Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2019-366-AC1, 2019

Hydrology and Earth System Sciences Discussions

Interactive comment on "Stream temperature evolution in Switzerland over the last 50 years" *by* Adrien Michel et al.

Adrien Michel et al.

adrien.michel@epfl.ch

Received and published: 3 October 2019

Dear reviewer,

First of all, we would like to thank the reviewer for his/her clear and relevant review. We provide our detailed answers below.

Review:

"What strikes me in reading this article is that it is billed as a trend assessment of stream temperature, but in reality, the authors have endeavored to characterize trends in discharge, precipitation, and air temperature as well. With this in mind, I recommend the authors slightly recast their scope and title to indicate the breadth of their analyses. Given so much of the results and discussion are focused on comparing amongst these

different trends, I think recasting will only strengthen the manuscript."

Answer:

Indeed, our analysis reaches further than stream temperature trends alone. This comes quite naturally, since discharge (Q) and stream temperature (T) are inherently linked to precipitation (P) and air temperature (TA). Isolated analysis of stream temperature does not give the full picture. The current title was motivated by the research focus of the underlying research project. We agree that a broader title would be beneficial and appropriate. An adapted title could be: "Understanding stream temperature and discharge evolution in Switzerland over the last 50 years: annual and seasonal behavior". In addition, in a revised version, we will emphasize in the introduction that stream temperature studies are intrinsically linked to discharge, and thus precipitations.

Review:

"First, their interpretation is largely based on data-driven relationships, and not mechanistic relationships. Therefore, inferring correlation means one variable is "driving" or altering the other is not an accurate interpretation. Therefore, I encourage them to revisit some of the statements in their manuscript to more carefully contextualize the responses they see and their interpretation (e.g., pg 15 lines 1 – 5; pg 21, lines 22 -23)."

Answer:

Thanks for this pertinent comment. Part of the analysis is based on correlations between the considered key variables. We agree that without underlying physical basis to infer causality, statements should only be about observed correlations. In the revision of the manuscript, we will either provide physical justification of the statements, which is easily feasible for statements such as in p.21 l.22-23, or alternatively statements will be changed to only describe the observed correlation, which is totally acceptable since the main goal of the paper is not to infer the physical processes.

Review:

“Second, I’m not sure looking at relationships between annual trends in stream temperature, air temperature, and precipitation are helpful. Would we expect a change in discharge to impact stream temperature, based on first principles? (Even when we know that more water is harder to heat up, if that cold water occurs in a time of the year with limited energy input, does it matter?) What matters much more is when that change occurs, as is described in in the seasonal analysis.”

Answer:

Sections 4.1 and 4.2 are meant to present the annual trends of the four discussed variables. We compare the evolution of air and water temperature on the one hand and of discharge and precipitation on the other hand. We think it is interesting to quantify how strong these relationships are and how meteorological variables can be used as proxy for the annual evolution of the hydrological variables (Q and Tw). But we agree that it is indeed somewhat speculative to discuss the impact of discharge/precipitation on stream temperature on an annual basis. Since this is clearly and more accurately discussed in the sections on the seasonal analysis, parts of Sections 4.1 and 4.2 will be rephrased or removed to avoid any confusion w.r.t. to the point raised by the reviewer (e.g. p.11 lines 5 to 11).

Review:

“As someone who thinks a lot about trend analysis of stream temperature, I have found that stream temperature trends can sometimes be driven by outliers, even when using methods that are robust to outliers. For this analysis, are trends robust? If the trends are recomputed with one or two years less of data, do the general trends hold?”

Answer:

Trends are computed on an annual basis, using de-seasonalized daily time series, and on seasonal basis using seasonal means. These two analyses use a number of points

differing by two orders of magnitude.

Regarding seasonal trends, we state in Section 3.3, in particular on p.9 l. 23-24, that seasonal trends are not robust. The calculated seasonal trends are used only in Figure 10, where actual values are used for a rather qualitative analysis. In addition, on p. 20 l. 3-5 we say: “This absence of correlation results from the noise in the individual trend values due to the relatively short time series available. This is a limitation of the applied method and thus trends cannot be used for an inter-variable interaction study.” We thus believe that the original text for seasonal trend analysis does not need modification.

