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Climate of the Past Discussions

Interactive comment on "Using data assimilation to investigate the causes of Southern Hemisphere high latitude cooling from 10 to 8 ka BP" *by* P. Mathiot et al.

Anonymous Referee #2

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Using data assimilation to investigate the causes of Southern Hemisphere high latitude cooling from 10 to 8 ka BP

by P. Mathiot, H. Goosse, X. Crosta, B. Stenni, M. Braida, H. Renssen, C. VanMeerbeek, V. Masson-Delmotte, A. Mairesse, and S. Dubinkina

This study investigates the mechanisms responsible for the cooling registered by proxy data at high latitudes of the Southern Hemisphere from 10 ka to 8 ka. To this end climate simulations performed with the LOVECLIM coupled climate model and constrained through data assimilation are used to assess two possible hypotheses: a change in atmospheric circulation and a cooling in the Southern Ocean sea surface

temperatures. The authors conclude that both are required in order to match the reconstructions.

This is a valuable study that assesses past climate changes using a novel approach in paleoclimate as data assimilation. The experimental design is thus original and the results interesting. Nevertheless, I think several issues should be improved. Thus I recommend publication subject to minor revisions.

General main comments (see also the specific comments below):

1) The authors should try to frame better the motivation and justification of the experimental design.

2) The text requires a thorough revision to improve several minor issues; often further explanations are required.

3) The authors should try to discuss a bit more the relevance of their study, the outlook and caveats in the Conclusions.

Specific comments:

P 5546 (Abstract): In lines 12 and 18 the magnitude of the simulated cooling in the assimilation experiments is indicated. To be able to quantify their contribution, the magnitude of the reconstructed cooling should be previously mentioned. Also, I do not understand the “However” in line 19, should it not rather be a “Thus”?

1. Introduction:

p 5546, l 23: Here it is stated that East Antarctic ice core records show a cooling from about 10 ka to about 8 ka. First, this cooling is more notable but not restricted to East Antarctica. Second, Figure 1 shows only the reconstructed temperature differences. This figure is useful to locate the data used and distinguish which are used in the assimilation procedure, but the magnitude of the temperature change is of limited value without knowing the variability. Since this is the central issue of this manuscript, addi-

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tionally showing some of the reconstructed time-series (as in Stenni et al. 2011) would be very helpful.

p 5547, l 5 - p 5548 17: Here the authors are reviewing the evidence from data from high southern latitudes. I was expecting that the data mentioned here would show up later on in Table 1 and Figure 1, but this is generally not the case. I would encourage the authors to make this discussion more coherent with Figure 1 and Table 1, referring to both, specially by discussing more of the data that these 1 show.

p 5547, l 7: I think the reference to Kim et al. (2012) might not be correct, see below.

p 5547, l 10: I suggest replacing "These" by "The".

p 5548, l 15-16: Please replace "explained" by "explain". Also "and potentially providing" does not fit here, please rephrase. Finally, I would not make a new line at the end of this paragraph since precisely the aforementioned climate simulations are explained next.

p 5548, l 17-21: The first sentence of this paragraph does not make full sense since the verb is missing; please rephrase. Also, I understand that Renssen et al. 2005 concluded that the long-term cooling could be explained by "the combined effects of local orbital forcing and the long memory of the system", with no need to resort to north-south teleconnections. Now a different perspective is taken, possibly in the light of new results. The authors should explain in more detail why this is the case and what was not fully answered in Renssen et al. 2005 to explain the need for the present work. Finally, I recommend joining this paragraph with the one above.

p 5548, l 23: Please suppress "the" before "both".

p 5548, l 28: This sentence is unclear. I assume you mean similar to the bipolar seesaw mechanism invoked for the last glacial period. Please rephrase. Also, I think it would be worth referring here to Shakun et al. (2012): Shakun, J. D., P.U. Clark, F. He, S.A. Marcott, A.C. Mix, Z. Liu, B. Otto-Bliesner, A. Schmittner, and E. Bard,

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"Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation", Nature, vol. 484, pp. 49-54, 2012.

p 5549, l 2-5: It would be helpful to elaborate a bit more on this last sentence referring to Renssen et al. (2010) to specify that this mechanism could override the effect of the bipolar seesaw mechanism.

p 5549, l 7: I suggest suppressing “This”.

p 5549, l 13-15: This paragraph states what the specific goal of this manuscript is, and which are the hypothesis that are investigated. First, I suggest merging with the paragraph below. Second, the motivation given in the text for an atmospheric circulation change hypothesis seems weak. The only previous reference is a change in the Southern Ocean westerlies leading to colder circumpolar deep water (CDW); is this what is meant? I suggest making the link more clear explaining what type of atmospheric circulation change is investigated and why.

p 5549, l 25: Please correct “it is admit”.

p 5549, l 28: Suppress “s” in “Models”.

