Review of “Impact of the Late Miocene Cooling on the loss of coral reefs in the Central Indo-Pacific” By generating the TEX86-based sea surface temperature (SST) record at the ODP Site 811 from the coral sea between ~ 2-6 Ma, combined with the published data between ~ 6-11 Ma from Petrick et al., (2023), the authors explored the impact of the late Miocene cooling on the regional coral reef loss. Compared to previously published Uk37-based SST records in the region, SST reconstructed in this study documented an unusually strong cooling in the Central Indo-Pacific, showing ~ 4 - 5°C drop from ~ 7 to 6 Ma, which is consistent with the cooling shown in a Mg/Ca-based SST record from the northern Indian Ocean. The authors made efforts to discuss how the temperature change (rapid cooling) could potentially act as a final stressor causing the collapse of coral reef and the known “Pliocene Reef Gap”. I think the dataset presented here is neat and compelling, contributing to the understanding of the temperature changes impacts on shallow water carbonate systems.

However, this manuscript is poorly written and does not read smoothly. It appears to be a casual draft that lacks proper polishing and organization. Additionally, the text suffers from a lack of clear structure, specifically for the introduction and discussion sections (see major comments). In terms of science, the manuscript does not cite enough related literature and definitely needs a deeper and re-organized discussion section. The discussion section in this manuscript fails to provide sufficient discussion related to the presented data and lacks clear explanations when comparing to other studies (see major comments). Overall, I believe this manuscript requires major revisions before it is ready for publication. Here I attached my major and specific comments, hoping to help the authors to revise.

The anonymous reviewer is gratefully acknowledged for the insightful comments. We would like to apologize for the organizational issues and take all comments into consideration. Please, see responses below.

Major comments:

Introduction:

1) The introduction is poorly structured, and it lacks leading or summary sentences for paragraphs, resulting in unclear logical connections between them. The introduction is a wired blend of LMC, site background, and the coral reef gap issue. It would be better to move the site background to a later section of the article. To improve clarity and conciseness, I suggest considering combining related content and ensuring a logical flow throughout the introduction.

The site background, though it is of high importance for this contribution due to the scarcity of GDGT-based temperature reconstructions from such reefal sites, to a large extent will be moved to the site description in results section. Focus will be placed on the potential causal relation between LMC and coral reef gap in the region, which is the main focus of our contribution.

2) The authors insufficiently cite other people's work in this section; there are several places that require additional references to support the statements (see the specific comments). 2. I think it is worth to add a section to introduce the oceanographic setting for Site 811 in the main context to offer basic information like the location, water depth, SST, salinity and regional currents in the modern ocean, as well as information about site

migration and coral reef history in this region (also put the related repetitive materials from the "Introduction" and "Discussion" sections to this section).
Reviewer 1 and 2 asked for more details, and we are pleased to add a section on this to the paper.

3. Discussion: This section is poorly structured and lacks organization. It fails to provide sufficient discussion related to the presented data and lacks clear explanations when comparing to other studies. 1) For section 4.1, the authors need to put more effort into explaining the driving mechanisms behind the cooling observed at other sites, as documented in relevant literature, instead of solely relying on comparisons of data and proxies. It's quite confusing when they compare the SST at Site 811 to the SST stack from Liu et al., (2022) without specifying the site locations included in the stack and the proxies used.

The sites of the Liu et al. (2022) SST-stack were shown in Figure 1, but we will provide more detail to improve clarity. We will also expand our explanation of the previously proposed driving mechanisms behind the LMC, though we think that changes in CO_2 are the most likely explanation based on the work of numerous authors(e.g., Herbert et al., 2016; Holbourn et al., 2018; Martinot et al., 2022). We will, however, explain the alternative hypothesis, such as gateway closures.

Similarly, the alignment of SST data at Site 811 with the model from Burls et al. (2021) and the absence of an anomaly in cooling, as noted by Martinot et al., (2022) when compared to the SST record at Site U1443, lack clear explanation.

Although we may not fully have understood the critique, we will try and clarify this section better. For a clear presentation of analytical data, we will add a table to demonstrate our cooling estimates and elaborate on the measured data versus model matches.

