Dear Editor Bettina Schaefli,

Please find below our reply to your Editorial review, As you will find, the manuscript has been significantly modified to address yours and the reviewer's criticisms.

Sincerely,

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Responses to the Editorial Review

In addition to my summary of the discussion of the HESSD manuscript, I would like to add a few detailed comments:

1) Literature review*: There are numerous simulation studies for this catchment but they are not all published in peer-reviewed papers, please refer namely to (Hingray et al., 2010;Tobin et al., 2012;Mezghani and Hingray, 2009). Hingray et al. (2010) discuss in detail how to calibrate a semi-distributed model for this catchment for design flood estimation but without modeling explicitly the hydraulic infrastructure. All the work related to the Minerve project (García Hernández et al., 2009) is based on a distributed model of the entire Upper Rhone River basin including the hydraulic infrastructure The literature review should certainly refer also to previous hydrological studies of this catchments even if they are only published in engineering journals or in PhD theses. You might want to check (Bérod, 2013) for an overview and the theses of (García Hernández, 2011;Tobin, 2012;Mezghani, 2009).*

Reply: We checked the mentioned literature and we made reference to it, whenever it was appropriate and/or relevant by adding citations in the introduction and method sections of the revised version of the manuscript.

2) Gridded meteo data - temperature?. *As far as I can see this is one of the first hydrological modeling studies making use of the gridded data of MeteoSwiss RhiresD. Given that apparently this product is very useful for hydrological modeling, it would be nice to have it mentioned in the abstract and the conclusion. It could also be useful to mention that it is freely available for research. Is there not a similar product for temperature? Why was it not used? And why does the study work with a generic temperature lapse rate rather than with a temporally and spatially distributed lapse rate? It is well known that the lapse rate plays an important role for hydrological modeling in this kind of environments (e.g. Tobin et al., 2011). Why is this not part of the meteo generation framework? Especially when it comes to extreme events simulation, the temperature interpolation and its effect on snow accumulation, snow melt and rain on snow effects cannot be neglected.*

Reply: We emphasized in the revised version the importance of using the RhiresD product in Section 2.2.1 and in the conclusions. A similar product for mean, maximum and minimum temperature (http://www.meteosuisse.admin.ch/web/en/services/data_portal/gridded_datasets.html), is now available. Unfortunately this product was not available when we started our research and ran the simulations. Even though interpolating temperature from ground stations is less uncertain than interpolating precipitation, we agree that a gridded temperature product would have been a very valuable information, especially to overcome the limitation posed by the assumption on the lapse rate. Therefore, we strongly suggest its use for future research. We did not use an hourly and spatially variable lapse rate because Topkapi-ETH did not allow for such a flexibility and we considered its implementation not critical, although we acknowledge that in certain circumstances it can be very important. These possible problems are now mentioned explicitly in the manuscript and references are included (Section 2.2.1).

3) Unnecessary details?. *I do not see the interest of including details on water consumption and irrigation if there is no information about it and if it does not have any effect on the reported results; if these aspects are included because the framework project required it, there is still no need to discuss this in the present paper.*

Reply: Following the editor's suggestion, we significantly shorten the Section 2.2.5 about water consumption and irrigation, transferring most of the material in Text S1 of the supplementary material.

4) Study area. *What is the mean elevation of the catchment and of the control points of table 1? Why did you not use the Swiss land use data? There should be proper references to all used products (with details on publisher and related webpages, e.g. also for the Swiss Committe on Dams and all maps).*

Reply: We now explicitly state the mean elevation of the catchment (Section 2.2). We also report a table in the supplementary material (Table S2) where the elevation, catchment area and glaciated fraction at the beginning of the simulations are given for all of the control points of Table 1. Finally, we included in the text references to a Table in the supplementary material (Table S1) which gives for all the used products the publisher and the source for documentation. Note that the website of the Swiss Committe on Dams recently changed and most of the information we used is not freely accessible anymore.

