Final Author Comment

Karatsolis et al. – cp-2022-60

We found the review comment by Mariem Saavedra (R1) very useful in several aspects. It helps us refine the presentation of the main points of the manuscript and clarify others, especially the ones regarding temperature proxy types. It also helps structure the manuscript in a clearer and more concise way. We therefore thank her warmly for her constructive review of our work.

In this manuscript, Karatsolis and Henderiks generated two calcareous nannofossil records from International Ocean Discovery Program (IODP) Sites U1463 and U1464, located in the NW Australian shelf, in order to reconstruct long-term changes in ocean circulation, seasonality and nutrient availability from ~ 6-3.5 million years ago (Ma). The authors characterised different periods of change in stratification and nutrient availability in the study area by analysing the shifts in the calcareous nannofossil dominant taxa and comparing them with palaeotemperature gradients between the NW Australian shelf and the eastern Indian Ocean.

Karatsolis and Henderiks found a marked regional change in the oceanographic conditions that affected the ecology of calcareous nannofossils across the Miocene to Pliocene boundary (5.4–5.2 Ma), which they attributed to an increase in seasonality and general intensification of the upper water column mixing. The authors also put the observed local variations in a more global context, considering events, such as the extinction of Sphenolithus spp. (~3.54 Ma) and the termination of the late Miocene to early Pliocene biogenic bloom in the eastern Indian Ocean (4.6-4.4 Ma).

General comments

This manuscript represents a substantial contribution to scientific progress within the scope of Climate of the Past and it is of interest for the coccolithophore, calcareous nannofossil, palaeoceanographic and micropalaeontological communities.

It is well written, logically structured, and presents a new calcareous nannofossil dataset.

The title reflects the contents of the manuscript and Karatsolis & Henderiks present an adequate summary of their work in the abstract. The state of the art and the main aims of this work are properly introduced in the first section.

The methods used in this piece of research seem adequate and are described section 2 of the manuscript. In my opinion, mathematical formulae, symbols, abbreviations and units are correctly defined and used through the text.

The interpretation and conclusions have been logically derived from their findings, and supported by the original data shown in section 3 (Results).

We thank the reviewer for her positive comments.

My main concern is that the authors should highlight more the variability between proxy types. They use different proxies, such as GDGT-based TEX86 temperature and alkenone

based U37k´ SST or Mg/Ca derived SSTs from Trilobatus sacculifer. I like that they use gradients, but in the manuscript, the uncertainty of working with different paleotemperature indicators need to be more clearly addressed. Perhaps adding some reference(s).

The uncertainty for working with different paleotemperature proxies will be clarified with additional information regarding the use of these proxies in Methodology section *2.4: Paleotemperature proxies and gradient calculation*, and the discussion section *4.2: Paleotemperature and inferred ocean circulation patterns.* We will include a set of references that highlight the previous use of these proxies in the area, but also globally, as well as the potential ambiguities that this may introduce when constructing gradients between them.

For example, we will further analyse the different interpretations of TEX86 as an SST versus whole water column indicator (De Vleeschouwer et al., 2019; Petrick et al., 2019; Smith et al., 2020; Smith et al., 2013) over shelfal areas of Australia.

Figures and tables are in general clear (a very good example of this is Figure 7). I just have minor suggestions regarding the figures (see specific comments/technical corrections). I would recommend merging some of them (4 and 6).

Detailed answers to figure suggestions are provided in the "specific comments" section.

I find that the references cited in the manuscript are adequate. I just found some typos.

Typos will be searched & corrected.

The supplementary material is also adequate, but it could be improved (in some of the plots there are just too many wiggles). I would probably move some of the supplementary figures/plates to the main manuscript (see specific comments).

Detailed answers to figure and supplementary figures suggestions are provided in the "specific comments" section.

Specific comments:

Abstract:

Line (L.) 9-10: "and …and", replace by "as well as" to avoid repetition.

We will follow this suggestion.

L.14: "and can therefore assist with more detailed reconstructions." sounds odd to me. Rephrase if possible.

This part of the sentence will be removed.

L.14-25: In the abstract I would suggest to talk first about the general (more global) changes and the jump into the regional variations (or reword this part in a similar was as in the introduction). I understand the way that the authors try to "zoom out", but perhaps that makes more sense in the conclusions, rather than in the abstract. Therefore, my suggestion would be to reorganise this part.

We will attend to stream-lining the abstract taking the reviewers' comments into consideration.

L. 21: Could you provide more detail when you mention "Major changes"?

More detail will be provided by replacing "Major changes" with "Significant changes in nannofossil species distribution and abundances". Examples of what these significant changes consisted of is also provided later in this sentence "*such as the extinction of Sphenolithus spp. (~3.54 Ma) and the termination of the late Miocene to early Pliocene biogenic bloom in the eastern Indian Ocean (4.6-4.4 Ma), occurred long after this regional regime shift*."

