Dear Editor,

We would like to thank the two reviewers and the editor for the feedback on our manuscript. Please find our detailed answers to the reviewers' comments and the changes we have made below (responses in italic blue). A track change version of the manuscript is also included. We excluded the mass balance analysis from the manuscript and clarified the text, as suggested by the reviewers. We merged two sections of the discussion. Page and line numbers refer to the track changed version of the manuscript.

##

Review #1

General comments

I want to thank the authors for their noticeably large amount of work for this very nice study and valuable scientific contribution. In my opinion, the study contains novel and highly interesting findings, the presented results seem solid overall (except maybe for how the authors calculated catchment-wide mass balance, see comments below) and are of high interest to the scientific community. In general, the manuscript is well written and very nicely illustrated (great figures!). I think that this work clearly deserves to get published in Hydrology and Earth System Sciences. The authors will need to put some effort into correction and improvement of their manuscript. In my opinion, there are still (even if only few) important major and a number of minor issues which need to be addressed, corrected, clarified, and implemented prior to publication. I guess that the majority of the specific comments listed below are easy to implement, whereas some general or specific comments will maybe need some additional work and time. I hope that my work for this review will help improving the paper, and I encourage the authors to implement and reply to all my comments as far as possible. Thanks a lot, it was a pleasure to review your study, congrats, all the best and kind regards.

List of some general comments:

-Abstract: very well written and very good overall! See some specific comments below. As you analyzed glacier-fed streamflow responses to WD in long-term streamflow observations (>50 years), in my opinion it would be beneficial for people interested in your paper to add some information about your observation periods for Canada, Norway, and the European Alps directly in the abstract as well...

>> We agree that this is a good idea. However, the different catchments have all different observation periods. For the Alps, streamflow and meteorological data overlap for the period 1961-2015/2016. Still, for Norway and Canada, individual catchments have a different observation period (but all at least 50 years), and therefore it is not easy to summarize that in the abstract.

-Introduction: I like the structure/storyline and content of the introduction, maybe it is a bit (too) long and could be shortened without losing important information and content? Sometimes I wondered whether the difference between "the buffering effect of glaciers" and "the compensation effect of glaciers" is always clear (or if there is any big difference at all...). Maybe you could check that point while going through the introduction (or the whole manuscript) again? Moreover, please find a number of specific comments which hopefully help to improve specific parts of the introduction below..

>> In our opinion, these concepts mean something different but are in the literature often used interchangeably when describing glaciers and droughts. We explain this in the discussion and added the following text in the introduction:

To distinguish these different buffer characteristics, we refer to compensation processes when describing the active role of glacier melt adding additional water and buffering when

describing the general function of catchment storages providing water when precipitation input is low. Such a distinction is important to quantify the effect of glacier melt during dry periods (L51-54).

In our view, buffering means 'something that helps protect from harm', i.e., it is usually a passive process but could also be an active process. In our context, glaciers act as a buffer to (meteorological) droughts because they still provide water while rainfall input is low, thereby preventing a severe impact on water availability, especially in relative terms. In this view, glaciers are always a buffer, regardless of the situation, because their water supply (on the short-term) is dependent on temperature and radiation rather than rainfall. Snow and groundwater can therefore be seen as buffers to meteorological droughts as well. 'To compensate', in our view, means to provide something to reduce the effect of something that has been lost or damaged, i.e., it is an active process. In our context, it means that excess (more than normal) glacier melt can reduce the effect of a rainfall deficit on streamflow.
In the case of buffering, the rainfall deficit in streamflow can still be present, but streamflow will not be affected entirely, because part of the streamflow comes from groundwater/snowmelt/glacier melt. In case of compensation, excess glacier melt can compensate for the rainfall deficit, and streamflow can be close to average or above average levels. Since glaciers do not only buffer but also compensate during warm and dry events, we argue (in the discussion) that such a distinction should be made and that this approach helps to quantify this specific role of glaciers.

