

Interactive comment on “Calibration of key temperature-dependent ocean microbial processes in the cGENIE.muffin Earth system model” by Katherine Anne Crichton et al.

Anonymous Referee #1

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General comments:

This study adds temperature dependency to the GENIE EMIC biological export and remineralization parameterizations, calibrates key parameters against observational data, and compares model biological pump characteristics and behavior to the previous temperature-independent version. Temperature dependency slightly improves the model against data but produces significant changes to transient behavior of the biological pump in response to warming. The application of temperature dependency for ocean biological processes in earth system models is generally recognized to be important, but updating the current suite of models already in use takes time and effort.

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This paper quantifies the importance of temperature dependency over the historical time period since 1700 for one of the more popular EMICs and is therefore relevant for GMD. The study is not a substantial advance, but uses valid methods and proposes an elegant parameterization that could be applied to other models, as well as having potential interesting further applications in GENIE. The results support the interpretations, although some of the conclusions should be reconsidered (see below). The material is presented clearly and in a reproducible fashion and the model code has been made available.

Specific comments:

Figure 2 highlights a key opportunity that has been overlooked in this study, which is that the fractional assignment of export to the DOM pool could easily be made temperature-dependent, and that would implicitly represent temperature-dependent fast recycling processes in the upper ocean. The authors should discuss why this parameter was not included in their calibration.

Application of temperature dependency to export and remineralization will have also affected turnover in the DOM pool, but this is never discussed or shown in the manuscript.

There are some relevant references missing from the manuscript:

In the Introduction:

Schmittner et al. 2008, GBC doi:10.1029/2007GB002953 Introduced a temperature-dependent remineralization parameterization to the UVic ESCM. The Hülse paper referenced in the present manuscript was not correct in that there is temperature-dependency in the interior ocean biological pump in the UVic ESCM (see Schmittner et al. 2008, equation A16). Unless explicitly stated, every UVic ESCM ocean carbon study since Schmittner et al., 2008 has used temperature-dependent remineralization (the rate of remineralization is temperature-dependent, while the sinking rate of detritus is depth-dependent), as well as a temperature-dependent microbial loop and

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temperature-dependent primary production and mortality, and since:

Keller et al. (2012) doi:10.5194/gmd-5-1195-2012 temperature-dependent zooplankton growth and grazing.

In Section 2, page 4, lines 103-110:

Kvale et al. 2015, ERL doi:10.1088/1748-9326/10/7/074009 This study explored the sensitivity to the NPP:respiration ratio and export efficiency response in a warming scenario to the application of mineral ballast in the UVic ESCM. The effect on export from ballasting inhibiting temperature-enhanced remineralization is arguably not secondary.

Kvale et al. 2019, BG /10.5194/bg-16-1019-2019 This study extended Kvale et al. 2015 to look at biological pump response to warming from an icehouse to a greenhouse state, and cooling from a greenhouse to an icehouse state. It demonstrates steady-state nutrient storage in warmer and cooler climates is counter to what is proposed in the Summary section for reasons of circulation.

In the Summary (or Introduction): Löptien and Dietze (2019) BG 10.5194/bg-16-1865-2019 This study demonstrates the increasing sensitivity of an earth system model to temperature-dependent biological processes and compensatory model tuning with warming.

Technical corrections:

P2L49: "homogenizing the ocean interior"

P2L51: What does "mean" mean in this context? Annual mean? Global mean is a crude approximation, after all this study adds local temperature effects.

P3L75: "However, higher temperatures lower CO₂ solubility. . ."

P3L78: "reduced"

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P3L80: "temperature"

P3L91: ". . .but is not employed. . ."

P6, Equation 5: Please either rename A or make it clear on this page that the value is different than the A in Equation 4.

P7L89: Meyer et al. (2016) prescribed several e-folding depths, which approximates, but is not the same as, temperature dependence in export

P7L197: "dominates export"

P7L198: "nutrient" should be "PO₄"

P7L201: please give units for V_{max}

P8L246: "low latitude"

P9L250: the North Pacific subsurface temperature profile is over-estimated in GENIE according to Fig 4, please correct this sentence

P9L256: What are the lowest RMSE for CB and CBRU?

P9L261: "nutrient" should be "PO₄"

P9L268: My understanding is the models are also tuned to O₂ (from P9L253-256)

P9L272: ". . .the Southern Ocean. . ."

P10L285: "circulation difference" should be "circulation control" or "circulation dominance"

P12L345: "the observed CO₂ transient" is awkward phrasing

P12L375: what is the Eastern Tropical North Pacific?

P13L380: "tropical POC"

P13L380-381: DOM cycling is also changed

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P13L392: “nutrient” should be “PO4”

P13L393: remove “in some way”

P13 Summary: Please see Kvale et al. 2019 BG /10.5194/bg-16-1019-2019

P19, Table 2 can be cut at no detriment to the manuscript. ‘CB’ and ‘CBRU’ are defined too late in the manuscript and the naming includes an extra (confusing) reference to BIOGEM. I suggest omitting the Table and renaming the simulations to something more descriptive, like ‘Temp’ and ‘NoTemp’, since all models contain ‘Remineralization’ and ‘Uptake’.

Table 3, Figs. 5 and 11: parens missing on Ea(1)

P20, Figure 1 can be cut at no detriment to the manuscript.

P21, Figure 2 caption: is “mixed player plankton” supposed to read “mixed phytoplankton”? Please add a key to clarify what dashed/solid/thick/thin lines, and shading, represent. Why is burial shown if there are no sediments? Should “nutrients” be PO4 (only PO4 in this model)? Why are autotrophic respiration/heterotrophic respiration/consumers shown if they are not included in the model?

P23, Figure 8. I see why the figure is normalized (the point made on P9L275), but normalization is misleading (small differences of low concentrations appear to be significant). The figure would be more informative presented without normalization, but the above point can still be made in the text.

Interactive comment on Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2019-344>, 2020.