Regarding the annual trend analysis, the robustness can indeed also be questioned and we definitely want to address this question in the revised paper. In particular since the main results from the annual trend analysis are presented in the abstract and the conclusion. In response to this reviewer’s comment, we propose using two methods for testing the robustness of the trends. The first method is, as proposed by the reviewer, to remove one year at the beginning of the period or one year at the end. Trends using these shortened periods are compared to trends over the full period. The results of this analysis are shown in Figure 1 and 2 at the end of the present response.

Figure 1 shows the analysis for the period 1999-2018. The trends for water and air temperature are indeed lower when the last year 2018 (which was extremely warm in Switzerland) is removed, while for discharge and precipitation the negative trends are less pronounced when the first year 1999 is removed. These differences are notable, but do not change the main message of the study. For the period 1979-2018, removing one year, both at the beginning or at the end of the time interval, leads to almost negligible difference, showing the overall high robustness of the trends over 40 years.

A second approach is to use a robust linear model method (Hampel, 1986) which is implemented in the “rlm” function from the MASS package in R (see https://www.rdocumentation.org/packages/MASS/versions/7.3-51.4/topics/rlm for details). This method aims at producing trends less sensitive to outliers. While it is well suited for temperature de-seasonalized time series, this method has an issue when coping with the remaining variability in the de-seasonalized discharge and precipitation time series. It even fails to converge for the precipitation time series.

Figure 3 and 4 show the differences in trends obtained from normal and robust linear model methods for the four variables. The only notable difference is for discharge during the period 1999-2018. However, the observed difference is smaller than in the first analysis using the shortened time periods.

As a result of this robustness analysis based on two independent methods, we conclude that the trends for the period 1979-2018 are robust. Regarding the trends over the shorter periods, the main message of the paper is not influenced by the result of this analysis. Nevertheless, we intend to indicate the uncertainty on the trend values in a revised version. We are aware that 20 years is a rather short time period for statistical analysis. However, as explained in the manuscript, many stations have been installed only at the end of the 20th century. It would definitely be worth reproducing such and analysis every ten years using corresponding extended data sets. We propose this study as a first assessment, with time series just long enough to be significant (note that many other stations have been installed after 2000 and therefore have not been used in this study because time series are too short for being significant).

Practically, here is what we propose to include in a revised manuscript:

- Explain the potential influence of outliers and boundary values in Section 3.3

- Explain in the same section the double robustness analysis performed here, adding the four figures in Supplementary.

- Use the maximum difference between trends over the full period and trends with one year removed at the beginning or at the end as an indication of the trend values uncertainty. This would be indicated e.g. in Tables A1, A2, S3 and S4. The current uncertainty indicated in the table is the uncertainty obtained from the linear model

computation, but it is indeed underestimated. The uncertainty on the mean values of the trends can be obtained from the RMSE as shown in the plots.

- Add the robustness analysis to the R package provided together with the paper.

Review:

“While I like that the article is strongly framed in the context of changes in Switzerland, what I currently feel is missing is a historical perspective on other stream temperature trend assessments. What have others found in the context of historical stream temperature trend analysis? How do the results from this study compare? Broadening the findings from this specific geographic region would place the study in a larger context, and would add to its impact.”

Answer:

Undoubtedly, this study focuses exclusively on Switzerland because it covers many different hydrological regimes and long historical records are available. Moreover, the present study is part of the boarder project HYDRO-CH2018, which aims at assessing the impact of climate change on the Swiss hydrological system in a wide sense (see https://www.nccs.admin.ch/nccs/en/home/the-nccs/priority-themes/hydro-ch2018/hydro-ch2018-forschungsprojekte.html).

We agree that our results could benefit not only to Switzerland but to a wider community. Comparison with results found in other locations is obviously relevant and of interest, both in terms of trends and in terms of correlations between variables and identified underlying physical processes. Some references to studies in other regions are given in the Introduction p.2 l. 3-4. We take up the reviewer’s remark and suggestion and plan to extend this paragraph in the revised version to inform the reader on the main findings of those studies, extend the list of studies presented (a few new papers have been published since), and comparison and discussion will be added in the Conclusion section when and where it is relevant.

Review:

“At current, the article may include too many figures. I’d strongly encourage the authors to reduce the amount of information they show in the main text, and translate more information to Supporting Information.”

Answer:

We are aware of it and already tried to reduce the length of the manuscript. Based on all reviewer comments, we will decide how to shorten the manuscript. Any suggestion would be welcome.

Minor comments:

Thanks for these comments; all of them will be addressed in the revised version.

