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Comment on hess-2021-194

Anonymous Referee #1

Referee comment on "Future water temperature of rivers in Switzerland under climate change investigated with physics-based models" by Adrien Michel et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-194-RC1, 2021

The manuscript by Michel et al details a study that uses a chain of models to simulate river temperatures in 12 Swiss catchments that encompass two main landscape types: alpine and lowland. They used downscaled climate change projections in a suite of models that simulate glacier, snow, soil temperature, runoff, and river temperature dynamics. They assess the ability of the modelling chain to simulate historic conditions using observations from around 2005-2018. They conclude that river temperatures will increase for both catchment types under climate change; however, the magnitude and seasonality of increases will differ. The lowland (Plateau) catchments are expected to see relatively uniform river temperature increases throughout the year, with slightly higher increases in summer. In contrast, alpine catchments are expected to see small increases in winter river temperature, but large increases during summer due to an earlier shift in peak discharge associated with lower amounts of snow and glacier melt contributions.

Overall, the manuscript is relatively well written (although a number of typos and grammatical errors need to be corrected), and the logical development and presentation of the study generally makes sense. This was clearly a significant logistical effort to build and work with this chain of models. I can also appreciate the challenge in synthesizing these efforts. Because of the amount of work presented, and that much of it builds on previous efforts (i.e., the specific model components), I found it an overwhelming piece of work to digest. I appreciate the amount of supplementary material included, but the decision to not always reference that material directly in the text (supposedly to 'alleviate the text'?) makes it very difficult for the reader to navigate the immense number of results shown. Despite the considerable amounts of results included, the key findings from these modelling exercises don't strike me as overly complicated; therefore, I think there is a great opportunity to streamline the manuscript by reducing the amount of results presented while still providing support for the key findings in this study.

I provide a few general comments followed by some specific comments.

1. Describing the model chain and key assumptions/limitations

Keeping track of the various model components, what they do, and how they were individually and collectively calibrated is challenging. Perhaps a flow chart or a diagram detailing how the models interact, what components are tested against observations and/or what parameters are calibrated would help readers? For example, I was really confused about the time periods used to calibrate the individual models. Alpine3D was calibrated to 2012-2018? StreamFlow was calibrated to 2012-2014, but then validated to 2015-2018? So this is not an entirely independent validation since Alpine3D was already calibrated to that period? In addition the 'Validation over climate change period (Section 4.2)' was validated for 2005-2015 - which encompasses the period used for calibrating the model. So again, this is not an independent validation? I'm likely misunderstanding this workflow, which is why a better description of the steps taken might help the reader.

In addition, key details or assumptions made by the various model components are not really addressed - although these assumptions can be critical for interpreting the model results. Instead the reader is often referred to other studies and publications to get these important details. I recognize that the authors don't want to duplicate information already contained in other papers; however, I think the key aspects and assumptions of those models relevant to this study need to be presented in this manuscript.

Also, were any 'spin-up' or 'warm-up' periods used for any of the models? If not, why?

2. Clarifying the advection term associated with runoff

Probably a consequence of the information overload outlined in my point #1 above, I'm struggling to understand if and how the advection term associated with hillslope/land runoff is treated in these models. Alpine3D simulates spatially distributed soil temperatures and water available for runoff. StreamFlow sums the water available for runoff for all the Alpine3D cells draining to a stream reach of interest? This water available for runoff is assigned a temperature by one of three methods: 1) the energy balance approach in Comola et al (2015), 2) the HSPF algorithm, or 3) a soil temperature value (I am assume taken from Alpine3D?). Very little detail is provided in the text or in the supplementary material about the details and differences in these approaches (other than different RMSE reported in Table S7) and the authors conclude that the HSPF is the most consistent, so they use that for all subsequent model runs. However, I'm confused by the statement that 'in the HSPF scheme, the soil temperature has a less important impact than in the other schemes (soil temperature is only needed for heat conduction between water and river bed).' In this statement, does this mean that the soil temperature output from Alpine3D is only used for the bed conduction term, but in the other schemes it is used for something else? I get that the soil temperature from Alpine3D is used to set the runoff temperature in scheme 3, but how is it used in scheme 1 (the Comola approach)? Also, it sounds like Alpine3D simulates soil temperatures at different depths - so which depth is used for scheme 3? Also, is it appropriate to use the Alpine3D soil temperature for the channel bed temperature? The channel bed has entirely different upper boundary conditions than the terrestrial parts of the catchment and it seems inappropriate to use

the Alpine3D soil temperatures to represent channel bed temperatures (especially since the authors note that some of these catchments experience substantial flow losses along their network; therefore, the stream bed temperature will likely be influenced by river water infiltrating the subsurface).

