Point-by-point response

We thank both reviewers and the Editor for their constructive comments which we address in this response.
In our initial response to both reviewers, we had already answered most questions. We therefore refer to the document "Response to Reviewer 1 and 2" uploaded online in addition to this response. Here we address some issues in further detail.

Reviewer 1

1) …why we used annual resolution Sr/Ca record and how to explain relatively low correlation with SST…

In our initial response to the reviewer, we had already outlined this answer. We therefore refer to the document "Response to Reviewer 1" uploaded online.
We have provided additional support for the validity of our annual coral Sr/Ca-SST and its correlation with ERSST5 and other SST products. Watanabe et al. (MS in prep.) have adopted the approach of Smerdon et al. (2016) testing the signal to noise ratio in proxy and instrumental SST (**see below Fig. 1**). Our correlation ranges between 0.3 and 0.4 in line with the expected correlation given the regional signal noise ratio. This is now included in the section 4.1. of the discussion, which reads:
"Furthermore, the standard deviations of mean annual SST at Ifaty is only 0.25°C which leads to a lower signal to noise ratio in annual Sr/Ca-SST estimates. With Sr/Ca-SST having an analytical uncertainty of ±0.15°C, the correlation between ERSST and coral Sr/Ca-SST should range between 0.3 and 0.4 following the method of Smerdon et al. (2016), exactly what we obtained in this study."
Furthermore, we have included a new Figure S3 that shows the number of SST observations drastically decling beyond 1970.

2) Agreement/disagreement between $\delta^{18}O_{seawater}$ based on Sr/Ca-SST vs. using HadISST…

This question was also answered in our initial response to reviewer 1. We have amended Figure 3a by showing the reconstructed $\delta^{18}O_{seawater}$ based on ERSSTv5 instead of HadISST as suggested by the reviewer. Figure S5 shows both $\delta^{18}O_{seawater}$ based on ERSSTv5 and HadISST in comparison to $\delta^{18}O_{seawater}$ based on Sr/Ca-SST.

3) Manuscript could benefit form more detailed description of model results and potentially re-framing of the aims for the model study…

We have modified sections 3.1 and 3.2 as suggested in our response to reviewer 1. The new section 3.1 "Validation of reconstructed Sr/Ca-SST and d18Oseawater at Ifaty" is focusing on a comparison of the coral reconstructions for SST and SSS variability at Ifaty with available gridded observation-based products and model data in the Ifaty-Tulear region. It includes a discussion of the discrepancy between the different products regarding the exact temporal evolution of SST and SSS caused by limited number of observations and highlights the best agreement of the coral data with ERSST and SODA. The new section 3.2 “Representativeness of SST and SSS variability at Ifaty for variability in the wider Agulhas Current region” then focuses on potential co-variability between SST and SSS at Ifaty and other locations in the wider Agulhas region. Here, independent of the mentioned disagreements in the exact temporal evolution, all observational products as well as the model agree that variability at Ifaty is indeed representative for variability in the AC core region (Figure 3). The fact that co-variability is not only found in observation-based products but also in the simulated NST and NSS from an ocean model without data assimilation, supports the idea that this relation is of dynamical nature. This section is further complemented by a new Figure 3b showing spatial maps of correlations between the $\delta^{18}O_{seawater}$ based on Sr/Ca-SST and SODA salinity. This map emphasize that co-variability is not only restricted to the AC core region but occurs for the wider AC region.

