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Biogeosciences Discussions

Interactive comment on "Coastal hypoxia/anoxia as a source of CH_4 and N_2O" *by* S. W. A. Naqvi et al.

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We thank Dr. G. Abril for his very constructive comments and suggestions most of which have been accepted as described below. In addition, we have also updated the manuscript citing several new papers that were published while the manuscript was in review (Brüchert et al., 2009; Solomon et al., 2009; Bange et al., 2010; Codispoti, 2010; Damm et al., 2010; Walker et al., 2010). There are some more references to the earlier work that have been included to support new text added in response to various comments by the two referees.

RC = RC; AR = Authors Response

RC - I have two major comments: first the authors use the term "coastal" in an inap-

propriate way in the title and throughout the paper; second, this is more a compilation than a review and some synthesis effort would greatly improve the impact of the paper.

AR - We have tried our best to address both concerns as detailed below:

RC - The coastal zone is defined as the area extending from estuaries at the limit of the tidal influence to the continental shelf break (generally the 200m depth isobath). So the coastal zone includes littoral ecosystems like estuaries, lagoons and embayments, that very often experience hypoxia and anoxia, behave as hotspots of CH4 and N2O fluxes, but that are not treated in this review. A famous site is Cape Lookout Bight that emits huge amounts of CH4 (see eg Martens C.S and Klump J.V. (1980) GCA). Also, the coastal zone excludes marine sites like the Black Sea or the Cariaco basin, which are treated here. I suggest the authors use the term “marine hypoxia” in their title and then use the term “continental shelf” when appropriate in the text. It must also be stated in the MS that this review does not include estuaries, fjords and lagoons.

AR - The title was given to us by the Hypoxia Working Group. We do agree with Dr. Abril that we do not deal only with and all of the coastal hypoxic areas. Accordingly, we have changed the title as suggested by the referee and made appropriate changes in the text as well, wherever needed, to reflect that while focussing on MAJOR coastal hypoxic systems our review also covers enclosed anoxic basins such as the Black Sea and the open-ocean oxygen minimum zones, and that it does not cover numerous other smaller water bodies such as estuaries, fjords and lagoons. By the way, to our knowledge the Cape Lookout Bight does not experience hypoxia (at least it did not when Martens and Klump made their observations), but we have cited their work as an example to show how a region not experiencing hypoxia could still have very high methane concentrations, emphasizing the dominant role of sedimentary diagenesis fuelled by high organic supply in overlying waters in methane production.

RC - Review or compilation? The MS is very long mainly because of the choice of a structure based on the geographic criteria. Less than 3 discussion pages are dedi-

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cated to synthesis and some kind of cross system comparison. Although such choice is understandable to some extend, is leads to many repetitions, when dealing with the processes that control N2O and CH4 within each geographic region. I would find interesting to put more synthesis effort by dealing together with systems that have similar patterns regarding hypoxia/anoxia and CH4 / N2O distribution.

AR - The systems we have dealt with show some similarities but also several important differences. For example, the methane cycling over the Indian and Namibian shelves seems to be completely different. We have to therefore describe each system in some detail. Inevitably it has led to some repetition, but we have done our best to keep it at a minimum. We disagree with the referee that our original BGD manuscript was more of a compilation of data from various systems. Under the “Discussion” section we did highlight important differences and similarities between various systems. Perhaps, it was not enough, and we have now expanded the discussion, also benefiting from some more work that has been published since the submission of the first version of our manuscript.

RC - Figures 2 to 11 are also very repetitive, although they deal with different geographic regions, many of them tell the same story: figure 3,4,6,10,11 deal with spatial variations and figures 2,5,7,8,9 deal with temporal variations. Note that all these figures have been already published, so publishing all of them here again is not necessary. Instead it would be better for readers to get some kind of "general" spatial and temporal patterns in few figures as examples, eventually some exceptional patterns in other figures, and also more synthesize information for all systems in other figures and tables (to that respect Fig 1 is great). Maybe groups like “river influenced and shallow” / “mid shelf” / “upwelling influenced” and “deep with anoxic bottom water” would match.

AR - In response to the referee’s suggestion, we have deleted Figures 4 and 6, and combined Figures 7 and 8 of the original manuscript. Note, however, that we were asked by the other referee to add "a figure or two" from the ETNP. As a result, the total mumber of figures has come down by one.

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We have included two tables presenting data from different regions that have been categorized under distinct groups, even though the criteria for grouping are somewhat different than those suggested by the referee.

RC - Some suggestion for more synthesis: First of all a table with all available data of CH4 / N2O concentrations by oceanic regions (range, average+/-SD). Classify sites and datasets according to oxic/hypoxic/suboxic/anoxic as defined in Table1. Note that it would be interesting to compare also with the well oxygenated ocean, as a reference. Another interesting table would provide calculated atmospheric CH4 and N2O fluxes from each sub-system, with their respective surface areas.

