

We thank two anonymous reviewers for their valuable comments on our revised manuscript entitled “Physiological flexibility of phytoplankton impacts modeled chlorophyll and primary production across the North Pacific Ocean”. Our response to each reviewers’ comment are as follows:

### **Comments to the author:**

Response to Reviewer #1

#### **Referee #1**

**In my opinion, the revised version of the manuscript \*Physiological flexibility of phytoplankton impacts modeled chlorophyll and primary production across the North Pacific Ocean\* [egusphere-2022-91] solved the major concerns and accounted for the criticism raised during the first round of revisions. I appreciate the effort of the authors to answer all my questions and clarify all doubts. In this round, I read again the manuscript and collated a list of minor suggestions below. One of the suggested edits ---to split the Results and Discussion section--- resulted in a thorough Results section but a very short Discussion. I think the authors have the opportunity to further comment and clarify their results and frame them in the wider context of BGC modelling efforts nicely described in the introduction and to comment on the relative importance of photoacclimation vs alternative mechanisms in shaping the DCM. My recommendation is thus to conduct a minor revision.**

We thank Reviewer #1 for valuable comments on our revised manuscript. The discussion section has been expanded as pointed out by the reviewer #1. Our response corresponds to each comment.

#### **\*Minor comments\***

**L001 - change ", and hence biomass responds to changes in" to varies with"**

Line 1: We changed from “... change ...” to “... to vary with light and nutrient ...”.

**L002 - "... capture \*variable chlorophyll:carbon ratios due to\* photoacclimation, i.e. ..."**

Line 2: We revised "... capture variable chlorophyll:carbon ratios due to photoacclimation, ...".

**L007 - recurrent, but why not just call it control model, constant PFT model or similar? [fixedPFT?]**

Line 7: We revised from "an inflexible control model (InFlexPFT)" to "an inflexible phytoplankton functional type model (InFlexPFT)". We removed "control" after "inflexible" in the body text.

**L013 - "yields faster growth rates \*that result in\* high Chl ..."**

New Line 14: We revised "... yields faster growth rates that result in high Chl ...".

**L018 - add concluding statement with implications for future studies and/or message to the ocean bgc community?**

New Lines 19-20: We added "These implications suggest improvement of chlorophyll and primary production patterns in the near-surface ocean in future biogeochemical models." after "... nutrient-(uptake) limitation."

**L086 - standard NPZD instead of inflexible?**

It only explains inflexible or flexible for phytoplankton growth rate equation. Most NPZD models only assume a fixed C:N:Chl ratios, not necessarily "inflexible" models.

New Line 88: We revised from "inflexible phytoplankton control model" to "inflexible phytoplankton functional type model".

**L164 - outline the tuning procedure?**

The biological parameters in Table 1 are changed and simulated to confirm the reproduction of the climatological observed distribution of N (WOA18) and Chl (Satellite), and the biological parameter values are determined.

New Lines 167-168: We revised "... for the phytoplankton growth rate were tuned, separately for each coupled model, to confirm the reproducibility of the climatological seasonal variability of observed N, and Chl patterns in the near-surface of North Pacific."

**L171 - reproductivity? [I did not understand the sentence]**

We removed this sentence after "... Chl concentration across the whole gyre."

**L185 - perhaps motivate a bit more why you focus on climatological patterns rather than point estimates (i.e. interest on large scale variation rather than short term noise, etc). In principle nothing precludes a direct comparison aligning model output with satellite data.**

New Line 188: We added "to investigate the large scale variation over the North Pacific." after "The last 20 years ... and the climatological data (Chl, nitrate, and temperature)".

**L190 - Ocean color data can be cited using a DOI; e.g. see [this website](<https://oceancolor.gsfc.nasa.gov/citations/>)**

New Line 194: We changed data citation site "http://doi.org/10.5067//AQUA/MODIS/L3M/CHL/2022" and added it in data availability and acknowledgment sections.