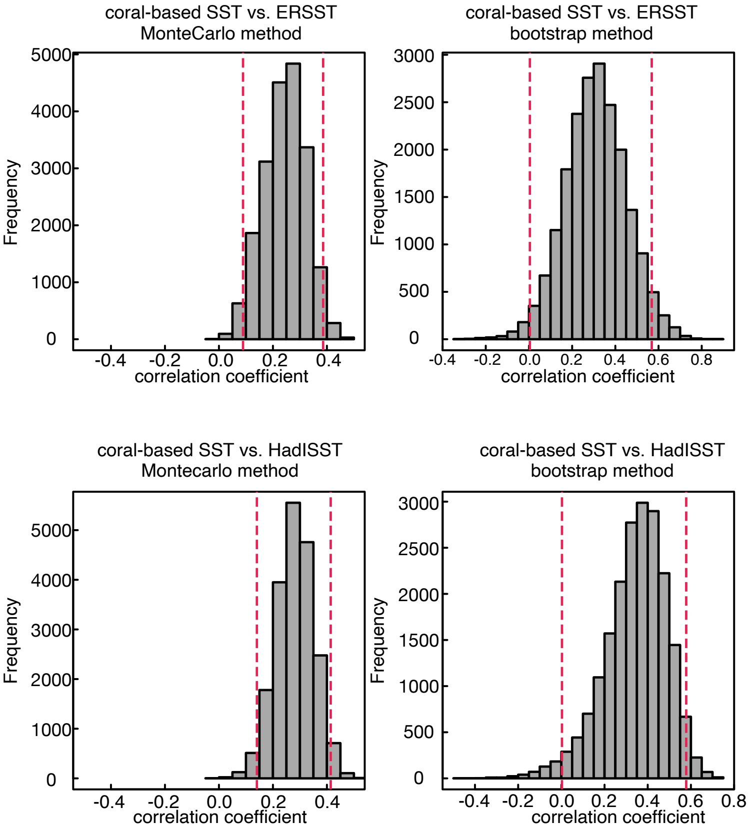

Figure 1 – Monte-Carlo (left) and bootstrap method (right) to estimate the distribution of correlation coefficient. Upper panels coral Sr/Ca-SST compared to ERSSTv5 and lower panels same but for HadISST. The red dot lines show 95 percentiles. As the lower border of 95 percentiles is higher than zero, the correlation coefficient is significant at a 95% confidence level (Watanabe et al., MS in prep.).

4) Question on lines 246 onwards: Reviewer asked if correlations between model SST and observations were done for the Ifaty coral site, the AC region or the SW Indian Ocean more broadly

Question was answered in our initial response.

5) More detailed description of interannual and decadal variability…explore links with ENSO, PDO etc.

We have expanded the analysis of ENSO teleconnections with Ifaty $\delta^{18}O_{seawater}$ based on Sr/Ca-SST in Figure 7g and h, Figure 9 b to d and a new Figure 10. These results are now discussed in the revised manuscript. Figures S10, S12 and S13 complement this expanded analysis.
Our wavelet coherence analysis shown in new Figure 9 indicates coherence with ENSO reconstructions on interannual and interdecadal frequencies, the latter involving phase lags. The 2-4 years and 8-16 years frequency bands appear to be important time scales of ocean climate variability in the greater Agulhas region.
We aim to avoid overinterpretation of ENSO's influence in our discussion mainly focusing on comparison of the interannual and decadal frequencies in our record and how that compares to proxy-based ENSO reconstructions. We draw some very careful conclusions regarding potential influences of ENSO in the pre-industrial period yet like to state here that ENSO alone may not be the only driver influencing salinity, $\delta^{18}O_{seawater}$ or SST. The results show that the 24-month lagged correlation between $\delta^{18}O_{seawater}$ and Nino3.4 is persistent for the majority of the record. Uncertainties in proxy-based ENSO reconstructions beyond 1880 and/or in our $\delta^{18}O_{seawater}$ record may have affected the lagged correlations beyond 1750. Nevertheless, the consistent lagged response of salinity and $\delta^{18}O_{seawater}$ to ENSO is most likely the most important finding of this study.

6) Question about the comparison of regional $\delta^{18}O_{seawater}$ reconstructions across the western Indian Ocean and why correlations are not significant.

We have expanded our analysis and interpretation of the comparison of regional $\delta^{18}O_{seawater}$ reconstructions across the western Indian Ocean. A new Figure S15 (next to Figure S14) shows the actual differences between individual $\delta^{18}O_{seawater}$ records to Ifaty $\delta^{18}O_{seawater}$. This analysis reveals that the absolute difference is smaller than the individual uncertainties from the reconstruction method, thus the $\delta^{18}O_{seawater}$ ranges for all western Indian Ocean sites fully overlap and are indistinguishable.

Technical comments:

Here we address the changes we made that were not yet addressed in our initial response.

Lines 191-192: Why was the MEI index used?

We now also show the same lagged correlation with the instrumental Nino3.4 index (back to 1880) and the Nino3.4 paleo-reconstructions of Emile-Geay et al. (2013) and Steiger et al. (2018) in our modified Figure 7 and Figures S10 and S12.

Lines 215-217: Equations for $\delta^{18}O_{seawater}$ reconstruction should be presented…

Done. Section 2.4 has been modified.

Lines 264-267: explain what positive correlation between d18Osw and rainfall means etc.
Done. Now added: "Rainfall and salinity or $\delta^{18}O_{seawater}$ should be negatively correlated when rainfall or freshwater runoff influences the signal."

Lines 282-282: …what a positive correlation means in terms of how changes in zonal wind stress impact $\delta^{18}O_{seawater}$ …
Done. It now reads: "Our low-pass filtered reconstructed $\delta^{18}O_{seawater}$ record indicates a positive correlation (r= 0.67, p= 0.0063) with the southern Indian Ocean (10-40°S, 50-100°E) ICOADS zonal wind stress, pointing to easterly wind anomalies driving ocean advection of the salinity signal across southern Indian Ocean."

Figure 2: Make dark red line darker
Answer: Done.
Figure 4: Caption difficult to understand
Done. We modified the caption.

Figure 5: Please use colour.
We increased the contrast of black and grey lines in Figure 5. It is consistent with Figure 4.

Figure 7: Use same Y-axis on all panels, explain green lines.
Figure 7 has been modified and expanded. Red and green lines are replaced by black and grey lines for clarity.