P 5550, l 25: Even though this is mentioned at the end of the previous section), here I suggest stating explicitly that the simulations are snapshots or time-slice experiments for 8 and 10 ka, not transient ones (I assume). Also, what is the length of the simulations? Personally I would rather start by describing the simulation proceure as in section 2.4 and after describe the assimilation method and proxy data (sections 2.2 and 2.3).

p 5551, l 1-2: It is unclear to me how the ice-sheets are treated: are they simply fix or are they prescribed or partially vary between the snapshots considered (i.e the Laurentide ice sheet)? Also, please write “FWF” in capital letters, here and elsewhere.

2. Experimental design

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p 5551, l 19: I am not familiar with the data assimilation method, but, I would assume that the atmospheric streamfunction is perturbed only in the experiments addressing atmospheric circulation changes, right? This appears to be corroborated in section 2.4, but from the statement here one would infer it is part of the general strategy. Also, I understand the one-year time-step for assimilation applies to the atmospheric hypothesis only.

p 5552, l6: insert “the” before “original”. Also, what is the basis for the assumption of an error for the data of 0.7 C for marine and pollen records?

p 5552, l 10: replace “on” by “of” and rephrase “remain difficult to fully quantify”

p 5552, l 16: separate “by” and “changes”

p 5552, l 26: delete “are” before “through”

p 5553, l16-18: I understand the initializations stem from two (not one) long equilibrium runs for 8 and 10 ka, respectively?

p 5555, section 2.5: This discussion is necessary but I am not sure that it belongs in this section (which by the way is already quite long); I would rather try to include it in the Introduction and possibly some discussion regarding the uncertainties in the Conclusions and Discussion section.

3. Results

p 5557 l9-25: These three paragraphs are part of the same story and should thus be merged into a single one. I understand this result agrees with Renssen et al (2010) but not with Renssen et al (2005); what is the reason for this discrepancy? I understand part of the explanation could be a “wrong choice of fwf” as stated in the text, but I think the authors could be a bit more explicit. Finally, this discussion on the model-data comparison would require taking into account the variability/uncertainty of model and data, to ascertain the significance of the differences. If this is not feasible it should be explained why.

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p 5559, l3: I assume here “AMS” should be “ATM”.

p5561, l 20: Replace “increase” by “change” (ATM actually leads to a decrease).

Conclusions:

After a big effort regarding the experimental design, the results and also Conclusions section appear quite short in comparison to the previous sections. I think the main value of this manuscript is that it provides a new means of constraining mechanisms that might have been relevant to explain past climate changes. I think the authors should try to discuss a bit more the relevance of their study, the outlook and caveats. In this line, I am not sure that the present exercise can really pinpoint the relevant mechanism. In this line, the combination of data assimilation with a perturbed atmospheric circulation and Southern Ocean freshwater appears to yield the best result in terms of the RMSE, but the experiments carried out are insufficient. For example, different magnitudes of the freshwater fluxes could provide a different impact capable of reducing the RMSE as well. I understand this is out of the scope of this paper, but addressing some of these caveats would be valuable.

References:

I think the reference to Kim et al. (2012) is incorrect; the correct year for that manuscript is 2008. Kim et al (2012) is rather:

Kim, J.-H., X. Crosta, V. Willmott, H. Renssen, J. Bonnin, P. Helmke, S. Schouten, and J. S. Sinninghe Damste (2012), Holocene subsurface temperature variability in the eastern Antarctic continental margin, Geophys. Res. Lett., 39, L06705, doi:10.1029/2012GL051157.

Figures:

Figure 1 (already mentioned above in the specific remarks): as mentioned above, the magnitude of the temperature changes is of limited value without knowing the variability. Thus, and since this is the central issue of this manuscript, additionally showing

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some of the reconstructed time-series (as in Stenni et al. 2011) would be very helpful.

Figures 2-3, 5: Please state differences are 10 ka minus 8 ka as done for figure 6. Figure 6a: Replace REF by STD for consistence.

Interactive comment on Clim. Past Discuss., 8, 5545, 2012.