Dear Anonymous referee #2,

Thank you for your care during your reading of the manuscript, your positive remarks and your comments that will help to improve the work. Please, find here below the responses to all your comments.

We will take into account all your constructive feedback in the revised version of the manuscript once we receive the editor's response.

With kind regards,

The Authors

This article presents an interesting method for estimating the young water fraction based on high-resolution EC measurements.

Thanks for the positive overall assessment.

My only two major concerns are:

1) the authors may consider providing more evidence or referencing literature to support their three main assumptions for the method.

Thank you for this comment. In the revised version we will certainly provide more evidence of our assumptions.

- **The assumption 1 of considering EC as a proxy of water age derives from the following reasoning and literature:**

  "*Mineral weathering can be seen as a sequence of complex geochemical reactions driven by properties of fluid flow, such as the contact time between the circulating water and mineral surfaces…*" (Benettin et al. 2017; Benettin et al. 2015). Thus, the longer the contact time of water with rocks and soils, the higher the mineral weathering. Since EC is a bulk measure of major ions in water, the time that water is retained in a catchment before being released as streamflow (i.e., its age) is expected to be related to the ion concentrations and, accordingly, with EC. Indeed, Mosquera et al. (2016), investigating the mean transit time (MTT) of water and its spatial variability in the wet Andean páramo, found that the mean electrical conductivity is an efficient predictor of mean transit time in this high-elevation tropical ecosystem. Also, Bonacci et al. (2023), analyzing the EC measured in a karst spring, stated that EC can be used to identify the time that water spent in the karst aquifer (Bonacci et al. 2023 cum bibl.). Riazi et al. (2022), modeling the EC variation using a travel time distribution approach, assumed that the salinity of water in catchment storages is a function of water age.

- **The assumption 2 of considering EC_{ow} higher than EC_{yw} derives from the following reasoning and literature:**

Following assumption 1, the ion concentrations (i.e., EC) in old (transit times (TT) longer than 2-3 months) water are expected to be higher than the ion concentrations (i.e., EC) in young water with shorter transit times (< 2-3 months). Moreover, young and old streamwater components can derive from different reservoirs in a catchment (Riazi et al. 2022). Among these reservoirs, old water is generally assumed to represent groundwater. This is also supported by the fact that the fraction of baseflow (representing groundwater contribution to streamflow) resulted to be complementary to young water fraction in the framework (including the three Swiss catchments of this study) investigated by Gentile et al. (2023). In this regard, different papers that characterized groundwater EC showed notable differences with EC of precipitation and meltwater. Indeed, Zuecco et al. (2018), by investigating the hydrological processes in an alpine catchment, found that EC of rain water and of recent snow is 19.2 µS/cm and 12.2 µS/cm, respectively. Conversely, they found that groundwater from springs had an EC of 166 µS/cm. Moreover, by investigating the conceptualization of meltwater dynamics in an alpine catchment through hydrograph separation, Penna et al. (2017) defined the snowmelt endmember ranging from 2.9 to 15.3 µS/cm, the glacier melt endmember ranging from 2 to 2.7 µS/cm and the groundwater endmember ranging from 210 to 317.7 µS/cm (average values from springs or streams in fall/winter). These examples are intended to show that groundwater (main source of old water) generally reveals an EC value much higher (around 10-fold) than other sources in a catchment that should preferentially contribute to the young streamwater component. Moreover, Kirchner (2016b) showed the concentrations of reactive chemical species as functions of young water fractions for streams draining three contrasting catchments at Plynlimon, Wales (Fig. 1, extracted from Figure 14 of Kirchner, 2016b and modified after). Calcium concentrations (one of major ions dominating EC in natural streams, Riazi et al., 2022) in streamflow were high for low young water fractions and decreased when young water fractions increased (Fig. 1). By indicating the general trend with gray lines, it is possible to infer the calcium concentration corresponding to F_{yw} = 0 (i.e., the old water end-member) which is shown to be higher than theoretical calcium concentration corresponding to F_{yw} = 1 (i.e., the young water end-member).

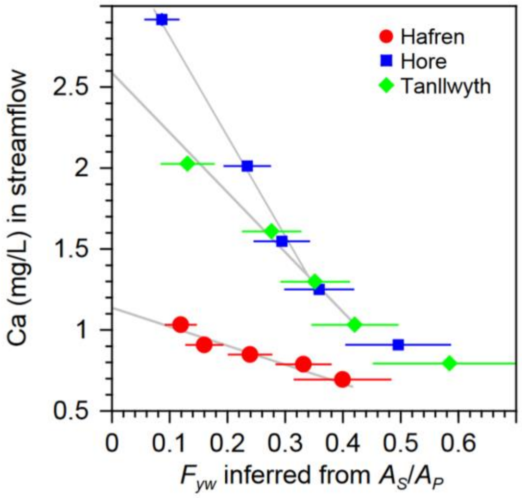


Fig 1. Calcium concentration as functions of young water fractions for three contrasting catchments at Plynlimon, Wales.

