Clim. Past Discuss.,
https://doi.org/10.5194/cp-2019-70-AC2, 2019

Interactive comment on "Millennial-scale variations of sedimentary oxygenation in the western subtropical North Pacific and its links to the North Atlantic climate" *by* Jianjun Zou et al.

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Received and published: 26 August 2019

Anonymous Referee #2 Received and published: 24 July 2019

Zou et al., present a rather interesting study focusing on reconstructing the oxygenationhistory in the Okinawa Trough covering the last 50 kyrs. Specifically, the authors attempt to disentangle the typically confounding influence of export production (and by inference the oxygen consumption related to organic matter degradation) and bottom water ventilation on the sedimentary redox condition. Their geochemical records largely corroborate previous findings in that oxygenation patterns at intermediate depths in the North Pacific were primarily controlled by the production and ventilation of North

Pacific Intermediate Water. Specifically, conditions were generally better oxygenated during stadials, when NPIW was generally better ventilated and vertically expanded. Furthermore, their data support a general expansion of oxygen-depleted waters at intermediate depths during the B/A occupying large swaths of the North Pacific. The manuscript is well documented and quite detailed in places. The argumentation could be somewhat streamlined (see comments below) and would certainly benefit from editorial support. I would also recommend the argumentation to focus on the aspects outlined in the title and abstract.

Reply#1: We thank the reviewer for the recognition of significance of this study. Based on the suggestion of the reviewer, we revised manuscript thoroughly in revised mode with a focus on sedimentary oxygenation changes in the subtropical North Pacific and its linkage to the North Atlantic Climate (supplements 1 and 2). In the following, we address each specific point raised by the reviewer.

l. 35 – deep ocean carbon sequestration is certainly one the reasons potentially explaining lower glacial pCO_2 concentrations, but certainly not the only one. Please rephrase to avoid unnecessary confusion

Reply#2: Thanks for your suggestion. Lines 32-34 in the revised MS.

We rephrased this sentence as the following. "Deep ocean carbon cycle, especially carbon sequestration and outgassing, is one of the competitive mechanisms to explain variations in atmospheric CO_2 concentrations on orbital and millennial timescales."

l. 36 – I would suggest rephrasing as follows – However, the potential role of subtropical North Pacific subsurface waters in modulating.

Reply#3: Agreed and we have done so. Thanks. Lines 34-36.

The sentence is amended as follows. "However, the potential role of subtropical North Pacific subsurface waters in modulating atmospheric CO_2 levels on millennial timescales is poorly constrained."

l. 48 and throughout – why is HS1 so much different from HS2 when considering their respective oxygenation history?

Reply#4: During HS1 and HS2, our RSEs suggest enhanced sedimentary oxygenation due to intensified GNPIW. As suggested by the Reviewer, a slight difference in the structure of ventilation mode can be observed (Figure 7). We think this slight discrepancy could be related to different climatic background during the formation of HS1 and HS2. Records from paleoclimate archives, such as ice cores and Chinese cave stalagmites, show differences in structure, duration, amplitude between HS1 and HS2. Such differences are thought to be related to the climate background state, such as, CO2 concentration, ice sheet volume, AMOC intensity, sea ice extent and source of freshwater, etc.(Flückiger et al., 2006; Hemming, 2004; Kaspi et al., 2004; Lynch-Stieglitz et al., 2014) The response of NPIW to HS1 and HS2 events could be different, and thus cause a slight difference in sedimentary oxygenation. On the other hand, the discrepancy in export productivity (CaCO3) during these two cold intervals at core CSH1 could also play a role in controlling sedimentary oxygenation.

l. 62 – agreed. But I would add that in addition of the flushing of a poorly ventilated deep water mass upon the resumption of NADW, many export production records show a drastic increase during the B/A (e.g. Kohfeld& Chase, 2011), which could account for enhance oxygen removal associated with organic matter respiration upstream of the core site location.

