

Earth Syst. Dynam. Discuss., referee comment RC1
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Review of esd-2021-42

Anonymous Referee #1

Referee comment on "Effect of the Atlantic Meridional Overturning Circulation on atmospheric $p\text{CO}_2$ variations" by Amber Boot et al., Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2021-42-RC1>, 2021

Boot et al assess the impact on $p\text{CO}_2$ of a few oceanic feedbacks using a simple box model. A few parametrizations are added to the box model to represent missing feedbacks (change in temperature due to change in $p\text{CO}_2$, changes in biological production as a function of changes in circulation and biological efficiency, rain ratio, and river input). Parameters values are assessed following the AUTO software program. It is suggested that internal $p\text{CO}_2$ oscillations can arise due to these feedbacks when the AMOC is $\sim 15\text{Sv}$. In principle, such an exploration of parameter space is useful. In addition, since the implemented feedbacks are usually included in more complex models, this set up could help highlight the impact on $p\text{CO}_2$ of these feedbacks. However, I find the paper hard to follow and more importantly I have some concerns with some of the assumptions taken to define the feedbacks in the internal oscillation scheme.

- The major issue relates to the parametrization added that gives rise to the internal oscillation. A part of this oscillation involves changes in the riverine flux of alkalinity as a function of $p\text{CO}_2$ and the other is linked to an increase in temperature due to an increase in ocean alkalinity within 1000 years. What are the reasons behind these parametrizations? I understand that weathering is modulated by $p\text{CO}_2$. However, I thought that this was a slow process, and I don't think that a change in atm. CO_2 should directly lead to a proportional change in alkalinity river influx (within 1000 years). Maybe the oscillations you highlight are relevant for longer timescales, i.e. glacial/interglacial changes in $p\text{CO}_2$. I suggest to carefully read the literature on changes in weathering during G-IG cycles. I can't find a reason for an increase in ocean alkalinity leading to an increase in temperature though (green box at $t=0$ to blue box at $t=T/4$ in fig. 6).
- The paper is hard to follow. A combination of 13×7 experiments are performed. They are labelled with 1 or 2 letters per feedback and numbers for experiments, making it difficult to recall what we are looking at. If more explicit labels were used in Figures 3 and 4, it would help. In addition, there is very little justification/discussion of the different experiments, leading to confusion. The parametrization of the rain ratio feedback is not common. I thought that the largest impact on rain ratio would come from changes in silicifiers, and thus silicate and/or iron concentration in the ocean. L. 278, the authors state that "for low rain ratios, we only have a constant dissolution", which confuses me, as I don't see a link between dissolution and rain ratio in the methods.

- Discussion and implication of the results

The study scans a large range of parameters yielding pCO₂ values of 70-300 ppm, but without really trying to assess physical plausability. For example, in Figure 4, multipliers 0.1-10 are included in the parametrizations, but without much justification. What can the authors deduce from their results? What are the probable ranges?

The discussion needs to put the results back in context and discuss them in light of previous experiments. In the Introduction, the authors cite previous studies that simulated the impact of AMOC changes on the carbon cycle with Earth system models (in which most of the feedbacks explored were included). Can your results help understand better these previous simulations?

Minor points:

L. 41: I am not sure that "not well understood" is appropriate, since a lot of studies have highlighted the impact of AMOC on pCO₂ and the reverse as highlighted in the 2 following paragraphs. It is however a complex interaction.

L 272: Please amend: "Fig. 4a, b is yellow.."

L. 295: What is the meaning of "we continue in the piston velocity"?