Review of: Relative importance of the mechanisms triggering the Eurasian ice sheet deglaciation in the GRISLI2.0 ice sheetmodel by van Aalderen *et al*.

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van Aalderen et al present the results of a number of ice sheet model simulations with GRISLI2.0 for the Eurasian Ice Sheet Complex. Their main goal is to identify which primary factor, out of surface temperature, subshelf temperature and sea level rise, is most important for triggering the deglaciation ofthe Eurasian Ice Sheet Complex after the Last Glacial Maximum. Their main conclusion is that surface temperature warming is the dominant control on initiating deglaciation, and unlike previous experimentswith the GRISLI model, subshelf melting is not so important. They emphasize that this could be a model dependent conclusion.

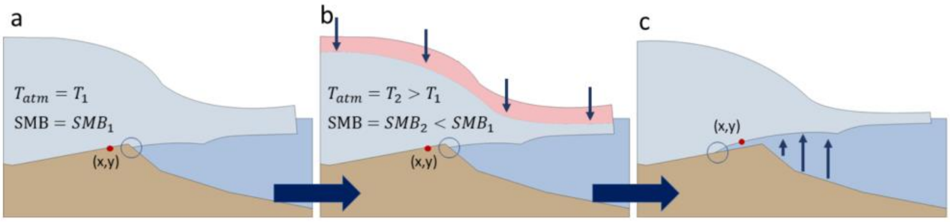
This paper has already gone through a cycle of reviews, where the main comments were that the results could be model dependent. I agree with this, and the authors have changed the text to reflect this possibility. In my opinion, this study does what I consider to be the ideal way to test ice sheet models. By changing the variables in a controlled way, they understand what causes the change of model behaviour. The conclusion of a surface temperature control is similar to an experiment we conducted using PISM (Niu *et al.*, 2019), though in that study our experiment design was different.

The authors are very grateful to Reviewer #3, Evan J. Gowan, for taking the time to review the manuscript and address useful comments. All the comments have been taken into consideration in the revised manuscript. Our responses are written in blue, and excerpts from the manuscript are italicized. Line numbers refer to the revised manuscript.

- We agree that the results of Niu et al (2019) highlight the major role of surface temperatures in the destabilisation of EIS. In order to highlight our similar conclusions, we have added the following sentences to the article:
  - Lines 326-329: *At the end of the 100 000-year spin-up simulations, a wide range of ice sheet geometries is obtained (Fig. 3). In the same way as Niu et al. (2019), we show that simulations performed with CNRM-CM5 and MRI-CGM3 do not succeed in maintaining ice cover over Eurasia as extended as in the reconstructions. In addition, we show that the simulation forced by MIROC-ES2L also fails to form an ice sheet.*
  - Line 704: *As in Niu et al. (2019), the results of our experiments suggest that the EIS ice sheet is very sensitive to the atmospheric warming that may have occurred at the beginning of the last deglaciation.*

In some ways, I ponder if the sensitivity to temperature is a product of the fact that it is uniformly changing the climate in a way that is probably not realistic, as the forcing does not react to the changes in ice sheet configuration. Thisissue is somewhat mooted by the fact that the authors are only looking at a short time window after inducing the change in forcing. However, the Eurasian Ice Sheets react dominantly to insolation forcing (at least during the last glacial cycle), so this conclusion is probably not wrong. Do note that there issome evidence of rapid marine ice sheet collapse in Norway (Batchelor *et al.*, 2023).

- This is a very interesting remark. We agree that several studies have mentioned the instability close to Norway (e.g., Gandy et al., 2021; Batchelor *et al.*, 2023). We also assume that these marine ice sheet instabilities can also be caused by a variation in the SMB. The figure below is a representation of the shift of the grounding line caused by surface melting. The blue circle represents the position of the grounding line. The figure on the left (a) shows an ice sheet in equilibrium with its environment, at atmospheric temperature T_1 and SMB_1 (surface mass balance), with a grounding line lying on an upward slope. In the middle figure (b), the atmospheric temperature has increased from T_1 to T_2, causing surface melting and therefore a reduction in ice thickness (in red). The figure on the right (c) shows the consequence of this surface melting. The decrease in ice thickness leads to a decrease in the ice mass above the point (x,y). Consequently, if the mass of the ice column above point (x,y) is no longer large enough compared with the buoyancy force, the ice will start to float. As a result, the grounding line initially located on an upward slope can move backwards and ends up on a retrograde slope. This hypothesis was confirmed in a study of the last deglaciation of EIS, not yet published.



Another possible weakness to the experiments here are that they do a 100,000 year spinup. In reality, the Eurasian Ice Sheet completely retreated during MIS 3 at about 55,000 years ago (Mangerud *et al.*,2023), and did not start advancing from mountain based ice caps until about 15,000 years before the LGM (Hughes *et al.*, 2016). The authors have mitigated this contradiction by doing an index run, whicheliminated one of the climate models from consideration. In the context of the experiments presented in this paper (building up an ice sheet complex similar to the LGM extent), the 100,000 year spinup isa good strategy. I would propose the authors consider a followup study to test a shorter 15,000 year spinup. I would be interested to see what it takes to build up the ice sheet complex in such a short period of time.