Reply#5: Agreed with your suggestion and revised. Line 52.

The sentence is changed to "......due to upwelling of aged, nutrient-rich deep water and enhanced export production......"

l. 70 – AT the sediment-water interface

Reply#6: We reworded the sentence. Lines 62-66.

The sentence is amended as follows. "The sluggish ocean ventilation and efficient bi-

ological pump in the ocean facilitate carbon sequestration in the ocean interior, linking to atmospheric CO2 drawdown, which in turn play a crucial role in regulating sedimentary oxygen on millennial and orbital timescales (Hoogakker et al., 2015; Jaccard and Galbraith, 2012; Sigman and Boyle, 2000)."

l. 83 . . . in marine sediment cores

Reply#7: Corrected. Line 75.

The sentence is amended as follows. "......in marine sediment cores."

l. 86 . . . in the subarctic North Pacific.

Reply#8: Corrected. Line 78.

The sentence is amended as follows. "...... last glaciation and Holocene in the subarctic North Pacific."

l. 92 – I would suggest to briefly explain what cabbeling means

Reply#9:Done. Cabbeling is a mixing process to form a new water mass with increased density than that of parent water masses.

We have added in Lines 85-86. "......that cabbeling, a mixing process to form a new water mass with increased density than that of parent water masses, is the principle mechanism responsible......"

l. 96 and throughout (incl. Fig. 6) – this may well be a semantic issue, but benthic d13C cannot be considered as a ventilation proxy per se, as the isotopic value can be obfuscated by air-sea gas exchange in locations where subsurface water masses form.

Reply#10: We fully agreed with the comment by the Reviewer that temporal benthic δ13C changes is influenced by a variety of factors, such as air-sea equilibration, ocean-circulation changes, and productivity changes, etc. Previous studies also revealed benthic δ13C pattern at basin-wide scales may reflect ocean-circulation changes (Charles and Fairbanks, 1992; Charles et al., 1996; Ninnemann and Charles, 2002). In this study we also noticed similar trends in benthic δ13C during $\sim$22 ka and $\sim$14 ka between cores PN-3 (Okinawa Trough) and PC23A (Bering Sea) (Figure 4), despite their great distance. In the revised manuscript, we add additional information for benthic δ13C. The sentence was amended Lines 90-93. "Benthic foraminiferal δ13C, a quasi-conservative tracer for water mass, from the North Pacific suggested an enhanced ventilation (enriched δ13C) at water depths of < 2000 m during the last glacial period (Keigwin, 1998; Matsumoto et al., 2002)."

l. 151 – processes that are related to the supply of oxygen by ocean circulation and.

Reply#11: Revised. Lines 151-154. The sentence is changed to: "Sedimentary redox condition is governed by the rate of oxygen supply from the overlying bottom water and the rate of oxygen removal from pore water (Jaccard et al., 2016), processes that are related to the supply of oxygen by ocean circulation and organic matter respiration, respectively."

l. 163 – technically one should specify that under reducing conditions it is the authigenic fraction of Mn (as opposed to its detrital background) that remains low.

Reply#12: Revised. Lines 163-164.

The sentence was amended as follows: "Under reducing conditions, the authigenic fraction of Mn (as opposed to its detrital background) ......"

l. 168 – please add adequate reference

Reply#13:The reference (Morford and Emerson 1999) has been included in the revised manuscript. Line 171.

l. 195 – volcanism

Reply#14: Revised. Line 199.

"volcanic " has been changed to "volcanism".

§3 – I would suggest to substantially shorten this paragraph as the general oceanographic setting is already outlined in the introduction. I would recommend focusing on the aspects directly relevant to the argumentation (nutrient, dissolved O2).

Reply#15: Thanks for your suggestion. In the revised manuscript, we removed the 1st paragraph of section 3 and then we reworded the sentences in previous 3rd paragraph of section 3. Lines 210-228.