**L225 - Active voice? [Figure 1 shows ...]**

New Lines 228-229: We revised "Fig.1 shows the surface Chl distribution ... .".

**L238-L241 - Please simplify; in my opinion it would be ok to just highlight that FlexPFT results  $\chi_{\theta} / Q$  ratios in 0.1-3.0 \*vs\* the fixed value of 1.59 in InFlexPFT.**

New Lines 243-244: We revised "... the difference between the FlexPFT's variable Chl:N ratios in 0.1 to 3.0, versus the fixed value of 1.59 in the InFlexPFT..".

**L247-L251 belong to discussion**

We moved these sentences in discussion section (New Lines: 436-440).

**L269 - better, ok, but how much better?**

New Line 266: We added “, especially, the depth and structure of SCM.” after “... Chl distribution much better than the InFlexPFT”.

**L280ff - please detail the nature of the figures provided, if they refer to a specific season, etc. It would be helpful to quote some integrated figures too, like those provided in the response letter. Quantities like the fraction of PP accounted for by the DCM and the thermocline are also of interest.**

New Lines 282-284: We added “In summer (Figs 2 and 3), the SCM is clearly formed in the subsurface layer except for the subpolar gyre (north of 40N). The vertical distributions of PP and phytoplankton growth rate form maxima along the nutricline depth.” after “... whereas it is constant for the InFlexPFT.”.

**L415 - subpolar [typo]**

Line 415: Yes, it's a mistake. We corrected “subpolar”.

**L419 - it would be nice to quote here other estimates, or to mention them in the discussion ...**

New Lines 421-423: We added “Although not directly comparable to our estimates, the global primary production as estimated by the satellite and global biogeochemical models remains large: from 38.8 - 42.1 PgC yr<sup>-1</sup> over the period of 1998 - 2018 (Kulk et al., 2020) and from 38 - 79 PgC yr<sup>-1</sup> (Carr et al., 2006).” after “... in the North Pacific basin ... twice that of the InFlexPFT.”.

**L431 - please expand a bit ... e.g. [Moeller 2019](<https://doi.org/10.1038/s41467-019-09591-2>) light dependent grazing, [Wirtz 2022](<https://doi.org/10.1038/s41558-022-01430-5>) motility ... and a long etc. As commented above, there is room to improve the discussion, even by moving some materials from results.**

New Lines 436-446: We revised and added “It is impossible to capture the vertical profiles of Chl with satellite observations, and it is therefore important to verify the SCM field reproduced by the model using in-situ observations (e.g., Shulenberger and Reid, 1981, Furuya 1990). Using a 3-D biogeochemical ocean model coupled with the same FlexPFT model, (Masuda et al., 2021) showed that the observed global scale SCM distribution can be reproduced by incorporating photoacclimation in response to varying nutrient and light conditions. Various mechanisms likely contribute differently in different oceanic regimes and other mechanisms are important for reproducing specific features of SCM (e.g., Moeller et al., 2019, Wirtz and Smith, 2020). Moeller et al. (2019) proposed a new mechanism, which is light-dependent grazing by microzooplankton reduces phytoplankton biomass near the surface but allows accumulation at depth, for SCM formation. Furthermore, vertical migration by phytoplankton can explain the occurrence of SCM consistently above the nutricline depth, which photoacclimation alone cannot (Wirtz and Smith, 2020). Wirtz et al. (2022) also suggested that phytoplankton vertical migration fuels up to 40 % ( $>28 \text{ tg yr}^{-1} \text{ N}$ ) of new production and directly contributes 25 % of total oceanic net primary production (herein estimated at  $56 \text{ PgC yr}^{-1}$ ) using their model.” after “... nutrient and light conditions.”.

**L452 - please remember the comment about featuring a concluding statement in the abstract**

We added “These implications suggest improvement of chlorophyll and primary production patterns in the near-surface ocean in future biogeochemical models.” in abstract (New Lines 19-20).

**L470 - please check whether it is possible to cite those dataset using a DOI**

We could not confirm a DOI. Web site is only.

