Response to Referee 2

In the following, we report the text of the review in blue italic, and in black our reply.

The paper presents a hydrosedimentary model that couples the TOPKAPI-ETH hydrological model to a physically based and spatially distributed erosion and sediment transport model. […] The authors provide the data used in the article in the « data availability » section at the end of the paper.

However, the questions asked are not precise enough. It is a bit ambitious to want to answer such generic questions with only 4 scenarios. The model is very little evaluated in terms of erosion before analysing the results of the different scenarios. It is therefore difficult to give credit to the results obtained. My advice would be to reformulate questions thar are compatible with the framework offered by the tested scenarios and to rework the results and discussion sections according to these new questions.
[…]

We will modify the research questions in order to be more specific on the expectations of the case study and the simulations that we performed. Results and conclusions will be adapted accordingly. We will also support some of the discussion statements with further analyses of the hydrological results, as suggested in some of the comments below.

General remarks:

- *The authors do not mention the DHSVM model although it would be a very relevant tool for this type of catchment. It is necessary to justify the development of a new model compared to existing models such as DHSVM.*

(1) DHSVM is indeed a relevant tool in the framework of these type of models. DHSVM features a rigorous description of the hydrological processes and the role of vegetation and simulates sediment production by hillslope erosion, road erosion and mass wasting. TOPKAPI-ETH presents a slightly more simplified description of the hydrological processes and only includes erosion by overland flow. These choices are aimed at avoiding over-parameterization of the model and at keeping it computationally efficient and thus suitable for mesoscale catchment applications and small grid sizes, even when further components would be added (e.g. additional sediment transport processes).
We will introduce the DHSVM model in the literature review (Introduction) and highlight the differences with our approach.

- *The description of the erosion model did not seem clear enough to me, especially the distinction between the representation of hillslopes and river processes.*

(2) Sediment production and transport on the hillslopes is based on a transport capacity-mass balance approach, i.e. sediment flux is assumed to be always at transport capacity, and the model simulates erosion or deposition when there is a change in transport capacity. Sediment delivered to the channel network is advected by the river flow, there is no possibility for deposition or entrainment from the bed in the channel. The transition between sediment transport description as hillslope process to channel process corresponds to the transition from water flow routing as overland flow to channelized flow. This takes place between hillslope and channel cells and is fundamentally determined by the drainage area threshold (RT) used to identify river cells in the DEM, i.e. the river initiation threshold which was a parameter in our model

We will make sure that this concept is clearer in the revised manuscript, by reworking section 2.1.

- *The authors use data from Swiss operational services. However the temporal frequency of SSC data is too low for a catchment of this size located in a mountainous area. Flood events are most likely under-sampled. High SSC values are probably missing from the data set for this reason.*

(3) We agree with the reviewer on this point and we will explicitly state this limitation of the data in the revised manuscript. We are aware that the observations are missing extreme SSCs during floods and, at the same time, the model underestimates highest SSCs coming from very localized sediment sources. For this reason in the calibration of the model we focused only on the lowest 85th percentile of the SSC dataset. There is nothing we can do about the temporal frequency of the data (twice a week). All sediment monitoring stations of the Federal Office of the Environment in Switzerland have such low frequency except for few automatic stations with turbidity measurements in recent years.

- *One could be interested in the impact of the scenarios on the hydrological response and the indirect impact this may have on sediment dynamics.*

(4) This is a good point. We will add a comparison of the hydrological response in the 4 simulations, by evaluating the mean annual flow, the annual flood and the variability of flow at the basin outlet and the mean annual surface runoff on the hillslopes. This plot will be useful to support some of the discussion statements.

- *The concepts of structural and functional connectivity, widely present in the literature, are not discussed although they are at the heart of the subject developed in the paper.*

- *Connectivity indices are not used.*

Both comments have been addressed in point (6) below.

- *The process of detachment by rain is not taken into account in the model. Only the process of detachment by runoff is taken into account. This is questionable when the objective is to estimate the effect of spatial variability of precipitation.*

(5) Detachment by rain, together with the overland flow entrainment capacity, defines the amount of sediment available for transport. In our model, we do not simulate the local rainsplash detachment processes separately from the mobilization processes at the grid scale, rather we assume that sediment on the hillslopes is always available to fulfill the overland transport capacity. Sediment availability is only limited by the soil depth (sediment layer thickness), however, this limitation doesn't play a role in our simulations. It would be necessary to include the process of rainfall detachment by rainsplash if the model distinguished between the processes of sediment detachment, determining the sediment available for transport, and sediment mobilization.
We agree that the manuscript is currently unclear in this regard and we will make sure this distinction is clearer in the revised version.

