The authors thank this reviewer for the many very constructive and helpful comments. Below we outline how we plan to improve the manuscript (ms) in response to these comments.

We will refer to the ms published in BGD as the original ms, and all figure and table numbers refer to the original ms unless otherwise noted. Please note that we plan to remove the STD configuration in our revised ms. QM will be taken as the new STD configuration in the revised ms, hence there will be no configuration designated as QM in the revised ms.

Comments: General comments: The authors use a 5-box model in order to explore controls on nutrient and oxygen dynamics in the ETSP OMZ. This work is complementary to a previous study by Canfield et al. (2006) that used a similar approach. Canfield et al. (2006) found that fixed N will persist in the OMZ provided that there is no N2 fixation in the overlying water. The addition of N2 fixation to Canfield's model drove the system to sulfate reduction. Recent work has shown that N2 fixation is in fact closely coupled to zones of N loss (OMZs), however NO3- is not observed to be exhausted as Canfield's model predicted. The current work by Su et al. explores the mechanisms by which NO3- is maintained at non-zero values in the OMZ even while there is N2 fixation in the overlying waters. They find that this condition is fulfilled when the remineralization rate by denitrification is substantially reduced relative to aerobic respiration. By also adding lateral ventilation and nutrient exchange with the subtropical ocean, the model produces realistic values of O2.
Response: We thank the reviewer for the positive evaluation and for pointing out the scientific significance of our work, which is also the information that we want to convey to our readers. Thereafter, we will concentrate on questions and suggestions from this reviewer to improve our ms.

Comment: It is an interesting topic given the discrepancy of Canfield's model results compared to observations in the OMZs. My main criticism with this work is that the results are not discussed in a way that is easy for the reader to understand. The authors present numerous model configurations although the physical significance of each configuration is not clear, nor do they all appear to be required to reach the conclusions of this work. The results of QM are similar to STD. It does not seem physically relevant to exchange O2 and 14C but not NO3- and PO4- (VD, VDRD, VI, VIRD). If those configurations were to test the importance of nutrient vs. O2 exchange, then I think that is sufficiently accomplished by the sensitivity experiments. Also, numerous sensitivity experiments were carried out but it is unclear on which model configuration and/or the relevance of all of the tests (Fig. 4-7). It may improve the reader's understanding if only the minimum number of model configurations needed to illustrate the conclusions of this work were presented. The rest of the model configurations could be placed in an appendix.
Response: We thank the reviewer for the generally positive comments and pointing out structural problems that could confuse our readers. Below we describe how we plan to modify the original ms in response to these suggestions and the comments of the other reviewer:
We will remove the STD configuration from the revised ms, because it contributes nothing to our conclusion, and rename the QM configuration from the original ms as the STD configuration in the revised ms. We will choose the new STD, RD, VIDRD and OBRD configurations as the main configurations, and mainly describe and discuss their results in the main text, since these are the configurations that illustrate our conclusions best. We will add a subsection "3.3 Model sensitivity experiments", where we will summarise all model sensitivity experiments. The VD, VDRD, VID and OB configurations will now be described briefly as sensitivity configurations in Appendix E of the revised ms. Accordingly, Fig. 2 and Fig. 3 will also be replaced by Figures. 1 and 2 in this response.
We will also include several more summary sentences and make some statements more specific in order to clarify the role of each model configuration and sensitivity experiment. These are:
1, P11101 L14 "Sensitivity experiments are also performed with a configuration where N_2 fixation is inhibited by NO_3^-, but overall results are found to be virtually unchanged (Appendix D).".
will be **reworded to**: "Sensitivity experiments are also performed with a configuration where nitrogen fixers preferentially use nitrate when available and cover only the residual nitrogen demand via N_2 fixation, denoted as facultative N_2-fixation, but overall results are found to be virtually unchanged (Appendix B)."

