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Biogeosciences Discussions

Interactive comment on "Oxygenation variability off Northern Chile during the last two centuries" *by* J. A. Díaz-Ochoa et al.

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Dear Antje,

We thank very much to Dr. Reitz for a constructive and useful review of our manuscript. Hereon we provide detailed responses to several comments and observations.

Kind regards,

Javier D.

General comments 1) " I would have expected that the authors try to correlate the obtained paleo-proxy profiles to the laminated sediments. This seems to be possible at least for the sediments deposited before 1960, e.g. peaks correlate with darker

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Interactive Discussion

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intervals Mo/Al, V/Al, (lycopane + n-C35)/n-C31, CaCO3 and others. I could imagine that this combination together with the correlation with the ENSO events would highly upvalue the manuscript."

Replay: It is true that dark/light intervals observed in contact print of core BC-3 seem to correlate with several proxies. However, it should be noted that several laminations were present within each dark/light area and that chemical analyses were only conducted with a resolution of ∼0.5 cm (mean) core depth (see Caniupán et al., 2008). In addition, there is a correlation between dry bulk density profiles and several proxies. In fact, dry bulk density is correlated with dark/light areas and might be considered as a proxy of the degree of lamination. Therefore, in the manuscript's correction we will discuss density data and their correlation with proxies of oxygenation and the ENSO. Furthermore, to provide a stronger basis to the relationship proposed between the ENSO and oxygenation we consider appropriate adding to the Gergis and Fowler (2009) ENSO reconstruction (mostly based on extensive extra-tropical data) a detailed comparison with other chronologies available for the area off Peru (i.e. Quinn et al., 1987; Quinn, 1992; Garcia-Herrera et al., 2008). We are adding such comparison in Table 2 on ENSO events (also see the inverted triangles on bottom panels of the attached figure, representing strong to very strong El Niño events). These ENSO chronologies also include estimations of events' strength to support our idea that "short-term" oxygenation variability in Mejillones Bay has been linked (within the uncertainty inherent to our age model) to oxygen fluctuations in the water column and ENSO-like variability represented by a series of consecutive strong or very strong El Niño events, during the last two centuries.

2) "The authors should explain what new findings and interpretations about the Mejillones Bay they can add to that one of Vegas et al. (2007), Vargas et al. (2007), and Valdes et al. (2004) except that the Bay experienced an additional shift towards higher productivity and enhanced anoxic conditions in the bottom water since 1960."

Reply: Compared with previous reports our manuscript adds a more detailed inter-

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pretation of the Mejillones sedimentary record. Previous works were mainly centered in interpreting centennial-scale oxygenation variability, mostly associated to increased upwelling and productivity (i.e. Valdés et al., 2000; Vargas et al., 2007). Although previous studies also analyzed shorter time scales, those analyses mostly described past productivity fluctuations and their probable connection with alternating "siliceous productivity" and "calcareous productivity" modes (e.g. Valdés et al., 2004; Caniupán et al., 2009), whereas a direct link between oxygenation fluctuations at "short time scales" and ENSO-like activity was not assessed. It is precisely the last aspects that we focus on in our manuscript and that we will highlight in manuscript corrections. In addition, after a close inspection of the Mo/Al, V/Al data and their apparent "anticorrelation" with S, we observed that this effect was due to interferences with Al (terrigenous) inputs, a fact that is particularly evident within the spongy layer. After normalizing S by Al a short scale pattern between Mo/Al, V/Al and S/Al emerges so that most inconsistencies disappear (see the attached figure). Moreover, taking into account a significant correlation between S/Al and Fe/Al much Fe must have precipitated in association with metallic sulfides. Furthermore, the inflexion toward higher S/Al values coincides with a pronounced decline of siliceous productivity proxies measured in MUC-1B (i.e. diatom valve count, biogenic opal, biogenic Ba, all summarized by a principal component accounting for 73% of total variance, see the attached figure) since the early 1960s. This observation suggests that siliceous productivity since the second half of the 20th century has been strongly limited by Fe availability, probably as part of a negative feedback mechanism. Such mechanism would consist in that the upwelling favorable winds strengthened (higher Ti/Al and Zr/Al) and primary production and sulfidic conditions also increased, but by the early 1960s a threshold was reached and too much iron was removed to the sediments and was not available for the phytoplankton in the water column. Therefore, we suggest that dissolved Fe in the water column was strongy limitant for siliceous primary productivity since the early 1960s. Our hypothesis is supported by experiments conducted in the Peru-Chile Current off Peru by Hutchins et al. (2002) and off central Chile by Torres and Ampuero (2009) which point to an iron limitation of

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phytoplankton productivity (i.e. the diatom).

