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.

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Dear Jacob Zwart,

First of all, we would like to thank you for this clear, constructive and helpful review. We provide our detailed answers and explanations below.

Review:

"The manuscript is quite long and I think could be distilled down to a few major points to improve readability. The most important points that came out tome were: 1) water temperature trends are increasing (Figure 2), 2) water temperature trends are influenced by air temperature but also modified by landscape position (I think a modified version of figure 5 would show this well, where water and air trends are plotted against each

other and points are colored based on catchment type; Fig 6 also shows this), 3) Seasonal difference underly the annual trends (Fig 8, 15, and 16 show this most strongly), and 4) there are important ecological and economic implications for these temperature trends (fig 17 and 18). I encourage the authors to reduce the number of figures and condense some of the text or move to supplementary to make the main text a little bit more concise."

Answer:

We are aware of this (it was also pointed out by the other reviewer) and we agree that some content could be moved to supplementary condensing the main findings of the paper. We take note of what you highlighted to be the main figures of the paper and will move some of the secondary figures to the Supplementary in a revised version. The suggestion regarding revision of Figure 5 is discussed further below.

Specific comments:

"Page 1 Line 13: example of ecological temp thresholds?"

These thresholds are for example the 15°C for the PKD spread impacting salmonid fish. We will change this sentence indicating "ecologically and economically relevant temperature thresholds", linking it to our investigation of the legally imposed threshold of 25°C for water usage for industrial cooling in Switzerland (most importantly for nuclear power plants).

"Page 2 Line 7: what is the global regime shift?"

Thanks for the question. It refers to a step change from the 1970s to the 1980s affecting climate and ecosystems mainly in central Europe but has been noticed also in other parts of the world. A good description can be found in Serra-Maluquer (2018):

"In the last four decades, a warming trend has been observed in the Iberian Peninsula; particularly, a rapid rise in temperatures has occurred since the 1980s followed by successive severe droughts in the 1990s, 2000s and 2010s (Gonzalez-Hidalgo and

others, 2015). Such abrupt warming occurred in the transition from the 1970s to the 1980s, and it was partly linked to changes in the winter atmospheric circulation over the northern Atlantic Ocean (Hurrell, 1996) and impacted ecosystems worldwide by accelerating climate warming (Reid and others, 2016). This climate shift has led to warmer and more arid conditions on several European regions, generating harsher climatic conditions for beech forests".

The appropriate references will be added in the revised version.

"Page 10 Line 7-8: why did the authors choose a 4 hours moving window average?"

The moving average is used to smooth the data avoiding to discard periods when the measured temperature was below 15°C just for one hour only. We also realize that the value of 4 hours was a typo, the actual value used is 3 (indeed moving window size for smoothing is always odd); this will be corrected in the revised version.

We made a sensitivity test on the value of the window size and on the total length of the periods while we developed this simple model. Results showed that the chosen values have little impact on the results (see examples in the additional Figures 1-3 in the present document).

"Figure 2: I like this figure but it is hard to tell which water station site is referring to which line on the top panel. Have the authors considered having the site labels point to the start or end of the 5 year moving average line for each site? This might improve the interpretation of site specific time series, but it also may make the figure too busy. Another option would be to order the site abbreviations in order of stream temperature from end of 5 year moving average line (i.e. year 2016) rather than what appears to be alphabetically-ordered currently."

Thank you for the suggestion; please see in Figure 4 a proposition for an updated version considering your comments. In our opinion, the best solution is ordering the site abbreviations in terms of stream temperature values at the end of the 5-year moving

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average period (as you suggested). This ordering will be explained in the revised figure caption. Adding labels to the plot, or even only numbers, resulted in too much confusion and was not retained as a satisfying solution.

"Figure 3. I think the labels could be ordered differently or point to the lines to which they correspond. See my comment for Figure 2 above. "

Absolutely. We modified analog to Figure 2 (see Figure 5 in the present document for a new version). We also realized that values for the Alte-Aare were missing in the plot (off-scale); we now divided these values by 4 to fit in the plot, and explained it in the caption of the figure. This high value for the specific discharge arises because the Alte Aare has a small proper catchment size (13 km2), but has been artificially connected to the Aare. As a consequence, the discharge is far higher than the discharge we would expect from a catchment that small (see https://hydromaps.ch/#en/13/47.0536/7.2962/bl_hds).

