Review of the article entitled:

"Physically-based modelling of glacier evolution under climate change in the tropical Andes"

In this study, the authors present a framework to *sequentially couple* the ice dynamical part of the Open Global Glacier Model (OGGM) with the full energy balance model for snow and ice from the Joint-UK Land Environment Simulator (JULES). The authors apply this sequential (offline) coupling to 500 glaciers in the tropical Andes and make projections of glacier mass loss until 2100 for different RCP scenarios. They conclude that under RCP4.5 17% of the ice mass will still remain by 2100 which is more than what other glacier modelling studies have predicted e.g., compared to 2% as predicted by GloGEM (Huss and Hock 2015) and Marzeion et al. 2012.

The authors present a very unique and clever workflow which consists of running both models separately; JULES is in charge of computing the annual specific mass balance over discrete points in the study domain. Thus, this model comes up with different relationships of surface mass balance as a function of height per year $SMB(z_i)_t$ for each glacier. OGGM then extracts the annual specific mass balance at a particular location, elevation and time. The ice dynamical flowline module of OGGM then inverts for the ice thickness via mass conservation and the Shallow Ice approximation (SIA). For the glacier evolution OGGM solves the continuity equation with the updated SMB distribution given by JULES.

The authors only calibrate parameters within JULES full energy balance model. Ice dynamical parameters in OGGM are not calibrated. JULES SMB calibration consists of several steps where JULES parameters are modified to achieve the best fit to geodetic mass balance data for a benchmark of 30 glaciers; then parameters are extrapolated to other glaciers within small subregions.

Overall, the manuscript is well written and the methods and discussion section has a clear narrative and description of model experiments. It is clear that the authors have put a lot of effort in model calibration and evaluation of SMB. However, some parts of manuscript lack order and could be re-arranged slightly to enhance the impact of the results and discussion section. There are certain aspects of the methods that require clarification and the discussion section neglects to highlight certain limitations of not updating changes in glacier geometry in JULES simulations. Also, the authors do not asses the implications of not calibrating ice dynamical parameters in their simulations.

I will definitely recommend the publication of the manuscript after the authors clarify some of my questions below and make some changes to the manuscript. I also recommend below how the authors could evaluate their framework limitations regarding ice dynamics.

Major comments:

- The JULES model is unaware of changes in the glacier hypsometry through time i.e., JULES is not aware of glacier retreat simulated by OGGM. Glacier retreat might affect the $SMB(z_i)_t$ relationships that JULES outputs; if at a specific height z_i and location that OGGM node becomes ice-free in a given year. Authors argue that changes in glacier hypsometry through time are accounted by lowering the ice surface and feeding into OGGM an SMB at a lower elevation. How this is decided between timespans and how authors deal with the transition between ice and ice-free areas is not clear. For example, given two points along the flowline, the $SMB(z_i)_t$ relationship might not hold if the second point (at a lower elevation) becomes an ice-free area. Given that ice free physics are qualitatively different than ice covered areas the interpolation might no longer hold. Limitations regarding this issue are not explained by the authors and this should be clarified in the explanation of step 2 in section 2.4.3. and the discussion part.

- The simulated glacier geometry that results from the interaction between mass balance and ice flow processes should be compared to ice thickness or volume observations. This is important as the initial glacier state can have a large impact on the simulated glacier evolution (Zekollari, et al. 2022). Authors do not validate the initial ice thickness distribution obtained with their JULES-OGGM framework before doing future simulations. They only evaluate the model by comparing simulated SMB to geodetic and in situ SMB observations.
  There might not be in situ glacier thickness measurements for these glaciers, however, the authors could check how their simulated initial ice volumes or ice thickness distributions compare to those from Millan et al (2022) at least for glacier wide volume estimates. Millan et al (2022) is a satellite derived ice thickness product and uses, like OGGM, mass conservation and the SIA, these are not in situ ice thickness observations but if compared to model initial model simulations could provide an idea of the calibration error for the ice dynamic part of the workflow. In other words, errors derived by not calibrating ice dynamical parameters in OGGM or by not updating glacier geometry changes in JULES. By looking at Millan et al (2022) Figure 3b seems to be data available for C Vilcanota glaciers. I encourage the authors to make such a comparison as this could strength the findings of the manuscript.

Minor changes:

Abstract:

L26-27: "We conclude that this inhibits the robustness of extrapolating the JULES parameters across multiple glaciers". I will remove this from the abstract because this is true for any glacier model, parameters describing specific aspects of each glacier can't be extrapolated to other glaciers. See calibrations sections from Marzeion et. al. (2012) and Zekollari, et al. (2022).

Authors should highlight the societal importance of their work in the Abstract and how important this region is for water availability.

Introduction

L44. Replace The is … with “That is especially true in…”

L49. “Sublimation” add citation and definition as this is the first time the authors mention the concept.

L49-50: “sublimation can account for the majority of energy consumed for ablation” change to “can reduce the energy available for melting” (clearer and in line with Winker et al. 2009).

Add at the end of the introduction the key takeaways from coupling these two models.

Methods

My main suggestion here is to change the outline in the following way:

2.1 Study Area. This section should be moved and integrated into the Introduction, here authors could make the point that a lot of people depend on these water resources (see Millan, et al. 2022 figure 3b) and given the little knowledge surrounding this area, the authors work is highly important.