3) The authors arguing with productivity and bottom water oxygenation proxies but quite often they do not provide the reader with the information if enrichment or depletion of a specific proxy is indicating oxygenation or anoxia, intensified or less productivity.

Reply: We should clarify that we do not think that Mejillones Bay during the last two centuries was oxygenated at any time. Instead of that we consider that the system fluctuated between more and less sulfidic conditions in response to periods with conditions "La Niña-like" and "El Niño-like", respectively. Since our oxygenation proxies are correlated with productivity proxies in core MUC-1B, we conclude that higher sulfidic conditions are also associated with higher productivity at short scales. In fact, this aspect has limited the quantitative utilization of redox-sensitive trace elements such as molybdenum and other proxies such as rhenium as proxies of oxygenation (e.g. Gooday et al., 2009). Therefore, what we propose in our paper is that oxygenation varied during the last two centuries as a function of siliceous productivity which in turn was modulated by ENSO-like activity. We are improving the text of the manuscript by providing additional explanations when a proxy indicates increased or decreased oxygenation (sulfidic conditions and productivity) as suggested by the reviewer.

Regarding the specific comments some of them were already discussed in the previous paragraphs whereas we still are going through the rest of minor corrections.

Thank you.

Interactive comment on Biogeosciences Discuss., 7, 4987, 2010.

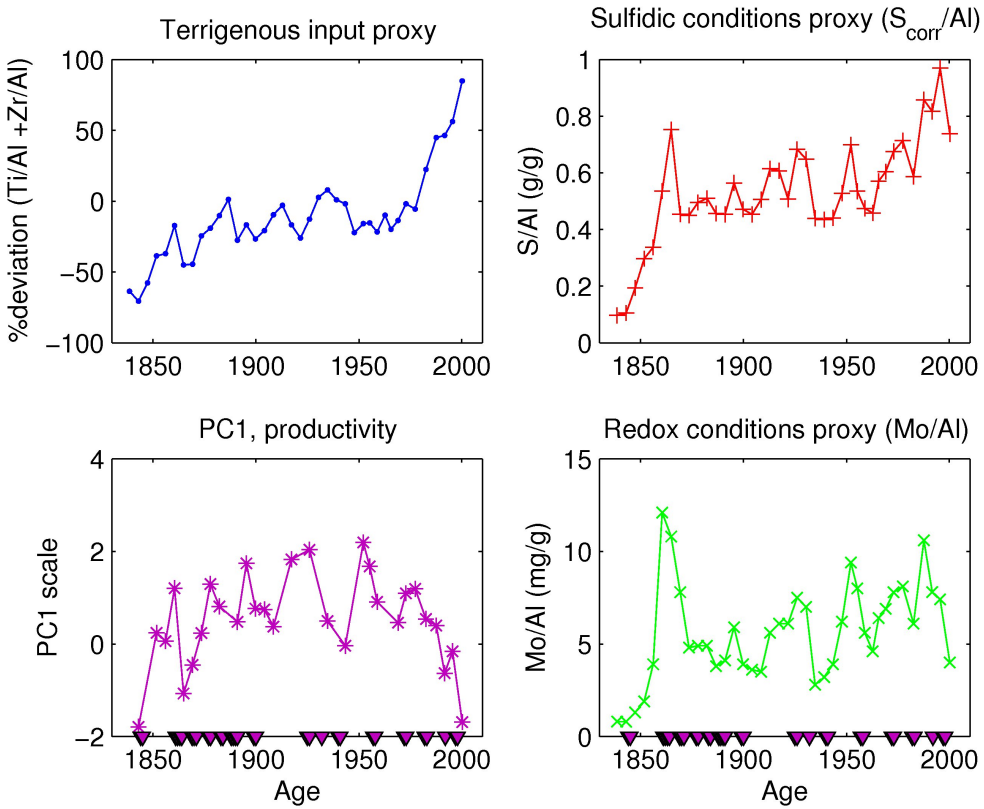

Fig. 1. Comparison of oxygenation and productivity proxies MUC-1B (PC1: principal components summarizing Ba_bio, BSi and diatom valve counts). Inverted traingles indicate strong-very strong El Niño events

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