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Biogeosciences Discussions

Interactive comment on "Reconstructing past variations in environmental conditions and paleoproductivity over the last ∼8000 years off Central Chile (30° S)" *by* Práxedes Muñoz et al.

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The introduction was re-written considering other aspects related to climatic past variability. The last paragraph highlights the objective of our study. The paleoclimate section (5.4) was rewritten, considering paleoclimatic conditions observed by other authors in the Chilean northern margin. We avoided comparisons with studies conducted over a wide range of time periods which extend beyond the Holocene. Our cores only show records from the mid-Holocene onwards and therefore, we focus our discussion on that time range. We made comparisons with studies conducted near the zone of influence in the northern part of the Southwest Winds so as to prevent the discussion from being

unnecessarily long. We included studies that work on our time scale, including: Lamy et al., 1999, 2001, 2010; and Hebbeln et al., 2002. Some of these studies mention the effects of the ENSO in the area, which is the main driver of environmental changes therein. Our objective was not to establish periods of occurrence of these events but to establish changes in productivity and redox conditions, which are obviously subject to climatic and oceanographic forces, such as El Niño. In addition, we included some works by Gutiérrez and Salvatecci conducted in southern Peru, which which considers the response of upwelling ecosystems to climatic changes during the last Holocene.

Answers to detailed comments: Detailed comments: - The presentation of results in the abstract is unclear:

The text was completely modified from lines 33 to 49.

- The introduction is a lengthy, disorganized list of unfocused information about upwellings in general and sediment proxies. It needs to be entirely rewritten to present the context, the motivation of the research, the scientific questions, the objectives and the scientific strategies chosen to achieve them.

We modified the introduction completely, from lines 56 to 102.

- L132-139: this paragraph on pigments seems unnecessary We rewrote the section about the study area and we are omitting superfluous information, we deleted the paragraph between lines 132 and 139.

- L145: the words "relevance" and "relevant" are repeatedly used in an inappropriate way throughout the manuscript.

We modified all lines and replaced the word for other more appropriate terms, except in lines 555 and 706.

- L167-172: unprecise - L176-178: the fact that two sediments cores were analyzed and their location should be mentioned in the introduction

We added extra information at the end of the introduction; see lines 118 to 122. We provided further explanation about our point at the end of the study area section, lines 161-167.

- Trace metal concentrations: The normalization of Me concentrations using Al does not seem justified to me. The analytic technique used here (ICPMS analyses of dissolved samples) yields quantitative and absolute concentration values thanks to the standards used. As far as I know, uncertainties related to machine variability and matrix effects are not an issue with this technique as it would be with laser ablation technique. In addition, Al does not have a conservative behavior as mentioned: figure 10 shows on the contrary a substantial increase of Al concentration through the Holocene. Normalizing systematically with this element may actually produce biased interpretations.

Al normalization is extensively used in geochemical studies. The conservative elements are not affected by chemical or biological processes, but affected by physical; it does not mean that their concentration does not change. It is important to estimate the authigenic enrichment of the elements. This process occurs in situ and in some way depends on the metal fluxes, but the environmental conditions determine the enrichment of these elements, see Calvert and Pedersen (2007), Tribovillard et al., (2006), Böning et al. (2004, 2005, 2009) among others. This allows discriminating between enrichment and terrestrial input; therefore the variability of Al can imply variability in some elements with greater terrestrial impacts than other processes. Some elements can be used as indicators of terrigenous inputs and their variability can display whether the variability in sedimentary records accounts for contributions from land or for changes in primary productivity or redox conditions. Therefore, each element must be normalized to Al or Ti, which is also useful to remove the effect of variability produced by changes in grain size. There is some concern about the use of Al and Ti for this purpose. However, caution must be used when using Al or Ti for the interpretation of metal distributions.

The normalization is not related to ICPMs technique. We do not use laser ablation.

I recommend to use the accumulation rate from the age model and absolute Me concentration to calculate metal fluxes to the sediment.

The accumulation rate could be a choice but is highly influenced by the age model used. Therefore, a better choice is to use the metal/Al ratio instead of the accumulation rate to establish authigenic enrichment. Accumulation does not depend on the fluxes, it depends on other on site factors that are useful to decipher the redox conditions at bottoms.

Since Al has mainly a continental origin, ratios with Al is informative for elements whose flux is related to productivity to discuss relative contribution of marine vs terrestrial contributions in the sediment.

All elements have an earth crust origin. While some elements follow different cycles, like nutrient type elements, they are incorporated into marine organism and deposited on the bottom when primary production settles down. After that, the elements follow other mechanism that allow for their enrichment, depending on their affinity to sulfides, for example. Therefore the normalization with Al is appropriate.

Finally, the usefulness of the enrichment factors is not obvious. Figure 9 is barely discussed. In addition, I wonder if wetland sediments are really representative of crustal metal concentrations since they also contain organic matter.

We decided to add a table with the most relevant information to indicate that the variations in metals during periods of higher productivity are due to authigenic enrichment, which in turn is a consequence of changes in redox conditions and not variations of continental inputs.