Image source: Figure 14 of Kirchner, J. W.: Aggregation in environmental systems-Part 2: Catchment mean transit times and young water fractions under hydrologic nonstationarity, Hydrology and Earth System Sciences, 20, 299–328, https://doi.org/10.5194/hess-20-299-2016, 2016., modified after.

Differences in young and old water EC end-members can also be partially justified by looking at differences in event and pre-event water EC endmembers. For example, Cano-Paoli et al. (2019) used the streamwater EC to investigate hydrological processes in alpine headwaters by separating the hydrograph into event and pre-event water. In this regard, they defined the event water end-member equal to 8 µS/cm (as in Penna et al. 2014) and the pre-event water endmember equal to 95 µS/cm (mean value during baseflow conditions). Laudon and Slaymaker (1997), by investigating the hydrograph separation using EC at the lower station of an alpine catchment, defined the rain water EC endmember equal to 6.15 µS/cm and the pre-event water endmember equal to 39 µS/cm. Old (TT > 2-3 months) water is a large fraction of pre-event (TT > few days) water, whereas event water (TT < few days) is a portion of young water (TT < 2-3 months). Due to this overlap (schematized in Fig. 2), would not be surprising a similarity of old and pre-event water EC endmembers, as well as young and event water EC endmembers. However, young and old water EC endmembers are expected to be higher than event and pre-event water EC endmembers, respectively.

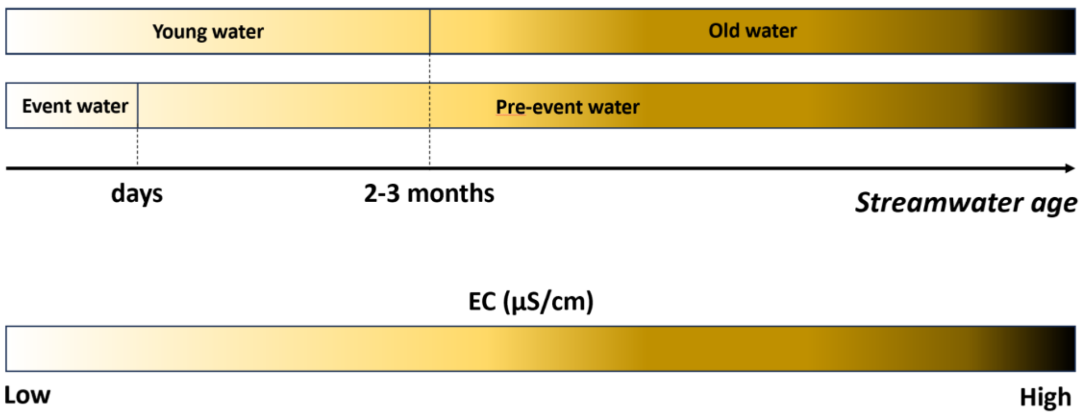


Fig. 2. Conceptualization of EC variations with streamwater age highlighting the overlap between old and pre-event water, as well as young and event water.

- **The assumption 3 of using an exponential mixing model that describes how the young water fraction varies with EC in streamwater can be further justified by looking at the relation between flow-specific young water fractions (F^Q_{yw}) and flow-specific electrical conductivity (see Fig. 1 in the first response to Anonymous referee #1) that we will include in the revised version of the manuscript.**

2) the authors could discuss how their method can be applied to other basins beyond their experimental watersheds.

Thank you for this comment.

We could expand the section 3.3 of the preprint renaming it as “"Limitations of the EXPECT method and recommendations for future applications" in the revised version.

We can add a paragraph at the end of section 3.3, briefly outlining the application to other basins beyond our experimental watersheds. We will better explain that a good starting point to choose the mixing model between young water fraction and EC is to visualize the relationship between flow-specific young water fractions and flow-specific electrical conductivities, as suggested in Kirchner (2016b). This relationship could be potentially different from an exponential mixing model. Indeed, the use of the exponential mixing model is not pretended to be the definitive answer to the problem of choosing the right mixing model. However, also if there will be changes in the mathematics, the general method structure to calibrate the endmembers can be applied. Please, note that in some catchments with short and sparse isotope timeseries, flow-specific young water fractions cannot be estimated reliably (von Freyberg et al. 2018).

I also have some smaller comments as follows:

1. Lines 52-55, readers may seek more detailed descriptions for the terms 'unweighted,' 'flow-weighted,' and 'time-weighted.'