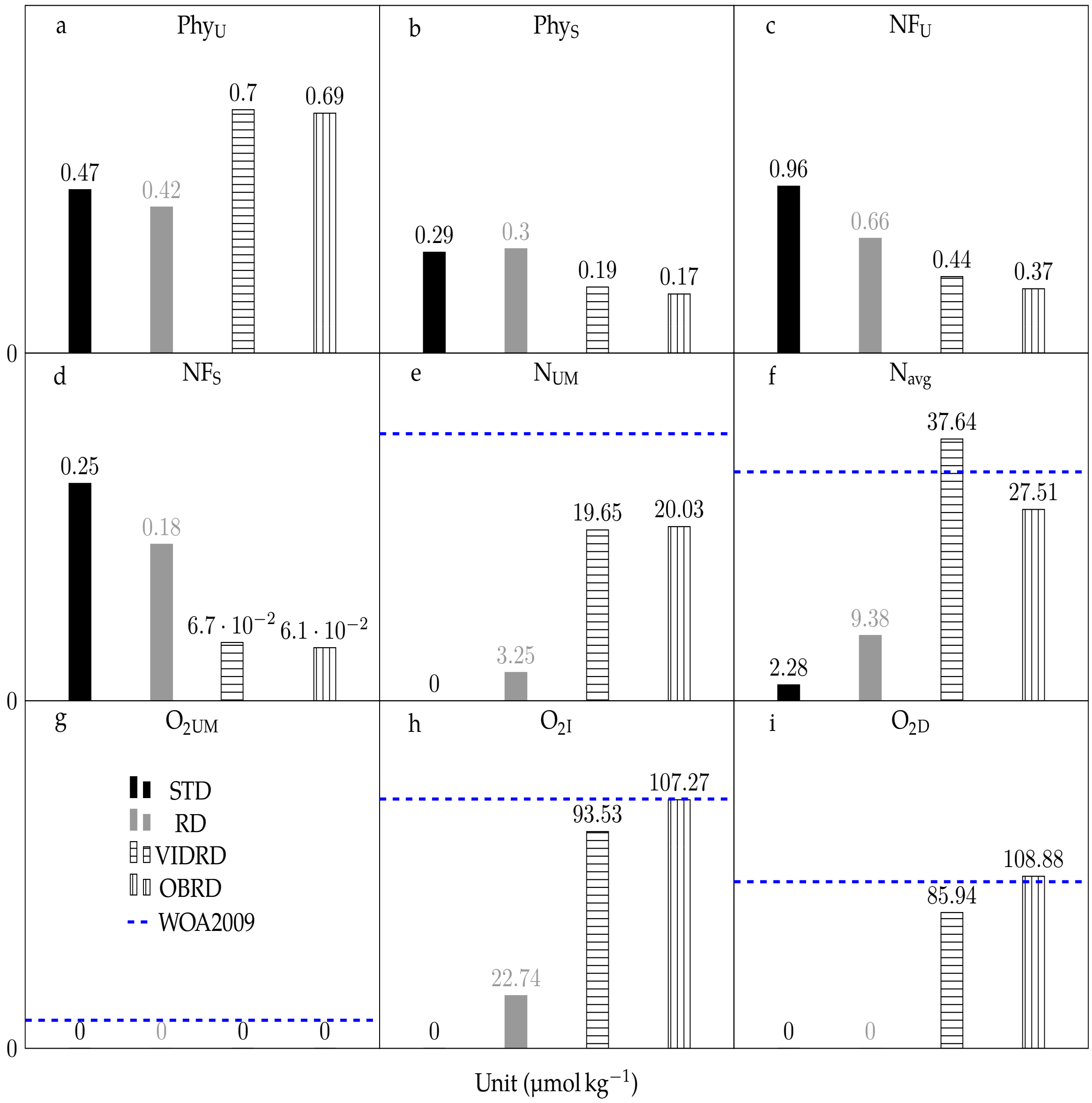

Figure 1: Simulated steady-state phytoplankton, nutrient and oxygen concentrations for the main model configurations defined in Tables 3 and 4. Each panel uses linear scale of the y-axis starting at zero. Dashed blue lines represent the average of the WOA2009 data of the corresponding boxes. There are no data for Phy_U, Phy_S, NF_U and NF_S.

2, P11103 L23:"In order to investigate the relationships between the different biotic and physical processes and the nitrogen cycle in an OMZ, we introduce eight additional model configurations (Table 3)"
will be **reworded to**: "In order to investigate the sensitivity of the nitrogen cycle in an OMZ to the different biotic and physical processes, we introduce seven additional model configurations. The main differences to the STD configuration are shown in Table 3."
3, "Two sensitivity experiments are performed for each of the VID and OB configurations to explore possibilities for preventing NO_3^- depletion in the OMZ: (a) different reduced remineralisation rates (f_{UM}) and (b) facultative N_2-fixation (see Appendix E)." will be **added** to P10L25–L27 of the revised ms.
4, P11105 L4–L11 will be **reworded to**: "For the OBRD configuration, three sensitivity experiments are performed to investigate our model sensitivity to variable physical transports and biogeochemical tracer concentrations: (1) The mixing rate with the southern boundary, K_H, is reduced for individual tracers (nutrients, oxygen) or combinations thereof from full rates to zero. (2) Simulations are repeated with individual circulation parameters varied by ±10 %, ±20 % and ±50 %, respectively, to

