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Response to Massimiliano Zappa (referee)

Erwin Rottler, Till Francke, Gerd Bürger and Axel Bronstert

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Dear Mr Zappa,

thank you very much for reviewing our manuscript. We are very grateful for your comments and suggestions. In the following, detailed responses to all your comments.

On behalf of all authors,

sincerely,

Erwin Rottler

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1 Comments on Abstract and Introduction

1.1 Page 1, Line 9-11

No real surpize, well supported by data. You might find interest in this paper to support this finding [Farinotti et al., 2016]

I very much enjoyed reading [Farinotti et al., 2016]. It provides interesting information that will help us to put our findings into context.

1.2 Page 2, Line 1

Here some classifications on changing snowmelt are presented in a climate impact framework [Speich et al., 2015]

Looks interesting. We are happy to include this information into our manuscript.

1.3 Page 2, Line 25

I miss some recent papers here. They focus on flood, but might offer information for discussion in your study. [Berghuijs et al., 2019, Blöschl et al., 2017, Blöschl et al., 2019]

This information will help us to improve our discussion.

1.4 Page 3, Line 2

Relatively small data basis

In addition to the three meteorological stations we present in the main manuscript, we include results of further meteorological stations into the appendix. Unfortunately, there are not many more recordings covering such a long time frame and having such high quality at the same time. With regard to discharge, we initially looked at other gauges as well and in an earlier version e.g. also included gauges Dresden (Elbe river) and Burghausen (Salzach river). However, this turned out to shift the focus away from what we wanted to discuss and made it very difficult to prepare a concise manuscript. In our study, we focus on the analysis of long and consistent time series. Therefore, it seems that, to a certain extent, we have to accept trade-offs in the number of stations included.

2 Comments on Methods

2.1 Page 3, Line 31-33

Very nice and useful graphical abstract

Thank you! It took us some time to come up with a proper graphical illustration to support our analysis tools.

2.2 Page 4, Line 2

Just a clarification here. You make the quantiles in a shape manner for every DOY and not for a window centered on every DOY. We have good experience with quantiles centered on +/- 15 Days for evry DOY. It gives more smooth regimes for pluvial basins. For large basins as yours this might not be necessary.

In step 1 of our analysis no moving windows or other averaging techniques are applied. We very much would like to keep it that way and avoid calculating averages before quantile estimations. Yes, most probably the size of the basins and the length of the time series (!) help that no prior averaging is necessary.

2.3 Page 4, Line 5-6

Thanks for this technical indication.

You're welcome.

2.4 Page 4, Line 8

Here you use the 30 days, but only to create a smoothed time series. As it is formulated, it can also be what I was describing in my comment above.

We do not use the window to smooth the data, but calculate quantiles within the moving window. Yes, it was also possible to average using a moving window prior to the determination of quantiles on a daily basis (QDAY). We will try to improve the description of our approach, particularly in section 3.2, as we still need to do a better job there.

2.5 Page 4, Line 29

Any sensitivity test prior to choosing these 30 and 90 days windows to report?

We made good experiences with moving average trend statistics using a 30 day window (see e.g. [Kormann et al., 2015, Rottler et al., 2019]). Monthly values provide stability and still enable the calculation of trends in a highly resolved manner. For precipitation, which is more variable than temperature or discharge, we had to increase the window size to get necessary stability. We tried different window sizes varying them by hand in our scripts. We did not conduct specific sensitivity tests/analysis, but settled on commonly used and established monthly (30) and seasonal (90) values. Our testing indicated that those window sizes also perform very well in our analysis. Additional information we think of including into the manuscript on this issue could sound like: 'We conducted tests with varying window sizes. These tests indicated that 30 (90) day constitute a good compromise between robustness of the signal and preservation of the signal variability.' We will work on this to further improve our manuscript.

3 Comments on Results and Discussion

3.1 Page 5, Line 9

Are you really plotting discharge with lowflow on the top of the y-axis and peak discharge on the bottom-part of the y-axis?!?!? This is absolutely contra intuitive! Change! Furthermore, I would plot the dry season in red and the wet one in blue .....

Indeed. Thank you for pointing at this. Reversing the y-axis/colors makes the understanding of our figures way more intuitive. We tried already and it looks better now. We will change our figures accordingly.

3.2 Page 5, Line 14

This has to do with size. For such large rivers is in my opinion quite challenging to attribute a distinct regime characteristic. I think that classic regime classifications (nival, glacial, pluvial) is something you can attribute to mesoscale basins (up to 1000 km2 or so).

Yes, the larger basins are, the more difficult it usually gets. We will rethink our regime descriptions and try to formulate a more suitable characterization.

3.3 Page 5, Line 23

I see it, very nice!

Cool.

3.4 Page 6, Line 1-6

Have you tought to createa proxy for liquid/solid precipitation and combining P and T? For the Rhine in Basel an additional station at elevation > 1000 m might be useful (Davos?)

We did not think of creating a liquid/solid precipitation proxy yet. It indeed might provide very interesting supporting information for our discussion. We will look into this. We did not include station Davos into our study as it did not fulfil our criterion that time series should not have data gaps longer than 60 days. But we will look at the time series again and try. Maybe also stations Samedan (1709 m) or Chaumant (1136 m) turn out to be useful in this regard.

3.5 Page 6, Line 19

Too few stations to make any speculation on that regard

Yes, the limited number of stations available with such data length and quality limits the significance of our results. This might be the most vulnerable point of our analysis. However, consistent analysis results for stations and parameters investigated make us confident that even if the number of stations is limited, we attain meaningful results that are worth discussing. We recognize that we have to be very careful on what speculations to make and to clearly indicated what to be a robust finding of our analysis and what just speculation. We will work through our manuscript again to improve our writing in this regard.

3.6 Page 7, Line 25

Also [Marty et al., 2017]

Thank you. We will include it into our manuscript.

3.7 Page 8, Line 25

See, in German https://hydrologischeratlas.ch/produkte/druckausgabe/fliessgewasser-und-seen/tafel-5-3 Fig. 1 https://hydrologischeratlas.ch/downloads/01/content/Tafel_53.pdf

Very nice maps! We were not aware of their existence. This information helps us to better understand the influence of hydropower and lakes on river runoff.

3.8 Page 8, Line 31

See also [Bosshard et al., 2013]

We will include information of the mentioned work into our manuscript.

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