C | A | U Christian-Albrechts-Universität zu Kiel Mathematisch-Naturwissenschaftliche Fakultät

Dr. Saori Ito | Inst. f. Geow. | Ludewig-Meyn-Str. 10 | 24118 Kiel

Dr. Saori Ito

Institut für Geowissenschaften
Ludewig-Meyn-Str. 10
24118 Kiel
e-mail: saori.ito@ifg.uni-kiel.de

Dr. Julien Emile-Geay
Editor of *Cliame of the Past*

Kiel, 18.12.2025

Response to reviewer comments for the manuscript titled 'The Northwest Pacific corals unravel the NPGO/Victoria Mode-related temperature back to the 19th century' by Ito et al., https://doi.org/10.21203/rs.3.rs-3861020/v3

Dear Editor,

We thank you and the two anonymous reviewers for the constructive comments and suggestions that have helped us significantly improve our manuscript. Major changes in the revised version will be:

1. We will provide additional analyses and clearer explanations regarding the appropriateness of the filtering approaches applied to each dataset, following the recommendations from both reviewers.
2. We will include analyses using the winter coral data and the Victoria Mode Dipole Index (Wen et al., 2024) for comparison to extend discussions, as suggested by both reviewers.
3. We will replace the HadCRUT5 dataset with the ERSST dataset for all comparison analyses, following Reviewer #2's suggestion.
4. We will revise the definition of seasons (3-month averaging), which helps address potential age model uncertainties at the seasonal scale, also following Reviewer #2's suggestion.
5. We will add additional supporting materials - figures, tables, descriptive text, and statistical tests - to reinforce the robustness of our results and interpretations.

We have confirmed that these revisions do not alter the primary objectives of our study; instead, they strengthen the manuscript, particularly the structure of the results, discussion, and conclusions.

Below are our detailed responses to the reviewer's suggestions (in red).

Thank you very much for your consideration.

Sincerely yours,
Dr. Saori Ito (as a representative of authors)

RC2: 'Comment on egusphere-2025-4054', Anonymous Referee #2, 14 Nov 2025

Ito and colleagues present a valuable 217-year (1798-2014 CE) temperature reconstruction from Shiomichi Bay, Kikai Island, Japan, derived from three *Porites* coral cores. The coral record demonstrates connections between low-frequency temperature variability in the Northwest Pacific (NWP) and major Pacific climate modes, specifically the North Pacific Gyre Oscillation (NPGO) and Victoria Mode (VM), which may be connected to Central Pacific surface temperatures via an atmospheric teleconnection. The analytical approach is rigorous, employing high-precision ICP-OES methods and incorporating multiple calibration slopes through Monte Carlo simulation to address uncertainties. This reconstruction makes an important contribution by expanding the limited network of coral and marine-based paleoclimate records in the Northern Pacific region, particularly those examining NPGO and VM variability.

While I find the manuscript appropriate and relevant for publication in this journal, I believe that the manuscript may require substantial revisions to fully realize its potential. Specifically, the manuscript would benefit from additional analyses, content reorganization, and strengthened argumentation to better support its key claims. Below, I provide my main comments and suggestions.

We deeply appreciate your time for reviewing our manuscript and your comments. Your insightful suggestions are very helpful to improve our study. We will revise our manuscript in accordance with your suggestions, including additional analyses.

General Comments

1. The introduction effectively establishes the importance of increasing the number of records in this region and the value of investigating past NPGO and VM variability beyond instrumental records. However, the manuscript would benefit from additional details from the literature. Specifically, clarification of the seasons and timescales on which the NPGO and VM typically operate would be valuable. Definitions could be made clearer throughout. The paper would also benefit from reorganization in the presentation of results and discussions.

G1. Thank you for your helpful comments. We will revise the manuscript to clarify the characteristics of NPGO and VM, in addition to the definitions used in NPGO and VM studies (Lines 45-50). We will also reorganise the content of Results and Discussion sections, particularly in accordance with your *General Comments 4* and *5.*

2. While the rationale for comparing the record to surface temperatures (ST) due to the coral's location (inside a bay, surrounded by landmass) is understandable, the use of ST rather than sea surface temperature (SST) may somewhat obscure the primary focus of this paper, which is identifying connections between NWP climate and the NPGO and VM, since both are oceanic expressions of North Pacific variability.

G2. Thank you for your comment. Following your suggestion in *Specific Comment 4*, we will use the ERSST5 dataset (sea surface temperature, SST, Huang et al., 2017) instead of the HadCRUT5 dataset (surface temperature, ST, Morice et al., 2021) for all analyses. We have confirmed that the ERSST5 dataset is suitable for our study (see our response *S4-1*). We agree with your comment that the focus of our manuscript - NPGO and VM, the oceanic expressions of North Pacific variability - will be clearer when combining an oceanic temperature proxy (coral skeleton) with an SST dataset (ERSST5).

Here, it should be noted: We will replace the abbreviations "Kikai-ST_{coral}", "Kikai-$ST_{HadCRUT5}$", and "CP-$ST_{HadCRUT5}$" with "Kikai-SST_{coral}", "Kikai-SST_{ERSST5}", and "CP-SST_{ERSST5}", which means temperature records from our Kikai-coral Sr/Ca dataset, the ERSST5 dataset for the grid covering Kikai Island, and the ERSST5 dataset for the Central Pacific, respectively. This revision has also been applied in this response document.

3. Throughout the manuscript, NPGO and VM are used interchangeably, sometimes combined as NPGO/VM and other times described separately, which may confuse readers. While the close relationship between NPGO and VM is acknowledged, they are considered distinct modes, one described as SSH variability, while the other as SST, respectively. Therefore, discussing them individually and separately in a clearer manner would be beneficial.

G3. We appreciate your helpful suggestion. We will reconsider our use of the terms "NPGO," "VM," and "NPGO/VM," and improve readability throughout the manuscript. In addition, we will treat the NPGO and VM modes separately when comparing our coral record with their respective indices (i.e., the NPGO Index, Di Lorenzo et al., 2008; the Victoria Mode Dipole Index, Wen et al., 2024).

4. Reorganization of Figures – Mentioning figures in chronological order would improve readability. Some examples (but not all) where figures appear out of sequence include:

- Figs. 1b, 1c, and 1e might be better placed in the latter part of the paper as results, as they are discussed toward the end
- Fig. 7 is mentioned before Fig. 6c
- Fig. A9 is mentioned before Figs. A6 and A7

G4. Thank you for pointing these out. We will correct and carefully reorganise the figure sequence throughout the manuscript.

