

General Comments to the Editor and Reviewers

Thank you for taking the time to evaluate our work. In the course of preparing our revised manuscript, we discovered a reporting error in the ODP Site 882 GC-CI-MS dataset archived on Pangaea (<https://doi.org/10.1594/PANGAEA.315092>). Specifically, U^{K}_{37} values in that dataset are incorrectly labelled as U^{K}_{37} . We were luckily able to access the original data table from Haug (1995), which we then used to quantify and offer a correction for the underlying methodological uncertainties with the GC-CI-MS dataset. This original data table also enabled us to somewhat refine the proposed correction as we were able to ascertain different populations of samples with different relationships between GC-FID and GC-CI-MS U^{K}_{37} values.

Please find the details of our line-by-line changes below.

Warm regards and on behalf of the coauthors,

Joseph Novak

Reviewer #1 Comments

Novak and colleagues present research that corrects for biases in previously published alkenone sea surface temperature records at ODP882. These biases stem from differences between analytical techniques for quantifying alkenone concentrations (GC-FID vs GC-CI-MS). The GC-CI-MS method enables analysis of alkenone-poor sediments that were inaccessible with GC-FID. The authors demonstrate that the original GC-CI-MS ODP882 measurements overstated climate variability, though the overall patterns and trends remain unchanged.

While the manuscript is well-written and the research methodology is sound, the manuscript's critical weakness is the absence of a meaningful discussion section. The authors successfully identify and correct the proxy bias, and highlight that the ODP882 record is very important, but fail to explore what this corrected record reveals about our understanding of Pliocene climate and Northern Hemisphere glaciation—which should be a key contribution from this methodological innovation.

[Initial response]

Dear Reviewer #1, thank you for taking the time to review our work. We are appreciative of your time and constructive comments, which will result in an improved revised manuscript. We completely understand the criticism that our work did not include a discussion of the implications of the overstated variability in sea surface temperatures at ODP Site 882 in the original GC-CI-MS record. We will include a

comparison of the original vs. corrected ODP 882 sea surface temperature dataset to mid-Pliocene model output. We expect that the most important change to the ODP 882 data will be the substantially increased uncertainty in the sea surface temperature estimates than was previously recognized, which we will highlight in a new figure.

[Action taken]

This is now discussed in the new sections **3.4** and **3.5** and new Figures 7–9 (Lines 275–363).

MAJOR ISSUE: MISSING DISCUSSION OF IMPLICATIONS

The research convincingly quantifies and corrects the ODP882 bias, but stops short of addressing why this matters for the current understanding of Pliocene temperatures and Northern Hemisphere glaciation. The authors need to address fundamental questions about their findings' significance:

How does this correction alter our understanding of Pliocene temperatures and the timing/intensity of Northern Hemisphere glaciation?

What are the implications for North Pacific temperature evolution during this critical climate transition?

How might this refined record affect estimates of Earth System Sensitivity (ESS), particularly given that ODP882 is frequently cited in multi-proxy compilations?

These questions are only meant to be illustrative and motivate deeper discussion as the current manuscript provides little context for understanding the broader implications of their correction. The paleoclimate community needs to understand not just that the record was biased, but what new insights emerge from the corrected data.

[Initial response]

Thank you for prompting the requested additional discussion with specific questions. Given that revisiting estimates of Earth System Sensitivity would be a major undertaking requiring a separate manuscript (and development of a new skillset by the authors, which does not seem realistic on the timeframe of manuscript resubmission), we will focus the new discussion of the implications of the corrected dataset for our understanding of regional sea surface temperature patterns in the late Pliocene:

1). How does the proposed correction to the ODP Site 882 manuscript impact estimates of the latitudinal temperature gradient in the North Pacific during the late Pliocene?

The mid-Piacenzian Warm Period will be a particular area of focus in this new section due to the widespread community focus on the mid-Piacenzian interval for data-model comparison. The new section will include a figure comparing the latitudinal temperature gradient as estimated from paleo sea surface temperature data with the original vs. corrected ODP 882 data to PlioMIP2 model output.

