

1 We wish to thank the referee for the detailed and constructive comments which will be helpful to the revision of our  
2 manuscript. According to the comments, we plan to make revisions and improvements as below: 1) to include more  
3 results of validations and comparison of model skills between our model and other published studies; 2) to give clearer  
4 descriptions and explanations about ‘physical modulation method’ and its associated concepts; 3) to have an English  
5 editor edit our manuscript and correct grammatical mistakes throughout the text.  
6

7 Detailed responses to all comments are given below. (Responses are shown in *Italic Font*)  
8  
9

10 **Comment:** This paper reports on the use of a three-dimensional modeling system to explore the biogeochemical and  
11 physical mechanisms regulating O<sub>2</sub> dynamics and bottom water hypoxia in the Pearl River estuary. A novelty of the  
12 study is the use of numerical O<sub>2</sub> tracers to quantify the source and sink processes dictating O<sub>2</sub> concentrations. The use  
13 of these tracers benefitted a diagnostic O<sub>2</sub> mass balance in this shallow and dynamic estuary. Further, the study  
14 demonstrates the spatial connection between processes occurring in different locations in the system. From this  
15 analysis, the conclusion is that air-sea mixing and sediment oxygen demand were the primary processes regulating  
16 bottom-water O<sub>2</sub> concentration and hypoxia. This is a different result than other well studied systems where hypoxia  
17 occurs such as Chesapeake Bay and northern Gulf of Mexico. Overall, I think this is an interesting paper that for the  
18 first time teases apart the biogeochemical and physical aspects of O<sub>2</sub> dynamics in a shallow, river-dominated system.  
19 Two major issues for the paper are the grammar and imprecise/incorrect use of language. I had to read many sentences  
20 two or three times for the meaning to shine through. These issues should be resolved by having a fluent English  
21 speaker edit the draft.  
22

23 **Response:**

24 *Thank the referee for the positive comments. As suggested, we will have an English editor edit the manuscript.*  
25

26 **Comment:** The use of ‘ambient’ here and throughout the paper is confusing to me. Do you mean to use ‘adjacent’? It  
27 seems like you are inferring the advective and diffusive fluxes from adjacent grid cells. Please clarify.

28 **Response:**

29 *Yes, the contributions of ambient biogeochemical processes represent the advective and diffusive fluxes of oxygen*  
30 *which is produced or consumed by the biogeochemical processes in the adjacent grid cells. According to Eq. 14, the*  
31 *contributions of ambient biogeochemical processes are described as  $\Delta t \times [-ADV(DO_{Bio}) + DIFF(DO_{Bio})]$ .*

32 *We agree that the word ‘ambient’ could be misleading. Therefore, as suggested, we will correct the word ‘ambient’*  
33 *to ‘adjacent’ in the revised manuscript.*  
34

35 **Comment:** P1, line 25: As you haven’t yet defined “modulation of physical processes” this phrase appears to be jargon

1 and is unclear to the reader.

2 **Response:**

3 *We will provide a clear definition of the ‘physical modulation method’ and its associated terms in the revised*  
4 *manuscript.*

5 *With respect to the phrase ‘modulation of physical processes’, it should be the modulation of biogeochemical*  
6 *effects on the oxygen due to physical transport. In our study, we considered that DO concentrations could be affected*  
7 *by the biogeochemical processes by two ways. Firstly, the biogeochemical processes can produce or consume oxygen*  
8 *to change the local DO concentrations directly. Secondly, the biogeochemical processes can also change DO*  
9 *concentrations in the adjacent grid cells and hence change the DO fluxes from these adjacent grid cell; as a result, the*  
10 *DO concentrations will be affected by the biogeochemical processes occurred in the adjacent grid cells. We defined the*  
11 *latter mechanism as the modulation of biogeochemical effects on the oxygen due to physical transport.*

12 *To make it clear, we will change “modulation of physical processes” to “modulation of biogeochemical effects on*  
13 *the oxygen due to physical transport” accordingly in the revised manuscript.*

14

15 **Comment:** P1, line 26: The values presented here and following seem like they should be process rates like 4.31 mg  
16 1-1 d-1. Or if this value is an average over some seasonal or annual period, please state this.

