Author's response: a point-by-point response to the II round of reviews.

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Dear Editor and Referees,

we would like to thank you for the appreciation of our efforts in revising the work. On one side, we are happy to see that Jana von Freyberg considered as excellent the scientific significance, scientific quality, and presentation quality of our work and that she accepted as is our manuscript for final publication. On the other side, considering the anonymous referee #1 comments, the Editor decided that publish is subject to revisions. The anonymous referee #1 comments have been very constructive for the paper improvement. The anonymous referee #1 helped the authors providing a code to satisfy her/his requests and we thank her/him very much for this. We have addressed all the issues raised in the Report #1 and all the applied changes are visible in the track-changes version of the manuscript.

Since the number of comments of the anonymous referee #1 is limited, we directly provide a point-by-point response to her/his comments also including info about the changes made in the manuscript.

In the hope of having met your scientific expectations in the revised manuscript, we kindly ask you to reconsider the publication of our work on the Hydrology and Earth System Sciences Journal.

With king regards,

The Authors

1 Response referee #1

The authors have made significant changes to the manuscript. I am satisfied with the authors' responses as well as the changes. I think the quality of the manuscript was significantly improved. In general, I only have one major comment regarding the F^*_{yw} and the age threshold of F^*_{yw} (please see below).

Dear referee #1,

We would like to thank you for the positive assessment and the detailed comments (including the source code for estimating F^*_{yw} and α), which contributed to our manuscript's improvement considerably.

Please find below a point-by-point response to both your main and minor comments. We have incorporated all your constructive feedback in the revised manuscript.

Sincerely,

The Authors

1.1 Major comments

As I understood from the manuscript. The authors use F^*_{yw} from 22 Swiss catchments from Freyberg et al. (2018). I am not sure if the authors and Freyberg et al. (2018) used the same code (method) for the calculation F^*_{yw} or not. In the attached data along with this review, I demonstrated that using different source codes (methods) could result in different values of F_{yw} (or F^*_{yw}) and the age thresholds of F^*_{yw}. If so, the differences in F^*_{yw} among catchments could be driven by using different methods (source code) rather than the physical factors (e.g., precipitation, elevation, LFD, Fbf,...). Therefore, I would suggest the authors to use the same source code (method) for calculating F^*_{yw} for all catchments and provide the source code for review/or make it publicly accessible.

The source code for calculating F^*_{yw} was different from that of von Freyberg et al. (2018). Accordingly, based on the source code provided by the anonymous referee #1, we developed a © Matlab code for estimating F^*_{yw}. This code was directly applied to the isotope data of all the 27 study catchments (consequently, we did not consider published F^*_{yw} values: the F^*_{yw} you will find in the revised version are a result of our work). The © Matlab code has been made available in the Supplementary material of the paper. The used methodology has been thoroughly described in Section 3.1 of the revised manuscript.

When applying the sine wave fitting, the authors will get F^*_{yw} corresponding to a specific age threshold (τ_{yw}), depending on the shape factor (alpha) of the gamma distribution (Equations 13-14 from Kirchner 2016). The age threshold could be 1 to 3 months (Figure 10, Kirchner 2016) and even beyond this range. Therefore, the variation in F^*_{yw} might be because of different age thresholds rather than physical factors. In this sense, the F^*_{yw} or F_{yw} might not be a useful matrix for catchment intercomparison studies. Therefore, I suggest showing the alpha and age thresholds for each catchment in the results (these values were often not shown in previous studies). Discuss the consequences of the differences found with the age threshold in the limitation section of the paper (e.g., will the relations between F^*_{yw} and other factors (e.g., precipitation, elevation, LFD, Fbf,...) change if somehow we can calculate F^*_{yw} that corresponds to the same age threshold).

Based on the source code provided by the anonymous referee #1, we developed a © Matlab code for estimating α and τ_{yw}. The © Matlab code has been made available in the supplementary material of the paper. As anticipated by the anonymous referee #1, we find different τ_{yw} for each study catchment, also if they vary modestly between about 1.5 to 3 months, in agreement with Kirchner (2016a). We explicitly said what should be the effect of choosing a constant threshold age and that using the amplitude ratio approach (as in our work) F^*_{yw} estimates refer to the proportion of runoff younger than a threshold age that is different among the studied catchments, and that this is the main limitation of our work. In this regard, please see completely new Section 4.1 of the revised manuscript. In addition, in all the figures in which the F^*_{yw} values are reported, we set the points size as proportional to the threshold age for having a more complete and exhaustive visualization of the results.

1.2 Minor comments

Figure 2c: Might be using a triangle (for P) and a circle (for Q) in combination with different colors (for rain, hybrid, and snow) for easier to differentiate between them.

Thank you for this comment. We use triangle for P and circle for Q in combination with different colours as you have suggested. We remove the catchments labels to improve the visualization. Please note that we have changed all the figures importing them as *.svg (scalable vector graphics) file.

L237-238: Should be noted that this demonstration uses thought experiments (not from real catchments)

Thank you for this. In Section 3.1, line 245 of the revised manuscript, we write: "<u>*By using thought experiments*</u>, Kirchner (2016a) has demonstrated that for a given shape factor α and across a wide range of scale factors β, the

theoretical young water fraction can be accurately predicted by the amplitude ratios of seasonal sine curves fitted to stream water and precipitation isotope values."

Figure 6: Why did the authors only show quaternary deposits for 7 catchments, I think either showing for all catchments or not showing the figure or not showing (Table 2 is sufficient)

Thank you for this suggestion. We have removed the figure from the revised manuscript.

L207-211: "Our data set includes NBPV, whose area is 42% glacier covered and consequently shows a characteristic glacier-dominated streamflow regime with a monthly peak in late summer. Thus, NBPV may belong to a fourth category of glacier-dominated catchments, for which the effect of glacier-melt on F^*_{yw} cannot be neglected, and this was partially discussed by Ceperley et al. (2020)": Why did the author still classify NBPV as "snow-dominated" catchment? Does glacier-melt account for when calculating F^*_{yw}?

We do not classify NBPV as glacier-dominated since the classification provided by Stoelzle et al. (2020) does not consider this regime and the definition of the classifiers for a new category is outside the scope of this work (as also suggested by Jana von Freyberg in her previous review). However, we say that our results suggest that NBPV should belong to a fourth category of glacier-dominated catchments. In this regard, please see lines 210-215 of the revised manuscript. Glacier-melt accounts for when calculating F^*_{yw} since we are using the direct-input approach where the snowpack and/or the glacier are considered as part of the catchment storage. This is clarified in Section 3.1 (lines 274-275) of the revised manuscript.

Section 4.1. Why did the authors discuss the Winter Flow Index (WFI) - F^*_{yw} relation in this section "The role of Quaternary deposits"?

This is because Arnoux et al. (2021) found a strong positive correlation between F_{qd} and Winter Flow Index (WFI). So, we discuss here the relation Winter Flow Index (WFI) - F^*_{yw} to compare our results with previous findings of Arnox et al (2021). We have partially rewritten Section 3.3 to better underline our choice of discussing WFI- F^*_{yw} relation in this section.

Section 4.2. To be consistent, I would suggest using another title, e.g., "the role of groundwater flow (baseflow) in F*yw"

Thank you, we use the title you have suggested in the revised version.

L414: I think the author mentions the fraction of based flow, not the amount of stored water.

Yes, thank you for noticing this. We have replaced "stored water" with "base flow".