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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 #2

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General comments This study presents the importance of modeling temperature-dependent microbial processes in the existing EMIC, evaluates the model performance using multiple tracer variables, and discusses the impact of the modified processes on marine carbon cycling under changing climates. The study employs a sophisticated approach for joint parameter tuning and shows that temperature-dependency introduces a significant difference (improvement) in biological pump efficiency estimates. Redeveloping a global biogeochemical model takes time and effort, and there is a limit to increasing complexity in the model due to computational- and data validation issues. Yet, this study presents significant findings by modifying the existing nutrient uptake and remineralization schemes without adding temperature-dependency into all differ-

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Discussion paper

ent levels of biological processes and trophic interactions. Overall, the model experimental design is constructive, and the manuscript is well-written, easy to understand, and relevant for GMD.

Specific comments Section 4.4 (line 308-315) and Figure 11 provide mechanistic insight into why CBRU results are different from CB results via the effect of model parameter variation on the model output. Though automated data assimilation or parameter optimization was not conducted in the study, the best parameter set that consists of Vmax, rPOM, and Ea(1) was indirectly determined based on the model-observation correspondence of multiple tracer variables. Compared to Vmax and rPOM, Ea(1) drives a much larger variation in POC export ($\sim$7 kJ/mol increases of Ea(1) drives $\sim$13 GtC/year decreases of POC export). Under higher Ea(1) values the sensitivity of POC export to Vmax and rPOM decreases, and Ea(1) higher than 54 kJ/mol might not be the "right" parameter value. At Ea(1) of >54.5 kJ/mol POC export becomes lower compared to the non-temperature dependent model. This could be concerning given that a small variation of the Ea(1) value ($\sim$0.5 kJ/mol) results in completely opposite patterns compared to the findings of the study, i.e., the temperature-dependent model simulates lower POC export than the non-temperature dependent model. The uncertainty related to this finding does not come across clearly and should be discussed. Also, it does not seem necessary for circles to be color-coded to reflect different rPOM in Figure 11.

In Introduction, in relation to "A deeper mean remineralization depth equates to a more "efficient" biological carbon pump" it would be good to calculate the remineralization depth as an additional measure of the biological pump efficiency from the model simulations. This could be helpful for cross-comparison with other modeling studies focused on the biological pump.

In Section 4.1 (line 244-251), it is discussed that cGENIE underestimates surface stratification and overestimates winter-time deep mixing due to an overly-strong AMOC in the physical circulation scheme of the model. The amount of phosphate returned to the surface is a function of deep mixing that increases organic matter production there,

and this would not be modeled well if the model underestimated surface stratification. Uncertainties in the warming scenario results should be discussed.

Technical comments In line 310, “measured” should be “simulated” or “modeled”

In Figure 2, the processes shown are not correct. Microbial (heterotrophic bacterial) respiration is also part of heterotrophic respiration (heterotrophic respiration = zooplankton respiration + bacterial respiration) and also occurs in the euphotic zone. The current schematic makes it look like microbial respiration is a separate process from heterotrophic respiration.

In Figure 12, Data “from” Mouw et al. 2016a.

In Figure 13, Please consider putting a global uniform value for POC transport efficiency in CB next to the CBRU plot, instead of presenting the stand-alone CB plot.

In all Figures, increase font size for better legibility as figure quality is currently poor; and use constant symbols in vertical profile figures for data, CB, and CBRU comparison.

In Table 1, “eqn” to “equation” here and throughout the manuscript, and it is better to say what the difference in each reference is in the first column rather than simply attaching references.

In Table 2, “x” to checkmark or “v” as it seems to indicate that the thing with “x” mark was not included in the study. “Standard model” to “non-temperature dependent model”.

In Table 3, “variable” in the first column to “parameter”

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