The paragraph is amended as follows. "Figures 2a and 2b show that the lower sea surface salinity (SSS) zone in summer relative to the one in winter in the ECS migrates toward the east of OT, indicating enhanced impact of the Changjiang discharge associated with summer EAM. An estimated $\sim$80% of the mean annual discharge of Changjiang is supplied to the ECS (Ichikawa and Beardsley, 2002) and in situ observational data show a pronounced negative correlation between the Changjiang discharge and SSS in July (Delcroix and Murtugudde, 2002). Consistently, previous studies from the OT reported such close relationship between summer EAM and SSS back to the late Pleistocene (Chang et al., 2009; Clemens et al., 2018; Kubota et al., 2010; Sun et al., 2005)."

l. 287 – why is the sedimentation rate so high during HS2 when both export production and detrital input (based on Al) are low? I would suggest verifying the age pointers for that interval.

Reply#16: Thanks for your suggestion and we have verified the age control points (Figure 3 and Table 2). In the original manuscript, higher sedimentation rate mainly occurred during HS2 and HS3 (>40-60 cm/ka) and is mainly caused by uncertainties of age control points at 23.476 ka (DO2) and 29.995 ka (H3). In the revised manuscript, these two age control points have been eliminated. Even with this more conservative tuning approach, the conclusions remain the same as before and robust.

l.291 – 85 samples covering 50 kyrs cannot provide an average time resolution of 200 yrs.

Reply#17: We thank the reviewer to point out this mistake. Now we have corrected it to $\sim$ 600 years. Line 289.

The sentence was changed to: "......with time resolution of about 600 years (every 4 cm interval)"

l. 345-346 – Maybe. But it may also suggest that the sedimentary CaCO3 content could be directly controlled by dilution. I would interpret the export productivity records with caution.

Reply#18: We thank the reviewer for the very helpful comments and suggestions. In the revised manuscript, we have discussed the effects of some factors, such as dilution and dissolution, on CaCO3. On the other hand, we have reworded this section to cautiously interpret CaCO3 as a reliable proxy for export production at core CSH1.

We have added the following information to Lines 342-361. "Several lines of evidence support CaCO3 as a reliable productivity proxy, particularly during the last deglaciation. The strong negative correlation coefficient (r = – 0.85, p<0.01) between Al and CaCO3 in sediments throughout core CSH1 confirms the biogenic origin of CaCO3 against terrigenous Al (Figure 4f). Generally, terrigenous dilution decreases the concentrations of CaCO3. Inconsistent relationship between percentage CaCO3 and sedimentation rate indicates a minor effect of dilution on CaCO3. Furthermore, the increasing trend in CaCO3 associated with high sedimentation rate during the last deglacial interval indicates a substantial increase in export productivity (Figures 4a and 4d). The high coherence between percent CaCO3 and alkenone-derived sea surface water (SST) (Shi et al., 2014) indicates a direct control on CaCO3 by SST. Moreover, a detailed comparison between CaCO3 concentrations and the previously published foraminiferal fragmentation ratio (Wu et al., 2004) shows, apart from a small portion within the LGM, no clear co-variation between them. These evidence suggest that CaCO3 changes are driven primarily by variations in carbonate primary production, and not overprinted by secondary processes, such as carbonate dissolution through changes in the lysocline

depth and dilution by terrigenous materials. Likewise, similar deglacial trend in CaCO3 is also observed in core MD01-2404 (Chang et al., 2009), indicating a ubiquitous, not local picture in the OT. All these lines of evidence thus support CaCO3 of core CSH1 as a reliable productivity proxy to a first order approximation."

l.371-372 – interesting idea!

Reply#19:Thanks.

l. 427 (438?) – supply seems more adequate than provision.

Reply#20: Agreed and revised. Line 446.

"provision" was replaced by"supply".

l. 487-488 – please also consider citing Galbraith et al., 2007. Reply#21:The paper has been included in the revised manuscript. Line 502.

l. 489-490 – please keep in mind that O2 can be consumed upstream of the core site location as the removal of O2 in relation to organic matter degradation is integrated over the flow path of a give subsurface water mass.