5) Target-level water management policy. *The selected approach is certainly useful for the present day situation even if I think that there is only one target level for a short temporal window (the only objective is the filling of the reservoir by end of summer (Schaefli, 2005)). In exchange, I do not understand how this rule can be applied to the future scenarios; were the target-levels recomputed for new reference periods? If the target-levels remain the ones of the present-day, how can the dams release any water through the turbines if the dam level is permanently lower than the target during the summer? The definition of the target levels for the future period should be clearer. I think that there would have been simple strategies to come up with new management scenarios; looking at recent hydropower lake filling curves for Switzerland, it is obvious that during some recent years, the behaviour of the dams was quite different from the past, this might have allowed to build scenarios (see the Swiss Federal Office for Energy, http://www.bfe.admin.ch/, look for "Water levels of reservoirs").*

Reply: We agree with previous reviewer's comments and with the editor that that future energy demand (and market controls) might have an impact on reservoir operations and we now emphasized this point in the discussion of the manuscript. However, we want to clarify that the flexibility in reservoir operations is likely to be confined to short temporal scales. Hourly, daily, weekly operations can be easily modified, but we respectfully disagree that the long-term management rules (the target level policy), i.e., the level to be achieved in different seasons is going to change. Very likely, it is going to remain similar also in the future or just shifted by few weeks, because it is mostly related to the seasonality of the available runoff to fill the reservoirs. All of the Valais reservoirs will still receive most of the water during the melting period (end of spring, summer), thus increasing reservoir levels and water will be used to produce energy in summer/autumn through winter, decreasing reservoir levels. The information provided by the Swiss Federal Office for Energy, is exactly suggesting this type of behavior, being water level differences for a given day of the year function of the climate anomaly of the specific year but not of a change in the seasonal target level policy.
We also want to emphasize that it is almost impossible in the simulations to have for the entire summer actual levels below the target levels. Reservoir levels lower than the target levels, in the

model assumption, imply that water is not released to the turbines. This consequentially leads to a very rapid increase of reservoir storages and the reaching of the target levels, especially at the beginning of the summer where most of the snow melt is available. This water is successively available for hydropower production, later in the season. In all of the simulations during the historical period we observed that target levels are mostly matched. In future scenarios this is not anymore the case for most of the reservoirs at the end (but just at the end) of the summer, beginning of fall, where indeed we don't have enough incoming water to reach the target level.
In conclusion, we think that the target level policy we applied is very likely consistent with both present and future climate condition needs for seasonal management. Flexibility of long-term management could be only provided by a "surplus" or water resources in comparison to the resource which is used right now. Currently, all the incoming water to reservoirs is used for electricity production, there is basically no overspill of water (or negligible) in Valais dams both in reality and in model simulations (see also our response below) and future predictions are not pointing toward an increase of resources, therefore management flexibility at the annual scale is likely to be very limited. This is now discussed in Section 4.0.

***6) Model performance**. It would be useful to clearly state in the paper that the good Nash values are essentially due to the hydrological regime (as discussed in an answer to a reviewer comment). It could also be useful to cite (Schaefli and Gupta, 2007). In fact, Nash values of 0.8 are already not very good for this kind of regimes with a strong annual cycle. This reinforces my critical view of the extreme event analysis. Furthermore, the Nash values for the different sub-catchments are not comparable to the ones of the Rhone river; the stronger the annual cycle, the higher the Nash values even for a "bad" model. (For this case study, it would have been useful to think about a hydrological performance measure that is not influenced by the hydrological regime but this is certainly beyond the scope).*

Reply: We fully agree with the editor. This has been now clarified in the manuscript (Section 3.1) and an explicit reference to Schaefli and Gupta, (2007) is provided.