5.Reorganization of Text – Several sections of the text would benefit from relocation or enhancement. A thorough revision is recommended. Some examples include:

- Lines 225-240 appear more suitable for the Discussion section
- Lines 259-263 could be placed earlier when describing the study site in the Methods section
- Some portions of the Results section would benefit from additional interpretation. For example, lines 269-271 present a correlation between the Kikai-ST_coral and Palmyra records, but do not discuss the implications
- Section 4.4 (Lines 350-365) may be better suited to the Methods section or presented as part of the Results, as some sentences introduce results for the first time in the Discussion.

G5. We appreciate your specific suggestions. We will revise our manuscript following them.

6. The manuscript's central conclusions become diluted across the Discussion section. I recommend restructuring the Discussion section to highlight and prioritize the most significant findings of the study.

G6. Thank you for your comments. Following your recommendation, we will reconsider the structure and improve the discussion section to clearly highlight the significant findings of our study.

Specific Comments

1. Study Site Description – A close-up map of the study site showing the precise coral collection location would help readers understand that samples came from within the bay rather than more open environments (as in Kawakubo et al., 2017). Including locations of other Kikai Island corals used for comparison would also be valuable. A more detailed description of reef conditions, submersion history, and potential local factors affecting Sr/Ca variability would enhance the manuscript.

S1. Thank you for your suggestion. We will add more detailed descriptions of the study sites, as well as a close-up map showing the locations of the coral cores, including those from previous studies. We have already explained the potential factor of differences in Sr/Ca variability from Kikai Island (i.e., difference in measurement methods, Lines 226-238; see also our response *S12*); however, we will reconsider potential factors that may affect coral Sr/Ca variability at the local scale.

2. Selection of Sampling Tracks – Before examining the relationship between the coral reconstruction and NPGO/VM, it would be valuable to provide additional justification for the sampling approach used for Core 2. I appreciate the authors showing the X-ray images with all sampling tracks. However, based on these images, it remains unclear how sampling along extending corallites or the maximum growth axis was ensured to yield reliable Sr/Ca ratios (see e.g., DeLong et al., 2013). Some portions of the core appear to show off-axis growth. Given that the coral paleoclimate community typically exercises considerable care in sampling track selection to avoid spurious measurements unrelated to climate/environmental change, additional documentation of the track selection criteria would strengthen confidence in the results.

S2. Thank you for your comments. Consistent with established practices in coral geochemical studies, we also selected our sampling paths with considerable care and avoided areas of off-axis growth (i.e., corallites oriented at 90° to the surface; DeLong et al., 2013). We will add a clearer explanation and improve the X-ray images of all cores (Figure A2) to show that the sampling paths follow the extending corallites and their growth direction.

3. Several overlapping tracks are present throughout the cores. While the Sr/Ca ratios for overlapping tracks between Cores 1 and 2, and between Cores 2 and 3, are shown, it would be helpful to see raw Sr/Ca data plotted for all overlapping tracks, particularly for Core 2 where annual bands and growth axes appear less distinct. Additional explanation of how tracks were identified for Core 2 under these conditions would be valuable. In Figure 2b, higher variance appears in the data during time periods represented by Core 2, and clarification of whether this reflects sampling considerations or natural climate signals would be helpful.

S3. Thank you for your helpful suggestion. We will include the raw Sr/Ca data for all overlapping paths as supplementary information. In addition to the summary of Sr/Ca records for each core (Table 1), we will provide further explanation regarding differences in variance among the cores. We evaluated the significance of variance differences in summer and winter Sr/Ca among cores using the Levene test. The results indicate that the variances are not statistically different (summer Sr/Ca: p-value = 0.19; winter Sr/Ca: p-value = 0.72). Therefore, we confirm that there is no detectable bias in the variance of the seasonal signals among the cores. This result does not affect our subsequent time series analysis.

4. Section 2.3 Chronology:

- Clarification would be helpful regarding the use of OISST v2.1 for delineating coral Sr/Ca seasonal cycles while HadCRUT5 is used for analysis. Are SST values from 1981-2015 similar between these datasets? If so, what motivated the choice to switch datasets? Consideration of ERSSTv5 reanalysis data (or other SST data products) might also be worth discussing.

S4-1. Thank you for your comments. To establish an age model for a coral geochemical record, we used the OISST v2.1 dataset (Huang et al., 2021) as a reference temperature product that reflects local water temperatures at high spatial resolution (0.25º × 0.25º grid).

We appreciate your valuable recommendation to use another SST product, ERSST5. Together with your suggestion regarding time assignment (*Specific Comment 5*; see our response *S5*), we confirmed that our coral record (3-month averaged summer and winter values) tracks the ERSST5 dataset well. When we apply ERSST5 for comparison, we obtain strong relationships with our coral record (see Table R2-1 for the comparison). Consequently, we will replace HadCRUT5 with ERSST5 for all analyses in the manuscript. We further confirm that this revision does not alter our primary objectives; instead, it strengthens the structure of the manuscript, particularly the discussion and conclusions. Again, we sincerely appreciate your excellent suggestions.

In summary, we will use the OISST v2.1 dataset (1981-2014 CE) to establish the coral age model, and employ the ERSST5 dataset for time-series analyses (1900-2014 CE). We provide a preliminary comparison between OISST v2.1 and ERSST5 (Figure R2-1). The ERSST5 dataset shows a statistically significant correlation with OISST v2.1 at the 99% confidence level (CL) (r = 0.99, n = 406). We will include Figure R2-1 as a supplementary figure and will clarify the appropriate roles of OISST v2.1 and ERSST5 in the revised manuscript.

Table R2-1. Correlation among coral record (this study) and instrumental temperature records (HadCRUT5 and ERSST5) around Kikai Island and in the Central Pacific.

The datasets for Kikai-ST_{coral} and Kikai-SST_{coral} are identical and were converted from Kikai-coral Sr/Ca (i.e., temperature proxy). When comparing our coral record with surface temperature (i.e., ST, HadCRUT5, Morice et al., 2021), the coral record is named Kikai-ST_{coral}. In contrast, when comparing our coral record with surface temperature (i.e., SST, ERSST5, Huang et al., 2017), the coral record is named Kikai-SST_{coral}. An 8–30 year bandpass filter was applied to all time series prior to calculating correlations. The statistical significance of correlation coefficients, i.e., confidence levels (CL), was tested using the method described by Di Lorenzo et al. (2009) and Di Lorenzo et al. (2010), which accounts for the reduction in effective sample size (N_{eff}) due to filtering. Notes: The results are preliminarily shown in this reply document for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript (orange shaded).

