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Editor of *Cliame of the Past*

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Kiel, 13.03.2026

Submission of revised manuscript titled 'The Northwest Pacific corals unravel the NPGO0 and Victoria Mode-related temperature back to the 19th century' by Ito et al. (egusphere-2025-4054)

Dear Editor,

We thank you and the two anonymous reviewers for the constructive comments and suggestions, which have helped us significantly improve and strengthen our manuscript. The major revisions are summarised below:

1. We have provided additional analyses and clearer explanations regarding the appropriateness of the filtering approaches applied to each dataset, following the recommendations of both reviewers.
2. We have included analyses using the winter coral data, as well as the Victoria Mode Dipole Index (Wen et al., 2024), to extend the discussion, as suggested by both reviewers.
3. We have replaced the HadCRUT5 dataset with the ERSST dataset for all comparison analyses, following Reviewer #2's suggestion.
4. We have revised the definition of seasons (three-month averaging), which helps address potential age-model uncertainties at the seasonal scale, also following Reviewer #2's suggestion.
5. We have added additional supporting materials—figures, tables, descriptive text, and statistical tests—to further demonstrate the robustness of our results and interpretations.
6. We have also corrected minor typographical and grammatical errors identified during the revision process. These corrections do not affect the main objectives or conclusions of the study.

We sincerely appreciate the time and effort devoted by you and the reviewers to evaluating our manuscript, and we look forward to the opportunity to contribute to Climate of the Past.

Sincerely yours,
Dr. Saori Ito (on behalf of authors)

Point-by-point response to the comments

Reviewer's comments: in black
Authors' responses: in red

RC1: 'Comment on egusphere-2025-4054', Anonymous Referee #1, 28 Oct 2025

Summary

Ito et al. present a highly novel coral record of Sr/Ca that monitors North Pacific Gyre Oscillation/Victoria Mode temperature variability from 1798 to 2014. The authors identify an important scientific question: the NPGO/VM has a tight and intensifying connection with the central Pacific in future simulations with strong greenhouse gas forcing, but how has this relationship changed over the common era? This record provides insight during an important gap in instrumental and coral observations and will be of interest to the paleoceanographic and coral communities. This record documents a variable relationship with instrumental observations from the central equatorial Pacific at 8-30 year timescales (sometimes the correlation between these two regions reverses sign, sometimes is significant, sometimes not). The manuscript is well structured and does a great job of acknowledging other paleo-derived reconstructions of NPGO variability, but could benefit from streamlining the central message of this analysis.

We sincerely appreciate your time for reviewing our manuscript and your insightful comments. We have revised our manuscript in accordance with your suggestions. In preparing the revised manuscript, we carefully checked the text, figures, and tables for inconsistencies and corrected them. Consequently, section numbers, figure numbers, table numbers, and their order may differ from the previous manuscript (the numbers cited in this point-by-point response document correspond to the revised manuscript).

Major Comments

1. The introduction attempts to differentiate between reconstructions of NPGO and Victoria Mode variability (~line 65-70) and states that this coral record will be the first record of Victoria Mode variability. However, the rest of the analysis compares the Kikai Island record and instrumental SSTs to the NPGO index by DiLorenzo et al. 2008. If the authors want to make the case that their record is the first of Victoria Mode variability (not NPGO), they should compare their record to the Victoria Mode. At the least, they could describe how the timeseries of the NPGO and VM indices differ. Ding et al. 2014 show that the NPGO and VM are different at decadal timescales (which would certainly apply when using the 8-30 year bandpass filter), writing "The NPGO exhibits a significant (at the 90% level) spectral peak around 10 years

that is absent from the VM; instead, the VM tends to have higher power at interannual time scales, with a peak at periods of 3-4 years (but not significant at the 90% level). “

Major1. Thank you for the insightful comments. In addition to the North Pacific Gyre Oscillation (NPGO), we have placed an emphasis on the Victoria Mode (VM). Specifically, in the revised manuscript, we now (1) describe the characteristics of the NPGO and VM separately (*Sections 1* and *3.1*), and then (2) directly compare our coral record with both the NPGO and VM using the NPGO Index (Di Lorenzo et al., 2008) and the Victoria Mode Dipole Index (VMDI; Wen et al., 2024), respectively (*Section 3.4*; *Figure 5*; *Table 3*).

Although their definitions differ (the NPGO represents the second-leading mode of sea surface height anomalies (SSHa), whereas the VM represents the second-leading mode of sea surface temperature anomalies (SSTa)), it is well established that the two modes are synchronised. For example, Di Lorenzo et al. (2008) demonstrated the alignment between the NPGO and VM (see their Figure 4c). We have also confirmed a similarity in their variability (*Figure A1*) and in the patterns observed in a temperature field (*Figure 1*). This coherence arises because both modes are fundamentally driven by NPO-related atmospheric forcing.

As noted in your comment, Ding et al. (2015) examined the spectral characteristics of these modes. They found a significant spectral peak around 10 years for the NPGO at the 90% significance level, whereas they did not identify a dominant frequency of the VM at the 90% level. 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) employed 11-year low-pass filtering and confirmed a robust correspondence between the conventional empirical orthogonal function-based VM index (Bond et al., 2003) and their newly proposed VMDI.

To verify the efficiency of our filtering approach, we have additionally conducted spectral analysis (*Figure A9*). For the NPGO (the NPGO Index), it exhibits significant frequencies at 9.8, 6.8-6.9, and 3.6 years at the 95% confidence level (CL), with and without 30-year high-pass filtering (*Figures A9-a* and *A9-c*). For the VM (the VMDI dataset) without filtering, time frequencies at 51.2, 10.6, 3.9, 3.7, 2.5, and 2.4 years are detected only at the 90% CL (*Figures A9-b*). With 30 year high-pass filtering, significant frequencies at 12.4 and 10.6 years are detected at the 95% CL (*Figures A9-d*). This result suggests that the 30-year high-pass filter effectively removes long-term trends/frequencies, such as global warming or external forcing. Based on the previous studies (Di Lorenzo et al., 2010; Ding et al., 2015; Nurhati et al., 2011; Wen et al., 2024) and our additional spectral results, we employ an 8-30 year bandpass filter for the NPGO analysis, and a 10-30 year bandpass filter for the VM analysis. These filters are appropriate for capturing the characteristics of both VM and NPGO. In the revised manuscript, we have inserted a new section, *Section 3.1,* describing the results of spectral analysis.