Moreover, only SST data at Site 811 exhibit full recovery after 5 Ma (unlike U1443, which shows a similar cooling trend between 9-5 Ma but lacks data after 5 Ma). What are the potential mechanisms behind this? Is it related to the proxy used or is it a local signal?

Several records published (see Herbert et al., 2016) and the figure attached below document the SST recovery. Furthermore, there are at least 4 tropical sites across the Central Indo-Pacific that further confirm this SST recovery: Both the Mg/Ca record from U1448 from the Andaman Sea (Jöhnck et al., 2020) and most individual records from the WPWP-stack (Liu et al., 2022; Zhang et al., 2014) show a recovery between 5-3 Ma. While the exact scale of this recovery varies for different sites, SSTs increased between 5-4 Ma at all these sites (Jöhnck et al., 2020; Liu et al., 2022). The cause for the recovery has not yet been identified but either changes in gateways or $p\mathrm{CO_2}$ have been suggested (Jöhnck et al., 2020). We will briefly explain this and add the U1448 record to Figure 4.

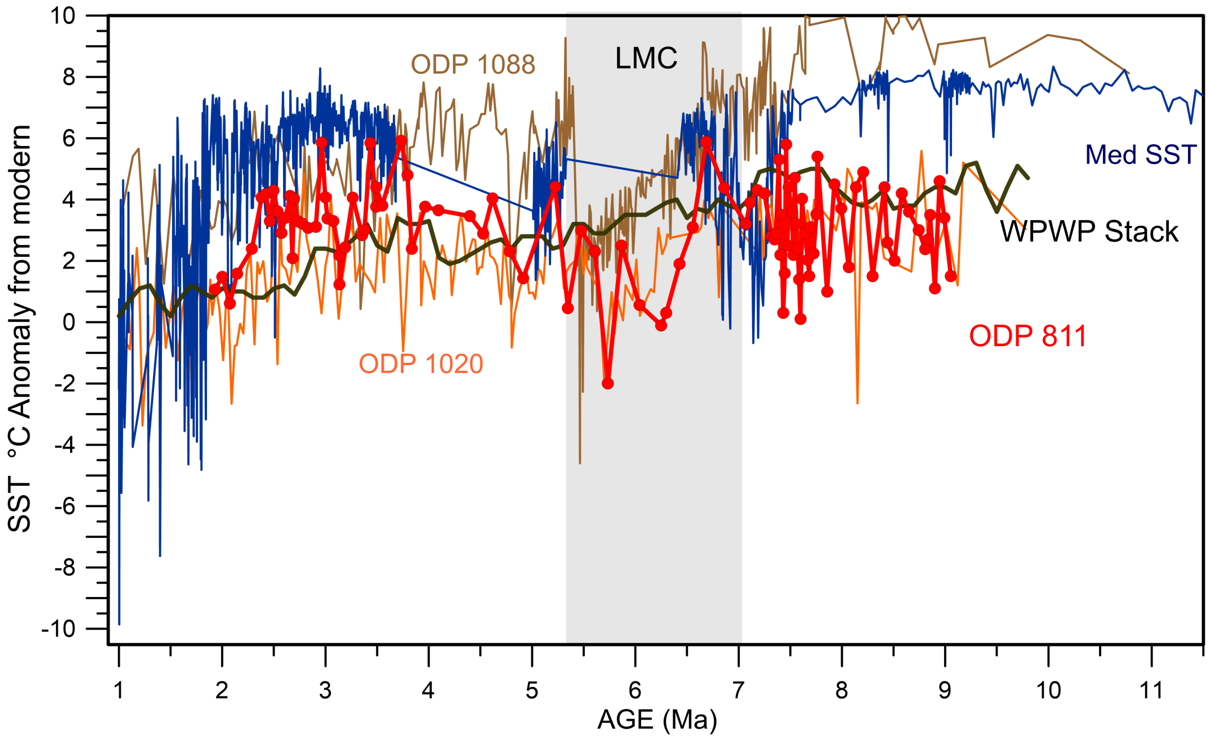

Figure (for reply to review only): This figure shows some of the records that show a recovery in SST similar to ODP site 811. Besides the ODP Site 811 record (red), the WPWP-stack is based on TEX_{86} values. A composite Mediterranean record (dark blue) (Herbert et al., 2016),ODP site 1088 from the South Atlantic (brown) (Herbert et al., 2016),and ODP 1021 NE Pacific (orange) (LaRiviere et al., 2012). The latter three SST-records are based on U^{K}_{37}'.

