

Hydrol. Earth Syst. Sci. Discuss., author comment AC2
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Reply on RC2

Anthony Michelon et al.

Author comment on "Hydrodynamics of a high Alpine catchment characterized by four natural tracers" by Anthony Michelon et al., Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2022-48-AC2>, 2022

Dear second reviewer,

We are very thankful for the time and feedback you gave us.

Please find below a point by point response (following double carrots >>) to your specific comments. In addition to general clarifications, we have 1) proposed a first conceptual figure; 2) made the specific improvements to figures that you recommend; and 3) clarified the technical details around lapse rates and spring locations and counts. The clarifications could be transferred to the manuscript in a more condensed manner, which we would be happy to implement. We will carefully revise the manuscript and incorporate your minor comments and technical corrections once we receive the editor's response.

Sincerely,

The Authors

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Title: Studying the dynamics of a high alpine catchment based on multiple natural tracers

Michelon et al., 2022 HESS

General comment:

The paper makes an important contribution to increasing the understanding on flow dynamics in alpine catchments. This is done by combining different datasets, including stable water isotope tracers, EC and Temperature. Sampling of stable water isotopes in different storage compartments in the catchment (including vegetation) helps disentangle different hydrological processes (i.e. how does the catchment function). The figures are well prepared and the fact that the data is available will surely aid further research in alpine areas. The methods are clear and sound. Having said that and despite the interesting topic and relevance of the study I have concerns with the presentation and structure of the manuscript. In general;

- The Methods section would benefit from being more brief.

>> We will work to condense it, relying more on the referenced papers.

- The results section should be revised and the sentences which discuss results moved to the discussion section.

>> Thank you for identifying our organizational mistake. We will make this rearrangement.

- Interpretation of results from the multi-tracer approach would benefit from the addition of a conceptual diagram (see specific comments in E).

>> Thank you for recommending a conceptual diagram. We include here a first idea (also benefitting from the suggestion of the first reviewer). It is visible as the first figure in the supplement to the reply to the reviewer.

- More references to international literature is needed in discussion and careful selection of figures to be referenced.

>> Thank you for recommending this. We will develop our connections to literature, as also suggested by the first reviewer.

- Conclusions section needs strengthening.

>> Thank you for suggesting this. We will do this in part by including a concluding paragraph with our lessons learned from our simultaneous examination of 4 tracers that is currently in the 5.6 section of the discussion.

Below I leave section by section comments which include both specific and technical comments.

- Introduction:

Line 51 - 70: It seems that you repeat in a way the study aim (see technical comments below). I suggest to restructure that part starting with a clear overarching aim and then

>> We've rephrased this section as follows:

To fill the gaps in existing studies, that is the elevational and the seasonal gaps, this work quantifies drivers of the hydrologic response of a high elevation catchment through continuous measurements of natural tracers covering a period of two years for the streamflow. Hence this includes periods of winter low flow, to different stages of the melt season and the autumn recession, all for the intensively studied Vallon de Nant catchment in the Swiss Alps (Benoit et al., 2018; Giaccone et al., 2019; Ceperley et al., 2020; Mächler et al., 2021; Michelon et al., 2021a; Thornton et al., 2021a; Beria et al., In revision; Antoniazza et al., Submitted).

Four different tracers are combined in a unique fashion. First, hydrogen and oxygen stable isotope compositions of water, a natural tracer that has been extensively used to characterize hydrological processes related to snow (e.g. Beria et al., 2018), which is particularly useful to examine the interplay of different sources of water (rainfall, snowpack, springs, groundwater), as well as recharge and evaporation processes (e.g. Sprenger et al., 2016). Second, electrical conductivity measurements that provide

additional information on subsurface flow paths and relative water residence times in the subsurface (Cano-Paoli et al., 2019). Third, temperature measurements of water that trace connectivity between water sources and the atmosphere (Constantz, 2008). And fourth, soil temperature measurements that identify periods of thermal insulation from the seasonal snowcover (Trask et al., 2020).

The specific objective of this work is to examine the dominant hydrological processes that explain the catchment-scale hydrological response during different periods of the year through a combined use of the four different tracers. Using these tracers, we principally address 6 questions: 1) What is the origin of winter streamflow (from subsurface storage versus from localized snow melting) (Floriantic et al., 2018; Hayashi, 2020)? 2) What are the dominant runoff processes that drive streamflow generation during early spring snow melt (Brauchli et al., 2017)? 3) What drives streamflow later on during the snowmelt season?, and 4) during the season of recession? 5) What is the role of shallow groundwater in the hillslopes and of alluvial or talus groundwater systems (Hayashi, 2020) in the streamflow generation throughout the year. Finally, what transferable insights into the value of these four tracers for hydrologic process investigation are relevant for comparable catchments?

- (Section 2.1.) Study area: this section is unnecessary long. Is all the provided information then related to the study results? If not, you can reference previous papers for details on e.g. geology, and save space here.

>> Thank you for this suggestion, we will proceed as recommended as you also suggested for the entire methods section.

Lines 98-102: as written currently this paragraph reads like a discussion and it is not (e.g. "this topographic particularity might seem enough"). Please rewrite or move to discussion (e.g. to section 4.3.2.)

>> We have rewritten this as follows:

The location of springs correlates with low slopes (see Figure S6 in Supplementary material), a topographic particularity explaining the location of springs along the right bank of the main stream and within the grassy slopes in the west area of the catchment, where the slopes are low. In the same way, the absence of tributaries over the north-western parts of the catchment are related to steep slopes, explained by the large hydraulic conductivity and locally well-developed soils.

Figure 1: There is no "A" on the Figure 1, as indicated in the caption, please add. In caption "where the spring is picked up" – what do you mean by this? Also, can you make the legend of the B map, at present it is difficult to read.

>>A is missing indeed, it will be corrected. The note in the figure legend has been

rephrased as :“Note that the AUBG spring location shows where the water is sourced from, even though it is sampled from a pipe at the Auberge weather station point, 800 m further north.” and will be moved to the main text. The two legends will be placed together to make a single more comprehensive legend.

- (Section 2.2.)

Line 130 – 135: This seems like results (i.e. you analysed the data to derive the annual average streamflow, for example). I would somehow include it in Results section.

>> section 2.2 will be split into results and methods with a similar section starting the results section.

Line 139 – 143 refers to the meteorology. Given the title of section 2.1. starts with meteorology, I suggest you present this first to follow a logical order.

>> This is a good point, we will reorganize it as you suggest.

- Method: This section is very long. While the methods described are worth mentioning the descriptions are too wordy and make the reading monotonous. Here a few examples/suggestions on how to change that along with some minor technical notes.

>> We will rearrange this section to first be instrumentation (meteorological then hydrological), then tracers with subsections of 1) stable H- and O-isotopes of water, 2. water temperature, 3. conductivity, and 4. soil temperature, followed by additional data.

Line 153: Change “Water” (first word) with “Streamflow”. Water is too generic, you sample water from various places.

>> Thank you for the reminder to be precise. We prefer to use a parenthesis for specificity as not all the water that we sample is streamflow: (from streams, springs, and piezometers)

Line 167: “ The same borosilicate glass vials were also used for...” – this sentence is long and redundant. Define the type of vials and their volume once at the beginning of the subsection 3.1.1. and then only refer to them as “vials”. It will save a lot of reading time.

>> thank you for the suggestion.

Line 179: remove “sampled”, as it is redundant

>> thank you for the suggestion.

Line 219: I can count 5 springs on Fig.1 but T was measured in four. Can you spell out in which one you did not measure temperature?

>> We will clarify that we didn’t measure temperature in the auberge spring (AUBG). We did not have access to the spring directly, only to a fountain where it was delivered by pipe. The information will be moved from the figure legend to the corresponding method section.

Subsection 3.1.2. Is extremely long and too much detail is given. These are standard

methods, just give references and keep it tight. Only if you did something different or unique in the calculations then spell out which part that is to guide the reader.

>> Thank you for this recommendation. Unnecessary details will be moved to a supplementary file.

Line 225: Reference "Figure 1" in "(At Auberge station).

>> Thank you for catching this omission

Line 227: see previous comment on excessive description of the vials

>> thank you for suggesting this.

236: change "particularly useful for us" to "particularly useful for this study"

>> thank you for this suggestion.

244: you mention that the gridded data was useful for gap filling but you do not say when did you have do gap fill and what % of your data that is. Please spell out.

>> Thank you, we will include this calculation.

- Results

Specific comment: The results section contains parts of discussion which should be moved to the discussion section (some examples below).

The interpretation of results and to connect findings via different methods I suggest that you include a new figure, a conceptual model/diagram, which can also serve as a graphical abstract. This figure can be composed of 4 panels (A to D) and each one of them can describe graphically what have you learned with the multitracer method in A) The baseflow period, early melt period, melt period and seasonal recession period (as described in lines 248-249). This will aid the reader and will align with the aim "to provide transferable insights into the value of observed variables for hydrological process investigations in comparable catchments" (see lines 68-70).

>> Thank you for this suggestion. We've included our first attempt at a conceptual figure as Fig. 1 in the supplement.

Other comments:

Lines 257-259: This is discussion. Move it there.

>> Thank you, we will.

Figure 3: Add to the legend what B, E, M R mean. This saves the reader having to go back to the text and search for definitions. What is the faint blue line in the bottom panel? It looks as faint as the streamflow. At present this bottom panel is a bit confusing. Refer to Figure 1 for the abbreviations of e.g. soils, piezometer, spring IDs.

>>B, E, M, R will be added in the figure caption. The faint blue line in the bottom panel is the temperature at the outlet (HyS1), we will pick a better color to be more distinctive from the streamflow, and also another color for streamflow to be more distinctive from PZ1 and PZ3. We propose to add a title and subtitles to the legend on the figure to help the reader to understand, i.e:

WATER TEMPERATURE

Outlet

- HyS1

Springs

- GRAS
- ROCK
- SPRING
- ICEC

Piezometers

- PZ1
- PZ3

Line 317: sentence is too long. Change to "Sampled spring and ground water sources show varying correlations..." and add..."having PZ1 the strongest correlations..."

>> thank you for this recommendation.

Lines 334 – 344: example paragraph where the conceptual diagram will help the reader understand the description.

>> indeed, good idea. Please note the illustration as figure 1 in the supplement.

Lines 353 – 359: this seems to belong to methods.

>> we will move it there.

Lines 364- 368: Move this to the beginning of subsection 4.3.3. as this presents a more general finding. Then discuss the rest but please rewrite and remove the details that may belong to the methods.

>> good idea.

(Section 4.1.)

374 – 379: This is more of a discussion, not a result.

>> We will move it to the discussion.

379-381: Sentence is too long. Rewrite or split in two.

>> According to your previous suggestion, part of this sentence will be moved to the discussion, thus we will break it in two. In the results, only a sentence stating that we observe an event-scale lag in both streamflow and EC.

Figure 4: You do not make use of the subplot annotations A,B,C, etc. in the caption. Please edit your caption and organise by subplots. Also, when you reference this figure in the text you start with Figure 4F (Line 370). Please organise your subplots so they match the story line (e.g. if you first talk about EC then present the EC plot as Figure 4A). Same comment on the order applies to subsection 4.5.1.

>> We will add the annotations, A, B, C, and rearrange the text and subplots to correspond to each other.

Line 406: this is the first time you use lapse rate. Please define it very briefly earlier (e.g. in methods).

>> We will add a sentence regarding how we calculated lapse rate in the methods.

Subsection 4.5.1. is structured poorly. You mention a lot of Figures but make little use of them.

>> We will develop and organize the section further.

Figure 5- 7: Similarly to Figure 4 you make subplot annotations A,B,C,..but do not use them in the caption. Also, is there a way to skip one or two of the subplots (and move them to supplementary materials) and consequently make the plots larger and horizontally oriented. At present it is very difficult to read them if you don't print the manuscript.

>> We will add the annotations, A, B, C, and rearrange the text and subplots to correspond to each other. We will consider moving some of them into the supplementary materials so that they can be horizontal. This is a good suggestion.

Subsection 4.5.2.

Line 427-428: if the variations are similar between the different stable water isotopes and you will comment only on $\delta^{18}\text{O}$ then why don't you save space and present those in supplementary material?

>> This is a good idea, thank you.

Line 439: remove "it's"

>> Thank you.

Subsection 4.5.3., 4.5.4.

Make more reference to your Figures in the text. And similarly to Subsection 4.5.2. - move to supplementary materials the figures you do not reference.

>> Thank you for this advice. We will.

Subsection 4.5.5.

Line 480: The first sentence is not a good start of a subsection. Remove is and simply reference the figure in brackets in a rewritten first sentence. In the first sentence present the general idea/finding from Ic-excess. Second sentence at present is too difficult to follow as it is too long- split in two.

>> Thank you for this advice. They now read as:

The range of values of LC-excess for the rainfall samples are related to the spread around the evaporation line (Figure 4F). We see that the median value of the snowpack samples is close to the reference for rainfall (0 ‰). Our observations validate Beria et al. (2020)'s review of snowpack data for entire snow seasons and does often not show a significant deviation from median values from the reference precipitation value.

- Discussion;

You discuss the results in terms of interpretation of the data but do not make a reference to other literature. In this regard the discussion needs more work and strengthening.

>> Thank you for this feedback. The first reviewer also said something along these lines. We look forward to the opportunity to develop our discussion particularly in terms of comparison and discussion of international literature.

Also, the terminology used in this section sounds a bit awkward. Examples below:

>> We will carefully edit and revise all the text with attention to this critique.

Line 515: "enrichment in light isotopes during winter" – which are the light isotopes of hydrogen and oxygen? Do you mean "stable water isotope signal becomes more depleted during winter"?

>> We've revised it to read:

However, we measured diverging isotopic ratios in two springs, one demonstrating an enrichment in the heavy H- and O-isotope composition (AUBG) and the other a depletion in these isotopes (BRDG) during winter (Figure 5).

Lines 516, 534: "light isotopes" – same comment. Revise the terminology

>> We've revised it to read:

Winter melt processes contributing to the groundwater system throughout the winter would lead to such a depletion in the heavy H- and O-isotopes.

Section 5.2. would benefit from reference to the conceptual diagram I suggest above.

>> Thank you, we look forward to adding it, built on the basis of figure 1 in the supplement.

Lines 555 – 558: this sentence is too long and difficult to follow. Rewrite.

>> We've rewritten it as:

During M2, both BRDG and PZ3 temperature is correlated with streamflow variations although one is a positive anomaly (BRDG) and the other negative (PZ3). The positive anomaly measured at BRDG suggests a snowmelt input that is heated up before

infiltration, which is understandable because BRDG collects snowmelt from the nearby riparian area and steep slopes facing west in direct sun exposure. In contrast, the negative anomaly at PZ3 suggests the melted snow is directly infiltrating as it begins with the melt period and ends when the area is free of snow (200 m from soil temperature sensor at 1,530 masl), suggesting that the infiltration of snowmelt is local.

Line 578: "streamflow isotopes" would sound better as "isotope signal in streamflow"

>> We've change this to "isotope composition of the water in the streamflow". Further more we will correct the language imprecision or colloquialism throughout the manuscript. We will use observe for what we see and measure for what we measure in our revision.

Line 611: "which locations become more enriched in heavy isotopes" – the location do not become more enriched, it is rather the water in those locations shows a more enriched isotope signal. Please rewrite.

>> We've rewritten this to read:

However, this requires year-round time series to measure where and when water becomes enriched or depleted.

- Conclusions

The conclusions section needs strengthening. Mention what are the implications of your findings and how is this study important in terms of better understanding the water dynamics of Apline catchments.

>> Thank you for this feedback. We will rewrite the conclusions.

Lines 650 – 655: This is not a strong ending of a conclusion section and it does not reflect the efforts employed in developing and executing the field study. I suggest a small subsection is dedicated on $\delta^{17}\text{O}$ somewhere earlier in the manuscript and all the findings are concentrated there.

>> This will be moved to a section of the discussion following "the added value of EC": "The added value of $\delta^{17}\text{O}$ and ^{17}O -excess".

Please also note the supplement to this comment:

<https://hess.copernicus.org/preprints/hess-2022-48/hess-2022-48-AC2-supplement.pdf>