Interactive comment on "Evidence of intense climate variation and reduced ENSO activity from $\delta^{18}O$ of *Tridacna* 3700 years ago" *by Yue Hu et al.*

Anonymous Reviewer #1:
We would like to thank this reviewer for her/his comments on our manuscript. Please find our detailed answers to each comment below. The reviewer comments are in normal black script, our answers are in blue italics and the revised texts are in blue normal script.

General Comments:

The article presents a new oxygen stable isotope 40-year long record of a 3700 yr BP fossil giant clam Tridacna from the South China Sea. The fossil record is compared to a modern tridacna shell and instrumental data. The authors show clearly that the shells faithfully record SST variations with a nearly monthly resolution. The sclerochronological work is precise and performed with caution. Great attention was given to the effect of sampling resolution. All records were resampled at the same resolution for better comparison of SST ranges and variability. The fossil tridacna shell recorded ENSO variability as shown by the spectral analysis and the 3-7 filtered signal. ENSO signal showed a slightly lower frequency and stronger events at 3700 cal BP compared to the modern reference period. As the author acknowledge, the studied period is too short to draw conclusion on ENSO variability but the study provides high quality new paleoclimate data. Such quantitative seasonally resolved datasets are necessary to achieve a more detailed understanding of the relationship between long-term background changes and seasonal to interannual climate variability.

We thank the reviewer for her/his positive evaluation of our manuscript.

I consider therefore that this is a valuable contribution that needs to be published with minor corrections. The text requires some work with the English. It is generally OK to be read and understood, except for a few sentences that I mention hereafter, but it contains numerous grammatical, syntax and vocabulary errors that need to be fixed. I did not note all the English errors because that is beyond a reviewer's work. In any case, languages issues should not prevent this paper from being published. I hope the journal can assist the authors with language edition.

Thanks for the suggestion, we have checked the errors in our best to improve our manuscript.

Besides this, the introduction and discussion should include a more complete bibliography of paleo-ENSO reconstruction. Key papers such as Koutavas et al. Paleoceanography (2012), Cobb et al. Science (2013), Carré et al., Science (2014) are neither cited nor discussed.

Thank you very much for the classical references. We have added them to our induction and clarified in brief.

A substantial part of the results and discussion is dedicated to changes in the SST seasonality. A new figure showing average seasonal cycles (mean and s.d.) from the fossil, modern, and instrumental record would summarize and clarify greatly the result.

We agree with the reviewer, a figure (Fig. 4e) have added with average seasonal cycles from the data and clarified the result in our manuscript. We only use the data of fossil Tridacna and the modern instrumental record in the figure. This is because they are both in North Reef. Modern Tridacna is located in Yongxing Island (the southern of North Reef), therefore, the seasonality may have deviation which is inappropriate to compare with data in North Reef. To avoid the deviation, we think the average seasonal cycles (minimum, maximum, s.d.) of fossil Tridacna and North Reef instrumental record is better to summarize and clarify the result.