(a) Comparison of seasonal coral record (this study) and annual mean instrumental temperature record, 1950-2014

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-ST_{coral} versus Kikai-$ST_{HadCRUT5}$	1950-2014	0.59	95%CL	8.51
Summer Kikai-ST_{coral} versus CP-$ST_{HadCRUT5}$	1950-2014	-0.65	99%CL	7.16
Winter Kikai-ST_{coral} versus Kikai-$ST_{HadCRUT5}$	1950-2014	0.35	*n.s.*	9.26
Winter Kikai-ST_{coral} versus CP-$ST_{HadCRUT5}$	1950-2014	-0.01	*n.s.*	6.13
Summer Kikai-SST_{coral} versus Kikai-SST_{ERSST5}	1950-2014	0.69	95%CL	7.66
Summer Kikai-SST_{coral} versus CP-SST_{ERSST5}	1950-2014	-0.66	99%CL	6.71
Winter Kikai-SST_{coral} versus Kikai-SST_{ERSST5}	1950-2014	0.68	95%CL	8.53
Winter Kikai-SST_{coral} versus CP-SST_{ERSST5}	1950-2014	-0.18	*n.s.*	6.02

(b) Comparison of seasonal coral record (this study) and annual mean instrumental temperature record, 1900-2014

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-ST_{coral} versus Kikai-$ST_{HadCRUT5}$	1900-2014	0.33	*n.s.*	17.67
Summer Kikai-ST_{coral} versus CP-$ST_{HadCRUT5}$	1900-2014	-0.64	95%CL	10.14
Winter Kikai-ST_{coral} versus Kikai-$ST_{HadCRUT5}$	1900-2014	0.32	*n.s.*	18.78
Winter Kikai-ST_{coral} versus CP-$ST_{HadCRUT5}$	1900-2014	-0.11	*n.s.*	11.20
Summer Kikai-SST_{coral} versus Kikai-SST_{ERSST5}	1900-2014	0.34	*n.s.*	15.86
Summer Kikai-SST_{coral} versus CP-SST_{ERSST5}	1900-2014	-0.65	95%CL	9.80
Winter Kikai-SST_{coral} versus Kikai-SST_{ERSST5}	1900-2014	0.41	*n.s.*	19.40
Winter Kikai-SST_{coral} versus CP-SST_{ERSST5}	1900-2014	-0.28	*n.s.*	10.96

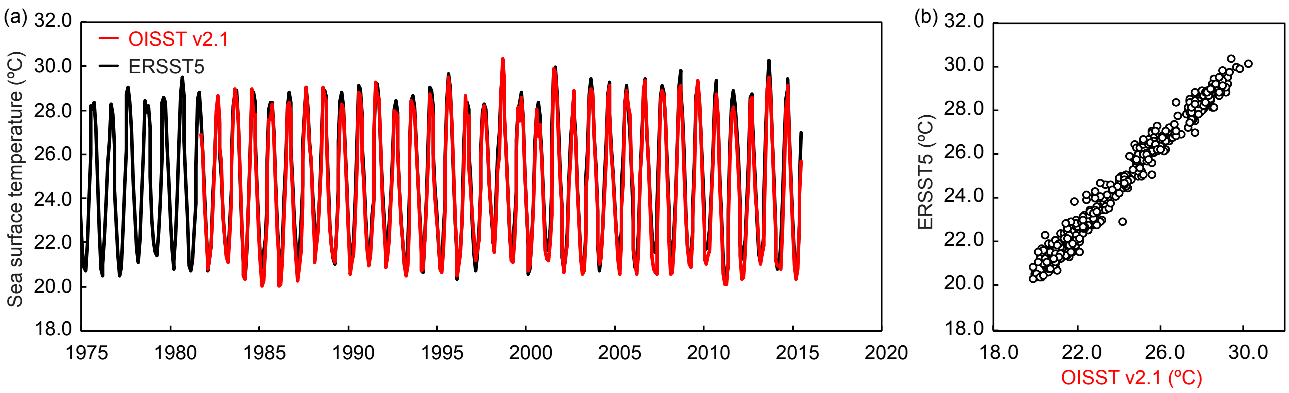

Figure R2-1. Comparison of temperature products (OISST v2.1 and ERSST5).

(a) Time series of OISST v2.1 (Huang et al., 2021, monthly resolved, converted from daily data, for the grid covering Kikai Island, red line) and ERSST5 (Huang et al., 2017, for the grid covering Kikai Island, black line). (b) Scatter plots for OISST v2.1 and ERSST5 for the period 1982-2014 CE. Notes: The results are preliminarily shown in this reply document for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript.

- Additional detail on the conversion of Sr/Ca from the depth domain to the time domain would be beneficial. Specifically, were values interpolated to 12 months per year? Explicit mention in the Methods section would be helpful. The citation to Ito et al., 2020 also appears to be missing from the references.

S4-2. Thank you for your comments. Following your *Specific Comment 5*, we will use 3-month averaged values for seasonal analyses (i.e., summer and winter). These 3-month averages will be calculated from a monthly-interpolated dataset. We will add more detailed information in Methods section.

We have confirmed that Ito et al. (2020, Sci. Rep.) is included in the reference list; however, we will double-check it carefully when revising the manuscript.

- Further explanation of the time assignment for Sr/Ca values beyond the instrumental period would be valuable. Was this based on climatology? If software such as QAnalySeries was used for assigning tie points, this should be mentioned with appropriate detail.

S4-3. We did not use specialised software for age model establishment, such as QAnalySeries, but instead estimated the time series manually using Microsoft Excel. The time assignment for the coral Sr/Ca record for the period beyond the satellite observation was based on SST climatology using an artificial time series composed of repeating mean monthly temperatures. Please also see our response *S5*.

5. The assignment of single peaks as summer (August) or winter (February) may warrant reconsideration, as the timing of highest/lowest temperatures can vary between years. This could potentially contribute to the observed lag between coral-derived reconstructions and NPGO or VM indices. Defining seasons more broadly (e.g., JJAS for summer or DJFM for winter) based on SST climatologies and performing analyses accordingly might provide more robust results.

S5. Thank you for suggesting an alternative method for developing an age model for coral Sr/Ca. For the period prior to the satellite observation (i.e., prior to 1981 CE), the age-model method using an artificial time series composed of repeating mean monthly temperatures is commonly applied in coral geochemical studies (e.g., Charles et al., 1997; Felis et al., 2000; Pfeiffer et al., 2009; DeLong et al., 2014; Cahyarini et al., 2021). This approach can produce approximately 1-2 months of error in any given year. However, the new definition of seasons, as described below, effectively resolves this issue.