The decision to use the HSPF approach seems like it could have important implications for the climate change modelling, particularly for the alpine catchments that see a decrease in snow cover. As the work by Yan et al (2021) highlights (and some of the calibration issues in this study also suggest), this runoff advective flux can be important in snow-dominated catchments. Based on a quick search, I see that the HSPF algorithm doesn't account for the presence of snow and therefore may be unsuitable for looking at climate change impacts in snow influenced catchments (see Leach and Moore, 2015). Assuming this is the same HSPF algorithm (I suspect it is), could this be partly why the modelling is under-estimating spring/summer temperatures for the alpine sites? Why not use the Comola or Alpine3D approach which, I presume (but no details on these schemes are provided) can account for the influence of snow cover on runoff temperatures? If it can account for the snow influence, I would argue that would be a preferable approach even if the calibration metrics aren't as good as the HSPF values, since it should better extrapolate to future conditions.

3. Other modelling studies from mountainous snow-dominated environments

The authors primarily reference other Swiss studies throughout the manuscript. There have been other studies looking at hydrology and river temperature response to potential climate change scenarios conducted in mountainous snow-dominated environments. I'm familiar with some of the work from western North America. Some examples include: Null et al 2013, Leach and Moore 2019, Yan et al 2021. In particular, Yan et al (2021) seems highly relevant here. I think it would enrich this manuscript to incorporate the findings from some of these studies in the introduction and discussion (there are some interesting similarities and differences between the findings from those studies and the results presented here).

4. Key assumptions on river temperature modelling

Maybe these details are contained in the StreamFlow references, but I was surprised by the lack of discussion on potentially key assumptions around some of the river temperature modelling. In particular, there is almost no details or discussion about the role of riparian vegetation and its influence on radiation exchange and the sensible and latent heat fluxes. The manuscript mentions that topographic shading is taken into account (at least for Alpine3D, it's not clear if this is also the case for StreamFlow) - is that the only source of shading for these rivers? Maybe that is the case? If so, I would recommend clarifying this point. If not, it seems prudent to discuss the potential issues that ignoring the role of riparian vegetation might have on the modelling. Along these lines, I also wonder if a discussion on potential land cover changes in these catchments over the next decades, and how they might also influence river temperatures, might be worth including? This is touched on a bit, but could be expanded.

Specific comments:

P1L3: Perhaps expand or give an example why rivers are important socio-economical factor.

P3L5: I would replace 'attributed to the' with 'associated with an', since it is fairly well established that although air temperature is often correlated with water temperature, air temperature itself, via the sensible heat flux, is not often a key control.

P6 Section 2.3: How were data from various met stations used as inputs to the models? Lapse rates? Thiessen polygons? Some other adjustment? Ok - I see this is provided in Section 3.2.

P9 Section 3.3: How are energy exchanges at the stream-atmosphere interface dealt with? Is radiation exchange adjusted for riparian conditions? Are the land-based meteorological measurements adjusted for above-stream conditions for the sensible and latent heat flux calculations? The reader is directed to Gallice et al 2016, but some general overview on this aspect should be included here.

P18 Section 4.4: The model's inability to reasonably simulate the extremely warm 2003 period seems to be a critical issue, particularly since this model is being used to simulate climate warming scenarios (the model seems to be clearly missing an important heat sink). The authors do a reasonable job of discussing this modelling error, but the justification for continuing with the climate change predictions is a bit confusing to me. It seems like the checks (by comparing the 2014 and 2015 summer periods) doesn't really get at the heart of the matter in that it seems to be checking whether the model gets the right answer, but doesn't care if it is for the right reason or not.

P32 Section 5.3: I think this section and analysis can be removed. The physics-based modelling exercise already highlights the differences in discharge and stream temperature response to climate change for the alpine and plateau catchments. I'm not sure what the statistical analysis adds and the hypotheses being tested with these analyses are likely not what is intended (see Greenland et al 2016 for a discussion on this topic). In particular, the conclusion made on P32L16 that 'changes in discharge have no impact on water temperature change' is clearly wrong when considered from first principles (except for very unique cases that would not occur in reality).

P19L8-9: Missing relatively cold runoff inputs seems like a plausible reason for the model overpredictions (see my general point #2 above); however, would we expect the mechanism proposed in the previous paragraph (snow and glacier melt flowing over

frozen or saturated soils) to be occurring during summer periods? Wouldn't it be more likely that HSPF is simply simulating warmer runoff temperatures than is actually occurring? Or maybe cold groundwater inputs (perhaps from a more regional source) are not being accounted for in the models? Or could not accounting for riparian vegetation shading be a factor here?

Table 1: I recommend including some metrics of dominant land cover in this table (e.g., %forest, %agriculture, %urban, %lake, %rock/meadow).

Figure 1: Perhaps distinguish between 'lowland' and 'alpine' catchments using colour?

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