Clim. Past Discuss., 7, C1922–C1926, 2011
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Climate of the Past Discussions

Interactive comment on "Role of CO₂ and Southern Ocean winds in glacial abrupt climate change" *by* R. Banderas et al.

Anonymous Referee #1

Received and published: 30 November 2011

Review on cp-2011-122 Role of CO2 and Southern Ocean winds in glacial abrupt climate change by R. Banderas, J. Álvarez-Solas, and M. Montoya

This paper decribes a modelling experiment with CLIMBER-3α, a model of intermediate complexity in order to investigate processes, which might be responisble for an abrupt stadial/interstadial transition during so-called Dansgaard/Oeschger (D/O) events during glacial times.

The model strategy is based on hypotheses (e.g. wind stress in Southern Ocean causes AMOC resumption) published elsewhere, thus this paper focuses if one or two of such hypothesis, in detail CO2 increase and/or wind stress increase in the Southern Ocean, might indeed be responsible for a stadial/interstadial transition and connected with that a bipolar temperature pattern, typically found in reconstructions.

The topic and form of presentation are well suited for publication in CP, thus I have mainly minor issues to be resolved, which are connected with the clarity of what is done and what is seen.

1. One major issue, however, is the question if the chosen model really shows a bipolar temperature pattern during stadial/interstadial transitions. So far, Fig 1c shown surface air temperature (SAT) in the Nordic sea (an abrupt resumption). This needs to be extended by southern hemispheric SAT simulations. Ideally, both Antarctic SAT (showing rather gradual changes, slow warming during stadial northern phase and then a switch to gradual cooling synchronous to the temperature switch in the north as seen in ice cores) and South Atlantic SAT or SST or shown. The second should according to the theory of the bipolar seesaw show similar abrupt changes as in the North, but of opposite sign as documented in proxy records, see

Barker, S.; Diz, P.; Vantravers, M. J.; Pike, J.; Knorr, G.; Hall, I. R. Broecker, W. S. Interhemispheric Atlantic seesaw response during the last deglaciation Nature, 2009, 457, 1007-1102.

Connected with that it is also necessary to discuss in more detail, that the "abrupt" SAT warming in the model in the North is still a lot slower than in the ice core records. Steffensen et al 2008 showed that in Greenland some changes occured within a few years, but the overall interpretation is that all chemical proxies change within 50 yr during the stadial/interstadial transition into the Bolling/Allerod, while the CLIMBER model here needs about 200 yrs.

Steffensen, J. P.; Andersen, K. K.; Bigler, M.; Clausen, H. B.; Dahl-Jensen, D.; Fischer, H.; Goto-Azuma, K.; Hansson, M.; Johnsen, S. J.; Jouzel, J.; Masson-Delmotte, V.; Popp, T.; Rasmussen, S. O.; Rothlisberger, R.; Ruth, U.; Stauffer, B.; Siggaard-Andersen, M.-L.; Sveinbjörnsdóttir, A. E.; Svensson, A. White, J. W. C. High-resolution Greenland ice core data show abrupt climate change happens in few years Science, 2008, 321, 680-684, doi: 10.1126/science.1157707.

2. Throughout the text it needs to be clear, what changes in the westerlies are proposed and investigated. Your experiment is a change in the WIND STRESS, but it is also mentioned that the westerlies might move north or south. In the final discussion (page 3498-33499) you also give as chain of argument: Southern westerlies move north, thus less upwelling, thus less CO2, in order to connect how CO2 and wind might be connected. Please be aware, that this westerly wind hypothesis brought up by Toggweiler (also for explaining glacial/interglacial CO2) was so far NOT reproduced by model, both Menviel and Tschumi do NOT find the proposed effect of westerly winds on CO2. This might need some discussion. I understand that Lee et al 2011, cited in the paper, finds some CO2 changes caused by Southern westerlies change, so this discrepancy might need to get some discussion.

Toggweiler, J. R.; l. Russell, J. Carson, S. R. Midlatitude westerlies, atmospheric CO_2, and climate change during the ice ages Paleoceanography, 2006, 21, PA2005, doi: 10.1029/2005PA001154

Menviel, L.; Timmermann, A.; Mouchet, A. Timm, O. Climate and marine carbon cycle response to changes in the strength of the southern hemispheric westerlies Paleoceanography, 2008, 23, PA4201, doi: 10.1029/2008PA001604

Tschumi, T.; Joos, F. Parekh, P. How important are Southern Hemisphere wind changes for low glacial carbon dioxide? A model study Paleoceanography, 2008, 23, PA4208, doi: 10.1029/2008PA001592

3. Also throughout the text: When you argue about changes in the Artic sea ice front, please make always clear if this is about its position in annual mean, or only summer or only winter. My understanding of the text so far was, that summer position of the sea ice front might be relevant, but maybe not.

4. abstract line 5: "implications of NADW" on what?

5. page 3490, line 25: Greenland warming during D/O events: Dansgaard et al 1993

shows only the water isotopes, but I think does not calculate how much warming that might be, maybe consider Lang et al 1999 for warming.

Lang, C.; Leuenberger, M.; Schwander, J. Johnsen, S. 16^{r}cC rapid temperature variation in central Greenland 70,000 years ago Science, 1999, 286, 934-937

6. Introduction: I think this should be expanded on more details of the bipolar seesaw, e.g. more gradual temperature changes in Antarctica, but similar rapid but opposite changes in the South Atlantic. Also, the similarity or differences to Lee et al 2011, cited p 3491, last lines needs to be clarified even further. Taken all together, my understanding is, that a) North Atlanitc cooling might change Southern westerlies (after Lee), leading to b) a resumption of NADW (after this study), and in consequences c) a rapid warming in the North (this study as well). If that might be amplified by CO2 might be a matter of debate (cycle climate models give different answers, Lee et al 2011 finds a CO2 response, Menviel and Tschumi did not, although the focus of the later two was on glacial/interglacial timescales). So, does this mean, the initial driver might be in the North Atlantic and everything else is a feedback loop reversing the initial temperature anomaly in the North? What would then be a cause for the cooling in the North?

7. Experimental setup: I am wondering what would happen, if you would follow in your simulations not only a stadial/interstadial transition, but also the reverse. My understanding of the bipolar seesaw ist, that at the same time when the North sees the rapid temperature rise, Antarctica switches from gradual warming to gradual cooling. This would imply you change your forcing once you reach interstadial northern temperature. This might be an interesting final experiment. Will the model return (with which time delay?) to stadial conditions?

8. Fig 3: Units are unclear to me. Fig 3b should be relative temperature anomalies in the range -1.3 to +1.3? Is SST in the stadial regime expressed in deg C or K, thus does +1.3 mean a rise in SST by 130 percent (then in deg C or K)??? Similar difficulites for the other subfigures of Fig 3.

9. Fig 4a: For what experiment are the timeseries?

10. Fig 6b: What about northward heat transport in the CO2+wind experiment?

Interactive comment on Clim. Past Discuss., 7, 3489, 2011.