Response to Referee 1

1. Model Context. The referee states that "*The authors all but ignored existing large-scale sediment flux models (see a most relevant review paper and a couple of examples below). This is a major emission that must be corrected; their model should be framed in reference to these models.*" In the submitted manuscript we indeed referenced only those models that in our opinion were directly comparable to the approach we took, like tRIBS (Francipane et al., 2012) and the model of Tsuruta et al. (2018), see lines 62-69. But, as the reviewer suggests, we will add a brief review of other selected physics-based large-scale approaches in the revised manuscript to help frame our work. We will highlight the differences between the approaches (see Section 2 below). At the same time, we prefer to stay focused in the paper on physics-based modelling approaches only. Most of the models reviewed or presented in the papers suggested by the referee (De Vente et al., 2013; Cohen et al., 2013; Pellettier, 2012; Syvistky and Milliman, 2007) are statistical and steady state models which cannot be seen as reference models, because they are developed for a different purpose and cannot answer the same questions we address in our work.

2. Novelty. The referee states that "*The authors greatly over-sell the novelty and capabilities of the sediment model. While it is true that the hydrological framework is physically-based, the sediment model is a simple empirical equation (Eq. 2) that predicts sediment as a function of discharge, slope and a spatially variable (alpha) coefficient… Sediment transport (Eq. 4) is a simple cell-to-cell and time-step balance. I see very little novelty in this model. The authors must make the argument of why this model is novel if they wish to continue claiming it.*" This point and criticism will require deeper explanation in the revised manuscript because we have clearly not managed to get the message through. Indeed the novelty is not in the sediment model per se, but in the combined hydrology-sediment system approach and the questions it allows to address.

The novelty we perceive is based on the combination of the following elements: (a) We combine physically-based unsteady hydrological simulation of surface overland flow with a simple hillslope erosion and sediment transport component. This ensures that sediment is produced and transported along hillslopes by overland flow respecting physical processes of hillslope erosion and sediment transport as we understand them. The sediment component is simple by design (sediment production and continuity in Eqs 2 and 4 mentioned above), so that the most uncertain part of the modelling system is not over-parameterized. (b) The high spatial and temporal resolutions of the model (100 m and 1 hr) allow the inclusion of detailed topographic variations, connectivity of sediment pathways in space and time, and fast response to heavy precipitation where it happens. (c) Continuous simulation (order of decades) by our approach, allows to track overland runoff generation and hillslope sediment transport by spatially distributed changes in soil moisture, snowmelt, and rainfall, not only for individual events, but over long periods of time reflecting also long-term changes in soil moisture states, rainfall seasonality, etc.

None of the physics-based models reviewed in De Vente et al. (2013) or mentioned in the introduction of the manuscript (lines 62-69) combines these three characteristics at a spatial scale comparable to our case study. This is the context in which we perceive the novelty of our work, and which allows us to explore the effects of the spatial variability in catchment erodibility and rainfall with higher confidence.

At the same time, we recognize that our model is not novel in the sense that it is the first and only such model. For example, it is similar to tRIBS (Francipane et al., 2012) and the model of Tsuruta et al. (2018). However, the former is not applicable to large catchments and long simulations at high resolutions due to computational demand, while our setup is computationally very efficient and applicable to medium and large-scale basins, and the latter is a coarser resolution model with less physical hillslope surface runoff generation routines. More details about the spatial and temporal resolutions of these models and the physics-based approaches reviewed in De Vente et al. (2013) are summarized in Appendix A.

In conclusion, we do think that our approach has unique strengths that allow us to explore the hydrology-sedimentology connections leading to sediment generation pathways at high resolutions, which other approaches do not have. In the revised manuscript we will carefully review the text to make sure this aim and the context of the work with respect to existing models is clear.