[Action taken]

We now show the modeled vs. observed change in the latitudinal temperature gradient in the west vs. east Pacific, along with zonal west vs. east Pacific temperature gradient, in a new figure (Figure 9). Please note that we favored the discussion of the zonal gradient and surface ocean density in the new text since the proposed correction was more impactful here (Lines 275–363).

2). We will compare the Western vs. Eastern subpolar North Pacific sea surface temperature estimates to understand whether the correction to the ODP Site 882 record changes our understanding of longitudinal gradient in SSTs in the late Pliocene. This analysis has relevance for observations made using Data Assimilation methods by Tierney et al. (2025) in *AGU Advances*, although we would like to emphasize that the comparison we will undertake is with the proxy data only as we lack expertise in Data Assimilation.

[Action taken]

This is now discussed in the new sections **3.4** and **3.5** and new Figures 7–9 (Lines 275–363).

Warm regards and on behalf of the coauthors,

Joseph Novak

SECTION 2.1

This section could use some more text, particularly since the methods of this manuscript are intertwined with the key message: that the ODP882 record is biased and this is how you quantified and corrected for that bias. In particular, a clearer explanation of how synthetic UK37 were generated is needed for the broad paleoclimate readership of *Climate of the Past*.

[Initial response]

We will add further text to explain how synthetic U_{37}^K values were generated to produce the black lines in Figure 3. We would like to emphasize that these synthetic values are for illustrative purposes only and are meant to give the reader an intuitive sense of how analysis by GC-CI-MS would result in different temperature estimates as compared to GC-FID, as this is a rather technical distinction that is not easily visualized from word on the page alone. The synthetic U_{37}^K values are not in any way used in the corrected ODP 882 record – the corrected values arise from a simple linear regression between GC-FID and GC-CI-MS U_{37}^K values in proximal samples from ODP 882.

[Action taken]

Changes were made to the text in Lines 126–129:

Here, a_{2M} , a_{3M} , b_{2M} , b_{3M} , c_{2M} , and c_{3M} are curve fitted constants reported by Chaler et al. (2003). These constants are instrument-specific (Chaler et al., 2003). We utilized the constants from GC-CI-MS “Instrument A” of Chaler et al. (2003) to calculate theoretical GC-FID-equivalent U_{37}^K values from theoretical GC-CI-MS alkenone measurements to facilitate comparison between the GC-FID and GC-CI-MS alkenone SST datasets from ODP Sites 882 and 883 (Table 1). **These theoretical GC-FID-equivalent U_{37}^K values were calculated over the range of U_{37}^K values in the alkenone SST records from ODP Sites 882 and 883 to understand the expected sign and magnitude of any potential analytical bias in the GC-CI-MS method (Novak et al., 2024; Studer et al., 2012; Yamamoto and Kobayashi, 2016).**

FIGURE 4

A direct comparison between the original and corrected SST records at ODP882 is conspicuously absent. Figure 4 would be the logical place to show this comparison, allowing readers to visualize both the magnitude of the correction and its impact on key climate transitions.

[Initial response]

We will add a direct comparison to this figure. Thank you for pointing this out – it completely slipped our minds that this is an important aspect of the data to display.

[Action taken]

The direct comparison is now shown in Figures 2 and 5.

MINOR COMMENT

Without demonstrating the impact of the corrected record, the manuscript somewhat overstates its importance. For instance, the abstract begins by discussing Earth climate sensitivity but many studies of Earth System Sensitivity rely on multiple records, so the authors should either: (a) demonstrate how this correction specifically affects multi-proxy compilations, or (b) focus on what unique insights about regional climate dynamics this corrected record provides.

[Initial response]

Thank you for pointing this out, as it is not our intention to present this work as particularly “high impact.” In fact, we attempt to temper the reader’s impression of the impact of this work by stating in the abstract that our findings do not invalidate the conclusions regarding Earth’s climate history originally drawn from the GC-CI-MS data from ODP 882. Rather, we think that the information presented here is necessary to put out for the paleoclimate science community as we strive to improve the data that we use to assess the skill of climate models at simulating sea surface temperatures under boundary conditions different from historical period.