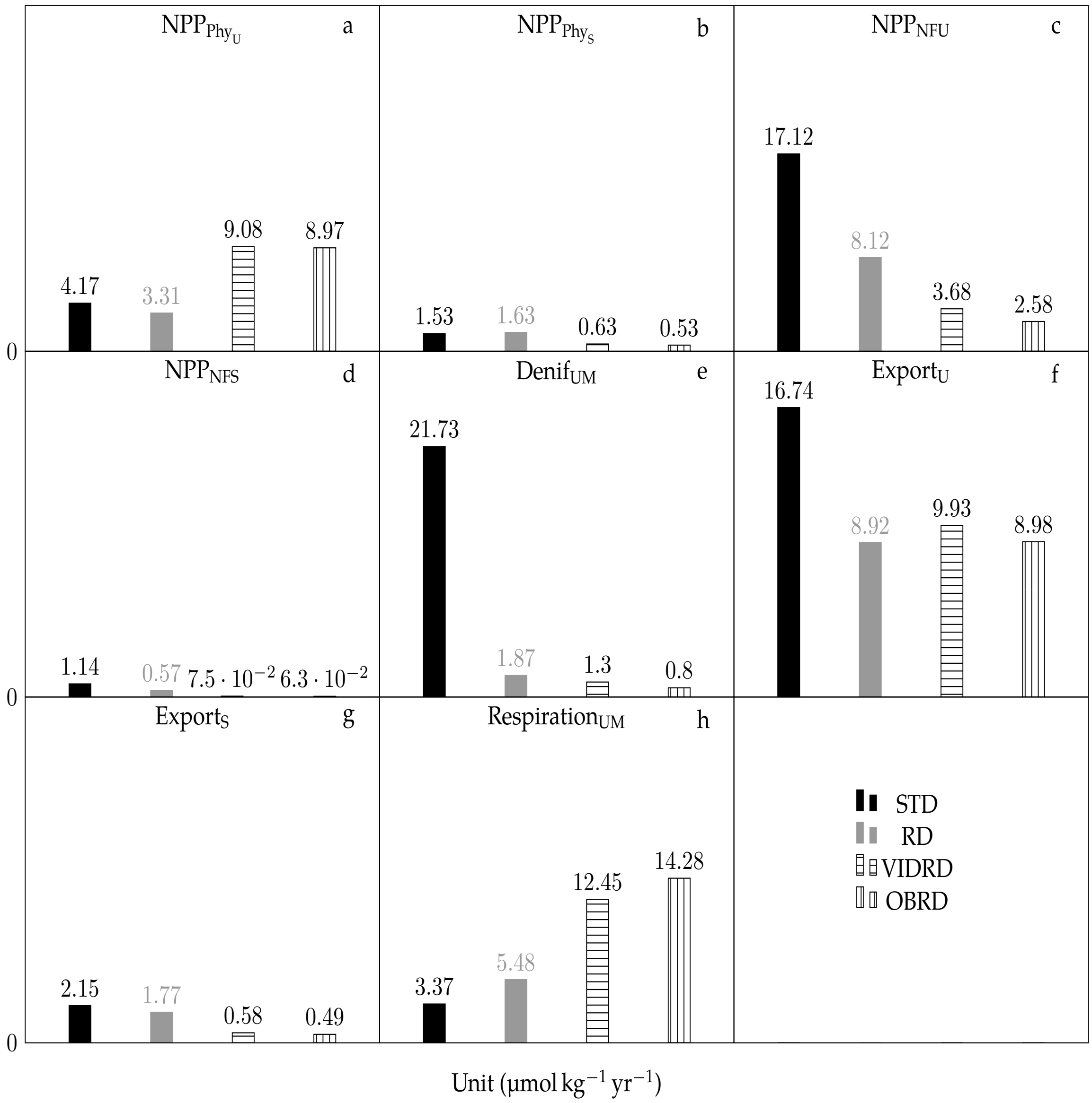

Figure 2: Simulated steady-state biogeochemical fluxes for the main model configurations.

explore the sensitivity with respect to the circulation parameters of the box model. (3) The sensitivity of NO_3^- and O_2 concentrations in the OMZ to different physical parameters derived from variations of the $\Delta^{14}C$ data and O_2 concentrations in the U-box is also examined."
5, P11105 L20 after "...exported organic matter." We will **add**: "The results for biogeochemical tracer concentrations of the STD, RD, VIDRD and OBRD configurations are shown in Fig. 2, since they are the main configurations that illustrate our conclusions, while those for the VD, VDRD, VID and OB configurations are shown in Fig. 8 and described in Appendix E, because these sensitivity configurations do not contribute significantly to explaining the existence of high NO_3^- concentrations in the OMZ. ".
Afterwards, a new paragraph is started with "In the STD configuration,...".
6, P11107 L5:"Several sensitivity experiments..." will be **reworded to**: "Two sensitivity experiments..."
7, P11108 L3 will be **reworded to**: "For the biogeochemical fluxes, we focus on the STD, RD, VIDRD and OBRD configurations (configurations in bold in Table 3), since they show most clearly which mechanisms might be responsible for preventing NO_3^- exhaustion in the OMZ (Fig. 4)."
8, P23 L25–L27 and P24 L1–L5 in the revised ms, will be **added**: "Two further sensitivity experiments were performed for each of the VID and OB configurations to explore how NO_3^- depletion in the UM box can be prevented. (1) Decreasing the fraction of export production remineralized in the UM box (f_{UM}) from 70 % to 56 % makes NO_3^- persist in the UM box. Together with the 20 % remineralization

Table 1: Phosphate concentration of each box for both models and WOA2009 data.

Box \ Configurations	STD	QM	RD	VDRD	VIDRD	OBRD	WOA2009
U	0.15	0.044	0.021	0.0096	0.012	0.0093	1.27
UM	3.22	3.22	1.73	1.80	1.92	1.73	2.53
S	0.13	0.0055	0.0037	0.0012	0.0012	0.0011	0.51
I	1.62	1.58	1.30	0.97	1.03	0.86	1.65
D	2.77	2.79	2.88	2.96	2.95	2.29	2.76

in the U box, this implies that 76 % of the export production is remineralized in the upper 500 m of the ocean. However, the resulting NO_3^- concentration in the UM box is far below the literature range of about 15 to 40 μmol L^{-1}. (2) Facultative N_2-fixation inhibits nitrogen fixation in an environment with high NO_3^- concentrations, but fails to prevent NO_3^- depletion in the UM box. ".

Comment: Please number all tables, figures, and appendices sequentially as they appear in the text. Some, but not all, examples: p. 11100, ln. 14. "Table 4 and 5" should be "Tables 2 and 3". p. 11101, ln. 15-16. "Appendix D" should be "B". p. 11102, ln. 9. "Appendix B" should be "C". p. 11102, ln. 13. "Table 2" should be "4". Et cetera.
Response: We will correct this problem in the revised ms.

Comment: In the "Biogeochemical tracer concentrations" section, most of the configurations where denitrification was not reduced were discussed though not shown in Figs. 2 or 3. There is a large amount of data presented in the figures for the reader to sort through and so it would be helpful if the authors could be more explicit in the text about what data can be found in the figures and what cannot.
Response: In the revised ms, we will only present the STD, RD, VIDRD and OBRD configurations in the "Biogeochemical tracer concentrations" section, and only the results of these four configurations are described in this section. Figs. 2 and 3 will also be replaced by Figures. 1 and 2 of this response letter, in which only the results of the STD, RD, VIDRD and OBRD configurations are shown. We hope that this improves the clarity sufficiently.

