Berthet et al. – How does the phytoplankton-light feedback affect marine N2O inventory?

Summary

The phytoplankton-light feedback (PLF) is the mechanism defining the absorption of short-wave radiation by phytoplankton in the ocean. This mechanism affects the distribution of light in the water column and thus the oceanic temperature. As a consequence, the oceanic heat content and the sea-air gas fluxes are affected, altering the whole climate system.

This paper presents simulations with a complete or incomplete representation of PLF and describes ocean physics and biogeochemistry accordingly. To answer this question, the authors use an Earth system model with oceanic, sea-ice and marine biogeochemical components only. What is novel and interesting is that (1) depending on the representation of PLF, the climate system can be highly modified, and (2) simulated N2O budget are highly uncertain. I believe that this study deserves to be published and provides implications for future climate models development. However, before accepting this manuscript, I think that there are some aspects that could be improved. Especially the description of the model setup and the description of the processes explaining the results. I may have misread some things but I hope that the following comments will help the authors to improve their manuscript.

Major comments

Section 1

The authors seem to say that a consensus exists on the effect of PLF on the thermal structure of the ocean (line 96-102). However, several studies report an increase in SST due to PLF (e.g. Oschlies, 2004; Anderson et al., 2007; Lengaigne et al., 2009) while others report a cooling of the surface of the ocean (e.g. Nakamoto et al., 2001; Manizza et al., 2005; Löptien et al., 2009; Paulsen et al., 2018). So far, no consensus exists but the cooling effect reported in these studies might be due to the non- or weak coupling between the oceanic and atmospheric components of the models (Tian et al., 2021).

Section 2.a

I understand that model configuration has already been described in Berthet et al. (2019) but it would be appropriate to give more explanation on the model configuration for the readers not familiar with Berthet et al. (2019). For instance, what is the vertical resolution of the oceanic grid? What is the depth of the first oceanic layer? Is phytoplankton simulated only in the first oceanic layer or can they go further down the water column? Additionally, I couldn't really understand the description of the simulations from the text. However, from Fig.1 it is clear that the authors run a spin-up for 2000 years and then run their simulations for 18 years only. In total, they run their model for 2018 years. Is the model in steady state? Maybe the authors should also state that their results are the average of the last 10 years of the simulations. In their simulations, do they prescribe the atmospheric CO2 and N2O concentrations or do they prescribe atmospheric CO2 and N2O emissions? Does the

ecosystem modelled consider only bulk phytoplankton or does it consider also e.g., cyanobacteria, diatoms? Is phytoplankton growth limited by light, nutrient and temperature? I think it would also be good to give the absorption coefficients used to parameterize PLF or directly give the equation of PLF.

Section 2.b

The paragraph line 240-252 would better fit in the introduction.

Section 3.a

I would suggest to put the chlorophyll maps in the results section rather than in appendix because it helps to understand to results. Especially, PLF affects the OHC via chlorophyll concentration so it might be easier to follow and easier to understand if the chlorophyll concentration maps are directly in the results section.

Furthermore, it seems that the authors use their two simulations with incomplete representation of PLF (chl_zcst and chl_zvar) as upper and lower limit of their uncertainties (line 403-405). I wonder why they think that? Do they consider that chl_zcst is a simple simulation giving the minimum OHC300 while they consider chl_zvar as a complex simulation (close to reality) giving the "real" OHC300? And that chl_inter is somehow fluctuating between these two simulations?

Section 3.b

As in Sweeney et al. (2005), the authors state that small changes in chlorophyll concentration drives important changes of the mixed layer depth in the subtropical regions (line 447-453). However, they do not explicitly explain what are the mechanisms behind these changes in MLD. Is it due to PLF? What is the link between chlorophyll and MLD? I think what the authors want to say is that changes in chlorophyll drive changes in temperature via PLF, which in turn drives changes in thermocline/pycnocline and thus in MLD.