2. The authors should clarify some of the assumptions that they make in their interpretation of the Kikai Sr/Ca index over the instrumental era.

Firstly, the authors focus on 8-30 year bandpass filtered summer Sr/Ca measurements to derive their Kikai-ST_coral record. This relationship has the highest agreement with annual instrumental data in the late 20th century, but I am concerned that this filtering may prevent capturing meaningful signals about the Victoria mode. For example, winter time SST variability is often noisier than summer SST variability at higher latitudes– the VM even shows high variance in late winter and early spring SSTs (Ding et al. 2014). Eliminating winter observations and bandpass filtering for 8-30 years may be smoothing out potentially important signals.

Major2-1. Thank you for the comments. Regarding the significance of time frequencies and the selection of pass filters, please refer to our response, Major1. As well as the indices (NPGO Index and VMDI; *Figure A9*), we have confirmed the validity of the filtering approach used for our coral record in this study (*Figure A11*). In the revised manuscript, we have included a detailed explanation of the significant time frequencies identified in our analysis and clarified how these results support our choice of pass filters (*Sections 2.6*, *3.1*, and *3.3*).

With respect to the winter coral Sr/Ca record, we have provided additional results using the winter dataset to broaden the interpretation of the Kikai-coral Sr/Ca record. The raw and 8-30 year bandpass filtered datasets are now shown in *Figure 2*. Also, *Figures 3*, *4*, and *5*; *Tables 2* and *3* now include the winter dataset. It is noted that we have used the ERSST5 sea surface temperature (SST, Huang et al. 2017) instead of the HadCRUT5 surface temperature (ST, Morice et al., 2021) following Reviewer #2's suggestion (see their *Specific Comment 4* and our response *S4-1*). By this revision, we have replaced 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 (Table A1). This revision has also been applied in this response document.

We obtained markedly different relationships between Summer Kikai-SST_{coral} and Winter Kikai-SST_{coral} when compared with instrumental temperature datasets (*Figure 3* and *Table 2*) (all datasets have been computed as 3-month averages following Reviewer #2's suggestion; see their *Specific Comment 5* and our response *S5*). As discussed in *Section 4.1.3*, Kikai-coral Sr/Ca_{winter} may be affected by growth biases at the seasonal scale (i.e., season-dependent growth-related bias, referred to as "seasonal growth bias"). This bias likely influences the winter temperature record derived from winter Sr/Ca values (i.e., Winter Kikai-SST_{coral}). Consequently, the Kikai-coral Sr/Ca_{summer} dataset is minimally affected by seasonal growth bias and more accurately reflects long-term SST variability. We therefore conclude that the Kikai-coral Sr/Casummer dataset is the most appropriate for reconstructing NPGO–VM-related temperature variability

in this study. Furthermore, we have tested comparisons using winter-to-spring averages; however, these did not yield significant relationships between Kikai-SST_{coral} and either instrumental temperature records or climate indices. For these reasons, we focus on the comparison between summer or winter coral records and annual means of instrumental temperature records and indices in this study.

Secondly, the authors demonstrate that their 8-30 year bandpass filtered summer Sr/Ca Kikai-ST record has stronger coherence with 8-30 year bandpass filtered SST (all months) observations from the central equatorial Pacific than the Kikai region (Figure 3). Why might this record not represent local conditions as well? Additionally, in Figure A8, the authors compare the Kikai summer Sr/Ca record with Palmyra Sr/Ca record and find a much weaker relationship. This is surprising given that Nurhati et al. 2011 published a strong agreement between Palmyra Sr/Ca and the NPGO index. Why might the relationship between Kikai-ST_coral have a stronger correlation with uncertain instrumental SST observations than another coral Sr/Ca record?

Major2-2. Thank you for the comments. As a preliminary note, the temperature product used in our study has been changed, and the correlation coefficients (*r* values) between our coral record and instrumental datasets have been updated accordingly. This revision follows Reviewer #2's suggestions (see their *Specific Comments 4* and *5*, and our responses *S4-1* and *S5*).

The comparison results are now summarised in *Table 2* (for time series, please see *Figures 3* and *A12*). For the period 1950-2014 CE (*Table 2a*), our coral record showed significant correlations at the 95% CL with local SST (Kikai-SST_{ERSST5}) and SST variability in the Central Pacific (CP-SST_{ERSST5}), except for the comparison between Winter Kikai-SST_{coral} and CP-SST_{ERSST5}. These results indicate that our coral record robustly reflects local temperature variability connected to the Central Pacific region. For the longer period 1900-2014 CE (*Table 2b*), only Summer Kikai-SST_{coral} shows a significant correlation with CP-SST_{ERSST5} at the 95% CL. These results imply the possibilities of (1) insufficient quality of instrumental SST record for the grid covering Kikai Island (i.e., Kikai-SST_{ERSST5}) prior to 1949 CE (*Section 4.1.1*, *Lines 406-408*) and (2) seasonal growth bias on winter coral data (i.e., Winter Kikai-SST coral, see also our response Major 2-1) (*Section 4.1.3*). In appropriate statistical practice, correlation strength should not be evaluated solely by r values when population variances differ across datasets. Importantly, Summer Kikai-SST_{coral} shows a significant correlation with Palmyra-SST_{coral} (Nurhati et al., 2011) at the 95% CL (*Table 2c*). Given that Palmyra-SST_{coral} exhibits high coherence with the NPGO, this significant relationship supports our interpretation that our coral record has the potential to reconstruct NPGO–VM variability.