Comment: p. 11107, ln. 11-15. "Next, a model of nitrogen fixation: : :" Why is this mentioned only here in the paragraph that discussed the VID configuration? Was this not addressed for all of the model configurations in Appendix D and Fig. 9?
Response: The model with an inverse relationship between NO_3^- concentration and the fraction of fixed nitrogen from nitrogen fixation was applied into all model configurations presented in the original ms (please see Fig. 9). NO_3^- depletion cannot be prevented in the VID configuration, even though there is O_2 ventilation into both the I and D boxes. In P11107 L3-L15 of the original ms, we have described two sensitivity experiments targeting to prevent NO_3^- depletion in the VID configuration, one of which is applying the Schmittner model for NF. That is why we have addressed it there rather than anywhere else. We will explain this better in our revised ms.

Comment: p. 11108, ln. 26-. "Compared with VIDRD configuration, total PO43-: : :" There is much discussion of PO43-. Please add panels to Fig. 2 to show PO43-.
Response: Table 1 in this response indicates the phosphate distributions in all our configurations. The reason of our phosphate inventory of the model domain being lower than in the WOA data in the OBRD configuration is that PO_4 is lost by mixing through the boundary with the southern subtropical ocean, which is shown in Fig. 4 (better shown in Fig. 3 of this response letter). We hope that this should be sufficient for phosphate, since (1) our study is primarily concerned with the N cycle, (2) no substantial changes in phosphorus inventory occur between the different model configurations except the OB and OBRD configurations.