To address the concern about the approximately 1-2 months of error, we accept your suggestion regarding the definition of seasons. We will first interpolate the dataset to a monthly resolution, and then define summer and winter seasons by averaging three months based on SST climatologies. Specifically, summer (winter) will be defined by averaging the Sr/Ca values for the month with the lowest (highest) Sr/Ca value and the preceding and following months. By employing this definition, consequently, we obtain a significant relationship between Summer Kikai-SST_{coral} and the NPGO Index at the 95% CL without any lags (see our response *S7*). In the revised manuscript, the newly-defined datasets will be referred to as "Summer Kikai-coral Sr/Ca" and "Winter Kikai-coral Sr/Ca", moreover, for the temperature-converted datasets, they will be referred to as "Summer Kikai-SST_{coral}" and "Winter Kikai-SST_{coral}". This revision has also been applied in this response document.

6. Additional justification would be helpful for comparing summer and winter seasons to annual instrumental data rather than season-to-season comparisons. Furthermore, the observation that summer temperature matches annual instrumental temperature better than annual coral temperature does (Fig. A6) warrants explanation.

S6. Thank you for the comments. We will add further explanation on this topic. We conducted season comparisons as a basic data analysis; however, we did not obtain consistent, statistically significant results. On the other hand, we found a significant relationship between our coral record (summer and winter records) and the annual mean instrumental temperature dataset. Therefore, in this study, we present comparisons of our summer, winter, and annual mean coral records with the annual mean instrumental data (ERSST5 in the revised manuscript) as a basic analysis to investigate the characteristics of our coral record (see also our preliminary results in Table R2-1, presented in our response *S4-1*).

Here, we present an additional comparison of ERSST5 for the grid covering our sample site (Kikai-SST_{ERSST5}), examining summer or winter values against annual mean values (Figure R2-2). The annual mean values of the Kikai-SST_{ERSST5} dataset show strong correlations at the 99% CL with summer ($r = 0.77$, $n = 115$) and winter ($r = 0.75$, $n = 115$) values for the period 1900-2014 CE. Even for the period 1950-2014 CE, significant correlations are confirmed at the 99% confidence level ($r = 0.72$ for summer values and $r = 0.79$ for winter values, $n = 65$ for each). These results suggest that the annual mean values of Kikai-SST_{ERSST5} capture both summer and winter signals and support the use of annual mean values for comparison with our coral summer/winter records.

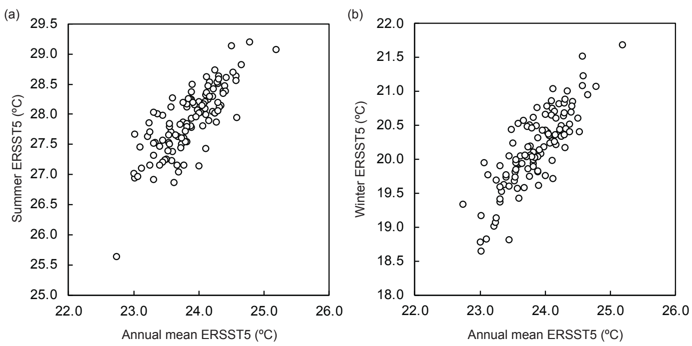

Figure R2-2. Scatter plots for summer/winter ERSST5 and annual mean ERSST5 for the grid covering Kikai Island.

(a) Summer values versus annual mean values of Kikai-SST_{ERSST5} for the period 1900-2014 CE (Huang et al., 2017, for the grid covering Kikai Island). (b) Same as (a), but for winter values versus annual mean values of Kikai-SST_{ERSST5}. Notes: The results are shown only in this reply document.

Regarding your concern about the different results observed when comparing coral summer and annual mean values with the annual mean instrumental temperature, this can be attributed to season-dependent growth-related biases in the coral Sr/Ca record, as noted in a previous study (Barnes et al., 1995). Such biases appear to be a common issue in coral geochemical records from subtropical and temperate regions (Kawakubo et al., 2014; Fallon et al., 1999). As shown in Figure A9 and described in Discussion section 4.1, the winter season of our coral record contains fewer data points than the summer season. Therefore, the winter dataset may not fully capture winter temperature variability due to growth effects. This bias also contributes to the comparison result between the annual mean Sr/Ca values and the annual mean instrumental temperature, because the annual mean Sr/Ca value is calculated from a 12-month interpolated dataset that includes winter-season values.

7. Clarification of whether NPGO or VM expression is more pronounced during boreal summer in the Northwest Pacific would strengthen the manuscript. While NPGO and VM are typically more strongly linked to winter climate patterns with the largest seasonal variance in winter, this paper compares coral-based summer temperature reconstruction to annual temperatures. If the expression or impact is indeed more evident in boreal summer for this region, this should be explicitly stated to justify the analytical approach.

S7. Thank you for your comments. As well as the results of comparison with the instrumental temperature records (ERSST5) (our response *S6*), we have tested season comparisons between our coral records and the NPGO Index as a basic data analysis. Our preliminary result is shown in Table R2-2 and Figure R2-3. For the season comparison, Summer Kikai-SST_{coral} correlates significantly with the summer NPGO Index at the 95% CL (r = 0.62, N_{eff} = 12.04, 8-year low-pass filtered), whereas Winter Kikai-SST_{coral} does not correlate significantly with the winter NPGO Index (r = 0.41, N_{eff} = 10.87, 8-year low-pass filtered, Table R2-2a. For comparisons with the annual mean NPGO Index, slightly different results are obtained. Consistent with your comments, the Winter Kikai-SST_{coral} record shows a possible relationship with the annual mean NPGO Index for the period 1950-2014 CE, although only at the 90% CL (r = 0.45, N_{eff} = 10.61, 8-year low-pass filtered; Table R2-2b and Figure R2-3b). The Summer Kikai-SST_{coral} record shows a significant correlation with the annual mean NPGO Index for the same period at the 95% CL (r = 0.63, N_{eff} = 11.99, 8-year low-pass filtered; Table R2-2b and Figure R2-3a). It is noted that these correlations are obtained without any lag.

These results suggest that both the summer and winter coral records have the potential to capture annual mean NPGO-related variability, but the summer values do so more accurately. This may be due to season-dependent growth-related biases in the coral Sr/Ca record (see our response *S6*). This bias would be an issue when reconstructing long-term NPGO and VM variability from the winter coral geochemical record in the subtropical Northwest Pacific. We recognise this is the limitation of this study. However, this issue can be addressed by employing several oceanic temperature proxies that can compensate for the potentially biased coral winter record. The multi-proxy-based reconstruction would provide further discussions. In the revised manuscript, we will include this explanation and emphasise the need for further study.