To shorten the introduction, we removed one of the paragraphs (L90 – 102)

-Data: I have, unfortunately, some concerns about how you deal with and use measured mass balance data in your study; you cannot just take a median of measured glacier mass balance data, you have to weight the measured data with glacier area, i.e. calculate area-weighted average mass balances, otherwise you might get wrong results. This is relevant when it comes to compare or correlate mass balance with levels of compensation C, I clearly think you need to check and clarify that; moreover, it does not really make sense to me to just use "country-wide" mass balance data for individual catchments you analyze, there are better ways to extrapolate measured mass balance data to individual catchments, especially in areas with a high density of measured mass balance data like Norway, Switzerland, Austria. Please see also specific comments thereupon below.

>> This part of the analyses is now removed from the manuscript

-Results: In section 4.2 you only refer to WD (or WWD) events, right (CD, and ND events are excluded)? Maybe make that clearer in the text (e.g. by changing the title of the section to "4.2 Glacier compensation during WD events in different catchments"); it was not very much clear to me why the chosen catchments and years for individual regions were selected for Figure 3 (just an example or do these three years and catchments reflect some of the "general observations, trends, and C values over the whole observation period"?)...

>> The reviewer is correct that section 4.2 only presents WD events; the other events are presented in section 4.3. We have added this in the title of section 4.2. The catchments in Figure 3 were chosen to represent the streamflow responses for catchments with different glacier cover, ranging from low to high. The example years were selected because a warm and dry event occurred in multiple catchments in those years, and in a specific month. We wanted to show an example for an event in September (European Alps 1985 in this case), one in August (Canada in 1981 in this case) and one in July. Still, we found that in 2006 in Norway, events in multiple months occurred, therefore nicely illustrating responses, trends and C values for different months and in a catchment with a different glacier cover. Figure 3 is meant to illustrate what we analyze in this study and show the range of responses regarding streamflow trends during the events, compensation levels, and dependence on

glacier cover. This explanation of this selection of example catchments and years was added to the revised manuscript (L280).

-Results: Section 4.4and figure 9: As I understood how you calculate catchment-wide mass balance or take into account measured mass balance data to correlate it with levels of compensation C, in my opinion this is not quite correct (see comments above and specific comments thereupon below), maybe by correctly calculate catchment-wide mass balance your resulting correlations of mass balance with levels of compensation would quite change and show another relation between these variables?!...

>> This part of the analyses is now removed from the manuscript

-Results: Still section 4.4 and figure 10: To be honest, I didn't really understand how you calculated correlations between changes in C and glacier changes over time (mostly retreat for your period of observation, but with intermittent phases of readvance, for instance for Norwegian glaciers in the 1990s!), this is neither very clear from the methods section nor very clear in the results section... what data sets did you take into account to check if glaciers in the analyzed catchments did change in area and volume over your observation period? – this aspect, relating also to figure 10, is not very clear...

>> The phrasing here might have caused some confusion, and we have clarified that in the revised manuscript; we do not correlate C with glacier changes, but analyze trends of C over time. Maybe the relative glacier cover on the x-axis is confusing here. Time trends were calculated for each catchment, so glacier cover, in this case, refers to the trends for different catchments, not to trends in glacier area or glacier cover of the catchment.

To calculate trends, correlations can be used. For each catchment and each month, we checked if there were eight or more events occurring in the time series. If so, the correlation between C and the year of the event was calculated. A negative value indicates decreasing C over time, and a positive correlation means an increasing level of compensation (C) over time. A decreasing trend may be attributed to retreating glaciers. We agree with the reviewer that in some regions, glaciers were not only retreating but also had intermittent phases of advance (we looked at glacier length data from WGMS and literature). However, since only a few (extreme) events occur in the time series, limiting the time series only to phases of glacier retreat will result in too few events to do a trend analysis. In the Discussion, Line 457, we added a sentence on the possible influence of different phases of glacier retreat and advance on time trends in C.

-In the whole manuscript: I think it would make more sense to use "southwestern Norway" instead of "Norway" and "western Canada" instead of "Canada" in the entire manuscript (these countries are so large and you analyze only catchments in specific regions)...

>> we have changed 'Norway' and 'Canada' into 'southwestern Norway' and 'western Canada'

Specific comments and technical corrections

To facilitate the author's correction of the manuscript I combined specific comments and technical corrections (including language or spelling and comprehensibility issues). Sometimes comments contain both specific comments and technical corrections, sometimes just one or the other. I would ask the authors to implement my comments and suggestions as far as possible.

