Response to egusphere-2024-123 RC2

Below is our response to RC2. Referee #2's comments are in **bold**. Our responses are in black. Changes to the manuscript are indicated in blue. The line numbers refer to the previously submitted manuscript without track changes.

This manuscript describes the improvement of an Earth system model by incorporating benthic denitrification, highlighting the importance of benthic denitrification in shaping the global distributions of NPP, N2 fixation, oxygen, etc. In addition, the authors conducted a large ensemble of simulations and applied the Latin-hypercube sampling method to choose the model parameters. The simulation identified that the N* is an essential parameter to calibrate the model, which has an important implication for future model calibration. Overall, the manuscript was well-written and organized, and the references cited are up-to-date and appropriate. I recommend publication after making the following clarifications and modifications.

We thank Referee #2 for the positive feedback.

I'd like to see more discussion on the pattern of N2 fixation. Currently, the distribution patterns in the S. Pacific and N. Indian Ocean (Fig. 4a) seem not correct to my eyes. What causes such distribution, is there anything to do with benthic denitrification?

We agree that our model may underestimate N_2 fixation rates in the South Pacific and N. Indian Ocean (Fig. 4a). However, it is unlikely that the underestimation stems from benthic denitrification, since the differences between new simulations with no_bdeni (Fig. 4b-d) indicate there is no strong pattern shift in these basins compared to the changes in other subtropical regions. We suspect there are two different dominant processes that contribute to the underestimation of the N_2 fixation rates at these two basins separately.

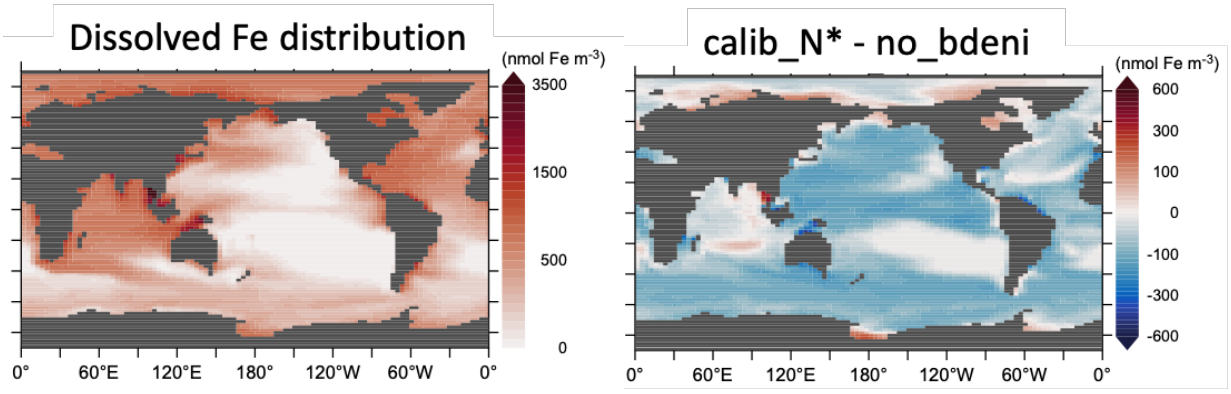
In our model, diazotroph growth and N_2 fixation in the South Pacific are subjected to the low Fe availability indicated by the low dissolved Fe concentration (see the left panel of Figure below), especially at the South Pacific Subtropical Gyre. Our simulated surface Fe concentration in the South Pacific Subtropical Gyre is lowest among all subtropics, whereas observations and other models (Huang et al., 2022) suggest that the surface dissolved Fe in the South Pacific is comparable to that in the North Pacific. We further assess the effect of benthic denitrification on dissolved Fe concentration (see the right panel of Figure below). In the South Pacific, the differences of surface dissolved Fe concentrations between calib_N* and no_bdeni shows only minor changes. This minimal influence of benthic denitrification on dissolved Fe suggests that benthic denitrification does not affect N_2 fixation through Fe concentration in this region.

The absence of nitrogen fixation in the Northern Indian Ocean may result from the absence of an oxygen-deficient zone (ODZ) and water-column denitrification in this area in our model. A proper representation of the ODZ in the Arabian Sea is one of our goals of ongoing model development.

We will add on Line 213: "The very low N_2 fixation rates in the South Pacific (Fig. 4a) can be attributed to the underestimated surface dissolved iron concentration in this region."

We will add on line 207: "This is also the main reason for the very low rates of N_2 fixation predicted for the Northern Indian Ocean, which could be unrealistic. Yet, there is considerable uncertainty about the regional pattern of N_2 fixation in the Northern Indian Ocean based on the

sparsity of available observations. For example, Shao et al. (2020) found strong N_2 fixation rates at only a few of places along the southwest coast of India in the eastern Arabian Sea, Löscher et al. (2020) could find no evidence for N_2 fixation in the Bay of Bengal, and vast areas in the Northern and Western Indian ocean remain unsampled."



In section 4 "Model and calibration limitations", the authors discussed multiple ways to improve the model, including applying different parameterization schemes for upper and deeper ocean sinking speed and resolving the dependency of remineralization rate on O2. The methods described are all reasonable. But why not try them, this is part of model development.

This research concentrates on the impact of benthic denitrification on global ocean biogeochemistry in our model. A full investigation of the possible development discussed in Section 4 requires calibrating the model configurations for each change, which is very time-consuming and goes beyond the scope of this work. We plan to do some of these in the future.

Some minor suggestions

Line 83 (Somes and Oschlies, 2015) --> Somes and Oschlies, (2015)

ok

Line 92 (Pahlow et al., 2020; Chien et al., 2020) --> Pahlow et al., (2020) and Chien et al., (2020)

ok

Line 149 Best models choices --> Best model choice.

ok

Line 305 Arabian --> Arabian Sea

ok

References

Huang, Yibin, Alessandro Tagliabue, and Nicolas Cassar. 2022. “Data-Driven Modeling of Dissolved Iron in the Global Ocean.” *Frontiers in Marine Science* 9. https://doi.org/10.3389/fmars.2022.837183.

Löscher, Carolin R., Wiebke Mohr, Hermann W. Bange, and Donald E. Canfield. 2020. “No Nitrogen Fixation in the Bay of Bengal?” *Biogeosciences* 17 (4): 851–64.

Shao, Zhibo, Yangchun Xu, Hua Wang, Weicheng Luo, Lice Wang, Yuhong Huang, Nona Sheila R. Agawin, et al. 2023. “Global Oceanic Diazotroph Database Version 2 and Elevated Estimate of Global Oceanic N2 Fixation.” *Earth System Science Data* 15 (8): 3673–3709.