

Interactive comment on “Warm Greenland during the last interglacial: the role of regional changes in sea ice cover” by Niklaus Merz et al.

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Merz et al. present an interesting study that for the first time quantifies the possibly important role of North Atlantic sea-ice changes, and there with the sea-ice sensitivity, in the last interglacial. This sea-ice sensitivity could to a large extent explain the model-data mismatch in terms of last interglacial Greenland temperatures, as well as explain large inter-model differences in simulated last interglacial climate changes at the high latitudes of the Northern Hemisphere. The methodology and analysis are well thought through and the manuscript well written. I suggest publishing this manuscript in climate of the past after minor revisions.

Main comments:

Main comment 1:

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The manuscript shows that differences in simulated North Atlantic SST and sea-ice cover patterns are important to explain reconstructed Greenland temperature anomalies as well as inter-model differences in terms of simulated last interglacial temperatures. It does not attempt to explain the origin of these SST and sea-ice cover differences, which would likely be a whole study on its own. However, in my view this topic cannot be fully ignored and should at least be introduced and its potential implications discussed. Questions that arise are for instance:

What are the causes of the large SST and sea ice differences between the two versions of CCSM3? Yeager et al. show that under pre-industrial boundary conditions there are important differences in the simulated northward oceanic heat transport between the low and high resolution versions of CCSM3. These findings could be shortly summarized here. Can it be deduced which model version is closer to observations in terms of the simulated pre-industrial North Atlantic ocean circulation?

Are the inter-model differences also visible in figure 4 of Lunt et al.? And is the cold bias described here for the low resolution version also the cause of the comparatively low CCSM3 temperatures (winter and annual mean) in the transient last interglacial results (see Bakker et al. 2013, 2014) for the Northern Hemisphere? If so, both could be pointed out in the manuscript.

One could think that a bias in the climate can be accounted for by looking at the anomaly of last interglacial temperatures with respect to a pre-industrial simulation. How does the bias impact the last interglacial climate? Is also the sensitivity of the overturning more sensitive to global warming, thus leading to cooling in the North Atlantic under last interglacial forcings?

Main comment 2:

The experiments successfully show the role of sea ice and SSTs in explaining the differences between two versions of the CCSM3 model, and provide a potential mechanism that can yield additional warming over Greenland. However, it does not give more

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warming over Europe, something that is mentioned a couple of times in the manuscript. Please come back to this point at the end of the manuscript. Questions that come to mind are for instance:

What does it imply that the model-data temperature mismatch over Europe is not improved when using a model with a more sensitive sea-ice cover? Is there another mechanism or feedback missing? Maybe even a mechanism that can explain both the warming over Greenland and Europe without the need for a larger sea-ice retreat? Please shortly discuss this in the manuscript.

Main comment 3:

An important difficulty of last interglacial climate research is the relatively small number of well resolved temperatures and, especially, sea-ice reconstructions. Does the Holocene thermal maximum possibly provide an analogue that can inform us about what happened during the last interglacial because of higher data availability and the existence of sea-ice reconstructions?

Minor comments:

General 1: It is a rather long manuscript, so perhaps the reader can be helped a little more to keep track of the aims and line of the manuscript by shortly repeating those aims and or by providing sort summaries at different points in the manuscript.

General 2: The potentially important role of sea-ice changes in the North Atlantic in the last interglacial climate have been suggested previously, in relation with observations from Greenland ice cores (Sime et al., 2013) and with large inter-model differences in simulated annual mean and winter temperatures (Bakker et al., 2013). It would be good to mention this in the introduction.

Line 7 page 1: 'thus', not everyone is familiar with this model-data mismatch, shortly introduce it in the abstract.

Line 12 page 1: 'accumulation', this is not mentioned before in the abstract and thus

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appears a little disconnected from the previously discussed issues.

Page 2: More work on the last interglacial and simulated temperatures over Greenland has been done previously, consider discussing that work, for instance by Loutre et al., Goelzer et al., Bakker et al. and Sanches-Goni et al. and Govin et al.

Line 19 page 1: As you are probably aware, the term Eemian is used to describe a pollen-based warm period in Europe, the regional continental equivalent of the general last interglacial period. Consider using last interglacial instead of Eemian throughout the manuscript.

Lines 3-6 page 2: These lines seem to suggest that proxies can resolve, annual, summer and winter temperature changes for the last interglacial. Please clarify.

Line 7 page 2: What 'Eemian proxies' is referred to here? From what region? Please provide references.

Line 31 page 2: Consider referring to Capron et al. and Govin et al.

Lines 29-33 page 2: What season is discussed here? Is it possible that the winters were warmer, but still the winters were not and neither was the accompanying sea-ice cover decreased?