Thirdly, the authors describe that the NPGO annual index lags the Kikai-ST_coral record by 1 year. Ceballos et al. 2009 describe that the NPGO can lead KOE variability by 2-3 years, but what processes might cause SSTs in the Northwestern Pacific to lead NPGO variability by a year? COuld this unusual lead-lag relationship be partially caused by the authors focus on summer Sr/Ca values?

Major2-3. Thank you for the comments. Following Reviewer #2's suggestion (see their *Specific Comment 5* and our response *S5*), we have revised the seasonal definition for our analyses, using 3-month averages for each summer and winter value. Based on our results shown in the revised manuscript (*Figures 5a* and *5b*; *Table 3a*), Summer and Winter Kikai-SST_{coral} show significant correlations with the NPGO Index without any lag. According to Di Lorenzo et al. (2013) and Ceballos et al. (2009), the Kuroshio-Oyashio Extension (KOE) variability is likely a consequent output in the NPGO mode-centred "Pacific climate dynamics and teleconnections" (Di Lorenzo et al., 2013, their Figure 1). In our study, we do not discuss the consequent output associated with the NPGO mode to maintain our study focus throughout the manuscript, which is the NPGO-related temperature variations propagated from the Central Pacific to the Northwest Pacific via the "ocean–atmosphere bridge" (*Section 4.1.1*).

3. I was also curious about the authors interpretation of the Kikai Sr/Ca index prior to the instrumental era (e.g. Figure 6). From 1798-1920, the reconstructed NPGO index is virtually always in a negative phase. Would the analysis be better served by detrending their coral record? Physically, it does not seem realistic for the NPGO/VM to be in a centuries long negative phase.

Major3. Thank you for the comments. In our manuscript, the coral-based NPGO–VM variability is presented as an 8-year low-passed record, following previous NPGO studies (e.g., Di Lorenzo et al., 2010; Ding et al., 2015; Nurhati et al., 2011) and our spectral analysis (*Figure A9*). While the number of NPGO studies focusing on the period that the NPGO Index does not cover (prior to 1949 CE) remains limited, there is still room to discuss multi-decadal features of the NPGO mode. Because our study provides the first reconstruction of NPGO–VM variability using Northwest Pacific coral and because detrending may suppress potential long-term NPGO signals, we chose not to apply detrending.

The revised figure for the coral-based NPGO–VM variability is now available in *Figure 6*, and we have revised the description accordingly (*Section 4.2*). From 1798 to 1920 CE, the reconstructed NPGO–VM variability alternates between negative and positive phases. The negative phases exhibit a greater magnitude than the positive phases. In particular, a pronounced negative-NPGO/positive-VM phase is observed from the 1860s to the early 1900s. We focus on this period, and discuss it in detail in *Section 4.2.1*, *Lines 491-508*. This strong negative-NPGO/positive-VM phase aligns well with previously reported low-temperature conditions recorded in coral archives from Kikai Island (Kawakubo et al., 2017) and

southern Taiwan (Ramos et al., 2020); therefore, this feature may represent a regional characteristic specific to the Northwest Pacific.

4. In the abstract and introduction, the authors mention set up the reader to think about how the relationship between the central equatorial Pacific and NPGO/VM changed over the 19th and 20th centuries as context for the projected changes over the 21st centuries. The authors don't focus on this as much as implied earlier on– the authors show a plot of 8-30year bandpass filtered CP SST observations with their 8-30year Sr/Ca record over the instrumental era. Given the uncertainties in SSTs in the early 20th century, wouldn't it make more sense to use the Nurhati et al. 2011 record? The authors could also loop in the Sanchez et al. 2016 Clarion record into this analysis. Is Figure 7 (the running correlation plot) substantially different if using all months from the Kikai Sr/Ca record? In addition, the authors are uniquely well suited to comment on how Kikai Sr/Ca variability changes during other periods of substantial volcanic or aerosol forcing for additional impact, if they want. The response of the climate system to the Mystery and Tambora eruptions is of interest to many in the paleoclimate and paleoceanographic communities.

Major4. Thank you for your helpful suggestions. We have revised the manuscript to ensure that the objectives and focus are clearly maintained throughout (including *Abstract* and *Section 1*). We had already shown comparisons of our coral record with the instrumental temperature record in the Central Pacific (1900-2014 CE; *Figure 3*, revised) and with Nurhati et al. (2011) (1887-1997 CE; *Figure A12a*, revised). In the revised manuscript, we have included comparison results with Sanchez et al. (2016) (1820-1997 CE; *Figure A12b*). The results are summarised in *Table 2c*. The corresponding discussions are available in *Section 4.4*, *Lines 593-608* for comparisons with Nurhati et al. (2011) and *Lines 609-627* for comparisons with Sanchez et al. (2016), respectively.

The quality of the temperature product depends on the grid and period (Chan and Huybers, 2021). The quality of Kikai-SST_{ERSST5} prior to 1949 CE may have been insufficient, as evidenced by the poor correlation with our coral record (*Table 2b*). 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 and 1950-2014 (*Tables 2a and 2b*). Therefore, we do not find any insufficiency in the quality of the CP-SST_{ERSST5} dataset. To avoid any misunderstanding, we have revised the sentence to clearly state that the quality of the Kikai-SST_{ERSST5} dataset prior to 1949 CE may be insufficient (*Section 4.1.1, Lines 400-405*). As *Figure 7* compares the CP-SSTERSST5 dataset (of sufficient quality) with our coral record, there is no concern about the quality of the datasets. Nonetheless, following your suggestion, we have included additional results using data from Nurhati et al. (2011) and Sanchez et al. (2016) in *Figure 7*. The interpretation of these results is available in *Sections 4.3* (*Lines 554-566*) and *4.4* (*Lines 593-608 and 609-627*). These extended analyses cover a longer period (1820-2014 CE) compared to the previous period (1900-2014 CE).

