# Author Response to Reviews of

# Inter-model differences in 21st Century Glacier Runoff for the World's Major River Basins

Wimberly et al.
*The Cryosphere*

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**RC:** ***Reviewer Comment***, AR: *Author Response*, ☐ Manuscript text

The authors thank the reviewers and the editor for their constructive comments. We respond to each point of the reviews below.

Among the changes we will make to the revised manuscript, some of the most notable include:

- Clarifying the definition of "peak water" and specifying that it refers to aggregate, annual total runoff from initially glaciated areas in each major river basin.
- Updating the methodology to use an 11-year rolling mean for determining year of peak water, ensuring consistency with Huss and Hock (2018).
- Addressing discrepancies in peak water projections, such as for the Skagit basin, by discussing model initialization assumptions and aligning our findings with relevant observational studies.
- Adding further discussion on observed seasonal trends and including a mid-century seasonal shift subplot to Figure 5.
- Indicating basin regions by marker style in Figure 6.
- Furthering discussion of melt and parametrization throughout the entire manuscript.

## 1. Reviewer 1

### 1.1. Summary

**RC:** ***I appreciate the authors providing an article that triggered my curiosity and motivates a desire to know more, this is indicative of a useful contribution. The evaluation of three glacier models and a suite of GCMs provides a useful quantification of the variation and congruence of the resulting glacier runoff and peak water timing. The comments below are directed at encouraging the authors to provide further context that will clarify the results and increase the impact. Responding to the comments are an opportunity not a requirement for publication of this study. Defining the seasonal/annual time interval of peak water identification is crucial. Further exploration of the reasons behind model variations, including referencing other related studies for basin comparisons if practical.***

AR: *We appreciate all of your comments! We have tried to integrate your ideas to the furthest extent possible and are optimistic that these changes will help maximize the impact of the study.*

## 1.2. Specific comments

**RC:** ***18: For consistency in the referencing in this section and to focus on aspects that are not human-centric, it would be appropriate to add an older reference for altering ecosystems to Bossons et al (2023), maybe Jacobsen et al (2012) or Pittman et al (2020).***

AR: *Good point. The first recommended citation will be added in the revised version.*

**RC:** ***26: Though the relative importance of glacier runoff varies by basin (Immerzeel et al., 2020), glaciers are projected to provide critical drought buffering, especially in arid basins (Ultee et al., 2022), despite already surpassing "peak" water in many regions (Huss and Hock, 2018).***

***Peak water can be defined seasonally or annually, in terms of the glacier runoff component or overall discharge. Is peak water evaluated on an annual or seasonal basis and is it for glacier runoff or encompassing of the area of the watershed initially occupied by the glacier?***

AR: *"Peak water," in this manuscript, refers to the year with the largest aggregate, annual total runoff from the initially glacierized area in each major river basin.. We will revise the above sentence as such:*

> *"Though the relative importance of glacier runoff varies by basin (Immerzeel et al., 2020), glaciers are projected to provide critical drought buffering, especially in arid basins (Ultee et al., 2022), despite already surpassing the year of "peak" water in many regions (Huss and Hock, 2018)."*

**RC:** ***152: Explain the rationale for using a 20-year rolling mean to determine peak runoff timing? This is a long-time interval.***

AR: *A 20-year rolling mean was initially used due to a miscommunication between collaborators. Revised figures and results have been generated using an 11-yr rolling mean (to be consistent with Huss and Hock, 2018). Results are consistent with those presented using a 20-yr rolling window and will not require considerable revisions beyond the regeneration of figures 4 and A4 and corrections in the methods section.*

**RC:** ***182: An interesting distribution of highest relative runoff for regions for OGGM and GloGem, as there is not a shared climate or glacier type. Huss et al (2017: Fig. 3) and other have provided nice global maps of contributions of snow and ice melt vs effective precipitation revealing a wide range that illustrates a different picture based on specific hydrologic variables.***

