Review of Goelzer, Langebroek, Born, Hofer, Haubner, Petrini, Leguy, Lipscomb, and Thayer-Calder: "Interactive coupling of a Greenland ice sheet model in NorESM2." (GMD, Paper: egusphere-2024-3045*)*

The manuscript of Goelzer and others describes the coupling between the Norwegian Earth System Model (NorESM) and the Community Ice Sheet Model (CISM), where the latter represents the Greenland ice sheet. The focus of the paper is the implementation of the coupling, a short description of the initialization, and a brief analysis of performed simulations starting in 1850 and ending in the year 2300, focusing on the future warming scenario following an extended SSP5-8.5 scenario. They briefly show the influence of the ice sheet interaction on the climate and the ice sheet evolution. I'm particularly intrigued by the related paper in preparation (Haubner et al.) and look forward to a more in-depth analysis.

It was an absolute pleasure to read the well-structured and prepared manuscript. The figures are of good quality, necessary, and informative. This work is highly relevant given the number of groups working on the forefront topic of the interaction between Earth System models and dynamical ice sheet models. This work is also intriguing for the general ice sheet modeling community and those using ice sheet model projections to determine the future sea level.

I recommend the publication of the manuscript after minor corrections.

General comments

The manuscript is well-organized and written.

In the coupled model, the Greenland ice sheet has a limited impact on global climatic conditions if we ignore the contribution of a declining ice sheet to the sea level. Is it characteristic of the used model system, or would the authors generalize these results? If we turn towards the sea level response, do the authors detect different sea level responses between simulations where CESM interacts with NorESM and where it "only" receives the forcing from an uncoupled NorESM simulation – without providing feedback? The latter would be comparable with typical ISMIP standalone simulations.

I'm unsure about GMD's standards, but you may please check the consistent use of "e.g." versus "e.g.," as well as " … and …" versus "…, and …" in lists.

Specific comments

Main document

Page 3, Line 97 (P3, L97): Since you are using an unequal on a variable-thickness sigma coordinate system, I wanted to ask if you have limited the vertical resolution of the lowest layer to avoid numerical issues. Furthermore, what is the typical and minimum lowest layer thickness?

P3, L99: I'm confused about the conflicting information about a domain on a polar stereographic projection while the horizontal resolution shall be 4 km (e.g., P4, L21). Please clarify.

P4, L15: Does the SMB calculation allow for positive and negative sublimation?

P4, L33: What justifies the uniform lapse rate of -6 K km^{-1}? Please also check the provided unit "°K/km," which might contain a mixture of Degrees Celsius and Kelvin.

P4, L41–42: You write, "… for lower snowpack depth, the accumulated snow does not directly contribute to the SMB." What is meant by direct contribution, and what would be an indirect contribution?

Please clarify.

P4, L44–45: You mention "a horizontal bilinear interpolation and a linear vertical interpolation between" the models. It raises the question of whether the order of these interpolations influences the results. If so, how big is the difference?

P5, L47: In the model setup, masks are used "for the accumulation region, and one for the ablation region." It appears these are computed for each year. Are these masks changing within a year? Please clarify.

P5, L67: You "update the topography every five years" in your simulations. I understand that the commonly small changes justify these five years. Nevertheless, would it be better to tricker updating the topography once an orography change exceeds a given threshold, e.g., $|\Delta h(x,y)| > h_{\text{threshold}}$?

P5, L77–78: Do the authors mean "Solid ice fluxes are cumulated and passed to the ocean annually" as a mean flux?

P9, L59: What are the starting carbon dioxide emissions in the year 2300 when the emission starts to decline linearly? Therefore, the authors may write: "... reduced linearly starting from XX Gt year^{-1} in 2100 to … ."

P10, L80–81, L82, L84: You may help the reader to link the provided information in the text to the related subfigure. For instance, the authors may write:"… directly by NorESM2-EC (Fig. 4a, NorESM ...) compared ... (Fig. 4b, NorESM2-MAR, Fettweis et al., 2017). This … for the same period (Fig. 4C, ERA5-MAR),… ."

P13, Figure 7c: If I understand correctly, a changing ocean forcing is not implemented. Therefore, what drives the elevation reduction in northeast Greenland at the mouth of the 79-glacier (nioghalvfjerds)? Might it be related to the tuning of the ice sheet's basal conditions?

P14, L94–95: I'm with you that "Reconstructions of the climate and ice sheet states further back in time … would be very useful in this context." Is the work of Kjær et al. (2012) and Bjørk et al. (2012) relevant in this respect? Could the authors please provide information on what they would like to obtain from the community?

P14, L104: Is the result that "freshening due to ice sheet meltwater fluxes has little additional effect" on the AMOC a consequence of the analysis of Mikolajewicz and Maier-Reimer (1994)?

P16, L65: Please check the indent of citations.

Figure

Figure 1: What do the arrows represent? Please clarify. Also, the authors should consider skipping all arrows that are not active instead of having one disabled arrow, e.g., the strikethrough arrow.

Figure 2: In subfigure c), the color bar indicates that the value range does not exceed surface elevation differences of ±250 m. If not, please adjust the colorbar or mention it in the figure caption. Also, check this issue for the remaining figures, e.g., four (4) and seven (7).

Figure 4: Since the caption says that all "fields are masked to the modeled ice sheet area in NorESM2 at the end of the year 2014," it raises the question of whether the ice sheet has retreated in some areas. If so, please indicate lost ice.

Figure 5: What does the gray-shaded area mark? Please clarify it in the figure caption.

Figure 6: In the figure caption, please add the information that the air temperature and surface salinity

are global, e.g., "a) global 2-m air temperature" and " d) global sea surface salinity."

Bibliography

Bjørk, A. A., Kjær, K. H., Korsgaard, N. J., Khan, S. A., Kjeldsen, K. K., Andresen, C. S., Box, J. E., Larsen, N. K., & Funder, S. (2012). An aerial view of 80 years of climate-related glacier fluctuations in southeast Greenland. Nature Geoscience, 5, 427–432. https://doi.org/10.1038/ngeo1481

Kjær, K. H., Khan, S. A., Korsgaard, N. J., Wahr, J., Bamber, J. L., Hurkmans, R., van den Broeke, M., Timm, L. H., Kjeldsen, K. K., Bjork, A. A., Larsen, N. K., Jorgensen, L. T., Faerch-Jensen, A., & Willerslev, E. (2012). Aerial Photographs Reveal Late-20th-Century Dynamic Ice Loss in Northwestern Greenland. Science, 337(6094), 569–573. https://doi.org/10.1126/science.1220614

Mikolajewicz, U., & Maier-Reimer, E. (1994). Mixed boundary conditions in ocean general circulation models and their influence on the stability of the model's conveyor belt. Journal of Geophysical Research, 99(C11), 22633–22644. https://doi.org/10.1029/94JC01989