"Figure 5. Rather than plotting boxplots next to each other, I think plotting the water temperature trends vs. air temperature trends as well as discharge trends vs precipitation trends would convey more information. These scatter plots could also be colored by stream regime. You could keep the boxplots as marginal plots on the scatter plot figure to retain quartile and median information. It would be interesting to see when water and air temperature trends are correlated and when they are not."

Thanks for this suggestion. Our original version of this figure was exactly what you proposed, see Figure 6 in the present document. As mentioned in the manuscript, there is far more noise in the water temperature trends than in the air temperature trends. Related to this, see details in our reply to reviewer one (pages C3-4), there is non-negligible uncertainty around the trend values. For these reasons, we decided to present the results with boxplots, which implies a statistical preprocessing allowing to better visualize the signal in the noise. For these reasons we prefer to keep the figures in the current version.

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We are not sure whether Figure 6 will make the situation clearer. However, this Figure could be added in the Supplementary.

Also, when looking at Figure 6, one could question the point in the top left corner. This point is a trend value for the water gauging station Rauss/Moutier, with meteorological values from Delemont. While the long-term trend in air temperature seems clear (0.43°C per decade for the period 1979-2018 and 0.46°C per decade for the period 1970-2018 obtained with the linear model for this station), no trend in air temperature is found for the last 20 years, explaining the unexpected position of this point. This is a good example of the noise obtained from a simple linear regression analysis (see more details about trend robustness on the answerer to reviewer one).

"Page 13 into Page 14: "Indeed, for both pairs, the hypothesis of different mean is clearly rejected with p-values>0.15." Is this testing the difference between DLA and SPJ, and ALP and HYP? I assume so, but I think this could be written a little bit more clearly to make explicit.""

Yes, here we refer to the values in Table-2, where each pair of regime trends is tested against each other to infer whether the means are similar or not. In a revised version we will rephrase this paragraph to make this point clearer to the reader.

"Page 15 lines 12-13: It isn't clear to me how the authors concluded that air temperature is this main driver of water temperature trends for the SPJ catchments. Figure 5 shows a comparison between water and air temperature trends but all of the catchment types are grouped together in this figure so it is impossible to see the effect of air temp on water temp for SPJ catchments specifically. Please be clearer as to how you came to this conclusion. "

Indeed, the required Figure to illustrate this statement is for now missing from the paper. A Figure corresponding to Figure 6, but for air temperature and precipitations, will be added in the supplementary. This new figure is shown in Figure 7 here below. By comparing the top-left panels of Figure 6 in the manuscript and Figure 7 here, we

clearly see that SPJ water temperature trends are, on average, close to the air temperature trends, which is not the case for HYP and ALP catchments (DLA catchments are discussed in Section 4.3). In Figure 7 in the present document we can also see that water temperature trends are spread around air temperature trends values for SPJ catchments, while they are systematically below for HYP and ALP below.

Nevertheless, we agree that the paragraph on p.15 lines 12-16 needs revision to clearly state that we talk about the mean behavior of the trend and not about single catchments. In addition, comments related to the noise in the single trend comparisons will be added. While part of this noise is caused by the method and the choice of the meteorological stations for the catchments, this noise shows that at the single catchment scale, independently of the regime, many factors other than the air temperature seem to be important. This will also be mentioned in a revised version. Please see our reply to reviewer 1 (page C3) for more detail.

"Page 15 line 20: include some citations for the statement that this is 'well known'."

We can cite for instance Råman Vinnå (2018) and Webb (2007). These references will be added in the revised manuscript.

"Figure 7: I suggest adding the label 'inflow' and 'outflow' to the figure itself to help the reader quickly understand the figure rather than having to read through the legend to understand which line is inflow and which is outflow."

Modified as suggested (see revised Figure 7 here as Figure 8). Indeed, this eases reading of the figure. Additionally, to avoid confusion, we changed the colors in the bottom panel since the meteorological stations do not necessarily match with the rivers shown (the number of available water temperature and meteorological stations can differ).

"Page 18 line 4: Is 'intra-annual' not 'infra-annual' more appropriate here?"

