Biogeosciences Discuss., 6, C4744–C4754, 2010
www.biogeosciences-discuss.net/6/C4744/2010/

Biogeosciences Discussions

Interactive comment on "Natural and human-induced hypoxia and consequences for coastal areas: synthesis and future development" *by* J. Zhang et al.

J. Zhang et al.

jzhang@sklec.ecnu.edu.cn

Received and published: 22 March 2010

We appreciate very much the review comments and suggestions made by the guest editor and two referees. The original manuscript has been revised taking into consideration of questions and comments raised by two reviewers. Tables and Figures have also been revised to be consistent with the revision of the text. The part of references was expanded with other published results in literature. Details of revision are summarized as below.

Anonymous Referee #1

General Comments

This biogeochemically-oriented review on hypoxia includes a comprehensive, well integrated synthesis of the state of the science of coastal hypoxia, including considerations of spatio-temporal variability, natural and human causes, impacts of hypoxia on coastal biogeochemistry and ecology, resilience and recovery of ecosystems affected by hypoxia, and identification of gaps in our understanding of hypoxia, and recommendations for future research. He emphasis in this review was on characterizing natural as well as human induced hypoxia in coastal environments occurring on temporal scales ranging from episodic (irregular occurrence) to persistent (hypoxic events taking place over a time scale long enough to cause damage to the biota) and with spatial dimensions from tens to tens to hundreds of thousands of square kilometers. In addition, paleo- and historical information on hypoxia from sediment cores was included in this synthesis. Lastly, the authors have made an effort to identify the requirements for observing and modeling hypoxia and its impacts in coastal systems; and they have documented synthetic publications that integrate results from the efforts listed above.

While it is mentioned in the introduction and sprinkled throughout the text, the article needs to specifically address the short- and long-term impacts of climate change (warming, altered rainfall and freshwater discharge) on hypoxia. It is anticipated that these elements of global change will have a strong influence on the frequency, magnitude, temporal and spatial extent of hypoxia. Furthermore, climate change interacts with human disturbance (and changes therein) in many watersheds. These interactions need to be identified and clarified if improvements in management in coastal watersheds are to be realized. There is some limited discussion on this topic on P. 28, but this is at best superficial and neither informative nor well-integrated.

Reply: We have followed idea of referee in the review comments and reorganized the section 12 with addition of paragraphs addressing climate vs human effects on the occurrence and development of hypoxia in the near future. More references were added to support the discussion.

Specific Comments

1. On P. 4, top of second paragraph, it is stated that “The earliest systematic records of coastal hypoxia appear in literature from Europe and North America in 1910-1920.” Can the authors provide documentation of this?

Reply: We added more information about the early system records of coastal hypoxia from Europe and North America in the periods of 1910-1920, with further references. The revised text now becomes: “The earliest systematic records of coastal hypoxia appear in literature from Europe and North America in 1910-1920. For example, episodic and/or seasonal hypoxic events were found from 10-15 coastal water bodies from European Countries (e.g. North Sea, Baltic Sea, and Adriatic Sea, etc.), as well as east coast of USA (e.g. Delware, Long Island Sound and Chesapeake Bay) in the period of first twenty years of 20th Century; the reported negative effects on marine ecosystems included fish kills and mortality of benthic species (cf. Petersen, 1915; Sale and Skinner, 1917; Brongersma-Sanders, 1957; Andrews and Rickard, 1980; Mirza and Gray, 1981; Justic et al., 1987; Rosenberg et al., 1987; Patrick, 1988; Gerlach, 1990; Rosenberg, 1990; Parker and O’Reilly, 1991; D’Andrea et al., 1996; Arau’jo et al., 1999; Bricker et al., 1999; Fonselius and Valderrama, 2003)”.

2. P. 5, 2nd paragraph, line 5. omit “by bacteria” from this sentence. Algae and higher plants can function heterotrophically as well.

Reply: We agree with the comments by the referee, and the correction was done accordingly in this revision.

3. P. 8, line 2. Do the authors mean to say “models” instead of “modules”?

Reply: We agree with the comments by the referee, and the correction was done accordingly in this revision.

BGD

6, C4744–C4754, 2010

Interactive Comment

4. P. 11, line 16. Omit “Note that”. Line 6 from bottom, omit “Coastal” at the beginning of the sentence.

Reply: We agree with the comments by the referee, and the correction was made accordingly in this revision.