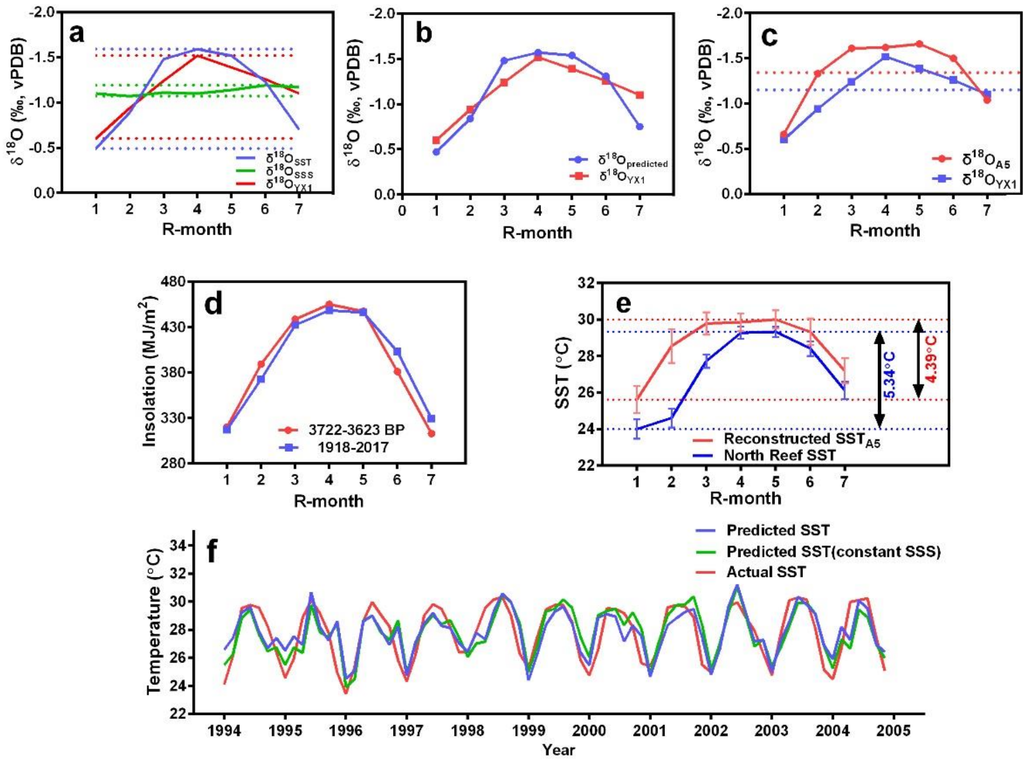

Fig. 4

Detail comments:

L59-60: “ontogenic reduction”: do you refer to the decreasing growth rate with ontogeny?

Yes, as K. Welsh (2011) indicated in his article, the ontogenic reduction in growth of Tridacna gigas does not reduce the reliability with which temperature and $\delta^{18}O_w$ variability can be reconstructed. Climate reconstruction in $\delta^{18}O_{shell}$ does not have an incongruity with temperature and $\delta^{18}O_w$ which might be an obviously declined or increased tendency. We rephrased this sentence to make this clearer:
and the reliability in reconstruction between temperature and $\delta^{18}O_w$ variability would not be reduced by the ontogenic reduction in growth of the *Tridacna* $\delta^{18}O$.

L65: “uncertainties”: did you mean “unclear”?

Yes, we have corrected this.

L76: “involved in Holocene Megathermal period”, did you mean “part of the Holocene climatic optimum”?

Yes, we have changed the expression to make it clear in the manuscript.

L86: “trigger” should be “source of”

Thank you for your advice. We have corrected this.

L91: Clement et al., 1999 is a modeling study, not a reconstruction.

Thank you. We have corrected it in the text.

L93-98: incomplete bibliography.

Thanks for the suggestion and classical references commends. We have added them to the text and clarified as followed:

Furthermore, the El Ninõ-Southern Oscillation (ENSO) is widely accepted to be the main source of interannual climatic variability in the Pacific Ocean. Previous studies suggested that the impacts of ENSO activity would not be limited to the tropical area, but also on the global atmospheric circulation through heating-up of the tropical atmosphere (Cane, 2005). Thus, the reconstruction of ENSO is very important for understanding its dynamics and predicting future change. Many early published ENSO behaviors were constructed with low-resolution proxy data using deposition events (Rodbell et al., 1999; Koutavas and Joanides, 2012), ice cores (Thompson et al., 1995;1998), to reveal the ENSO variance in thousands of years. However, the periodicity of ENSO was short compared to those low-resolution data, it’s difficult to demonstrate the strength and variability of ENSO activity. Recent studies focus on seasonal or monthly data to examine the precise variation in ENSO activity (Arias-Ruiz et al., 2017; Ayling et al., 2015; McGregor et al., 2013; Welsh et al., 2011; Yan et al., 2017), but those fragmental data cannot fully understand the Holocene ENSO dynamics. Therefore, fragments at different times according to different high-resolution samples are needed and can provide an integrated framework for examining ENSO theory and models in Holocene. Besides, studies on the mid to late Holocene ENSO evolution yielded controversial findings: Coral records showed a reduced ENSO variability around the late Holocene (McGregor et al., 2013; Cobb et al., 2013; Woodroffe et al., 2003). Other carbonate species like fossil mollusk shells suggested that ENSO variance was severely damped ~4000 years ago (Carré et al., 2014). Yet some other studies indicated a strengthening ENSO activity at 4 to 3 ka BP (Tudhope et al., 2001; Duprey et al., 2014; Yang et al., 2019). Thus, this further points to the importance of high-resolution isotopic geochemical data such as *Tridacna* in unraveling the dynamics of ENSO.

L123-125: "Due to⋯⋯actual month". This sentence needs to be rewritten. I understood

that the records were resampled at 7 data points per year to have comparable time resolution across the records. This number was chosen because it corresponds to the lowest resolution achieved in the fossil record. The verb "rehandle" is used throughout the manuscript but I think "resample" would be more appropriate and clearer. What technique was used for the resampling? Linear interpolation?

