Responses to the reviewers' comments:

Reviewer 1

I am generally satisfied with the revision. My only concern is the paragraph introductory sentence on lines 315-316, "It appears that the asymmetric distributions differ largely between biological parameters, and there are almost opposite patterns between oxygen consumption (or DOM remineralization) and DOM concentration". I do not understand what the authors are trying to convey. Are the authors trying to say that observations suggest that the model cannot simultaneously simulate the concentrations with the same set of biological parameters? From what model or observational constraint does the phrase "It appears" come from?

Response: Thank you for the constructive comments. It should be "biological fields" not "biological parameters". We have revised as "It appears that the asymmetric distributions differ largely between biological fields in the tropical Pacific. In particular, there are almost opposite patterns between oxygen consumption (or DOM remineralization) and DOM concentration, which may be attributed to the difference in the rate of DOM remineralization between north and south". This sentence is not only an introductory sentence for the second paragraph but also a summary of the first paragraph.

Reviewer 2

This is the second review of the paper and the manuscript has improved significantly compared to the initial submission. However there are some remaining comments that need to be taken into account, before it can be considered for publication. The differentiation between physical, biogeochemical and coupled feedback mechanisms is still not shown in a sufficient way. The experimental setup allows to show the inter-dependecies between physical and biogeochemical processes in more detail than it is done. I would further rate this to be the main scientific impact of this study rather than allocating that to future studies. The general conclusion - physics have a big impact and there are complicated interactions - are too general and doesn't bring new insight into the topic. In particular processes in the depth range 400-700m, that are of key importance for the OMZ, are explained only in a perfunctorily manner. I would guess that a great deal can be done by changing Fig 10-12 and show here the same difference of simulations as done e.g. in Fig 9. Then you are able to differentiate between a change in the physical supply that results from a biogeochemical process and value/rate that against the change of the physical process and the combined change. The limitation of the study is clear, that only two processes are considered here, but the impact of these two processes should be fully investigated and explained here.

Response: Thank you for the constructive comments. We have made major revisions to address all the comments/suggestions. In particular, we have conducted further analyses (with new/revised figures, as suggested) and discussions, with some rewriting on the differentiation between physical, biogeochemical and coupled feedback mechanisms (section 4.4). We have carefully re-evaluated the analyses on the relative roles of physical and biological processes, and made corrections regarding the depth range 400-700 m (see further explanation/responses below).

Further comments:

1. Abstract line 17 - this result is logically inconsistent: DO is more sensitive to biological processes between 200-700 m and to physical processes between 400-1000 m → so what is

the case in the region between 400-700 m which is the key region where models show large representation deficiencies?

Response: Thank you for the constructive comments. Our previous statement "DO is more sensitive to biological processes between 200-700 m and to physical processes between 400-1000 m" is not really correct or accurate. We have corrected as "DO is more sensitive to biological processes between 200-400 m but to physical processes below 400 m".

2. ll 26-28 - cite missing - as the carbon cycle has raise much attention ...

Response: We have added some references related to carbon cycle (line 27-28).

3. ll 68-69: A motivation why these two processes are chosen is missing. In particular it should be mentioned that vertical mixing is not added to the model as a physical process in general, but only to two of the tracers, as well as the resulting consequences of this choice.

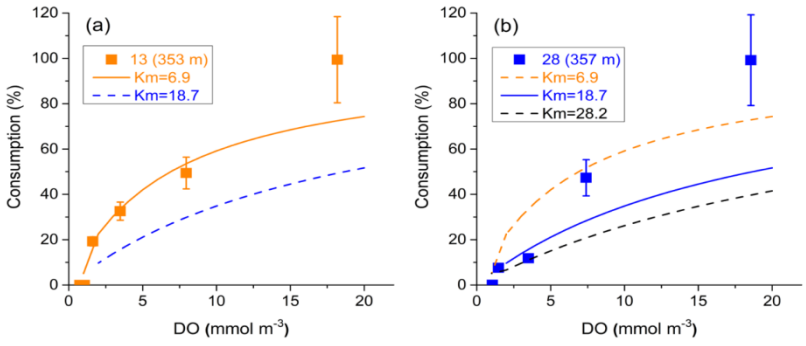
Response: Thank you for the constructive comments. We have revised the introduction to emphasize the motivation (line 59-67). We have also mentioned "The reference run applied a zero value for background diffusion (see eq. 9). However, a previous modelling study demonstrated that vertical background diffusion was an important process for DO supply at mid-depth (Duteil and Oschlies, 2011). Accordingly, we conduct a sensitivity experiment to test a set of values for background diffusion (Kb as 0.1, 0.25 and 0.5 cm2 s-1). The addition of background diffusion is only applied to the two key variables (DO and DON) in this analysis to eliminate any potential interactions and feedbacks between various physical and biogeochemical processes (note: our model experiments showed no significant effects on modelled DO dynamics with background diffusion applied to the nutrients)".

