Response to the interactive comment of Reviewer #1 on

"Sensitivity of young water fractions to hydro-climatic forcing and landscape properties across 22 Swiss catchments" by Jana von Freyberg et al.

General comments

This discussion paper presents an analysis of young water fractions (Fyw) in contrasting catchments across Switzerland. The paper first examines the influence of interpolation methods, flow-weighting of measurements and snow in the calculation of Fyw. The second part studies correlations between young water fractions and catchment characteristics. The authors then introduce a new metric (i.e., the discharge sensitivity of Fyw) and relate this metric to catchment characteristics. The paper concludes with a conceptualization of the relationship between young water fractions and streamflow. The paper is well written and addresses important problems in the analysis of isotope data, i.e., interpolation, impact of snow and flow-weighting. Moreover, the paper presents a new concept derived from the recently introduced young water fractions. However, there are some parts that need clarification and rearranging especially in the theoretical and methodological sections.

We thank Reviewer #1 for his/her thoughtful comments, which helped to improve the manuscript. Please find our detailed responses below.

Comments of the reviewer are shown in italics. Responses from the authors are presented in regular font below each comment. Citations from the manuscript are in Times New Roman, changes of the cited manuscript text are underlined.

Specific comments

****Abstract***

- Page 1, line 23: suggest clarifying what "this relationship" is (i.e., the relationship between flow and young water fractions).

We will change that.

****Theoretical background***

- Page 5, lines 17-20: please clarify that equations (3) and (4) follow from (1) and (2).

We will change that.

- Page 5, lines 25-27: it is not entirely clear what is meant with volume-weighting. I assume it does not refer to the isotope values themselves (so volume-weighting over several samples to obtain a weighted catchment average, as done for the precipitation isotope values), but to the weighting scheme within the IRLS algorithm.

Within the iteratively reweighted least-squares (IRLS) algorithm we allow for optional point weights (in addition to residual weights that are adjusted to down-weight data with unusually large residuals, as in conventional IRLS). In the R-script provided in the supplementary material the user can choose between three weighting functions: Bi-square, Welsh or Cauchy. In our analyses, the weighting of the isotope data was carried out with the Cauchy weight function.

****Data set***

- Page 8, lines 6-10: suggest dropping the German terms of the soil properties as this will not mean anything to most readers.

We will change that.

***Results/Discussion**

- Due to the concise description of the interpolation methods in the main next, it is not easy for the reader to follow the different steps of the two interpolation methods, although this would be helpful to better understand the differences between the two methods. Moreover, method 2 has been developed by the authors, so this method should be introduced more extensively in the main text. I would thus suggest restructuring the paper by moving major parts of the methodology description from the Supplement to the main text. This could be placed into a subsection of section 3 or a separate methodological section. Please also explain method 2 in a bit more detail – in the main text, this method is described with one long sentence only. The comparison between the two methods can be kept in section 4.1, which would be more consistent with presenting results only in section 4.

We will move this part into Chapter 3 and keep the short discussion of the results in Section 4.1. With this, Chapter 4 becomes considerably shorter, while both interpolation methods are still described in a short manner in the manuscript (new: Sect. 3.4 Precipitation isotope data). A detailed description of method 2 will still be available in the Supplement.

- Page 8, line 26: are these cumulative monthly d18O-values in precipitation (so sampling bottle emptied each month)?

Yes, the GNIP reports isotope values from cumulative samples. We will clarify this.

- Page 9, line 25; page 11, line 5 and line 16: "statistically (in)significant" using which statistical method?

We will include a definition of that term in Page 9, line 25: "… (i.e., smaller than twice their pooled uncertainties, Figure 3b)."

- Page 11, line 25: this is the first time the authors mention "gamma distributions". Please clarify that this refers to the underlying transit time distribution model.

We will clarify that: "The average values of F_{yw}^{*} and F_{yw} were 0.22±0.02 and 0.17±0.02, respectively, meaning that approximately 1/5 of total discharge was younger than roughly 2.3±0.8 months (assuming that the catchment transit times can be described by gamma distributions with shape factors α ranging from 0.3 to 2)."