5. P. 12, 2nd paragraph, line 1. Change “Coastal eutrophication develops in the area adjacent to the river discharge” to “Coastal eutrophication often occurs in waters receiving river discharge”. Line 5. Change “vegetations” to “vegetation”. Line 6. Change “fresh-water” to “freshwater”. Line 9. Change “deep” to “deeper”. Bottom line. Change “modulates” to “modulate”.

Reply: We agree with the comments by the referee, and the corrections were made accordingly in this revised manuscript.

6. P. 13, top of page. Expand the discussion of effects of climate variability on coastal hypoxia.

Reply: We agree with the comments by the referee, and several paragraphs were added in the section 12 to address climate variability on coastal hypoxia.

7. P. 17, line 10. Change “environment” to “environments”.

Reply: We agree with the comments by the referee, and the correction was made accordingly in this revision.

8. P. 18, 2nd paragraph, line 8. Change “is” to “are”.

Reply: We agree with the comments by the referee, and the correction was made accordingly in this revision.

9. Figure 3, is at best inferential. They are many products of human activities; pollutants, sediment loads, increased freshwater discharge due to channelization, that have increased over the time span indicated. They all correlate in one fashion or another. I did not find this figure very helpful.

BGD

6, C4744–C4754, 2010

Reply: We tend to agree with referee on this but to a certain limit. Yes, the referee is right in that individual coastal hypoxic systems can be related somehow to other human activities, like hydro-engineering and regulation of freshwater and sediment loads, discharge pollutants from land and marine sectors, etc. However, from a global point of view, these products of human activities have a character of system specific and remain most likely at local and/or regional scale. Apart from the pollutants from industrial sectors that have been reduced in recent decades (e.g. use of leaded fuels in Figure 3), nutrient discharge from global rivers has been increased over last 50 years, and the model predictions show that nutrients from land-sources will continue to increase in the 21th Century. It has been shown that in a global scale, nutrient input from land-sources is of critical importance in affecting occurrence and severity of hypoxia in coastal waters.

Review Comments by Dr. J. Carstensen

General Comments

This is a well-written and well-structured manuscript reviewing our current knowledge on coastal hypoxia. As several reviews on coastal hypoxia have been published already this ms partly re-iterates previous reviews and extend beyond, particularly in synthesising the biogeochemistry. Overall, I enjoyed seeing this bulk of knowledge put together although there was also a large fraction of "dejavu". However, I think that the feedback mechanisms of the benthic biota on eutrophication could deserve more attention, just as much or perhaps even more than the feedbacks on the climate. Knowing that several of the authors have suggested regime shifts associated with events of hypoxia (hysteresis behaviour also proposed by e.g. Diaz and Rosenberg 2008) I was slightly disappointed not to see this addressed. Section 6 describes coastal hypoxia and benthic biota mostly as a one-way relationship, and I would encourage the authors to extend this section to also describe how changes in the benthic community affect the biogeochemistry of the sediments. In general, most of my comments below have arisen from my own curiosity to have more information on specific issues that I would like to see expanded, rather than disagreements with the views and formulations. The authors should be able to address most of these comments, and I therefore recommend publication after minor revision.

Reply: We have followed Dr. Carstensen his advice and added two paragraphs about the effects of oxygen on sediment biogeochemistry via its impact on benthic animals. However, we have kept it short because other papers in this special issue have dealt with it (cf. Levin et al., 2009; Kemp et al., 2010) and in particular Middelburg and Levin (2009). Sections 4 and 5 of the latter paper deal with this in detail. The link with hysteresis is also identified in these added paragraphs.

Moreover, the whole section 6 has been reorganized with discussion in more details about effects of benthos on biogeochemical cycles.

Specific Comments

1. Page 11038, l. 10-13: I would suggest making this more specific by adding something like "enhancing emissions of greenhouse gases to the atmosphere", since "active feedbacks" is too general and doesn't say much.

Reply: We agree with the comments by the referee, and followed his advice with correction made accordingly in this revision.

2. Page 11045, bottom of page: After reading the last sentence the next question naturally arises: what is needed then to disentangle eutrophication from trends in the physical forcing? This question is answered later on a more general level, but I would suggest that the authors elaborate on this question at this point in the ms.

