

## ***Interactive comment on “Assessing Carbon Dioxide Removal Through Global and Regional Ocean Alkalinization under High and Low Emission Pathways” by Andrew Lenton et al.***

### **Anonymous Referee #2**

Received and published: 12 December 2017

Lenton and colleagues explored the impacts of different artificial ocean alkalinization (AOA) scenarios on the global carbon cycle, surface temperatures and seawater carbonate chemistry under two contrasting Representative Concentration Pathways (RCPs), namely the “high” (emissions) RCP8.5 and “low” RCP2.6. They used the CSIRO-Mk3L-COAL model in its emissions driven configuration. Each AOA experiment simulated either a global (i.e. 60S-70N) or regional (i.e. subpolar northern and southern oceans (40S-60S; 40N-70N), subtropical oceans (15-40N; 15-40S) and equatorial oceans (15N-15S)) annual addition of 0.25 Pmol of alkalinity into the surface ocean.

This publication aims at answering:

C1

- a) Does the region in which AOA is implemented play a role in the associated (global and regional) response?
- b) Does the state of the climate (mainly driven by the underlying RCP) make any difference in such a response to AOA?

These questions are really interesting and definitely worth studying. In general, their modelling approach is suitable for the purpose. However, I think that the authors still need to work on this manuscript in order to improve the presentation of the results and (even more important) explain them properly. I would not suggest changes in the order of the (sub)sections, but I strongly recommend that the narrative is modified since they are grammatical errors, typos and the current text does not seem to me reader-friendly. I do not find this manuscript ready for publication in its present form. In the following I describe my (major and minor) comments, from which I based my opinion.

Major comments:

Major comment 1: The changes in the land carbon uptake (table 2) in the AOA simulations based on the RCP2.6 are around 4 times higher than those of the simulations based on the RCP8.5. This is an important aspects because the variations in these carbon fluxes determine the final state of the climate. That is why I think that these results should be discussed properly and the cause of this differential behaviour should be explained.

Major comment 2: The statements given between the line 285 and 289 are really confusing. On the one hand, it reads as the temperature change in the RCP8.5 experiment is higher than the one associated with the RCP2.6, which is not what I see in the numbers. And on the other hand, making reference to “potentially reflecting feedbacks” in order to explain this cooling signal does not help to understand the signal. Instead, it confuses the reader. Please explain properly how these feedbacks affect the results.

Major comment 3: The reduction in atmospheric CO<sub>2</sub> concentrations by 2100 associ-

C2

ated with the AOA scenarios under RCP8.5 emissions (app. 84 ppm) is higher than the one associated with the AOA scenarios conducted under the RCP2.6 (app. 40 ppm). Yet, the mitigated warming in the AOA simulations under RCP2.6 is higher than those conducted under the RCP8.5. This is one of the main findings of this publication, however, there is not any discussion/explanation of this result. Only stating what the model delivers is not enough, since it could be a model artefact, the signal might not be caused by AOA, etc. The RCP8.5 and 2.6 scenarios have atmospheres with quite different levels of CO<sub>2</sub>, which might lead to differences in the CO<sub>2</sub>-forcing response to changes in CO<sub>2</sub> levels. Not only that, but also the RCP8.5 and 2.6 scenarios differ in the assumed land use and the sea ice extent by the end of this century. This might also cause changes in albedo and therefore in the cooling response due to changes in forcing.

Major comment 4: Between the lines 325 and 334 an explanation to the differential pH and aragonite saturation state responses between simulations is given. This explanation seems confusing and it refers to the other main finding of this publication. Because of this I think that it requires some supporting figures (which could be added into the supplementary information) and some extra work in order to clarify the message. I suggest to look at the buffer factors and the effects of AOA under the two different DIC/ALK regimes associated with the RCP8.5 and 2.6 scenarios. More information can be found in the paper by Egleston et al. (2010) (<http://onlinelibrary.wiley.com/doi/10.1029/2008GB003407/abstract>).

Minor comments:

L16, L27 and L561: "is capable of" gives the impression that AOA has not real big limitations to be implemented which is not the case, please modify the wording

L18, L19: there are acronyms which the reader might have never seen in the abstract, please spell them out or remove

L25: "lower" and "higher" emissions than what? I think that you meant "low" and "high"

C3

L26: our simulations show that AOA during the period ... ; in any case I do not think that this very last sentence in the abstract is needed

L46: ... could help to ...

