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Interactive comment on "A Process-Based Rating Curve to model suspended sediment concentration in Alpine environments" *by* Anna Costa et al.

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We thank Referee #2 for her/his helpful review. We have analysed the suggestions and we report in the following our response to the comments and give indications on how we will revise the manuscript.

1) Addressing the impacts of hydropower operations on SSC in the Rhone valley. This has been investigated by numerous authors, some of which are cited but not correctly put in context in the current ms. How much of the winter discharge comes from hydropower reservoirs? How much smaller is the discharge in summer due to storage in reservoirs? How does this affect SSC?

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We are aware that hydropower operations affect the flow and sediment regime of the upper Rhone basin, through flow and sediment impoundment and flow regulation, which results in a substantial decrease of discharge in summer and increase in winter. Our empirical model partially accounts for the effect of hydropower operations on SSC magnitude and timing because we calibrated the parameters of the PBRC using the observed time series of SSC at the outlet of the basin, which are impacted by the hydropower operations. Therefore, the coefficients (a1, a2, a3), the exponents (b1, b2, b3) as well as the time lags specific of each hydroclimatic variable (l1, l2, l3) include the impacts of reservoirs and hydropower operations (e.g. delays in sediment transfer are accounted for in the time lags chosen by the IIS algorithm). Even though our approach is relatively simple and cannot capture all the complexities of the sediment dynamic of the upper Rhone basin, the results show that the PBRC, which accounts for hydropower operations only indirectly through the model parameters, performs better that the traditional RC, which accounts more directly for the hydropower regulation because it accounts directly for discharge. We will make this point clearer in the revised manuscript. Because we consider the suggestion of the Referee #2 valuable, we will also test an alternative PBRC model which distinguishes among the contribution to SSC of the area of the catchment in natural conditions and the area impacted by hydropower operations.

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2) The estimation of ER, SM and IM is complex and in my opinion should be addressed using a hydrological model, taking into account the complexity of the Rhone valley. I find it inconsistent to adopt some model parameters (e.g. temperature threshold and ice melt parameters) from previous studies and calibrate other parameters to direct observations. Perhaps this can be addressed within a sensitivity analysis.

The aim of the PBRC approach is to relate SSC to the potential sediment sources and fluxes represented by the three hydroclimatic forcings in the basin and not to discharge which is the outcome of the basin water balance. This is a data−based approach which

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uses a simple temperature−based model to simulate ER, SM and IM and require less data to be calibrated and used than most of the available hydrological models. The results of the calibration and validation show that, although simple, the model to estimate ER, SM and IM performs satisfactorily both in space (snow cover) and time (see Costa et al., 2017). In past work we have in fact used a hydrological model to simulate the Rhone Basin streamflow including all relevant hydrological processes (Fatichi et al., 2015), but this includes additional model−related uncertainties which in this work we aim to avoid. However, thanks to the reviewer's comment, we realized that we should better clarify how we calibrated the model for ER, SM and IM. In fact, the model was consistently calibrated on observed data (more details in Costa et al., 2017) and not adopting parameters values from previous studies as suggested by the Referee. Moreover, we performed a sensitivity analysis on the parameters of the snow model, more specifically on the snowmelt factor and the temperature thresholds for snow accumulation and melt (see Costa et al., 2017, Supplementary Material). We will discuss some of the results of the sensitivity analysis and we will describe more extensively the calibration procedure in the revised manuscript, in order to avoid possible misunderstandings.

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3) I recommend to compare total suspended load estimations with methods described in other studies and published by regional and federal agencies, e.g. FOEN. Furthermore, an uncertainty analysis would be very helpful. I also would like to see a plausibility check of all major conclusions: can rain be responsible for 75% of SSC, how does this compare to other studies? Is a time lag of 1, 2 and 5 days realistic, how does this compare to flood peaks after heavy precipitation events? How much is delayed in hydropower reservoirs? How does the IM contribution compare to other studies?

In the revision we will compare the mean annual suspended sediment load from SSC predicted by our model and observed/derived from observations, together with other estimates that we can find, including uncertainty in the mean. We agree with Referee

#2 that it would be valuable to also compare other modelling results with previous works. We have compared IM with previous studies and we will discuss this in the revised manuscript. As for the other suggested comparisons, we are not aware of any study which distinguishes among the relative contributions of the different sources to SSC. However, we will look further into the literature and, if any, we will include in the revised manuscript references to comparable works. Finally, as already commented in the manuscript, we believe that the time lags automatically identified by the iterative input selection algorithm are realistic, considering the process involved in suspended sediment production and transport and the extent (mean flow pathway length) of the catchment. It should be remembered, though, that these time lags represent average values in space, over the entire catchment, and in time, thus accounting for both dry and wet conditions as well as for meteorological events of different intensities which are peculiar of the different seasons. We could partially account for the effect of flood peaks by including time varying parameters in the PBRC formulation or by spatially explicit computation, which we are testing in future research. A more complex formulation which accounts for monthly varying parameters was tested, but the improvement in the results was not significant to justify the increased number of parameters (from 6 of the presented PBRC to 6*12 of the time varying formulation).

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4) I recommend to avoid mass referencing (e.g. pg2, ln15, 6 references are listed) but to be more specific why references are relevant. Three relevant references are sufficient to fortify a statement. I recommend to select only directly relevant references and build on previous works.

In the revised manuscript, we will review the references, in order to avoid mass referencing.

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5) Figure 4 and 9: why are there three panels for one heading (or letter, I would recom-

mend adding a heading) on the left and only one heading for one panel on the right? I would present annual loads rather than SSC, this would make your study more relevant for future studies.

We agree with Referee #2 that the panels heading can confuse the reader, and we will adjust the figures accordingly. Regarding suspended sediment load estimations, see reply to comment number 3.

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6) I recommend shortening the text.

We will try to identify the parts of the manuscript which can be shortened without compromising the information content and the clarity of the paper.

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7) Finally, I recommend to add a reflection why this study is needed and how it complements previous studies. I would also recommend to start the abstract and introduction by introducing the problematic of high sediment loads, rather than jumping directly to the methods.

We intend to strengthen the comparison between this and other approaches for modelling SSC and making clear the added−value of this work, as a data−based empirical analysis of potential suspended sediment sources as they are reflected in hydroclimatic triggering variables. Based also on the comments of Referee #1, we will discuss this point in the revised manuscript (see our Reply to the Referee #1, bullet point n. 2 and Fig. 5). In addition, we will mention both in the abstract and the introduction why the estimation of suspended sediment concentration and load are relevant.

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