Reply: We followed the advice of Dr. Carstensen and added following text in the revision.

"In the Changjiang Estuary and East China Sea Shelf, ratio between different nutrient species [e.g. NH_4^+ vs NO_3^- and organic vs inorganic phosphorus (i.e. DOP vs DIP)] has been used to disentangle nutrients related to coastal eutrohpication versus physical effects. The levels of NO_3^-/ NH_4^+ and DIP/DOP over the broad shelf of East China Sea indicate the replenishment of nutrients from incursion of Kurosio across shelf-break, whereas in the eutrophic waters further to the coast, ratios between oxidized to reductive forms as well as inorganic to organic forms of nitrogen and phosphorus become much lower (Zhang et al., 2007)."

3. Page 11046 and Figs. 2 and 3: The number of reported coastal hypoxic sites is a pragmatic but not a "true measure" of the hypoxia problem. The authors should acknowledge this, particularly in Fig. 3 where a correlation between fixed nitrogen and hypoxia is implicitly assumed. The number of publications in the ecological literature or natural sciences has probably increased at a similar rate over time, so strictly speaking it is difficult to make explicit inference to hypoxia as an increasing global problem, although I certainly believe it is. Moreover, the number of hypoxic sites in Fig. 3 – where do they come from? Are they the >400 sites from Diaz and Rosenberg (2008) partitioned into decades?

Reply: We agree with Dr. Carstensen on the point that an increase in reported coastal hypoxic sites from literature may also reflect the increased interest in research, hence in the revision we added discussion on this question.

"It should be remembered that cumulated numbers of reported hypoxic events may not be a true measure of hypoxia problem, like other deteriorations in coastal environments (e.g. Harmful Algal Blooms). Although there is a correlation between nutrient export from watersheds (e.g. fixed nitrogen) and coastal hypoxia can be inferred from publications in literature, this can be result that hypoxia becomes an topic that is more interesting to scientific and public societies today since last fifty years. Locally, there are many types of human activities that cab be related to the evolution of coastal hypoxia, like change in land-sources input (e.g. freshwater, sediment, nutrients and other pollutants), coastal engineering (e.g. channelization and mariculture) that have increased over the time span indicated in Figures 2 and 3 and ca be linked to individual hypoxic systems, in a regional and global scale, nutrient enrichment owing to nitrogen fix and nutrient loss from watersheds is believed the major anthropogenic forcing for the reported hypoxia in coastal environment (Rabalais et al., 2009)."

The number of >400 sites for coastal hypoxia in Figures 2-3 are from Diaz and Rosenberg (2008), Levin et al. (2009) and Rabalais et al. (2010), and data are regrouped into different periods (e.g. decade).

4. Page 11051, l. 12-13: I assume that this 3-times increase is due to further reduction processes under anoxic conditions (that are described in the following text). Explaining this at this point in the ms will help the reader better understand the sentence!

Reply: We have followed the advice of Dr. Carstensen and added text to deal with the question in more details as below.

"The more complex chemical reduction chains in low oxygen conditions (e.g. hypoxia) further stimulate trace elements (e.g. Fe and Mn) and nutrients (e.g. N and P) recycling, and hence affects the function of benthic communities relative to the situation under aerobic respirations (Middelburg and Levin, 2009). The combined effect of anaerobic reduction and heterotrophic metabolism in hypoxic conditions can retard recovery of oxygen deplete conditions (Kemp et al., 2010)."

5. Page 11054, l. 22: Here, it is suggested that atmospheric feedbacks can have a strong impact on climate change! On page 11058, it is stated that N2O is an important contributor to greenhouse gasses, whereas CH4 is moderate! Then on page 11060, l 5-10 it is stated that the ocean's contribution to CH4 is insignificant. Knowing that these two atmospheric constituents combined are responsible for _10% of the overall greenhouse effect, I cannot see that the atmospheric emissions have a strong feedback to climate change, probably a considerable impact, I'd say. Moreover, I would suggest moving section 11 up before section 8 and integrating these two sections better, because many site-specific results are presented in section 11 which are then scaled-up and discussed in both section 8 and 11. Hope this was clear!

BGD

6, C4744–C4754, 2010

Reply: We have followed the advice of Dr. Carstensen and used the words "considerable impact" when dealing with the feedbacks to atmosphere (e.g. emission of trace gases), and kept consistent in the manuscript.