We have inserted complete information about these terms in the supplementary material, but we missed adding a reference to supplementary material at line 55. We will add this reference. We will also specify that time-weighted or unweighted young water fractions are synonymous). Thank you for this.

2. Lines 85-86, what do you mean by the 'uncertainty of the discharge sensitivity of the young water fraction'?

The discharge sensitivity of young water fraction estimation is described in the supplementary material of the preprint. By fitting Eq. (S4) directly to the streamwater isotope values by using the IRLS method it is possible to estimate the parameters F^*_0 and S^*_d, as well as their associated standard errors. When we talk about the 'uncertainty of the discharge sensitivity of the young water fraction' we are referring to these standard errors. In Table 4 of the preprint we show that with the *EXPECT* method we reduce the standard errors of such parameters.

3. Table 2, are the numbers of 18O samples and EC samples the same?

Please, consider that we are not referring to physical samples. We have a daily EC time series obtained from averaging 10-minute data from an EC probe in the stream. When we apply the *EXPECT* method at the "sampling resolution", we subset those EC values from the daily time series that correspond to the time of isotope sampling. In this sense we can say that we have the same number of EC and isotope samples. We will clarify this better in the text. Thank you.

4. Eqs. 2.1-2.2, I would appreciate more details on the estimation of As, A*s and Ap.

As for your first minor comment: we have inserted complete information about these terms in the supplementary material, but we missed adding a reference to supplementary material at line 150. We will add this reference.

5. Figure 5, could you explain what Qmed and Q50/50 represent?

We will add what Q_{med} and $Q_{50/50}$ represent in the figure caption. Thank you for this.

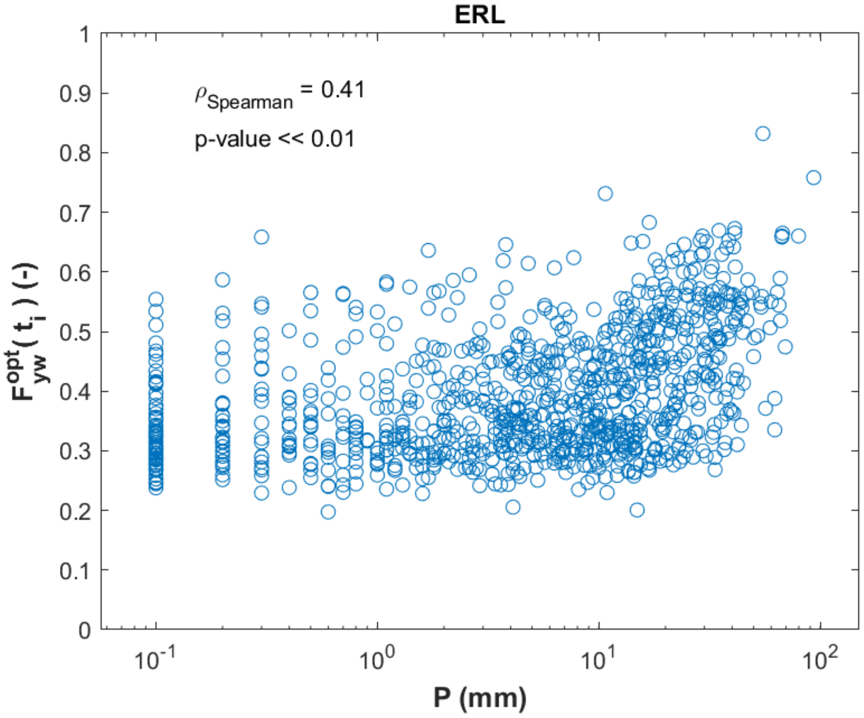
6. Figure 6, is the variable snow depth represented as HS in the figure? Please specify the years in each of the panels.

Yes, H_S and "snow depth" are the same variable. We did not realize that we have used two different names in the figure. We will add "(H_S)" in the legend after "snow depth". Thank you for having noticed this.

We will specify the years in each of the panels.

7. Figure 7, why not include a scatter plot for Fyw and P, which might better illustrate the correlation?

The first attempt of Figure 7 was a scatter plot. However, it was not so evident the threshold-like behavior, while it is clear with a binned scatter plot. However, we report hereafter the scatter plot to show how the figure looks like with the representation you suggest:



8. Line 395, 'significantly reduced the uncertainty of'—how can we observe this reduction in uncertainty from the results section? Please provide more details in the text.

Following our answer to your second minor comment: in Table 4 of the preprint we show that with the *EXPECT* method we reduce the standard error of the same parameters that can also be obtained with the method presented in Gallart et al. (2020), i.e., the method used to estimate the discharge sensitivity of young water fraction.

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