Table R2-2. Correlation between Kikai-SST$_{coral}$ and NPGO Index

The dataset of Kikai-SST$_{coral}$ was converted from Kikai-coral Sr/Ca (i.e., temperature proxy record). An 8-year low-pass filter was applied to all time series prior to calculating correlations. The statistical significance of correlation coefficients, i.e., confidence levels (CL), was tested using the method described by Di Lorenzo et al. (2009) and Di Lorenzo et al. (2010), which accounts for the reduction in effective sample size (N_{eff}) due to filtering. Notes: The results are preliminarily shown in this reply document for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript (orange shaded).

(a) Comparison of seasonal Kikai-SST$_{coral}$ record and seasonal NPGO Index

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-SST$_{coral}$ versus summer NPGO Index	1950-2014	0.62	95%CL	12.04
Winter Kikai-SST$_{coral}$ versus winter NPGO Index	1950-2014	0.41	*n.s.*	10.87

(b) Comparison of seasonal Kikai-SST$_{coral}$ and annual mean NPGO Index

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-SST$_{coral}$ versus annual mean NPGO Index	1950-2014	0.63	95%CL	11.99
Winter Kikai-SST$_{coral}$ versus annual mean NPGO Index	1950-2014	0.45	90%CL	10.61

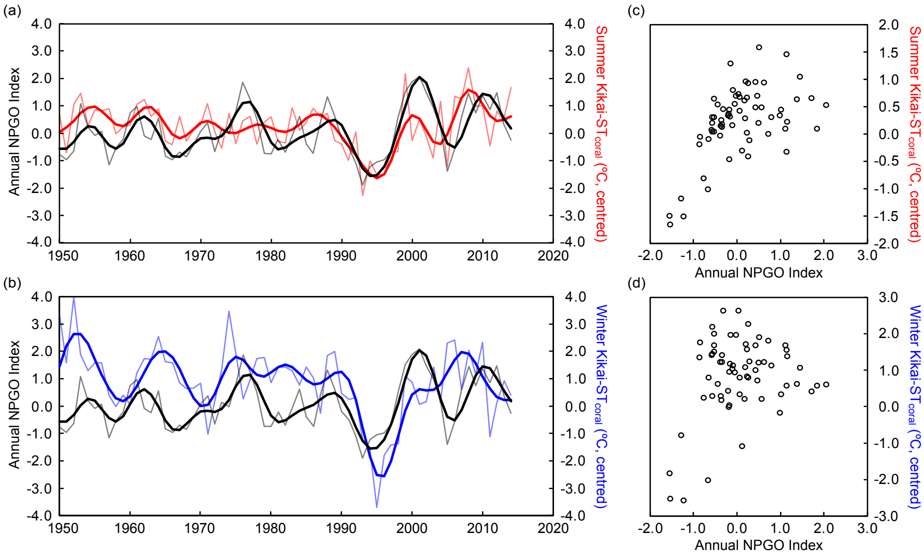

Figure R2-3. Comparison of the annual mean NPGO Index and Kikai-SST$_{coral}$ (1950-2014 CE).

Time series of the annual mean NPGO Index (thin black line, Di Lorenzo et al., 2008) and (a) Summer Kikai-SST$_{coral}$ (thin red line) or (b) Winter Kikai-SST$_{coral}$ (thin blue line). Bold lines represent the 8-year low-pass filtered time series. (c)(d) Scatter plots corresponding to (a) and (b), respectively. Notes: The results are preliminarily shown in this reply document for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript.

In addition, we present an additional comparison of the NPGO Index between summer or winter values and the annual mean values (Figure R2-4). The annual mean NPGO Index shows strong correlations at the 99% CL with summer (r = 0.96, n = 65) and winter (r = 0.92, n = 65) values for the period 1950-2014 CE. These results suggest that the annual mean NPGO Index captures both summer and winter signals and support the use of annual mean values for comparisons with our coral summer/winter records.

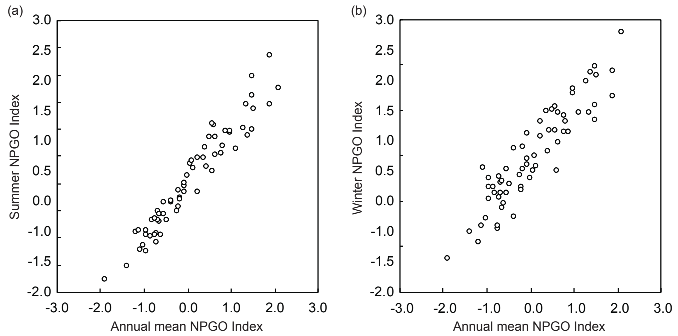

Figure R2-4. Scatter plots for summer/winter NPGO Index and annual mean NPGO Index.

(a) Summer values versus annual mean values of the NPGO Index (Di Lorenzo et al., 2008) for the period 1950-2014 CE. (b) Same as (a), but for winter values versus annual mean values of the NPGO Index. Notes: The results are shown only in this reply document.

8. Choice of 8–30 year bandpass filter and 30-year running correlations (Fig. 7) – Additional rationale for these frequency ranges would strengthen the analysis. Does the coral record show significant power at these timescales? An explanation of why this frequency range (8-30 years) is particularly important for understanding NPGO and VM variability would be beneficial.

S8. Thank you for the comments. To verify the efficiency of our filtering approach, we will additionally conduct spectral analysis (the preliminary results are shown in Figure R2-5).

For the NPGO (the NPGO Index), it exhibits significant frequencies at 9.8, 6.8-6.9, and 3.6 years at the 95% CL, with and without 30-year high-pass filtering (Figures R2-5a and R2-5e). For the VM (the VMDI dataset) without filtering, we do not detect any significant time frequency at the 95% CL (Figure R2-5b). In contrast, with 30-year high-pass filtering, we detect significant frequencies at 12.4 and 10.6 years at the 95% CL (Figure R2-5f). This result suggests that the 30-year high-pass filter effectively removes long-term trends/frequencies, such as global warming or external forcing.