AR: *Unfortunately, runoff components are not available for the entire period. We requested partitioned components for the historical period in order to generate fig. 6; however, it is not realistic to obtain the partitioned runoff datasets for the entire century. Given the already large scope of the study, we believe it makes sense to maintain the focus of the paper on "glacier runoff" rather than partitioned hydrological components. A complete exploration of the components would make for a really interesting follow-up study.*

**RC:** ***184: Moore et al (2020) utilized the glacier wastage contribution to runoff to distinguish glacier mass loss vs runoff from seasonal snow melt loss or precipitation. In looking at your results does this consideration explain any of the SSP variation? They observe that glacier-melt contributions have already passed peak water in the Columbia River headwaters. and there is a declining trend in realized streamflow.***

AR: *Yes, this is a good point. Differentiating between ice melt and snow melt/precip — in a follow-up study, for reasons explained above — would allow us to determine whether SSP dependency is due to large ice volumes or change in precipitation trends. We elaborate on this in the Discussion, L 281-287 of the original manuscript, and we will add discussion of Moore et al (2020) there:*

*Basins with later peak water tend to be more heavily glaciated (not shown) and/or in regions that receive more precipitation (e.g. Copper, Yukon, Indus). In those basins, increasing future warming may melt more ice later in the century as well as alter precipitation trends. Both phenomena would serve to push the peak water year later in the century with increasing radiative forcing, which produces the apparent sensitivity of peak water year to SSP scenario (Figure A4).* ***Although our study did not analyse runoff components due to data limitations, the partitioning of runoff into glacier wastage or "excess melt", equilibrium ice melt, seasonal snow melt, and precipitation could support additional insights into peak water year sensitivity to SSP scenario. For example, Rounce et al. (2020a) found that basins with large excess meltwater signals (e.g. Amu Darya, Indus, and Tarim) had a later-century peak water whose timing was sensitive to SSP scenario. Moore et al. (2020) found that for several smaller Canadian basins, glacier wastage had already passed its peak in 2019 and that observed streamflow was already below what would be expected if glaciers were in equilibrium. The latter study emphasises the need for glacio-hydrological modelling studies with evolving glacier cover.***

**RC:** ***185: It would be useful to provide a bit of a comparison for these five basins shown in Figure 2 and 3. % of basin with glaciers, mean annual precipitation range for glaciers, % of discharge during peak season provided by glaciers. Does not have to be these specific variables, but some that differentiate the basins.***

AR: *We have added annotations showing the continent and percent glacier cover for each basin in the figure and/or captions of Figure 2 and 3. Basins were selected to highlight the fact that different glacier models project more/less absolute annual runoff in different regions and display the variety of regions included in the study. We hope the annotations make this choice more transparent. Previous investigations revealed no consistent correlations between runoff projections and geographic or climatological characteristics.*

**RC:** ***192: The Yukon basin much different in terms of glacier size/type then Rhone or Glomaa. Another interesting geographic range in shared response that could be explored further.***

AR: *Agreed! Differences in long-term runoff response between polar/mid-latitude and maritime/continental/arid regions are very interesting, and explored further in Schuster et al., 2024 preprint [8].*

**RC:** ***Figure 4. This is an exceptionally valuable figure. The time frame/range of overlap is relatively narrow in most cases in Column b, not sure if it is worth trying to better illustrate this with a shading of some sort.***

AR: *Thank you! Upon discussion with the authors, we feel that, while shading would highlight the area of range overlap nicely in the small figure, our methodology means shading in this range could be misleading. The GCM range relies on glacier model medians while the glacier model range relies on GCM medians. Thus, these values are not independent and shading in the overlapping area would suggest a level of certainty within peak water year estimates that would be misleading. Let us know if we are misunderstanding the suggested figure revision.*

**RC:** ***212: Why is the GCM peak water timing range so large compared to SSP and GM?***

AR: *This is due to the fact that glacier models appear to project similar century-scale annual runoff trends (with respect to their historical runoff baseline). i.e.: the shape of annual runoff projections–looking past the vertical "baseline" offsets–are highly consistent. This contrasts single-GCM runs which exhibit a range of century-scale signal shapes.*