***7) Discussion:** p. 3768, line 21: this sentence seems to imply that the hydraulic infrastructure had an effect on the hydrological budget; I would reformulate to reflect that the hydraulic infrastructure only impacts the seasonal distribution of water.*

Reply: The hydraulic infrastructure has, in fact, an effect on the overall amount of available water and not only on the seasonality whenever river diversions are diverting water in a different catchment. This is typically the case for many sub-catchments of the upper Rhone, especially for Vispa and Drance. We modified the sentence accordingly, to better clarify this concept.

p. 3770, line 20: As far as I know, there are no observed floods in spring in this catchment and its subcatchments (but my analysis dates back to 2005). It is, in fact, difficult to say whether there are no spring floods or whether any spring floods would be absorbed by the empty accumulation lakes. It would be interesting to know whether this is a general statement (in this kind of regimes, spring floods are to be expected), whether it is based on observed data or on simulation without hydraulic infrastructure. Please also include the following reference here: (Bieri and Schleiss, 2012).

Reply: We analyzed maximum annual flow occurrence for Rhone - Port Du Scex from observations (1905-2011). It emerges that annual maxima can be located in Spring, Summer and Autumn. Specifically, the day of the year (doy) where the annual peak occurred ranges from 138 (beginning of May) to 289 (middle of October), with a median doy of 189 (beginning of July). For sub-catchments this variability is even larger. We think the editor referred to "major catastrophic floods" when she said that floods are not observed in spring. Therefore, occurrence of annual maxima in spring-summer and autumn is rather general in the upper Rhone in both observations and simulations with and without hydraulic infrastructure (which gave a similar range of doy 129-288).

We included the reference to Bieri and Schleiss, 2012.

p. 3771: "We We argue that even with a different management of the dams, the total energy production of the control scenario would be unlikely maintained in the 2030– 2050 period". This is a very strong statement and I would argue that it is wrong: there is at present more water available in the relevant sub-catchments than what can actually be stored in the lakes. The lake of Mauvoisin (which I know best) could be filled 1.3 times every year (see Schaefli, 2005, the lake volume is 204- 10 6 m3, the annual runoff from the catchment is 265 -10 6 m3 yr). Furthermore, water repumping will become standard in most hydropower systems. Accordingly, there is no reason why the total energy production might not be maintained in the future with new management strategies.

Reply: We respectfully disagree with the Editor. In basically all the reservoirs of the Valais, overtopping of the spillways and therefore "wasting water" in terms of hydropower use (electtricity production) is systematically avoided, both in reality and in the case in our simulations. The relative size of the reservoir with respect to the total annual runoff is not indicative of how much water can be stored and sent to turbine, because the latter depends on the capacity of the hydropower station/s and on the seasonality of the incoming water. Theoretically with a capacity of the turbines larger than the maximum peak discharge, we would not even need a reservoir. Conversely if the turbine capacity is smaller than the annual incoming discharge, regardless of the size of the reservoir, some of the water will be over-spilled in the long-term. For all the reservoirs of Valais including Mauvoisin, over-spilling is avoided (Grand Dixence does not even have a traditional spillway). This implies that all the incoming runoff (after subtracting evaporation from the lake) is used for hydropower production (265 -10 6 m3 yr in the case of Mauvoisin). At the same time, this automatically implies that if less water is available because of a lesser contribution of ice melt, less electricity is produced. This is true regardless of how dams are operated because the total resource is lower. Obviously companies, can play on the price and can maintain or increase revenues by generating power when price is high, but can NOT change the total electricity produced which depends on the available resource. Regarding pumping, any pumped storage system is overall an energy consumer because it requires more energy to pump water uphill than can be generated with that same flow. The advantage is only monetary and gained by pumping when price of electricity is low and producing when price is high. Therefore pumping cannot be used to increase overall electricity production as the Editor seems to suggest.

8) Minimum flow requirements. *In Switzerland, there is an important ongoing discussion on the minimum flow requirements and whether they reduce the hydropower production potential. The present study offers great potential to answer some important questions in this field (interaction of flow requirements and climate change). It would have been nice to see something in this direction.*

Reply: We are aware of the ongoing discussion on environmental flow requirements and their importance. However, we think that this is going far beyond the scope of this study, which is already rather long and comprehensive. A detailed analysis of environmental flow requirements and their impact on hydropower production, as well as climate change interactions can be the topic for another article which would need to address criteria on the basis of which environmental flow requirements could be defined. However, a sentence regarding environmental flow has been added in the discussion section.