Furthermore, compared to SST at U1443, SST at Site 811 generally indicates lower values during cold intervals but agrees with high-temperature peaks, a point that has not been discussed.

Some caution should be used here because both TEX_{86} and Mg/Ca based SST-proxies have individual errors, and choices on proxy calibration at either site could alter the relationship. For instance, although taken close together, U1448 and U1443 have a completely different SST relationship with ODP site 811, even though both are based on the Mg/Ca-proxy. This may be due to variation in proxy calibrations including assumptions on pH and the assumed Mg/Ca of surface waters (Jöhnck et al., 2020; Martinot et al., 2022). However, the most likely explanation for the temperature relationship of the lower values during cold intervals is that ODP site 811 was further south during this time (25 ° southern latitude). Therefore, cold Southern Ocean-sourced water could have affected the site (Isern et al., 1993), especially at the height of the LMC when currents shifted norward, as is shown in the attached figure taken from Petrick et al. (2023). Site U1443 remained in the tropics during this time, with little Southern Ocean influence at the site (Martinot et al., 2022). However, because of the error uncertainties, we feel that this relationship is interesting but not robust enough for this publication.

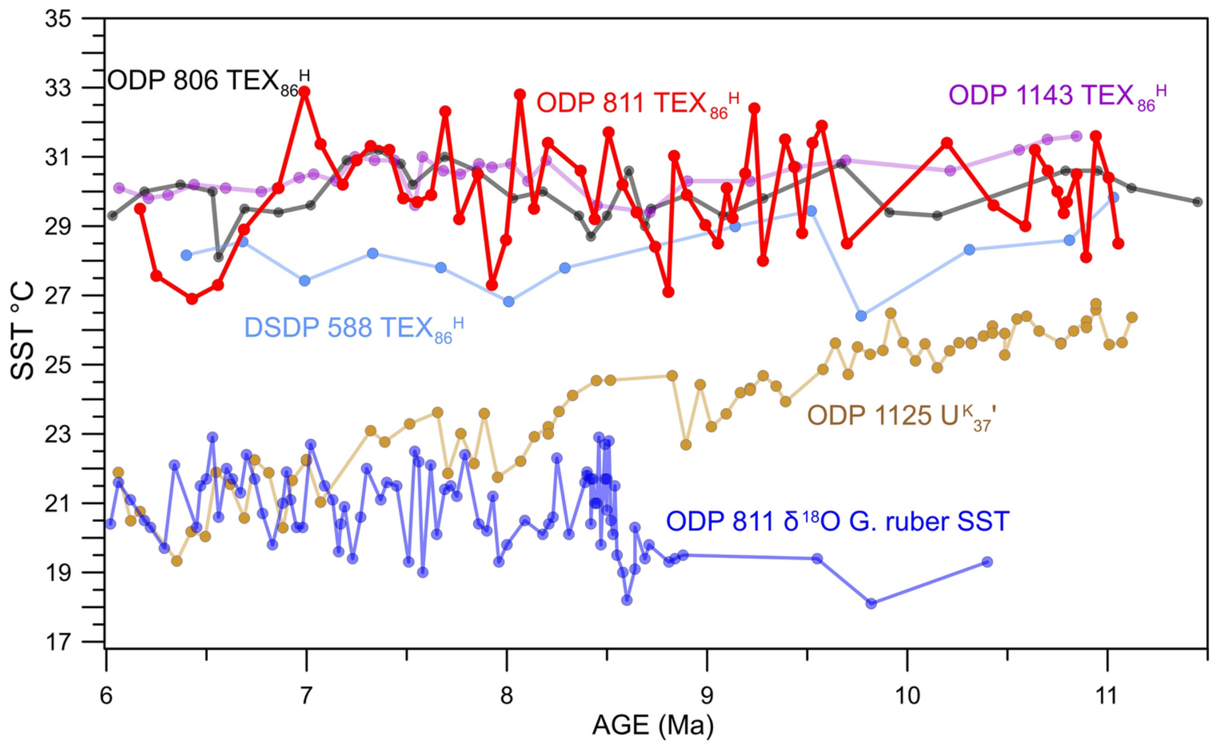

Figure from Petrick et al. (2023): A comparison of different SST records from the western Pacific. The new 811 TEX_{86}^H records from ODP site 811 (red) and the old $\delta^{18}O$ record (dark blue)(Isern et al., 1996)are compared to other Sites from the western Pacific (Fig. 1). These include ODP site 806 from the WPWP to the north of the Coral Sea (black), ODP site 1143 from the southern South China Sea (purple)(Zhang et al., 2014), and DSDP site 588 from the Lord Howe Rise at the southern limit of the Coral Sea (light blue)(Auderset et al., 2022) all of which are TEX_{86}^H records. ODP site 1125 east of New Zealand south of the Tasman front (gold)(Herbert et al., 2016)is a U^K_{37}' record.

To improve this section, I suggest: 1) Clearly state the related stacks/records (including the proxy and site information) from other studies at the outset when comparing data and refer to Figure 1 when necessary. 2) Rewrite the second paragraph, adding more details on how the models can support the SST data and its relation to CO2 decrease.

We will do this and elaborate on how our data fits the models presented in Martinot et al., (2022).

2) For section 4.2, this section primarily delves into the historical context of coral reef loss in the region since the Miocene. However, the authors fail to link other studies to the data in their study until the end of this section, with only the last two sentences referencing their own results. Much of this background material should be condensed and summarized in the discussion section, with a closer connection to their own data throughout the text. Furthermore, the presence of many illogical transitions (e.g., 'however') disrupts the coherence of the section.