The authors state that the decrease/increase in N2O concentration is driven by different mechanisms depending on the region studied. For instance, the decrease in N2O concentration in the South Pacific is due to increased temperature, enhanced circulation and deepening of the pycnocline. But in the North Atlantic the increase in N2O concentration is only due to the shoaling of the pycnocline. Additionally, in the North Pacific, the decrease in N2O concentration is due to the higher O2 concentration. Why do we have different mechanisms involved at different places of the world? For instance, why does O2 concentration is important for the North Pacific region but not for the North Atlantic or South Pacific regions?

Section 4

In conclusion, the authors detail some results about oxygen without showing them previously. I think they should talk about these results in the result section rather than showing them suddenly in the conclusion section.

Furthermore, the authors should also discuss the fact that their model setup does not consider an atmospheric component. Do they expect similar results if they use a coupled ocean-atmosphere model rather than using an atmospheric N2O and CO2 forcing? For instance, Asselot et al. (2022) show that PLF affects the climate system mainly via sea-air greenhouse gas fluxes. Adding an interactive atmospheric component could therefore lead to higher greenhouse gases in the atmosphere, increasing the atmospheric temperature. The higher

atmospheric temperature might increase the oceanic temperature and thus enhance the effect of PLF on N2O fluxes.

Specific comments

Line 17: Replace “thanks to” by “by”.

Line 22: Replace “experiments” by “simulations”.
This comment is valid for the entire manuscript.

Line 23: Replace “have been performed” by “are performed”.

Line 34-35: Replace “shine a light on a current uncertainty of the modelled marine nitrous oxide budget in that climate models.” by “shine light on current uncertainties of modelled marine nitrous oxide budget in that climate model.”

Line 41: Replace “suffers” by “undergoes”

Line 43: Replace “uncertains the forecast” by “leads to uncertain forecast”

Line 92-94: The authors state that “Two main causal chains have been proposed to interpret the sign of the final heat perturbation” but they do not give these two causal chains. Furthermore “causal chains” could be directly replaced by “causes”.

Line 132: I guess the authors are speaking about atmospheric emissions here.

Line 132: Which decade?

Line 136: Replace “model marine” by “simulate marine”

Line 157: Parameterization.

Line 202-203: Rephrase please

Line 213: Replace “biogeochemical element cycling” by “biogeochemical cycles”.

Line 325: Replace “by the Ifremer” by “by Ifremer”.

Line 332-337: The authors compare their modelled temperature and oxygen with several database. Is it shown somewhere? In figures or appendix?

Line 388-392: I cannot say what the authors mean with these two sentences.

Line 393: green on Figure 1?

Line 394: directly use OHC300 as it is previously used.

Line 400: blue on Figure 1?

Line 427: Replace “modifying” by “different”.

Line 442: Replace “raising” by “shallowing”.

Line 445-447: “Over these … the pycnocline” please rephrase.

Line 460: Replace “upper line” by “upper panel”.

Line 466-469: Please rephrase.

Line 474: Replace “By contrast” by “In contrast”.

Line 484: Remove “next”.

Line 484-486: “Approaching … heat uptake” please rephrase.

Line 500: Should be section 3.c rather than section 3.d

Line 502: Replace “the degree of realism of the PLF” by “the way PLF is simulated/modelled”.

Line 504-507: Please rephrase because it seems that you consider that Dpn2o anomalies reflect only differences in surface N2O concentration while Dpn2o anomalies can also reflect differences in N2O solubility.

Line 512-513: Are the units atm or natm?

Line 548: Remove “and”.

Line 551: Replace “add” by “added”.

Line 552: Remove “, and”.

Line 552: Remove “with time”.

Line 556: Replace “their” by “a”.

Line 591: Replace “so why it used” by “that is why it uses”

Figure S4: I don’t understand how densities (y-axis) can be negative. Is it a density anomaly represented?

Figure 3a: The colorbar can be improved.

Thank you for considering my input to your research.
Rémy Asselot

References

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