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Climate of the Past Discussions

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Interactive Comment

Interactive comment on "Climate and vegetation changes around the Atlantic Ocean resulting from changes in the meridional overturning circulation during deglaciation" *by* D. Handiani et al.

Anonymous Referee #1

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D. Handiani and colleagues describe several freshwater hosing experiments under different boundary conditions (Preindustrial, Last Glacial Maximum and Heinrich Event 1) in order to change the strength of the Atlantic Overturning Circulation with the UVic ESCM. They find that the model's response to freshwater fluxes into the Southern Ocean depends on the boundary conditions. They then compare simulated vegetation biomes with paleo reconstructions during the Bølling-Allerød event and evaluate changes in vegetation biomes due to changes in the AMOC during their simulations.

1 General Comments

This paper focuses on both, changes in vegetation and changes in the ocean circu-

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Discussion Paper

lation, without really connecting these two subjects. I would therefore recommend to re-write the paper in a way to tie the ends together and make a more consistent story.

In addition I have several major concerns as listed below.

1.1 Vegetation:

I find the vegetation part of the paper a little too light. The vegetation model used in this study is quite simple; it is therefore not surprising that the model-reconstruction comparison under BA boundary conditions is far from being perfect. This deficiency could be overcome by analyzing changes in vegetation cover under different boundary conditions and compare those to changes seen in the reconstructed vegetation during abrupt climate change. The authors go only half way, (a) comparing simulated equilibrium vegetation with reconstructions for the BA and (b) comparing changes in simulated vegetation due to changes in the AMOC. Therefore, one of my first suggestions/ideas after a first read was to analyze biome reconstructions for both H1 and BA and then compare the main differences in these reconstructions with modeled vegetation shifts (namely between T2 and T0; I do not think that the vegetation had enough time to recover in T1 to show an equilibrium response). I then went on to read Handiani et al. (2012) and realized that most of the H1 comparison has been done. I therefore wonder if there is enough new science in this paper? I would also like to point out that the same model has been used in the past to analyze vegetation changes during Heinrich Events in Africa (Carto et al. 2009).

1.2 Ocean:

This paper lacks a concise literature review about well-known stable equilibria in coupled models and how one can switch between two or more of those (including discussions of box models, etc). There is a confusion in this paper between the:

*NADW/AABW see-saw (which is also the best known and best covered in the literature)

*NADW/AAIW seesaw (e.g., for the UVic model, Saenko et al. 2003) and the

*NADW/NPDW seesaw (e.g., for the UVic model, Saenko et al. 2004; or for LOVE-CLIM, Okasaki et al. 2010)

In addition to expanding the literature review, I think that the simulations need to be analyzed further. According to the figures, it looks like the simulations presented here are displaying the NADW/AABW seesaw, although the authors claim at least at one point that the NADW/AAIW seesaw plays a role too. This needs to be analyzed and rectified. I would also like to encourage the authors to double-check that none of their simulations is forming North Pacific Deep Water, especially when hosing the North Atlantic.

One of the most interesting results in this study is the fact that adding freshwater to region B has different results on NADW formation depending on the boundary conditions. This should be further explored. Is it maybe the sea ice cover in the Southern Ocean that plays a major role here? On page 2833 the authors mention the freshwater transport into the Atlantic Basin – maybe they should show these time series in the paper? On the other hand, adding salt to the Atlantic Ocean would rejuvenate any AMOC, so I do not think that there is need to dwell on this mechanism too long.

Finally, I find it puzzling that some simulations show a warming in the North Atlantic Ocean, although the AMOC does not recover. What is causing this warming? Are there changes in the North Pacific circulation? An analysis of heat fluxes and budgets in the ocean might shed light to this question.

1.3 Winds:

Most of the vegetation changes, which are a crucial component of the paper, are due to changes in precipitation. The authors explain that these changes are due to "a northward shift of the Intertropical Convergence Zone" without any further analysis. The UVic ESCM has a very simple atmospheric component, which does not calculate winds diagnostically. As the authors did not specify which wind fields they used to force the model, I suspect that the model is integrated with present-day winds and a superimposed wind anomaly due to geostropic adjustment calculated based on temperature changes. Am I right? In that case it might be interesting to at least discuss this simple parameterization and how it might be successful (or not) to simulate a shift in convection zones. Given that this paper is centered on vegetation shift, one might even want to go a step further and reintegrate the simulations with wind fields diagnosed from an atmospheric GCM.

Figures 3 and 4 tell the same story, I would suggest to only show (and describe) one of them.

2 Specific Comments:

Page 2824, line 7: 2000 years is quite short for an equilibrium simulation. What is the drift in ocean temperature at the end of our equilibrium simulations?

Page 2824, line 17: Before making this statement, please double-check where AAIW is formed in your simulations. I doubt that this is in region B.