**RC:** ***222: Does seasonality increase as you go further south in the Andes. If so that is worth noting.***

AR: *Good question – it does not exactly. Based on Figure A2 and A3, and the Major River Basins map on the GRDC (link), we assess that the Serrano and Santa Cruz basins are farthest south. North of them are the Chico and Pascua (stronger seasonality, more inter-GCM spread), the Baker (weaker seasonality again), the Aisen (stronger) and the Cisnes (stronger). The relationship between seasonality and latitude seems non-monotonic here; it may reflect differences in the dominant drivers of seasonal cycle — monsoon versus westerlies versus ENSO, for example. We find this fascinating but beyond the scope of the current study, so we have not pursued it further here. We do address a difference between the tropical Andes and elsewhere:*

> *Many basins in the **midlatitudes of** North America, **South America,** and Europe tend to show **some months of increasing runoff and some decreasing, consistent with a change in shape of the seasonal peak** (e.g. Rhone, Figure 5). By contrast, basins in tropical South America have a weaker seasonal cycle overall, consistent with a tropical climate, and show relatively small changes in monthly runoff (e.g. Magdalena, Figure 5).*

**RC:** ***223: Is the range of increase from arid to maritime basins indicative of the precipitation trend?***

AR: *This is a very insightful thought. We did a preliminary analysis of the raw GCM precipitation trends, and we find it inconclusive. Figure below shows preliminary trends. The arid and maritime basins we identified with increasing seasonal peak do indeed all have increasing precipitation trend, as the reviewer suggested. However, other basins such as the Yellow River, Yangtze, and Uvs Nuur have an increasing precipitation trend but decreasing strength of glacier seasonal runoff. The magnitude of the seasonal increases and the precipitation increases are hard to compare across basins because we study them as percent change from a basin-specific baseline. This is another compelling analysis that would be made easier with the availability of partitioned runoff components. For now, we have not made changes to the manuscript in relation to this comment.*

**RC:** ***224: The increasing magnitude of peak runoff reported for the Skagit basin is not in agreement with other modelling or observations of glacier runoff. A peak water year of 2026 is noted, although peak flow has already occurred in this area according to (Riedel and Larabee, 2016; Pelto et al 2022) based on streamflow and glacier runoff observations in the region and modelling from (Bliss et al 2014; Moore et al 2020; Ultee et al 2023). Are the glaciers models utilized generating too much runoff from this region, or is this discrepancy the result of accounting for runoff from the same area, including former glaciated and currently glaciated areas as time progresses, and hence the models reflect increased precipitation/snowfall? If so it is worth providing a description of this using a specific use case. For maritime Alaska, the rising maximum peak runoff observation is supported by results from Young et al (2021).***

AR: *We appreciate the reviewer's detailed observations regarding the Skagit basin and the noted discrepancies with local studies (Riedel and Larabee, 2016; Pelto et al., 2022; Bliss et al., 2014; Moore et al., 2020; Ultee et al., 2023). The behavior observed in the results for this basin is likely caused by the model initialization and simulation starting conditions. All three models are initialized under the assumption of equilibrium, while the glaciers in this region are far from equilibrium. This discrepancy will produce a slight peak in runoff at the start of the simulation that may not align with observed peak water timing. We will expand our discussion of year of peak water projections to address this caveat:*

