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Biogeosciences Discussions

Interactive comment on "Wind-driven stratification patterns and dissolved oxygen depletion in the area off the Changjiang (Yangtze) Estuary" *by* Taavi Liblik et al.

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Dear Anonymous reviewer,

Thank you for reviewing the paper. We have taken both of your main concerns seriously and have made corrections accordingly. Please find our specific responses below. Please notice that our replies include preliminary texts from the revised manuscript. We might do small changes in language, in this phase revised manuscript won't be submitted yet.

Best wishes, Taavi Liblik

Comment: 1. Observations from 27 August to 5 September in 2015 and from 24 to 29 July in 2017, are actually snapshots in different months and different years. So, their differences result from seasonal or interannual variation or both? In fact, the hypoxia off the CE has prominent seasonal variation and annual cycle, e.g., hypoxia appearing in coastal areas south of the CE in early summer and severe hypoxia in the area north of the CE in August, and also interannual variations (Zhu et al., 2011). 2. The conclusion mentioned that the annual cycle was dominated by wind and the interannual variation by wind and river runoff. But the manuscript did not provide enough evidence for these conclusions.

Reply: The annual cycle and inter-annual variability were discussed in the first two sections of the discussion in originally submitted manuscript. In the revised manuscript we have dealt with this question more deeply. Since the 2015 measurements are done one month later in the end of summer, probability of the occurrence of northerly wind is much higher. This is clear from the Fig. 13a. Therefor the snapshot of 2015 describes rather late summer situation and 2017 rather the mid-summer situation indeed. For the inter-annual variability we have analyzed wind and river data (1993-2018) and compared later years with remotely sensed salinity (2015-2018). Mentioned data well agrees with the concept we are suggesting. 2015 distinguishes as special summer in terms of wind forcing and CDW. Weaker summer monsoon resulted in more frequent CDW spreading to the south (as we also observed). Summer 2017 was closer to the "typical" climatological mean summer. We have checked also earlier studies (added more examples during revision, including Zhu et al. 2011) and found similar observations as you mentioned in August. If summer monsoon is at least close to climatological mean, then hypoxia in north is typical. Shortly, our observations somewhat reflect the annual cycle, but 2015 was also special year with weak summer monsoon. We have added also citing to other similar years, when hypoxia in south was observed (Wang and Wang, 2007, Li et al. 1999). The statement in the conclusion you referred was not well worded. We cannot say "Wind forcing and river runoff are main contributors", but we believe we can say based on the study: river runoff and wind are important (not saying it is main) factors in inter-annual and annual cycle of DO.

Action: We added following text to the second section of discussion: " Thus, our observations conducted in late August - early September 2015 and late July 2017 illustrate the annual cycle of forcing and latter reflect in oxygen and stratification patterns. On the other hand, summer monsoon and river discharge were close to average in summer 2017 while the summer monsoon was clearly weaker in 2015 (Fig. 13a-b). Thus, our observations reflect also the differences in forcing and concurrently in DO distributions between two summers" and to the fourth section: "However, on the top of the inter-annual variability and annual cycle are synoptic scale changes of wind-driven currents and river forcing, which influence the distributions (Fig. 10). Thus, when planning future hypoxia related measurement campaigns, it is worthwhile to take into account wind-driven transport, river discharge and remotely sensed salinity to forecast spreading of the CDW and potential hypoxic area location prior field works. This could allow more efficient use of ship time and more detailed sampling of the hypoxic area."

Statement you referred is modified: "Wind forcing and river runoff are important contributors of inter-annual variations and annual cycle, determining the size and location of low DO areas. The DO minimum is located more likely in the northern part in July-August during summer monsoon and in the southern part during rest of the stratified period."

Comment: 2. The CE and adjacent area are highly dynamic and complicated, affected by the river plume, the Yellow Sea Coastal Current, East China Sea Coastal Current, the Taiwan Warm Current and the Kuroshio. The influence of the intrusion of the TWC and Kuroshio on hypoxia has been discussed previously. But the manuscript just considered the river runoff and wind, and did not discuss the role of the TWC and Kuroshio. The intrusion can be recognized by the current pattern, bottom salinity and temperature. The authors should analyze the differences of open ocean intrusion in 2015 and 2017 and their impact on hypoxia distributions.

Reply: Thank you for this comment. We think this suggestion helped to improve the manuscript. Indeed the role of intrusion was hidden in the manuscript, although we are well aware of intrusion of subthermocline water.