4. l 149: I guess this is a typo and the reference run is not model version V1.2, but V1.4

Response: We have corrected as V1.4.

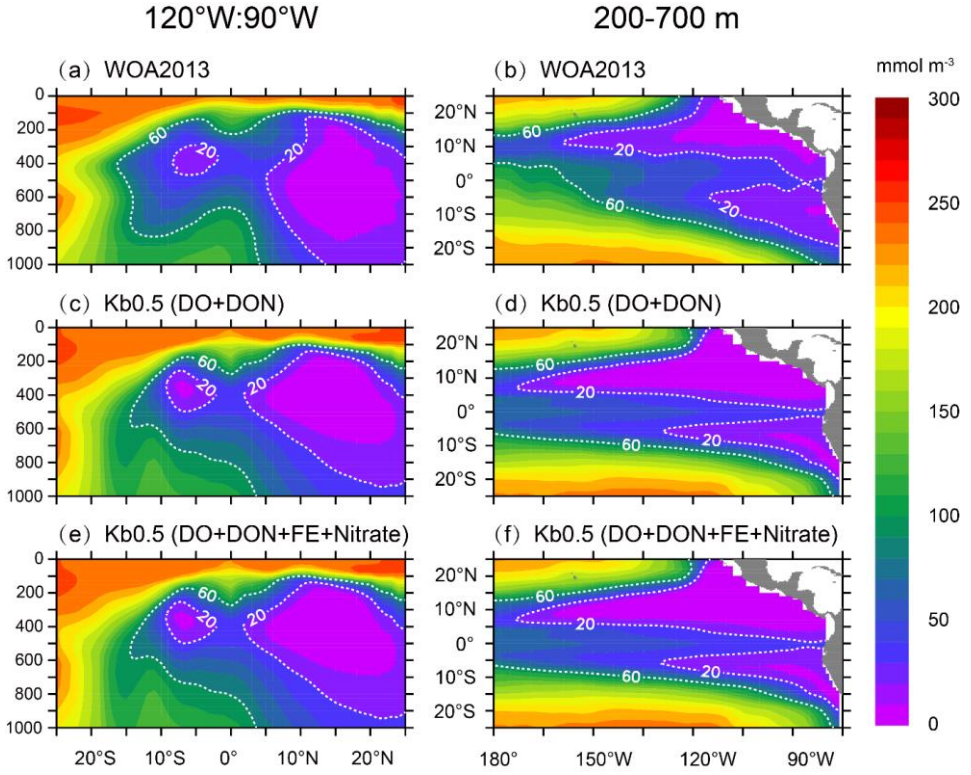
5. I have a problem with Fig 3 - the fittet functions seems a bit random ... I like the idea of taking two different sites to get an estimate, but the fit itself is not convincing, in particular for Fig. 3b. Is there some kind of weighting applied? What fitting method has been used? In addition, how does the kinetic function that is derived and added to equation 5 look like - what is the finally used equation for the introduced sensitivity simulations?

Response: We used the fitting method of least squares, and did not apply any kind of weighting. But, for the old Fig. 3b, we only used four data points (excluding the smallest value) because the fitting curve using all five data points is too far away from the most data points (see the black line in the new Fig. 3b). It seems that the curve with Km=6.9 fits well for both sites, but our model sensitivity experiments show that applying Km=18.7 gets better performance for DO fields.



6. ll 172-173: I am struggeling with the approach that addtional diffusion is not added to all tracers in the model, but solely to DO and DON. This approach needs a justification. What are the potential consequences when adding the background diffusion only to DO and DON? How does it look like when additional background diffusion is added to all tracers in the model? In addition it is important to clarify this in the abstract as well as in the conclusions.

Response: Thank you for the constructive comments. Our model experiments showed no significant effects on modelled DO distribution (see figure below) with background diffusion applied to dissolved iron (Fe) and nitrate (Ni). We have added "The addition of background diffusion is only applied to the two key variables (DO and DON) in this analysis to eliminate any potential interactions and feedbacks between various physical and biogeochemical processes (note: our model experiments showed no significant effects on modelled DO dynamics with background diffusion applied to the nutrients)" in the text.



7. Fig 4: Is that averaged between 120°W and 90°W? Please specify.

Response: Yes, we have added "over 120°W-90°W" in the figure caption.

8. From Fig 5 I cannot deduce that Km18.8Kb0.5 gives the best results as it is done in the text. I would agree for the correlation, but by eye it seems that this is not the case for the standard deviation. This needs to be specified/clarified in the text.

