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Biogeosciences Discussions

Interactive comment on "Impact of seasonal oxygen deficiency on the phosphorous geochemistry of surface sediments along the Western Continental Shelf of India" *by* Josia Jacob et al.

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Response to the short comment (SC C3332) by nbsp and N. Nath

Comment 1: Contouring an area with single data points in each transect in ECMI (Fig.7), which can erroneously make a generalized distribution pattern for entire area.

Author's response: The contour plots were presented to give the readers a general idea of the distribution of the different phosphorus species in the study area. For a clear presentation of the data sets, the speciation data will be given in a table in the

revised version of the manuscript.

Comment 2: Detrital P values as low as 1.5 ppm cannot be easily explained (which geological phases can have so low values? Upper crust and shale values are nearly 800 ppm) as even the carbonate sediments in WCMI have at least 50 ppm of P.

Author's response: From the clay mineral studies Rao and Rao, 1995, reported that the influence of river borne clay minerals were found to be greater along the outer and slope sediments of the western continental margin of India compared to the inner shelf. They also found that the river-borne clay minerals were deposited along the region mostly during south west monsoon. As noted by the commentators, the lowest value (1.5 ppm) of Pdet (which originates from the deposition of weathering products of terrestrial igneous or metamorphic rocks) was observed along the inner shelf of the WCSI during SIM. In the present study, the Pdet was the least along the inner shelf during both SIM and LSM (1.5 – 463; average 104) which may be due to the lesser influence of terrigeneous materials along the region. In contrast, the outer shelf sediments had comparatively higher Pdet during both the seasons (41 – 2916; average 869). The spatial variations in the Pdet between the outer and inner shelf sediments were tested by two-way ANOVA by taking depth and latitude as factors (2, 7 degrees of freedom). During LSM, the spatial variations in Pdet (outer and inner shelf) were significant ($F=4.74$, $P<0.05$) whereas it was not significant during SIM ($F=3.74$). Hence, the observed low values of Pdet along the inner shelf of the WCSI can be explained by the lower deposition of the terrigeneous source materials which will be discussed in detail in the revised version of the manuscript.

Comment 3: In absence of a table (it is hard to interpret the numbers from contours), the data quality cannot be assessed. For example, when the precision of measurements is 5 to 15 %, representing the data with two decimal points even when the concentrations are in thousands of ppm is not logical.

Author's response: As mentioned earlier, the data will be given in a table in the revised

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version of the manuscript in which the numbers will be presented with one decimal point.

Comment 4: A patch of high authigenic, organic and detrital P seen in one season in the central portion of outer shelf is seen as P-Fe in another season at a place south of the original location suggesting the influence of lateral transport and may not be strictly be related to seasonal water column anoxia. Detrital P also shows a clear signs of dispersal as it is concentrated in the central portion in one season is seen to be dissipated to entire area in another season. In effect, the differences they see may be mainly related to lateral transport, and invoking water column anoxia as a reason is without a strong base.

Author's response: The commentators are mentioning about the transport of the various phosphorus species spatially along the shelf by the influence of the physical processes such as currents, resuspension and/or deposition etc. These physical processes can redistribute or disperse the various phosphorus species along the WCSI during a particular season. But they cannot lead to a shift of the phosphorus species from phase to another seasonally. Such redistribution of the various phosphorous species are observed in the sediment column due to diagenesis and is unlikely to happen in the surface sediments on a seasonal scale due to physical processes. Hence as the commentators describe, the shift of Paut and Porg concentrated along the central portion of the WCSI during LSM can be observed as PFe along the southern region of the WCSI during SIM, seems to be illogical. However, the seasonally varying spatial redistribution of Pdet during LSM and SIM by these physical processes as the commentators mentioned seems to be reasonable since it is non-reactive in the marine environment. The effect of the various physical processes on the distribution of the phosphorus species will be discussed in the revised version of the manuscript. Except Pdet, all the other phosphorus species (Pbio, PFe, Paut, Porg) are reactive and sensitive to productivity variations or redox conditions of the overlying water column (Ruttenberg, 1992; Hensen et al., 2006). An enhanced flux of phosphate and iron

