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Climate of the Past
Discussions

Interactive comment on "Greenland climate simulations show high Eemian surface melt" *by* Andreas Plach et al.

Anonymous Referee #1

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The paper by Plach et al. addresses two topics of interest. First, it simulates the frequency of surface melt over Greenland during the Eemian from ∼130ka to 115ka. The authors use the surface mass balance output from the Norwegian Earth System Model with time slices at 125 and 115ka in combination with the Modele Atmospherique to attain regional climates over Greenland. To test the viability of their approach, the models were validated by comparing them to preindustrial conditions. The authors conclude from the preindustrial comparison that their model is likely conservative in estimating the percentage of melt. They find that at 125ka the percentage of melt could exceed 25% of the annual accumulation at GRIP and up to 90% in less central locations such as Dye-3. These are impressive results and could be important for understanding seasonality effects on surface melt and on ice sheet mass balance.

Secondly Plach et al. addresses how surface melt can affect ice core records, particularly TAC. The authors point out that the interpretation of TAC as a unique proxy for elevation is complicated by the influence of surface melt during warm periods especially the Eemian where these layers cannot be visually identified due to thinning. Melt layers are generally bubble free with the amount of air in the melt layer being primarily dictated by Henry's law. The result is that melt layers have significantly lower TAC. Plach et al. use the results of their melt simulations to calculate theoretical Eemian TAC values which they call TACred and then compare these values to published data. The results of the model derived TAC is consistently lower than the measured data at 125ka but similar at 115ka and the preindustrial.

General comments, suggestions and edits

Both the extent of melt over Greenland, and how melt can affect TAC during warm periods are important topics and of value to the paleoclimate community. The approach of the authors to account for melt in TAC is novel and could help explain some of the anonymously low TAC values we see during the Eemian in some ice core records. I find that the subject matter fits well within the scope of Climate of the Past. However, the paper could use substantial revision, as noted below.

First, I wonder if it would be better to split this into two papers, one on the Greenland surface melt simulations and a second on the potential effects of melt on TAC records and their interpretation. This would enable a more detailed analysis of the surface melt simulations and the interpretation of them, as well as a more robust comparison between the derived or simulated TAC and the measured data. On both the melt simulation results and the derived TAC, I would like to see a more robust interpretation of the results. Assuming the authors choose to keep this as a single paper the following are my suggestion.

Major Suggestions: Title: The title makes no mention of total air content but yet this is a major component of the paper. I suggest changing the title to include total air content.

Abstract: In contrast to the title the abstract is excessively focused on the TAC results. I suggest adding a few sentences about the melt simulations.

Ln 101-120: Calculation of the model-derived total air content (TAC) The derived TAC does not account for insolation. As mentioned earlier in the paper (Eicher et al. 2016) show that TAC at high accumulation sites such as in Greenland have a similar imprint from insolation as in Antarctic records. The implication is that the comparison shown in figure 6 is between TAC records with the effects of insolation and derived values without the effect of insolation. This will bias the results. While this discrepancy is included in the Discussion section, it would be preferable here. Note that (Eicher et al. 2016) provides an insolation sensitivity (5.7 *10-9 mL kg-1 J-1) for the integrated insolation threshold over 390Wm-2. This should provide the framework to approximate how much insolation affects the analysis in this paper.

Ln 164-170: Results: Total air content (TAC) and Figure 7 In addition to comparing the derived results with data, it would be useful to compare the derived results with and without TACred included. This would help determine the magnitude of the effect on TAC. While the derived TAC may be lower than the measured TAC for a number of reasons including insolation effects and elevation uncertainty, the difference between derived TAC and TACred may still be fairly accurate and informative.

Ln 95-96: and Figures 6 and 7 It is not clear to me why only the lowest 10% of TAC values (20% for GRIP) were used to determine the Eemian measured values for comparison to the derived values at the 125ka time slice. For the derived TAC the melt effect should be applicable to all TAC samples not just the ones with the lowest TAC values. This may just be a misunderstanding on my part but regardless some clarification would be helpful.

Also note that in addition to the TAC values for GRIP there is also TAC data for GISP2 in the Eemian. See (Yau, Bender, Robinson, & Brook, 2016).

Minor suggestions: Ln 20 – The integrity of the ice core record is not the issue as much

as our ability to interpret the records of CH4, N20 and TAC when they are affected by melt layers. Questioning the integrity of the ice core record makes me think something happened during analysis or storage of the ice core.

Ln 24 . . .only direct proxy for past surface elevation of the interior of an ice sheet.

Ln 25-26 It should also be mentioned that TAC responds on millennial time scales as noted by (Eicher et al., 2016). Their hypothesis is that these affects were due to rapid changes in accumulation. As this is unlikely to occur in the Eemian this can probably be ignored for the rest of the analysis but should still be mentioned here.

Ln 30 . . . TAC is the only direct method . . .

Ln 33 . . . NEEM-derived surface temperature anomaly relative to the last 1000 years . . .

Ln 115 -117 What assumptions are being made in using Henry's law to calculate air in melt water i.e. is the meltwater saturated with O2 and N2 when it is refrozen and are any bubbles incorporated into the meltwater? I think the assumption of using Henry's law works but the assumptions should be noted.

Ln 153 -Ln162 Melting and Refreezing and Tbl 1 Add accumulation to table 1. This will be useful when discussing refreeze relative to accumulation rates in the later section Ln 153-162. Alternatively plot the model accumulation rates.

Ln 204-206- This sentence is not clear to me. What part of the simulation would fit better?

Ln 257-258 – It is worth noting that if the lower TAC values in GRIP and NGRIP are related to surface melt rather than elevation, then CH4 over this period should be elevated with NGRIP being higher than GRIP and GISP2 due to the greater melt percent.

Readability:

There are sections of the paper that could use a revision for readability. The following are a few examples:

Ln 6 can not -> cannot

Ln 20 . . . the presence of surface melt during ice formation can be a problem-> the presence of surface melt can be a problem

Ln 25: However, TAC was also found to have an insolation signal-> However, TAC is also affected by insolation at both Greenland and Antarctic sites (Eicher et al., 2016; Raynaud et al., 2007)

Ln 36 – unclear antecedent- Despite these concerns

Ln 62 moderate -> moderately

Ln 62? smaller Eemian ice sheet equivalent to ∼0.5 m of sea level rise.-> smaller Eemian ice sheet with the difference equivalent to ∼0.5 m of sea level rise

Ln 260 have an ensemble of climate to explore-> have an ensemble of climate models to explore

Final thoughts: I found this paper thought provoking. While I think there is work left to do, I look forward to seeing the next iteration.

Yau, A. M., Bender, M. L., Robinson, A., & Brook, E. J. (2016). Reconstructing the last interglacial at Summit, Greenland: Insights from GISP2. Proceedings of the National Academy of Sciences of the United States of America, 113(35), 9710-9715. doi:10.1073/pnas.1524766113

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