17 **Response:**

18 *This value (4.31 mg L<sup>-1</sup>) represents the decrease in DO concentrations due to the sediment oxygen demand using*  
19 *the physical modulation method. It is averaged over July-August 2006. Specifically, the value of 4.31 mg L<sup>-1</sup> indicates*  
20 *that the two-month averaged bottom DO concentrations will be higher by 4.31 mg L<sup>-1</sup> if the effect of the sediment*  
21 *oxygen demand on DO is ignored. As suggested, we will clarify that this value is one averaged over the two months in*  
22 *the revised manuscript.*

23

24 **Comment:** P1, line 32-33: This sentence doesn’t make sense. On the one hand it is stated that photosynthesis  
25 increased the O2 concentration, but then it also increased the hypoxic area (decreased O2 concentration). Please  
26 clarify.

27 **Response:**

28 *Yes, there is a mistake here. What it should be is that the hypoxic area is increased when turning off the*  
29 *photosynthesis and water column respiration. This will be corrected in the revised manuscript.*

30

31 **Comment:** P2, lines 2-7: These sentences are not clear and appear unnecessary. I suggest deleting them and starting  
32 the Introduction with line 8,

33 **Response:**

34 *As suggested, we will delete these sentences in the revised manuscript.*

35

1 **Comment:** P3 line4: “Pearl River Estuary”, estuary should not be capitalized

2 **Response:**

3 *As suggested, we will change it to ‘Pearl River estuary’ in the revised manuscript.*

4

5 **Comment:** P3, line 18: Describe here what you mean by “physical modulation of biogeochemical terms”.

6 **Response:**

7 *As suggested, we will provide a further description to the physical modulation method and its associated terms*  
8 *here in the revised manuscript (please see response above).*

9

10 **Comment:** P3-8: Nice description of the modeling

11 **Response:**

12 *Thank the referee for the positive comments.*

13

14 **Comment:** P8, line 7: In the ‘Model Validation’ section you might also suggest some additional observations that  
15 could be measured to assess the modulation model. Perhaps oxygen isotopes or additional rate measures would be  
16 useful to validate the biogeochemical O2 terms.

17 **Response:**

18 *As suggested, we will provide more results for our model validation (e.g., water elevations, temperature and*  
19 *salinity profiles, chlorophyll-a, primary production, and particulate organic carbon) and also put forward some*  
20 *suggestions for further observations (e.g., oxygen isotopes) that could be used to evaluate the modulation model*  
21 *performance in the revised manuscript.*

22 *In addition, our model results show that the spatial distribution and duration of hypoxia in the Pearl River*  
23 *estuary were mainly controlled by the re-aeration process and the sediment oxygen demand. In order to make our*  
24 *conclusions more persuasive, we have compared our simulated results associated with these two important*  
25 *biogeochemical processes with historical observations (Table 2). Such model-data comparison is of great importance*  
26 *but not enough at the current stage due to data insufficiency. Therefore, in the revised manuscript we will also suggest*  
27 *that the observations related to the important biogeochemical processes affecting DO should be strengthened in the*  
28 *near future.*

29

30 **Comment:** P11, line 29: unclear what ‘9051 t’ is

31 **Response:**

32 *Here it means 9,051 tons. We will change it to “9,051 tons” in the revised manuscript.*

33

34 **Comment:** P12, lines 4-6: I disagree with this statement. The O2 gradient driven by photosynthesis would only be  
35 uniform or small if the light were at levels saturating to photosynthesis throughout the water-column

1 **Response:**

2 *Okay, this sentence should be better stated. In our study, the oxygen gradient driven by photosynthesis was*  
3 *represented by the gradient of  $DO_{Phot}$ . We calculated the vertical diffusive fluxes of  $DO_{Phot}$  and  $DO_{Rea}$  and found that*  
4 *the diffusive flux of  $DO_{Phot}$  ( $-0.04 \text{ mg L}^{-1} \text{ day}^{-1}$ ) was much smaller than that of  $DO_{Rea}$  ( $-0.48 \text{ mg L}^{-1} \text{ day}^{-1}$ ) (Fig. 8c). This*  
5 *result indicated that the gradient of  $DO_{Phot}$  was much smaller than that of  $DO_{Rea}$  since the diffusion coefficients were*  
6 *the same. From Fig. 8a it can be seen that at the surface layer of the PRE, the rates of re-aeration and photosynthesis*  
7 *were estimated  $0.55$  and  $0.28 \text{ mg L}^{-1} \text{ day}^{-1}$ , respectively; at the middle layer, these two rates were estimated  $0$  and  $0.14$*   
8  *$\text{mg L}^{-1} \text{ day}^{-1}$ , respectively. The difference of photosynthesis between the surface and middle layers was much smaller*  
9 *than the difference of re-aeration, which means that the oxygen gradient driven by photosynthesis was also much*  
10 *smaller.*

