Review of "Antarctic climate response in Last-Interglacial simulations using the Community Earth System Model (CESM2)"

by Mira Berdahl, Gunter R. Leguy, William H. Lipscomb, Bette L. Otto-Bliesner, Esther C. Brady, Robert A. Tomas, Nathan M. Urban, Ian Miller, Harriet Morgan, and Eric J. Steig

The climate of the Last Interglacial was characterized by warmer temperature and higher sea level, in response to different orbital parameters. The sea level rise was likely partly due to a partial West Antarctic ice sheet melt, possibly due to Southern Ocean warming. The ocean warming could be related to an AMOC weakening induced by fresh water originating from Northern ice sheet melting. To better understand what could have caused an Antarctic ice sheet melt, Berdahl et al. analyse two CESM2 simulations run with 127ka orbital parameters, including one with fresh water fluxes. The simulations are compared to data with a focus on Antarctica to evaluate the possibility of favouring an Antarctic ice sheet melt.

Neither of the two simulations capture the full magnitude of the temperature increase at 127ka recorded in proxy data, but the 127ka simulation shows a small ocean temperature increase that could favour West Antarctic melt. The 127ka simulation with fresh water fluxes displays a local cooling around Antarctica despite general warming in the Southern Hemisphere, indicating that this is unlikely to explain the Antarctic ice sheet melt according to CESM2.

The paper is well written and well organized, and the two simulations are interesting. But this study is relatively limited. It would have been more comprehensive and useful to test the impacts of Antarctic changes such as local fresh water fluxes and a smaller ice sheet to evaluate the impact on climate and possible feedbacks.

General comments

Since the focus is the Antarctic climate and the possibility of the Antarctic ice sheet collapse it would have been interesting to test the impact of fresh water flux from Antarctic, whether this could trigger a positive feedback. There is a small discussion on it, this could be developed.

On the same topic, it would have been great to test the impact on climate of having a smaller Antarctic ice sheet and the possible feedback through ocean temperature and surface mass balance changes.

Finally, the fresh water flux addition results in large changes in disagreement with proxy data, but a smaller fresh water flux could improve the model-data comparison.

Would it be doable to do one (or several) additional simulations? How long does it take to run 1000 years? Additional simulations could be shorter than the ones presented here, even if the equilibrium is not reached it would still be interesting.

Three complementary simulations might be worth considering:

- With 127ka ice sheets / smaller West Antarctic ice sheet (this could have a regional impact)

- With fresh water fluxes in the Southern Ocean
- With less intense fresh water fluxes in the North Hemisphere

and possibly a combination of the three.

Since the number of figures is reasonable, and looking at the additional figures while reading the manuscript is not very comfortable, I would advise to switch some of the additional figures to the main text, especially those including Southern Ocean temperature (as this is the most relevant for possible Antarctic ice sheet melt) such as figures A2, A3 and A5.

Specific comments

Abstract

Could you include a sentence on the comparison with data and which simulation is best, or more likely?

Model description

Line 67 explain what is FV1? 1-degree model? It is mentioned as the 1-degree model but only much later (p.19).

How long are the simulations? What is the gain compared to the 1degree resolution version?

Results

Line123: "the orbital-only forcing underestimates" -> the orbital-only simulation underestimates

Line 125-126: can you give the temperature change in CESM 1degree to compare with? And also, you could compare to other models as described in Otto-Bliesner 2021.

Line134-135: are you showing this (AMOC change) somewhere? Or are you referring to another paper? Is the AMOC change the same in the two model versions?

Figure 3. What is the variable plotted in the background? Either specify the variable adding units and colorbar if it is useful to keep, or remove the background colors to only keep the different regions.

Section 3.2.2

The eddy component seems to play an important role. Can you elaborate on how eddies are represented and how this could change (or not) in a higher resolution model? In other model experiments with fresh water fluxes (apart from CESM, and in other than LIG period), has this cooling been observed before? Is this robust or model dependant?

Discussion

Line 307-312. The bipolar seesaw response is too large with the imposed fresh water flux. Could you discuss the possibility of having a better response with a smaller fresh water? It would be interesting to have a simulation with a smaller fresh water flux to evaluate the climate response.

Line 329- 333. It would have been great to have a simulation with a fresh water flux in the Southern Ocean to evaluate its impact.

Line 337- 342. You could discuss the implication in terms of transient evolution if this cooling and delayed warming is a robust feature: could it result in preventing the Antarctic ice sheet from melting too early when the Northern ice sheets are melting, and allow the Antarctic ice sheet to melt later?

Conclusions

Do you have ideas on what could be missing to obtain temperature changes in better agreement with proxy data?