Line 3 page 6: Why is a 2m thick sea-ice cover used? What are the potential implications of this assumption, please discuss.

Line 3 page 9: It would be helpful for the reader if the 125ka external forcings (GHG and orbital) and their impacts are shortly described (perhaps in the method section), in terms of their annual mean and also seasonal impact.

Line 13-14 page 9: Perhaps an order of magnitude difference can be given to illustrate the dominant role of the turbulent fluxes over the radiative fluxes.

Line 4 page 10: Perhaps at this point come back to the large inter-model spread suggested by previous work (Lunt et al., Otto-Bliesner et al., Nikolova et al. and others) to

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put the findings in a bigger picture as an introduction to the next section.

Line 21 page 11: So what are the SATs discussed before if not 'lowest terrain-following level'?

Line 13 page 12: Is the feedback by clouds also small over the Nordic Seas?

Line 3 page 13: Earlier on, when winter changes are discussed, mention that seasonality will be covered later.

Line 12 page 15: Are these SATs for Greenland averages over the whole of Greenland (and also in Figure 11E)?

Line 21-23 page 16: Consider repeating what EEM-PIdiff stands for to make this point more clear.

Line 15 page 17: Consider giving the ages covered by the NEEM core.

Line 17 page 17: Give distance between NEEM and pNEEM to give the reader an idea of the difference.

Lines 29-32 page 17: It is not clear how this connects to the topic of this manuscript, please clarify.

Line 7 page 18: Give range of temperature estimate. Is this number altitude corrected? This seems relevant with the discussion later on.

Line 15 page 18: Is this 3.1K because of elevation changes, circulation changes? Please shortly summarize. What about other work on this topic by for instance Stone et al., Langebroeck et al. and Fyke et al.?

Line 34 page 18: Be more specific about what 'climate change' means here.

Line 2 page 19: What about changes in the seasonality of precipitation?

Line 11 page 19: Is this for specific regions? Please clarify.

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Lines 24-26 page 19: Make clear that this combined experiment has in fact not been performed.

Figure 2: So does this indicate that the atmosphere is of little importance in determining the LIG climate response to the orbital forcing? What about the role of vegetation?

Figure 3: The patterns are very different for the high and low resolution model runs. Does this point to an important role of differences in ocean dynamics?

Figure 3: Why is there no EEM-PI-diff row in this figure?

Figure 3: Why are the patterns in SST so different from the SAT (Figure 4) patterns for, for instance, the Arctic region?

Figure 8d-e: There appears to be a dipole kind of structure over Greenland for HTdyn-core and HTpar. Why is that and how are they related to the large scale wind changes?

Technical comments:

Line 3 page 1: Perhaps 'Northern Hemisphere high latitudes'.

Line 11 page 1: Perhaps 'Nordic Seas sea ice retreat'.

Line 14 page 3: The line 'Thereby the authors...' seems a little redundant and could be removed.

Line 3 page 5: Remove 'it' and put comma after 'Sect. 4'.

Line 16 page 5: A new type of idealized.

Line 10 page 6: Consider replacing 'cutting through' with 'in'.

Line 22 page 7: Twice CCSM4, should one of them be CCSM3?

Line 17 page 11: HTdyn-core is not a very descriptive acronym. Consider using something else that makes it clearer that it deals with resolved heat transport.

Line 19 page 11: Giving the field names is perhaps not necessary.

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Line 19-20 page 11: Consider rewording to “Note also that all simulations are run into equilibrium, so the total temperature tendency (dT/dt) is almost zero.

Lines 13-12 page 17: words ‘which are mostly drilled on top of the Greenland ice sheet’, is not very relevant, consider removing.

Line 3 page 18: Refer to table 4.

Lines 12-14: Difficult to read, please reword.

Line 22 page 18: Should instead of shall.

Line 32 page 18: Remove ‘Thereby’.

Line 34 page 18 to line 2 page 19: Difficult to read, please rephrase.

Figure 1: Explain meaning of solid versus stippled green boxes.

Figure 2: Mention ones, here or in main text, how significance level is determined. Using yearly averaged time series?

Figure 6: Continents are either white or grey in the different panels.

Figure 7: Perhaps a personal preference, but I like better the colour scales that have white around the zero value (for instance figure 5).

Figure 10: Perhaps in panels b and d remove the vectors if they are not significant.

Figure 12: Indicate on a map (perhaps in figure 1) where the NEEM or pNEEM site is located.

Figure 12: Indicate significance of simulated temperature changes.

Table 1: Why are the other sensitivity tests not included?

Table 3: Perhaps a printing issue on my side, but the bold letters are very difficult to distinguish.

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Table 3 and 4: Using different regions for Greenland (whole island, central Greenland or pNEEM) is a little confusing and perhaps not necessary.

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