In response to your question regarding *Figure 7*, we provide supplementary results for annual mean values calculated from all monthly data (Figure ACR1-1). Although the individual correlation coefficients (*r* values) differ slightly from those in *Figure 7*, the main conclusions are still supported: (1) a significant historical correlation persists from the early 20th century until 2014 CE, except for the period from the 1970s to the 1980s (*Lines 545-546*); and (2) the degree of correlation observed between the 1920s and 1940s is nearly equivalent to that of recent decades (*Lines 561-565*).

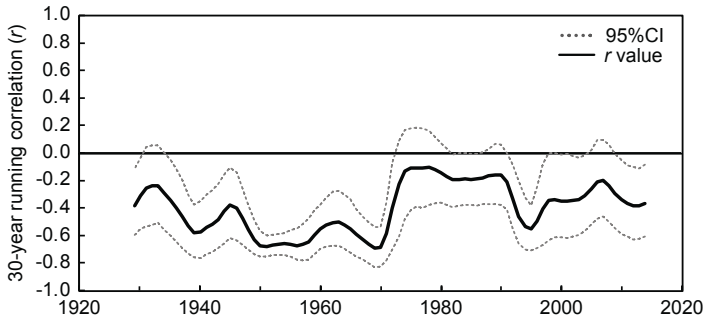

Figure ACR1-1. 30-year running correlation between CP-SST$_{ERSST5}$ and coral-based NPGO–VM variability (calculated using annual mean values).
The solid line represents the 30-year running correlation coefficient (*r*), and the dashed lines indicate the 95% confidence interval (CI). An 8-year low-pass filter was applied to both time series of CP-SST$_{ERSST5}$ and coral-based NPGO–VM variability (calculated using Kikai-Sr/Ca$_{annual\ mean}$) prior to calculating the correlation. Notes: The results are shown only in this point-by-point response document.

We also appreciate your suggestion regarding volcanic forcing as a potential impact, and we have included this possibility in the revised manuscript (*Section 4.2.1, Lines 486-491*). According to previous studies (e.g., Brönnimann et al., 2019), major volcanic eruptions occurred between the 1800s and 1830s (late phase of the Little Ice Age), including the 1808/1809 CE "Mystery" eruption, the 1815 CE Tambora eruption, the 1822 CE Galunggung eruption, the 1831 CE Zavaritskii caldera eruption (Hutchison et al., 2024), and the 1835 CE Cosigüina eruption. These eruptions caused sustained cooling for several years following each event. Both our coral Sr/Ca record (*Figure 2*) and our coral-based NPGO–VM variability (*Figure 6*) show a modest cooling phase between the late 1820s and the early 1830s, coinciding with this period of frequent eruptions. While we cannot entirely rule out volcanic forcing as a contributor to this cooling, its overall influence appears to be limited. Furthermore, we observe a transition from a warm phase to a pronounced cooling phase in the 1860s, which occurred well after the late phase of the Little Ice Age and after the major eruptions that significantly affected the climate. Therefore, the substantial cooling observed at our study site during the mid-19th century is unlikely to be attributable to volcanic forcing during the early-mid 19th century.

Minor Comments

- I suggest replacing instances of “ST” with “SST” for sea surface temperature. This abbreviation is more conventionally used and will decrease reader confusion

Minor1. We appreciate your comments; however, we respectfully decline this suggestion. In the previous manuscript, we used “ST” and “SST” as abbreviations for “surface temperature (i.e., land-surface air temperature and sea surface temperature)” and “sea surface temperature,” respectively.

It should be noted that, following Reviewer #2’s suggestion (see their *Specific Comment 4*), we use the ERSST5 (SST) dataset instead of the HadCRUT5 (ST) dataset. We have ensured consistent use of all abbreviations in the revised manuscript.

- Figure 1 has a handful of typos:

– Figure 1 B,C,E, the word “annual” is misspelled

Minor2. We have corrected the typos. Thank you for pointing them out.

— How does 1B differ from 1C? The heading is exactly the same?

Minor3. The difference between *Figure 4a* and *4c* (previously Figures 1b and 1c) is the time periods of the datasets used. The figure headings are not identical: *Figure 4a* is labelled “... 1950-2014 CE,” whereas Figure 4b is labelled “... 1900-2014 CE.” These differences are noted in both the figure captions and the figure headings.

–The authors should indicate that they limit the analysis to the year 2014 to heighten similarity with their Sr/Ca record or use the latest available data through 2025. The authors should consider using the most recent decades– it would double the available years for their SSH analysis.

Minor4. We appreciate and accept your suggestion to use datasets through 2014 CE to facilitate comparison with their Sr/Ca record. Following this suggestion, we have tested a comparison using the latest available data for the SSH analysis (through 2021 CE). We confirmed that the NPGO pattern is consistent in both periods, 1993-2014 CE and 1993-2021 CE.

- The authors analysis would be clearer if they also provided raw correlation coefficients between coral Sr/Ca and local SST. Instead their focus is on only using summer months, then using an 8-30 year bandpass filter. It would be nice if there was a supplementary table or something to see how this seasonal focus influences the interpretation of this record. Would the relationship with local SST also be improved if examining seasonal correlations?

Minor5. Thank you for the comments. In the revised manuscript, we have provided additional results using the winter dataset to broaden the interpretation of the Kikai-coral Sr/Ca record (please see also our response Major2-1). We conducted season comparisons as a basic data analysis; however, we did not obtain consistent, statistically significant results. This may be due to the seasonal growth biases in the coral Sr/Ca record (*Section 4.1.3*) and/or the insufficient quality of the instrumental temperature records (for the grid covering Kikai Island, *Section 4.1.2, Lines 406-408*). On the other hand, we found a significant relationship between our coral record (both summer and winter data) and the annual mean instrumental temperature dataset (*Figure 3*; *Table 2*). We also have included correlation coefficients between our coral Sr/Ca record and the SST product for the grid covering our study site without filtering, before presenting the comparison using 8-30-year band-pass filtered datasets (*Section 3.2.2*).