Action: We have made changes thorough manuscript to highlight importance of the intrusion. We defined the upper boundary of the Kuroshio subsurface water mass (as isoline 24.5 temperature) and relate it to the upper boundary of oxygen depletion (2 mgl-1). This simplification is needed as we don't want to go to fine details of subsurface water mass formation in this study. The same isolines were used also in the original manuscript, but named as thermocline and oxycline. We believe the terms we use now, are more correct. Our main suggestion is that position of intrusion is largely related to the wind forcing. Intrusion climbs higher to coastal slope, as compensation for the offshore transport in the surface layer. And it is located deeper and further offshore, when there is downwelling with northerly winds. Our second suggestion is that existence of intrusion is necessary precondition for hypoxia formation. In order to come up with the two suggestions and react to your comment we: (1) described and analyzed both boundaries more deeply in subchapter 3.1. Particularly, the vertical sections are described more comprehensively in the revised version. 2015 and 2017 are compared in the context of intrusion there. (2) We have added satellite altimetry to give more evidence to our suggestions. The two surveys differ each other clearly by upwelling (2017) and downwelling (2015) and we claim the main reason for this difference is wind forcing. (3) We have highlighted the importance of intrusion, related to oxygen depletion in discussion: "Importance of KSSW thickness on the oxygen depletion estimations reveal well also if near bottom oxygen maps are compared with the total AOU maps (Figs. 6g-h). Bottom hypoxia in north in 2017 was much more intense comparing to hypoxia in south in 2015. However, the total AOU was similar in hypoxic zones in both years due to thicker oxygen depleted layer, i.e. thicker KSSW in south in 2015." (4) We have added new section to the discussion highlighting the importance of intrusion. The main point we make there is that strong stratification strength as such, does not necessarily mean hypoxia. We copy the last part of the section here." Two features must be present for hypoxia formation: 1) KSSW, 2) CDW and/or subsurface water upwelling. We can conclude that colder KSSW determines where (including in what depths) hypoxia could develop. Thus, latter provides necessary precondition for hypoxia. The CDW spreading and/or surbsurface water upwelling (and related biogeochemical, biological processes) determine the magnitude, exact location and timing of oxygen depletion. (5) Since in this paper we deal with the position of the intrusion only, we added another section to discussion that mentions other aspects of intrusion: "Besides the barrier effect by creation of the thermocline, intrusion of KSSW has other implications on oxygen dynamics. First, the subsurface water is oxygen depleted already before local impact of oxygen consumption. The furthest stations in the southeast (Fig. 1) had AOU of 2-2.5 mg l-1 in the deep layer in 2017, i.e. in the same order that has been estimated in the KSSW before (Qian et al., 2017). The total AOU in the water column there was 50-60 g m-2 (Fig. 6h). This water is still rather well ventilated comparing to the deep layer waters that had been impacted by upwelling or CDW induced production in the surface layer (Fig. 6g-h). Despite its initial oxygen depletion, Kuroshio intrusion is important source of oxygen import to the study area (Zuo et al., 2019). Without this lateral oxygen advection, hypoxia could form much faster in larger area (Zuo et al., 2019). Kuroshio intrusion is nutrient rich (Zhang et al., 2007b; Zhou et al., 2019) and its upwelling or vertical mixing could intensify sequence of primary production in the surface, consequently organic matter sinking producing oxygen consumption in the near-bottom layers.."

Specific comments: Line170: how to define weak or strong stratification based on density difference here?

Reply: we do not define it, just comparing different regions.

Action: We changed "relatively weak" to "weaker" to avoid confusion.

Line239: U is the river velocity. How is U calculated?

Reply: It was calculated as discharge divided by cross-sectional area in the river mouth

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(which is a bit subjective, depending on exact location). However, we realized during revision that the calculation and topic is not necessary to mention in results, as there are more sophisticated studies already available, where estimates can be taken.

Action: We now have about this topic section only in discussion: “The faith of the river plume can be separated to the regions and processes: circulating bulge near the mouth and downstream current along the coast (Fong and Geyer, 2002; Horner-Devine, 2009). The question is how much of riverine water remains in the river plume bulge and how much is advected to the neighboring areas. It has been estimated that about 80-90% of the discharge accounts to freshwater transport of coastal current (Li and Rong, 2012; Wu et al., 2013)

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