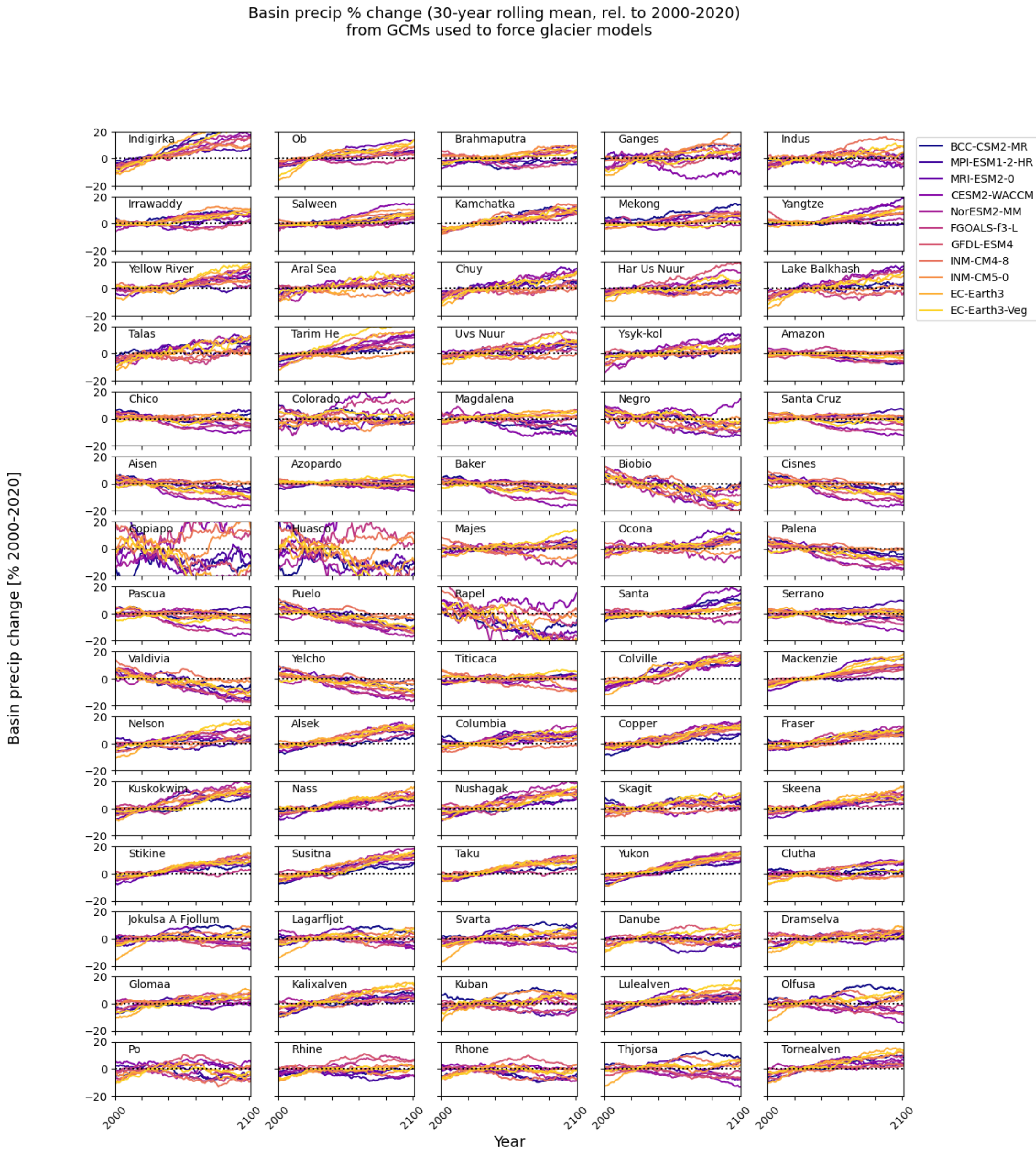
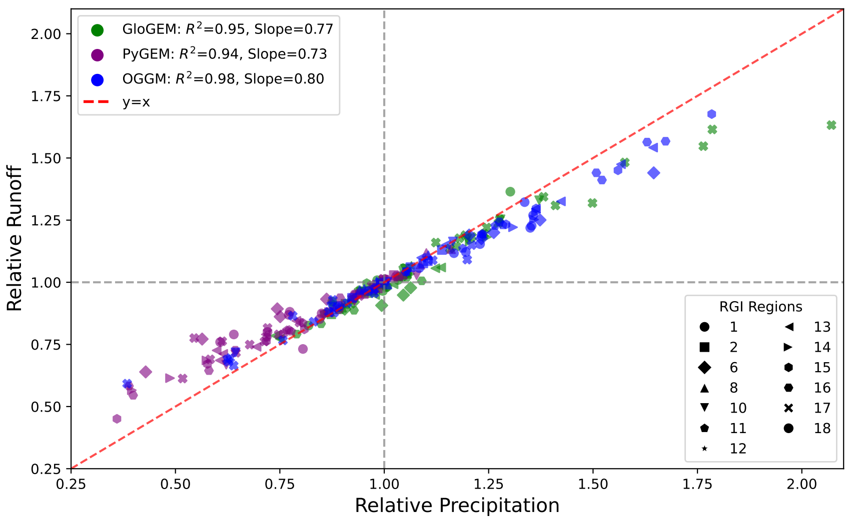