In the previous NPGO studies, an 8-year low-pass filter has been commonly applied for time series analysis (Di Lorenzo et al., 2010; Ding et al., 2015; Nurhati et al., 2011). Although the number of previous VM studies is fewer than the NPGO studies, Wen et al. (2024), who applied an 11-year low-pass filter, confirmed a robust correspondence between the conventional empirical orthogonal function-based VM index (Bond et al., 2003) and their newly proposed VMDI. Based on the previous studies and our additional spectral results (Figure R2-5), we will employ an 8-year low-pass filter and/or an 8-30-year bandpass filter for the NPGO analysis, and a 10-year low-pass filter and/or a 10-30-year bandpass filter for the VM analysis. These filters are appropriate for capturing the characteristics of both VM and NPGO.

Besides, there are significant time frequencies at 16.4 and 15.2 years at the 95% CL for the Summer Kikai-SST_{coral} dataset (3-month averaged), which fall in the range of our filters (8-year low-pass filter, 8-30-year bandpass filter, 10-year low-pass filter, and 10-30 year bandpass filter) (Figure R2-5g). While the Winter

Kikai-SST$_{coral}$ dataset shows significant time frequencies at 18.2, 12.8, 9.3 and 8.3 years at the 95% CL, which fall in the range of our filters (Figure R2-5h). In the revised manuscript, based on Figure R2-5, we will provide further explanation regarding filter selection and the significant frequencies in our coral record.

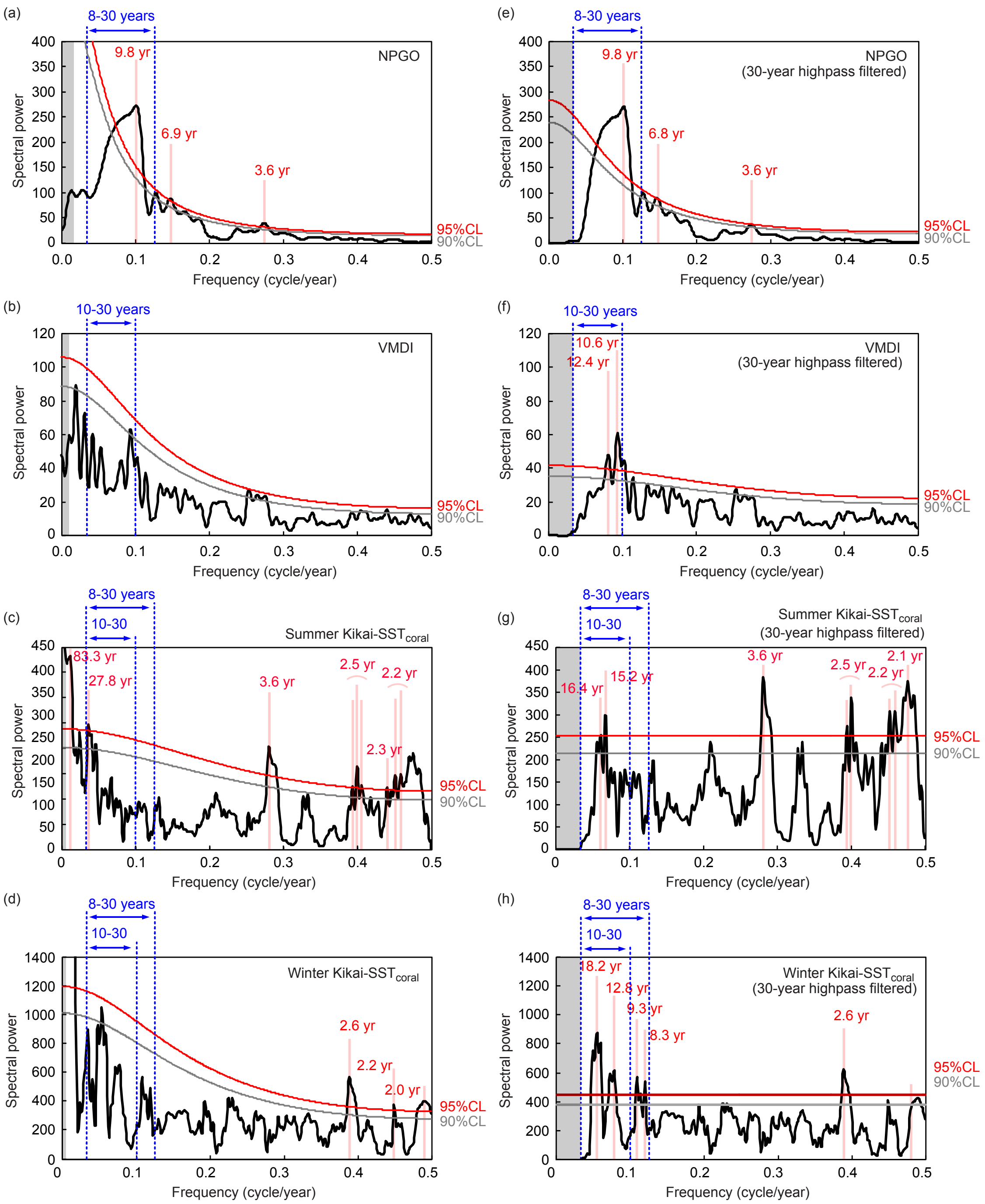

Figure R2-5. Spectral power analysis for the NPGO Index, the VMDI, and Kikai-SST$_{coral}$.

(a) Annual mean dataset of the NPGO Index (Di Lorenzo et al., 2008) for the period 1950-2014. (b) Annual mean dataset of the Victoria Mode Dipole Index (VMDI, Wen et al., 2024, calculated using ERSST5, Huang et al., 2017) for the period 1900-2014 CE. (c) Summer-Kikai-SST$_{coral}$ and (d) Winter Kikai-SST$_{coral}$ datasets for the period 1799-2014 CE. (e)(f)(g)(h) Same as (a), (b), (c), and (d), respectively, but for the dataset, which was 30-year high-pass filtered. The detected significant frequencies at the 95% confidence level (95% CL) are denoted with years (yr). Indetectable frequencies are shaded in grey. The spectral power analysis was computed using Past software (v. 4.0.3; Hammer et al., 2001). The time frequency between the blue dashed lines with a note (year) indicates the range of the pass filter that is employed in this study. Notes: The results are preliminarily shown in this reply document, and conclusive results can be found in a revised manuscript.

9. The manuscript would be strengthened by comparing the temperature record to other major Pacific climate modes (ENSO/PDO/IPO) and explicitly discussing why NPGO and VM appear to be more dominant at this site. Currently, the relative influence of NPGO/VM compared to other major modes of Pacific climate variability is not directly addressed. Clarification of why this coral record preferentially captures NPGO and VM variability would enhance the interpretations.

