Reviewer 2_Comments in black, Responses in Violet

DIVERGENT ESTIMATES OF MIOCENE TO PLEISTOCENE UPPER OCEAN TEMPERATURES IN THE SOUTH ATLANTIC OCEAN FROM ALKENONE AND COCCOLITH CLUMPED ISOTOPE PROXIES- EGUSPHERE

0. Abstract
    a. The abstract does a good job at outlining the purpose and results of the paper
1. Introduction
    a. You start by talking about how latitudinal temp gradients are important for atmospheric circulation, rainfall, etc. I'd also come back to this at the end, either in the conclusion or in section 4.2, just to bring it full circle. I have notes on this below
    b. Line 54: I'm guessing you submitted this while Clark et al. 2025 was in review, but I think it's out now, so the citation should be updated
       The citation has been updated in the revised text.
2. Settings, Sediments, and Analytical Methods
    a. Sample preparations and analysis
        i. I'm not super familiar with clumped isotope preparation, when you say 'oxidized for 5 hour or 8-14 hour' (line 101), I'm assuming there was a reason some samples required the longer reaction time. Was this simply a matter of looking at the sample at hour 5 and noting there were still organics present, thus they were oxidized longer?
            1. Ok, after reading further in section 3 and the supplemental, it sounds like two samples from each depth underwent oxidation to compare the 5 hr oxidation time to the longer 8-14 hr time. Can you clarify this in the methods? Also, I noticed that you didn't do this for each sample, only a few, is this due to sediment availability or was there another reason you chose to do the 5 hr vs overnight oxidation comparison for these specific samples vs the others?

We clarify this by adding the following to section 2.2 :

To reduce potential interferences by organic phases during measurement, sediments were oxidized with 10% H_2O_2 buffered solution with NH_3 to pH=8-9 and the oxidant removed. Where the abundance of material in the size fraction allowed, two oxidation times were compared, a 5-hour long oxidation and an 8–14-hour long oxidation, and where material was limiting the 5-hour long oxidation was performed.

3. Results
    a. Line 150: "the three samples with minor detrital carbonate… temps are 1-4 degrees warmer than Uk37." This is hard to tell from figure 3d, can you add a running average for the ODP 1090 Uk37 like you did for the ODP 1088 temps?

Or a table to directly show the clumped isotope temps vs uk37 temps?
We thank the reviewer for this suggestion. We add a LOESS smooth also for the Site 1090 Uk37 SST record (see figure at end of this document).

b. Unless I missed it in the text, I don't believe you discuss in depth the potential influence of detrital carbonate on your temperature calculations. Is there a connection between the detrital carbonate inclusion and warmer temperature calculations for those three samples from ODP 1090? Are they less likely to be accurate because of the presence of carbonates?

   We clarify this in section 3.1 adding the following:

   Wind transport of detrital minerals to this location via strong westerlies has been documented from Patagonia and southern South America as well as Southern Africa (Barkley et al., 2024). For the cold coccolith temperatures (5 °C), small amounts (<5%) of detrital carbonate would warm the measured clumped isotope temperatures by <1.5°C if the clumped isotope signature of detrital carbonates reflected temperatures of carbonate precipitation in earth surface environments at temperatures <35°C. However, if the source of the detrital carbonates has had clumped temperatures reset to much higher burial temperatures (>100°C) it could shift the measured temperatures warmer by several degrees in coccolith fractions containing >3% of such detrital carbonates. Since the origin and burial history of the detrital carbonates cannot be readily constrained for this setting, and they cannot be effectively isolated from the coccoliths for analysis of their clumped temperature, it is not possible to predict if they appreciably impact the measured temperatures in the samples containing them. As a conservative approach, we do not make further interpretations from these samples.

c. Line 209-213: I feel like there should be a citation or reference here – we add the reference to the temperature profiles, so the revised paragraph reads:

At Site 1088, like most regions of the ocean, upper ocean temperatures are warmer than those at the seafloor (Locarnini et al., 2013). If the measured coccolith carbonate represented a mixture of primary biogenic calcite produced in the euphotic zone and secondary diagenetic carbonate precipitated in the colder waters on the seafloor, this could cause coccolith Δ_{47} temperatures to be significantly colder than those in the euphotic zone. However, in the higher latitudes such as Site 1088, because of the relatively modest temperature gradient between the seafloor and the euphotic zone (Locarnini et al., 2013), extreme degrees of diagenetic overgrowth would be required to significantly shift the temperature signal of the measured carbonate.