Figure R.1: Percent change in precipitation versus a 2000-2020 baseline for the GCMs used to force our glacier model ensemble. We understand that this plot may become publicly visible in the open discussion forum, but we hope viewers will understand it is preliminary and should not be used without further (ultimately peer reviewed) analysis.

> *...The SSP range of the year of peak water is generally larger than the glacier model range, but smaller than the GCM range.*
>
> ***Basins that have already passed observed peak water may nevertheless show an early-century year of peak water in the projections. This discrepancy arises because glacier models are initialized under the assumption of equilibrium, whereas many glaciers are far from equilibrium. As a result, runoff may exhibit an artificial peak at the beginning of the simulation that does not align with real-world observations. The Skagit River basin, which is well past peak water based on observations, highlights this limitation in our simulated peak water years (Riedel and Larabee, 2016; Pelto et al., 2022).***

**RC:** ***Figure 6: This figure illustrates the variation by model, would be useful to add to this figure a geographic domain using same color scheme but adding symbol variation.***

*AR:* *Thanks for this suggestion! This adds important information to the figure while maintaining its readability. We have incorporated this suggestion in a revised Figure 6 (see just below).*




**RC:** ***310: Reword –"are much more similar" to "significantly reduced offsets".***

*AR:* *Good catch. We will make this change.*

**RC:** ***320: Utilize a reference that has attempted to quantify this precipitation variability in GCM projections.***

*AR:* *We will add a citation to the IPCC AR6 WG1 Chapter 8: Water Cycle Changes [2]. See, for example, Figure 8.14, "Projected long-term relative changes in seasonal mean precipitation."*

**RC:** ***339: In terms of human intervention is probably worth noting key mechanisms, most importantly diversions for agriculture or hydropower and reservoir storage.***

*AR:* *Will revise sentence to:*

> *Glacier runoff may infiltrate to groundwater reservoirs (Somers et al., 2016; Mackay et al., 2020), sustain high altitude wetlands (López-Moreno et al., 2022), flow through proglacial lakes or streams, evaporate while transiting arid downstream regions (Wang et al., 2013), and encounter human management interventions* ***such as diverting runoff towards agricultural lands, hydroelectric plants, or storage reservoirs.***

**RC:** ***352: Given the quantitatively consistent earlier shift in runoff timing and lower magnitude of runoff, reported across glacier models. Comment further on the impact on drought buffering.***

*AR: Thank you for this prompt! We have analysed the impact on drought buffering directly in a technical note, which we submitted to HESS last week. We will add the following line and cite the preprint or eventual published note in HESS:*

> *Despite differences in annual runoff, changes in runoff seasonality are qualitatively consistent across glacier models, with most basins' seasonal runoff peaks moving earlier and having lower magnitude than their historical runoff peaks.* ***These robust seasonal shifts could be expected to impact drought risk in mountain areas, though changes in glacial drought buffering were not apparent in an analysis of the Standardized Precipitation-Evapotranspiration Index (Ultee et al., 2022; 2024 preprint).***

## 2. Reviewer 2

### 2.1. Summary

**RC:** ***This study compares the performance of three glacier models fed with GCM and reanalysis data to assess the future impact of glaciers on discharge variability in 75 major river basins globally. It assesses the timing of peak-water, future trends in seasonality and glacier contribution for different climate scenarios, climate model configurations and glacier models.***