We thank again the reviewer for the constructive and useful comments.

Adrien Michel, on behalf of all authors.

References:

F. R. Hampel, E. M. Ronchetti, P. J. Rousseeuw and W. A. Stahel (1986) Robust Statistics: The Approach based on Influence Functions. Wiley.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-366, 2019.

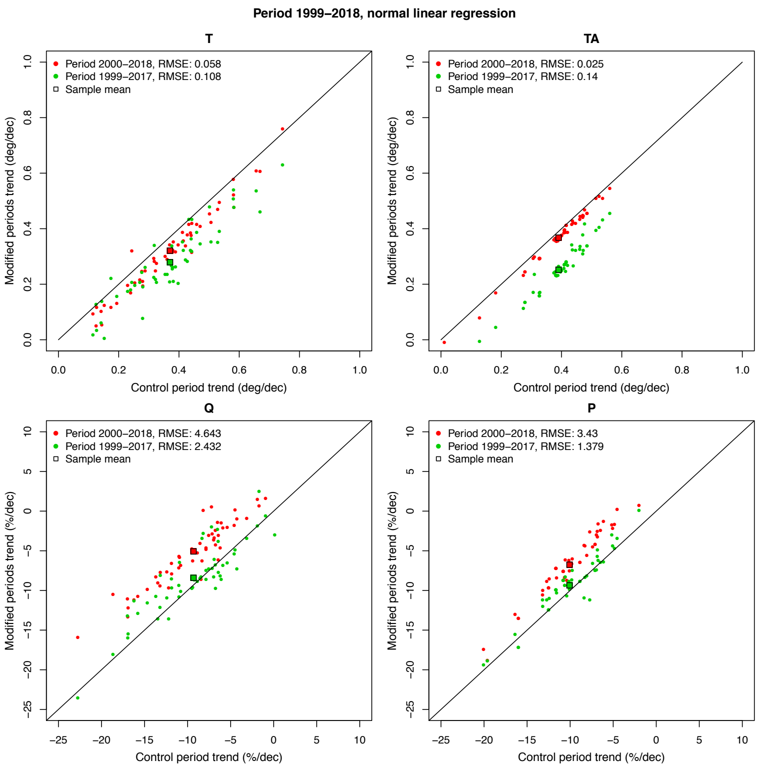

Fig. 1. Comparison between trends over the full period and between trends obtained by removing on year at the beginning (red dots) or at the end of the period (green dots). Period 1999-2018.

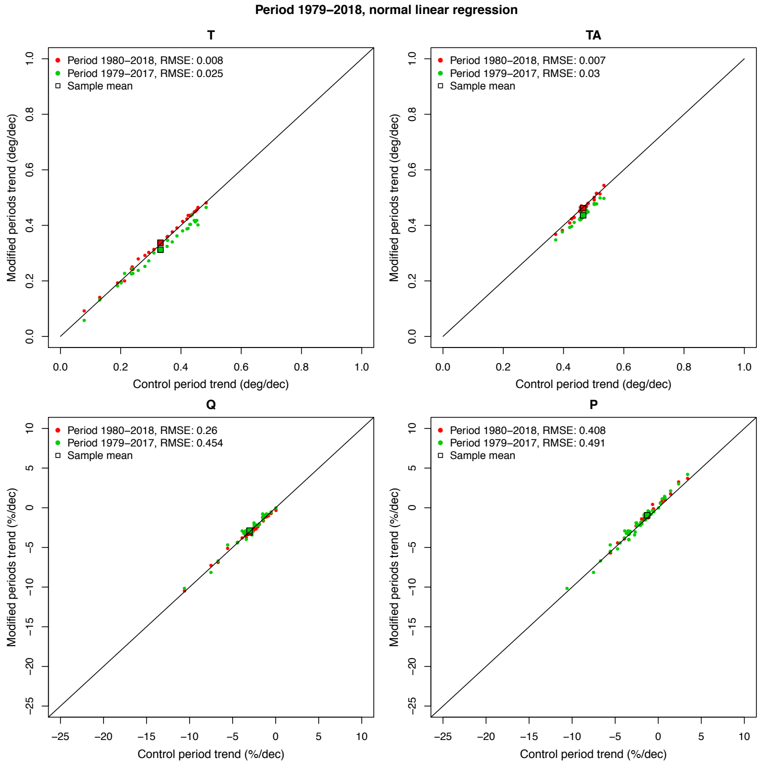

Fig. 2. Comparison between trends over the full period and between trends obtained by removing on year at the beginning (red dots) or at the end of the period (green dots). Period 1979-2018.

