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Climate of the Past Discussions

Interactive comment on "Evaluating the Biological Pump Efficiency of the Last Glacial Maximum Ocean using δ^{13}C" *by* Anne L. Morée et al.

Anonymous Referee #1

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Review of "Evaluating the Biological Pump Efficiency of the Last Glacial Maximum Ocean using d13C" by Moree et al.

The authors discussed about the glacial changes in d13C distribution in the ocean by comparing LGM ocean (NorESM-OC model) simulations with proxy data. The model significantly underestimates the glacial d13C changes compared with the proxy data; for example, negative signal of d13C in the deep Atlantic Ocean inferred from the proxy data is not reproduced in the model. At the same time, the model shows the decrease of the ocean biological pump efficiency in the LGM (33%) compared with the PI (38%), opposite to the fact that this is believed to be increased from the proxy data. The authors discussed the response of d13C by artificially increasing the ocean biological pump efficiency. The authors concluded that an approximate doubling of the global

mean biological pump efficiency from 38% (PI) to 75% (LGM) leads to the best-fit of d13C distribution between the model and the proxy. The manuscript deals with an important topic and contains interesting result which contributes to our understanding the glacial changes in the ocean carbon cycle. However, I think that the manuscript needs considerable revision. Followings are my comments about the manuscript, which I think needs to be seriously addressed before its publication.

Major comments

(1) The authors artificially increased the efficiency of the carbon pump at the LGM for their discussion. However, the mechanism behind this increase is not discussed enough in the manuscript. In other words, why do the original NorESM-OC model fail to simulate the glacial increase of the efficiency of the carbon pump? This needs to be more seriously discussed in the revised manuscript.

(2) Related to the above comment, the authors' conclusion "an approximate doubling of the global mean biological pump efficiency from 38% (PI) to 75% (LGM) reduces model-proxy biases the most" appears to depend highly on the reproducibility of their original LGM simulation. For example, the strength of the AMOC in the LGM simulation appears to significantly affect this number: the weaker AMOC tends to increase the efficiency whereas the stronger AMOC tends to decrease it. I request the authors to discuss about the robustness of their conclusion.

(3) I think that discussion about the effect on glacial changes in pCO2 is important. The authors stated that only 21 ppm lowering is found in their original LGM simulation. How much lowering of pCO2 is expected after the efficiency of the carbon pump is doubled in the LGM simulation?

Specific comments

Line15-26 (Abstract) : In my reading, I think that "relative roles of physical and biological changes" is not clearly evaluated in the manuscript.

Line23 (Abstract): The word “theoretical” appears not appropriate. (“potential” might be better)

Line26-35 (Abstract): I think that this sentence (which describes remaining issue and future work rather than the direct conclusion of the study) should be removed or shortened.

Section2.4: This is key section for understanding how the authors control the efficiency of the ocean carbon pump, but I feel that its description is not very clear and difficult to fully understand. For the demonstration, I request the authors to show the Figure of PO4_new after the adjustment by methods 1, 2, and 3, together with PO4_model.

Line28 (page 6): Definition of deltaPCO4(reg) is given at lines 1-4 on page7 but should be described before eqns. (2)-(3).

Line20-26 (page8): The discussion here is not clear for me. What do the authors mean by “the transition line in the PO tracer in Fig.1”?

Line2-28 (page11): The discussions made here are difficult to understand because the information on Bern3D is not given to readers at all.

Line16 (page11): What does deltaDIC stand for? Its definition is missing.

Line29-38 (page11): For the authors’ reference, as for the discussion about O2, Yamamoto et al. (2019, Climate of the Past) discuss the role of glaciogenic dust in glacial O2 changes.

Line12-29 (page12): For the authors’ reference, as for deep water formation processes in the Southern Ocean, Kobayashi et al. (2015, 2018; Paleoceangraphy) discuss about its representation in the OGCM and its potential role in glacial water mass age and ocean carbon cycle. This study appears closely related to the discussion the authors made here.

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