Thanks for the suggestion. We agree with you that change the verb "rehandle" into "resample" will be better. The technique we used for the resampling is a cubic spline model in AnalySeries 2.0.8. This method was first applied by Schöne and Fiebig (2009), who used bivalve shells (Arctica islandica) to reconstruct climate. They suggested that 7 points per month would elapse during the core growing season of the shell (i.e., time interval of fastest shell growth covering the seasonal extremes). And only the annual sample number for which equal to or more than seven existed could be used. Therefore, we used 7 points per month.

L144-146: some clarification is needed about the radiocarbon date calibration. What DR value was used? "Conventional" cannot refer to the calibrated date. The calibrated date should not have a +/-28 year uncertainty. Calibration yields a 1sigma or 2 sigma confidence interval and a median date.

From the modern Tridacna samples we collected in this area, the dating results showed no obvious "reservoir effect" (Liu et al., 2019). Tridacna might exchange its carbon with the atmosphere through photosynthesis. Therefore, we used the atmospheric ^{14}C yield model to calibrated. We have clarified the details about the radiocarbon date calibration as followed:

The radiocarbon age determination was performed at Institute of Earth Environment of Chinese Academy of Sciences. The ^{14}C Accelerator Mass Spectrometry data revealed the fossil *Tridacna gigas* age was 3437 ± 28 yr BP. Due to no obvious "reservoir effect" in dating results of modern *Tridacna* shells, the atmospheric ^{14}C yield model was used to calibration. The calibrated date (2σ) was range from 1783 to 1663 cal BC, with the median date is 1741 cal BC by using the IntCal13 of Radiocarbon Calibration Program CALIB 7.10.

L163-167: this part is unclear. Are you comparing values of the internal standards obtained during the analyses of both shells? Is it the same standard material?

The two standard materials are the same material with a different name, we have corrected both of them into "GBW04405" in the text to avoid confusion. This ordovician carbonate is from Zhoukoudian Country, Beijing, China. The certified value and standard deviation had been obtained depend on the comparing with international standard NBS-19, and the result is in ‰ relative to VPDB.

L170-171: "which contained……life span". This is unclear

What we want to express is that the 100 years contain the probable life span of Tridacna when considering the 2 sigma confidence interval of corrected age. We have clarified it clear in the manuscript.

L192: "daily increments are obvious". They are not to me on the figure. Clarify

We have retreated the picture and clarified the details of the daily increments in the text.