Response: Thank you for the constructive comments. We have reworded as "Figure 5 also illustrates that the Km18.7Kb0.5 run produces the best outputs, according to the combined assessments of the correlation and normalized standard deviation (NSD) (the distance to the observation). The distance is shortest over 400-700 m and 700-100 m in both the ETNP and ETSP in the Km18.7Kb0.5 simulation. Clearly, the correlation coefficient was largest (0.38-0.99) in all sections; and the NSD is most close to 1 in the core OMZ of ETNP".

9. ll 193 - 199: Why did you choose the threshold 20 and 60 mmol m^{-3}? You choose the same range for the added background diffusion as Duteil and Oschlies (2011) used, and they found a tipping point, where the suboxic volume starts decreasing when further increasing the diffusivity, but for a much lower threshold. Is that the same case for your model? What does that mean regarding your best choice?

Response: Based on some previous studies, they selected DO < 20 mmol m^{-3} as the boundary of OMZs (Bettencourt et al., 2015; Fuenzalida et al., 2009; Paulmier and Ruiz-Pino, 2009), and DO < 60 mmol m^{-3} as the define of hypoxic water (Vaquer-Sunyer and Duarte, 2008). Accordingly, we use the criterion of <20 mmol m^{-3} for both suboxic water and OMZ volume, criterion of <60 mmol m^{-3} for hypoxic water.

Our model simulations show a decrease in OMZ volume with the increase of Kb from 0.1 to 0.5, which is not the same as that in Duteil (2011). Our best choice is based on a set of statistics on model performance for the estimates of DO concentration and OMZ volume (Tables 1 & 2, and Figure 5).

10. Fig 6: Figure caption needs to explain the figure without referencing to the text.

Response: We have added more information in the caption of Figure 6: "Observed DO data are from CCHDO (https://cchdo.ucsd.edu/), along (a) P04 (10°N) during April 02 - May 19, 1989, (c) P21 (17°S) during March 27 - June 25, 1994, and (e) P21 (17°S) during April 10 - May 19, 2009".

11. ll 229-230: Same sentence as in the Abstract. Please be more specific for the depth rage 400-700m. It's the key region of interest and currently it is treated not as such. Are both processes of equal importance, is one more important than the other or is this all just a result of how the background diffusion is applied?

Response: The sentence "the dominant process regulating the DO dynamics is biological consumption over 200-700 m, but physical supply over 400-1000 m" is not really correct or accurate, thus we have corrected as "the dominant process regulating the DO dynamics is biological consumption over 200-400 m, but physical supply below 400 m".

12. Fig 9 shows differences in the northern and southern hemispheric responses in mid depth - why do you find this relatively large impact of the reduced O:C utilization ratio in the region of the northern OMZ?

Response: Applying a smaller O:C utilization ratio leads to lower consumption rates, thus relatively higher DO concentration particularly in the OMZs, which alters the gradients of DO concentration in the water column thus changes the intensity of vertical mixing inside and around the OMZs. In order to show these effects, we have added the the variation of vertical DO gradient in Figure S1 and the changes of vertical gradient of DO caused by different model parameters in Figure 11.

13. Fig 10 caption - what is shown? An average between 120°W and 90°W? Black contour lines? Please be more precise. And I don't understand what you intend to show by the difference plots such as d-a, that is Km18.7kb0.5-Km18-Kb0.5+Ref- ... if the responses would be linear, then the result would be Ref ...

Response: They are averages over 120°W-90°W. Black lines denote contours of DO concentrations of 20 mmol m^{-3} and 60 mmol m^{-3} from the Km18.7Kb0.5 simulation. We have added all these information in the captions of new figures. We have merged the old Fig 10 and Fig 11 into a new Figure (Figure 10).

14. How is the physical supply estimated? I couldn't find the relevant information in the manuscript.

Response: We have added description for the calculation of physical supply in the methods section (line 155-156).

15. How is the biological consumption estimated?

Response: We have added description for the calculation of biological consumption in the methods section (line 139-144).

16. ll 264-165: what are the various physical, biological and chemical processes? Please explain the potential processes that lead to the results shown in Fig 10.

Response: There was a problem in that sentence. We have reworded as "The small increase in consumption is attributable to increased DON concentration (Figure 10c) that results from the enhanced vertical mixing".

17. l 281 - there is no Fig S2 - I guess you mean S1 ...

Response: It should be Fig S1 in our previous version. But it is Fig S2 in the revised manuscript.

18. I would suggest that you refer all your difference plots to the reference run. So when you would like to show the impact of reduced O:C utilization then you show km18.7-Ref (as you do), when you would like to show the impact of added vertical mixing (to DO and DON) then you show kb0.5-Ref and when you want to show the combined impact it's Km18.7kb0.5-Ref. That's how you started when showing changes in the oxygen concentration and it would make it much easier for the reader to follow.