As noted in our previous response, we will add a new section and figures to the manuscript that assesses the extent to which the corrected record improves our understanding of regional climate dynamics.

[Action taken]

This is now discussed in the new sections **3.4** and **3.5** and new Figures 7–9 (Lines 275–363).

RECOMMENDATION

This manuscript makes a valuable methodological contribution by identifying and correcting an important bias in a widely used proxy from an important site. However, it currently reads more as a technical note than a full research article. To maximize its impact, the authors must add a robust discussion section that explores what this corrected record teaches us about Pliocene climate that we didn't know before. I enjoyed reading this manuscript and hope the authors find my comments useful.

[Initial response]

Thank you for taking the time to evaluate our work.

Reviewer #2 Comments

Novak et al. present a method to correct systematic biases in UK'₃₇-based SST reconstructions from ODP Site 882. The original published SST estimates (Haug, 1995; Haug et al., 2005; Martínez-García et al., 2010) were derived from alkenone measurements using GC-CI-MS, a method known to introduce non-linear, concentration-dependent biases. The original SST record shows systematic offsets relative to subsequent GC-FID-based records from overlapping samples at ODP Sites 882 and 883. The authors propose a linear correction approach based on the relationship between GC-CI-MS (Haug, 1995) and GC-FID (Studer et al., 2012) SST estimates where data overlap at ODP Site 882.

[Initial response]

Dear Dr. Rattanasriampaipong,

Thank you for taking the time to evaluate our work. We are appreciative of your constructive comments and criticisms, which will result in an improved revised version of the manuscript. In particular, we will add a new section to the revised manuscript that explores the implications of our proposed correction to the ODP 882 alkenone sea surface temperature dataset for our understanding of regional sea surface temperature patterns in the Pliocene. Please find our responses to your specific comments below. Given the similarity of your comments to the criticisms raised by Reviewer #1, you may find our responses to those comments of interest as well.

Warm regards and on behalf of the coauthors,

Joseph Novak

Major comments:

- **Insufficient discussion of the implications and broader significance of the correction:** I echo the other reviewers' concern that the manuscript lacks adequate discussion of why this SST correction matters and how it changes our understanding of North Pacific climate evolution. The following additions would significantly strengthen the manuscript:

[Initial response]

We agree and will take steps to add data-model comparison and a reassessment of regional sea surface temperature gradients in the revised manuscript.

[Action taken]

This is now discussed in the new sections **3.4** and **3.5** and new Figures 7–9 (Lines 275–363).

- **Data-model comparison:** The authors mention that the original SST record is unsuitable for evaluating Earth System Models but provide no actual model-data comparison. Including this comparison (either with existing model outputs or literature values) would demonstrate the practical impact of the correction and justify the effort.

[Initial response]

We have requested access to PlioMIP2 model output for this purpose and will include this comparison in the updated manuscript. This section will focus on how the correction (and resulting increase in the quantified uncertainty) to the ODP 882 alkenone record might change late Pliocene data-model comparison assessments of the latitudinal temperature gradient in the North Pacific basin.

[Action taken]

This is now discussed in the new sections **3.4** and **3.5** and new Figures 7–9 (Lines 275–363).

- **SST gradients and ocean circulation dynamics:** The corrected SST record will substantially alter the temporal evolution of meridional temperature gradients in the northwestern Pacific. Given ODP Site 882's position within the Kuroshio Extension region, the authors should discuss implications for our understanding of western boundary current dynamics and their role in North Pacific climate variability over the past 6 Ma.

[Initial response]

We will include a new section that reassesses the longitudinal gradient in proxy sea surface temperature estimates in the subpolar North Pacific. We will also discuss the implications of the correction for the community's understanding of the sea surface temperature variability of the Kuroshio Extension region over the past 5.7 Ma. This new discussion will focus on the reduction of the magnitude of reconstructed sea surface temperature changes that result from the proposed correction.

[Action taken]

This is now discussed in the new sections **3.4** and **3.5** and new Figures 7–9 (Lines 275–363). Please note that we focused our attention on the mid-Piacenzian Warm Period

and 2.7 Ma interval since we are able to independently constrain our proposed correction during these intervals.