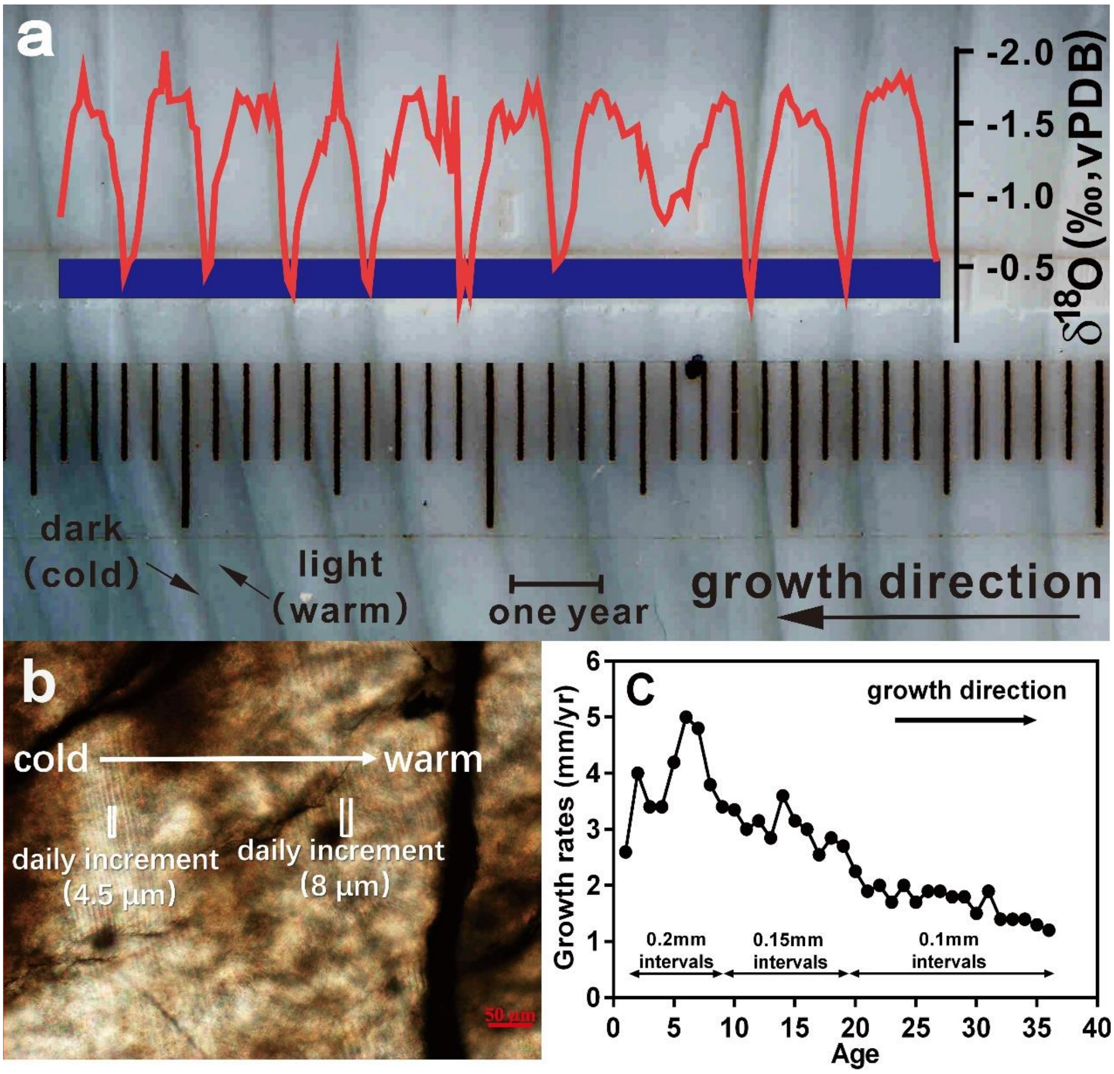

Figure 3. (a) Dark/light lines consistent with $\delta^{18}O_{A5}$ profiles. Dark and light lines correspond to high $\delta^{18}O$ (cold seasons) and low $\delta^{18}O$ (warm seasons), respectively. The distance between the dash lines represents a year that *Tridacna* grew. Blue line represents the sampling line. (b) Under the microscope, daily increments (a dark coupled with a light increment) grow slower when seasons are cold, but faster when temperature rises up. (c) Growth rates (line 2 in Fig. 1c) in fossil *Tridacna* A5.

L226: "perfect match, r=0.81". perfect sounds too strong. Why is $\delta^{18}O_{YX1}$ better correlate to $\delta^{18}O_{SST}$ (r=0.91) than to $\delta^{18}O_{predicted}$ (r=0.81) if this latter includes both SST and SSS and should therefore be more realistic?

Thank you for your advice, we have rewrote this phrase.
$\delta^{18}O_{SST}$ were calculated in actual varied SST and constant SSS, $\delta^{18}O_{predicted}$ were calculated in both actual varied SST and SSS. Theoretically speaking, $\delta^{18}O_{YX1}$ should have a better correlation to $\delta^{18}O_{predicted}$. But our results are not. These might due to the significant control on SST to $\delta^{18}O_{shell}$. $\delta^{18}O_{SSS}$ are nearly negative correlated with $\delta^{18}O_{SST}$. This might reduce the correlation when using both actual varied SST and SSS to calculate.

L214 – L240: these paragraphs could be shorter and clearer if the information was better organized and presented.

We have rewrote these paragraphs into:

The $\delta^{18}O_{shell}$ reflect a combination of SST and SSS variation. In order to quantify more precisely what extent those factors influence on $\delta^{18}O_{shell}$ composition, two $\delta^{18}O$ profiles are calculated: $\delta^{18}O_{SST}$ (constant SSS but varying SST) and $\delta^{18}O_{SSS}$ (constant SST but varying SSS) (Fig. 4a). R-monthly mean values are used to minimize the influence of extreme events. The results show $\delta^{18}O_{YX1}$, $\delta^{18}O_{SST}$, and $\delta^{18}O_{SSS}$ profiles are range from -0.57 to -1.52 ‰, -0.48 to -1.58 ‰, -1.07 to -1.19 ‰, respectively. It is obviously that $\delta^{18}O_{YX1}$ and $\delta^{18}O_{SST}$ have same trend and high correlation ($r = 0.91$, $n = 7$; $r = 0.78$, $n = 77$), but the variation range in $\delta^{18}O_{SSS}$ is only 14 % of $\delta^{18}O_{YX1}$. Therefore, this indicates $\delta^{18}O_{shell}$ in the Xisha Islands correspond predominantly to the seasonal SST variation. Besides, the calculated $\delta^{18}O_{predicted}$ (by using both local actual SST and SSS) were used to compare with $\delta^{18}O_{YX1}$ (Table S1). The $\delta^{18}O_{YX1}$ and $\delta^{18}O_{predicted}$ profiles have nearly the same mean value (1.15 ‰ and 1.14 ‰, respectively). And their positive correlation ($r = 0.81$, $n = 77$) indicates the local *Tridacna* precipitates its shell in oxygen isotopic equilibrium.