11 *We will modify this sentence and include the discussion above in the revised manuscript.*

12  
13 **Comment:** P15, line 27: Correct ‘Fig.9921a and Fig.9921b

14 **Response:**

15 *Okay, we will correct this to “Fig.12” in the revised manuscript.*

16  
17 **Comment:** P16, line 11: ‘8 km<sup>3</sup>’, use units consistent with what you present from the Gulf of Mexico and PRE (km<sup>2</sup>)

18 **Response:**

19 *The Chesapeake Bay and the northern Gulf of Mexico are the two well-known and well-studied areas which suffer*  
20 *from sever water hypoxia. We believe that it could be interesting and helpful to compare the hypoxia and its controlling*  
21 *mechanism between the Pearl River estuary and these two areas. Generally, the hypoxic volume was frequently*  
22 *estimated and reported for the Chesapeake Bay, while the hypoxic area was frequently estimated and reported for the*  
23 *northern Gulf of Mexico. To facilitate the comparison, we will calculate the hypoxic area ( $\sim 237 \text{ km}^2$ ) and hypoxic*  
24 *volume ( $0.1255 \text{ km}^3$ ) for the Pearl River estuary and compare them with the northern Gulf of Mexico and the*  
25 *Chesapeake Bay accordingly in the revised manuscript.*

26  
27 **Comment:** Table 2: In the heading do you mean ‘WCR’ instead of ‘respiration by phytoplankton’, which is hard to  
28 measure in practice and which is usually small in comparison to WCR.

29 **Response:**

30 *In fact, it is the respiration rate that was calculated by subtracting the nitrification oxygen consumption rate from*  
31 *the total oxygen consumption rate, neither WCR nor the respiration by phytoplankton (as the referee mentioned, it is*  
32 *difficult to measure). This respiration rate was reported by He et al. (2014) and was used to validate our model. We*  
33 *will correct this in the revised manuscript.*

34  
35 **Comment:** Fig. 1b: Did you mean to show the cross-section (side-view) as noted in the figure

1 caption? Here it shows the map view of the river network.

2 **Response:**

3 *We realize that it could be misleading using “cross-section” here, which in fact denotes the computational grids*  
4 *for the 1-D river network model. To clarify this, we will change it to “computational cross-sections” in the revised*  
5 *manuscript.*

6  
7 **Comment:** Fig. 5: In the caption state the bias is between the two models, RCA and modulation

8 **Response:**

9 *Yes. We will explain the bias in the caption of Fig. 5 in the revised manuscript.*

10  
11 **Comment:** Fig 6: Perhaps I missed it in the text, but why do the two models differ? Please discuss in text.

12 **Response:**

13 *As suggested, we will discuss the reason for the differences between the two models in the revised manuscript.*  
14 *Theoretically, there should be no differences between the two models since the transport equation is a linear equation.*  
15 *However, in the numerical model, the partial differential equations are approximately represented by difference*  
16 *equations. Some nonlinear numerical methods were applied to restrain the errors caused by discretizing the partial*  
17 *differential equations. We found that the differences between the two models are caused by these nonlinear numerical*  
18 *methods. We have conducted a test by turning off these nonlinear methods and found that the differences between the*  
19 *two models are removed but the model results become inaccurate. We would like to emphasize that the differences*  
20 *between the two models in our study are small and have little impact on the analysis of the hypoxia.*

21  
22 **Comment:** Fig 8e: define ABio and LBio in the caption Technical corrections: There are too many for me to  
23 enumerate here. Please have an English editor assist with fixing plural noun/verb issues and other grammatical  
24 mistakes.

25 **Response:**

26 *As suggested, we will have an English editor edit our manuscript and correct grammatical mistakes throughout*  
27 *the text.*

28  
29 **Reference**

30 He, B., Dai, M., Zhai, W., Guo, X., and Wang, L.: Hypoxia in the upper reaches of the Pearl River Estuary and its  
31 maintenance mechanisms: A synthesis based on multiple year observations during 2000–2008, *Marine Chemistry*,  
32 167, 13-24, 2014.

33  
34