>> Thank you for the detailed specific comments and technical corrections. We changed all of them. Please find below all reviewer comments and our response where there was more than a simple change..

Title

Personally, I am also for short and concise, attractive titles (and I like yours), but maybe it would be good to add short information about your period of observation and study areas in the title? Up to you...

>> We decided to keep the title, to not make it too long. The study areas and observation period are in the abstract.

Abstract

Lns11f: "C was, in general, higher than 100% for catchments with a higher relative glacier cover" is it possible to give a number of the (average) relative glacier cover (XY% of the catchment glacierized over the observation period) needed to result in a C≥100%? Would be quite interesting...

>> We added that information from the conclusion to the abstract.

Lns17ff: I know that you have to summarize and make short statements in the abstract, but, in my opinion, the last two sentences of the abstract could be a bit clearer and more precise (how do glaciers not compensate straightforwardly? What are "the different streamflow contributions and their variations" you refer to here?)

>> changed into: Overall, our results suggest that glaciers do not compensate straightforwardly, and the range in compensation levels is large. The different streamflow components, glacier, snow and rain, and their variations are important for the buffering capacity and the compensating effect of glaciers in these high mountain water systems.

Introduction

Ln 31: "..., because of temperature-driven water supply." why not directly write what you refer to here? i.e. enhanced snow and ice melt due to high temperatures?...

>> Indeed, we refer here to enhanced snow and ice melt. However, we want to indicate the contrast here between precipitation-driven water supply and temperature-driven water supply. Regions that also have temperature-driven water supply can be less prone to meteorological droughts (lack of precipitation). For clarification, we added '…., instead of only precipitation-driven, water supply (L34).

Lns42f: "Hence, groundwater and snow storages might not always be a perfect buffer during warm and dry periods." Please be a bit clearer and more precise here, I guess what you want to say here is something like "Hence, groundwater only has a limited buffering capacity (in terms of runoff, provides only baseflow), while the buffering capacity of snow is higher (in terms of additional runoff) but temporally limited (if all snow has melted, there is no buffer anymore).

>> changed

Ln 55: “...from other streamflow contributions such as snowmelt.” maybe add some additional important streamflow contributing processes (in high mountain areas) here “...from other streamflow contributions such as snowmelt, surface runoff, interflow, groundwater flow or melting permafrost.”?!?!
>> changed into ‘such as snowmelt, rainfall-runoff and groundwater’

Lns 60ff: “During warm and dry years, glaciers can provide more meltwater to streamflow, and during cold and wet years they generate less meltwater so that altogether the interannual streamflow variability is relatively low.” do the studies you refer to here give a “lower threshold ratio of glacierization” for individual catchments (i.e. minimum percentage of glacier-covered area in a catchment) from which the dampening effect of glaciers on interannual streamflow variability applies? –would be interesting added value here...

>> The studies referred to here show that there is a convex relationship between streamflow variability and glacier cover, i.e., there is no lower threshold but rather an optimum. However, van Tiel et al. (2020a) discuss that such an optimum is not clearly distinguishable looking at observed data. To give a rough idea, we added here that the optimum is usually found between 10 and 40% relative glacier cover in different studies.

Lns66f: “...but also other climate and catchment characteristics appear to influence the streamflow sensitivity to climatic anomalies...” other climate and catchment characteristics like what? –can you give some examples mentioned in the studies you refer to here?
>> added

Ln 72: “...provided an additional source of water in the summer compared to the seasonally delayed contribution.” why “COMPARED TO the seasonally delayed contribution”? rephrase in order to be clearer...
>> changed into: in addition to

Lns80ff: “However, this contribution may reach a maximum, as the higher glacierized catchments are generally located at higher elevations that receive more orographic precipitation amounts...” can you please check that statement? In my opinion, it is not primarily the increased amounts of precipitation that causes a maximum value of relative catchment glacier cover in terms of increased streamflow contribution by glacier melt, but rather air temperature and climatic conditions in highly glacierized catchments, isn’t it?