AR - Accepted. The tables provide concentration ranges in surface waters for various regions, highest observed concentration and depth at which it occurs, and sea-to-air fluxes.

RC - Try also to find some general trends between parameters (plot CH4/NO2 versus oxygen for instance, try correlations with water depths, water residence time:) indentifying the different oceanic regions with different symbols. Think also about some conceptual drawing starting from oxic to hypoxic, suboxic and anoxic.

AR - Unfortunately, we could not implement this suggestion the required data are not available from all systems.

RC - Detailed comments: P9459L7 dealing with nitrification “the yield of N2O relative to N2” is “relative to NO3-“

AR - That was an error, which has been corrected.

RC - P9462L24 the final step : : : using CO2” refer to acetate

AR - Done.

RC - also P9465top and elsewhere in the paper: any possibility of N2O production also by dissimilatory nitrate reduction to ammonium? See eg Welsh et al. Marine Biology.

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139: 1029-1036.

AR - There is a general belief that DNRA is not so important in the water column, except for the work by Lam et al. (2009). Even less is known about its role in N2O production in the water column. Nevertheless, we have cited the paper by Welsh et al.

RC - L11 and P9466 top definition of EBUE?

AR - Provided.

RC - P9467top what are the water depths of these sites?

AR - Included.

RC - P6468L19-24 not understandable L26 explain and define more clearly “high coastline-to-ocean area ratio”

AR - The “high coastline-to-ocean area ratio” in the North Indian Ocean arises from the fact that the region is surrounded by land masses on three sides. We have now deleted this term and rephrased the text for brevity.

RC - P9471: geographical definitions not clear: inner shelf, mid- outer shelf. L21-23 be more explicit

AR - Clarified and rephrased.

RC - P9472 and elsewhere in text: the potentially important processes of ebullition/bubble dissolution is ignored in this review: why? Read : McGinnis et al. (2006). Fate of rising methane bubbles in stratified waters: how much methane reaches the atmosphere? Journal of Geophysical Research 111.

AR - The role of bubble ebullition is now been discussed in considerable detail also considering a more recent paper by Solomon et al. (2009).

RC - Computed fluxes appear here alone for the Arabian sea. It is important to compare with other sites.

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AR - More information is now provided for individual regions as well as in Section 6.

RC - P9474 bottom : where can we see the record of 765nM in table or figure?

AR - Included in Table 2; the reference has also been provided.

RC - P9475 top: in water incubation where not suboxic, what where they?

AR - Hypoxic (O2 $\sim$ 15 micromolar); this has been clarified.

RC - P9475 again a calculated flux here that should be in a special section.

AR - The two new tables provide information on sea-to-air fluxes. The fluxes are also discussed in detail in Section 6.

RC - P9491 Section 5 is entitled “methane and nitrous oxide in anoxic zones”. This title is too general.

AR - Changed to “Methane and nitrous oxide in enclosed anoxic basins”

RC - Estuarine circulation is something else that what is written on L4.

AR - The relevant text has been rephrased deleting the term "Estuarine Circulation".

RC - Section 4.5 and section 5 both deal with the Baltic Sea

AR - We had considered this overlap. However, in order to focus on processes in enclosed anoxic basins in a separate section, we decided to split the information from the Baltic into two parts.

RC - P9493 interesting information is given concerning processes involved in N2O cycling in the black sea, based on N and O stable isotopes. It would be interesting if this information could be compared with what is discussed other sections.

AR - Stated; in the other regions d15N and d18O are positively correlated.

RC - P9496top explain “nitrifier denitrification”

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AR - Explained.

RC - Figures: F1: the numbers given here follow a different order from the one of the different section, which makes reading more difficult.

AR - Even if we label various areas by numbers in the order they appear in the figure, it will still require some effort to locate them if the reader does not have any idea of where these sites are. Therefore, we prefer to retain the order we had chosen from west to east in the map.

RC - F2 MSexcell default format

AR - Does the referee want to change it to some other format? It is not clear.

RC - F3&4 where is Goa?

AR - Coordinates have been added in the caption. Note that Fig. 4 has been dropped.

RC - F6 Where is Mangalore. CH4 at SK37? I cannot see H2S

AR - This figure has been dropped making the comment not applicable.

RC - Combine F7&8

AR - The two figures have been combined.

RC - F10 convert O2 mg/L to uM

AR - Done.

RC - F11: can the influence of the Mississipi plume be seen with salinity?

AR - Yes, it has now been stated in the text (although the salinity data presented by Kelley (2003) are not included in the figure).

RC - F12 Caption Kessler not Kesseler

AR - Corrected.

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RC - F13 an “O2” is missing in panel (b)

AR - The label "O2" has now been included.

Addional References

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