- Geochronology L248: Calpal2007_HULU calibration curve is an odd choice for radiocarbon calibration.

We made corrections in the text; we use Clam2.2 program.

It is also inconsistent with L255 in which Marine13 is mentioned (which is the correct

calibration curve to use). There is a couple of issues with the regional radiocarbon reservoir age used for calibration. First, the method to calculate it is not correct. 14C reservoir age should be calculated in the 14C age scale, not in the calendar scale as it was done here. dR is the difference between the marine sample 14C age and the 14C age that corresponds to the absolute age (here obtained from the 210Pb model) using the Marine13 curve. See Southon et al. (1995) for details on the technique. The dR value obtained here is larger than any dR values obtained previously on the Chilean coast Authors should read and use Ortlieb et al., 2011; Carré et al., 2016; and Merino-Campos et al., 2018. The latter reference presents 37 prebomb dR values all along the Chilean coast measured with a reliable technique. Using a value from this publication would be more reliable. The first 2 references show changes in dR values through the

We added an explanation in the text. We think upwelling waters are affecting the age of foraminifers in our cores sites; other records at deeper areas have also used a DR $\sim$ 400 years (De Pol-Holz, 2007). The samples of Carré and Meirno-Campos are submareal species that live at shallows depths (<30 m), not highly affected by the upwelling. We resorted to the method used by Sabatier and we added a table for informational purposes. We considered the Carré value because we lack more data to corroborate our findings. We only have two pre-bomb data. We changed all Cal AD/BC to Cal BP ages. Discussion:

L505-L514: unclear L521-L536: the discussion about d13C values is unclear, in part because there seem to be a confusion between Total organic carbon(TOC) in the water column and suspended particulate organic Matter (SPM). Is it possible that the difference between d13C values in the water and in the sediment are due to the difference between TOC and SPM? A preferential degradation of 13C enriched particles is mentioned (L528-529): could you support this with a reference?

L563-L568: the discussion about K is not very convincing. A reference about the detritic origin of K is needed. Ca could also have a detritic origin so close to the shoreline. Al, Fe are also clear terrestrial input indicators. Why not discuss them

together?

We added the reference and Ca is normally used as an indicator of marine productivity versus K, which is a major element that has no implications on marine productivity. Fe is more complicated due to its double origin. In all cases, we attempted to use the best proxy in order to interpret each process.

L602-L606: references needed Section 5.3 should be shortened. It is somewhat redundant with other discussion sections and the result section. - Climatic interpretations

We rewrote this section completely. This section lacks in-depth discussion. The results here should be compared to published results to understand how they contribute, support or contradict existing hypothesis about millenial oceanographic variability in Chile. L720-L723: “past changes are analogue with the present meridional displacement of the ITCZ and the SPCH”. This should not be taken as a fact. It is only a hypothesis used as an interpretation model. L744-L747: this part is unclear and sounds contradictory (a poleward shift of SWWshould not promote humid conditions in central Chile). In addition, this is a model result. Why not compare with existing paleoenvironmental and paleoceanographic data? There is a series of sediment cores that document past oceanographic conditions in the Peru-Chile upwelling system during the Holocene. This includes Lamy et al (1999, 2001, 2002, 2010), Kim et al. (2002), Hebbeln et al. (2002), Rein et al. (2005), Salvatecci et al. (2014, 2016). On a regional scale, the data presented here confirm a La Niña-like situation in the early to mid-Holocene, which is in agreement with previous datasets including Koutavas et al. (2002), Fontugne et al. (2004), Conroy et al. (2008); Carré et al. (2012), and model experiments such as Brown et al. (2008); Braconnot et al. (2012), Luan et al. (2015). This list is clearly not exhaustive. The first version of this manuscript considered the information of studies by Lamy, Hebbeln, Salvatteci. We added others from the list suggested, but focused on the range of time that covered our study and on Chile’s central margin. Some studies about southern Peru were also cited. We re-wrote the paleoclimate section and considered the main studies focused from mid-Holocene in the region, identifying the

main environmental conditions prevailing during the maximum periods of primary productivity. The influence of ENSO variability needs obviously to be discussed. It is here briefly mentioned in the text, appears in the key words, but there is no discussion. Data on past ENSO activity do exist (Koutavas et al., 2006; Cobb et al., 2013; Carré et al., 2014) and they need to be included in the discussion if the role of ENSO in the presented data is to be evaluated. We discussed some details about ENSO. Our study is not focused on the ENSO variability, but on changes in primary productivity and redox conditions. Figure 2: what about st14? Font on Y scale too small Figure 3: SPM is not the same as TOC Figure 5: it is not clear which curve is grain size and which is susceptibility We have no oxygen data for st14 and we made the corrections in the figures. Figure 6: Al and Fe are both related to terrestrial input. What information does Fe/Al provide? It could show enrichment of Fe by oxidation. Figure 9: This figure is not commented in the text. EF calculation does not seem useful. We changed it for a more informative and brief table.

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