>> We are not entirely sure what the reviewer means here. Higher glacierized catchments can be at higher elevations, but also the gauging station can be located closer to the glacier. In the latter case, the climatic conditions on the glacier do not change. Overall, these may affect the total glacier melt contributions, but less in a relative way. Anyway, we removed this part of the introduction to shorten it.

Ln 83: “...is generally assumed to be highest in August and September, ...” of course, this is only true for mountain glaciers in the northern hemisphere with a mass balance regime similar to the one in the Alps... I am sure you are aware of that but it might be good to be more precise here... (as your study is interesting to people from all over the world ;-))

>> indeed, but this paragraph is now removed from the introduction.

Lns99f: “...we analyzed observed hydrological responses to WD events for catchments with varying glacier cover in Norway, Canada, Switzerland and Austria.” I recommend to add some information about the observation periods / temporal time frame of your study here

>> we added the overall period. In the table in the supplementary material, the individual periods for each catchments can now be found.

Data and hydroclimatology of selected glacierized catchments
Lns 109f: “A few of these catchments are nested.” What does this exactly mean here? –Can you maybe briefly explain in key words in parentheses after the sentence?

>> We have added:
(meaning part of the meteorological conditions and streamflow responses are similar)

Ln 110: “...derived from gridded data products...” “...derived from gridded reanalysis data...”?
>> No, we used here gridded data that comes from the interpolation of meteorological observations – we added this information in parentheses

Ln 118: “...but the selection of events...” “...but the selection of WD events...”?
>> We changed into dry events because all types of events could only be selected until 2012 in western Canada.

Lns 122f: “Therefore, regional average mass balance time series were calculated from all available mass balance observations per year per country (Austria, Switzerland, Norway and Canada) by taking the median.” If I understood your approach right, then, as a glaciologist, I have some concerns here: 1) Taking just an average or median value from measured mass balance data of individual glaciers is not really correct, you need to calculate area-weighted average mass balance values (as for instance large valley glaciers have their ablation area at lower elevation (therefore more melt, therefore more negative mass balance) compared to smaller mountain glaciers having their terminus at higher elevation (therefore less melt, therefore less negative mass balance)) ;i.e. you have to multiply all mass balance data you take into account by glacier area, then calculate the sum of these values for all glaciers, and finally divide that sum by the summed up glacier areas 2) Even though for instance Switzerland and Austria are small countries, measured in-situ mass balance sometimes comes from glaciers with significantly different regional climatic conditions (the same must apply for Canada, for Norway your catchment sample lies in a more or less similar climatic zone I guess)... So my point here is that, in my opinion, it does not make sense to calculate average mass balance values “by country” for the catchments you analyze! For example, Schaefli et al. (2019, The role of glacier retreat for Swiss hydropower production, Renewable Energy) calculated area-weighted mass balance data for all glacier-covered catchments with hydropower plants using data by Fischer et al. (2015, Surface elevation and mass changes for all Swiss glaciers 1980-2010, The Cryosphere). I think you should find a way to reasonably derive catchment-wide mean annual mass balance data from existing measured mass balance data and extrapolation techniques(for the latter see for instance Huss (2012), Extrapolating glacier mass balance to the mountain-range scale: the European Alps 1900–2100,The Cryosphere); you might also work with Huss and Hock (2015, A new model for global glacier change and sea-level rise, Frontiers in Earth Science, there, past and future glacier mass balance data is available(per glacier!)from the Global Glacier Evolution Model (GloGEM)). Whatever data you use or method you apply to extrapolate (measured)mass balance data to glaciers of your analyzed catchments, do not forget that you have to calculate area-weighted values again if you have to work with “catchment-wide” mass balance data for your analyses. If you want you can also contact me personally (mauro.fischer@giub.unibe.ch) and I would be happy to discuss that with you and try to help you there.

>> The glacier mass balance analyses were removed from the analyses.

Ln 128: “...(GI4, 2015)...” I think you need to add the correct reference for the Austrian glacier inventory used here.