S9. Thank you for your suggestion. The relationships between NPGO/VM and its associated major Pacific climate modes (NPO, CP-ENSO, KOE Zonal Mode, North Pacific Current) have been summarised by Di Lorenzo et al. (2013). In our study, we selected CP-ENSO (Central Pacific ENSO region temperature anomaly) from these major Pacific climate modes and compared it with both our coral temperature record and the local temperature at the coral site. Our results indicate that temperature variability observed in the Northwest Pacific, including at our coral site, is likely influenced by NPGO-related temperature variations propagated from the Central Pacific via the “ocean–atmosphere bridge,” particularly on long-term temporal scales (Discussion section 4.2).

In addition, we will include a comparison between our coral record and the NPO mode variability (Trenberth and Hurrell, 1994) for the period 1950-2014 CE. Preliminary results are presented in Figure R2-6. Cross-wavelet coherence analysis indicates that our coral records, especially Summer Kikai-SST_{coral} and the NPO mode variability (derived from sea level pressure over the North Pacific, 30-65° N, 160°E-140°W), are coherent at interannual-to-decadal frequencies throughout the period. These results suggest a linkage between our coral record and NPO mode variability, supporting our argument in Discussion section 4.2.

Given the observed linkage between the Northwest Pacific and the Central Pacific, which acts as an “oceanic bridge” connecting the NPO and CP-centred ENSO phenomena (Ding et al., 2015; Qi and Mao, 2022), and the feedback connecting CP and NPO/NPGO temperature variability through an “atmospheric bridge” (Alexander et al., 2002; Di Lorenzo et al., 2010), our coral record from the Northwest Pacific would reflect the NPGO-mode-centred Pacific decadal dynamics and teleconnections, as proposed by Di Lorenzo et al. (2013, see their Figure 1). Based on these evidential results and references, we will provide further interpretation and strengthen our argument in the revised manuscript.

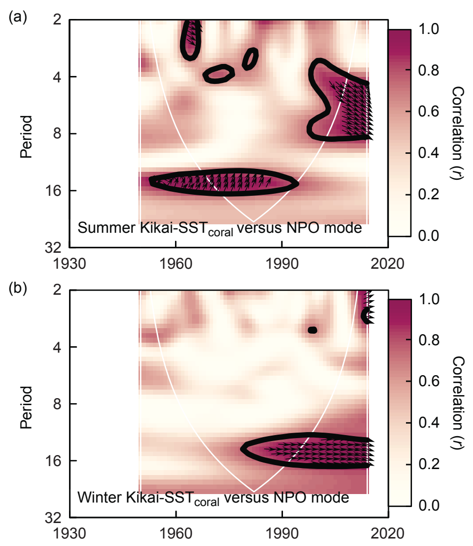

Figure R2-6. Cross-wavelet coherence analysis between Kikai-SST$_{coral}$ and NPO mode variability.
(a) Cross-wavelet coherence between Summer Kikai-SST$_{coral}$ time series and NPO mode variability (December-February) for the period 1950-2014 CE. The NPO dataset is calculated from the Hadley Centre Sea Level Pressure dataset (HadSLP2r, Allan and Ansell, 2006; 30-65º N, 160ºE-140ºW) using the empirical orthogonal function method of Trenberth and Hurrell (1994) at KNMI Climate Explorer. Regions of significant coherence (p-values < 0.1) are outlined by solid contours. Arrows indicate the phase relationship. The cross-wavelet coherence was computed using the "biwavelet" package (version 0.20.21) on R software (Gouhier et al., 2021; R Core Team, 2023). (b) Same as (a), but between Winter Kikai-SST$_{coral}$ time series and NPO mode variability (December-February). Notes: The results are preliminarily shown in this reply document for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript.

10. Have the authors considered comparing their record directly to the Victoria Mode Dipole Index (VDMI) (Wen et al., 2024, *Dyn.*) to further verify the relationship of their coral record to the Victoria Mode?

S10. We appreciate your helpful suggestion. We will use the Victoria Mode Dipole Index (VMDI, Wen et al., 2024) to investigate the relationship between our coral record and the Victoria Mode. Although it is well established that the VM and NPGO modes are well synchronised (e.g., Di Lorenzo et al., 2008) (our preliminary analysis also suggests a strong correlation between them at the 99% CL: the NPGO Index versus VMDI, r = –0.70, n = 65, annual mean datasets for the period 1950-2014, non-filtered), a direct comparison with our coral record and VMDI would be valuable. As with the NPGO Index comparisons (see our response *S7*), we conducted season comparisons as a basic analysis. Our preliminary results are similar to those of the NPGO comparisons: the annual mean values of VMDI show a reasonable relationship with both Summer Kikai-SST$_{coral}$ and Winter Kikai-SST$_{coral}$. Based on this basic analysis, we will use the annual mean values of VMDI, rather than summer or winter values, for subsequent analyses in the manuscript.

11. The observation that the coral record leads the instrumental record warrants further discussion. Could this result from age model uncertainties or from comparing summer coral values to annual instrumental records? Additional analysis of this temporal relationship would be valuable.

S11. Thank you for your comments. Following your suggestion in *Specific Comment 5*, we will revise the definition of seasons by using a 3-month average for summer and winter values. Based on our preliminary results, Summer Kikai-SST_{coral} shows a significant relationship with the NPGO Index **without any lag** (r = 0.63, N_{eff} = 11.99, 8-year low-pass filtered, Figure R2-3 presented in our response *S7*). Therefore, your concern regarding the previously noted "1-year lag" will be resolved. We again appreciate your helpful suggestion on the definition of seasons.

12. Given the proximity of this coral core to other records from Kikai Island, the differences in captured variability (e.g., winter records compared to Kawakubo et al., 2017) merit additional discussion. Potential explanations related to location or site-specific characteristics would be valuable to include.

S12. Thank you for your suggestion. In our manuscript, we have presented season comparisons between coral records from this study and Kawakubo et al. (2017) (Figure A6). In the revised manuscript, we will compile detailed information about other records from Kikai Island and provide explanations of potential factors influencing Sr/Ca variability.

As described in Lines 226-233, the records from our study and Kawakubo et al. (2017) were produced by different analytical methods. Our coral record was analysed by the solution ICP-OES method (Watanabe et al., 2020), whereas Kawakubo et al. (2017) employed the laser ablation ICP-MS method (Kawakubo et al., 2014). Both methods have advantages and weak points. For example, (1) the analytical uncertainty of our solution ICP-OES method (0.1% RSD, 1σ) is better than that of Kawakubo et al. (2014)'s laser ablation ICP-MS method (0.3% RSD), and (2) winter signals can be captured better by the laser ablation ICP-MS method than the solution ICP-OES method (as reported by Kawakubo et al., 2014). As seen in Figure A6, our Kikai-coral Sr/Ca_{summer} significantly correlates with the summer values of Kawakubo et al. (2017), whereas our Kikai-coral Sr/Ca_{winter} does not correlate with the winter values of Kawakubo et al. (2017). This would be explained by the season-dependent growth-related bias observed in the winter season (Discussion section 4.1 and Figure A9) and by differences in analytical methods between our study and Kawakubo et al. (2017).