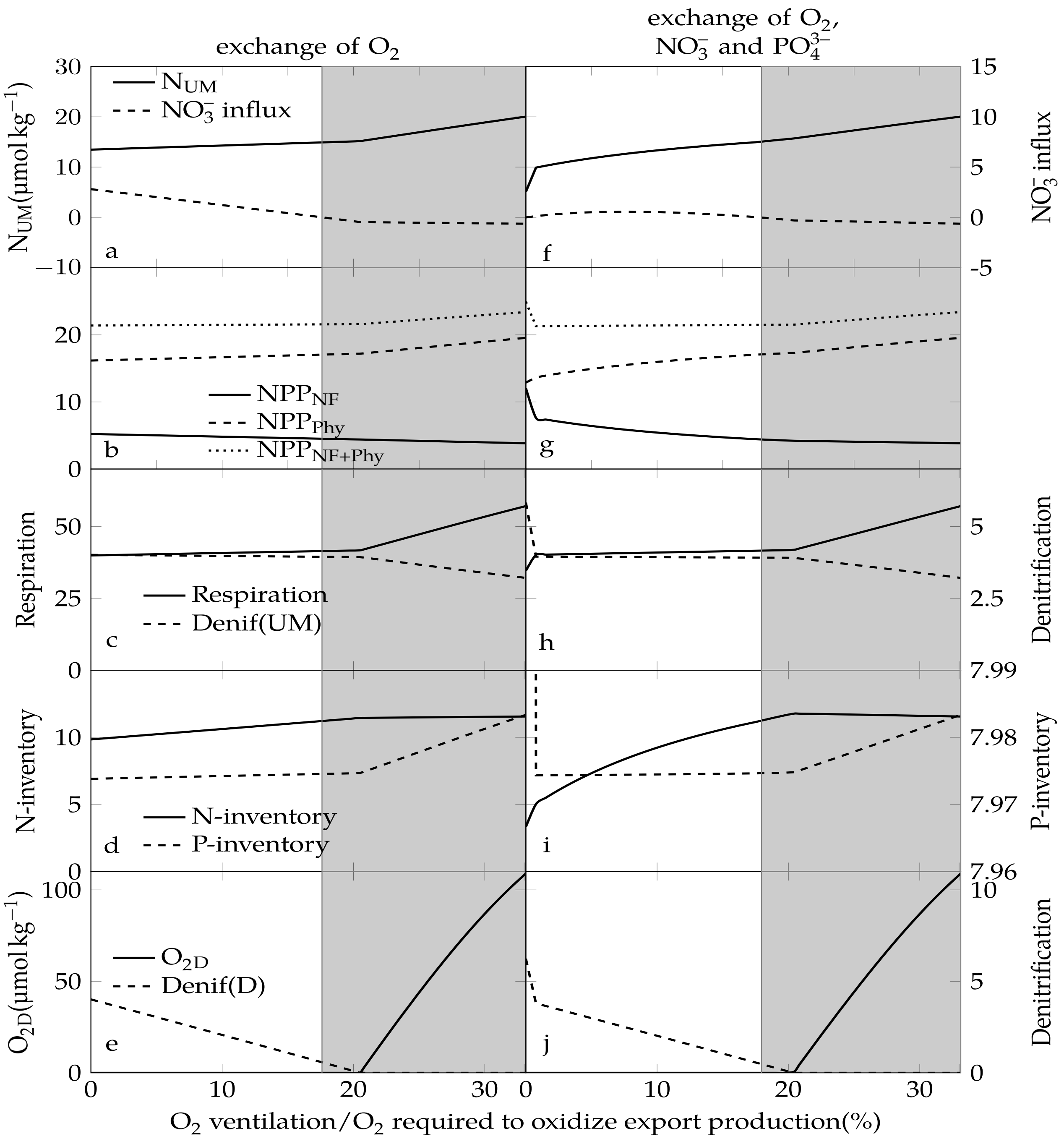

Figure 3: Dependence of biogeochemical processes on the exchange of O_2, NO_3^-, and PO_4^{3-} with the subtropical ocean through the southern boundaries of the I and D boxes. The x-axes indicate the contribution of O_2 supplied from the subtropical ocean relative to that required to oxidize all export production from the surface ocean (boxes U and S). (a–e) only O_2 is exchanged through the southern boundaries; (f–j) exchange of O_2, NO_3^-, and PO_4^{3-}. N_{UM} is NO_3^- concentration in the UM box and NO_3^- influx is the NO_3^- flux through the southern boundary (positive into model domain). NPP_{Phy}, NPP_{NF} and NPP_{NF+Phy} are net primary production by ordinary phytoplankton, nitrogen fixers, and the sum of both in the surface ocean. Respiration and Denif (UM) represent O_2 consumption by aerobic remineralization and NO_3^- removal by anaerobic remineralization, respectively, in the UM box. N-inventory and P-inventory are the total nitrogen and phosphorus inventories in the model domain, including all organic and inorganic species. O_{2D} and Denif (D) represent O_2 concentration and NO_3^- removal by anaerobic remineralization in the D box. Units of all variables are 10^{11} μmol yr^{-1} m^{-1} except for N_{UM} and O_{2D}, which are given in μmol kg^{-1}. The shaded area denotes the parameter range for which the model domain is a net source of NO_3^-.

Comment: 11109, ln. 13. "The fluxes associated with the fixed-N: : :" The authors refer to the "OB" configuration, however according to Table 6 it is the "OBRD" configuration being discussed. Please clarify.
Response: Yes, it is the "OBRD" configuration and we will correct it in the revised ms.
Note: we will correct the export production of Kalvelage et al. (2013) to1.85 $\mu mol\,N\,kg^{-1}\,yr^{-1}$ in Table. 6.

Comments: p. 11109, ln. 21-. "In sensitivity experiments: : :" For which model configuration?
Response: It is the sensitivity experiment for the "OBRD" configuration, which is the most realistic configuration (NO_3^- and O_2 concentrations closest to observations). We will address it better in the revised ms as "In sensitivity experiments of the OBRD configuration, designed to elucidate the importance of the influence of the subtropical ocean on the model domain,".

Comment: p. 11110, ln. 20. "The behaviour of the model domain as a small pelagic net NO3- source: : :" Is it a source of NO3- or fixed-N (as the caption for Fig. 4 indicates)? They are close but not the same especially since we are discussing N2-fixation and assimilatory uptake of N by phytoplankton. Also, I do see that the OBRD configuration results in the model domain consistently being a net source of NO3-. Fig. 4 shows that whether or not the model domain is a net source depends on the ventilation of O2 from the subtropical ocean. Or do the authors mean that WHEN it is a source, it is insensitive to physical transport parameters? How could it be insensitive when increased ventilation involves an increase in physical transport of O2? These seem to be contradictory statements. Please clarify.
Response: Our model domain is a source of fixed-N, which in the model exists only in the form of ${NO_3}^-$. We neglect other forms of fixed-N such as ${NO_2}^-$ and ${NH_4}^-$ for simplicity since ${NO_3}^-$ is the most abundant species. To make the statements consistent, we will use ${NO_3}^-$ throughout our revised ms.
In Fig. 4, our model domain switches from a ${NO_3}^-$ sink to a ${NO_3}^-$ source with increasing O_2 ventilation from the southern boundary (sink: white area; source: grey area). We have indicated in Fig. 4 that whether or not the model domain is a net source depends on the ventilation of O_2 from the southern boundary, and the switching point is when the lateral mixing K_H is about 24% of the original value defined in Table 4 for the OBRD configuration (Fig. 4 of this response letter).
In Fig. 5, we have varied individual physical parameters by up to ±50%, whereby K_H represents the mixing rate between the southern boundary and I and D boxes, and also the mixing rate between the I and UM boxes. The maximum variations for K_H in Fig. 5 are ±50%, in which range our model domain is still a NO_3^- source. Our model domain can turn into a NO_3^- sink only when lateral O_2 supply (K_H for O_2) is less than about 24% of the original value.
We will **reword** "The behaviour of the model domain as a small pelagic net NO3- source: : :" **to** "The conclusion that the model domain is a small pelagic net NO_3^- source in the OBRD configuration does not change when individual physical transport parameters vary by up to ±50%. Varying biogeochemical parameters also does not affect this conclusion.".

Comment: p. 11110, ln. 23-25. "The finding that the model domain: : :D-box is oxic (Fig. 7)." The text implies that the entire model domain is a source of NO3- yet N-influx for only I and D boxes are presented in Fig. 7. Please show all boxes or at least the net of all of the boxes in Fig. 7.
Response: In our model only the I and D boxes are open to allow for nutrient and O_2 exchange with the southern boundary in the OB and OBRD configurations. Thus, I and D are the only boxes through which nitrate can flow into or out of the model domain and the fluxes into/out of boxes I and D represent the total budget of the 5-box model. We will add a clarifying statement to the caption of Fig. 7.
We will also correct the unit mistake of Fig. 7 by replacing it with a new figure (Fig. 5 of this response letter).

Comment: p. 11110, ln. 25-28 and Fig. 6. "The oxygen concentrations: : :increase in sensitivity model runs: : :" This is not what Fig. 6 shows. O2 in UM remains zero across variations in 14C. p.

