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Climate of the Past Discussions

Interactive comment on "Rapid changes in ice core gas records – Part 2: Understanding the rapid rise in atmospheric CO_2 at the onset of the Bølling/Allerød" *by* P. Köhler et al.

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The review of M. Siddall added various details to certain parts of our study, and helped to shape the language. We therefore thank for his suggestions and comments. Please find our detailed responses below.

GENERAL COMMENTS:

- *Reviewer comment:*

  1. *The authors mention direct effects of continental shelf flooding but there are*

other effects relating to the extent of the tidally mixed zone on carbon burial on the submerged shelf:

Rippeth, T. P., J. D. Scourse, K. Uehara, and S. McKeown (2008) The impact of sea-level rise over the last deglacial transition on the strength of the continental shelf CO2 pump. Geophys. Res. Lett., 35, L24604, doi:10.1029/2008GL035880

note that this paper itself documents a first-order effect of tides on shelf carbon sequestration. There are also second-order effects of tidal energy dissipation on the shelf to keep in mind:

Green, J.A.M., Green, C.L., Bigg, G.R., Rippeth, T.P., Scourse, J.D. and Uehara, K. 2009. Tidal mixing and the strength of the Meridional Overturning Circulation from the Last Glacial Maximum. Geophysical Research Letters 36, L15603

Our response: The paper of Rippeth et al. (2008) contains a hypothesis, that the flooding of continental shelves would increase the marine biological carbon pump. Their idea is based on recent observations that shelf areas are sinks for atmospheric CO_2. Thus, increasing the area of flooded shelves by sea level rise would according to Rippeth et al. (2008) increase the marine net primary and export production and reduce atmospheric CO_2, the opposite of what we found in the ice core data for the onset of the B/A warm period around 14.6 kyr BP and in parallel to melt water pulse 1A. Therefore, this hypothesis can not explain observed CO_2 data in our time window of interest, but would increase the fraction of the rise in CO_2 which need to be explained by other processes.

The second order effect of tidal energy dissipation (Green et al., 2009) seems to be of importance for the physics of ocean, but not for the carbon cycle injection case studies used here, in which we applied a carbon cycle box model. The potential of associated bio-physical feedbacks is outside the scope of this study.

- *2. It is not clear to me that the model should be in an AMOC off state during the whole experiment. It seems to me to be important to consider a hypothetical transition from the off to the on state as one experiment.*

  Our response: As explained in section 2.2 our intention is to find which process in addition to all those processes typically found during D/O events can generate such a rapid rise in CO_2. Common understanding is, that the transition in the AMOC from an off to an on state is related to the bipolar seesaw pattern seen during D/O events. In our approach we argue that by comparing the B/A with other D/O events in MIS 3 we are able to exclude all those processes typical for the bipolar seesaw to be responsible for the rapid rise in atmospheric CO_2 around 14.6 kyr BP. Therefore, the state of the AMOC should not change during the experiments.

  However, it might be questioned then, if the AMOC should be on or off during our investigations. We have chosen to set the AMOC in the off mode to be as close as possible to the climate conditions at the onset of the B/A warm period. At that time climate was characterized by the Heinrich event 1, a stadial in the northern hemisphere known to be connected with cold temperatures in the north, and ice rafted debris in North Atlantic sediment core (Heinrich, 1988), which together with other tracers (McManus et al., 2004) strongly suggest the AMOC to be in an off mode. We therefore made some additional sensitivity studies to investigate how important the background climate is for the rapid rise in CO_2. Results with the BICYCLE model are very similar if we perform them with the AMOC in an on or off mode throughout the experiments. The background CO_2, of course, is different (223 and 255 ppmv with AMOC in off and on mode, respectively), but the amplitudes are nearly the same: In the fastest experiment with an injection time of 50 yr atmospheric pCO_2 rises by 33 and 35 ppmv for AMOC in off and on mode, respectively.

- *3. The authors note differences between MIS 3 and the termination in terms of the phasing of the CO2 response and also in terms of the rate of sea level change. We found some similar differences in a recent study which may be worth referring to (at the complete discretion of the authors). Although our results are tentative, it seems to me that the links to the conclusions of the paper in review are intruiging:*

  Siddall M., Kaplan M.R., Schaefer J.M., Putnam A., Kelly M.A., Goehring B., 2010: Changing influence of Antarctic and Greenland temperature records on sea level over the last glacial cycle, Quaternary Science Reviews, 29(3-4), 2010, 410-423

  Our response: The difference between MIS 3 and Termination I, proposed by our study and by the cited paper (Siddall et al., 2010), and the link of both studies is certainly worth mentioning in the discussion of our results.

- *4. Although the text is mostly good I did spot a good number of typos and other language errors. I have tried to identify these where I can but I do not guarantee that I have managed to spot them all. It may be worth getting a native speaker to have a proof read.*

  Our response: We carefully checked the language again.

SPECIFIC COMMENTS:

- **Our response:** Most of the following "specific comments" include suggestions how to improve various sentences / figures in detail. They will all be considered

and implemented in a revision of the manuscript. A response is only added to the comments #7 and #10.

- *7. P1475, L26: unclear which Köhler 2010 paper is being referred to.*

  Our response: There is only one paper cited as "Köhler 2010" (published in Climate of the Past Discussions), the two other papers are cited as "Köhler et al., 2010" and thus clearly distinguishable.

- *10. P1483, L5: is Smith and Sandwell 1997 the most accurate, up to date bathymetry you can use? This is not likely to affect your result but this is an old reference by now.*

  Our response: The underlying dataset is updated and revised through time. We here used the version 12.1, release date 03 Sept 2009. It is still recommented to use this reference to the 1997 paper.

References

Heinrich, H.: Origin and consequences of cyclic ice rafting in the northeast Atlantic ocean during the past 130,000 years, Quaternary Research, 29, 142–152, 1988.

McManus, J. F., Francois, R., Gheradi, J.-M., Keigwin, L. D., and Brown-Leger, S.: Collapse and rapid resumption of Atlantic meridional circulation linked to deglacial climate changes, Nature, 428, 834–837, 2004.

Interactive comment on Clim. Past Discuss., 6, 1473, 2010.