

Answer reviewer comments for manuscript

[egusphere-2026-3415]

Comments from the reviewers are marked as “**rev {reviewer no./comment no.}**” in italicized font. The answers of the authors follow immediately after the reviewer comments and are **given in blue**. General statements made by the reviewers are not reproduced here. Line numbers (L) mentioned in our replies correspond to the original single-column (unrevised) version of the manuscript.

Reviewer 2

This manuscript presents new high-resolution alkenone-based SST and carbonate stable-isotope records across the Oligocene-Miocene transition from ODP Site 1168 in the Tasman region and IODP Site U1406 in the North Atlantic. The dataset is valuable and fills an important gap in orbitally resolved surface-ocean records across the Mi-1 interval. I consider the manuscript suitable for eventual publication. However, several interpretations are currently unclear by the chronology and proxy uncertainties. In particular, I have concerns about the non-independence introduced by the Site 1168 age model, uncertainty in reconstructed surface-water delta O18, and the attribution of benthic delta O18 changes to deep/intermediate-water cooling. I therefore recommend a major revision.

Major comments:

rev 2/Maj1 *The Site 1168 age model is refined by tuning maxima in delta O18 bulk to maxima in Site 1264 delta O18 benthic, based on the assumption that the two records contain a common in-phase component (line 147-157). This creates some circularity when the subsequent similarity in timing between these records is used to support synchronous surface, deep-ocean, and cryosphere changes. The large changes in inferred sedimentation rate across Mi-1 should also be discussed in this context.*

The tuning is used only for fine adjustment of the age model between ^{87}Sr tiepoints. We propose to clarify this distinction in the text. Where the Site 1264 benthic record is compared to the 1168 new records in the discussion, we propose to clarify that it is coincident within uncertainty of the ^{87}Sr tiepoints, removing circularity.

e.g. section 5.1

“This new record confirms the onset of surface ocean cooling in the Southern Hemisphere mid-latitudes by 23.8 Ma and its subsequent intensification starting around 23.3 Ma; this is coincident **within the uncertainty in ^{87}Sr age tiepoints** with the positive $\delta^{18}\text{O}_{\text{benthic}}$ shift interpreted as the two-step AIS expansion (Liebrand et al., 2017).”

Likewise at the end of section 3.3.2 we would add:

“ For comparison with other benthic records (Beddow et al., 2016) we generate a 10% LOWESS smooth of the benthic dataset; the scale of this smoothing is comparable to the uncertainty on the ^{87}Sr age **tiepoints**.”

Commented [HS1]: Give clearer reference on the timescale of the smoothing

However, we agree that there is an undesirable circularity in the calculation of the difference between $\delta^{18}\text{O}_{\text{benthic}}$ at 1264 and Site 1168 $\delta^{18}\text{O}_{\text{sw}}$ since the latter was tuned. This calculation was described at the end of methods section 3.4, in original lines 296-299 and Fig 8 in results, and lines 435-441 in discussion). Because the interpretation of this parameter also is subject to considerable complexity and therefore adds little to the main message of the paper, we will remove the presentation of and discussion of the difference between $\delta^{18}\text{O}_{\text{benthic}}$ at 1264 and Site 1168 $\delta^{18}\text{O}_{\text{sw}}$. We will only present the result from 1406 where benthics and $\delta^{18}\text{O}_{\text{sw}}$ are estimated in the same sediments with no age model uncertainty.

Regarding sedimentation rates, we propose to add for context at the end of section 4.1: “Threefold changes in sedimentation rate over this time interval have also been inferred at other margin sites such as U1406 (van Peer et al 2024). “