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from the sediments into the water column is a well-documented phenomenon in hypoxic/anoxic zones (Diaz and Rosenberg, 2008; Middelburg and Levin, 2009). Such high fluxes of phosphate have been reported from the sediments underlying many hypoxic/anoxic zones (Aigar, 2001; Conley et al., 2009; Kemp et al., 2005; Mort et al., 2010). The present study is the first documentation of the seasonal variability observed in the phosphorus geochemistry of the surface sediments of the WCSI in response to the seasonally varying hydrographical and productivity patterns observed along the region during LSM and SIM. Underestimating the present observations interpreting them only on the basis of spatial variations due to physical processes is not acceptable.

Comment 5: Overall the paper lacks thorough discussion of benthic biogeochemical processes (for a journal of repute such as yours) to explain the variability of all the phases (except to invoke desorption of sorbed P from Fe). For example, what are the processes which control the variability of organic and authigenic P. What is happening to all the fractions of reactive P and their relation to biogeochemistry of carbon (diagenesis, benthic fluxes: : :..; sink switch: : :.)?

Author's response: As explained in the manuscript the aim of the present study is to investigate and discuss the influence of the seasonally varying hydrographical and productivity patterns on the speciation of phosphorus in the recently deposited (surface) sediments of the WCSI. The study was extended to the ECSI for a comparison with the speciation of phosphorus in the surface sediments from the ECSI where the hydrographical and productivity variations on a seasonal scale are not much pronounced. As suggested by the commentators, a discussion of the benthic fluxes and sink switching (diagenetic redistribution of phosphorus between phases after burial) is beyond the scope of this work since the study is limited to the speciation of phosphorus in the surface sediments. To explain the benthic fluxes, this study did not analyse the pore water phosphorus concentrations and also to discuss sink switching the study was not carried out in the sediment column. The discussion of these processes is not required to address the objectives of the present work.

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Comment 6: Though they claim that this is the first study of ECMI sediments, the data does not provide any new information except to find that the sediments predominantly contain P-detrital.

Author's response: The phosphorus speciation pattern in the surface sediments of the ECSI presented in this manuscript happens to be the first data set from this region. Hence, the distribution of the five phosphorus species (Pbio, PFe, Paut, Pdet and Porg) in the surface sediments presented in this manuscript itself is new information from this region. The speciation pattern observed was in general agreement with the hydrographical characteristics of the region, which is presented and discussed in detail under sections 3.3 and 4.4 of the manuscript.

Comment 7: There are spelling mistakes (for example they spell deposits as "deposites").

Author's response: The manuscript will be edited for English language. We hope to correct all such mistakes then.

Comment 8: At one place, outer shelf sediments are termed as inner shelf.

Author's response: We could not notice such a mistake in the manuscript. However, if we find it in a closer scrutiny, it will be corrected.

Comment 9: While they claim that this represents the first study on ECMI in the Introduction itself, first citation of 3 papers published on the same subject in the past on the Arabian Sea sediments in the front line oceanographic journals is relegated to p.15.

Author's response: The earlier published works on the speciation of phosphorus in the Arabian Sea sediments is referred and discussed under section 4 (Discussion). We could not understand p15 of the manuscript which the commentators are mentioning.

Comment 10: They mention the ship's name, but it would have been good to write the cruise nos. of two seasons for posterity.

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Author's response: Sampling along the WCSI during LSM was done onboard Sagar Sampada during cruise number 217. Sampling during SIM was carried out during cruise numbers 223 and 224 of Sagar sampada. Section 2.1 (sampling) will be modified to include the cruise numbers of the sampling vessel in the revised version of the manuscript.

Comment 11: How good is their analytical accuracy of dissolved Fe measurement is not mentioned. What are the standards used and what accuracies have they obtained?

Author's response: Working standards of iron (2-10 ppb) solution were prepared by diluting the stock solution (E-Merck) with Milli-Q water in 1% HNO3. To check the accuracy of the analytical method we used a river water reference material (SLRS-4) from National Research Council Canada (iron concentration 103$\pm$5 ppb). The analytical precision obtained for triplicate reference material was better than 5%. This will be included under section 2.2 (analysis) of the revised version of the manuscript

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