- **Prevalence of GC-CI-MS measurements:** The authors state that GC-CI-MS is used when alkenone concentrations are very low but cite only a handful of studies employing this method. A more systematic assessment of how commonly GC-CI-MS has been applied in the published literature would help readers evaluate the broader applicability of this correction approach. If this method has been widely used (particularly in low-productivity regions or deep-time studies), the implications extend well beyond ODP Site 882.

[Initial response]

We conducted a literature review and will include in the introduction citations to published studies that used the GC-CI-MS technique without explicitly stating that the analytical setup accounted for the concentration-dependent ionization efficiency issues that we suspect are the reason for the issues with the ODP 882 record that we report here. These studies primarily aimed to understand paleo sea surface temperature trends through time (Durham et al., 2001; Madureira et al., 1997; Martínez-García et al., 2010; McClymont et al., 2008; McClymont & Rosell-Melé, 2005; Roberts et al., 2017; Sánchez-Montes et al., 2020; Weaver et al., 1999), but also includes a study of particulate organic matter in the modern ocean water column (Bendle & Rosell-Melé, 2004).

[Action taken]

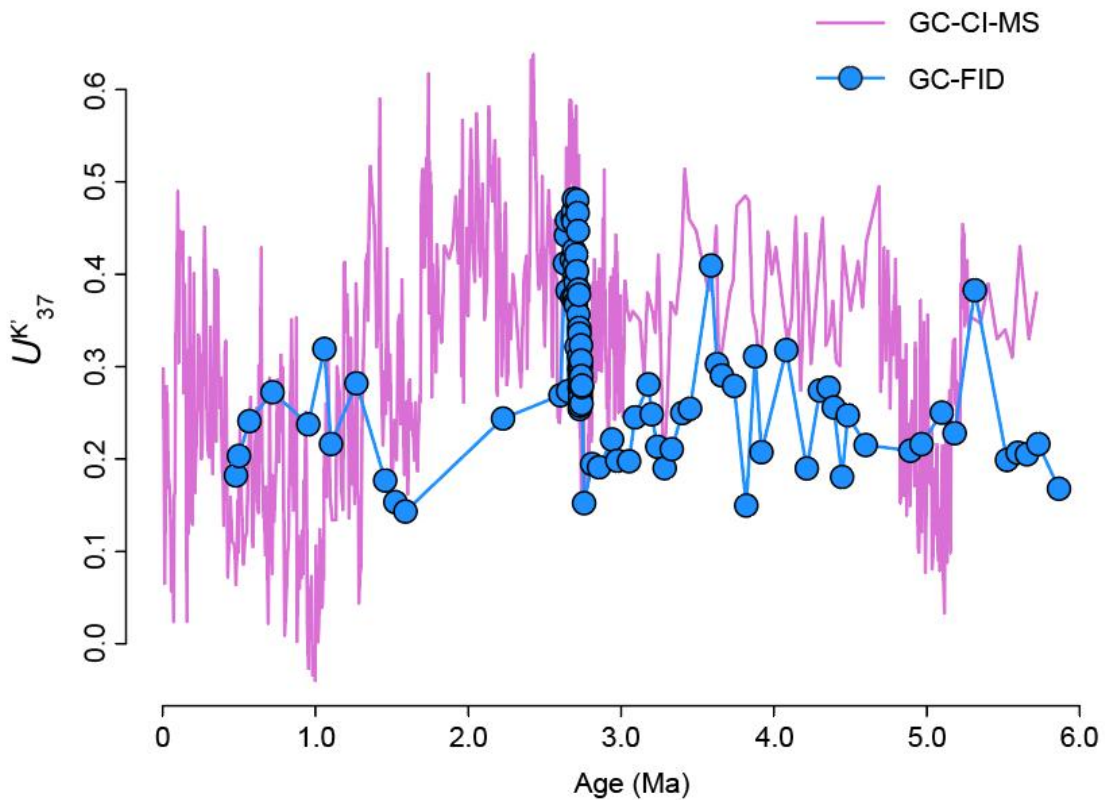
These studies are now cited in Lines 50–54.