***The authors followed a rigorous methodology, studied uncertainty in a convincing way and presented interesting results, unveiling large discrepancies in the results for peak water between different climate model configurations and climate scenarios, but also significant differences between different glacier models for certain catchments.***

***The authors put in good efforts to compare the intrinsic differences between different glacier models by comparing precipitation inputs for the 2000-2019 period, by normalizing model results with the reference period and comparing glacier models for 75 different catchments.***

***Ultimately, the article highlights the need for more mountain hydrological observations to better set-up and constrain glacier evolution models and glacio-hydrological models.***

*AR: Thank you for your suggested revisions! We are extremely grateful for your input and have integrated your ideas as best as we could.*

**RC:** ***L13: Sounds a bit vague. Which component contributes how much in uncertainty?***

*AR: We assume the reviewer refers to the statement:*

*Our findings highlight the comparative roles of glacier evolution model, global climate model forcing, and emissions scenario as important sources of uncertainty across different metrics of projected glacier runoff.*

*We have added the following sentence immediately afterwards:*

***For example, inter-glacier-model uncertainty in absolute annual runoff is large, but the year of projected peak water has much greater inter-climate-model uncertainty.***

*The key point is that different runoff metrics have different dominant sources of uncertainty (see Discussion).*

**RC:** ***L15 runoff. "We recommend steps to account for glacier model uncertainties in glacio-hydrological modelling efforts.» This could be formulated more explicitly.***

*AR:* *We will revise the sentence to:*

*We recommend* ***that users pay particular attention to how a selected glacier model parametrizes and calibrates the glacier climatic mass balance*** *in glacio-hydrological modelling efforts.*

**RC:** ***Figure 1: "... basin's average annual glacier runoff over the entire period" Why not show the percentage of runoff that comes from glacier melt? This would show how important glaciers are for each catchment. Absolute numbers may be less important.***

***The colors in this figure make it hard to distinguish between different catchments and their glacier runoff. A different, non-linear, color ramp could be appropriate (more distinct scaling for smaller numbers).***

*AR:* *The data to compute glacier percentage of total basin runoff is not available, or at least we have not found it in a few months of searching (we want to know this too!). We agree with the reviewer's suggestion in principle and can add that coloring to the online map if and when data becomes available. For now, we have revised the figure to color basins by year of peak water.*

**RC:** ***L147: How were the 12 forcing GCM realizations chosen among the 250 realizations in the CMIP6 ?***

*AR:* *See L129. GCM selection was a modeler decision and informed largely to be consistent with previous studies and glacier model runs.*

**RC:** ***L152: For calculating peak water, 20 years is a long time for a rolling mean, especially in the context where you consider the time scale of one century for the entire simulations. Could you elaborate on the choice of the 20-years' time interval for the rolling mean?***

*AR:* *We have revised figures and results with an 11-year rolling mean, consistent with Huss & Hock 2018. Results are consistent with those presented using a 20-yr rolling window and will not merit considerable revisions beyond the regeneration of figures 4 and A4 and corrections in the methods section. We thank both reviewers for noting this inconsistency with earlier work.*

**RC:** ***L155: GCM range of peak water: How did you decide on calculating the range like this? Could it have been calculated in a different way?***

AR: *The chosen method was deemed the most direct approach to quantify the general GCM variability across all three glacier models by all coauthors. We wanted the GCM range to be calculated using a similar methodology as the glacier model range, such that the two values could be compared. Given that the glacier model range was calculated using GCM medians, we took the median value of GCM ranges across glacier models in an attempt to maintain a level of symmetry. However, we remain open to considering alternative methodologies, particularly if they are demonstrated to be more rigorous or align with established precedents.*