Figure S1: add a, b, c and d
Answer: Done.

Figure S8: Can't read any of the small text at top of panels.
Answer: Done.

<u>**Reviewer 2:**</u>

1) Add details on which samples were drilled in previous studies and which ones for this study…some fine tuning of wording around use of growth banding or high-resolution oxygen isotopes profiles

We added the data in a new Supplementary Table S1.

2) Simplify description of Monte Carlo approach for seawater oxygen isotope reconstructions…clarify if Monte Carlo approach was also used for 1881-1661 section.

Done. Entire section was modified.

3) Why was average Sr/Ca-SST slope used? Why HadISST for $\delta^{18}O_{seawater}$ reconstruction and not ERSST?

We now shows $\delta^{18}O_{seawater}$ based on ERSSTv5 In Figure 3a and Figure S5.
For the slope, please refer to our initial response to reviewers comments.

4) Improve discussion of model results in comparison to coral-based reconstructions.

Done. See response to Reviewer 1 above.

Minor comments:

Line 17: Might be helpful to define the acronyms for sea-surface temperature and salinity as they're used later in the abstract.

Answer: Done.

Line 22: please indicate the full time period of comparison (1958-1995?)

Answer: Done.

Line 42: possible formatting issue on one of the references?

Now corrected.

Lines 202-205: Interestingly the $\delta^{18}O$-SST variability appears to be more consistent with ERSST than Sr/Ca-SST (which has some very large spikes that aren't observed in temperature). Any thoughts on why this is the case?

Please see our response to reviewer 1 above. And please have a look at the estimation of correlation we present in this letter which takes into account the signal to noise ratio between ERSSTv5 and coral Sr/Ca-SST following Smerdon et al. (2016). We also expanded the discussion.

Line 400: Cobb 2003 is a more appropriate reference

Cobb, 2003 now added.

<u>Response to Editor</u>

1. Your response clarifies reviewer #2s question about methods for sampling annual average coral material, though it would be good to understand more about the potential uncertainties in this approach. For example what is the uncertainty on the timing of the annual d18O and annual density markers (and I would expect that the uncertainty is larger for density-based approaches), and could you run some tests to see what these levels of uncertainty do in terms of reducing correlations between true annual averages and coral-cycle derived pseudo-annual averages?

We have computed the pseudocoral annual averages and performed a Monte Carlo simulation to test for age model uncertaintities in annual mean sampling based on density banding. We introduced a new section "2.3. Age model uncertainty" where we outline the approach. New Figures S1 and S2 illustrate the results.
It reads: "The difference of Sr/Ca between the true and pseudo values is 0.003 ± 0.007 mmol/mol (1σ) (i.e., about ± 0.1 ºC) while the difference in δ^{18}O is 0.02 ± 0.014‰. Because of SST-related seasonality, Sr/Ca and δ^{18}O may have a bias towards positive values (lower SST), yet this bias is low. $\delta^{18}O_{sw}$ estimated from paired coral δ^{18}O and Sr/Ca measurements (see section 2.4 for methodology) is not significantly affected by the age model error (0.00±0.03‰ between true and pseudo values)."

2. The reviewers are both keen to see more description/analysis of the processes by which ENSO variability manifests at your site. It would be good to elaborate on this in the text and possibly with an additional figure.

Please see our response to the reviewers in the point-by-point response above. We have modified the figures 7 and 9 and included a new Figure 10 to show the results of band-pass filtering, cross-spectral analysis and wavelet coherence analysis.

3. One of the really important contributions of this work is a multi-century d18O-sw reconstruction, and it would be good to include some additional interpretation of the long-term trends/changes in this. In addition to the comparisons with similar reconstructions from other Indian Ocean sites it would be good to also show a comparison of your record with other long-term reconstructions of d18O-sw, including from other ocean basins. This could give some interesting perspectives to long-term drivers of change.

We have tested the relationship between Ifaty $\delta^{18}O_{seawater}$ and $\delta^{18}O_{seawater}$ reconstructions from the central Pacific Line Islands. There is no correlation between the records. In our opinion this comes as no surprise. It is already complicated to draw conclusions about relationships between Indian Ocean $\delta^{18}O_{seawater}$ records. Our analysis of all published western Indian Ocean

$\delta^{18}O_{seawater}$ records (Fig. 11; Figs. S14 and S15) demonstrates that the absolute difference is smaller than the individual uncertainties from the reconstruction method, thus the $\delta^{18}O_{seawater}$ ranges for all western Indian Ocean sites fully overlap and are indistinguishable. We propose that $\delta^{18}O_{seawater}$ is modified by site-specific atmospheric (P-E) and oceanic variability, and likely involve temporal lags.

We have, however, now included the comparison to two established Palaeo-Nino3.4 reconstructions and show the relationship over the full record in our modified Figures 7, 9, 10, S10 and S12.