Review of hess-2021-512, by Philipp Wanner, Noemi Buri, Kevin Wyss, Andreas Zischg, Rolf Weingartner, Jan Baumgartner, Benjamin Berger, and Christoph Wanner, entitled: Quantifying the glacial meltwater contribution to streams in mountainous regions using highly resolved stable water isotope measurements

By Bettina Schaefli

This paper proposes to quantify the contribution of ice melt to total streamflow in three highly glaciated catchments in the central Swiss Alps with the help of astable isotopes of water. The aim is to come up with results that are more reliable than previous modelling-based results and with recommendations for future sampling campaigns.

I cannot recommend the paper for publication because some fundamental hydrological process knowledge is ignored. The obtained results are not plausible (glacier melt contribution of between 80% and 95% to total streamflow during August in catchments with only between 6 and 28% glacier cover). One key result is summarized in Figure 8, which shows glacier melt in Mio m^3 against glacier area. For the smallest glacier investigated, this result indicates meltwater production of $4*10^6$ m^3 on an area of 0.3 km^2, which corresponds to a melt water production of $4*10^6\ m^3/0.3*10^6\ m^2 = 13.3$ m of melt water production over the glacier area. For the largest glacier, it is $18*10^6\ m^3/6.8*10^6\ m^2 = 2.7$ m of meltwater production. The first value is impossible, the last values is in the order of observed summer mass balances in Switzerland in 2019 (see Figure 1).

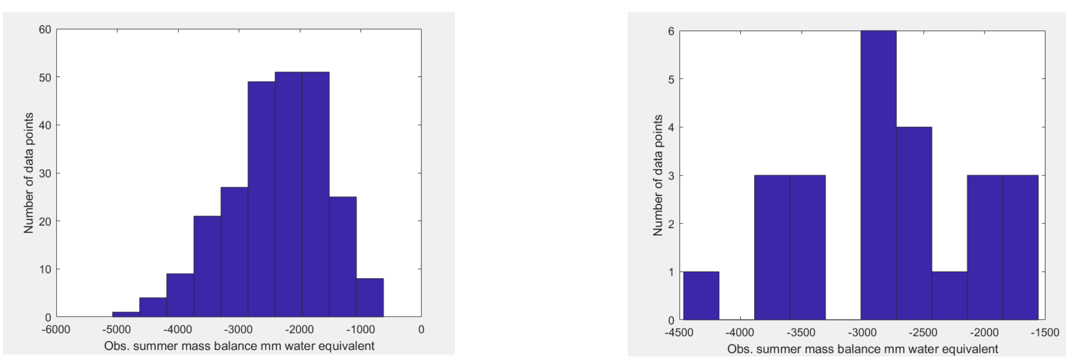

Figure 1: Observed summer mass balances in Switzerland from (GLAMOS, 2020), all values since 2011 (left) and for summer 2019 (right)

The reasons for the erroneous estimates are certainly related to the wrong assumption that streamflow during summer is only composed of glacier melt and of rainfall. In reality, an important part of streamflow is groundwater (baseflow) released by the hillslopes; the isotopic values of groundwater are strongly influenced by snow melt and thus close to the values of glacier melt (see below). Accordingly, the separation into glacier melt and not-glacier melt is impossible with the help of isotopes alone. EC values could help separating ground water from non-groundwater input but this would require values for groundwater and values for ice melt at the glacier snout (which was already in contact with the ground).

Detailed comments

The analysis of the contribution of ice to streamflow is based on a total of 2 ice melt samples taken each from a different glacier, both located in only one of the three catchments, i.e. there are no ice samples in two of the catchments. One catchment has no snow samples, all snow samples have (according to the sampling location figure) been taken at low elevations, there is only a total of 19 snow samples (the paper does not contain a clear overview of dates and elevations when and where the snow samples were taken).

Ice melt can have considerable variability (Figure 2) and be overlapping with the values of snowmelt and of the snowpack (Figure 3). Since groundwater is strongly influenced by snowmelt, it most likely has isotopic ratios that are also rather low.