d. Line 216: Not sure what the convention is in EGUsphere for referring to figures within citations, but I think this citation needs to be either ((Bolton and Stoll, 2013) Figs S6, S7) or (Bolton and Stoll, 2013; Figs S6, S7) we adjust accordingly

e. Implications for estimation of latitudinal temperature gradients
   i. That's a huge difference in the temperature gradient, something that would certainly have impacts on both atmospheric and oceanic circulations. Considering the role that a changing latitudinal temperature gradient is thought to pay in the intensification of Northern Hemisphere Glaciation and, eventually, the Mid-Pleistocene Transition, I think it would be interesting to include a comparison of

Uk37 and clumped isotope temperatures for the ~1Ma timeslice, however I know this is a new technique and the data might not be available yet. Maybe you could include a sentence or two in this section or the conclusions to say that it's not just the Miocene's latitudinal temp gradient that could be stronger, it could be other time periods as well. The implications of this are big for time periods in which a shifting latitudinal temp gradient are important (like the MPT). This might inspire further research.

We appreciate the suggestion from the reviewer. Indeed, there are very limited surface ocean temperature estimates available from clumped isotopes in planktic foraminifera or coccoliths at this time; in the last 1 myr the new data in this paper and in the cited Mejia et al. (preprint), so it is not possible yet to include a compilation. However, the suggestion to add a comment in the conclusions about testing latitudinal gradients at other times is one we would be happy to add. We add the bold phrase to this sentence in the end of section 4.2:

…a revision of proxy latitudinal gradients may necessitate reconsideration of the scope of feedbacks required to simulate polar amplification in past warmer climates, **including not only the Miocene but also the Plio-Pleistocene.**

ii. I'd also like to see more of a discussion of whether such a dramatic meridional temperature gradient would impact our current understanding of late Miocene climate, considering the new data suggests the gradient is almost double what the previous data suggested.

We add the following at the end of section 4.2:

Latitudinal sea surface temperature gradients affect the strength of the atmospheric (Hadley cell) circulation as well as the upper ocean vertical stratification (Boccaletti et al., 2004). If there is a widespread overestimation of high latitude temperatures and underestimation of latitudinal temperature gradients during past warm periods such as the Pliocene or Miocene, this would have several implications for data model comparisons. Pacific latitudinal temperature gradients in models and proxies have been compared using high latitude temperature as an index of climate state (Liu et al., 2022), but if absolute high latitude temperatures are overestimated by proxies, then an alternate set of model characteristics (such as climate sensitivity) may provide a better match to observations. Because of the influence of latitudinal SST gradient on atmospheric circulation and precipitation patterns, some model data comparisons have imposed a proxy-based SST gradient in an effort to generate more consistent model-data comparisons (Lu et al., 2021; Burls and Fedorov, 2017), and the robustness of this imposed SST pattern would need to be reassessed. Additionally, tuning of model latitudinal gradients in cloud properties such as cloud albedo is one mechanism which has been applied to reduce the model-data discrepancy in latitudinal SST gradients (Fedorov et al., 2015), but a revision of proxy latitudinal gradients may necessitate reconsideration of the scope of feedbacks required to simulate polar amplification in past warmer climates, including not only the Miocene but also warm intervals of the Plio-Pleistocene. Finally, an overestimation of sea surface temperature may also lead to overestimation of atmospheric CO_2 concentrations from proxies which directly reconstruct $[CO_2]_{aq}$, such as phytoplankton carbon isotope fractionation or boron isotopes. For example, a reduction in SST from 21°C to 16°C would reduce the estimated pCO_2 from a given $[CO_2]_{aq}$, by ≈13% due to the higher gas solubility at colder temperatures. Our analysis suggests that further assessment of absolute proxy temperature estimates and their calibrations is needed before robust model-data comparisons can be carried out.

iii. How do your reconstructed temperatures compare to Mg/Ca ratios from the Southern Ocean or South Atlantic? Other proxies? Do these proxies more closely agree with clumped isotopes or alkenone proxies?

We thank the reviewer for suggesting that we increase the comparison to other proxies. From the core in which we produced our new time series, Site 1088, existing surface ocean temperature estimates are available only from alkenones and the new clumped isotope records. From the Southern Ocean core Site 1171, in which planktic foraminiferal clumped isotope temperatures were illustrated in Figure 6b, there are additionally TEX86 determinations (Leutert et al., 2020) and Mg/Ca on the planktic foraminiferal species *G. bulloides* (Shevenell et al 2004, 2006, recalculated in Leutert et al 2020). We therefore propose to include the Site 1171 TEX86 and Mg/Ca records in Figure 6b. As noted in Leutert et al, 2020 the choice of calibration for TEX86 has a strong influence on the absolute temperatures, so we illustrate in the figure all four temperature calibrations presented in Leutert et al (2020). Additionally, for the temperatures calculated from planktic foraminiferal Mg/Ca we illustrate the six SST calculations presented in Leutert et al (2020), which include three different calibrations for *G. bulloides* and three different scenarios for Mg/Ca seawater values. Because of the calibration and Mg/Ca seawater issues affecting TEX86 and planktic Mg/Ca, the inclusion of these results does not serve to "validate" clumped vs alkenone temperatures but rather illustrate the challenges in delineating robust absolute temperatures that has motivated previous studies (e.g. Leutert et al 2020) to focus on trends rather than absolute values from the TEX86 and Mg/Ca proxies.

