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Interactive comment on "Dependence of Eemian Greenland temperature reconstructions on the ice sheet topography" *by* N. Merz et al.

Anonymous Referee #2

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This manuscript by Merz et al. studies the climatic conditions in Greenland during the last interglacial period (the Eemian). The Eemian was a period with slightly higher global temperatures than present, and the GrIS was likely reduced, but to which extent is a subject of debate, as is its contribution to sea level. Orbital forced enhanced summertime solar radiation is the main driver of warmer conditions and resulted in a retreat of the GrIS, but feedbacks in this system are likely of large importance. Moreover, paleoclimatic reconstructions based on ice cores from Greenland give information on local climate conditions. However, these records are strongly affected by, for example, changes in local topography. Therefore, interpretation of these records can benefit from an improved understanding of feedbacks within the ice sheet – climate system. The manuscript describes a set of climate model simulations in which different topographies of the GrIS are used. In this way, the influence of a reduced GrIS topography on

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the interglacial climate is assessed. This work shows that the surface air temperature is strongly affected by changes in the local surface elevation, even when a first order correction using lapse rates is applied. Changes in the local energy balance are most important: in winter, the sensible heat flux is strongly increased due to changes in the slope, through the strength of the katabatic wind, while in summer the largest influence is exerted by changes in the albedo. This work is a valuable contribution in this subject. Nevertheless, I have three major issues that need more attention.

1.

My main point of concern is that, in my opinion, the followed approach results in an overestimation of Eemian surface air temperatures in Greenland. It is a misconception that Eemian optimum climate conditions coincide with the minimal ice sheet extent. During peak warming, ice sheet mass balance is minimal (strongly negative), and hence ice sheet retreating rate is large. The minimum ice sheet extent is a consequence of that, but occurs later, when changing climate conditions (cooling) lead to a positive mass balance, and thus a reversal from a retreating to an advancing ice sheet. The time between the maximum retreat rate an minimum extent is at least several millennia, assuming that summertime NH insolation is the dominant forcing for GrIS mass balance. The goal of this study is to reconstruct surface air temperature (SAT) during Eemian optimum conditions. However, four different ice sheet topographies are used that are reconstructions of minimum Eemian GrIS extent:

- EEMr1 minimum extent at 123.3 ky BP (Robinson et al., 2011)

- EEMr2 and EEMr3 minimum extent at 121.1 ky BP (Robinson et al., 2011)

- The timing of the EEMr4 minimum extent is not given in Born and Nisancioglu (2012), but as their result is obtained after a constant Eemian forcing over 6000 yr, this geometry has also most likely not been reached at 125 ky BP.

Hence, the topographies used in these sensitivity experiments are all underestimations of GrIS surface elevation during Eemian optimum conditions (125 ky BP). With this in mind, results on the influence of topography on SAT are still valuable as sensitivity experiments, but statements on absolute values of Eemian maximum SAT do not hold. Perhaps the results from experiment EEMr1 as the closest approximation to the GrIS configuration at time of maximum insolation, and as such Eemian optimum climate reconstructions can only be taken representative from experiment EEMr1.

2.

The comparison with the Greenland temperature reconstructions (section 6.3) also suffers from the above-mentioned issue, which needs revision. Apart from that, temperatures reconstructed from ice cores are essentially a measure for condensation temperature, due to the isotopic fractionation process occurring along the moisture pathway. Isotope records are nevertheless often corrected for that using lapse rate considerations, to translate the isotopic signal to a SAT record. This study shows that the modified GrIS geometry has an imprint on SAT (warming), due to a larger sensible heat flux from a strengthening of the katabatic wind. Although this is a very likely mechanism, this argument cannot be used to (partly) explain the isotope-derived temperature (+8K), as any warming of the surface as a result of an enhanced SHF induced by strengthening of the katabatic wind would not show up in an isotope-derived SAT record. Hence, the disagreement between SAT from this study and the NEEM SAT remains even larger, and as such this section needs to be revised.

3.

Greenland ice sheet surface air temperature changes are for a major part determined by the local surface energy balance, as also shown in this study. Therefore, it is of large importance that the climate model is able to realistically describe this surface energy balance over the GrIS. Not much information is given on the performance of the coupled atmosphere – land model scheme, merely references to Neale et al (2013), Evans et al (2013), and Merz et al (2013) where I did not find information on the performance of the surface energy balance scheme over ice sheets.

How reliable are the results obtained over GrIS?

How well does the present-day run represent the observed SAT distribution over Greenland?

As the katabatic wind is an important driver of the sensible heat flux, how well does this model represent the katabatic wind pattern, considering the limited resolution (100x50km)?

Have there been comparisons carried out with present-day measurements of the energy balance components?

As the summertime net solar radiation is a large component of the surface energy balance, the albedo parameterization strongly influences the results. More info on the albedo scheme is needed, e.g. aging effects; does the albedo depend on grain size/snow density/water content? The albedo values in Figure 9f (maximum 0.68) seem far too low for a realistic snow surface (albedo of 0.8-0.9).

What is the design of the snow scheme in CLM4? Multiple layers? Is there a transition from snow to ice? What happens with melt water? Does it run-off immediately of can it refreeze in the firn?

I suggest adding a section on this subject, for example in section 2 and section 5, add information on surface heat fluxes in the PI simulation (before dealing with the EEMpd run).

Other comments

Abstract: Not clear what kind of climate model simulations are used to arrive at these conclusions

Introduction P 6686, L9: The term “GrIS sensitivity” is poorly defined. Is it the sensitivity of the climate to a change in the topography of the Greenland ice sheet? Suggestion:

use “sensitivity to GrIS topography”?

Section 2.3 It would be interesting to compare these results (EEMpd) with the findings of Van de Berg et al 2011 (Nature Geosc.).

The large variability in temperature (Fig. 1) is noteworthy; perhaps this can be put in perspective to Eemian proxy temperatures (CAPE Last Interglacial Project Members, 2006, Quat. Sci. Rev. 25, 1383-1400).

Section 4.1 P6697,L2-4: A forcing due to a horizontal gradient in temperature deficit is a thermal wind forcing: make a distinction between the katabatic forcing and the thermal wind.

Section 5 To me it seems strange to average 3x3 grid points, especially when these include glaciated and non-glaciated points. Why not only show the nearest grid point?

Section 6.2 P6709, L20-21: Figure 9f does not clearly show a decreased albedo for EEMr2 for pNEEM.

Section 6.3 P6712, L4-7: This statement is not really supported. It seems not likely that surface wind have a great impact on moisture source pathways. Moreover, this should also

Generally, the abbreviation for sensible heat flux is SHF, instead of SHFLX (and likewise for LHF).

Interactive comment on Clim. Past Discuss., 9, 6683, 2013.