

## ***Interactive comment on* “Controls on spatial and temporal variability of streamflow and hydrochemistry in a glacierized catchment” by Michael Engel et al.**

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Response to Reviewer #1

“Controls on spatial and temporal variability of streamflow and hydrochemistry in a glacierized catchment” by Engel et al.

General comments:

The focus on data presentation is one of the current limitations of the manuscript, already somewhat outlined in the introduction, when the authors stated that they want to fill the current research gap in alpine hydrology by “presenting data”. This may be

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the wrong start for this research paper, as it leads to a case study and simple report style manuscript, I rather expect that a detailed question will be answered or a theory challenged by hypothesis testing. For this – the otherwise very good introduction – may need to pinpoint the research gaps more specifically and could more often summarize how something influences response rather than what influences responses of alpine watersheds (cf. lines 81 ff.). I think this will help to narrow the focus and ease the writing. This is necessary, as I feel that parts of the manuscript are somewhat premature and not fully developed yet. The current focus of the manuscript is too much on the presentation of the data and thus becomes quite a heavy read in some sections (for me), where I felt that the selection of what is important for the understanding of the research gaps and the watershed was left to the reader. A more careful selection of the data and results that are presented in detail is necessary as it will help to streamline the manuscript and better guide the reader, e.g. how far is the presentation of turbidity data relevance for the processes (among other)? The current version seems to present all derived data without carefully considering the why behind the structure of the results and the presentation thereof. This relates to the most major limitation of the work: the lack of a clear story line (already mentioned above). I found some inconsistencies in the manuscript. It starts with the title where it is stated that spatial and temporal variability of streamflow will be assessed, while neither the hypotheses, the research objectives, nor the results come back to this. Therefore I would remove the hydrometric question from the title, especially since only one station was investigated. Next, the conclusion does not clearly link back to the research objectives, and actually cover quite a range of findings from controls on streamflow chemistry to the similarity the chemical composition of glacial melt and outflow from a rock glacier; yet the main finding is rather obvious “hydrometric and geochemical dynamics were controlled by an interplay of meteorological conditions and the geological heterogeneity”. Several decades have looked at this (cf. Wolock et al., 1997); the finding is very general, probably applies to nearly every watershed and one does not require such an extensive sampling campaign to be answered. A clearer analysis of the research gap, and a

more specific formulation thereof (the statement about the current gaps is rather general 103-106) may help, as a very general question leads to a very general answer, and a rather speculative discussion. This is obviously ok for parts of the paper, but also a sign that the questions asked may not be specific enough for being answered with the existing data set. So I would recommend to analyze the research gap more detailed and formulate objectives/hypothesis to tackling this. From there one can tidy up the results for a better guidance (helpful to the authors and the reader). I am convinced that this is possible considering the detailed and extensive field data sets and the experience of the research group in alpine environments. Last, I felt that quality of writing declined after the introduction, you may have another careful revision before submitting the revised manuscript.

We thank the reviewer for her/his work in reviewing this manuscript and appreciate the comments and suggestions made to guide us improving this manuscript. We share the reviewer's opinion that the story line, and thus the focus of this manuscript needs essential improvements. We will solve this aspect by better working out the research gaps and scientific contribution of such a study. With respect to the research gaps, we will focus on the following ones: – the effect of catchment characteristics and environmental conditions on stream hydrochemistry at different spatial and temporal scales. – the hydrochemical characterization of permafrost (i.e. rock glaciers as a specific form).

Furthermore, as it is closely linked to this point, we will streamline the manuscript by sharpening the research questions and providing more specific and clearer results and main messages of this work. In this context, research questions will be modified and provided as follows: 1. What is the role of geology on the hydrochemical stream signatures over time? 2. Which are the most important nivo-meteorological indicators driving stream hydrochemistry during the melting period? 3. What is the temporal relationship of discharge and tracer characteristics in the stream?

Consequently, we will also revise the manuscript regarding the order of data presented

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(e.g., considering to change the order of figures) and the selection of data presented. Most likely, data referring to the LMWL are not necessarily needed to answer the research questions and therefore will be skipped.

Comment 1 line 68 “: : , and topography with drainage and catchment shape” maybe delete the first “and”

We agree and will change it.

Comment 2 line 103ff, please revise and streamline. Maybe some more detail before this is needed.

We agree and will revise this part by evaluating carefully the research gaps.

Comment 3 line 127ff, please also report mean elevation.

We agree and will add the mean elevation of the catchment.

Comment 4 line 134, “current” does this mean 2018? Figure refers to 2006, which is not current. If 2018, why not unify this information with the figure?

We agree that this is misleading and will remove the word “current”. Unfortunately, no recent data on glacier extents are available.

Comment 5 line 151, change “is” to “are” We agree and will change it.

Comment 6 l155, add “At the catchment outlet”

We agree and will change it.

Comment 7 l157, the conversion to discharge is done via a rating curve, not via the salt dilution measurements. Yet, the rating curve is derived from these measurements.

We agree and will modify as follows:“... via a flow rating curve using salt dilution/photometric measurements. . .“

Comment 8 l164, suggestion: replace “tracer” with stream chemistry. Chemistry be-

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comes a tracer when you infer processes, flow paths, etc. Otherwise, it is stream chemistry.

We agree and will modify the subtitle to "Hydrochemical sampling and analysis".

Comment 9 I165, technically the sampling is not continuous.

We agree and will remove "continuous".

Comment 10 I166, delete "Generally"

We agree and will remove this word.

Comment 11 I168, "respecting its seasonal variation", not sure what this should mean.