Page 2828, line 15: As already mentioned above, I would compare the vegetation at T2 with vegetation at T0. At T1 the vegetation won't be in equilibrium yet.

Page 2830, line 6: I do not agree that the reconstructed biomes are similar to proxy reconstructions; they only get one or two locations right, mainly in Southeast Africa? Maybe a slight rewording here?

Page 2831, line 11-13: isn't it the difference in densities between AAIW and NADW that is crucial? I am not sure if one needs to increase NADW densities?

Page 2831, line 22: you probably mean "less dense AAIW" and not "denser AAIW"? Also, I am not convinced that it is the NADW/AAIW seesaw that plays the major role in your simulations. Please double-check and change discussion accordingly.

Page 2831, lines 24-26: please do not draw conclusions on a potential mechanism without proving that this mechanism is at play.

Page 2832: lines 23-25: Again, please do not draw conclusions without proving them. You need to calculate freshwater budgets to prove this point (or, even better, introduce a colour tracer with the freshwater added to region B, so that you can track it).

Page 2834, lines 18-19: Did Weaver et al analyze this change in behaviour depending on CO2 concentrations, and if so, does the same mechanism apply here?

Page 2834, line 25: Are the changes in Peru just one grid box? If this is the case, is that a solid result worth discussing?

Page 2836, line 16-18: this is a conclusion you cannot draw. By construction there are "seeds" of each PFT in every grid box. Nothing can therefore go "extinct". Nothing can "migrate" either, as vegetation will just pop up whenever the climatic conditions are right. This model is therefore ill-suited to test if plant species went extinct or migrated (in the sense to allow for slow propagation).

Page 2837, line 7: Adding salt to the North Atlantic is not mimicking a reduction of iceberg calving. A reduction of iceberg calving would be the weakening of the positive freshwater perturbation.

Page 2837: lines 20-23: see above. You cannot draw this conclusion. The model is constructed to react that way.

Page 2849: Figure 5: Why is the Atlantic Ocean uniformly colder? I do not understand this? Did the atmospheric CO2 change? Also why is the warming for the other plots concentrated along the African and European Coast? Where are your deepwater formation sites?

Page 2850: Figure 6: Can you please include western North America in these plots as these regions are discussed in the text?

Page 2852: Figure 8: it would be very helpful to add the symbols from Figure 1b into all the panels of this picture (smaller symbols than in 1b so that one can still see the model result). Also, I find it surprising that there is no change in vegetation between H1 and H1-EXT, the two plots look almost identical. If true, it means that the strength of the NADW has no effect on vegetation under BA boundary conditions? And if that is true, the main conclusion/focus of this paper should probably be re-written.

3 Technical Comments

Page 2821, line 22: Ganopolsky and Rahmstorf do not reduce the meltwater flux, they add salt (negative meltwater flux in their Fig 5).

Page 2824, line 5: the PI simulation should be called “preindustrial” and not “present day” simulation throughout the text. (E.g. 2825, 7 etc)

Page 2824, line 10: HE1 was probably closer to 500 years long. Although I agree that this does not really matter, as these are sensitivity studies.

Page 2825, line 17: Please do not call the increase of 1Sv (from 1Sv to 2Sv) an “increase” in AMOC. In both cases the AMOC is collapsed.

Page 2827, line 2: “a small change of” should read “a small change in”

Page 2829, line 18: Wording: “before and after the AMOC recovery”; would mean “AMOC off and AMOC recovered” although I think you mean “before H1 and after the AMOC recovery”.

Page 2831, line 16: see above – I would not call the increase of 1 Sv “intensifies”.

Page 2832: line 14: “atmosphere-ocean general circulation”. . . please add the word “model”.

Page 2833, line 11: Atlantic with only one “l”.

Page 2833, line 24: one of the first publications with a coupled model that analyzed feedbacks between ice sheet mass balance and overturning is probably Meissner and Gerdes (2003).

Page 2834, lines 12-15: Where did Weaver et al add this freshwater flux?

Page 2834, line 22: How can the warm climate be caused by changes in tropical precipitation and vegetation?

Page 2845, Figure Caption 1 a: please change "discharge" to "forcing". Discharge is usually used in the context of river discharge.

Page 2847, Figure Caption 3: please add that these are Atlantic only plots (same for Figure 4).

References

Carto, S.L., A.J. Weaver, R. Hetherington, Y. Lam and E.C. Wiebe, 2009: Out of Africa and into an ice age: On the role of global climate change in the Late Pleistocene migration of early modern humans out of Africa. Journal of Human Evolution, 56, 139-151.

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Okazaki, Y., A. Timmermann, L. Menviel, N. Harada, A. Abe-Ouchi, M.O. Chikamoto, A. Mouchet, and H. Asahi (2010). Deepwater formation in the North Pacific during the Last Glacial Termination, Science, 329 (5988), 200-204.

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Interactive comment on Clim. Past Discuss., 8, 2819, 2012.