Review of "Hysteresis of phytoplankton communities over Subpolar North Atlantic to CO2 forcing" by Lee et al.

'Comment on egusphere-2025-1474' | Review by editor

Dear Authors,

Your response to the reviewer comments and the accompanying revised manuscript address many of the clarifications and changes requested by the reviewers.

However some additional revision to the manuscript is required to address the reviewer comments more fully, and also to correct issues of grammar and presentation. Please can you address the issues listed in the reviewer reports and in the detailed editor comments on this version.

In particular, your more detailed clarifications and responses to the comments of Reviewer 1 should be included in the revised manuscript; this includes the additional discussion you provide on nutrient recovery, the behaviour of the GFDL model and on the SPNA region.

Response to Reviewer 1's comments: In your response you have provided more clarification to Reviewer 1's comments on several issues, however the revised manuscript does not always include the more detailed discussion and figures provided in your Response (e.g., on nutrient recovery (Figs R3 and associated discussion) and on the behaviour of the GFDL model (Figs R4 and associated discussion). In addition, the more detailed response you provide on the SPNA region is not reflected in the revised manuscript. Please can you provide more detailed responses to the comments of Reviewer 1 in your revised manuscript.

Response : In the revised manuscript, we have included discussion on the explanation of delayed nutrient recovery and the behaviour of the GFDL model in the discussion section, with supporting references (Moore et al., 2018; Laufkötter and Gruber, 2018; Oh et al., 2022). In addition, we have added a figure showing that diatom concentrations follow distinct pathways during CO_2 ramp-up and -down as Supplementary Figure 8c in the revised manuscript.

(225-232): During the weakened AMOC phase, MLD in the SPNA region remains in a shutdown state, and its recovery depends on the gradual build-up of salt-advection accompanying AMOC strengthening (Oh et al., 2022). In addition, warming-induced enhanced Southern Ocean (SO) productivity weakens global nutrient redistribution—intensifying deep-ocean nutrient trapping and reducing surface nutrients that might persist even under climate mitigation (Moore et al., 2018; Laufkötter and Gruber, 2018). Therefore, when the AMOC starts to recover, the amount of nutrients transported from the Southern Hemisphere and low latitudes remains reduced compared to the climatology period. As a result, the recovered nutrient levels stay below the climatological state, giving rise to the delayed recovery.

(296-299): In GFDL-ESM4, diatom concentrations recover comparably after CO_2 is decreased to the initial level, yet the pathway during the CO_2 ramp-down period does not follow the same pathway as the CO_2 ramp-up period (Fig. S8c), indicating irreversibility in both GFDL-ESM4 and CNRM-ESM2-1.

Minor comments

I also suggest careful proof-reading of the manuscript to check grammar, and to replace symbols with words (e.g., use ‘and’ instead of ‘&’ on line 34).

Response : Corrected.

Title: Suggest some rewording: e.g., “Irreversible phytoplankton community shifts over Sub-polar North Atlantic in response to CO2 forcing”

Response : We changed the title accordingly.

Abstract Line 14: change ‘cycles’ to ‘cycle’

Response : Corrected.

Abstract Line 19: Should ‘followed by’ be ‘following’ ? i.e., the lower nutrient availability follows the AMOC slowdown ?

Response : Corrected.

Abstract line 22: suggest replace ‘downsizing’ with ‘reduction’. (This use of ‘downsizing’ also occurs in several places in the text)

Response : We believe the term *“downsizing”* is more proper, as our results do not indicate an overall reduction of the phytoplankton community, but rather a compositional shift from large phytoplankton toward smaller taxa. Thus, *“downsizing”* more accurately reflects the transition toward smaller-sized phytoplankton being dominant.

Line 79: some grammar issues with this sentence – please correct. (Do you mean the model includes 3 PFTs ?)

Response : We have revised the grammatically incorrect sentence, and to clarify that the model explicitly simulates three phytoplankton functional types (PFTs: diatoms, small phytoplankton, and diazotrophs) with distinct source–sink parameters as below:

(77-80): The simulations incorporate biogeochemical processes coupled with a biogeochemistry model, and explicitly simulate three phytoplankton functional types (PFTs): diatoms, small phytoplankton, and diazotrophs, each with distinct source-sink parameters (See Methods for details).

(86-89): The marine ecosystem within CESM2 is represented by the Marine Biogeochemical Library (MARBL), which incorporates three explicitly modeled phytoplankton functional groups—diatoms, diazotroph, pico/nano (small) phytoplankton—as well as one implicit group (calcifiers) and a single zooplankton group, each with distinct source-sink parameters.