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Point-by-point response to the comments

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Authors' responses: in red

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 were very helpful in improving our study. We have revised our manuscript in accordance with your suggestions, including additional analyses. In preparing the revised manuscript, we carefully checked the text, figures, and tables for inconsistencies and corrected them. Consequently, section numbers, figure numbers, table numbers, and their order may differ from the previous manuscript (the numbers cited in this point-by-point response document correspond to the revised manuscript).

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 have revised the Introduction section to clarify the characteristics and definitions of NPGO and VM (*Section 1*, *Lines 43-57*). Also, we have reorganised the content of the 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 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 in the revised manuscript. For comparisons, please 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 - would be clearer when combining an oceanic temperature proxy (coral skeletal Sr/Ca) with an SST dataset (ERSST5).

Here, it should be noted: We have replaced 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 (*Table A1*). This revision has also been applied in this point-by-point 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 and the other as SST. Therefore, discussing them individually and separately in a clearer manner would be beneficial.

G3. We appreciate your helpful suggestion. We have reconsidered the use of the terms "NPGO," "VM," and "NPGO/VM," and improved readability throughout the manuscript. In the Introduction section (*Section*

1), we introduce NPGO and VM individually, with definitions, dominant seasons, and time scales (*Lines 43-57*), and then focus on the close relationship between the two modes.

Although their definitions differ, it is well-known that both modes are well synchronised (e.g., Di Lorenzo et al., 2008). We have demonstrated this synchronicity for the period 1950–2014 (*Figure A1*). Our results showed a strong correlation between the annual mean NPGO and the annual mean VM datasets for the period 1950-2014 at the 99% confidence level (CL) (non-filtered: r = –0.70, n = 65; 8-30 year bandpass filtered: r = –0.84, N_{eff} = 6.10). It means both modes have coherent temporal variability, particularly on interannual-to-decadal timescales. *Figure 1* (revised) also confirms their similar patterns in the SST field. This coherence arises because both modes are fundamentally driven by NPO-related atmospheric forcing. In this sense, the NPGO and VM can be regarded as dynamically linked components of a broader extratropical ocean–atmosphere system, referred to as "NPGO–VM variability."

In the revised manuscript, we treat NPGO and VM modes individually 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; the use of the Victoria Mode Dipole Index (VMDI) for comparisons follows your suggestion in *Specific Comment 10*). As a result, our coral record (Summer Kikai-SST_{coral}) showed robust relationships with both NPGO and VM variability (see *Section 3.4*), which indicates that Summer Kikai-SST_{coral} captures signals of the oceanic expression of the dynamically linked mode between NPGO and VM and its long-term variability (i.e., "NPGO–VM variability") (Noted that we have replaced the term "NPGO/VM variability" with "NPGO–VM variability" in order to express more correctly the dynamically linked mode between NPGO and VM.). Based on the overall similarity between the NPGO Index and VMDI time series and the robust relationship between the Summer Kikai-SST_{coral} record and the dynamically linked mode, we employ a standardisation approach to reconstruct past NPGO–VM variability using our coral record (see *Equation 1* in *Section 2.7*). This approach can yield results that are easier for readers to understand and more consistent than those from the regression approach.

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 have corrected and carefully reorganised 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:

G5. We appreciate your specific suggestions. We have reorganised the Methods, Results, and Discussion sections. This revision includes subdivisions of the Discussion section (*Section 4.1*) to improve readability. The revisions following your specific text or sections are as follows:

- Lines 225-240 appear more suitable for the Discussion section

This content has been relocated to the Discussion section (*Section 4.1.2*).

- Lines 259-263 could be placed earlier when describing the study site in the Methods section

This content has been deleted in accordance with the revision related to your suggestion in *Specific Comment 10* (the use of the ERSST dataset instead of the HadCRUT5 dataset). However, basic information about the sample site has been included in the Methods section (*Section 2.1*).

- 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

The additional interpretations for the correlation between the Kikai-SST_{coral} and Palmyra-SST_{coral} records are now available in the Discussion section (*Section 4.4*, *Lines 614-627*).

- 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.

This content has been relocated to the new section in the Methods (*Section 2.7*) to detail the approach.

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 have reconsidered the structure and improved the discussion section to clearly highlight the significant findings of our study. The revised discussion section (*Section 4*) is now subdivided as follows:

4.1 Potential ability of corals derived from Kikai Island to reconstruct NPGO–VM variabilities

4.1.1 Ocean–atmosphere bridge over the Central and Northwest Pacific

4.1.2 Potential factors underlying differences in response to the NPGO–VM-related temperature variations recorded in coral geochemical records from Kikai Island

4.1.3 Growth effects on seasonal differences in the coral Sr/Ca record

4.2 Coral-based NPGO–VM variability reconstruction back to the 19th century

4.2.1 NPGO–VM variability in the 19th and 20th centuries

4.2.2 NPGO–VM variability in the 21st century

4.3 Contribution of NPGO–VM in the North Pacific or NWP

4.4 Advantages of proxy-based reconstruction of NPGO–VM variability

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 have added more detailed descriptions of the study sites. *Figure A2* includes maps of Kikai Island and close-up maps showing locations of the coral cores from our study and previous studies. The close-up maps indicate the differences in environmental conditions (reef habitat distribution and geomorphic distribution). We describe the characteristics of each sample site environment, and mention it as one of the potential factors underlying differences in coral Sr/Ca records from Kikai Island (*Section 4.1.2*, *Lines 427-437*). Unfortunately, we are unable to include submersion histories for this area because the relevant datasets are unavailable. Instead, we have included coastal lines prior to and posterior to 2000 CE on the close-up maps.