rev 2/Maj2 *The manuscript interprets negative anomalies in $\delta^{18}\text{O}_{\text{sw}}$ - $\delta^{18}\text{O}_{\text{benthic}}$ during Mi-1 and Mi-1.1 as evidence for significant deep-ocean cooling. This interpretation is plausible, but not unique. The difference also depends on local surface-water salinity and hydrography, deep-water $\delta^{18}\text{O}$, water-mass changes, age-model uncertainty, and the SST reconstruction itself. Indeed, Section 5.3 emphasizes substantial regional hydrographic influences from the Leeuwin Current and Gulf Stream. I suggest reframing deep-ocean cooling as one possible explanation rather than a uniquely diagnosed mechanism, unless independent deep-water temperature evidence can be provided.;* **rev 2/Maj 3** *The description in Section 3.4 appears internally inconsistent. For Site U1406, the text describes subtracting benthic $\delta^{18}\text{O}$ from surface $\delta^{18}\text{O}_{\text{sw}}$, whereas for Site 1168 it states that surface $\delta^{18}\text{O}_{\text{sw}}$ is subtracted from Site 1264 benthic $\delta^{18}\text{O}$. Later discussion and Figure 8 consistently refer to $\delta^{18}\text{O}_{\text{sw}}$ - $\delta^{18}\text{O}_{\text{benthic}}$.*

As described in response to Rev2/Maj 1, we remove to the comparison of 1168 with 1264 benthic $\delta^{18}\text{O}$, to avoid circularity due to the age model tuning of Site 1168.

Furthermore, we acknowledge that there are many potential interpretations of the difference between the $\delta^{18}\text{O}_{\text{sw}}$ records and the regional benthic records, and that at the moment there are few independent additional constraints which help to narrow down the range of interpretations. Consequently, we propose to transfer the plots of these differences for Site 1406 (Figure 8) and relevant interpretation on them to the Supplementary (new Figure S4), where the reader interested in reviewing some of the details can access them, but where they will not distract from the main and more straightforward discussion of the SST records. In the new figure caption multiple possible interpretations are commented. The correct description of the calculation for 1406 is given in the axis and the revised Figure caption.

The proposed transfer to supplement and brief interpretation:

Supplementary Figure S4. Relative local surface water freshening calculated as $\delta^{18}\text{O}_{\text{sw}} - \delta^{18}\text{O}_{\text{benthic}}$ for Site U1406 and with the heaviest values anchored to 0‰. B) $\delta^{18}\text{O}_{\text{benthic}}$ for Site U1406 (Van Peer et al., 2024) with a ~50-kyr moving average. C) Eccentricity (Laskar et al., 2004). The $\delta^{18}\text{O}_{\text{sw}} - \delta^{18}\text{O}_{\text{benthic}}$ is lower between 23.0 to 23.2 Ma and at 22.5 Ma. If the $\delta^{18}\text{O}_{\text{benthic}}$ were responding only to ice volume with a comparable magnitude $\delta^{18}\text{O}_{\text{sw}}$ change in the surface and deep oceans, the $\delta^{18}\text{O}_{\text{sw}} - \delta^{18}\text{O}_{\text{benthic}}$ would be constant. One explanation of the negative shift in the $\delta^{18}\text{O}_{\text{sw}} - \delta^{18}\text{O}_{\text{benthic}}$ would be deep ocean cooling at Site U1406 during the Mi-1 event, consistent with the interpretation of a component of temperature variation in Site U1406 $\delta^{18}\text{O}_{\text{benthic}}$ (Van Peer et al., 2024). Alternatively, this negative shift could result from local surface-water salinity and hydrography changes, such as changing influence of the Gulf Stream, uncertainty in the SST reconstruction, or changes in deep-water $\delta^{18}\text{O}$ unrelated to a common ice volume component.

rev 2/Maj 4 The manuscript converts the larger Site 1168 benthic $\delta^{18}\text{O}$ excursion into up to ~4°C greater intermediate-water cooling relative to deeper sites. This calculation implicitly attributes most of the excess $\delta^{18}\text{O}$ change to temperature. However, Site 1168 was located at intermediate depth in a region likely affected by changing Southern Ocean circulation and water masses. Changes in local water $\delta^{18}\text{O}$ or salinity could therefore also contribute to the larger benthic $\delta^{18}\text{O}$ excursion. The ~4°C estimate should be presented explicitly as an upper-bound end member assuming no local change in water $\delta^{18}\text{O}$.

We agree this is a good point to present the temperature component as an upper bound.

As suggested by Rev 1, we will also add some sentences to discuss the complexity..

rev 2/Maj 5 At Site 1168, the SST reconstruction combines and , using where is saturated or affected by co-elution, and averaging the two proxies where both are considered reliable. Because these proxies have different calibrations and behavior near their upper limits, it is important to demonstrate that the inferred two-step cooling is not sensitive to proxy switching.

