Review of
"Modelling the historical and future evolution of muliple ice masses in the western Tien Shan, Central Asia, using a 3D ice-flow model"

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In this manuscript, Van Tricht et al. use a 3D higher-order ice flow model to study 6 ice masses in the western part of Tien Shan in great detail. They used the 1820-1850 average climatic conditions to derive an initial state, representing the ice masses at the end of the LIA. The model was carefully calibrated based on a different set of available observations (e.g SMB measurements, moraines, ice thickness data) and various meteorological input data are used for the past. A validation based on geodetic mass balances shows a good agreement with independent observations. To provide projections over the 21th century, the model is forced with CMIP6 data (multi-model mean) considering 5 shared socioeconomic pathways and a no change scenario, representing nowadays conditions. All results show a clear reduction of ice masses, but with individual responses which are discussed in further detail.

The manuscript is of great interest of the community as it gives a good picture about the detailed modeling of those 6 ice masses, especially in their calibration based on a bunch of different sources. The validations showed in the paper, give confidence that the model performs well for the future as well.
The paper is well written and presented in a clear and well-structured way. However, I have the feeling that some parts of the manuscript deserve more consideration (rather equivalent to major revisions) in this study:

General Comments

- **'hot model' problem (selection of GCMs)**: A subset of the CMIP6 models are 'too hot' and simply taking an average of all available gcms leads to higher projections of warming than the IPCC's assessed-warming averages and consequently to an overestimation of glacier mass loss. Hausfather et al. (2022) suggested the following in order to avoid the overestimation: models with a TCR that lies outside the 'likely' (66% likelihood range) of 1.4-2.2 °C should be screened out. You should check out your GCM selection and consider a recalculation of multi-model means. Hint: The supplementary of Hausfather et al. (2022) contains a table with the TCR values for the different GCM's.

- **Uncertainty range of projections**: The flow model is only forced with a multi model mean. It is known that the spread over different GCMs is huge and thus not only the mean

value, but also some kind of error range (e.g. standard deviation) should be taken into account here as well. It would give more strength to the results.

- **better highlighting of the strength of the story** Especially the abstract and the introduction are at some points misleading and contradictory. On the one hand you are saying that conducting detailed studies to understand different processes is important (p.2, l.44). This is exactly the strength of your study and should be more highlighted than it is at the moment. But often you try to set the context to a regional importance. As your study is not saying anything about a regional pattern, you should try to avoid any kind of those statements and focus much more of the strength of studying those 6 ice masses in such detail. Comments about regional importance are only misleading the reader.

Specific and technical comments

Abstract

- p.1, l.8-10: An abstract should only concise a summary of the content of the paper. These three sentences explain more the context of the story behind and therefore belong more to the introduction than to the abstract. It raises false hopes to the reader as regional patterns are not part of the simulations nor being discussed in the paper.
- p.1, l.17: 'since the Little Ice Age' → 'since the end of the Little Ice Age' (or even better the exact time period (years) directly)

1 Introduction

- p.2, l.42: But none of the 6 ice masses is debris covered, why is this relevant for the study?
- p.2, l. 43-44: This is true, but it calls for a regional study simulating ALL glaciers in the region individually and not for a study picking only 6 glaciers out. I'm not sure if the sentence as it is, is really a good argumentation for the relevance of the study.
- p.2, l.53: 'today's ice masses are still reacting to past climate conditions' : Please, add a reference.

2 Location and climate

2.1 Selected ice masses

In general, I'm missing in this section explanations why those 6 ice masses were selected. Do those glaciers represent well other glaciers in the region? Are those the glaciers with most observations? What was the reason to pick exactly those glaciers ?

- p.3, l.71: 'annually': Please, add the information since when.
- p.3, l.94: '500 km to the west of the previous 4': Is there an explanation why you choose one glacier so far away from all the others?
- p.5, Fig.1:
  - add a legend for the altitude range of the underlying DEM in the upper panel.
  - black outlines: What is the source of the 2021 outlines?

- What is the date of the Sentinel-2 data?
- I would prefer lon/lat coordinates.
- the ticks and labels on the axes are quite small.
- Please, order the information in the caption by panels. You first explain the background data of the 6 small figures, than the outlines of the upper panel, than the outlines of the 6 figures and again some background information about the upper panel. A label number for the upper panel would be good as well.

2.3 Meteorological data

You have used many different sources for the temperature data series. This will require a bias correction to combine them. How was this done?

2.5 Future climate

- p.8, l. 181: There are CMIP6 historical runs starting in 1850, why did you not use this one (if available).
- p.9, l.188: 'are repeated until 2100': a random shuffling of the years 2001-2021 would be more realistic than just a repetition of the years.
- p.9, l.189: Does this refer to the 'no change' scenario only?
- p.9, l.191: 'by using an observed data sequence': Which one exactly?
- p.9, l.193-194: Please, take my general comment concerning the 'hot-models' into account. This might largely influence your mean value!
- p.10, Fig.2:
  - I'm confused a bit by the figure. You mentioned in the text, that you have downloaded the historical data for 1984-2014. The plot shows data between 1950 and 2021. Where does the data from 1950-1984 come from?
  - Please, rethink the choice of colors here. Unfortunately your color selection did not take colorblindness (e.g. red-green) into account. Perhaps you could use the same colors for the SSP as are used in the IPCC?

