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Hydrology and Earth System Sciences Discussions

Interactive comment on "Elevational dependence of climate change impacts on water resources in an Alpine catchment" *by* S. Fatichi et al.

S. Fatichi et al.

simone.fatichi@ifu.baug.ethz.ch

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K. Rahman *The authors developed a hydrological model for upper Rhone river watershed. Which has paramount importance in Swiss economy since the river drains into the Lake Geneva However I found some serious limitations First of all in the Introduction part [P 3747 L.9] It is written: "Because the technical data of existing infrastruc-ture are not always available, we adopted a very pragmatical engineering approach for simplifying the representation of hydraulic infrastructures whenever this was the case" Which is completely wrong!!*

Reply: We openly state that the representation of the hydropower infrastructure required some pragmatic assumption for those systems, for which the data required to

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implement their functioning into the model were unavailable. Given the high level of anthropogenic control, we considered as fundamental to represent all the major system elements, although with a certain degree of approximation, rather than modeling the systems with only few hydropower plants, for which information was more extensive. We disagree that this approach is "completely wrong", because this statement would question most of the studies in ungagued catchments and a number of studies found in the literature, which are based on incomplete information or considerable simplifications. Among these studies we can cite also the study by the author of the comment, Rahman et al. [2] (page 328 end of the sub-section).

K. Rahman *After having a literature review I found two existing work in the same watershed with the similar objective :*

[1] Modèle de prévision et de gestion des crues optimisAtion des opérations des aménagements hydroélectriques à accumulation pour la réduction des débits de crue" Written by Jordan.F

Moreover, there is another recent paper from ALPIQ hydropower company (which gives very detail information about the watershed :

[2] Rahman, K., Maringanti, C., Beniston, M., Widmer, F., Abbaspour, K., and Lehmann, A., 2013, Streamflow Modeling in a Highly Managed Mountainous Glacier Watershed Using SWAT: The Upper Rhone River Watershed Case in Switzerland: Water Resources Management, v. 27, no. 2, p. 323-339.

Therefore, please make sure that your model provided some "added value" to the exiting literature not the first time that you did.

Reply: We were well aware of both studies, and indeed we quoted the PhD Thesis of F. Jordan twice (P3753, L24 and P3770 L25) from where we took many important information for our analysis and for the definition of the hydropower network. However, Jordan (2007) study was totally different from ours, since it was aimed at optimizing the

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reservoir management operations for flood mitigation purposes. For this purpose, he used a very different hydrological model, based on autoregressive principles, but he did not carry out any analysis of the effect of hydraulic infrastructure on the overall water budget of the upper Rhone. Finally, he did not investigate effects of climate change. In this respect, we are persuaded that our study provides an added value, as it is very different in terms of both model representation, and question addressed.

With regard to the study by Rahman et al., we consider it of limited significance with respect to our study, since it essentially reports about an application of the SWAT model, which does not seem to have a specific focus and does not provide any elaborated insight or specific result analysis. Moreover, many methodological choices are vague or totally missing (e.g., the definition of the climatic inputs, the computation of the fraction of snow covered area, or the way hydropower infrastructure is implemented). In addition, there is no comparison between hydrological simulations obtained with the actual infrastructure in place and those corresponding to a natural flow regime, being the only comparison provided by a figure illustrating "observations" at Port du Scex and Gletsch for three different periods. Accordingly, also in this respect, we are persuaded that our study addresses totally different and new questions (e.g. the effects of climate change across a range of scales, including stochastic climatic forcing, and their analysis combined with existing hydraulic infrastructure), from a perspective not presented before.

K. Rahman *I believe there is a mistake in the release point of G.Dixens: there are three outlet functioning from 2002 they are [Nandez-Fionnay-Chandoline] please make sure you are using the updated information.*

Reply: There is no mistake in the representation of release points of Grand Dixence. We are well aware that there are three possible hydropower stations for the water released from the reservoir. These are Fionnay-Nendaz (see correct name), Bieudron, and Chandoline. According to our information (Jordan, 2007) these have capacities of respectively 45, 75 and 10.2 m3/s. The derivation to Chandoline is represented

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explicitly in our manuscript (Figure 2). The other two derivations are grouped together, because indeed the hydropower stations of Nendaz, and Bieudron are very close to each other in the main Rhone stream (within one of our grid cells). Therefore, there is no advantage in adding an additional derivation that starts from the same point and arrives to the same point. The compensation reservoir of Fionnay is not accounted for as all the other small compensation or pumping reservoirs because, although important for sub-daily operations, they do not have any influence on the overall water budget.

K. Rahman *I do not see much discussion about 'future energy driven scenario' Only it is written in the Discussion [P 3768 L26] This is mostly related to the fact that flow in these catchments is controlled by river diversions and reservoirs that are assumed to operate similarly in the future and buffer the climate variability to a certain extent. New management rules ora significantly different energy demand might, however, reduce this effect. That makes very little sense! Future energy demand should have very significant impact! So there should be a section on how the future energy demand will affect.*

Reply: We fully agree that future energy demand (and market controls) might have an impact on reservoir operations and we will emphasize this point in the discussion by adding an additional comment to the text (P3771 L4 –L7). However, the assumption of unchanged operational rules for the reservoirs was basically the only possible at the moment, without venturing into a speculative exercise that would not be more realistic than assuming unchanged operation. In order to get future operational rules we will need to know changes in the electricity market and changes in the energy policy of Switzerland (both rather uncertain). These changes will further interact with changes in the resource that our study has investigated. In the EU-ACQWA project, which has funded this study, there are partners that on the basis of our results will work to anticipate possible changes in hydropower operations. We are confident that on the basis of their results, additional investigations will address the combined effect of climate change and changes in reservoir operations as well as feedback mechanisms.

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K. Rahman *Nothing discussed about Land-use change. I believe Landuse also has severe effect in such watershed. shrinking of glacier will lead more surface flow and vegetation type is changing in such watershed. Please discuss how the land use change will impact simultaneously with climatic change or clearly mention that your analysis is only for meteorological variable.*

Reply: Changes in land-use due to glacier retreat are accounted for in the model by changing the land-cover of cells where glaciers totally melt to the category "bare soil/unproductive land". This is a reasonable assumption, considering the time scale over which the establishment of productive soil and vegetation, which can modify significantly the water balance and the flood runoff generation mechanisms, are longer than those analyzed in the study. In the revised manuscript, we will better specify this but we will also stress that the study is only related to the impact of changes of the climatic forcing. However, we also argue that land use changes due to glacier retreat could be rather minor and non detectable when compared to the stochastic variability of climate (especially precipitation). Furthermore, the author of the comment should note that accounting properly for land-use changes, requires to include various effects, such as the CO2 fertilization of vegetation and its establishment, thus leading to models of significantly different level of complexity (e.g., Fatichi et al., 2012a,b J. Adv. Model. Earth Syst.). Unfortunately, the use of such models would pose strong limitations to the simulations of large areas like the entire upper Rhone catchment, due to the exceptionally high computational requirements, when associated with the use stochastic forcings, like in our study.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 3743, 2013.