We thank the reviewer for the prompt to clarify this point. Precisely to provide full transparency, we have shown both U1'37 and Uk38 ME records in Figure 3. To further clarify the relationship between these records and the proposed averaging of the indicators shown in Figure 5, **we propose to illustrate the curve derived only from Uk'38 ME additionally in Figure 5 to illustrate no effect of switching the indicator.**

We propose to add an additional sentence in the methods section 3.2:

“ Consequently, for subsequent temperature-dependent calculations for Site 1168, $U^{K'_{38me}}$ -derived SSTs were used where the $U^{K'_{37}}$ values were saturated or affected by co-eluting compounds, while the average of the $U^{K'_{38me}}$ and $U^{K'_{37}}$ temperature was used where both proxies yielded reliable results. **The main discussed trends are identical if only the $U^{K'_{38me}}$ curve would be used throughout the entire sampled interval.**”

The first sentence of the discussion transparently describes that the two step cooling is resolved in the Uk'38 ME, so no change is required in the presentation of results.

rev 2/Maj 6 The claim of “coherent” cooling across both hemispheres should also be moderated. Site U1406 does not resolve the first major cooling step seen at Site 1168, and the two sites show opposite SST trends between approximately 23.5 and 23.3 Ma. The records clearly indicate cooling at two widely separated midlatitude sites, but they do not demonstrate uniformly synchronous hemispheric-scale cooling.

We agree with the suggestion of moderation and propose to remove the word “coherent” from the last sentence of the abstract, stating that Mi-1 was associated with surface cooling across both hemispheres.

Minor comments

rev 2/min 1 Line 11: Please provide the time of Mi-1.

Excellent suggestion, we will add this.

rev 2/min 2 Lines 40-50: The motivation for high-resolution SST records is not clearly developed. The discussion of deep-ocean temperature and Antarctic ice-sheet albedo motivates surface-temperature constraints, but not high temporal resolution. I suggest linking the need for high-resolution SST more directly to orbital-scale variability in benthic $\delta^{18}\text{O}$ and the risk of aliasing in lower-resolution records.

We appreciate the suggestion and in response to this comment and Reviewer 1, we have adjusted the motivation. The final sentence of the paragraph will now read:

“ Yet, one challenge in such comparisons is that high-amplitude astronomical variations during the late Oligocene and early Miocene (evident in $\delta^{18}\text{O}_{\text{benthic}}$) increase the risk of aliasing in the available sea surface temperature trends, which are in many cases sampled at much lower resolution than astronomical variability. Adequately addressing this challenge requires higher temporal resolution records of surface ocean conditions.”

rev 2/min 3 Lines 284-288: The statement that a third cooling occurs between ~22 and 21 Ma appears inconsistent with the main interval presented in this manuscript. Please clarify the data supporting this statement.

We thank the reviewer for bringing this to our attention. We will remove the last comment since we decided to focus the paper on the 24 to 22 Ma interval common to both sites.

rev 2/min 4 “bulk carbonate”, “fine-fraction carbonate”, and “coccolith fraction” appear to be used somewhat interchangeably. Please use consistent terminology and clearly state what material was actually analyzed.

We will correct the reference in figure 4 caption (fine fraction carbonate) to bulk carbonate. Then in Methods section 3.3.1 clarify that bulk carbonate it is coccolith dominated (fine fraction).

rev 2/min 5 Figure 8: The caption refers to eccentricity as panel (e), although the figure appears to contain panels(a)-(d).

The figure caption will be revised, since it will be now a supplementary Figure S4

rev 2/min 6 Conclusions: The phrase “ 10^5 to 10^6 yr timescale resolved by our sampling density” seems inconsistent with sample spacing of approximately 10–60 kyr. Please revise.

We will clarify

“ At the timescale resolved by **our 10 to 60 ky sampling density**, bulk carbonate $\delta^{18}\text{O}$ at Site 1406 and Site 1168 exhibit similar timing and magnitude changes as deep ocean benthic $\delta^{18}\text{O}$ records from the North Atlantic (Site 1406) and South Atlantic (Site 1264) basins, respectively.”

rev 2/min 7 Please use “significant” only where statistical significance has been demonstrated.

The use of the term “significant” will be carefully evaluated in the revision.