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Title: Effect of the Atlantic Meridional Overturning Circulation on Atmospheric pCO_2 Variations

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Point-by-point reply to reviewer #2

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We thank the reviewer for his/her careful reading and for the useful comments on the manuscript.

1. *In the Inroduction section, are there any papers using 3D OGCM to simulate the atmospheric pCO2-AMOC strength relationship under PI and LGM? If so, these papers need to be properly cited.*

   Author's reply:
   In the introduction we already cite multiple papers that simulate the atmospheric pCO_2-AMOC relationship using EMICs, ESMs and (A)OGCMs.

   Examples of the cited papers are:
   Menviel et al. (2014) (EMIC in the LGM); Menviel et al. (2008) (EMIC in the LGM and PI); Mariotti et al. (2012) (AOGCM in the LGM); Nielsen et al. (2019) (ESM with a PI control simulation); Huiskamp and Meissner (2012) (ESM in the LGM); Gregory et al. (2005) (AOGCMs and EMICs with a PI control simulation); and Gottschalk et al. (2019) (ESMs and EMICS in the LGM).

   However, we may have missed some interesting papers.

   Changes in manuscript:
   We will look into the literature again, and add new citations to the introduction.

2. *I didn't see any experiments to test the plausibility of the box model to address the AMOC-pCO2 relationship problem. I would suggest that you set up two more experiments fully including all the feedbacks you mentioned in Table 2 and check if the atmospheric pCO2 is reasonable under two scenarios.*

Author's reply:
That is a good suggestion.

Changes in manuscript:
Suggestion will be followed. We will include results of these two extra experiments.

3. *In general, I think all the experiments should be set up with other feedbacks properly included to make the case more realistic. For example, when studying the role of biological feedback (x-0 and x-1 in Table 2), the x-0 could be set up with all λ = 1, x-1 then should be only with λ_{BI}=0, etc.*

   Author's reply:
   We chose to set up the experiments as in the original paper, since we base our model on the SCP-M and this model contains no feedbacks. The SCP-M is tuned to accurately represent both the PI and LGM conditions. We therefore consider that we start with a "realistic model" if all feedbacks are switched off (i.e. experiment x-0). Switching on all the feedbacks would not necessarily lead to a more realistic case, since the SCP-M is not tuned to include these parameters.

   Changes in manuscript:
   We will better justify our approach.

4. *In lines 266-270, the three parameters are selected as control parameters: the rain ratio, the biological production and the piston velocity. Please explain the reasons for picking these parameters. Also, the multiplier changes from 0.1 to 10 without reasonable explanations. I would suggest using more realistic ranges.*

   Author's reply:
   We use these three parameters since they more or less represent the three carbon pumps often used in the traditional view of the oceanic carbon cycle. The rain ratio affects the strength of the carbonate pump, the biological production the soft tissue pump and the piston velocity the solubility pump. We chose these three parameters to see whether a (large) change in one of the traditional pumps can invoke large non-linear changes or bifurcations in this model.

We agree that the multiplier range does not necessarily reflect realistic values. One of the goals of this study was to get a better understanding of the sensitivity of the carbon cycle to these parameter changes and whether bifurcations can arise.

Changes in manuscript:
We will better motivate the reasons for varying these three parameters, and why we choose a large range in parameter values.

Comments/concerns about specific feedbacks/parameters are below.

1. *In equation (2), the authors chose 0.54 °C/(Wm-2) to compute the temperature change. As this parameter is important in equation (12) to control the AMOC strength, what is the sensitivity of this parameter to coupling AMOC-carbon cycle?*

   Author's reply:
   The precise value of this parameter (0.54) is not very important in this study as the sensitivity to this parameter is generally low. This can also be seen in section 3.2., where we check the sensitivity of atmospheric pCO_2 to the value of λ_A. This can also be interpreted as the sensitivity of the relationship to this 0.54 (since 0.54 is multiplied with λ_A), which is low.

   We do see that the system is prone to show Hopf bifurcations when λ_T is increased. However, this is when we increase λ_T to relatively large values (order 20).

   Changes in manuscript:
   No changes necessary.