**RC:** ***182: What do these regions have in common to result in such similar projections for one model?***

AR: *This is a good question without a consistent answer. There are many factors contributing to the patterns of runoff projections, and they may vary inconsistently across different climatic regions. That is, similar runoff projections do not necessarily reflect similar climatology (or latitude, or mean initial glacier area, etc.). On a global scale, we used k-means clustering and pairwise correlation analyses to investigate possible drivers for inter-glacier-model differences in runoff response, and the only meaningful sources of difference we found were those described in the manuscript: the model-modified precipitation and the initialized glacier volume. We will add the following to highlight that L182 is descriptive, not mechanistic:*

> *OGGM projects the largest amount of glacier runoff across the entire century for nearly all basins located within Alaska, Iceland, the European Alps, central Asia and the low latitudes. GloGEM projects the largest annual runoff totals for all basins located within North Asia, the Southern Andes, and New Zealand. PyGEM projects the most runoff in Scandinavia.* ***Analyses of climatological and geographical factors (e.g. historical aridity index, mean precipitation, central latitude, mean glacier altitude) did not reveal regionally consistent drivers of inter-glacier-model differences in runoff; we elaborate on two drivers of differences at global scale in the Discussion.***

**RC:** ***Figure 2: Very interesting figure. How did you select exactly these basins?***

***Maybe elaborate a bit more (in the text) why the models are so different for the Aral sea, and two of the models are very different for Serrano.***

AR: *Will revise figure caption to:*

> *... of projections, both in $km^3/yr^1$, computed following Sect. 2.2.* ***These basins were selected to sample the range of regions in which glacier models project more or less absolute annual runoff.***

*We tried to focus on characterizing runoff trends in this section; however, the reasons for these large inter-glacier-model differences are covered in the discussion.*

**RC:** ***198: A reduction in variability due to normalization is something that is to be expected...***

AR: *We agree. However, the relative reduction in inter-glacier-model variability versus inter-GCM variability under the same normalization is not necessarily expected. We have revised wording in this paragraph to emphasize this point.*

> *Normalizing runoff as a percent change relative to the model's historical mean dramatically reduces the range in glacier model projections (Figure 3). While the Yukon basin's glacier model range was comparable to its GCM range, the normalized glacier model range was one-seventh of the* ***normalized*** *GCM range.*

**RC:** ***Figure 4: This is a very instructive figure. Some of the GCM ranges of peak water are very large, and this is concerning when thinking about future scenarios.***

*AR: Agreed, thank you! We have tried to emphasize this point in the Discussion and Conclusions.*

**RC:** ***211: Explain better why you do the rolling mean analysis, and why you chose 20 years as a time span.***

*AR: See above comment regarding switching to an 11-yr rolling mean. Generally, the rolling mean analysis is performed to ensure that the selected year of peak water is a long-term runoff peak rather than a random, single year spike.*

**RC:** ***212: This means that determining peak water timing depends largely on the climate model that is chosen. Meaning that there is substantial uncertainty in those results - not due to the differences in glacier evolution models, but due to the GCMs. (just in the case of basins with little to no evolution of runoff over time. . . )***

*AR: Will revise sentence to address this:*

> *In such basins, the year of peak water is predominantly determined by any shorter timescale fluctuations that persist through the smoothing process of the rolling mean analysis. Thus, these peak water estimates are determined primarily by GCM variability and have a high degree of uncertainty.*

**RC:** ***Figure 5: Could these flows be put into relation with total (not just glacier) basin runoff? Both as a percentage and as absolute numbers... to illustrate how important glaciers are in each catchment – in the present, and in the future.***

*AR: We would very much like to do this, but we cannot find the data for total basin runoff (see also response re: Figure 1, above). Many of these basins are not gauged, and if they are it is not close to the glaciers (which also means limited "ground truth" for runoff simulations...). We have pointed out this data limitation in the Discussion.*

**RC:** ***229: It would be helpful to your argument to show seasonal runoff also for the period 2040-2060.***

*AR: We will add a row for mid-century (2040-2060) to the revised Figure 5.*

**RC:** ***248: "Glacier models have generally been calibrated to match per-glacier mass change observations...": This could be better explained.***