Sections 2.2 – 2.3.
Should be a new section called: **2. Input data and pre-processing**. There authors should explain all the data input used in the model and the pre-processing stages needed to ingest the data into JULES-OGGM workflow.
E.g., The authors used their own Glacier inventory. The processing of these outlines and why they choose those instead of the Randolph Glacier Inventory could be specified in a subsection e.g., 2.1. Glacier outlines.

With this format authors could also expand into the analysis done to the climate input data.

2.3 Glacier Mass Balance data: Specify the advantages of Dussaillant et al (2019) vs Hugonnet, R and others (2021)? Most glacier modelling studies use Hugonnet, R and others (2021) to calibrate parameters in the glacier mass balance. E.g. Rounce et al. 2023.

2.4 JULES – OGGM glacier modelling workflow
Here I think authors could make a simple change to make the outline of the methods more organised:

3. Methods: glacier modelling workflow

3.1 JULES

3.2 OGGM

3.3 Sequential (offline) coupling of JULES-OGGM

This change will make it clear that the coupling is sequential and that both models are not fully coupled but one feeds input to the other.

L179. Replace “they” with Shanon et. al (2017).

L194. Replace “the flowline model” with “ice dynamical flowline model”

L194. Replace “: in effect,” with “– i.e.,” …

L199. Point the reader to the Figure 3a.

L202-203. Climate data pre-processing details could be moved to the input data and pre-processing section.

L252. Add citation for the Randolph Glacier Inventory (RGI). Move that part of the workflow to the Input data and pre-processing section (e.g., add a Glacier outlines section).

Here the authors should mention the implications of not using the RGI, which limits the comparison of JULES-OGGM results with previous model estimates that use the RGI. e.g., Li, F., et al. (2023) found that in High Mountain Asia projected mass loss differences between inventories are higher than between adjacent emission scenarios, illustrating the vital importance of high-quality inventories.

This might not be as relevant for the Andes but having an idea of how different they are in total area coverage per glaciers should justify why authors do not use the RGI when comparing JULES-OGGM results to GloGEM and Marzeion et al. 2012 in Appendix C1.

Authors should add a calculation of how different the Area coverage per glacier is between the RGI and their inventory of choice.

L257 When describing OGGM equilibrium assumption. Authors should specify the OGGM version used in their study. (e.g., v.1.4) as that assumption is not required by OGGM in the latest version (see model updates and documentation).

L268 "while the default parameters for the ice flow component of OGGM were used." Add the implications of this in the discussion and limitations, point to that section.

L271 "except for the temperature lapse rate" Add (See Appendix A).

L280. Add citation to the Monte Carlo framework used and add citations for other studies which have used the same strategy.

L294. "Used across environmental modelling applications". Add citations.

L298. Add safepython library citation, version used.

Results

L307-308. Fig 4a shows a perfect correlation, I wonder if multiple parameter combinations could achieve the same thing?

Model Evaluation

L347. The authors could enhance the discussion and provide an explanation from where the errors come from. This could be down to several limitations in their approach:

i) The JULES full energy balance model is not aware of changes in glaciers hypsometry through time. Thus, the SMB(z) relationships do not incorporate well ice dynamical feedback from OGGM. In other words, lowering the ice surface might not be a realistic representation of glacier retreat.

ii) the ice dynamical parameters in OGGM are not calibrated per glacier. Is it known that ice thickness (and ice volume) decreases as a function of the A factor; thus, perhaps the default parameter in OGGM might not be the right value for these glaciers? See Maussion et al. (2019).

iii) A comparison between the ice thickness obtained with JULES-OGGM vs Glacier thickness observations (or satellite derived thickness like Millan et al. 2022) should be made for a benchmark of glaciers to assess errors of using a default A and default sliding parameter (if sliding is also activated in OGGM).

L377-378. Authors could expand their conclusions and use these results to suggest better approaches to simulate albedo in JULES. And expand the very short conclusions.

Discussion

The authors should consider validating their initial glacier state (see Major comments).

L483-484. This is an important find and should be included in the abstract.

L486. "wght_alb". Give the full parameter name then refer to the abbreviation in (). Check this throughout the manuscript.

L490-493. Again, another good find that should be highlighted in the Abstract, Introduction and Conclusions.

Figures and Tables

Figure 1. It will be nice if in this Figure the authors could add the resolution of JULES grid.

Table 2. Add in the table caption each parameter name description and units.

Figure 4. Add error bars to scatter plots with confidence interval.

Figure 6. Add error bars to scatter plot with confidence interval.

Figure 8. Maybe it is more intuitive for the reader if the authors visualize % of Area change or % of Mass change (e.g., Rounce et al. 2023)

Figure 10. Is too small and very hard to read. I suggest perhaps dividing this in to two figures: Fig 10 for Mean elevation and Fig 11 for Energy Balance.

Appendix C. Specify what are the implications of comparing this study to GloGEM and MAR2012 if this study uses a different glacier inventory, thus a different initial glacier area. Add initial glacier area coverage by each study.

Appendix Figure E. Same problem as Figure 10.

Code availability

Specify the OGGM version used in this study and provide a zenodo doi for that version. See OGGM documentation on how to cite the model. https://docs.oggm.org/en/latest/citing-oggm.html

Provide versions and citations for any other python code or tools used.

References

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