In addition to local environmental conditions, coral Sr/Ca methodological factors may account for variations in coral Sr/Ca from Kikai Island. We had already included this discussion in the manuscript (*Section 4.1.2*, *Lines 438-454*, partly revised) (see also our response *S12*).

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 sampling paths with considerable care and avoided areas of off-axis growth (i.e., corallites oriented at 90° to the surface were avoided; DeLong et al., 2013). We have added a clearer statement (*Section 2.2*, *Lines 113-114*) and improved the X-ray images of all cores (*Figure A3*) to show that the sampling paths follow the extending corallites and their growth direction (with higher image resolution, higher colour transparency of the sampling paths, and enlarged image).

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 have included the raw Sr/Ca data for all overlapping paths as supplementary information (*Figure A6*). In addition to the summary of Sr/Ca records for each core (*Table 1*), we have included 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 Levene's 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) (*Section 3.2.1*, *Lines 253-255*). 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 use 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 ACR2-1). Consequently, we have replaced HadCRUT5 with ERSST5 for all analyses in the manuscript. We further confirm that this revision does not alter our primary objectives; moreover, it strengthens the structure of the manuscript, particularly the discussion and conclusions. Again, we sincerely appreciate your excellent suggestions.

In summary, we use the OISST v2.1 dataset (1981-2014 CE) to establish the coral age model, and employ the ERSST5 dataset for long-term time-series analyses (1900-2014 CE). We have included *Figure A7* showing the statistically significant correlation between OISST v2.1 and ERSST5 at the 99% CL (r = 0.99, n = 406). In the revised manuscript, we have clarified the appropriate roles of OISST v2.1 and ERSST5 (*Section 2.4*).

Table ACR2-1. 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 shown in this reply document only for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript (orange shaded, *Tables 2a* and *2b*).

(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	7.94
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	8.94
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.*	15.26
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	90%CL	18.74
Winter Kikai-SST_{coral} versus CP-SST_{ERSST5}	1900-2014	-0.28	*n.s.*	10.96

- 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 use 3-month averaged values for seasonal analyses (i.e., summer and winter) in the revised manuscript. These 3-month averages are calculated from a monthly-interpolated dataset. We have added this information in the Methods section (*Section 2.5, Lines 174-178*). We also reorganized reference list and double-checked.

- 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 accepted your suggestion regarding the definition of seasons. We first interpolated the dataset to a monthly resolution, and then defined summer and winter seasons by averaging three months based on SST climatologies. Specifically, summer (winter) was defined by averaging the Sr/Ca values for the month with the lowest (highest) Sr/Ca value and the preceding and following months. We have included this approach in the Methods section (*Section 2.3, Lines 144-152; Section 2.5, Lines 174-178*). By employing this definition, we consequently obtained 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 are referred to as “Summer Kikai-coral Sr/Ca” and “Winter Kikai-coral Sr/Ca” (*Table A1*); moreover, for the temperature-converted datasets, they are referred to as “Summer Kikai-SST_{coral}” and “Winter Kikai-SST_{coral}” (*Table A1*). 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 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 (*Table 2*).

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 ACR2-2). The annual mean values of the Kikai-SST_{ERSST5} dataset show strong correlations at the 99% CL with summer (r = 0.72, n = 65) and winter (r = 0.79, n = 65) values for the period 1950-2014 CE. Even for the longer period 1900-2014 CE, significant correlations are confirmed at the 99% confidence level (r = 0.77 for summer values and r = 0.75 for winter values, n = 115 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.

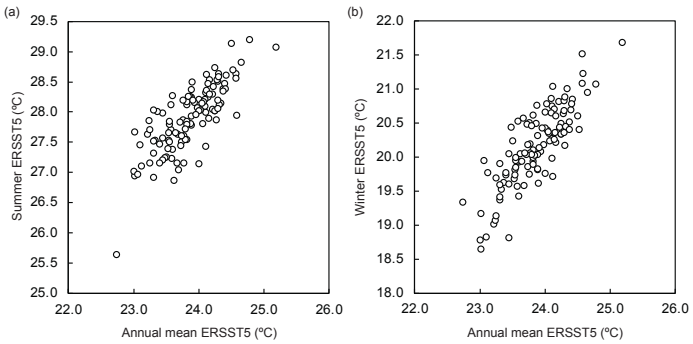

Figure ACR2-2. Scatter plots for summer/winter ERSST5 and annual mean ERSST5 for the grid covering Kikai Island.

(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 the seasonal growth bias in the coral Sr/Ca record, as noted in the 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 A15* and described in the Discussion section (*Section 4.1.3* partly revised), the winter season of our coral record contains fewer data points than the summer season. It suggests that 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 (Table ACR2-2). Summer Kikai-SST_{coral} correlates significantly with the summer NPGO Index at the 99% CL (r = 0.67, N_{eff} = 7.23, 8-30 year bandpass filtered), whereas Winter Kikai-SST_{coral} does not correlate significantly with the winter NPGO Index (r = 0.41, N_{eff} = 5.87, *n.s.*, 8-30 year bandpass filtered; Table ACR2-2a). For comparisons with the annual mean NPGO Index, slightly different results are obtained. The Summer Kikai-SST_{coral} record shows a significant correlation with the annual mean NPGO Index for the same period at the 99% CL (8-30 year bandpass filtered; Table R2-2b; also shown in *Figures 5a and 5e*). 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 (8-30 year bandpass filtered; Table ACR2-2b; also shown in *Figures 5b* and *5f*). 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. The consistent results were obtained when comparing the Kikai-SST_{coral} record and VMDI (10-30 year bandpass filtered; Tables ACR2-2c and ACR2-2d; also shown in *Figures 5c*, *5d*, *5g*, and *5h*). This may be due to seasonal growth bias in the coral Sr/Ca record (see our response *S6*). This bias would be an issue when reconstructing long-term NPGO and VM variabilities 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 have included this limitation (*Section 4.1.3*) and emphasised the need for further study (*Section 5*, *Lines 646-654*).