Methods section: The section on the Bray-Curtis dissimilarity metric should probably be moved to come after the 'Experimental Design' section – or be included in it. This section on the BC metric references simulations and analysis periods that are described in the Experimental Design section, and therefore it is out of place when placed early on in the Methods section.

Response : Corrected. We have moved the description of the Bray–Curtis (BC) dissimilarity metric to follow the "Experimental Design" section.

Line 87 and 90 : should be '…the BC index…'

Response : Corrected.

Line 95: Please provide supporting reference(s) for CESM2

Response : Corrected.

Experimental Design: Lines 117-129: Please provide supporting reference(s) for the emissions scenarios used. Do you include figures outlining the emissions pathways/CO2 concentrations employed in your analyses ? If so, please reference these here.

Response : We have added a supporting reference (Park et al., 2025) for the negative emissions scenario used in the Experimental design section. In addition, we now include a figure illustrating the prescribed CO_2 emissions and atmospheric CO_2 concentration pathways **(Figure R1),** and we have

added it as Supplementary Figure 1 in the revised manuscript and referred in Experimental Design section.

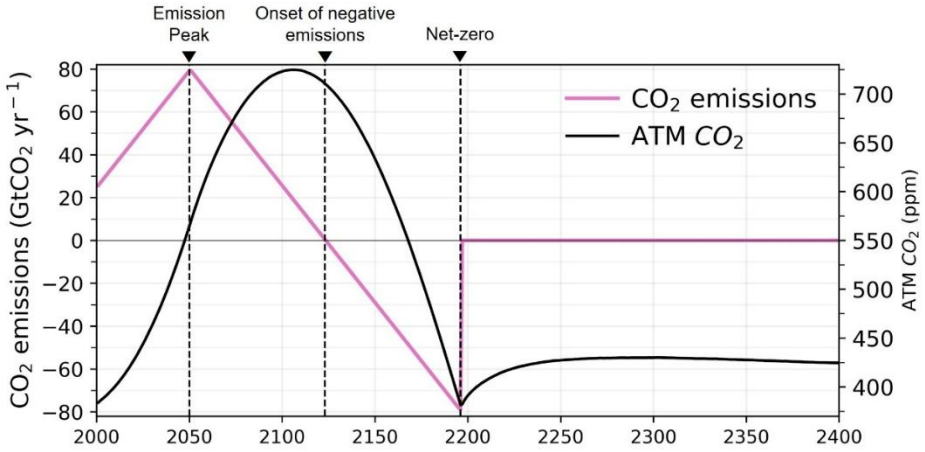

Figure R1. Time series of annual anthropogenic CO_2 emissions, and annual mean atmospheric CO_2 concentration.

Lines 291-292: "…yet the pathway during the CO2 291 Ramp-up period does not follow the same pathway as the CO2 Ramp-up period…". This is not clear – do you mean "ramp-down" in one of the cases?

Response : We thank the reviewer for catching this typo. We have corrected this in the revised manuscript as below:

(296-299): In GFDL-ESM4, diatom concentrations recover comparably after CO_2 is decreased to the initial level, yet the pathway during the CO_2 ramp-down period does not follow the same pathway as the CO_2 ramp-up period (Fig. S8c), indicating irreversibility in both GFDL-ESM4 and CNRM-ESM2-1.

Line 292: Should "hysteresis" be replaced with "irreversibility" ?

Response : Corrected.

References

Keith Moore, J., Fu, W., Primeau, F., Britten, G. L., Lindsay, K., Long, M., Doney, S. C., Mahowald, N., Hoffman, F., and Randerson, J. T.: Sustained climate warming drives declining marine biological productivity, Science (80-.)., 359, 113–1143, https://doi.org/10.1126/science.aao6379, 2018.

Laufkötter, C. and Gruber, N.: Will marine productivity wane?, Science (80-.)., 359, 1103–1104, https://doi.org/10.1126/science.aat0795, 2018.

Oh, J. H., An, S. Il, Shin, J., and Kug, J. S.: Centennial Memory of the Arctic Ocean for Future Arctic Climate Recovery in Response to a Carbon Dioxide Removal, Earth's Futur., 10, https://doi.org/10.1029/2022EF002804, 2022.

Park, S. W., Mun, J. H., Lee, H., Steinert, N. J., An, S. Il, Shin, J., and Kug, J. S.: Continued permafrost ecosystem carbon loss under net-zero and negative emissions, Sci. Adv. , 11, 1–10, https://doi.org/10.1126/sciadv.adn8819, 2025.