Reply#22: Thanks for your suggestion. We fully agree with the comment and think that the signal of accumulation of organic matter degradation along the flow can be recorded by epibenthic δ13C.

Fig. 6C – shouldn't the grey triangle right of the vertical axis be flipped upside down (i.e. high Mo/Mn coincident with low oxygenation)?

Reply#23: Thanks. High Mo/Mn ratio indicates low oxygen conditions.

The sign in Fig. 6c has been corrected (see new Figure 6).

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Captions Figure 3. (a) Lithology and oxygen isotope (δ18O) profile of planktic foraminifera species Globigerinoides ruber (G.ruber) in core CSH1. (b) Plot of ages versus depth for core CSH1. Three known ash layers are indicated by solid red rectangles. (c) Time series of linear sedimentation rate (LSR) from core CSH1. (d) Comparison of age model of core CSH1 with Chinese Stalagmite composite δ18O curve of (Cheng et al., 2016). Tie points for CSH1 core chronology (Table 2) in Figures 3c and

3d are designated by colored crosses.

Figure 6. Proxy-related reconstructions of mid-depth sedimentary oxygenation at site CSH1 (this study) compared with oxygenation records from other locations of the North Pacific and published climatic and environmental records from the Okinawa Trough.

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2019-70/cp-2019-70-AC2-supplement.zip

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2019-70, 2019.

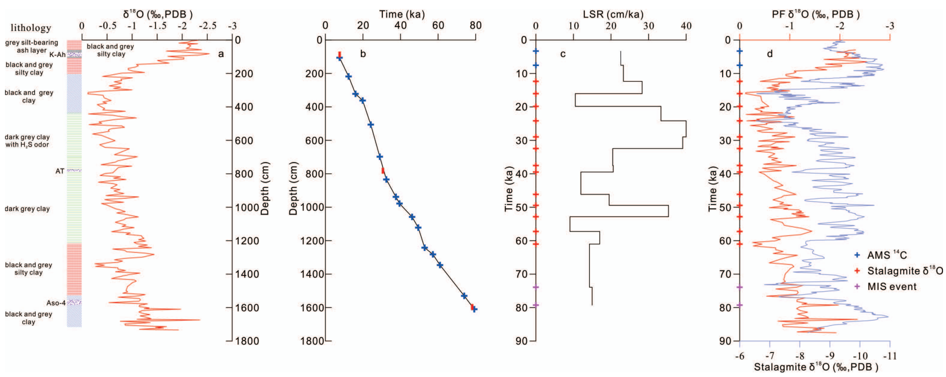

Fig. 1. Figure 3

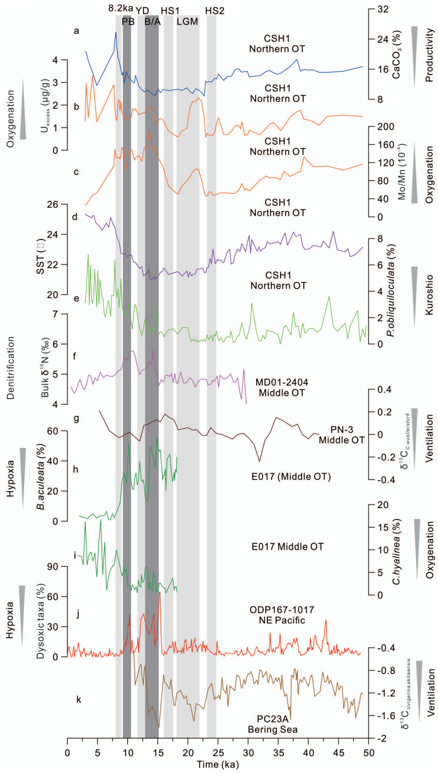

Fig. 2. Figure 6