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Interactive comment on "Greenland temperature and precipitation over the last 20,000 years using data assimilation" *by* Jessica A. Badgeley et al.

Anonymous Referee #2

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The authors present new reconstructions of temperature and precipitation over the last 20,000 years over Greenland. For this, they apply a data assimilation technique on δ^{18}O and accumulation records from Greenland ice cores and use the temperature and precipitation outputs from the TraCE-21ka simulation to extend the information to all the continent. The paper is in general clear enough for that people not having skills in data assimilation can read and understand quite easily the methodology presented in this manuscript. In my knowledge, the technique presented here is innovative for such a long period, and the different assumptions are presented and tested in a very rigorous way. This manuscript is worthy for publication in Climate of the Past, after having considered the comments below.

General comments

1. Compared to the ice cores part, which is well discussed in the Methods section and in the Supplementary Material, the results of the TraCE-21ka simulation are not discussed enough in my opinion. More details about the similarities/differences with other PMIP simulations and/or climate reconstructions for PI and LGM could be discussed for example. How do the last 1000/2000 years fit well with last millennium simulations or reconstructions from isotopic proxies? Moreover, the rapid climate transitions are not so well captured by the TraCE-21ka, especially the Younger Dryas. This point should be discussed in terms of potential consequences for the reconstructions by data assimilation. The spatial resolution (T31 and 26 atmospheric vertical levels for the atmosphere if I am not wrong) should be clearly stated, and the uncertainties related to this aspect could be discussed (even if it is mentioned later). For example, is the limited number of grid points over Greenland a problem for the paleo DA technique? The ice sheet boundary conditions are also of major importance in this type of simulation. The expected differences if a more recent ice-sheet reconstruction would be prescribed could be discussed. Last point: what about the precipitation seasonality in TraCE-21ka over Greenland? Is it consistent with observations? Is the seasonality different for Holocene and glacial periods? I guess it could have an important impact on the δ^{18}O PSM and the final temperature reconstruction...

2. The way how the prior ensemble is made should be clarified. To avoid misunderstanding, the authors should state at line 175 that the prior is constant in time (and not later at line 206). If I understand clearly, 10 different 100-member prior ensembles are made (it should be said directly at the beginning). To form a prior ensemble, do you then randomly pick up 100 snapshots from the resampled TraCE-21ka temperature and precipitation outputs (see my minor comment for the line 146)? Or do you take randomly from the yearly TraCE-21ka outputs 50 consecutive years of data that you average in time for a member, other 50 consecutive years of model outputs for another

time period for the second member, and so on…? Or another way? Anyway, it needs clarification (in the way of the section 2.3 of Hakim et al. 2016 for example). I have the same remark as the first referee: what would be the difference if you would use, for instance, a “glacial prior” to reconstruct climate variables from glacial period and a “Holocene prior” for the warmer period instead of a constant prior for all the 20,000 years? In link with my first major remark, what would be the impact on the seasonality of precipitation, that influences the reconstructions of the authors?

Minor comments

Line 14: “requires understanding its sensitivity to changes…”

Line 18: I would put into brackets the terms “and arid” and “and wet”.

Line 31: the spatial resolution, especially for paleoclimate simulations, brings also uncertainties.

Line 37 and passim: I think this is TraCE-21ka and not TraCE21ka.

Paragraph lines 106-116: Does the matching of δ^{18}O from Dye3 to the δ^{18}O record from NGRIP bring a dependency when evaluating the posterior against Dye3 δ^{18}O record?

Section 2.2: I understand when you use the term “transient ice-sheet” that the prescribed ice-sheet is changed over time. But some people can misunderstand and think that it is done dynamically with a coupled ice-sheet model. I would use an expression like “prescribed transient ice-sheet boundary conditions” for example.

Line 146: What is the initial temporal resolution of TraCE-21ka outputs? Monthly mean? When you talk about “average of 50-year resolution”, do you mean “resampling” every 50 model years? If you take the last 20,000 years, it makes something like 400 time steps, right?

Lines 230-232: Other model studies like Gierz et al. 2017 (JAMES) for the LIG and Cauquoin et al. 2019 (CP) for 6k-PI climates have shown that the seasonality of precipitation affects the δ^{18}O-temperature relationship over Greenland.

Line 286: “that the proxy y and prior estimate of the proxy $\mathcal{H}(x_b)$”.

Lines 311-316: What does it give compared to the TraCE-21ka results?

Line 326: “from nearly +2°C in northern…”

Line 367: “has a large effect on our evaluation.”

Line 380: “the ECR is…”

Line 404: the slower warming trends are hard to see. Make a zoom in the figure or give numbers.

Line 428: For S4 and high P cases, say clearly that it refers to the “sensitivity” curves on figure 12.

Line 486: you can add the reference Okazaki and Yoshimura 2017 (CP).

Line 488: Add the references Cauquoin et al. 2019 (CP) and Okazaki and Yoshimura 2019 (JGR Atmos).

Figure 4: add maybe contours for more clarity. And change the scale for the precipitation fraction at the peak warmth in the Holocene (panel b).

Figures 7,8, S3 and S4: quite normal that the correlation is improved for the full period compared to the constant prior climate state.

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