- Page 12, lines 29-31: suggest weakening this statement ("consistent with . . .") as results from a global analysis should be compared with caution to regional analyses and the smaller Fyw in this study could also be caused by various factors other than the gradient dependence. See also page 19, lines 7-8.

With this comparison we aim to put our regional results into a global context. However, we do acknowledge that the range of young water fractions is wide ("[…] 10th to 80th percentiles of the F_{yw} values estimated by Jasechko et al. (2016) […]"), which suggests that other factors than gradient are likely controlling the discharge of young water. This is further analyzed in the following section 5

"Relationships between young water fractions, hydro-climatic conditions and landscape characteristics"

- Page 14, lines 15-20: please give a bit more details on the procedure: how many measurements were on average available in each sine-wave regression after separation by flow regimes? Was the number of values sufficient to obtain reliable results? I would expect the seasonal variations to be small and potentially indiscernible under low-flow conditions, when streamflow is dominated by the well-mixed signal of slow flowpaths.

The separation of the flow regimes was carried out in dependence of the flow at the time of sampling, so that roughly similar numbers of data points were available for each flow regime. For instance, at the Erlenbach site, the total number of streamwater isotope samples was 140, and thus each quartile of *Q* comprised 35 samples, while the upper 20 % and 10 %, of daily discharges comprised 28 and 14 samples, respectively. At other sites with much smaller numbers of streamwater samples, this separation procedure would not yield enough isotope samples to reliably estimate F_{yw} for each flow regime. Therefore, we used the alternative approaches presented in the following Sect. 6.2.

- Page 15, line 3 – page 16, line 4: suggest introducing the concept of discharge sensitivity earlier in the manuscript as a methodological (sub)section and just presenting the results in section 6.2.

We would like to keep the current order of the manuscript as it would possibly cause confusion to present the discharge sensitivity too early in the manuscript (i.e., in Sects. 2 or 3) before the strong linkages between catchment wetness and young water fractions could be established. The discharge sensitivity analysis in Sect. 6 consequences immediately from the comparison of flow-weighted versus unweighted young water fractions (Sect. 4.3) and the catchment-comparison analysis (Sect. 5).

- Page 15, lines 13-14: add "algorithm" to "analytic Gauss-Newton".

We will change that.

- Page 17, lines 7-14: this paragraph is closely related to the paragraph on page 16, lines 16-29. I suggest moving it accordingly.

We agree with the reviewer that Page 17, lines 7-14 repeats some of the results presented previously, however, we would like to keep this paragraph as it is to better compare the opposite correlations of the young water fraction and its discharge sensitivity with respect to the catchment characteristics.

- Page 17, lines 8-10: please rephrase this sentence to clarify. Do you mean ". . .exhibit significant positive correlations with Fyw but also statistically negative correlations with the discharge sensitivity of Fyw."?

We will change that.

Summary and Conclusions

- Here or in previous section: please discuss in a bit more detail the additional information content of the discharge sensitivity. Long-term isotope data of good resolution such as in this study are not a given, so it might be good to know if (what) Fyw can tell us more than "traditional" hydrologic indices addressing flow variability (e.g., CVQ)?

Traditional hydrometric metrics such as *CVQ* of *QFI* solely allow to draw conclusions about the response times of a catchment, while no information can be obtained about how much young water a flood peak contains. In contrast, the discharge sensitivity expresses how the fraction of young water changes with catchment wetness (expressed by *Q*), and thus we gain more information about the storage behavior of a catchment.

- Page 18, line 31: suggest dropping "however" as this might be confusing to the reader

We will change that.

- Page 19, line 19: suggest replacing "found" by, for example, "hypothesize" as this follows from the conceptual model.

We will change that.

***Figures**

- Figure 6: it might be the pdf version, but I can barely discern light blue points.

We will increase the color contrast between the data points shown in Fig. 6.

***Supplement**

- suggest adding a map showing the 22 catchments and the 19 long-term monitoring stations for d18O-values in precipitation so the reader can get an idea of the spatial coverage of the measurements. Alternatively, the station locations can be added to Fig. 2.

We will include an overview map of the stations in the Supplement.