- *Connectivity index maps could be used to study the spatial organization of erosion (Section 4.2). It is questionable whether there is any real added value in using the model presented in this study to address this issue.*

(6) The vast majority of connectivity indices provides a static description of the structural or functional sediment connectivity, based on the upslope contributing area as a proxy for discharge to estimate stream power (Heckmann et al., 2018). The sediment delivery ratio SDR simulated by our model quantifies the proportion of eroded sediments that are routed to a point on a river network or outlet of a selected subbasin, by action of overland flow and channel flow. As such, SDR is a dynamic indicator of functional connectivity, where the discharge (and thus stream power) is considered explicitly as a function of the hydrological forcings and topographic characteristics, instead of being represented by the upstream area only. Besides accounting for the time dependency of discharge, SDR also integrates the variability in space of the functional connectivity, by substituting the unique Q-A relationship used in traditional connectivity indices, with the explicit simulation of overland flow on the hillslopes. We have applied this analysis at the subbasin scale, but SDR could be potentially computed for each grid cell to build a connectivity map. Mahoney et al. (2018) propose a comparable approach that quantifies dynamic functional connectivity, based on hydrological modelling too.
We believe that this is an interesting discussion point to complement section 4.2.

- *In section 3.4, the authors examine the results at the temporal scale of the flood event. It is difficult to examine the effect of soil moisture on erosion and sediment transport without giving guarantees on the performance of the model in reproducing flows under dry and wet conditions.*

(7) We will evaluate the hydrological model performance for the low and high initial soil moisture events analysed in section 3.4, by means of the performance indices used in Table 1. Accordingly, we will adapt the discussion of Fig 9 to take into account the new hydrological analysis. However, we do expect to see an effect of soil moisture on erosion and sediment transport, given the different hydrological response of the catchment that Paschalis et al. (2013) found for low and high initial soil moisture storms with the same hydrological model without sediment transport.

- *The summary at the beginning of Section 4.3 is interesting.*

Specific remarks :

-p2 l33: I would suggest adding "especially in small to medium catchments (up to 1000 km2) after "the strong non-uniqueness of suspended sediment concentrations (SSCs)".

-p2 l37: I would suggest adding "and transfers " after "in sediment mobilization".

-p2 l39 to 52: rewrite this part which is not clear and take into account the concepts of structural and functional connectivity.

-p2 l48: add reference Misset et al (2018)

Misset C., Recking A., Legout C., Poirel A., Cazilhac M., Esteves Michel, Bertrand M. (2019). An attempt to link suspended load hysteresis patterns and sediment sources configuration in alpine catchments. Journal of Hydrology, 576, 72-84. ISSN 0022-1694

- p2 l56: replace "transport" by "transfer" in several places in the text

- p3 l65: replace "cesar-lisflood" with "caesar-lisflood".

-p3 l62 to 75: add the reference to the DHSVM model and explain the added value of the model presented in relation to this model

See point (1)

-p3 l77: "a physically explicit spatially distributed deterministic model": simplify the formula. What does "explicit" mean here?

"Explicit" means that the model is based on a physical representation of most processes, but it still contains some conceptualisations or approximations of the processes. For general understanding, we will replace "explicit" with "based" in the revised manuscript.

- p3 l83: "mean annual discharge" instead of "average discharge".

- p3 l87 : " mostly driven by overland flow ". What about rainfall processes ?

This is correct, we will modify the sentence.

- p4 l97: what is the scale for the soil map?

The scale is given by the coordinates on the x- and y- axes (units are the same as in Fig 1a).

- p4 l103: Is it really 2D whereas the equations presented p5 are 1D?

The solution is 1D in the direction of the steepest descent at the grid scale for surface and subsurface flow. All inflows from the neighbourhood cells are integrated in space.

- p5 l105 to 114: I do not understand how the hydrographic network is represented and discretized. The same question applies to the hillslopes. A specific part is missing for describing the discretization used in the model.

The entire basin is discretized as a 100 m resolution grid in the horizontal dimension, and with 3 layers in the vertical direction (one upper soil layer, one lower soil layer and the groundwater layer). Some of these cells are hillslope cells, others are partially hillslope and partially river network cells, depending on the river width. The river width has been set in these cells between a minimum of 10 m and a maximum of 48 m, proportionally to the upstream area of the cell (the min and max widths are derived from cross section measurements provided by the Swiss Federal Office of the Environment). The river network cells are identified in the DEM by means of a flow accumulation routine in the preprocessing phase, and the initiation of the river network is set by the drainage area RT threshold (see point 2 above).