L53-54: CO<sub>2</sub> that enters the ocean does not react with seawater to reduce the carbonate ion concentration, please reconsider this statement and use correct grammar

L59: ...changes in calcification...

L60: are you sure that ocean acidification alters nutrient availability

L62: please change order of Munday's cited publications

L69: semicolon needed?

L77: weathering of minerals play a crucial role in modulating the state of the climate in geological timescales, please write an assertive statement

L91: reviewed

L92-95: way too long sentence, please simplify and split it

L98: Did Kohler used one or several models?

L110: ocean only without the hyphen

L110: and they showed

L111: high CO<sub>2</sub> emissions

L114: also concluded that

L115, L118, L131, ...: impacts of

L124: from a high

L126: it would be required

C4

L127: and it would come  
L134: 78 ppm between brackets might look better  
L134: a net atmospheric cooling  
L139: "to be very large" - (very) large in what respect? please clarify  
L141: currently assume (instead of "utilize")  
L141 to L145: way too long sentence, please simplify and split it  
L149: and surface warming  
L149: questions  
L147 to L152: I think that the novelty of this study could be better emphasise. In any case, this last paragraph is crucial and therefore it should be improved since it does not read well.  
L158: extra dot after citations?  
L160, L163, ...: please remove the brackets in those citations which are subjects of the sentences, this occurs several times in this manuscript  
L164 to L166: does this sentences really add any relevant information? Such a feature of the model is basic to conduct this study  
L171 to L172: the land carbon cycle currently has too many uncertainties to state something in such an assertive manner, please consider to modify this or even remove it  
L185: from 2006 onwards, ...  
L186: corresponding to the Representative ...  
L218: Subpolar addition

C5

L232: is seen in 2100  
L233 to L235: if you mention this feature of the modelling tool, please explain the associated consequences for the simulations of AOA  
L242 and L256: "more than compensates" and "more than offset" are really confusing ways of describing the obtained values, please clarify  
L247: 50% instead of 1.5 maybe?  
L253: total ocean uptake ...  
L254 to L258: this explanation reads really confusing, please clarify  
L266: addition studies such as Ilyina ... which demonstrated ...  
L270: 181 PgC is in ... (instead of was)  
L277: I think the authors meant "positive denotes enhanced uptake" (instead of "negative")  
L288: "large" twice in the sentence  
L294: "projected" instead of "anticipated"  
L295: why is this publication here cited?  
L298: standard deviations with respect to what? what is this (1 - sigma)? Please clarify  
L302 to L304: please consider to reformulate these sentences since "variability" might refer to many different things (e.g. inter annual, inter model, model internal, ...). In any case I think that "variability" is not really the term to use since what is described here are differences between simulations.  
L308: mean surface cooling  
L318: What is the point of this statement and citation? The pH and aragonite saturation state correlate really well as I can see in the figures.

C6

L321: despite the return  
L344 and L377: the citation here to Groeskamp et.al. seems unfounded  
L348 and L349: Please elaborate on this so that the reader understand the context, e.g. discuss how this change in pH might (or not) matter, ...  
L380: How can one of the experiments (AOA\_ST) reflect the timescales of the circulation of the subtropical gyres? Please explain this.  
L382: ice covered (instead of "non-ice-free")  
L386: by 2100 (instead of "in")  
L387 and L388: please clarify this, is not understandable  
L404: ...seen in the...  
L421 to L425: please work on the grammar of these sentences  
L442: ... in the ratio ...  
L444: Dot missing  
L445: ... remain poorly...  
L457 to L459: why do you obtain this result?  
L463: remove (SAT)  
L468 to L470: why do you obtain this result?  
L538 to L554: why no figures are shown in this section on seasonality to support this discussion? Also, only AOA is implemented in the summer season under RCP8.5 emissions, which does not seem to me enough to explore the effects of seasonality.  
L560: please remove (COP21)  
L593 to L595: What do you mean? Please clarify this.

C7

L605: double "that"  
L620: mention "preindustrial period" and remove (1850) reads better  
L621: cases (subject?) leads ...  
L633: for the role  
L638: ...therefore it needs ...  
L642 and L645: Earth system (instead of earth system)  
L649: please put "e.g. mesocosm experiments" between brackets  
Please keep an eye on the format in which the references are given and be consistent with it.

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Interactive comment on Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2017-92>, 2017.

C8