3. Model Evaluation. The referee states that "*The evaluation of the sediment model is odd - referring to the relatively low scatter in the SSC-Q plot (Fig 3) as an argument for strong model performance. A standard model performance analysis is offered for the model's hydrological predictions (Table 1). It seems that the observed sediment is used for model calibration so we actually left with little knowledge about how well the model is doing. Given the relative simplicity of the model and the way it was calibrated, the interpretation of the model results extends much beyond the model's ability to represent the discussed processes…*". Indeed the referee is correct that it is much easier to calibrate the hydrological part of the model than the sedimentological one, mainly because we do not have the data to do so. There is only one suspended sediment measurement point at the outlet of the basin where bi-weekly measurements are available for a reasonably long period. We do not consider it meaningful to tweak the simple advection-based sediment transport routine implemented in the model, to match "perfectly" the observed hourly concentrations at the outlet measured twice a week. A comparison of sediment transport at the daily scale is also not possible with the given resolution of the measurements. Rather we assumed as a qualitative measure of success the reproduction of properties of the observed sediment rating curve (SRC), i.e. the relationship between hourly discharge and suspended sediment concentration (SSC), which captures the catchment sediment dynamics. Concretely, we calibrate the sediment model parameters, i.e. the river initiation threshold RT and the α_1 erodibility parameter (Eq. 5), to (a) reproduce the observed slope of the SRC as best as we can, as well as (b) the frequency distribution of observed SSCs. As a quantitative indicator of the model performance, we propose to introduce in the revised manuscript the percentage of modelled SSCs that fall within the 5th and 95th percentile of the observations and this equals to 90.4% in our simulation. We also omitted a traditional validation with a part of the dataset not used in calibration as our observed records are too short and our main focus is on the sensitivity to input data (spatial variability in surface erodibility and rainfall) not on the predictive uncertainty in SSC per se.

Regarding the last point that the "…*interpretation of the model results extends much beyond the model's ability to represent the discussed processes…*" we do not fully agree with the referee. The spread around the SRC in our deterministic approach is due to (a) the spatially distributed nature of the model, which allows to simulate the heterogeneous response of the basin to hydrological forcing, based on the topographic characteristics, depth and properties of the soil, (b) the spatial variability of surface erodibility and the connectivity of hillslope flow paths to the river network, and (c) the spatio-temporal distribution of rainfall leading to overland flow and erosion (lines 293-302). We are of the opinion that all of these processes are robustly included in our modelling approach. They of course cannot explain all the SRC spread because in the real natural catchments there is an added element of stochasticity in sediment mobilization, transport, and sediment supply limitations, which add to the SRC variability (lines 306-312). However, we believe that this does not invalidate our modelling results or their ability to provide insights into process effects, like the role of spatial variability in erosion drivers. In the revision we will be more clear on these limitations of the results and their interpretations.

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Appendix A:

Comparison of spatial and temporal scales from “Physics-based Models” in DeVente et al. (2013), tRIBS, Tsuruta et al. (2018) and the model presented in the manuscript.

	SPATIAL SCALE AND RESOLUTION	TEMPORAL SCALE AND RESOLUTION
AGNPS [1,2]	Basin scale: <2.3 km^2 Discretization: sub-basins	Continuous Daily
LISEM [3,4,5]	Basin scale: <5.7 km2 Resolution: 10/20 m	Individual rainfall events Minutes
PESERA [6,7,8]	European scale Resolution: 1 km	Steady state
SWAT [9,10]	Basin scale: up to 185 000 km^2 HRUs (resolution 1-100 km^2)	Continuous Daily
WBMsed [11]	Global scale Resolution: ~11-55 km	Steady state Representative daily sediment flux
Pellettier, 2012	Global scale Resolution: 10 km	Steady state
tRIBS [12]	Basin scale: 0.037 km^2 Multiple resolution (irregular mesh)	Continuous Minutes/hours
Tsuruta et al., 2018	Basin scale: 230 000 km^2 Resolution: ~7 km	Continuous Hourly
This paper	Basin scale: 477 km^2 Resolution: 100 m	Continuous Hourly

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