Response: Thank you for your suggestion. We have merged Figure 10 and Figure 11 into a new figure, showing the differences in physical supply, biological consumption, DON and net flux under the enhanced vertical mixing (Kb0.5-Ref), a reduced O:C utilization ratio (Km18.7-Ref), and combination (Km18.7Kb0.5-Ref).

19. l 284: How does Ref look like in this case - these difference of the difference plots should be close to Ref.

Response: We have added a new figure (Figure S1), showing horizontal advection, vertical advection, vertical mixing and vertical DO gradient from the reference, Kb0.5, Km18.7, and Km18.7Kb0.5. They are not close to those in the reference simulation.

20. l 284-285: Fig 12 e and f: The small difference between these plots just shows that the applied changed add up almost linearly ... KM18.7-Ref is supposed to show the impact of the reduced O:C utilization and the same is done by Km18.7Kb0.5 - Kb0.5

Response: We have changed Fig 12 (now Fig 11) to show the differences in horizontal advection, vertical advection, vertical mixing and vertical DO gradient under the enhanced vertical mixing (i.e., Kb0.5-Ref), a reduced O:C utilization ratio (i.e., Km18.7-Ref), and combined effects (i.e., Km18.7Kb0.5-Ref).

21. l 285-286: Why is this the case? Mixing depends on the gradient - how does the reduced O:C utilization change that?

Response: Applying a smaller O:C utilization ratio leads to lower consumption rates, thus relatively higher DO concentration particularly in the OMZs, which alters the gradients

of DO concentration in the water column thus changes the intensity of vertical mixing inside and around the OMZs.

22. ll 289-290: I am not convinced that 12j is showing that - How does mixing look like in Ref?

Response: We have added a new figure (Figure S1), showing horizontal advection, vertical advection, vertical mixing and vertical DO gradient from the reference, Kb0.5, Km18.7, and Km18.7Kb0.5 simulations. Vertical mixing shows large differences in the OMZs between the simulations, which are caused by the differences in the vertical gradient of DO. We have changed Figure 12 (now Figure 11) as suggested, and the interactive effects can be seen in the new Figure 11o (which is the same as the old Figure 12j).

23. l 303 and l 315 (probably also in other places): The use of ”biological parameter” is incorrect, the parameters that are used in the model are, so far as I see spatially and temporally constant values, wheres the resulting tracer distributions show differences.

Response: We have replaced “biological parameter” with “biological fields”.

24. I appreciate the added sections 4.4 and 4.5. However the discussion is in the current version not very clear and easy to read and needs to be rewritten: Is this only taking the reference version into account? From which simulation are the DON concentrations taken that are mentioned here? Implication of current research should be the differentiation between the biogeochemical and physical impact in mid-depth (400-700m). Limitation of the study is that two explicit processes have been investigated. These should be set into relation to other processes of potential importance.

Response: Thank you for the constructive comments. We have revised the two sections with some rewriting and new figures showing the distributions of DON and remineralization (Figures S3). The analyses in these two sections are based on the best model simulation (i.e., the Km18.7Kb0.5 simulation), which has been clarified in the revised manuscript (line 345-347). Our previous statement “DO is more sensitive to biological processes over 200-700 m but to physical processes over 400-1000 m” is not accurate, we have corrected as “DO is more sensitive to biological processes over 200-400 m but to physical processes below 400 m”.

Reference:

Bettencourt, J. H., Lopez, C., Hernandez-Garcia, E., Montes, I., Sudre, J., Dewitte, B., Paulmier, A., and Garcon, V.: Boundaries of the Peruvian oxygen minimum zone shaped by coherent mesoscale dynamics, Nature Geoscience, 8, 937-U967, 2015.

Fuenzalida, R., Schneider, W., Garces-Vargas, J., Bravo, L., and Lange, C.: Vertical and horizontal extension of the oxygen minimum zone in the eastern South Pacific Ocean, Deep-Sea Res Pt Ii, 56, 1027-1038, 2009.

Laufkötter, C., John, J. G., Stock, C. A., and Dunne, J. P.: Temperature and oxygen dependence of the remineralization of organic matter, Global Biogeochemical Cycles, 31, 1038-1050, 2017.

Paulmier, A. and Ruiz-Pino, D.: Oxygen minimum zones (OMZs) in the modern ocean, Progress in Oceanography, 80, 113-128, 2009.

Sun, X., Frey, C., Garcia-Robledo, E., Jayakumar, A., and Ward, B. B.: Microbial niche differentiation explains nitrite oxidation in marine oxygen minimum zones, The ISME journal, 15, 1317-1329, 2021.

Vaquer-Sunyer, R. and Duarte, C. M.: Thresholds of hypoxia for marine biodiversity, PNAS, 105, 15452-15457, 2008.