Good catch. Indeed, this is a language mistake, "infra" meaning "below" while "in-

tra" means "within". 'Infra-annual' will be replaced by 'intra-annual' in the whole text. Thanks for pointing this out.

"Figure 8: indicate what the panel months mean (DJF, JJA, etc...). I was confused until read the main text."

The letters refer to the initials of the three months of a season defined as December-January-February (DJF) and so on. This information will be added in the caption of the figure.

We thank again the reviewer for the useful and pertinent comments and for taking the time to go through this comprehensive manuscript.

Adrien Michel, on behalf of all authors.

References:

Gonzalez-Hidalgo JC, Peña-Angulo D, Brunetti M, Cortesi N. 2015. Recent trend in temperature evolution in Spanish mainland (1951–2010): from warming to hiatus. Int J Climatol 36:2405–16. https://doi.org/10.1002/joc.4519.

Hurrell JW. 1996. Influence of variations in extratropical wintertime teleconnections on Northern Hemisphere temperature. Geophys Res Lett 23:665–8

Råman Vinnå, L., Wüest, A., Zappa, M., Fink, G., & Bouffard, D. (2018). Tributaries affect the thermal response of lakes to climate change. Hydrology & Earth System Sciences, 22(1)

Reid PC, Hari RE, Beaugrand G, Livingstone DM, Marty C, Straile D, Barichivich J, Goberville E, Adrian R, Aono Y et al. 2016. Global impacts of the 1980s regime shift. Glob Change Biol 22:682–703. https://doi.org/10.1111/gcb.13106. Serra-Maluquer, X., Gazol, A., Sangüesa-Barreda, G. et al. 2019. Geographically Structured Growth decline of Rear-Edge Iberian Fagus sylvatica Forests After the 1980s Shift Toward a Warmer Climate. Ecosystems 22: 1325. https://doi.org/10.1007/s10021-019-00339-

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z Webb B. W. & Nobilis F. (2007). Long-term changes in river temperature and the influence of climatic and hydrological factors, Hydrological Sciences Journal, 52:1, 74-85, DOI: 10.1623/hysj.52.1.74
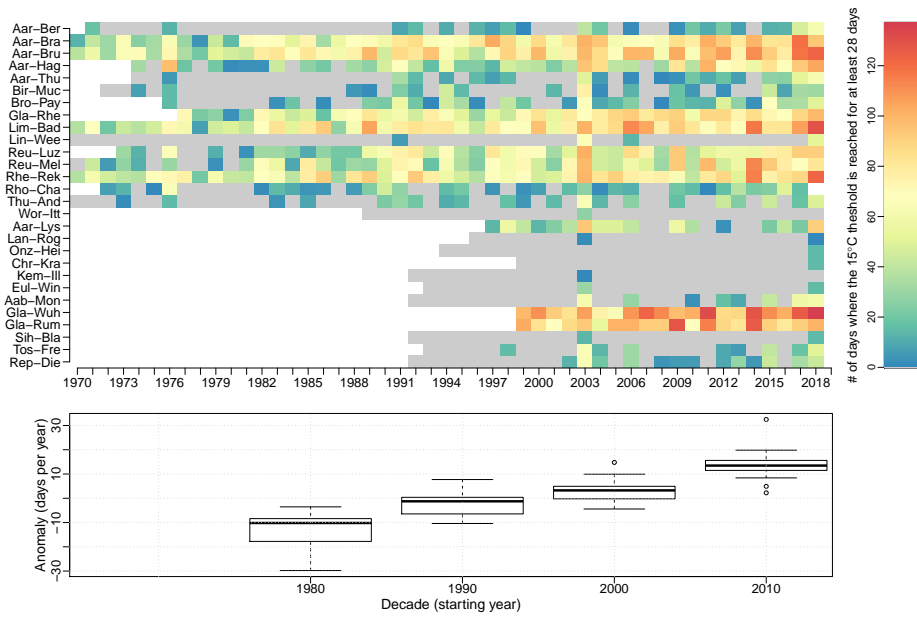
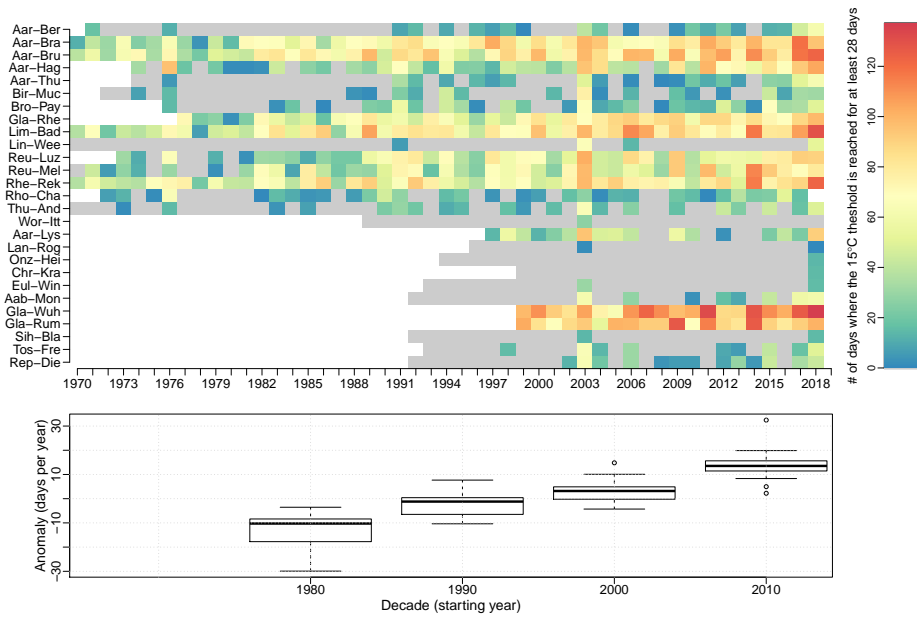**Fig. 1.** Sames as Figure 18 in the paper, but without moving window average.

