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Interactive comment on "Carbon isotopes support Atlantic meridional overturning circulation decline as a trigger for early deglacial CO₂ rise" *by* A. Schmittner and D. C. Lund

Anonymous Referee #2

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This is an interesting study compiling d13C data and model results. A series of freshwater hosing experiments for preindustrial climate conditions are carried out with the UVIC climate-carbon cycle model. Model results in terms of changes in d13C and in atmospheric CO2 are compared to the ice core d13CO2 and CO2 records and to marine records of d13C as compiled from the literature for the period of the HS1 event (19 to 15 ka BP). The authors postulate that the early deglacial rise in CO2 was caused by a collapse of the Atlantic Meridional Overturnig Circulation that triggered a decline in ocean carbon storage.

This study presents interesting results and is a valuable contribution to the field complementing earlier studies investigating the response of CO2 and d13C to freshwater

hosing experiments. I like the figures, the model analysis and the compilation of the d13C data. The study, however, does not consider the sequence of AMOC collapse and recovery nor takes into account the LGM initial state as done by earlier studies (e.g. (Menviel et al., 2008a;Marchal et al., 1999).

The manuscript requires substantial revisions regarding the interpretation of the results and of the main conclusion. This will require a revision of the abstract, the introduction and the discussion section and I also suggest that additional simulations are performed.

There is a broad literature on freshwater hosing experiments and their impacts on CO2 and d13C in the land, ocean, and atmosphere system. This body of literature is simply disregarded by the authors. While I appreciate that it is getting increasingly difficult to follow the literature, the authors apparently did not pay any attention to refer to earlier work. This is very disturbing in particular as both researchers have a long-standing track record in the field. Clearly, the authors should do a literature survey and point the reader to earlier work to place this work in the appropriate context and to discuss their findings in comparison with earlier results.

In addition, the range of studies on the potential influence of SH wind changes on ocean circulation and the carbon cycle is not very well reflected.

1. Main conclusions are to be refined:

1.1) There are issues which need attention regarding the simulated rise in atmospheric CO2. First, the simulations are started from a preindustrial steady state. This caveat and its implication must be fleshed out more clearly and already be stated in the abstract. While discussed in the conclusion, the obvious implication, an overestimation of the CO2 change by the model, is not mentioned.

The AMOC was shallower in the NA during the LGM than at preindustrial. Consequently a smaller body of water was affected by a slow-down of the AMOC in the real ocean as compared to the model run. This mismatch is reflected in the too large changes in d13C in the North Atlantic as evident in Figure 6A-C and even more clearly in Figure 7, where all model results show substantially larger d13C changes than reconstructed. (The high correlation given in Fig 9 and the text is a bit misleading as the slope is quite different from the 1:1 line)

Similarly, the Brazilian margin data show a d13C change between 1.6 and 2.1 km (line22 p2863) whereas the model shows a substantial d13C change in the entire water column below 1500 m.

These features indicate that the overall change in d13C in the North Atlantic is overestimated by the model and thus also the change in DIC and in turn the change in atm. CO2 during H1.

I suggest that the author perform a spin-up under LGM condition and repeat their freshwater hosing experiment that show a collapse of the AMOC.

1.2) Various proxy data and studies indicate a distinct evolution of the North Atlantic ventilation and the AMOC. For example, (Robinson et al., 2005) document the radiocarbon history in the western North Atlantic and show that ventilation strength varied from LGM, H1, Bolling/Allerod, Younger Drias and the Holocene. The AMOC recovered at the onset of the Bolling/Allerod (McManus et al., 2004). This may have reversed earlier changes in CO2 associated with an AMOC slow-down. However, this sequence is not reflected by the model and not discussed by the authors.

I suggest that the authors continue their simulations and force their model (e.g. by freshwater removal) to trigger an onset of the AMOC, ideally for an LGM spin up. This would allow the authors to compare the simulated d13C changes not only during H1 but over the period from H1 to the end of the B/A.

2. Reflection of earlier work is missing

I find the introduction weak. In particular the literature on the subject is not reflected. Why? There is a range of (modelling) studies available that address the influence

of AMOC changes on atmospheric CO2 and/or d13C and both from a terrestrial and oceanic perspective. Example that come immediately to my mind are (Menviel et al., 2008a;Marchal et al., 1998;Marchal et al., 1999;Menviel et al., 2012;Menviel et al., 2014;Köhler et al., 2005;Bozbiyik et al., 2011;Obata, 2007) and there is certainly much more in the literature.