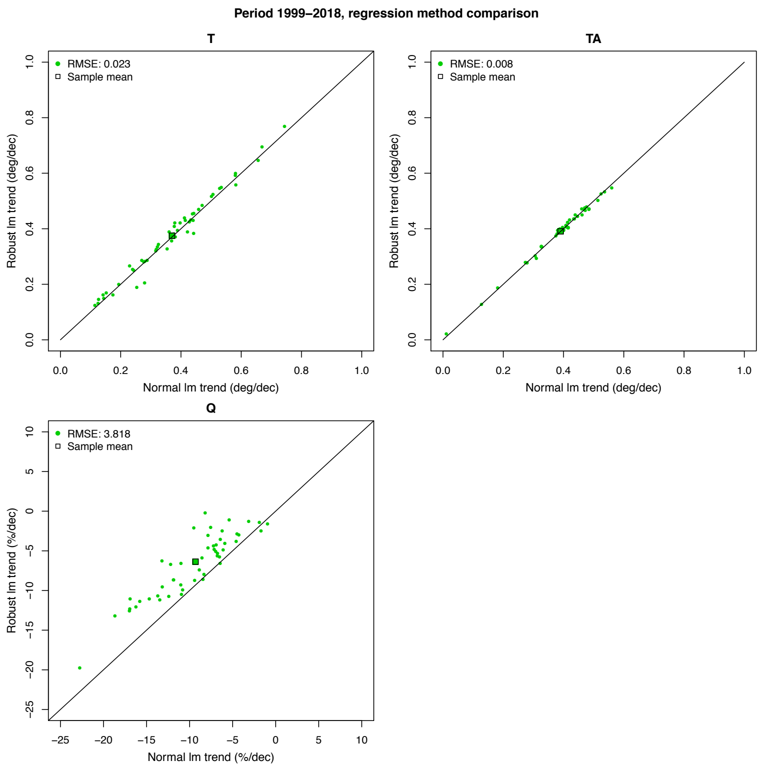

Fig. 3. Comparison between trends obtained using a standard linear model and a robust linear model. Period 1999-2018.

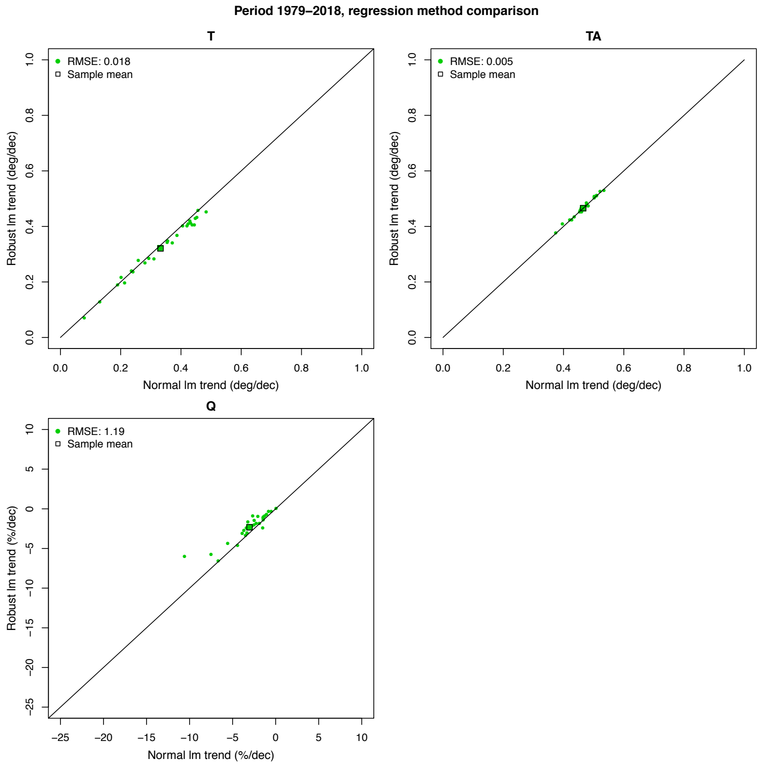

Fig. 4. Comparison between trends obtained using a standard linear model and a robust linear model. Period 1979-2018.