This section will be reorganized and parts be transferred to the discussion section. Thereby, illogical and superfluous words or phrases will be omitted.

3) For section 4.3, this section includes seven paragraphs that are poorly organized and somewhat chaotic. For instance, the first three paragraphs need to be merged into one, and the sixth paragraph, which also discusses the impact of cooling to the loss of the coral reef, should be moved to the beginning too. After that, the discussion should flow into other stressors related to the cooling (e.g., changes in currents and terrigenous input). In the third paragraph, It is not clear how the major SST drop became the final trigger for coral reef collapse in terms of the coral's ecological and physical characteristics, which requires more discussion. In the fourth paragraph, additional explanation is needed on how changes in terrigenous input caused by cooling would impact the loss of coral reefs.

The organization and conciseness of the section will be improved following reviewer recommendations, emphasizing on the following aspects. Modern studies show that many species of coral exhibit lower carbonate extension rates at lower temperatures (Lough & Barnes, 2000; Lough & Cantin, 2014). Such a cooling effect may be responsible for the global latitudinal reduction of the coral reef belt during the end of the Late Miocene (Perrin & Kiessling, 2012). Sites to the south of ODP Site 811, such as the Marion Plateau (which today is about 4 °C cooler than the central Coral Sea), would have experienced temperatures which are below the ideal coral growth window. As we pointed out in the manuscript, the impacts of the LMC would exceed those of cooler SSTs but include other driving factors. For instance, there was a southward displacement of the Winter Monsoon belt, which would have increased the rainfall in Indonesia and Australia (Holbourn et al., 2018; Jöhnck et al., 2020). This likely would have led to an increase in detrimental siliciclastic input into the reef systems in this area. Evidence for increased primary planktonic productivity in the Pacific has been proposed by Holbourn et al. (2018). Both of these factors have been shown to be major stressors on coral reefs (Hallock & Schlager, 1986; Hinestrosa et al., 2016; Sanborn et al., 2024; Webster et al., 2018; Wiedenmann et al., 2012). A potential reason that these impacts have not been recognized previously is that coral reef reconstructions often rely on benthic $\delta^{18}O$ reconstructions to investigate climatic changes (Harrison et al., 2023). Therefore, the discussion we intend to raise is that the full impact of cooling on the reef gap has never really been evaluated. We will add these aspects and clarify this point in the paper.