Additionally, we do not rule out the local factor that is associated with the coral sample site. Our coral collection site is located in the semi-closed Shiomichi Bay, northeast of Kikai Island. In contrast, Kawakubo et al. (2017) collected their coral offshore of Arakizaki Point, southwest of Kikai Island. Kubota et al. (2017) also provided detailed information regarding the coral core location in Kawakubo et al. (2017). We will add detailed descriptions of the study sites, presenting a close-up map with the locations of the coral cores.

13. Section 4.1 – While growth-related biases in Sr/Ca depending on season are discussed (with faster coral growth during summer than winter), the manuscript would benefit from systematic documentation of this effect. Providing information on average growth rates would be helpful. Currently, the lack of quantitative growth rate data makes evaluation of potential growth biases challenging. Analysis of relationships between Sr/Ca and annual growth rates could help ascertain whether growth biases are present in the record.

S13. Thank you for the comments. We will report the annual growth rate for each coral core (Core-1 to Core-3) as supplementary information. However, unlike bivalves (daily growth bands) or tree rings (light/dark rings), corals exhibit only annual growth bands in their skeletons. This characteristic of corals poses a challenge for estimating seasonal growth rates (e.g., 3-month-averaged summer or winter growth rates) and for comparing summer and winter growth in absolute values. Nonetheless, season-dependent growth-related biases in the coral Sr/Ca record (i.e., less accuracy of Sr/Ca as SST proxy) have been reported in previous studies (e.g., Barnes et al., 1995), and these biases are quantitatively evidenced by comparisons of data points from summer and winter seasons (Figure A9).

14. Section 4.2, Lines 311-313 – The attribution of poor correlation to insufficient quality of instrumental ST datasets prior to 1950 would be strengthened by consideration of alternative SST products. Additionally, Figure 7 shows strong relationships between CP-ST_HadCRUT5 and the coral-based reconstruction both before and after 1950. If HadCRUT5 data quality was indeed poor prior to 1950, the strong pre-1950 correlation at these frequencies requires explanation.

S14. Thank you for your suggestion and comments. Following your recommendation (*Specific Comment 4*), we will use the ERSST5 dataset instead of the HadCRUT5 dataset in this study. Our preliminary comparisons between the Kikai-SST_{coral} record and temperature products are shown in Table R2-1 (see our response *S4-1*). The quality of the temperature product depends on the grid and period (Chan and Huybers, 2021). The quality of Kikai-SST_{ERSST5} prior to 1950 CE may have been insufficient, as evidenced by the poor correlation with our coral record (Table R2-1b). While we have confirmed significant relationships between Summer Kikai-SST_{coral} and the annual mean CP-SST_{ERSST5} at the 95% CL, both periods 1900-2014 CE and 1950-2014 CE. Therefore, we do not find any insufficiency in the quality of the CP-SST_{ERSST5} dataset. Additionally, we have confirmed that revised Figure 7 (Figure R2-7) shows a strong correlation between the CP-SST_{ERSST5} dataset (of sufficient quality) and our coral record. The significant relationship in both before and after 1950 CE, seen in Figure R2-7, is supported by the sufficient quality of the CP-SST_{ERSST5} dataset and its significant relationship with the Kikai-SST_{coral} record in both periods.

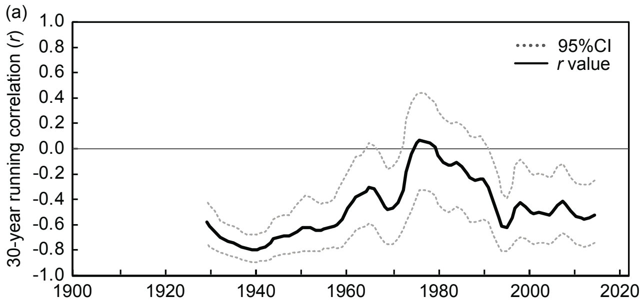

Figure R2-7. 30 year running correlation between CP-SST_{ERSST5} and coral-based NPGO/VM variability. The solid line represents the 30-year running correlation coefficient (*r*), and the dashed lines indicate the 95 % confidence interval (CI). An 8-year low-pass filter was applied to both time series of CP-SST_{ERSST5} and coral-based NPGO/VM variability prior to calculating the correlation. Notes: The results are preliminarily shown in this reply document for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript.

15. Additional comparison with the Palmyra record might be preferable to the Clarion $\delta^{18}O$ record, given the Palmyra record's stronger documented relationship with the NPGO (as shown in Figure 6).

S15. Thank you for your helpful suggestion. In addition to the Clarion $\delta^{18}O$ record (Sanchez et al., 2016), we will include a comparison with the Palmyra-SST_{coral} record (Nurhati et al., 2011).

16. Line 455 – The claim that this record is based on "an oceanic temperature proxy" may require qualification, given that comparisons were made to surface temperatures (HadCRUT5), which blend land and ocean measurements.

S16. We appreciate your suggestion to use the ERSST5 (sea surface temperature) dataset in our study (*Specific Comment 4*). This revision further supports our argument that the coral skeleton serves as a reliable oceanic temperature proxy.

Minor/Technical Corrections (Typographical errors):

1. Fig. A1 – Adding year labels next to annual growth bands (at 5- or 10-year intervals) would help readers connect Sr/Ca data with positions on the coral slab.
2. Table 1 caption – "Fig. A2" should be corrected to "Fig. A4."
3. Line 253 – Table A4 could not be located in the manuscript.
4. Lines 318-321 – The sentence structure could be improved by emphasizing the significance of findings before citing figure numbers, rather than using primarily descriptive phrasing.
5. Line 464 – The citation should read "Yeh et al., 2011."

6. Fig. A4 – Clarification of what "recomputed datasets" represent would be helpful. The magenta and light blue lines are difficult to distinguish on the plot; using dashed lines might improve visibility.
7. Fig. A5 – Including slope values directly on the plot or providing equations from the cited papers would facilitate reference.

M/T1. Thank you for your specific comments and corrections. We will revise and improve the corresponding text, figures and tables.

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