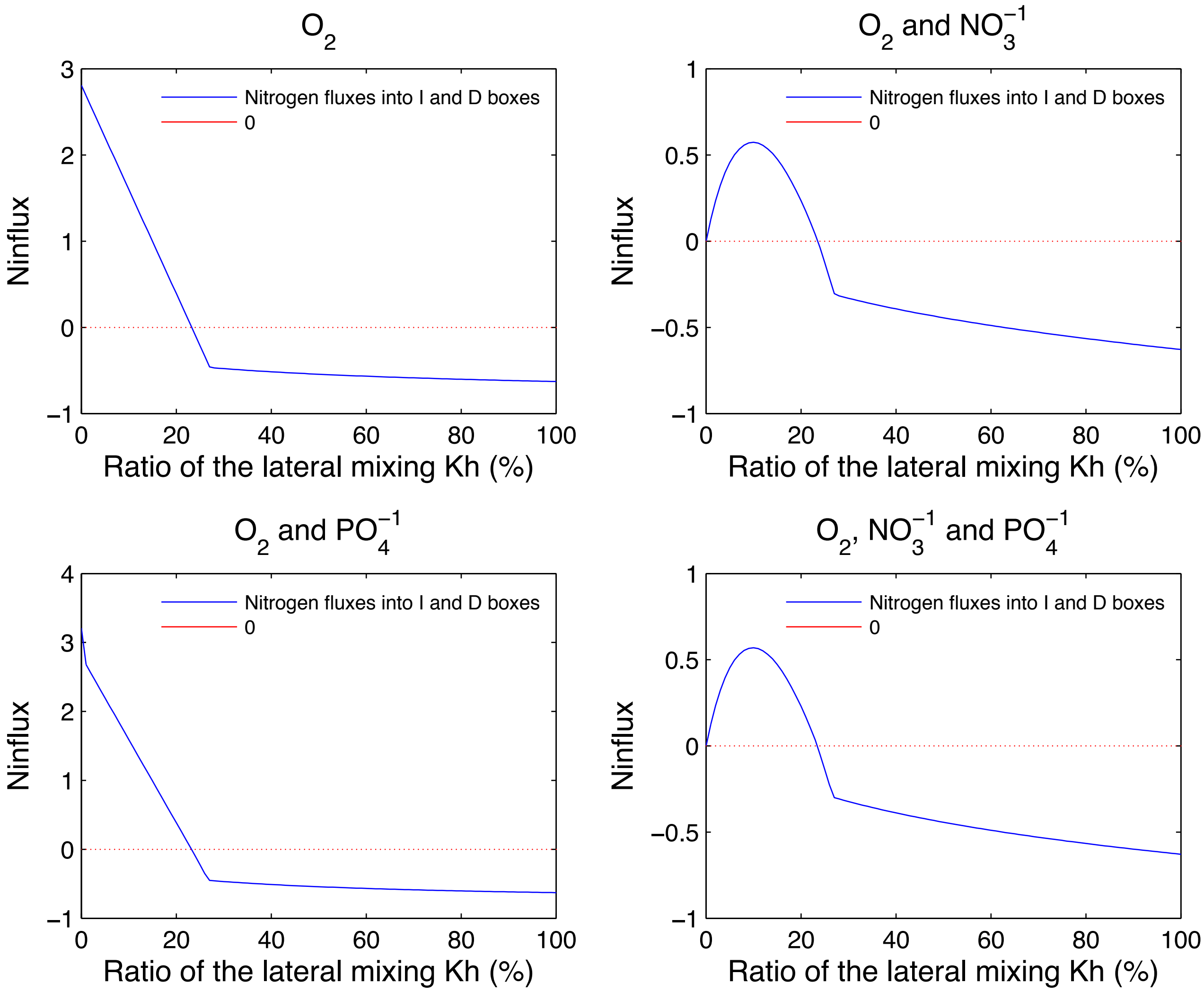

Figure 4: Positive values indicate that our model domain is a NO_3^- sink, and negative values represent a source.

11111, ln. 1-. "The UM box remains anoxic: : :" This statement appears to contradict the first sentence in this paragraph although is consistent with Fig. 6. Please clarify.
Response: We will **reword** p. 11110, ln. 25-28 **to**: "The oxygen concentrations in the I and D boxes increase in sensitivity model runs with physical parameters calibrated with increased ^{14}C concentrations (lower water mass age, not shown).". The O_2 concentrations in the I and D boxes provide the O_2 boundary conditions for the OMZ in our model. Higher concentrations can also be a result of lower water mass ages (more intense ventilation). In the sensitivity experiments for the OBRD configuration, we observed that the O_2 concentrations in the I and D boxes increase for physical parameters calibrated with increased ^{14}C concentrations (Fig. 6 of this response letter).

Comments: p. 11113, ln. 29 and p. 11114, ln. 1. "we" The authors must mean "they", referring to Eugster and Gruber (2012).
Response: When we estimated the nitrogen budget of that region from their box model results, we found that the water column of the IndoPacific is a large fixed-N source. This conclusion is not stated directly in their paper. We will **reword** "We find" **to** "Their results indicate".

Comment: Table 3. Please add a short description of each model configuration so the reader does not have to keep flipping back to the text.
Response: Table 3 is the summary of section 2.4 (Model configurations), which is to help the readers understand the main differences among different model configurations. We will include the follow-