As for the structure of the manuscript (e.g. sections 8 and 11), section 8 is an integration of previous sections 1-7; whereas sections 9-11 deal with the interactions of coastal hypoxia with other parts of global system and effect on social and economic development. Although we intend to keep the original structure of this work, we do keep in mind concerns of Dr. Carstensen in his review comments and revised the text accordingly.

6. Another issue that I think the authors should address is the combined effect of low oxygen and high pCO2 that will further increase the "dead zones", particularly in connection to the OMZ (See Brewer & Peltzer 2009, Science 324: 347-348).

Reply: We have followed the advice of Dr. Carstensen and added a paragraph about low DO and high pCO_2 in the section 12 as below.

"It has been shown that combined effect of lox oxygen and high CO2 in the future ocean may increase the severity of oxygen inventory by spatial expansion and reduction of O2 to CO2 fugacity ratio in the oxygen minimum zone (OMZ) (Brewer and Peltzer, 2009). Where the coastal hypoxia is fueled with low oxygen waters from open ocean, particularly in the "dead zones" of upwelling systems, the synergistic effect of low oxygen and high pCO2 on the evolution of coastal hypoxia will be more severe and with greater uncertainty than previously predictions using models."

7. Page 11059, l. 28 ff: I don't see the point here. Elevated CH4 concentrations in the plume of the Yangtze River are most likely due to terrestrial inputs, but where is the link to hypoxia and CH4 releases from the sediments caused by hypoxia. I would suggest removing sentences until page 11060, l. 5. Moreover, my knowledge of the Chinese geography is limited, so I would suggest restating where Kuroshio is located.

Reply: We revised the text taking into consideration of comments by Dr. Carstensen with addition of new information below.

"Zhang et al. (2008) found the sea-to-air flux of CH4 as high as 250-400 μmol m-2 day-1 in the areas of hypoxia, which is twenty times higher than the flux from shelf mixed water (e.g. 10-15μmol m-2 day-1) of East China Sea and up to three orders of magnitude higher than the flux from surface waters of the Kuroshio ($<$0.5μmol m-2 day-1). It should be noted that high sea-to-air flux of CH4 in the area affected by the Changjiang effluent plums is higher than the water-to-air flux in the river itself."

8. Page 11064, l. 16-20: The authors focus only on the potential negative effects of altered wind patterns, but there could be positive effects as well. The authors should acknowledge this and give a more balanced presentation.

Reply: We have followed the advice by Dr. Carstensen and revised the manuscript accordingly to have more balanced discussion on the effect of change in wind pattern as below.

"Warming can also alter wind patterns with changes in coastal circulation, upwelling and down-welling, which in one side reduces open coast oxygen levels through mixing suppression and lead to expansion of oxygen minimum zones on to continental shelves (Bograd et al., 2008; Stramma et al., 2008; Stramma et al., 2009); on another side, change in wind patterns can increase the inventory of dissolved oxygen through advection and renewal of water mass (i.e. exchange with DO replete waters)."

Further discussions on the effect of wind pattern have been elaborated within the predicted frame of global change in section 12.

Technical Corrections

1. Page 11042-43: Use "Fig. 2a" and "Fig. 2b" in the text to distinguish the panels.

Reply: The corrections were made in this revised form according to the ideas of Dr. Carstensen.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

2. Page 11054, l. 27: Should be “through”.

Reply: The corrections were made in this revised form according to the ideas of Dr. Carstensen.

3. Page 11056, l. 22-28: Repeated sentence.

Reply: The corrections were made in this revised form according to the ideas of Dr. Carstensen.

4. Page 11061, l. 14: Should be “advection”.

Reply: The corrections were made in this revised form according to the ideas of Dr. Carstensen.

On behalf of all co-authors of this manuscript, I would like to express our sincere gratitude to anonymous referee and Dr. J. Carstensen, again for their very kind support to this work and thoughtful ideas that help to improve this manuscript.

Thank you very much for your consideration of this manuscript for publication in Biogeosciences, and if you have any questions about this revision, please do not hesitate to let me know.

Yours sincerely,

Jing Zhang

Interactive comment on Biogeosciences Discuss., 6, 11035, 2009.