

Biogeosciences Discuss., referee comment RC2
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Comment on bg-2021-320

Anonymous Referee #2

Referee comment on "Diazotrophy as a key driver of the response of marine net primary productivity to climate change" by Laurent Bopp et al., Biogeosciences Discuss.,
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This study by Bopp et al. investigates how changes to N₂ fixation affects NPP in a suite of climate model simulations (IPSL) with PISCES biogeochemistry under historical and future warming scenarios. They simulate 5 different model versions, 4 of which apply different formulations for biogeochemistry, most notably N₂ fixation, and 1 simulation with different ocean physical circulation and resolution. The simulation with higher resolution (IPSL-CM6A) did not significantly affect N₂ fixation compared to the simulation with similar biogeochemistry and lower resolution (PISCES-v2) so they mainly focused this study on the differences in N₂ fixation parameterizations.

They implemented a variety of different N₂ fixation parameterizations including phosphorus limitation, temperature-dependent growth, elemental stoichiometry, and underlying biogeochemistry (the latter not well described in the paper). Their model simulation with a strong increase in N₂ fixation (PISCES-v2) caused a strong increase in NPP, whereas the other simulations with a slight increase or decrease in N₂ fixation projected a decrease in NPP throughout the 21st century. They focus on a region in the western tropical North Pacific to better understand the mechanisms responsible for the difference in these simulations. The one clear driver for driving the high N₂ fixation rates in PISCES-v2 was the exponential temperature-dependence growth rate, whereas the PISCES-quota simulations using the Breitbarth et al. 2007 bell-shape reduced diazotroph growth rate at high >26°C temperatures.

Overall I think this is a fine manuscript that highlights the importance of N₂ fixation on NPP, which is often neglected or not analyzed in model simulations. Another aspect I liked was how the authors distinguished between NPP and phytoplankton biomass instead of only focusing on NPP like most studies. My one major issue with the manuscript is the insufficient description of which processes are causing N vs. P vs. Fe limitation and thus driving the N₂ fixation response in the different biogeochemistry model simulations, but this can be addressed in revisions. This information is included in some of the references, but given the emphasis on N₂ fixation in the paper I think some additional details should be included and discussed in this manuscript as well.

Major Comment

The one critical issue I do not understand in this study is why N₂ fixation in IPSL-CM5A-LR does not increase more similarly to IPSL-CM6A-LR. Since they have the same temperature-dependent growth rate, the authors state this is "due to the Ln term (limitation of excess inorganic nitrogen)" (line 339). However, all N₂ fixation parameterization contain this Ln term (Figure 2). Why does Ln only decrease in IPSL-CM5A-LR and not any of the other simulations?

My guess is that it is caused by some changes in the underlying biogeochemistry (e.g. iron limitation or denitrification), which is only mentioned in one brief sentence in the description section 2.2 (lines 143-145) and not further discussed. The processes that contribute to the decreasing Ln term in IPSL-CM5A-LR but not the other simulations should be described and discussed to understand these results presented here.

Minor Comments:

Lines 144-145: "... external sources of nutrients and the treatment of water-sediment interactions"

Following my comment above, these processes can significantly impact N₂ fixation rates. While I understand they are described in previous papers, the important processes controlling N₂ fixation in these simulations presented here should be described and discussed.

Line 155: "... phosphorus is added to the phosphate pool"

I thought diazotrophs are responsible for consuming PO₄ and DOP to very low levels e.g (Mather et al., 2008), not providing a source. These fluxes are generally small among the entire circulation-biogeochemical system so it is likely not significant, but I am concerned

that this PO4 source could be supporting additional NPP in an unrealistic way.

Line 158: "... annual restoring of global mean PO4 concentration ..."

I am surprised to see a PO4 restoring term in a prognostic climate model. I assume this is applied only during the spin-up and not historical/future projections? Does this occur at all depths?

Line 306: "The regional changes changes of NPP resemble those simulated in IPSL-CM5A"

Is this also true for N2 fixation?

Lines 307-309: "... differences between PISCES-quota and two other offline simulations originate from the major developments in PISCES-quota such as variable C:N:P stoichiometry and the inclusion of a third phytoplankton ..."

This comes back to my major comment. It is interesting that newest (PISCES-quota) and the oldest formulation presented (PISCES-v1 in IPSL-CM5A-LR) give very similar projections of changes to NPP and N2 fixation (Figure 5a,b), despite their large differences in biogeochemical model structure/parameterizations, whereas the in-between version (PISCES-v2) shows a significant difference. I would be interested to know which changes mainly contributed to the large increase in N2 fixation and NPP and PISCES-v2 compared to v1.

This statement specifically mentions stoichiometry and the additional phytoplankton type, but I thought it was pretty clear that the change in temperature-dependent N2 fixation growth rate was responsible for these decreases in N2 fixation and NPP in PISCES-quota compared to v2 as described in the following section so I am confused by this statement. Please describe how variable C:N:P stoichiometry and a third phytoplankton class causes higher N2 fixation because this is not clear. I think this emphasizes the need to better

understand the key processes causing the N₂ fixation differences in the different simulations.

Mather, R. L., Reynolds, S. E., Wolff, G. A., Williams, R. G., Torres-Valdes, S., Woodward, E. M. S., Landolfi, A., Pan, X., Sanders, R., and Achterberg, E. P.: Phosphorus cycling in the North and South Atlantic Ocean subtropical gyres, *Nature Geoscience*, 1, 439-443, 10.1038/ngeo232, 2008.