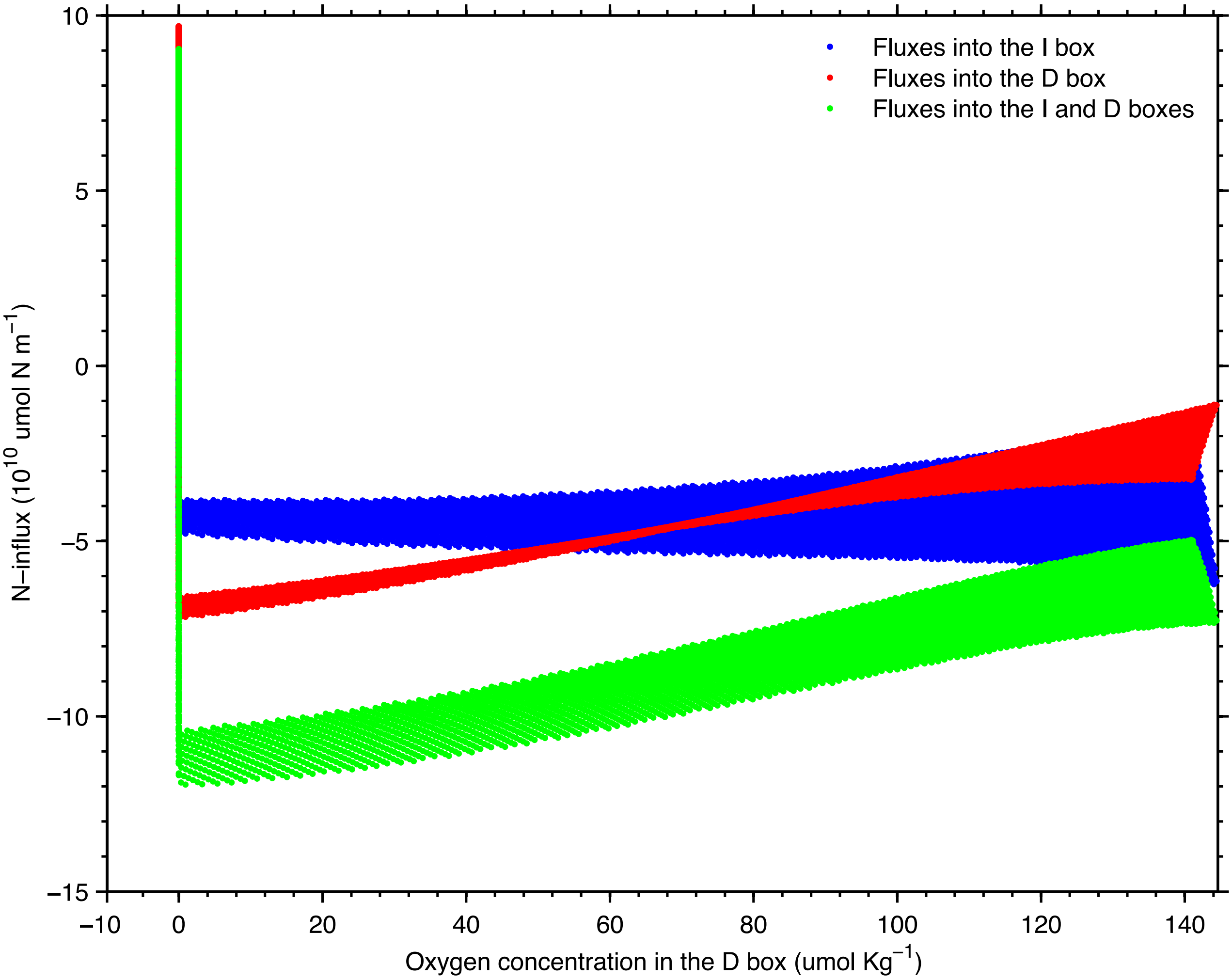

Figure 5:

ing text in the caption of Table. 3:
"+" means that the modification applies to this configuration. The configurations in bold are the main configurations, and the others are sensitivity configurations described in Appendix E. STD is the standard configuration defined in sections 2.2 and 2.3; in RD, a reduced denitrification rate is applied; VD indicates that the southern boundary of the model domain is partially opened to allow ventilation of O_2 and ^{14}C (but not NO_3^- and PO_4^{3-}) to the D box; VDRD is the configuration when a reduced denitrification rate is applied in VD; VID differs from VD only in that the partially open southern boundary is extended to allow ventilation of O_2 and ^{14}C also into the I box; VIDRD is the configuration when a reduced denitrification rate is applied in VID; in OB, nutrient (NO_3^- and PO_4^{3-}) mixing is added to VID; OBRD is the configuration in which the reduced denitrification rate is added to OB.".

Comment: Table 5 and Fig. 1. Please be consistent with variable names. "DS" or "SD" for the southern boundary of the deep box? Same for the intermediate box.
Response: Thanks! We will use "SD" and "SI" for all variables.

Comment: Figure 1. Define "SO" in the caption.
Response: We will **reword** the second to last sentence in the caption of Fig. 1 **to** "The model can be configured to exchange nutrients and oxygen with the southern subtropical ocean (right, denoted as "SO")".

Comment: Figure 2. Add panels to present phosphate.
Response: We only discuss the total phosphate inventory of the whole model domain rather than the