I encourage the authors to do a thorough literature research, to discuss this earlier work and to compare their findings with earlier studies. The findings of earlier studies have also implications regarding the authors' main conclusion. Earlier studies find that the response in CO2 and the carbon cycle is sensitive to the initial state (e.g. (Menviel et al., 2008a;Köhler et al., 2005)

3. Literature on SO wind changes is poorly represented

Again, the authors should search and carefully read and reflect studies addressing SO wind changes. The SO wind hypothesis has been challenged meanwhile by a broad range of studies. See (Tschumi et al., 2008) (Menviel et al., 2008b) and follow-up studies by others (e.g. (Lauderdale et al., 2013;d'Orgeville et al., 2010). Unlike stated in the introduction and reiterated in the conclusion, (Tschumi et al., 2011;Tschumi et al., 2008) do not support the suggestion that SO wind changes are responsible for the deglacial CO2 rise. To the contrary, Tschumi et al., 2008 state in their abstract: "Our results are in conflict with the hypothesis that Southern Hemisphere wind changes are responsible for the low atmospheric CO2 concentrations during glacial periods" P2860, line 18ff: please provide details how freshwater forcing is applied. Is there a compensation of salinity elsewhere? How are tracers affected by the freshwater input?

Bozbiyik, A., Steinacher, M., Joos, F., and Stocker, T. F.: Fingerprints of changes in the terrestrial carbon cycle in response to large reorganizations in ocean circulation, Climate of the Past, 7, 319-338, 10.5194/cp-7-319-2011, 2011. d'Orgeville, M., Sijp, W. P., England, M. H., and Meissner, K. J.: On the control of glacial-interglacial atmospheric CO2 variations by the Southern Hemisphere westerlies, Geophys. Res.

Lett., 37, L21703, 10.1029/2010gl045261, 2010. Köhler, P., Joos, F., Gerber, S., and Knutti, R.: Simulating changes in vegetation distribution, land carbon storage, and atmospheric CO2 in response to a collapse of the North Atlantic thermohaline circulation., Climate Dynamics, 25, 689-708, 2005. Lauderdale, J., Garabato, A. N., Oliver, K. C., Follows, M., and Williams, R.: Wind-driven changes in Southern Ocean residual circulation, ocean carbon reservoirs and atmospheric CO2, Climate Dynamics, 41, 2145-2164, 10.1007/s00382-012-1650-3, 2013. Marchal, O., Stocker, T. F., and Joos, F.: Impact of oceanic reorganizations on the ocean carbon cycle and atmospheric carbon dioxide content, Paleoceanography, 13, 225-244, 1998. Marchal, O., Stocker, T. F., Joos, F., Indermühle, A., Blunier, T., and Tschumi, J.: Modelling the concentration of atmospheric CO2 during the Younger Dryas climate event, Climate Dynamics, 15, 341-354, 1999. McManus, J. F., Francois, R., Gherardi, 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, http://www.nature.com/nature/journal/v428/n6985/suppinfo/nature02494_S1.html, 2004. Menviel, L., Timmermann, A., Mouchet, A., and Timm, O.: Meridional reorganizations of marine and terrestrial productivity during Heinrich events, Paleoceanography, 23, PA1203, 10.1029/2007pa001445, 2008a. Menviel, L., Timmermann, A., Mouchet, A., and Timm, O.: Climate and marine carbon cycle response to changes in the strength of the Southern Hemispheric westerlies, Paleoceanography, 23, PA4201, 10.1029/2008pa001604, 2008b. Menviel, L., Joos, F., and Ritz, S. P.: Simulating atmospheric CO2, 13C and the marine carbon cycle during the Last Glacial–Interglacial cycle: possible role for a deepening of the mean remineralization depth and an increase in the oceanic nutrient inventory, Quat. Sci. Rev., 56, 46-68, 10.1016/j.quascirev.2012.09.012, 2012. Menviel, L., England, M. H., Meissner, K. J., Mouchet, A., and Yu, J.: Atlantic-Pacific seesaw and its role in outgassing CO2 during Heinrich events, Paleoceanography, 29, 58-70, 10.1002/2013pa002542, 2014. Obata, A.: Climate–Carbon Cycle Model Response to Freshwater Discharge into the North Atlantic, Journal of Climate, 20, 5962-5976, 10.1175/2007jcli1808.1, 2007. Robinson,

L. F., Adkins, J. F., Keigwin, L. D., Southon, J., Fernandez, D. P., Wang, S. L., and Scheirer, D. S.: Radiocarbon Variability in the Western North Atlantic During the Last Deglaciation, Science, 310, 1469-1473, 2005. Tschumi, T., Joos, F., and Parekh, P.: How important are Southern Hemisphere wind changes for low glacial carbon dioxide? A model study, Paleoceanography, 23, PA4208, doi:10.1029/2008PA001592, 2008. Tschumi, T., Joos, F., Gehlen, M., and Heinze, C.: Deep ocean ventilation, carbon isotopes, marine sedimentation and the deglacial CO2 rise, Clim. Past, 7, 771-800, 10.5194/cp-7-771-2011, 2011.

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