4. Data description: The authors' description of their data is inconsistent throughout the text. The SST record exhibits a temperature drop of around 4-5°C and the authors mention it as a stronger cooling compared other studies (Section 4.1). However, they also state that the average temperature drop is around 2°C (and consistent with other records) by using confusing average calculation (Section 3.2). I suggest showing the error margins of the temperature reconstruction and include a smoothed line of the data to help identify the absolute SST drop.

We apologize that this discussion got too confusing, e.g., due to variable definition of the LMC in the literature, which will be clarified by this contribution via strictly using the definition of the LMC (7.0-5.4 Ma) put forward by Herbert et al. (2016).

SST-averaging was conducted to minimize the effects of SST spikes biasing the record. Yet different publications have calculated the periods of cooling differently. Therefore, we used both the periods described in Martinot et al. (2022) and Herbert et al. (2016) and a window based on our own records to show that the cooling was compatible, regardless of the averaging procedures applied. SST-averaging yielded an average temperature drop of 2 °

C. To improve readability of this section and provide solid background data, we will add a table showing our average values and those for the different time-window definitions of the LMC taken from the literature. For visual improvement of the figure, we will add error bars of 2.5°C taken from literature, as was suggested by reviewer 1, and add a smoothed line to the data points.

5.

Figures: The LMC time interval boundary is inconsistent in all their figures. The blueshaded LMC in figure 2 covers a different time interval than that in figures 4 and 5, and the gray bar indicating LMC in figure 4 differs from that in figure 5. I suggest combining figures 2, 4, and 5. Presenting all the records on the same time scale will facilitate a better evaluation of the data and related events.

As stated before, the revised version consistently will apply the traditional definition of the duration of the LMC, given by Herbert et al. (2016) as 7-5.4 Ma

Specific comments:

1. Lines 16-18: This sentence should be excluded from the abstract but put it in introduction instead since the "reef gap" has been explained in the abstract already.

We will do this

2. The first part of abstract can be more concise, and it should address more about the indication from the data/results of this study in the second half of the abstract.

We will do this

3. Lines 30: Using Herbert et al., (2016) as the main and only ref. in the first paragraph to introduce LMC is not enough, need more recent refs.

We will do this.

4. Lines 37: Need to add ref for benthic d13C shift associated with biogenic bloom.

We will do this by adding citations for this event (Grant & Dickens, 2002; Pillot et al., 2023)

5. Line 59-60: This sentence should be combined with the text later and it does not make sense as a leading sentence for this paragraph.

We will do this

6. Line 60-62: Too many "however" transitions are used in the whole article and several instances do not align with the logical flow of the text (e.g., line 60).

We will do this

7. Lines 67-68: Need to add ref when stating that LMC was muted in the benthic d18O record

We will do this

8. Lines 82-83: Need to add ref for the "records produced".

We will do this

9. Lines 112: Not clear. What is the standard error related to? how about error of calculated temperature?

   We will make it clear that the errors are based on the Kim et al. (2010) (2.5 C +/-) paper and describe in more detail what this is

10. Lines 130: Not clear. What does it mean by “we used the 2/3 index to ensure…..”
This is about the use of the 2/3-index, meaning the ratio of GDGTs with 2 versus 3 rings, in order to check the GDGT-based SST-reconstruction for environmental influences other than temperature. The 2/3-index is used to evaluate the depth of production and associated water temperature of archaeal GDGTs, which impacts on the TEX_{86} (Rattanasriampaipong et al., 2022). Unlike the other accuracy tests for molecular SST-proxies, it does not have a defined cut-off published and is only used to eliminate data where the 2/3-ratio is exceptionally high. In our study, the 2/3-index was very low, suggesting mainly surface production of archaeal GDGTs (Rattanasriampaipong et al., 2022). We will expand on this in the paper.
Lines 132: Is it “supplemental data 1” (line 125) or “supplement 1”?
We intended to refer to “see the supplemental data in Petrick et al. (2023).”

