We sincerely thank Michael McCarthy and Lander Van Tricht for their encouraging feedback and the constructive comments! We very much appreciate the time the reviewers and editor have spent on the manuscript and will be happy to address the comments. Please find responses to specific points below in blue text.

Review by Michael McCarthy

General comments

This study presents an improved observational dataset of recent glacier change in the Ötztal andStubai mountain range and uses it with the large-scale glacier model OGGM to make projections of future glacier change in the region to the end of the century. OGGM is run in two different configurations: OGGM default and OGGM regional, where OGGM default uses globally available datasets for initialisation and calibration, and OGGM regional uses more accurate, local datasets in combination with an updated initialization and calibration workflow. The OGGM projections are compared with each other and with projections from other large- and local-scale glacier models. The observational dataset consists of homogenised multi-temporal glacier outlines and volume estimates.

OGGM regional projects faster glacier decline in the Ötztal and Stubai mountain range than other large-scale glacier models, and suggests around 2.7% of glacier volume will remain by 2100 if climate warming is limited to 1.5 C. Under higher warming levels, it suggests glacier decline will occur faster, and remaining glacier volumes will be smaller by 2100. The observational dataset points to extensive glacier decline in the region in the last two decades.

The study is very clearly presented, appears to have been carefully implemented, and, in my view, makes at least three valuable contributions to the field:

1) By using more and higher quality data for initialisation and calibration and developing an updated initialisation and calibration workflow in OGGM regional, it addresses one of the key challenges of large-scale glacier models, which is that they tend to be over-parameterised due to a lack of observational data (e.g., Rounce et al., 2020). As such, it provides a framework for better regional-scale glacier modelling in the future.

2) By presenting new projections of glacier change in the Ötztal and Stubai mountain range, it adds to the evidence base around future glacier change in this region. It provides new and useful information about the impacts of different warming levels on regional-scale glacier evolution.

3) Via the improved observational dataset, it provides a more detailed understanding of recent glacier change in the region.

I have no major comments but think some minor modifications, listed below, could improve what is already a very good manuscript.

Thank you!

Specific and technical comments

Title and elsewhere in text: I don't suggest you change it, but is only 2.7% of 2017 glacier volume remaining by 2100 under 1.5 C not already 'near complete' glacier loss?
Yes, 2.7% of the 2017 volume is "near complete" glacier loss in practical terms. We discussed how to present these numbers and settled on the current phrasing since we feel it best reflects the model output. While the glaciers will largely be gone by the end of the century even in the 1.5°C scenario, we feel that the "near complete glacier loss" phrasing allows for the possibility of small ice bodies in sheltered or otherwise topographically favoured locations to remain beyond the end of the century.

L45: Suggest remove 'between'.
Changed as suggested
L240 and throughout the text: Suggest 'evaluation' is preferable to 'validation', e.g., Oreskes et al (1994).
Changed throughout the text as suggested

L303: What happens to the remaining 18 glaciers?
The 18 glaciers for which OGGM Regional was unable to perform a successful model run were omitted from further analysis. The primary issue with these glaciers was that they were too small to create an elevation band flowline. We added the following sentence to the text for clarification: "The 18 glaciers that could not be successfully simulated, mainly due to their limited elevation range, are excluded from further analysis."

L311: I agree the model seems to reproduce the WGMS mass balance observations relatively well from 2000 onwards, over the calibration period. But it seems to produce more positive mass balances than the observations before 2000, which makes me wonder if it will produce too negative mass balances in the future. I think this offset should be mentioned explicitly in the text, for transparency. Do you have any idea what might be causing it? Could it be the observations themselves, or are potentially more data still required for calibration? It could also be helpful to provide some performance metrics for the period before 2000 in a second table in the Appendix.
Thank you for pointing this out. Before the year 2000, the model had no information about the past glacier state, resulting in many possible trajectories to reach the observed glacier state (e.g. Eis et al., 2019). This can be partly attributed to the diffusive nature of glacier dynamics. Therefore, the further we go back in time from the model's first 'observed' state (2000 for OGGM default and 2006 for OGGM Regional), the more we deviate from the actual past and instead follow one of many possible trajectories. Additional observations could help constrain the model trajectory to align more closely with actual historical events.

To be transparent about this limitation, we added the following sentences: 'However, the further back in time we look from 2000, the larger the discrepancies between the models and observations become. This is due to the diffusive nature of glacier dynamics, and in the absence of past observations, the model selects one possible trajectory among many possibilities (e.g. Eis et al., 2019).'

Section 3.3: My understanding is that all the results presented in this section are from OGGM

regional. If so, it would be helpful to say this, e.g., on L314, 'The aggregated OGGM regional outcomes …'.
Changed as suggested

L327: The point about mitigation measures might be better in the Discussion than the Results?
Yes, thank you. Moved to discussion and rephrased slightly.

L328: Does this increase in the number of individual glaciers account for fragmentation?
No, fragmentation is not incorporated in the analysis. We have added this information to the text to clarify.

L338: On the topic of 'the full range of possible outcomes', it would be interesting to see the sensitivity of future volume change to the mean annual precipitation of the difference scenarios. Is this the major control on inter-scenario variability within warming levels?
Even when using temperature levels for aggregation, we observe a significant spread in individual temperatures within the defined temperature levels. Figure 1 shows the mean annual temperature for melt (T_melt) and the mean annual solid precipitation (Prcp_solid) across all model runs plotted against total glacier volume. T_melt and Prcp_solid are defined such that the annual Mass Balance (MB) can be calculated as:

MB = Prcp_solid - T_melt * melt_factor.