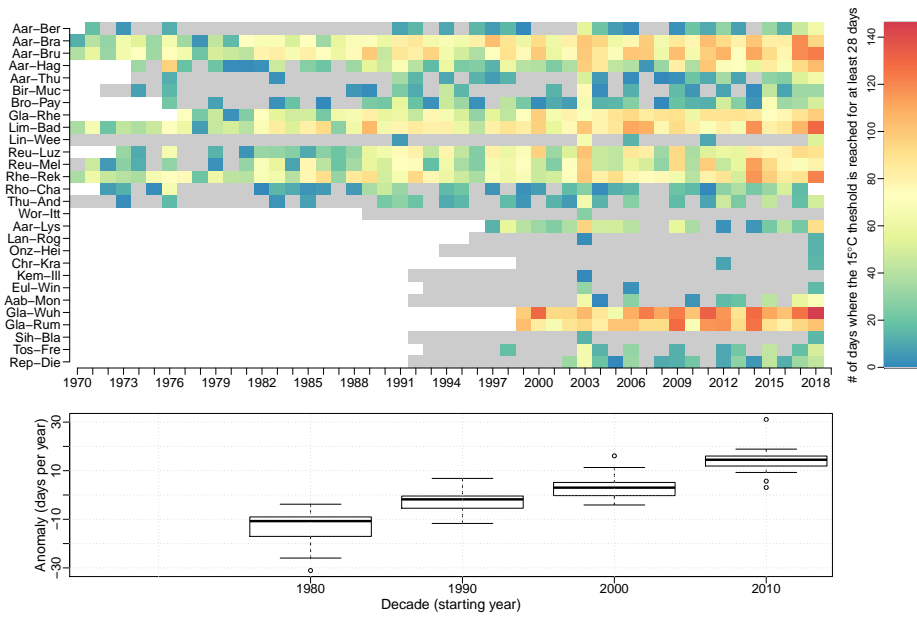**Fig. 2.** Sames as Figure 18 in the paper, but with 5 hours moving window average.