>> we added the correct reference

Ln 128: “...ranging in size from...” rather put the “in size” at the end of the sentence (after the numbers)

>> Ln 141? changed

Ln 174: I would delete the “(not shown)” here... but would it maybe make sense to add a table with catchment name, location, size, mean elevation, mean annual temperature, mean annual precipitation and resulting levels of compensation to the Supplementary Materials? – This would add some relevant detail for people interested in catchments you looked at..

>> We added a table in the supplementary material, showing the catchments and their characteristics.

Methods

Lns 202ff: “It was assumed that in these high elevation catchments there is an immediate response to the WD events (or the other dry events) and streamflow data of the dates exactly corresponding to the events were selected.” can you add some information on why (from a process understanding point of view) it is ok to work with that assumption? I argue that you’re right with this assumption but giving some rationale here would be good I think.

>> Because we work with 7-day smoothed values of P, T and Q, any delayed effect of P on Q is averaged out. Still, some effects may be there, but as we discuss in the discussion, the delay is difficult to assess and may vary from catchment to catchment and from event to event. We changed this part now into (L222-224):

Once the WD (or other dry events) periods were selected based on the P and T data, the corresponding streamflow data were analyzed. For the sake of simplicity, we selected the streamflow event to start and end on the same dates as the meteorologically dry events, aware that this assumption is only an approximation. Due to the use of 7-day smoothing for streamflow and precipitation, precipitation events before the dry events may only have a limited effect on the 7-day mean streamflow signal during the dry events.

Lns 227f: “...the importance of different event drivers.” as for example?

>> added examples: (e.g., antecedent streamflow conditions and winter precipitation)

Ln 231: “...at least 8 or more events...” what is your rationale behind this threshold?

>> To be honest, there is no clear rationale. If the threshold is much higher, then no relationships can be analyzed because there are few events. If lower, then n might be too low (is already relatively low/too low) for any statistical analyses.

Results

Lns240f: “...and different numbers of catchments per region.” I would also argue that they are not comparable due to different (hydro-)climatological settings of the individual catchments!?

>> yes, but this information cannot be extracted because of the differences in a number of catchments and length of the time series.

Lns 295f: “Different rainfall amounts...”; “...high rain amounts in summer...”; “...low rain amounts in summer...” I guess you refer to the climatological statistics here (how much rain

falls on average in one region in summer, cf. figure 2)... I would write that somehow in this sentence in order to be clear...
>> we added: Different average summer rainfall amounts

Lns 300f: “Also, the relative glacier covers of the Canadian and Alps catchments are more complementary than comparable in this sample of catchments.” I believe to see your point here, but doesn’t make this statement figure 7 and your rationale/descriptions here about the influence of the amount of average summer rainfall on the levels of compensation a bit obsolete?...
>> we agree and therefore decided to add it in the discussion instead of in the results section. We still want to show the analysis because it is often assumed that dry and wet summer catchments have different responses because of a different relative glacier melt importance. However, it becomes clear that relative glacier cover is important as well so that a 1:1 comparison between Canadian and European catchments cannot easily confirm this hypothesis on the event scale.

Lns 323f: “...when MB_{sum} is larger (more negative).” “...when $MB_{sum}$is more negative.” as I wrote above, try to avoid speaking of larger/higher and smaller/lower mass balance, this is always confusing (use “more negative” and “more positive”)...
>> Thank you for the suggestion. This is now removed from the manuscript.

Lns 328f: “Most significant trends were found in June (Canada) and September (European Alps), which were all negative. Norwegian catchments showed mostly positive trends, except in September.” ok, what does that mean? Can you maybe relate these correlations to observed glacier changes in the analyzed catchments? For Switzerland, see for instance M. Fischer et al. 2014 (The new Swiss glacier Inventory SGI2010, Arcitc, Antarctic and Alpine Research, section Study Region), for Austria, see for instance A. Fischer et al. 2015 (Tracing glacier changes in Austria from the Little Ice Age to the present using a lidar-based high-resolution glacier inventory in Austria, The Cryosphere), for Norway see for instance Winsvold et al. 2014 (Glacier area and length changes in Norway from repeat inventories, The Cryosphere), for western Canada see for instance Bolch et al. 2010 (Landsat-based inventory of glaciers in western Canada, 1985-2005, Remote sensing of Environment)..