*AR: Will revise to:*

> *Glacier models have generally been calibrated using* ***single-glacier mass change observations from global datasets (Hugonnet et al., 2021), rather than local or regional-scale glacier runoff metrics. Runoff has been a variable of secondary interest to model development focused on glacier contributions to sea level (e.g. Hock et al., 2019; Marzeion et al., 2020); further, local and regional-scale runoff data is too limited to permit its use in global model calibration (van Tiel et al., 2020b).***

**RC:** ***257: Temperature variability and its impact on glacier melt could be discussed more, also related to large GCM variability. Significant differences in temperature for different GCM realizations or for different climate scenarios will naturally also lead to differences in partitioning between liquid and solid precipitation.***

AR: *Thank you, agreed. We have revised later in the discussion to address this:*

> *We emphasize that the results we present are a sample of 12 GCM realizations* ***per scenario****, selected from the more than 250 plausible realizations from the CMIP6 archive. Our results thus likely under-sample the true uncertainty arising from CMIP6 projections. All GCMs struggle to represent precipitation processes, particularly in areas of high relief typical of glaciated basins* ***(Douville et al., 2021). In addition, the spread in surface air temperature among GCM realizations, which we have not quantified here, will produce differences in melt and in how much precipitation falls as solid or liquid phase, and that will affect both magnitude and timing of glacier runoff.*** *As such, there is a high likelihood of systematic biases in the GCM forcing that cannot be quantified and that are not easily addressed with bias correction (e.g., if bias impacts longer timescale climate variability and change). Those interested in water availability for a specific basin should conduct a regional analysis to select an ensemble of GCMs that best represents precipitation* ***and temperature*** *trends and variability for that basin.*

**RC:** ***267: Here, it would be interesting to explain more about the influence of different melt parameterizations.***

AR: *We have added a sentence about the melt parametrization to each glacier model description in the Methods section. We have also revised L267 to emphasise it:*

> *This indicates that while increasing precipitation will increase runoff, runoff is also affected by the amount of melt occurring.* ***The melt in turn depends on additional*** *calibrated model parameters (degree day factors and temperature biases)* ***and the implementation of the melt parametrization (Schuster et al., 2023a; and see Methods above) as well as the air temperature forcing.***

**RC:** ***292: Which properties of GloGEM could be responsible for maintaining broader seasonal peaks, and which properties of OGGM lead to maintaining strong seasonal peaks?***

AR: *The model developers on our coauthor team interpret that a "spiky" peak could be indicative of a strong ice melt contribution, rather than relatively slow snow melt. However, without the hydrological component data discussed above, this interpretation remains speculative and cannot be supported in the manuscript. We have revised to give general guidance without stretching beyond our data:*

> *Seasonality of simulated runoff is controlled by the temperature downscaled to the glacier sites as well as by the partitioning between solid and liquid precipitation. Each glacier model uses different methods for those tasks, which we expect to produce some slight differences among their projections. ...* ***These slight differences in seasonality may reflect differences among the models in the underlying components of runoff (ice melt, snow melt, liquid precipitation) all of which have distinct seasonal curves; a detailed analysis of hydrological components could guide basin-level seasonal runoff projections.***

**RC:** ***335: The role of glacier melt could be discussed more in detail here and throughout the paper.***

AR: *Although we agree that it would be helpful to partition the role of glacier melt from other runoff components, data limitations prevented us from comparing it across all three glacier models in this study. Please also see response to Reviewer 1, above.*

*We have addressed glacier melt more generally in the revisions above, including:*

- *Section 2.1.: added a brief description of the glacier melt parametrization to each model*
- *L287: added discussion of Moore et al. 2020 and Rounce et al. 2020a "excess melt"*
- *L267: added reminder of melt parametrization*
- *L322: added note on temperature dependence of runoff*

**RC:** ***Figure A1: I cannot see the line indicating the year of peak water.***

*AR: Line was removed to simplify the already-busy plot. We will remove the second sentence from the caption which mentions the peak water year line.*

## References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