3.1 Higher-order ice dynamic flow model

- p.12, l.253: 'spaced more closely': Please, give an exact resolution here.

3.2 Surface mass balance model

- p.13, Tab.3: Please, use a consistent type of brackets. In previous figures and tables round brackets were use.

3.3 Calibration of flow parameters

- p.13, l.296-297: 'typical response time of 30-60 years': Please, add a reference here.
- p.14, l.303: enhancement factor (m): This looks like a unit and not like a parameter name.
- p.14, l.305: Please, also give the step size for the basal sliding parameter
- p.14, Tab 4: Please, use different kinds of brackets for parameter names and units.
- p.14, l.321-322: But this additional velocity observation was not taken into account? Why?

4.1 Ice geometry at the end of the LIA

- p.15, l.354: 'uniform mass balance bias': Does this mean that the same bias is applied for all years?
- p.15, l.354: '.. bias is searched': By which method and what is the step size used here?
- p.16, l.362: 'geometry of the LIA': The 1850 geometry would be better here.
- p.16, l.362-363: 'larger than present-day outline': I 'can't see the present-day outline in Fig. 3. So either add them or highlight them better (with a label and description in the caption).
- p.16, l. 370-371: I find it very critical that the neighboring glaciers are not modeled, if they were merged in the past. This will change ice dynamics and might have a huge impact on the ice flow as it changes the boundary conditions. When does the ice cap looses the connections?
- p.16, Fig.3:
  - It would be great to add the present-day outline in the plot, as well as the in flowline profiles.
  - I would prefer lon/lat coordinates.
  - the axes ticks and the labels are too small (in all plots, the ice thickness plots and in the flowline plots)
  - add year of the Sentinel-2 data

4.2 Ice evolution between 1850 and 2021

- p. 17, l. 384: How are the flowlines derived (in general and the 4 separated). Did you draw them manually or did you applied any kind of algorithm? You did not mentioned this before, but as you used a flowline model, this is crucial.

4.3 Comparison with observed ice thicknesses and surface velocities

- p.18, l. 411: 'with measured ice thickness': Which ones exactly? The ones you have used for the calibration? If so, this is not a validation. This would need a different kind of data that was not used for calibration.
- p.18, l. 414: 'areas with GPR measurements': Where are those regions? From where can I read this information? Is it possible to mark the areas in the profile plots?
- p.19, l. 421-424: To which date/years does this refer to?

5.1 Projected ice volume and area for 2022-2100

- p.21, Fig.7:
  - Please, use for the 'no change' line the same style and color as in Fig. 2
  - caption: 'Historical and future evolution': 2000-2021 isn't really historical, when you present in the same study results up to 1850
  - time range: The time range is again a bit confusing. Why are you starting here from 2000? You showed before the evolution from 1850-2021. Why not combining this to one time series? Here again one wonders, if the historical line stem from CMIP6 historical data or represents a part of the previous results.

5.2 Ice masses in 2100

- p. 24, Fig. 9:
  - The patch color for present day outline can only purely be distinguished from the ssp119 and ssp585 scenario.
  - I would prefer lon/lat coordinates.
  - The ticks and labels are too small

5.3 Runoff

- p.25, Fig. 10
  - It would be great, if you could mark the peaks of the individual ssp with a vertical colored line labeled by the year of the peak.
  - Why does the time series not start with the year 1850?
  - Why aren't all lines equal to 1 at t=2021?

6.1 Uncertainty and limitations

- p.26, l. 553: One could get a better impression about the uncertainty range here, if not only the multi-model-mean, but also an error range of the GCMs would have been calculated (e.g. based on standard deviation). I highly recommend to calculate those values as well.
- p.26, l. 558-569: There even exist a global study (across multiple glacier models) that gives more insights about uncertainty sources of glacier projections. You should definitely update this part based on findings from Marzeion et al. (2020)

6.2 Comparison with geodetic mass balances

- I rather see this section as part of section 4.3 (as validation with data not used for calibration). Please, consider to reorder.
- title: 'Comparison' → 'Validation'
- p.27, Tab. 6: A color marking of the cells would improve the readability of the table, because one could see at a first glance which values are low/high/close to zero

7 Conclusion

- p.28, l.600: 'present day' : Please, use the same spelling in the hole text. Previously you wrote 'present-day'.
- p.28, l. 600: 'present-day observations': To which ones you refer here, the geodetic mass balances? Please, clarify.

Additional comment

I would appreciate an additional section about the hardware requirements and the performance (running time). This would give the reader an impression about how easy/hard it will be to repeat those experiments for more glaciers/regions.

References

Z. Hausfather, K. Marvel, G. A. Schmidt, J. W. Nielsen-Gammon, and M. Zelinka. Climate simulations: Recognize the 'hot model' problem. *Nature*, 605:26–29, 2022. doi: 10.1038/d41586-022-01192-2.

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