- This remark on the method used to construct the initial state is very interesting and raises one of the main limitations of modelling experiments. In order to run sensitivity experiments, we need an initial state that is in equilibrium with its environment, in order to avoid possible biases linked to other unknown factors. That's why we decided to build our initial states in equilibrium with the LGM climate. We are aware that this approach has its own limits. Moreover, Batchelor et al. (2019) show that EIS was far from in equilibrium with the DMG climate. This is why, in section 4.3, we have decided to carry out new sensitivity experiments using an initial state constructed using a transient method based a climatic index. However, this new approach also has a number of limitations linked to our poor knowledge of past climate changes at the global scale.
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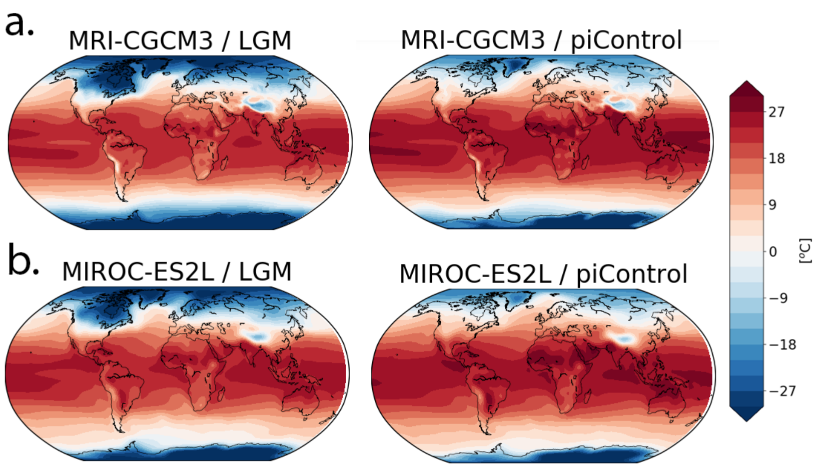
I have a few minor comments that the authors can address if they choose, but otherwise am happywith the paper as it is.

Minor comments

- Section 4.1 - That the CNRM-CM5 PMIP3 climate forcing failed to build up an ice sheet is nota surprise. When I investigated that forcing, it looks very much like they ran the LGM simulation without including the ice sheet topography (check the temperature anomaly in Antarctica versus the preindustrial, for instance). However, I am surprised about MRI-CGM3 and MIROC-ES2L. Is there any indication that they might have also forgot to include the ice sheet topography in thosesimulations? I personally have not checked these simulations.

    - Pre-industrial and LGM atmospheric temperatures obtained with the MRI-CGM3 (a) and MIROC-ES2L (b) models are shown in the figure below. It can be seen that at LGM, significantly colder atmospheric temperatures are simulated in the ice sheet regions. This result could be due to the presence of ice sheet in the boundary conditions, highlighting that the simulations were run with the LGM topography, unlike the CNRM simulation.

      As a result, we think that the absence of ice in the GRISLI2.0 simulations forced by MRI-CGM3 and MIROC-ES2Lis likely due to the higher atmospheric temperatures at LGM over FIS and BKIS compared to the other PMIP simulations.



- Section 4.3 - What is the index used for the climate index experiments?

    - Line 571: *The transition between these two climatic states is obtained by using a multi-proxy following the same method as Quiquet et al. (2013). For the period between -127 and -122, we used an index based on SST reconstructions (McManus et al., 1999 ; Oppo et al., 2006) and from -122 to -21 we chose an index based on North GRIP δ18O (North GRIP members, 2004)*

- EXP2 needs to be introduced better in the text.

    - Line 250: *We know from the Clausius-Clapeyron relationship that the water content in the atmosphere is directly related to atmospheric temperature. An increase in atmospheric temperature can therefore lead to an increase in precipitation. This is what is currently being observed in the eastern Antarctica (Frieler et al., 2015). As a result, the increase in precipitation in response to increased temperatures (Eq. 5) is considered* *in the second set of experiments (EXP2).*

- EXP5 - it should be noted that the local sea level change is a result of glacial isostatic adjustment.The local sea level is higher than the global average because of the combination of Earth deformation and gravitational attraction of water towards the ice sheets. Though the simplistic GIA model usedin the GRISLI model will not precisely calculate these changes compared the model we used in Gowan et al (2021), I would assume using a eustatic rise in sea level in combination with this is sufficient to simulate the impacts of sea level change. There is no harm in trying these experiments, though.

  - I guess that the reviewer is referring to the need of improving the modelling of sea level, which in GRISLI2.0 is only a climate forcing that does not represent local variations. In this context, the reviewer's comment is scientifically interesting and a technical improvement to the ice model could be considered. In order to observe whether a change in local sea level would have an impact on the sensitivity of EIS, the ice sheet model could be forced by the sea level inferred from the use of 2D maps in future studies, as proposed in Gowan et al (2021).

- Figure 11 - please include explanations of the different symbols in the caption

  - Done

- Figure 12 - please say what Kt is in the caption

  - Done

Best Regards, Evan J. Gowan

References

Batchelor, C.L., Christie, F.D.W., Ottesen, D., Montelli, A., Evans, J., Dowdeswell, E.K., Bjarnadóttir, L.R., Dowdeswell, J.A. 2023. Rapid, buoyancy-driven ice-sheet retreat of hundreds of metres per day. Nature **617**, 105–110. https://doi.org/10.1038/s41586-023-05876-1.

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