

Phytoplankton calcifiers control nitrate cycling and the pace of transition in warming icehouse and cooling greenhouse climates

Author response to RC2

The authors would like to thank the Referee for their careful reading of our manuscript and thoughtful comments. Our responses are given below. Major modifications to the manuscript text are reproduced in red font.

Review of manuscript: "Phytoplankton calcifiers control nitrate cycling and the pace of transition in warming icehouse and cooling greenhouse climates" by Karin F. Kvale, Katherine E. Turner, Angela Landolfi, and Kathrin J. Meissner

In their manuscript the authors address the question which role phytoplankton calcifiers might play during rapid climate transitions on centennial time scales in affecting oceanic tracer distributions and the marine biogeochemical cycles. Therefore they have employed an Earth system model of intermediate complexity (UVic) which was recently upgraded by implementing coccolithophorides and biogenic calcite as a fully prognostic tracer, which also accounts for the mineral ballast effect. By ramping atmospheric pCO₂ levels up (RU) and down (RD) between 285 and 1257 ppm in their experiments, the model was driven from icehouse to greenhouse conditions and vice versa. The main result of the study is the discovery of a mitigation effect of PIC ballast on several biogeochemical tracers. As an example, in the RU scenario which runs the model from a low CO₂ icehouse to high CO₂ greenhouse conditions, an increasing ballast effect due to enhanced PIC production mitigates changes in export fluxes and prevents the development of augmented oxygen minimum zones (OMZ). The paper is interesting, well organized and clearly written. Therefore, subject to minor revisions, I can recommend publication in Biogeosciences.

General comment: As mentioned in the manuscript, and in contrast to earlier studies, recent literature points towards elevated coccolithophoride production rates under rising temperatures and ocean acidification. However, this is not necessarily the case for biogenic calcification. Keeping temperature, alkalinity and nutrient concentrations fixed, increasing CO₂ concentrations will lead to diminished calcification rates in many of the coccolithophoride species (see Bach et al., 2015). As a result, reduced calcification rates under high CO₂ conditions could counteract the overall stimulating effects on coccolithophorides and weaken the PIC ballasting effect, which then could even lead to a spread of OMZs, as found by Hofmann and Schellnhuber (2009). To my knowledge, UVic does not account for a pH-value (or Omega) dependent calcification rate. Therefore, I would appreciate a short paragraph in the manuscript clarifying this issue.

This is an important point that was missing from the Discussion section. The following has been added (page 11, line 10):

It is important to remind the reader that the UVic ESCM does not currently account for any potential effect of pH or alkalinity on biological calcification. Therefore increases (decreases) in primary production result in corresponding increases (decreases) in calcium carbonate production. This assumption might or might not be valid at a global scale, in which a large diversity of calcifier species are exposed to rapid changes in pH and alkalinity (e.g., Balch 2018, Krumhardt et al 2017, Monteiro et al 2016). How rates of forcing compare to rates of changes to global carbonate weathering might also determine the legitimacy of our assumption (Bach et al 2015). We acknowledge that pH-dependent calcification could lead to different sensitivities that might result in different conclusions than what we find here (i.e., the CAL model would respond to forcing more like the NOCACO3TR model). However, the CAL model does account for thermodynamic dissolution so that CaCO₃ dissolution rates increase with decreasing pH (Kvale et al 2015a).

Minor comments: page 2 line 3 : The sentence “... marine carbon export production is well-established Balch (recently summarized by 2018)” should be rewritten as : “.. marine carbon export production is well-established (recently summarized by Balch, 2018)”

The sentence is changed.

page 7 lines 2 and 3: “ ... suboxic (defined here as below 5 mmol O₂)”; did you mean 5 mmol/m³ O₂ ?

The units are fixed.

pages 18 and 20: The labels on axis of figures 1 and 3 are rather small, please enlarge.

The labels are enlarged.

Page 12 lines 18-21: In the sentence starting with: “The MIXED model shows a slight decline in NPP ...” refers to figure A2, which shows plankton biomass but no NPP. Please correct this mismatch or rephrase the sentence.

The sentence is rephrased.

Reference:

Bach, L.T., et al. A unifying concept of coccolithophore sensitivity to changing carbonate chemistry embedded in an ecological framework. Prog. Oceanogr. (2015), <http://dx.doi.org/10.1016/j.pocean.2015.04.012>