Moreover, the comparison of predicted SST (under constant SSS and actual SSS with $\delta^{18}O_{YX1}$) further confirms that the SSS variation have no significant affection in local reconstructed SST (Fig. 4f). Two predicted SST values have high similarity ($r = 0.93$), and they are well correlated with the actual SST ($r_{vary} = 0.79$, $r_{constant} = 0.78$). Thus, we can use $\delta^{18}O_{shell}$ to roughly estimate the seasonal local SST variation, and establish a new SST-$\delta^{18}O_{shell}$ linear regression: SST (°C) = 22.69 - 4.41 × $\delta^{18}O_{shell}$ (or $\delta^{18}O_{shell}$ (‰) = -0.136 × SST + 2.634). A 1 ‰ change of $\delta^{18}O_{shell}$ is roughly equal to 4.41°C of SST. Yu (2005) summarized many published $\delta^{18}O$-SST slopes for the other marine carbonate species, *Porites lutea* coral, and suggested that the slopes could range from -0.134 to -0.189. Corals from Hainan Island revealed a good $\delta^{18}O$ vs. SST correlation with a linear regression slope of -0.137 (Su et al., 2006), very similar to our result (-0.136). Consequently, it is reliable to use the new linear regression for reconstructing the past SST with the fossil $\delta^{18}O_{shell}$.

L244: “variance”. Do you refer to the seasonal range?

We have rephrased this sentence in the text to clarify:

The difference in seasonality between $\delta^{18}O_{YX1}$ and $\delta^{18}O_{predicted}$ is 0.18 ‰, which is accounts for 19 % of $\delta^{18}O_{YX1}$.

L244: 0.19% check this number.

Thank you. The number should be 19 %. We have corrected it in the text.

L277: “indicates” do you mean “associated with”?

Yes, we have corrected this.

L269-280: The total range of the signal includes not only seasonality but also interannual to decadal variability. To evaluate the change in the seasonal range, it would be more appropriate to estimate and compare the mean seasonal ranges.

Thank you for your advice, we have added this figure in Fig. 4e (see above).

L288: "Moreover……slope" this is unclear

We have rewrote the sentence:
Moreover, comparing from each r-monthly value to average value, cold seasons have a larger deviation with greater slope.

L290-292: a figure of mean seasonal cycles would be useful

We have added this figure in Fig. 4e.

L296-299: these short introductions about global warming are not necessary

Thanks for your suggestion, we have removed these sentences.

L320: unclear

We have rewrote this sentence to:
The local accumulated positive percentage of monthly SST anomalies threshold could respond to 76.47 % El Ninõ and 79.41 % La Niña events in Ninõ 3.4 region (Liu et al., 2016).

L333: unclear

We have rewrote those sentences to:
To acquire more precise ENSO reconstructions, modern observation data were analyzed and compared with the SST in Ninõ 1 + 2 region. The SST anomaly series were calculated by subtracting the r-monthly mean values.

Reference

Schöne, B. R. and Fiebig, J.: Seasonality in the North Sea during the Allerød and Late Medieval Climate Optimum using bivalve sclerochronology, Int. J. Earth Sci., 98(1), 83–98, doi:10.1007/s00531-008-0363-7, 2009.

Welsh, K., Elliot, M., Tudhope, A., Ayling, B. and Chappell, J.: Giant bivalves (*Tridacna gigas*) as recorders of ENSO variability, Earth Planet. Sci. Lett., 307(3–

4), 266–270, doi:10.1016/j.epsl.2011.05.032, 2011.
Liu, C., Yan, H., Fei, H., Ma, X., Zhang, W. and Shi, G.: Journal of Asian Earth Sciences Temperature seasonality and ENSO variability in the northern South China Sea during the Medieval Climate Anomaly interval derived from the Sr / Ca ratios of *Tridacna* shell, J. Asian Earth Sci., 180(June), 1-9, doi:10.1016/j.jseaes.2019.103880, 2019.