>> The reasons for trends in C were already included in the discussion, but we extended it to discussing more explicitly the effect of glacier changes. See also comment before

Discussion
Ln 346: “...as in these rapidly changing systems...” “...as it concerns rapidly changing systems...”?
>> changed to: The latter might present some additional challenge because in these rapidly changing systems, the daily regime benchmark can change significantly over long periods

Ln 351: “...in the summer shoulder season...” “...in midsummer...”?
>> no, we mean not high summer (July and August) but the shoulder seasons, June and September

Lns 366f: “But Figure 4 shows that there are exceptions.” I guess you refer to catchments and C values in Canada here? –Thus, exceptions concern catchments in drier average summer climates (cf. Figure 2) with already low relative glacier cover? be more concrete/precise here...
>> no, we mean here that Figure 4 shows that all the WD events show quite a large spread in compensation levels. On average, if glacier cover reduces to ~5% there is no full compensation anymore. But still, in some events, it can still be the case (gray bars in figure 4). We changed the sentence:

However, there are exceptions, for some catchments in Canada with a low relative glacier cover and for some events in all of the low glacierized catchments because the ranges in compensation levels can be large (Figure \ref{fig:04}), i.e. some events in low glacierized catchments can still result in C levels above 100\% (L402-404)

Ln 372: "...also make it difficult to answer when glaciers compensate because it depends on the situation." a bit vague and not very clear to me, can you rephrase in order to be more precise here?
>> Changed into: These wide ranges hamper a clear conclusion on the question in which situation do glaciers compensate because it does not only depend on catchment characteristics but also on the specific situation in which the event takes place (L408)

Ln 376: Why do you refer to Figure 11 here? –Shouldn't you refer to figure 8?
>> We refer to Figure 11 here to explain the concept of different streamflow contributors. We now also refer to Figure 8.

Ln 384: "...became less clear..." "...is less clear..."?
>> Over the summer, the relation in their study became less clear. Became refers to a changing process here over the summer.

Ln 392: Can you shortly explain in parentheses what "carry-over storage" exactly means?
>> We added this in parentheses: (storage from the previous period that is released in the current period)
For example, if streamflow is high in July – it can still have an effect on streamflow in August because of water stored in a 'wetter' July, slowly releasing into August. Or high July streamflow may relate to extreme snow accumulation years, resulting in more streamflow in July and August (Moore et al., 2020)……

Ln 400: Why do you refer to Figure 11 here? –Shouldn't you refer to figure 8?
>> See other explanation

Lns418f: "Also, increasing high temperatures or more often occurring relatively extreme temperatures will not be sustained with higher melt contributions when glaciers retreat." this is only true for time periods after "peak water" of individual catchments, I am sure you know that, but maybe you could include that in some way in your statement here...
>> Yes, with not sustained we mean in the long run. We added: 'when glaciers have retreated considerably'.

Peak water, often referring to annual or summer streamflow or glacier runoff changes over time, if it exists so clearly, may not be directly transferable to responses to extremely warm and dry events. There may still be higher melt contributions during such extreme events, despite an overall post-peak streamflow trend. But we do know, in the long run, retreating glaciers will also reduce such event glacier melt contributions. But how to relate extreme events and the overall peak water concept is not yet clear, and therefore we would argue not to include peak water in this statement here.

Ln 421: "...400 mm higher." I am not sure how I can interpret this value, is it per m^2(for the entire catchment)? Add some information here...
>> 400 mm are for the catchment, yes. Per unit area of the catchment, streamflow was 400 mm higher when the glacier outline of 1979 was used. We added that this value refers to the catchment scale.

Ln 513: "...there is quite a risk of internal model compensation..." can you add some information here (maybe in parentheses)? What does that actually mean? What exactly do you refer to here?

>> We added: (e.g., lack of precipitation or snowmelt, due to input or model process uncertainties could be compensated for by extra glacier melt)

Figures

Figure 1: Maybe add scales to a), b), c). I would write “Norway” (in green), “European Alps” (in blue), and “Western Canada” (in pink) at the lower right of the figure 1d). Moreover, can you add a more detailed legend for the circle sizes which signify the relative glacier cover of a catchment (i.e. how much relative glacier cover do the different circle sizes in 1d) represent?). Moreover, would it possibly make sense to additionally draw areas with “similar hydroclimatological regimes” (cf. chapter 2.3) in Fig. 1? –Maybe this would add valuable graphical information...