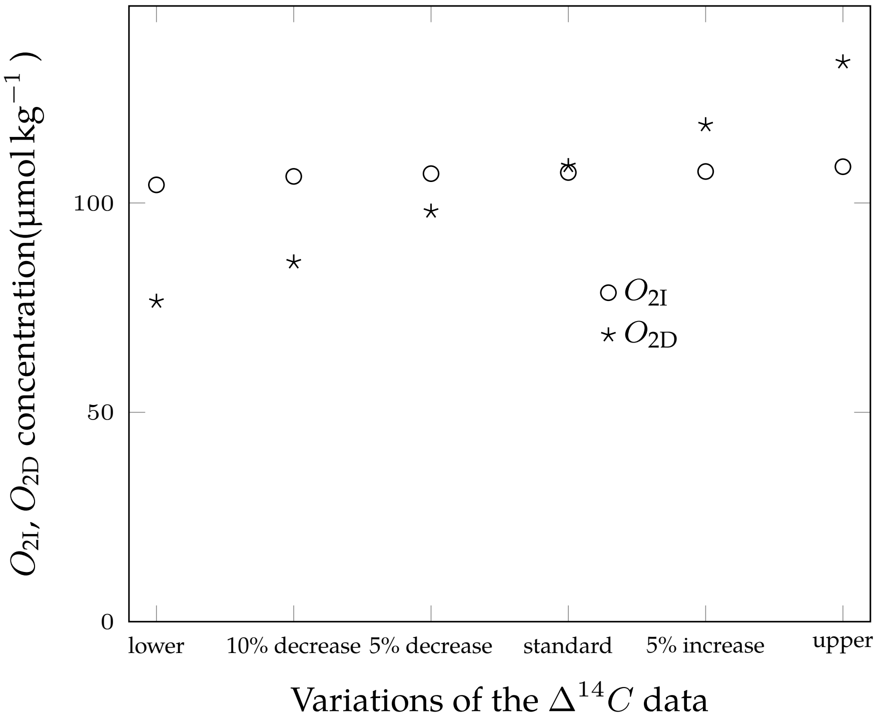

Figure 6: NO_3^- and O_2 concentrations in the I and D boxes for the OBRD configuration for different physical parameters derived from variations of the Δ^{14}C data.

individual boxes, as shown in Fig. 4 for the OBRD configuration. We hope that this should be sufficient for phosphate, since (1) our study is primarily concerned with the N cycle, and (2) no substantial changes in P inventory occur between the different model configurations, except OB and OBRD.

Comment: Figure 4. Hard to read. Text is too small.
Response: We now enlarge the font in the legend and modify the caption for this figure (Fig. 3 of this response letter). We will separate the figure and caption into 2 pages, which will make the figure larger and more readable in the revised ms. We also remove the two columns named "O_2 and NO_3^-" and "O_2 and PO_4^{3-} ", since they produce quite similar results with the other two columns. The caption of this figure will be **reworded** as shown in Fig. 3 of this response.

Comment: Figure 5. "N source" and "N sink" w/arrows. It is ambiguous what these mean if OBRD is always a net source of NO3- (as the text states). Is the position of these text and arrows on the graph arbitrary?
Response: We agree that the position of the two arrows was confusing. To rectify this problem, we will replace Figure 5 with Fig. 7 of this response. We have included model sensitivity experiment results for the biogeochemical parameters in Fig. 7 and shown the absolute fluxes instead of the normalized fluxes. In Fig. 7, negative flux values indicate our model domain being a net NO_3^- source. This will be clearly stated in the caption of Fig. 7.

Comment: Figures 9. Since this is only referred to in the appendices, should this also be appended?
Response: We will remove this figure from our original ms, because it does not show significant differences from Fig. 2.

Comment: Technical corrections: p. 11110, ln. 6. Second to last word in line should be "high" not "hight".
Response: We will correct it in the revised ms.

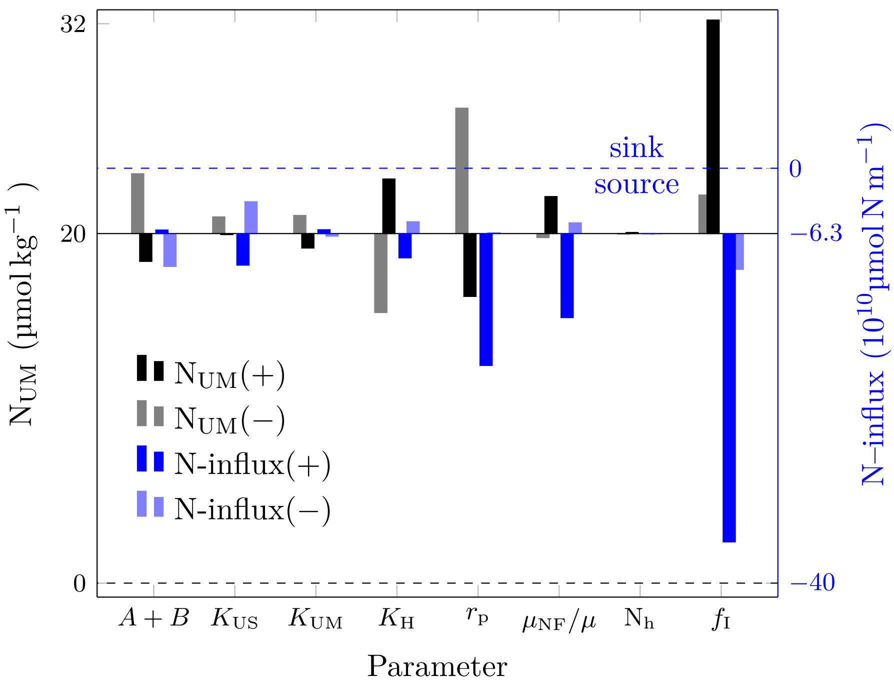

Figure 7: Sensitivity of NO_3^- concentration in the OMZ (N_{UM}) and the net NO_3^- flux out of the model domain to variations of the individual parameters describing ocean transport and biogeochemical processes (see Tables 2,5 and Fig. 1 for a description of the parameters). Black and blue bars represent changes in N_{UM} and N-influx, respectively. "+" and "−" indicate the response to increased and decreased parameters. Physical circulation parameters are varied by ±50%. r_P is varied between 12 and 20. μ_{NF}/μ is varied between 1/4 and 1/2. Nh varies between 0.3 and 0.9 μmol kg^{-1}. For f_i, "+" indicates f_U=f_S=60% and f_{UM}=f_I= 30%, and "−" means 40% and 50%, respectively.

Comment: Table 5. Last 2 lines should be "Southern boundary OXYGEN concentration....." not "phosphate".
Response: We will correct it in the revised ms.