Lines 137-138: I would love to see a covariance plot between SST and BIT. BIT index is high for the dataset and the cutoff the authors using in Figure 3c is about 0.5 (but not exactly at 0.5), which is weird. Based on the similarity between the SST at site 811 and site U1443, I doubt there is serious terrigenous input impact on the samples before ~ 5 Ma but not sure about the younger part. However, after seeing the high BIT index values (most of them higher than 0.2), I think it would be helpful if the authors can offer some other evidence to support that there is little terrigenous derived source influence at site 811 during the Miocene (e.g., information from other studies like organic carbon isotopes) or using lower cutoff in the discussion (if removing those samples still doesn’t affect the major trends or conclusions of the paper).
The presently accepted cut-off for the BIT should be 0.45, which will be corrected in the figure. A covariance plot (see below), for space limitations within the text body, will be added as a supplementary figure. We also include a figure showing % carbonate as part of the new lithological column, demonstrating that the amount of terrestrial input to the site is very low. See response to reviewer 1.

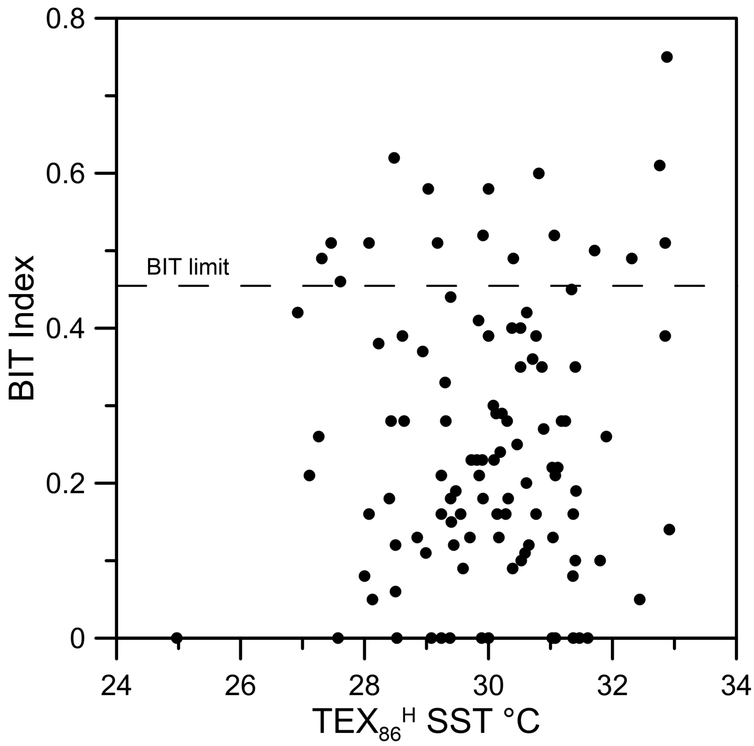

Figure: BIT compared to TEX_{86}^{H} SST values.

11. Lines 160-162: I am confused about the sentences describing the SST change at site 811. Is it decreasing around 5 °C from ~ 30°C to ~25°C from 7 Ma to 5.9 Ma? I think the temperature is keep decreasing since around 7 Ma and it is not reasonable to calculate the average temperature between 6.7-5.9 Ma and stating that it is about 2 °C cooling at site 811.

We used the 6.7-5.9 Ma window to match data shown in Martinot et al. (2021) and included further time averaging windows, including the one by Herbert et al. (2016) and the "cool" period as defined here, to identify averaged SST-change, as explained above. All average calculations yielded a 2-2.5 °C shift in SSTs. Please, see above for explanations on spikes in the SST-record.

Line 161: Same as "however", too many "finally" transitions are used in the whole article, which does not help with logical transitions.

To our own regret, the previously submitted manuscript version contained an unduly number of unneeded and superfluous "filling or transition phrases", which will be omitted in the revised version.

Citation List

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