- **Uncertainties in extrapolating the correction beyond the calibration interval:** The linear correction is derived from a relatively brief temporal interval where the Haug (1995) and Studer et al. (2012) datasets overlap. Applying this correction to the entire 6 Ma record likely introduces additional uncertainties that must be properly quantified and propagated. Specifically:
 - The magnitude of the GC-CI-MS bias may vary systematically with alkenone concentration, sample matrix effects, or instrumental drift over time.
 - The bias may differ between glacial and interglacial periods due to changes in alkenone preservation, sediment composition, or productivity regimes.

- The authors should provide uncertainty estimates for the corrected record and discuss how confidence in the correction degrades outside the calibration interval.

[Initial response]

In the course of preparing our response to the reviewer comments, we came across an additional GC-FID alkenone dataset from ODP 882 (Yamamoto & Kobayashi, 2016) that expands the temporal range of the data available to attempt a correction of the Haug (1995) GC-CI-MS alkenone dataset through the entire 5.7 million year interval spanned by that record (see figure below). These new data allow us to identify more confidently: (1) the systematic differences between the GC-FID and GC-CI-MS data from Site 882 and (2) the substantial uncertainty inherent to correcting the GC-CI-MS dataset. The revised manuscript will feature an expanded discussion of these uncertainties.



U^K_{37} data from ODP Site 882 generated by GC-CI-MS (purple) and GC-FID (blue).

We will also more thoroughly explore the differences between the original and proposed correction to the ODP 882 record by systematically comparing the

original vs. corrected glacial vs. interglacial SST values in the Pliocene and Pleistocene through a new figure presenting box-and-whisker plots for this purpose. Lastly, we will add published Early Pliocene data from ODP Sites 883/884 (Herbert et al., 2016) to expand the timescale of the independent validation of the corrected ODP 882 record shown in Figure 4 of the original manuscript submission.

[Action taken]

The Yamamoto and Kobayashi (2016) dataset is now incorporated into the correction (Figure 2, Section 3.1). The effect of the correction is now clearly shown in Figure 2 and Figure 5. We elected to not include the box and whisker plots since the high $\delta^{13}C$ content (which we did not appreciate at the time of writing out initial response) makes us unsure of the significance of the Pleistocene SST values and instead chose to focus our attention on the late Pliocene portion of the data (see Figure 9, for example).

General comments:

- Ensure consistency in citing Haug (1995) versus Haug et al. (1995) throughout the manuscript. For example, Figure 3a shows "Haug et al. (1995)..." which appears incorrect if the reference is to a single-author 1995 publication.

Thank you for pointing this out. Yes, the proper citation here is to Haug (1995). We will correct this issue.

[Action taken]

Fixed.

Figure comments:

Figure 1 – Consider adding modern SST contours or climatology to emphasize that these sites are located in the subarctic North Pacific, where accurate SST reconstructions are critical for quantifying meridional temperature gradients and evaluating climate model performance in this sensitive region.

We will add modern SST contours to the figure.

[Action taken]

Done.

Figure 2 – Please extend the x-axis to cover the entire range of the data

We will extend the x-axis.

[Action taken]

Done.

Figure 4 – Include a comparison showing the original versus corrected SST estimates for the entire ODP 882 record, not just a subset. This would clearly demonstrate the magnitude of the correction during different climate states (e.g., glacial-interglacial extremes) and help readers assess whether the bias is constant or varies systematically with SST.

We will add the requested comparison of the original vs corrected SST estimates from ODP 882 to Figure 4.

[Action taken]

Done. This is now Figure 5.

Line-by-line comments:

L17-18: Should "Haug 1995" be cited here along with "Studer et al., 2012"?

Yes – we will cite the Haug (1995) paper here also, thank you for catching that.

[Action taken]

Done.

L18: Either remove "long" or change it to "long-chain." "Long alkenone SST" sounds odd.

Here long is intended to describe the temporal length of the record. We will replace long with the age range covered by the record to be more exact.

[Action taken]

Done.

L65: Please provide lat/lon and water depth coordinates of ODP sites 882 and 883.

We will do this in the revised manuscript.

[Action taken]

Done. These are now in the abstract.