Table ACR2-2. Correlation between Kikai-SST_{coral} and NPGO Index or VMDI
The dataset of Kikai-SST_{coral} was converted from Kikai-coral Sr/Ca (i.e., temperature proxy record). For comparisons between Kikai-SST_{coral} and NPGO Index, an 8-30 year bandpass filter was applied to all time series prior to calculating correlations. For comparisons between Kikai-SST_{coral} and VMDI, a 10-30 year bandpass filter was applied to all time series prior to calculating correlations. The filtering approach was based on the results of spectral analysis, shown in *Figure A9* (see also our response *S8*). 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 shown in this reply document only for discussion in *Climate of the Past*, and conclusive results can be found in a revised manuscript (orange shaded; *Table 3*).

(a) Comparison of seasonal Kikai-SST$_{coral}$ record and seasonal NPGO Index (1950-2014 CE)

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-SST$_{coral}$ versus summer NPGO Index	1950-2014	0.67	99%CL	7.23
Winter Kikai-SST$_{coral}$ versus winter NPGO Index	1950-2014	0.41	*n.s.*	5.87

(b) Comparison of seasonal Kikai-SST$_{coral}$ and annual mean NPGO Index (1950-2014 CE)

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-SST$_{coral}$ versus annual mean NPGO Index	1950-2014	0.67	99%CL	7.27
Winter Kikai-SST$_{coral}$ versus annual mean NPGO Index	1950-2014	0.45	90%CL	5.80

(c) Comparison of seasonal Kikai-SST$_{coral}$ record and seasonal VMDI (1950-2014 CE)

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-SST$_{coral}$ versus summer VMDI	1950-2014	–0.69	99%CL	8.53
Winter Kikai-SST$_{coral}$ versus winter VMDI	1950-2014	–0.60	*n.s.*	6.92

(d) Comparison of seasonal Kikai-SST$_{coral}$ and annual mean VMDI (1950-2014 CE)

Pair of correlation analysis	Period	*r*	significance	$N_{eff.}$
Summer Kikai-SST$_{coral}$ versus annual mean VMDI	1950-2014	–0.74	99%CL	7.90
Winter Kikai-SST$_{coral}$ versus annual mean VMDI	1950-2014	–0.45	90%CL	7.40

In addition, here, we present an additional comparison of the NPGO Index between summer or winter values and the annual mean values (Figure ACR2-2). 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. The annual mean VMDI shows strong correlations at the 99% CL with summer (r = 0.71, n = 65) and winter (r = 0.85, n = 65) values for the period 1950-2014 CE. These results suggest that both the annual mean NPGO Index and the annual mean VMDI capture both summer and winter signals and support the use of annual mean values for comparisons with our coral summer/winter records.

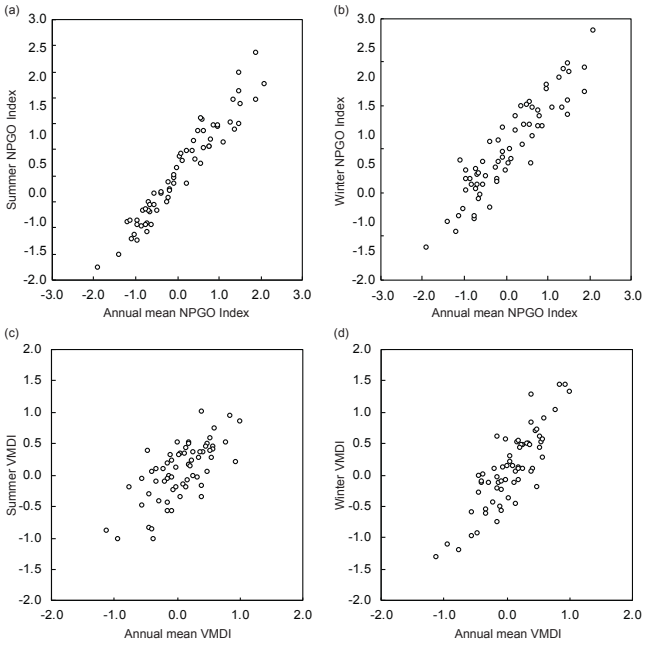

Figure ACR2-2. Scatter plots for summer/winter values and annual mean values of the NPGO Index and VMDI.

(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. (c) Summer values versus annual mean values of the VMDI (Wen et al., 2024, calculated using the ERSST5 dataset) for the period 1950-2014 CE. (d) Same as (c), but for winter values versus annual mean values of the VMDI. 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 have conducted spectral analysis. The results are shown in *Figure A9*. We have added a new section to describe the results in detail (*Section 3.1*).

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 A9a* and *A9c*). For the VMDI without filtering, distinct frequencies are detected at 51.2, 10.6, 3.7-3.9, and 2.4-2.5 years only at the 90 % CL (*Figure A9b*). In contrast, with 30-year high-pass filtering, significant frequencies at 12.4 and 10.6 years are detected at the 95% CL (*Figure A9d*). This result suggests that the 30-year high-pass filter effectively removes long-term trends or low-frequency components, such as global warming or variability associated with external forcing.

In previous NPGO studies, an 8-year low-pass filter has been commonly applied for time series analysis (e.g., 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) applied an 11-year low-pass filter and confirmed a robust correspondence between the conventional empirical orthogonal function-based VM index (Bond et al., 2003) and their newly proposed VMDI. Based on those previous studies and our additional spectral results (*Figure A9*), we employ an 8-30 year bandpass filter for the NPGO analysis, and a 10-30 year bandpass filter for the VM analysis. These filters are appropriate for capturing the characteristics of both NPGO and VM.

