

## ***Interactive comment on “The [simple carbon project] model v1.0” by Cameron O’Neill et al.***

### **Anonymous Referee #1**

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O’Neill et al., present a new simple carbon cycle model, mostly focused on the ocean. The model comprises an atmospheric box, 7 boxes in the ocean and 2 boxes for terrestrial carbon. The model also includes a simple weathering parametrization and can be forced by volcanic and anthropogenic emissions of carbon. The manuscript includes a description of the model, as well as a demonstration of the model performances under late Holocene and LGM conditions as well as for the RCP6.0 scenario. Please find below some comments that should be addressed before publication.

Main comment: There is a lot of different topics/issues presented in this paper (e.g. model description and concept, LGM pCO<sub>2</sub> change, partition of carbon under anthropogenic forcing), however I would have liked to see additional information on the model experiments as well as more background information. The model description is incomplete without information on temperature, salinity and the carbon isotopes section should be moved to the main text. Sensitivity studies are performed but the initial set

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of parameters are unclear and the reasoning behind the changes to these parameters is not substantiated, leaving the reader guessing as to why such experiment was performed and figuring out whether the range of parameters studied made physical sense or not.

1) Introduction The introduction focuses on glacial/interglacial variations in atmospheric CO<sub>2</sub>. This is indeed one part of the study, but not only. I would have thought that (at least) the first part of the introduction should be devoted to the reasoning behind setting up such a box model. P1, L.18: Despite years of research, and significant progress, the sequence of events leading to glacial/interglacial changes in atmospheric CO<sub>2</sub> is still poorly constrained. However, I don't think this can be called the "LGM Holocene dilemma". And I think the authors mean "glacial/interglacial" variations and not "interglacial" (here and throughout the text, e.g. p2, L.4). P1, L.22: I am not sure these two references are the best to define the "LGM" P1, L. 26: and to the fact that the terrestrial carbon content was most likely reduced (e.g. Ciais et al., 2012, Peterson et al., 2014). P2, L.2: only the reference to one review (Sigman et al. 2010) is given, while additional references could be given for all the hypotheses cited (at least one per mechanism). Another review could be mentioned: Kohfeld and Ridgwell, 2009.

P2, L.4-11: I would strongly suggest to significantly revise this paragraph, which really does not do justice to the last 15 years of work on the topic of glacial/interglacial changes in atmospheric CO<sub>2</sub>. Many sensitivity experiments and transient simulations have been performed with box models, models of intermediate complexity and OGCMs to understand glacial/interglacial changes in pCO<sub>2</sub>. A few references (non-exhaustive list) include Stephens & Keeling (2000), Toggweiler et al., (2006), references within Kohfeld and Ridgwell (2009), Hain et al., (2010), Tagliabue et al., (2010), Hesse et al., (2011), Bouttes et al., (2012), Tschumi et al., (2011), Chikamoto et al., (2012), Menviel et al., (2012), Ganopolski & Brovkin (2017), Menviel et al., (2017). . . . Many of which (if not all of them) also included a thorough model-data comparison.

On the contrary, I would have liked to see in the introduction more details with respect

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to the rationale of constructing a new carbon cycle box model. P2, L. 25: Please reformulate “extra-ocean” (Please also reformulate header of section 2.4)

2) Model description The model description is incomplete. In section 3, it is stated that the model is forced by SST and SSS, however there is no mention of the treatment of temperature and salinity in the model. There is no description of the parametrization of the carbon isotopes in the main part of the manuscript. Since the manuscript focuses on carbon isotopes, the main formulations have to be clearly laid out. In addition, marine export production is prescribed (p9), but there is little information on the values used, how they were chosen and how they vary in the experiment. Figure 4 could be helpful in that sense: the late Holocene and/or modern day values of all parameters should be clearly indicated in that figure.

Specific comments:

P 3, L. 5-6: “simulates sources and sinks”. Some of these sources and sinks are really simplified, for example anthropogenic and volcanic emissions are a simple prescribed flux into the atmosphere. Weathering and river fluxes are also close to a simple prescribed flux. So, for some it might be more precise to state “includes forcing” than “simulate sources”.

P3, L. 13-15; I am confused by this sentence

Ocean circulation and mixing: Box 4: why is there no exchange with boxes 3, 5 and 7 in equation 1? From the matrix, it looks like there are exchanges with boxes 5 and 7 but not 3, why? Box 1: why no exchange with boxes 2 & 7 in equation 2?

P11, L. 15-17: “around glacial cycles” is not precise enough. In addition, I don’t think this sentence is correct, as changes were opposite in the Atlantic and Pacific Oceans.

3) Modelling results P16, L. 17: Is [CO<sub>3</sub>] approximated by ALK-DIC or fully calculated using ALK, DIC, T, S, P? P16, L.20: please reformulate as “remineralization of organic matter” P17, L. 2-7: Please explain your reasoning behind varying the rain ratio . I don’t

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understand why changing the rain ratio impacts atmospheric D14C and I suppose that the surface ocean pCO<sub>2</sub> change could eventually impact atm d13C, but not “heavily” (L. 6-7). P19, L. 6: Please add “and there is a reduced outgassing of old low D14C waters.” P19, L. 8: please remove “around the interglacial cycles.” And please note that the year of the ref is actually 2008 (Toggweiler, 2008).

P19, L. 9-14: I suppose the authors expect a change in pCO<sub>2</sub> due to the change in ocean area resulting from varying sea-level (and thus ocean volume) on G/IG timescales. Please spell it out. Please take out “volume” on L.9. The impact on D14C is surprising though.

P22, L. 7: This sentence is not correct. Please reformulate. P22, L. 10-14: I don't really agree with this paragraph. It is probably true for simple carbon cycle box model for which all parameters have to be tested and therefore the G/IG CO<sub>2</sub> problem is explored by assessing the impact of each parameters. But, over the last years the G/IG CO<sub>2</sub> problem has also been studied with coupled models providing a representation (granted this representation is associated with large uncertainties) of physical and biological changes occurring during glacial times. P23, L4-6: I am not sure what is meant here or what has been done.

4) Discussion A discussion of the capacity of the model and the results is missing. I would have liked to see a paragraph on why this model should be used. What are its benefits and limitations? Its fast processing time should be discussed there too (instead of the introduction). I would have liked to see the results of the future experiments discussed in the context of the CMIP5 results. Only Jones et al. (2013) and Wang et al. (2016) are referenced for this part. I would have liked to see a discussion of the results of the LGM experiments in comparison with other studies. Recently Muglia et al., (2018 EPSL) studied the impact of ocean circulation and iron fertilization on the LGM oceanic carbon and on its carbon isotopic distribution. Menviel et al. (2016)'s conclusion was also consistent with your conclusion: a slightly weaker AMOC and a weaker global overturning circulation. Among others these two studies could help

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discuss the effects of Z,  $\psi_1$  and  $\psi_2$  shown in Fig. 10.

Abstract: The second part of the abstract focuses on the LGM simulations. I would suggest to tone down that part and instead add some information about the use and limitations of the model.

Minor and typos: P3, L. 10-12: please reformulate P16, L. 29-35: please reformulate this paragraph. P17, L.10: “decreases” P19, L. 19: please reformulate this sentence P19, L. 26: Maybe “appropriate” instead of “accurate”

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