- p5 l107: " catchment scale ": it is not precise enough. What scale?

- p5: put the dimensions of the variables presented in the equations. I do not understand the distinction between hillslopes and rivers in terms of erosion and transport processes. What is the link between the terms D and E?

The erosion and transport processes on hillslopes and channels are clarified in point (2). D and E are not related to each other. D represents the erosion or deposition of sediment on the hillslopes, while E is the flux of sediments between the water column and the river bed in the river network.

- p5 Eq.4: I do not understand the definition of X. It should be a width rather than a length for the calculation of the flux.

X is the length of the river cell. Eq (4) is the integration over the longitudinal dimension of Eq (3), which is a 1D equation and therefore is already integrated over the cell width.

- p7 l166-167: is this a wash load hypothesis?

Yes, it can be described as such. However, we estimate that sediment transported in suspension in this catchment is between clay and medium sand grain size, therefore it includes also rather coarse grain sizes.

- p8 Fig3 : SSC values seem low for a mountainous catchment area. This is certainly related to the lack of observed values during floods.

Indeed, the bulk of observed SSCs are not very high (less than 20 mg/l) but during floods they can be much higher. We will discuss this it as proposed in point (3).

- p8 l186-188: it is questionable to use the slope of the Q-SSC relation given the dispersion that exists between these two variables (even in log scale)

We aim at reproducing the Q-SSC relation, as representative of the basin sediment dynamics, by matching the modelled and observed clouds of points, i.e. their trend and their dispersion, by looking at the SSC frequency distribution. In the revised manuscript, we will clarify that we did not match the slope of regression lines of observations and simulations, rather we looked at both the trend and the dispersion. In the revised manuscript, we will add the percentage of simulated SSC that fall within the observed percentiles, as proposed in the reply to Reviewer 1.

- p10 l226-228: what forms of erosion are observed within the basin?

Deep, permanent gullies and small shallow landslides characterize soil erosion in the eastern part of the basin (Fontanne catchment). The southeastern region is characterized by shallower gullies and scree, the major landslides are also located in this area and have a significant role in the sediment budget of the basin (Norton et al., 2008, Van der Berg et al., 2012).

- p10 l234: "Hinderer et al. (2013)" is not present in the reference list.

Hinderer et al. (2013) is in the reference list in p20 l 475-477.

- p10 l237: "The underestimation of sediment load (...) we do not like to reproduce the largest measured sediment concentrations". This is a working hypothesis that should be placed in « Material and Method ».

We will explain better that since we underestimate highest hourly SSCs we also underestimate annual sediment loads and therefore cannot compare our yields directly with other estimates in the literature.

- p10 Fig5: indicate the observed data as red dots on the SSC time series.

We will consider this option.

- p11 Fig6(a): over which periods are the intensities calculated: over the rain periods only or over the whole period of simulation?

Intensities are calculated over the entire simulation period.

- p11 l242: I suggest modifying "where SIM 2 and 3 are compared respectively with SM1".

We agree.

- p13 Fig8(b): There is a black dot without a text caption

This is T3, we will fix this.

- p17 l369-372: I am not convinced by this hypothesis, which depends heavily on the nature of the soils and the infiltration model used.

We will further discuss this point according to the results of point (7).

References

Mahoney, D.T., Fox, J.F., Al Aamery, N., 2018. Watershed erosion modeling using the probability of sediment connectivity in a gently rolling system. J. Hydrol. 561, 862–883, https://doi.org/10.1016/j.jhydrol.2018.04.034.

Heckmann, T., Cavalli, M., Cerdan, O., Foerster, S., Javaux, M., Lode, E., Smetanová, A.,Vericat, D., Brardinoni, F., 2018. Indices of sediment connectivity: opportunities, challenges and limitations. Earth Sci. Rev. 187, 77-108.

Norton, K. P., von Blanckenburg, F., Schlunegger, F., Schwab, M., and Kubik, P. W.: Cosmogenic nuclide-based investigation of spatial erosion and hillslope channel coupling in the transient foreland of the Swiss Alps, Geomorphology, 95, 474–486, https://doi.org/10.1016/j.geomorph.2007.07.013, 2008.

Van Den Berg, F., Schlunegger, F., Akçar, N., and Kubik, P.: 10Be-derived assessment of accelerated erosion in a glacially conditioned inner gorge, Entlebuch, Central Alps of Switzerland, Earth Surface Processes and Landforms, 37, 1176–1188, https://doi.org/10.1002/esp.3237, 2012.