Furthermore, we have conducted spectral analysis of our Kikai-SST_{coral} datasets (*Figure A11*). 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 within the range of our filters (8-30 year bandpass filter and 10-30 year bandpass filter) (*Figure A11c*). 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 A11d*). These results support our filtering approach for detecting the characteristics of both NPGO and VM in our coral records.

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 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). To ensure that the objectives and focus are clearly maintained throughout the manuscript (following the Reviewer #1's suggestion), we focus on these NPGO-mode-centred Pacific modes, especially CP-ENSO, and compare 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 (*Section 4.1.1*).

In addition, we have additionally included a comparison between our coral record and the NPO variability (Trenberth and Hurrell, 1994) for the period 1950-2014 CE. The results are presented in *Figure A14*. Cross-wavelet coherence analysis indicates that our coral records, especially Summer Kikai-SST_{coral} and the NPO 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 *Section 4.1.1*.

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 have further improved our argument in the revised manuscript (*Section 4.1.1*).

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. In the revised manuscript, we use the Victoria Mode Dipole Index (VMDI, Wen et al., 2024) to investigate the relationship between our coral record and the Victoria Mode. As with the NPGO Index comparisons, we first conducted season comparisons as a basic analysis. The 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} (see our response *S7* and Figure ACR2-2). Based on this basic analysis, we use the annual mean values of VMDI, rather than summer or winter values, for subsequent analyses in the manuscript. Although it is well established that the VM and NPGO modes are well synchronised (e.g., Di Lorenzo et al., 2008) (see also our response *G1*; *Figures 1* and *A1*), a direct comparison with our coral record and VMDI is valuable. As stated in the Introduction section (*Section 1*, *Line 77-81*), there have been long-term coral records that complement or

extend instrumental data from the tropics, which have been used to reconstruct the NPGO mode in the past (Nurhati et al., 2011; Rafter et al., 2017; Sanchez et al., 2016); however, none have focused on VM variability and NPGO- or VM-related temperature variations propagated extra-tropically from the Central Pacific. Therefore, our study shows the first comparison between the coral Sr/Ca-based temperature record and VM, and the first reconstruction of the oceanic expression of the dynamically linked mode between NPGO and VM (i.e., NPGO–VM-related temperature variability).

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 have revised the definition of seasons by using a 3-month average for summer and winter values. As a result, Summer Kikai-SST_{coral} showed a significant relationship with the NPGO Index without any lag (*Figure 5* and *Table 3*). Therefore, your concern regarding the previously noted "1-year lag" has been resolved. We again appreciate your helpful suggestion regarding the definition of seasons, which has improved this study.

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 previous manuscript, we had already presented season comparisons between coral records from this study and Kawakubo et al. (2017) (*Figure A10*). In the revised manuscript, we have compiled detailed information about other records from Kikai Island and provided explanations of potential factors influencing Sr/Ca variability (*Section 4.1.2*).

As described in *Lines 438-444*, 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 A10*, 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 seasonal growth bias in the coral Sr/Ca dataset, especially on winter values (*Figure A15*) 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. We have added descriptions of the study sites (*Section 4.1.2*, *Lines 427-434*) based on the close-up maps showing the differences in environmental conditions among the coral collection sites (*Figure A2*; see also our response *S1*).

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 have included the annual growth rate for each coral core (Core-1 to Core-3) as supplementary information available in the figure caption of *Figure A6*. 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, seasonal growth bias in the coral Sr/Ca record (i.e., less accuracy of Sr/Ca as SST proxy) has 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 A15*).

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 use the ERSST5 dataset instead of the HadCRUT5 dataset in the revised manuscript. The results for comparisons between our coral record (Kikai-SST) and the ERSST5 dataset are summarised in *Table 2*. The quality of the temperature product depends on the grid and period (Chan and Huybers, 2021). The quality of Kikai-SST_{ERSST5} prior to 1949 CE may have been insufficient, as evidenced by the poor

correlation with our coral record (*Table 2b*). To avoid any misunderstanding, we have revised the sentence to clearly state that the quality of the Kikai-SST_{ERSST5} dataset prior to 1949 CE may be insufficient (*Section 4.1.1, Lines 403-408*). 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 and 1950-2014 (*Tables 2a and 2b*). Therefore, we do not find any insufficiency in the quality of the CP-SST_{ERSST5} dataset. Additionally, we have confirmed that *Figure 7a* (revised) 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 7a*, 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.

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 have included a comparison with the Palmyra-SST_{coral} record (Nurhati et al., 2011). The results are shown in *Figure 7*, and the related discussion is available in *Sections 4.3* (*Lines 557-565*) and *4.4* (*Lines 593-608, 609-627*).

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):

M/T1. Thank you for your specific comments and corrections. We have revised and improved the corresponding text, figures and tables. The revisions following your specific text, figures and tables are as follows:

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.

We have added year labels next to annual growth bands at 5-year intervals (*Figure A3*).

2. Table 1 caption – "Fig. A2" should be corrected to "Fig. A4."

We have corrected it and double-checked.

3. Line 253 – Table A4 could not be located in the manuscript.

We have located it and double-checked. We apologise for the missing table.

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.

We have rewritten the sentence (*Line 342-344*).

5. Line 464 – The citation should read "Yeh et al., 2011."

We have corrected it and double-checked (*Line 640*).

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.

We have rewritten the sentence (the figure caption of *Figure A6*). We mean “interpolated datasets.” Also, the lines in the panels (b) and (c) of *Figure A6* have been changed to be more easily distinguished, following your suggestions (coloured-dashed line).

7. Fig. A5 – Including slope values directly on the plot or providing equations from the cited papers would facilitate reference.

We have included slope values on the plot (*Figure A8*).

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