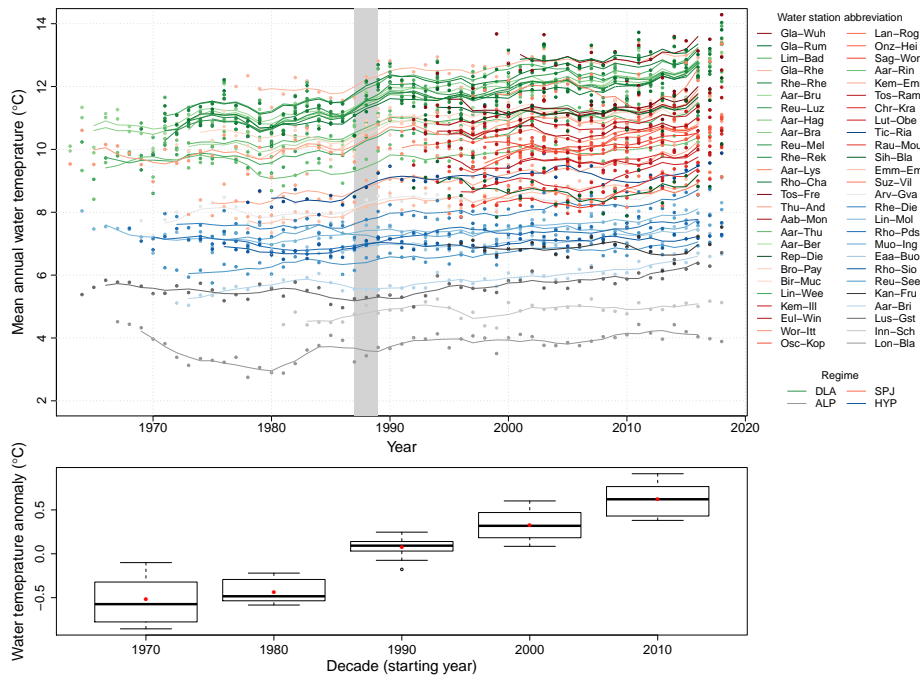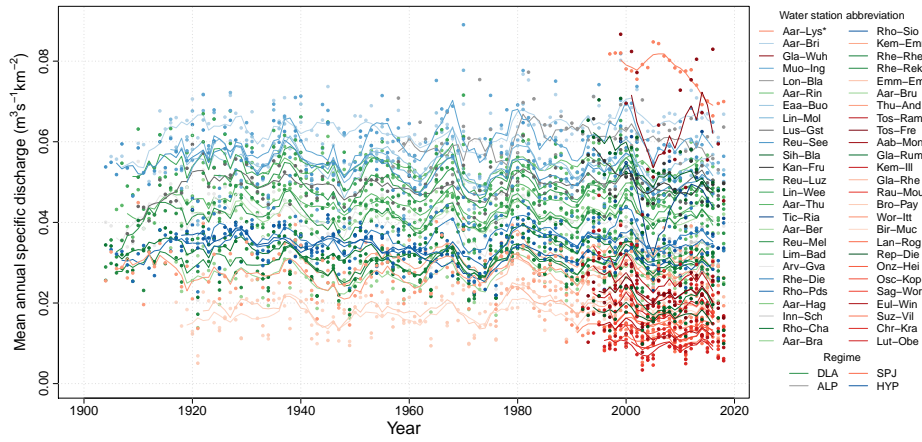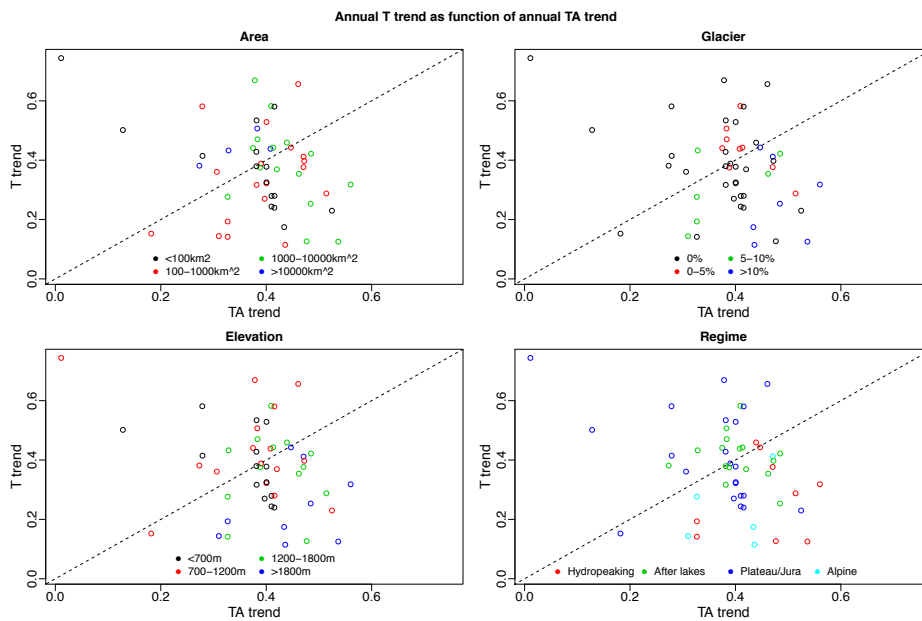**Fig. 3.** Sames as Figure 18 in the paper, but with 7 hours moving window average.