**L481 - if there is a single  $k$  then it is just one coefficient, and the question is whether it is sensible to assume similar diffusion in the vertical and the horizontal; otherwise, if there is a  $k_{x,y}$  that differs from  $k_z$  please update the notation ...**

New Line 489: We revised “ $K_h$  is the lateral diffusion coefficient and  $K_v$  is the vertical diffusion coefficient in the OFES2, ...” .

**L489 - please comment on the need to include a linear respiration term and, especially, a quadratic mortality term ... as highlighted in the first round, the formulation is a bit conterintuitive or nonstandard ...**

The NPZD model used in this study is constructed based Sasai et al. (2016) “Coupled 1-D physical-biological model”, and it differs from the widely used NPZD model. A linear respiration term may not have been necessary for our study, but it is left as is because it has a smaller effect than the other terms. By using quadratic mortality equations of phytoplankton and zooplankton, the 3-D NPZD model simulation can be stabilized (do not generate unforced oscillation) in low-concentration regions (e.g., subtropical gyre and below the euphotic layer). In the future, we will verify the uncertainty of each biological processes.

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Response to Reviewer #2

**Referee #2**

**The updated manuscript "Physiological flexibility of phytoplankton impacts modeled chlorophyll and primary production across the North Pacific Ocean" by Y. Sasai and colleagues highly improve the clarity and readability of the manuscript. However, I have found several grammatical mistakes and incomplete sentences that should be looked at before submission. The authors have responded to my reviewed concerns, and I am happy to recommend this manuscript for acceptance with minor revisions, as it provides valuable results that are important for the future implementation of plankton community models. However, authors should go over the manuscript and correct any grammar mistakes.**

We thank Reviewer #2 for valuable comments and English grammar checks on our revised manuscript. Our response corresponds to each comment.

**Minor comments:**

**L80 – remove “of”**

New Line 81: We removed “of” between “Most” and “biogeochemical models”.

**L80 – add “a” after have**

New Line 81: We added “a” after “have”.

**L80 – change food-web to “food web” to be consistent with how you write it in the introduction**

[L23]

New Line 81: We changed “food web” to be consistent with previous sentence [New Line 24].

**L81 – “dissolved” instead of dissolve**

New Line 82: We revised “dissolved”.

**L94 – replace “the” to “a” before physical ocean model?**

New Line 95: We replaced “a” before “physical ocean model”.

**L95 – replace including to “that includes”**

New Line 96: We replaced from “including” to “that includes”.

**L104 – add “the” after performing and before coupled**

New Line 105: We added “the” after “performing” and before “coupled”.

**L125 – specify what “Its” is referencing.**

New Line 126: We revised from “Its” to “The phytoplankton growth rate equation”.

**L161 – add “the” after is and before potential uptake rate**

New Line 154: We added “the” after “is” and before “potential nutrient uptake rate”.

**L409 – “Because the nutricline depth ...” is not a full sentence, please correct.**

New Lines 394-395: We revised “In this region, the nutricline depth ...”.

**L415 – “,” after 9c**

New Line 400: We added “,” after “(Figs. 9c”.

**L430 – correct suporal to “subpolar”**

New Line 415: We corrected “subpolar”.

**L450 – remove comma before and**

New Line 440: We removed “,” before “and other mechanisms ...”.

**L452 – remove space after Smith**

New Lines 444-445: We removed space after “(Wirtz and Smith)”.

**L457 – change its to it**

New Line 451: We changed from “its” to “it”.

**L457 – add comma after nutrient**

New Line 451: We added “,” after “nutrient”.

**L462 – “With respect to food ...” this is not a complete sentence. Please correct.**

New Lines 456-457: We corrected “This may be important with respect to food quality effects (e.g., Kwiatkowski et al., 2018; Mastsumoto et al., 2020)”.

**L478 – add comma after future**

New Line 471: We added “,” after “future”.

**L482 – comma before “and recycling”**



New Line 475: We added “,” before “and recycling”.