>> We made a new version of the figure, including scales and adding the three regions in the lower right of figure 1d. We added an explanation about the circle sizes in the caption. We added the hydroclimatological regimes in the overview table of all catchments, see the new SI table.

Figure 2: Looking at figure 2 I cannot really understand why two different graphs for Norway, four different graphs for Canada, and three different graphs for the European Alps. Can you please add something on that in the figure caption? You explain it in chapter 2.3 but I think to add some information thereupon in key words would be good for the figure caption.

>> we added: *The precipitation distribution over the year of the different catchments were grouped into several precipitation regimes per region: two in southwestern Norway, four in western Canada and three in the European Alps.*

Figure 3: You have to add a bit of information in the figure caption there: Write what exactly the i) black line, ii) blue line, and iii) the red dots signify (I know it’s written in abbreviations at the bottom of the graph but it would be helpful to have that information (as text) in the figure caption as well). The same for the relative glacier cover (bold black number in the upper right corners), write it as text in the figure caption as well to be clear. Can you please also add somewhere in the manuscript (text or figures) based on what you chose to show the selected results for some selected catchments and selected individual years for the three regions (shown in Figure 3)? What was your rationale behind that? And maybe also which catchments (names, location) are shown?

>> Changed into: Examples of streamflow responses (Q_{r} in red) to WD events in different catchments and in different months. Each row represents one region and one specific year. The columns are different catchments, which are sorted from low to high relative glacier cover (left to right). The relative glacier cover of the catchments is indicated in the top-right corner. The black line shows the 7-day smoothed streamflow in the summer of the respective year and the blue line shows the long-term daily regime. Note the different y-axis for some of the plots.

Figure 4: Figure caption: Write “Mean catchment level of compensation...” as in the figure caption of Figure 6!?;“...
>> No, this would not fit here. In Figure 4 we show the mean catchment level of compensation (in colors), but also the ranges. In Figure 6 we only show the mean level of compensation for each catchment to all events.

Figure 8: Figure caption: “Explained variance of C...” “Explained variance in C...”; moreover, neither from the figure nor from the text it is evident how the thresholds to separate individual classes of relative glacier cover were chosen... can you add some information on that please?

>> We added in the methods section: The grouping was done based on the glacier cover distribution of the catchments and previous findings that around 10\% glacier cover streamflow sensitivities to precipitation and temperature variations change \cite{VanTiel2020}

Figure 9: Figure caption: Delete the “9” at the beginning of the figure caption; you would have to write out the used abbreviations for annual, winter and summer mass balance somewhere (I would argue better in the text than here in the figure caption, for MB_{win}you did it in the text);“Colours and symbols indicate the three regions (as in other figures).” why not be concrete and directly write colours of symbols together with corresponding regions here; can you explain the “r_s” (y-axes)? I would just add (r_s) in the figure caption in parentheses after “Spearman rank correlation”...

>> Figure is deleted from the revised manuscript

Figure 10:Figure caption: I would again write colours of symbols together with corresponding regions here; moreover, it is not really clear to me how time trends of C were related to time trends of relative glacier cover here (see general comments thereupon above...), I would need some more information in the figure caption to know how to exactly interpret this figure...

>> Changed into: Time trends of C for each catchment calculated as Spearman Rank Correlation Coefficients (r_s) between C and year of the WD event. Norwegian catchments are indicated in green, catchments in the European Alps in blue and Canadian catchments in pink. Circles indicate significant trends (a=0.05).

Tables

Table 2: Table caption: “...level of compensation. (C)” “...level of compensation (C).”; “Higher elevated glaciers:.” “Glaciers at higher elevation:...”; “Percentile of mean temperature in spring (MAM)” which percentile?; “Percentile of sum of precipitation in winter (DJF)” which percentile?; “The streamflow percentile of the 30 days before the WD event” which percentile?;

>> There is no which in this case. To compare the different catchments and the different months, we did not look at absolute streamflow amounts or winter precipitation amounts but instead looked at percentiles. For each of these variables, the variable for that year was expressed as a percentile compared to the rest of the time series. Percentiles are just used here as an anomaly that could be compared between different catchments.