We agree and will remove this part of the sentence. The 23 o'clock sampling was set to capture the early summer discharge peak, while later summer discharge peaks occur much earlier. Not knowing this at the beginning of the study, we rather preferred to be consistent with the sampling time throughout the summer.

Comment 12 I172, "less than an hour"

We agree and will change it.

Comment 13 I190ff., needs more detail

We agree that more information on snow sampling could be needed here. However, in the context of streamlining the manuscript, we will evaluate whether snow sampling data are still needed to address the research questions.

Comment 14 I198, "before the analysis", delete "the"

We agree and will change it.

Comment 15 I223ff., "Then: : :" I do not understand this

We agree and will rephrase this paragraph to make it more understandable.

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Comment 16 I232, change tracer to hydrochemical

We agree and will change it.

Comment 17 I246-256, this is a little awkward and the use of the terms old and new water quite confusing. What you actually do is calculating the discharge for the sub-catchments via the isotopic data and known discharge. So rather avoid the hydrograph separation terminology.

We agree and will modify this paragraph as follows: “We will apply a two-component mixing model based on EC and  $\delta^{18}O$  data to separate the runoff contributions “

Comment 18 I264, “signatures”, “: : area are”

We agree and will change it.

Comment 19 I312, compared to what?

We agree and will change as follows: “...reaching the most increased conductivity at S6 during the study period compared to all sampled water types, . . .”

Comment 20

I329, maybe l/km<sup>2</sup> to compare the watersheds

We agree and will add a sentence on the runoff contributions translated into the specific runoff of both sub-catchments.

Comment 21 I430ff., I found this section rather irritating. From my perception daily max temperature, max solar radiation, and the change (at least the decrease) of the snow cover are correlated. So how can you assess their impact in stream chemistry independently? Further, are you not mixing causation and correlation in this section? Hydrochemistry is caused by the amount of snow melt contributing to the streamflow, while you correlate the metrics that will lead to snowmelt with the hydrochemistry.

We agree on this important comment. First, we will better describe our intention that

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we aimed at providing proxy data for snowmelt, in a catchment where up to now no simulated snowmelt data are present. Second, when revising the scientific gaps and research questions, we will argue that simple nivo-meteorological indicators such as losses in snow depth being relatively easy to measure may be needed to explain changes in stream hydrochemistry. Finally, we will better separate the different parameter relationships by showing first only meteorological parameters against snow depth differences (new Figure 9) and then snow depth differences compared with discharge, EC and isotopic data (new Figure 10), to represent both hydrometric and hydrochemical stream response and avoid mixing causation and correlation. Therefore, we will remove the former Figure 9 – 11.

Comment 22 l481ff., what is the link to the hypotheses or research question?

We agree and will most likely remove this section when making the manuscript more concise.

Comment 23 l495ff., As connectivity is in the section header, one expects to more clearly link and discuss connectivity here, while the text itself is more about rock weathering etc. What is connected when?

We agree and will add few sentences or rephrase this section to focus to justify the aspect of connectivity in the subsection header.

Comment 24 l569ff., see comment on l430.

As mentioned for comment 21 (referring to l430), we will address this point when revising the corresponding result section. As suggested for comment 21, we will modify the figures so that they better reply to the research questions and avoid the issue on mixing causation and correlation.

Comment 25 l594, are other met-station in the region available. Can one correlate these? The effect of topography is only marginally considered here, contrary to the sub-section's header

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We agree and will add further discussion with respect to topography. Regarding the presence of other meteorological stations, we will address it by focusing on the availability of meteorological parameter such as snow depth. We will also argue that high-elevation snowmelt (represented by snow depth differences as proxy) controls downstream isotopic stream composition due to the large amount of snow stored, being available for melting in spring.

Comment 26 l619ff., Why are you not performing a hydrometric data analysis?

We think that a hydrometric analysis is beyond the scope of this manuscript and may be addressed within future work.

Comment 27 l721, this is actually something we can say about every catchment without sampling for 2 yrs

We partly agree that this result is too vague and leads the concern addressed by the reviewer. However, as we will argue within the introduction, this kind of hydrochemical evaluation of new study sites is essential when focusing on hydrological model calibration and storages. In consequence, we will rephrase this part by providing more specific results replying to the new research questions previously posed.

Comment 28 l739, see comment on l430

We agree and will modify in accordance to our replies for comment 21 and 24.

Comment 29 l743ff., how? Can you show this or elaborate on this final conclusion.

We agree and will work on this aspect further.

Comment 30 Table1, change “average discharge (median)” to “median discharge”

We agree and will change it.

Comment 31 Table2, can you indicate the locations in the map of Figure 1.

We agree and will put the sampling locations in Figure 1.

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Comment 32 Figure 1, add locations of table 2., font sizes are different between the subplot and too small

We agree and will modify accordingly.

Comment 33 Figure 2, please adapt the figures after fig.2 to font size and font type of this figure.

We agree and will modify accordingly. However, as stated in the reply to the reviewer's general comments, we will likely remove this figure.

Comment 34 Figure 4, adapt color scale of a) b) to the same range for inter-comparison, font size too small

With respect to Fig.5, we initially used the same range of values to better compare both sub-catchments. As Trafoi variability in EC is less pronounced than the one of Sulden, colour differences are not large enough to separate all Trafoi water sources. However, we will follow the reviewer's suggestion as the focus of this plot is more on the Trafoi – Sulden hydrochemistry comparison.

Comment 35 Figure 7, 9, too small

We agree and will modify the figure accordingly.

Comment 36 Figure 10, see comment I.430

We agree and will revise this analysis and its figures accordingly. We will make these figure more concise by, for example, focusing only on the most important nivo-meteorological indicators and changing the way these data are presented.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2018-135>, 2018.

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