site the large majority of sediment export occurs during a small fraction of the time during extreme events. For example, for the Galabre catchment, Navratil et al. (2011) found that 90 % of the sediment was exported in 2 % of the time. This is why we focused on the event scale, but it is undoubtedly true that we are facing the problem of different initial conditions for different events. For future research we plan to include storage and remobilization of sediments in our model and to simulate chains of events.

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

This is a very interesting question, thank you for sharing your ideas on the topic. We agree that overland flow is a crucial factor in rainfall-runoff-sediment transport modeling, but would like to extend the discussion to erosion and sediment transport. As many studies have shown, we are still not able to reliably reproduce observed sediment fluxes with physically based or empirical models (Jetten et al., 1999; Alewell et al., 2019). Furthermore, studies that combine sediment fingerprinting with erosion modeling have shown that even when modeled suspended sediment output was similar to measured one, this is not necessarily for the right reasons. E.g. Theuring et al. (2013) found that their model underestimated riverbank erosion and overestimated surface erosion, thus, the model predicts the right output but for the wrong reasons.

As demanded by other authors, this clearly shows that we need alternative strategies for model validation than the traditional comparison of modeled hydrographs and sedigraphs with observed ones at the outlet alone. We agree that there is much to gain from combining modeling and sediment fingerprinting and your work (Battista et al., 2020b) is a good example. This was also a motivation for our work. Furthermore, we also think that it is justified to bid farewell to the idea of exactly reproducing absolute fluxes at the outlet as proposed by Alewell et al. (2019):

“Nearing (2004) concluded that model validation is not just a matter of comparing measured to modelled data, one must also ask the question: 'How variable is nature?' We would like to add, that in bidding farewell to the idea of accurately predicting absolute values with models but rather concentrating on the prediction of relative differences, trends over times and systems reactions to processes and management practices, we can use models as tools to learn about the modelled systems and their reactions. In this conceptual approach, modelling in general and large-scale modelling specifically will per se not aim at an accurate prediction of point measurements.”

In this sense, our aim was not to reproduce absolute liquid or solid discharge at the outlet but rather to understand the conditions (processes, forcing, model parameterization) that explain the observed patterns of sediment source contribution within and between events.

3. Identifying and tracking sediment sources?

We agree that it is very important to accurately map the locations of sediment sources and to include all potential sediment sources into the model and here we briefly give some thoughts on that topic that are based on our (previous) work. Again, we think that there is a high potential in combining modeling with sediment fingerprinting, especially at a high temporal resolution to gain insight in within events and between events variability. E.g. the methodology proposed by Poulenard et al., 2012 and applied in Legout et al., 2013 and Uber et al., 2019 to quantify source contributions separately for each source can give us some confidence that we are not missing an important source. When the contributions of the individual sources in the mixing model are not forced to sum up to 100% but each sources contribution is determined independently, the simple calculation whether the contributions of all sources add up to approximately 100% is a simple test that can indicate problems in the fingerprinting protocol or hint at missing sources.

We would also like to stress that we did not use the model to identify the main sediment sources. This was achieved before with sediment fingerprinting (quantified source contributions were averaged over 11 floods in 7 years in the Claduègne catchment and over 77 flood events in 7 years in the Galabre catchment). This knowledge was imposed on the model by adjusting the erodibility coefficient for each source. In this way, we could use the model to go beyond the identification of main sources and use it for process understanding by tracking the sources and by analyzing the dynamics of their respective contributions to sediments at the outlet.

Regarding your concern that many events and longer time periods are needed to identify main sediment sources we fully share this view. Our work in the two catchments (not reported in the presented manuscript, but the fingerprinting studies by Legout et al., 2013 and Uber et al., 2019 as well as the modelling article including rainfall variability that we are currently working on) shows that sediment sources can differ considerably between events. This is in agreement with your conclusion in Battista et al., 2020b that the catchment can shift between different regimes.

In conclusion, we agree that there is a lot of potential for future studies to combine hydrosedimentary modeling with field data that can be used for source quantification with sediment fingerprinting. To our knowledge, past studies have mainly done so to identify main sediment sources within catchments (e.g. Palazon et al., 2016; Theuring et al., 2013; Wilkinson et al., 2013). This is certainly an excellent approach to validate model results and highly valuable for management purposes such as the question where to apply erosion control measures. However, several fingerprinting studies have shown important variability of source contributions within and between events (e.g. Evrard et al., 2011; Brosinsky et al., 2014; Vercruysse and Grabowski, 2019). Thus, physically based distributed models are excellent tools to understand this between and within event variability and we think that the studies of Battista et al.(2020b) as well as our study are interesting steps in this direction.

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