Fig. 4. New proposition for Figure 2 (legend orderred by stream temperature values at the end of the moving window average time series).
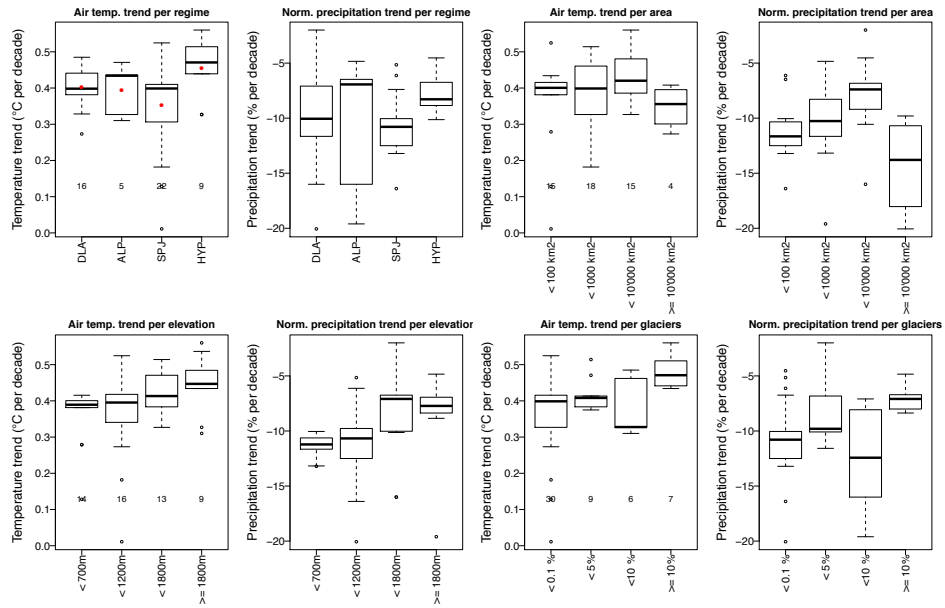
Fig. 5. New proposition for Figure 3 (legend orderred by discharge values at the end of the moving window average time series).
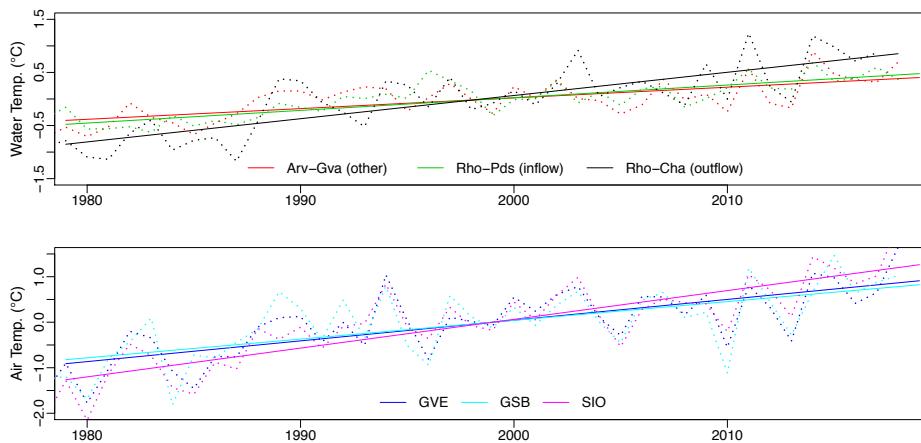
Fig. 6. Scatter plot of air temperature trends (TA) and water temperature trends (T).

Fig. 7. Same figure as Figure 6, but for air temprature and precipitation, to be added in Supplementary.

Fig. 8. New proposition for figure 7.