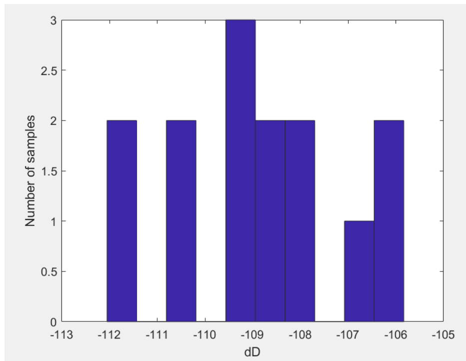

Figure 2: delta-Deuterium values in ice melt samples from the Otemma glacier (Müller et al., 2021), see also the display material here: https://presentations.copernicus.org/EGU21/EGU21-7182_presentation.pdf

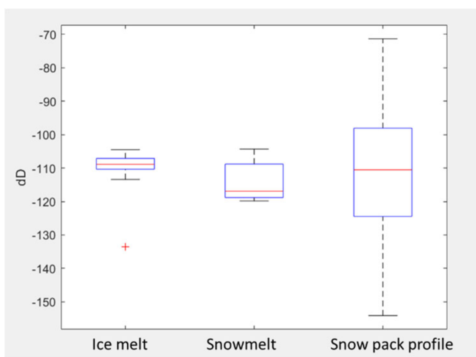

Figure 3: delta-Deuterium values in ice melt and snow melt samples from the Otemma glacier (Müller et al., 2021)

Additional specific comments

- Introduction: There is no reference to mixing analysis in the introduction despite of the huge body of hydrologic literature in this field. There is very little reference to isotopes studies in Alpine areas (e.g. Penna et al., 2014)
- Line 252 following: The text mentions the enrichment in heavy isotopes in the snowpack over the accumulation season and attributes it to melt/refreeze cycles and moisture exchange with the ground. This explanation is a priori not plausible for enrichment during the accumulation phase

at elevations around 2000 masl (exact sampling elevations unknown) where ground is often frozen in winter and melt only occasion. However, the sampled period might well correspond to an exceptionally warm winter. This should be specified. We would need actual temperature recordings to shed light on this.

- Line 283: mistake, “The more enriched d18O and d2H snow values in the *ablation* compared to the *ablation* period”
- Line 288: I would not interpret a single solid ice sample with respect to two ice melt samples.
- Line 363 following: would be more interesting to compare the streamflow in terms of specific discharge (normalized to catchment area), in mm/d, (and thus remove the log-scale in the figure)
- Line 381: “The significant contribution of snow and glacial meltwater to the stream discharges is further reinforced by the low electrical conductivity (E.C.) in the Steinwasser catchment discharge (~ 30 µs/cm) between June and August 2019 (Fig. 6C)”: you omit that the two others seem to have values of around 100. Do you have any groundwater / spring sample to judge how high this is?
- Line 389 following: you make the point that during winter low flow, which is dominated by groundwater, the separation of streamflow components (rain, snow, ice) is difficult. This applies also during the rest of the year
- Line 405 following: do you have evidence of the absence of snow in August and September? Perhaps at least the largest glacier has still a firn / permanent snow area? Even for the other two glaciers, snow might persists in August and might come back in late September? Complete absence might hold maximum for a week or two. Snow might even persist in August in shady areas outside the glaciers?
- Line 415: you could test the sensitivity of the results to a lapse rate in precipitation, since you have such an effect for part of the year as far as I understood?
- Line 420: “it can be expected that the isotopic signature of the melting ice changes minimally between in August and September (Beria et al., 2018).” Different locations on the glacier might show different values for melt; but the actual problem is that the hillslopes provide high baseflow, which has isotopic values of groundwater, which in turn has the values of snow;
- Line 424: your main result with very high glacier melt shares for all three catchments is not in-line with your EC measurements?
- Figure 8: fitting a power-law to three points is clearly over-fitting
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References

GLAMOS: Swiss Glacier Mass Balance, release 2020, Glacier Monitoring Switzerland, 10.18750/massbalance.2020.r2020., 2020.

Müller, T., Schaefli, B., and Lane, S. N.: Assessing the effect of the geomorphological complexity of glacier forefields on the multi-temporal water dynamics will provide better future models, EGU General Assembly 2021, EGU21-7182, 10.5194/egusphere-egu21-7182, 2021.

Penna, D., Engel, M., Mao, L., Dell'Agnese, A., Bertoldi, G., and Comiti, F.: Tracer-based analysis of spatial and temporal variations of water sources in a glacierized catchment, Hydrol. Earth Syst. Sci., 18, 5271-5288, 10.5194/hess-18-5271-2014, 2014.