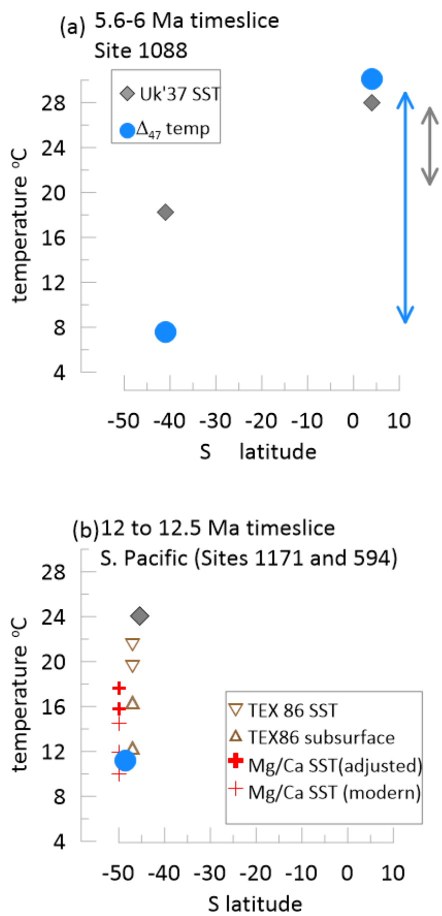

Figure 6: Comparison of Δ47 upper ocean temperature estimates with alkenone temperature estimates. (a) compares Δ 47 coccolith temperatures averaged over the 5.6 to 6 Ma time interval from Site 1088 (this study) and low latitude Atlantic ODP Site 926 (Tanner et al., in prep.) to the U_37k' temperatures from Site 1088 (Herbert et al., 2016) and Site 926 (Tanner et al., in prep.). (b) compares Δ 47 temperatures from planktic foraminifera G. bulloides (Leutert et al., 2020) at Site 1171 with to the U_37k' temperatures from nearby Site 594 (Herbert et al., 2016) for which the modern mean annual SST differs by <1°C (Levitus et al., 1994); also shown from Site 1171 are TEX86 temperature estimates from Leutert et al. (2020) using calibration to SST (Tierney and Tingley, 2015; Kim et al., 2010) and calibration to subsurface temperature (Ho and Laepple, 2016; Tierney and Tingley, 2015), and Mg/Ca temperatures from *G. bulloides* (Shevenell et al., 2006; Shevenell et al., 2004) recalculated by Leutert et al. (2020) with three calibrations (Gray and Evans, 2019; Vázquez Riveiros et al., 2016; Mashiotta et al., 1999) assuming modern seawater Mg/Ca and a proposed scenario for Miocene seawater Mg/Ca (Lear et al., 2015). The TEX86 and Mg/Ca temperatures from Site 1171 are plotted with a + and -1.5° latitudinal offset, respectively, to improve clarity in the figure.

4. Conclusions
    a. Again, I'd circle back to your point at the beginning that latitudinal temp gradients are vital for atmospheric circulation, rainfall etc. Emphasize the importance of getting this gradient accurate for other fields

    We expand the end of the conclusion to the following:

The significant deviations in reconstructed absolute temperatures pose a challenge because most climate model-data comparisons are based on comparison of absolute proxy and model temperatures. Robust simulation of atmospheric circulation patterns including rainfall distribution require accurate estimates of temperature gradients on land and in the ocean (Burls and Fedorov, 2017), and the prediction of high latitude ice sheet stability depends on accurate estimates of high latitude temperature amplification (Gasson et al., 2013). The results of this study suggest that while proxies show high fidelity in reconstructing past temperature trends, the issue of absolute temperature estimation, crucial to evaluation of models, requires continued scrutiny.

5. Figures:
    a. Fig 1: Are the contours temperature? If so, can you include that in the caption?

Good point, the revised figure caption notes this.

b. Fig 3: As I mentioned above, would it be possible to add a running average for the ODP 1090 Uk37 like you did for the ODP 1088 temps? – we add the LOESS fit and the figure now appears like this: