Answers to Reviewer #2

We thank Reviewer 2 for valuable feedback to this manuscript. Hereunder follow our answers (normal text) to the reviewers' comments (marked in *italic*).

This is an interesting paper examining the effect of climate change on alpine lakes. Climate change exerts a dual influence on alpine rivers: changes flow rate and temperature. River temperature and sediment load influence density, and hence the nature of river intrusion into lakes. Future river discharge rates, temperatures and SSC are all predicted in order to assess the future dynamic state of two lakes, Lake Biel (LB) and Lake Geneva (LG), out to the far-future of 2099. The work is interesting and certainly very appropriate for HESS.

There are two parts to the work, the prediction of inflow conditions of the two main inputs to LB and LG, respectively, and secondly the lake dynamics. I believe the assumptions and range of expected behaviours for the first part are well documented, but more discussion is needed for the lake dynamics part.

The paper uses the 1-D Lake model SIMSTRAT. There is very little discussion of SIMSTRAT and, given its key importance in the forecasting, some more details are needed here so that the paper is more self-contained. SIMSTRAT has eight numerical constants, and the assumed values are summarized in Table 3 for each Lake, and there is little explanation of what these constants represent. A key point is these constants are considered fixed, based on best estimates for current conditions. Why will these parameters also be valid out to 2099?

The SIMSTRAT model has successfully been used in many different lakes with very different eco-physical boundary conditions (and therefore different calibration coefficients). It is obvious that some of the constants would change with different boundary conditions in the future. However, to affect our model results these changes have to be large and are usually not associated with climate change. For example, if the trophic status would change to highly eutrophic or to ultra-oligotrophic, then the absorption coefficient would change. Likewise, constructions of dams would ultimately alter river discharge patterns and thereby river temperature and SSC content. The most critical phenomenon associated with climate change for our model results, are the glacier retreating rate. Fortunately, as shown by *FOEN* [2012] and stated in the manuscript, this rate is not expected to decrease the glaciers in the catchments used here past ~30% of today's glacier extent. Thus the model constants, calibrated and validated for current conditions, are expected to be useable as long as the systems are not severely structurally altered. As climate change, re-evaluation of the model constants will be required. However, the parameter change is not expected to significantly alter the model results.

We agree with the reviewer that the description of SIMSTRAT can be extended. We propose that the revised manuscript will contain a more detailed section 2.4, describing the main features of SIMSTRAT including clarification of the model parameters and what they represent. However, a detailed description of the model with all equations are available in *Goudsmit et al.* [2002], and will thus not be repeated in this manuscript.

Figures 7g and 7h shows increased stability, particularly in the far-future scenario for both LB and LG. This is particularly associated with predicted warming of the epilimnion. So estimating the downward transfer of heat and vertical mixing generally is key to model predictive performance. In future, why can we assume such key quantities, as the downward penetration of radiation into the water column will be unchanged? If the density stratification changes due to climate change, the internal wave climatology will also likely evolve, so can we assume the mixing is the same?

Turbulent mixing (turbulent diffusivity) is dependent on both the kinetic energy input into the system (wind) which is enhancing mixing, and the stabilising effect by heating which reduces mixing. Therefore, the reviewer is correct in that the downward transport of heat will change with altered forcing and stratification. Such changes are however already included in the k-epsilon turbulence closure and therefore included for changing climate forcing.

In this particular application, we only need to consider the increased stabilizing effect due to increased air temperature which limits mixing. In general, parameters which are expected to change in the future and affect stratification and mixing include air temperature, turbidity (light penetration), wind, cloud cover and humidity. The confidence in future prediction of wind, cloud cover and humidity remain still too low [*CH2011*, 2011] and have therefor been kept constant here.

The sensitivity of SIMSTRAT to changed light penetration during climate change in Lake Geneva has already been investigated by *Schwefel et al.* [2016]. Who showed that lower transparency (increased absorption), warms the surface more, strengthens the thermocline and overall cools the deeper layers of the lake. Opposite, increased transparency (weaker absorption) heats the lake surface less and the deep-water more and therefore causes a weaker thermocline.

In the revised manuscript we will include a sensitivity analysis of SIMSTRAT using observed long-term fluctuations of the atmospheric forcing. The sensitivity analyses done by *Schwefel et al.* [2016] will also be discussed.

Also lake volumes can evolve, leading to potential changes in residence time as discussed in Figure 9 and text around lines 455 and following. So what is the uncertainly associates with the use of a 1D model like SIMSTRAT in some of these scenarios? The two lakes currently have very different residences times, and LG already has an 11.5 y residence time, so how accurate is a 1-D assumption even now, let alone into the future? These issues need to be clarified in the paper and their influence on the uncertainly of the predictions in the paper.

Here we use the one-dimensional (1D) model SIMSTRAT, thereby horizontal averaging all lake process. The simplicity of the one-dimensional approach is its main strength for long-term (far into the future reaching) climate studies, enabling long temporal scales including natural variability to be modelled under a multitude of different climate scenarios. The performance in Lake Biel of SIMSTRAT has been compared to the state of the art three dimensional (3D) model Delft-3D by *Råman Vinnå et al.* [2017]. Showing that lake-wide processes could be equally good represented in both 1D and 3D. The difference between these models lays in the representation of local processes. In fact the term uncertainty should not be used in climate research, where future predictions only valid for certain scenarios are considered. Here, we give the possible range of our model results under the A1B emission scenario, as well as our models performance in the past (reference period).

A change in volume has to be extremely large, which is topographically not possible, in order to affect the systems considered here due to the depth of such lakes. The predicted shift in river discharge regime flattens the discharge curve, while maintaining the overall volume entering into both lakes. Assuming no drastic local river altering takes place in the future, a change in volume of both systems would require a geological temporal scale, outside the scope of this study.

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