“Higher MBsum...” I would delete that because “higher” means more positive and here you mean more negative (it is always easier to talk about “more negative” or “more positive” glacier mass balances in order to avoid misunderstandings when using “higher” or “lower” mass balances!), moreover you use the abbreviations MBsum and MBwin but don’t explain them (I can easily guess what it means but someone else not too familiar with glaciers might not at first glance); please see also my comments above about how you calculated “regional mass balances”, I think if you calculate catchment-wide mass balance or mass balance anomalies in a more appropriate/more correct way you can use these numbers much better for a more realistic interpretation of “C” with the help of mass balance data...
>> This part is removed from the table

Table 3: Table caption: “in brackets” “in parentheses”; Add full stop at the end of the table caption; “Years most events” “Years with most events”; in my opinion it would be good to add the actual observation periods (e.g.19XY-19XY) in parentheses after “Alps”, “Norway” and “Canada”!

>> We made the changes but do not add the bservation periods because they are different for each catchment.

Review #2

I found this study interesting and well-written. The findings are novel and the methodology is clear. My one concern is with the portion of the study dealing with glacier mass balance – which has already been brought up by in the review by Mauro Fischer, see my further general comment on this topic below.

The detailed review by Mauro Fischer caught most of the minor and technical comments that I would have included in my review. To save the authors time in responding to duplicate comments, I will not repeat them here. The few comments below are those I have tried to prune for overlap with Mauro's review. I enjoyed reading this study and, in my opinion, it is worthy of publication in HESS with some minor revision.

General Comments

Like the other reviewer, I have concerns about using the median of measured mass balance data. Using the area-weighted average, as has already been suggested, is a better option and has already been demonstrated in the response from the authors. I recognize the data limitations the authors are contending with, and I wonder if the mass balance analysis could just be removed from the study. I understand why the authors would like to include this type of analysis, but, in my opinion, it is a very minor part of the study and novelty and importance of the manuscript would not be hindered by removing this small piece. It would be a great avenue for future research. I will leave it up to the authors to decide whether a revised version of the mass balance analysis with the area-weighted averages should or should not be included in the revised manuscript.

>> yes, we removed this part from the study.

Specific Comments

Discussion:

Two sections in the discussion seem to overlap: '5.3 Drivers of Event-to-event variability in compensation levels', and '5.5 Temporal variability in event responses'. Both sections are discussing results presented section 4.4 (drivers of event-to-event variability). From the headings, it is not clear to me what the difference is between the two sections. I suggest combining the two sections into one.

>> 5.3 and 5.5 were merged and part of 5.5 was removed.

There are several places in the discussion where I found myself wanting a reference back to the relevant results. Below I've listed two locations. In my opinion, cohesion through the manuscript would be improved by adding a few figure, table, or section references to the discussion.

Line 381 – refer to the results supporting this stated finding.

Line 438-439 – refer to the results supporting the stated finding

>> Thank you for pointing that out, we included more references to relevant results in the discussion.

Other minor comments:

Figure 1 and Figure S1: Are there just two line thicknesses used in these figures? What gc values do these thicknesses correspond to? What is the break value?

>> No, the link thicknesses scale with the relative glacier cover. Since only a few catchments are highly glacierized, the differences between the lower glacierized catchments are minor. We added in the caption that line thickness corresponds to relative glacier cover – the thicker the line, the higher the relative glacier cover.

Figure 2 – Add a legend to clarify the relation between color and region.

>> We changed figure 1 instead of Figure 2?

Figure 8 – What are the glacier cover classes? Perhaps just list them in the caption.

>> They are in the topleft figure – this has been added to the caption

Table 3 – Heading should be 'Average duration of events [d]'?

>> Changed

Line 270: Missing comma in sentence starting with 'All variables,'

>> Changed

Line 393: 'and follow up studies Moyer et al. (2016)).' Seems like part of this sentence is missing

>> Changed