The figure highlights a spread in both precipitation and temperature, demonstrating that the range of possible outcomes is driven by a combination of both variables. For instance, model runs that project a larger glacier volume in 2100 tend to have both a smaller T_melt and a larger Prcp_solid (as solid precipitation is also a function of temperature), and vice versa.

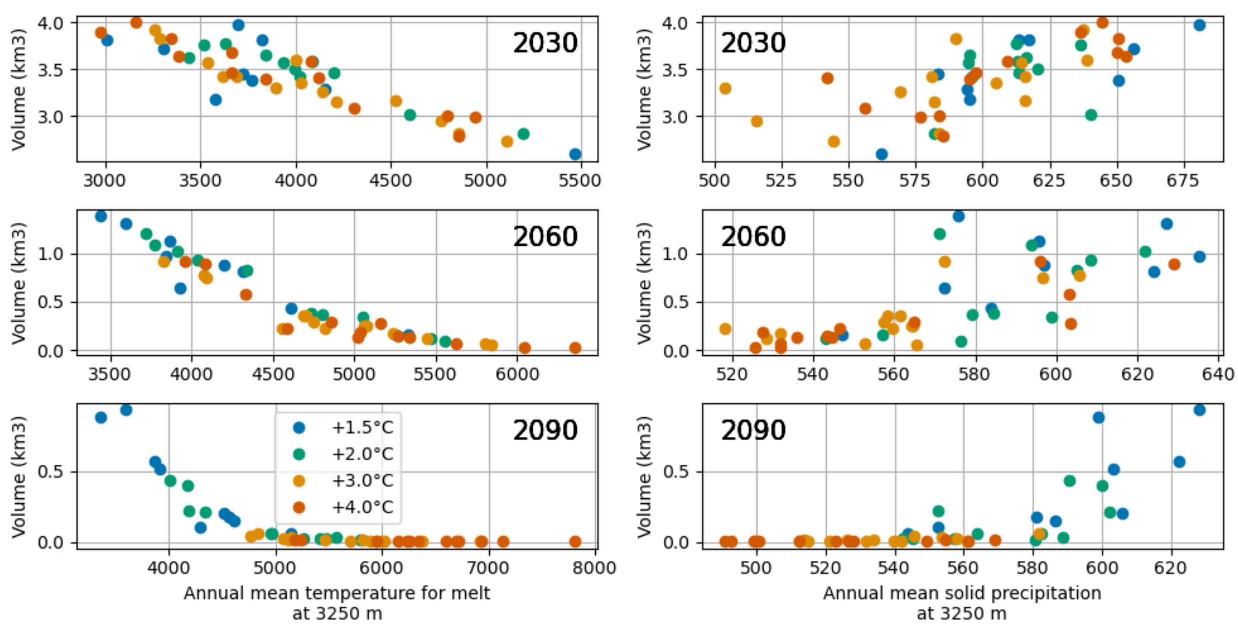

Figure 1: Left column shows annual mean temperature for melt and the right column annual mean solid precipitation on the x-axis, relative to the total volume on the y-axis, for individual model projections of OGGM regional. The individual models are colored, depending on their aggregated temperature level.

L426: 'This is primarily due to their initialization strategy' seems like an assertion? 'This may be due to …' might be a better formulation.
This is really due to their initialization strategy, as explained in the second part of the sentence. Their initialization strategy differs significantly from the other models, resulting in a larger volume in 2020. To improve clarity, we removed the term 'primarily' from the original text. See also answer to Reviewer#2.

Section 4.4.2: Earlier in the text, debris and avalanching are mentioned. These could be added explicitly here in relation to 'unresolved processes', as both are potential sources of error compensation and therefore calibration difficulties, and as both are starting to be considered in largescale glacier models (e.g., Compagno et al. 2022).
Yes, good point. We have added the following text:
"OGGM also does not explicitly account for the impacts of debris cover or avalanches on mass balance. These processes are increasingly being incorporated in glacier modeling at local and larger scales with promising results for improved representation of mass balance distribution (e.g., Compagno et al, 2022, Kneib et al, 2024)"

Figure S4 caption: 'see Table ??' needs to be updated.
Fixed.
Figure S10 caption: Suggest 'For future projections except 1.5 C'.
Changed as suggested, thanks.
Table S4 caption: Instead of 'supp. Figures S3 and S4' just 'Figures S3 and S4'.
Adjusted.

References

Rounce, D. R., Khurana, T., Short, M. B., Hock, R., Shean, D. E., & Brinkerhoff, D. J. (2020). Quantifying parameter uncertainty in a large-scale glacier evolution model using Bayesian inference: application to High Mountain Asia. Journal of Glaciology, 66(256), 175-187.

Oreskes, N., Shrader-Frechette, K., & Belitz, K. (1994). Verification, validation, and confirmation of numerical models in the earth sciences. Science, 263(5147), 641-646.

Compagno, L., Huss, M., Miles, E. S., McCarthy, M. J., Zekollari, H., Dehecq, A., ... & Farinoti, D.(2022). Modelling supraglacial debris-cover evolution from the single-glacier to the regional scale: an application to High Mountain Asia. The Cryosphere, 16(5), 1697-1718.