1. Introduction:

L. 28-34: It is confusing to the readers the way that the authors introduce the different terms "coccolithophores", "coccoliths", "nannoliths" and "nannofossils". Please rewrite this part.

We will clarify (and simplify) this introduction. We will keep (calcareous) nannofossils as the main term to be used throughout the manuscript, since it includes both the coccoliths and the nannoliths.

L. 41: Please double check (here and elsewhere in the manuscript) that "equatorial warm water valve" is the right term. I have only encountered "equatorial valve" in the literature.

This is a nonstandard term, so we expect that it has not been used in the literature. However, since we would like to pinpoint that this is the only equatorial valve that allows the flow of major warm water currents nowadays, we will keep this term and add quotation marks.

L. 48-49: Change to (/weaker)… (/El Niño)… (/3Sv)

We will follow this suggestion.

L. 57-57: Sounds redundant. Double-check that sentence.

The redundant part of the sentence will be removed.

L. 61, 63: dot instead of circle

"Circle" will be replaced with "dot"

L. 63-64: Change to "The main surface oceanography of the Indo-Pacific region (dark red lines) and main path of the LC (lighter red line; adapted by (Auer et al., 2019; Gallagher et al., 2009) and the HC, which in this study are considered as one, are shown."

We will follow this suggestion.

L. 65: The base map…

"The" will be added.

L. 71-76: Reword. Make it more concise.

We will follow this suggestion.

L. 79: Mention somewhere what time Auer et al. (2019) previously covered.

We will add this within the reference brackets.

L. 80: 100 km away

Noted.

L. 92: Change to: (a) mixed layer and increased stratification (c) and SST…

We will follow this suggestion.

L. 94: (b, d) there a space missing.

A space will be added.

L. 103-105: As is Figure 2, I recommend putting (a), (b), etc before the description. E.g. (a) chlorophyll

We will follow this suggestion.

2. Material and Methods:

L. 118: Specify seconds if possible.

The seconds will be added (30-60 seconds).

L. 125, L. 135: Double-check the use of coccoliths /nannoliths etc here and elsewhere.

We will double-check the use of these terms as suggested and follow terms as introduced in revised Introduction.

L. 129: Specify what is N (you do later in the text, but this is the first time).

We will specify what N stands for when using this abbreviation for the first time.

L. 131: Make sure the comma is in the right place. It looks very close to the W, but I guess it is just a visual perception.

We will check if the comma following the equation is in the right place.

L. 139: Was the DBD calculated or downloaded from a specific site? Specify.

DBD was calculated for the respective holes from the information provided in the LIMS database of IODP. Since values were not changing significantly across cores, an average of the available data for the interval of interest was calculated, and then used to calculate nannofossil accumulation rates (NAR). We will specify this information in the text.

L. 139: considered for…specify

We will specify this to read "Nannofossil flux records older than 5.8 Ma at IODP Site U1464 were not included in the interpretation of changes in nannofossil abundance".

L. 141: were instead of " can still be"

"Can still be" will be replaced with "were".

L. 148-149: (column principal with ages representing distinct columns) is unclear to the reader.

Indeed, this is a confusing technical detail that does not add to the description of the method. We will remove it.

L. 156: I would suggest using the whole name, Nannofossil Stratification Index.

We will use the full name of the index.

L. 157: Write the whole name of the ratio and add (NSI) to introduce this term somewhere.

We will follow this suggestion.

L. 160: Add a reference for that datum.

The reference of the datum will be added.

L. 182: I would delete or reword "Similarly, a ratio between Reticulofenestra species and Florisphaera has been used to monitor changes in the nutricline and thermocline during the Pleistocene (Flores et al., 2000)." This ratio is a bit different from what was previously mentioned…

Good point. These two ratios were not used to infer the same conditions. We will remove this analogy.

L. 189: The authors should acknowledge the existing differences among different proxies to reconstruct the same environmental parameter (.e.g., SSTs) and reference it. Part of the last sentence (L. 200) should be moved up in this subsection.

This is a very valid point. The three different paleotemperature proxies have been previously used to infer paleotemperatures from various depths of the water column, from a variety of different environments and with various seasonal and geographical biases. As we mentioned in our response to the "general comments", we will present in more detail the differences among TEX86, U37k' and Mg/Ca reconstructions. We will mainly focus on the previous use of these proxies in shelfal areas of Australia and the tropical Indian Ocean during the Miocene and Pliocene, as presented by the studies where the paleotemperature information were retrieved. The relevant references will be added.

For the same purpose, we will follow the suggestion of moving L.200 up in this subsection.

This needs to be discussed further in the (sub-)section 3.4.

Having acknowledged the differences between proxies, we will further discuss the use of the calculated gradients, the information they can provide and their limitations in section 3.4: *Paleotemperature gradients*. We will also integrate this discussion to the reasoning behind the different paleotemperature gradient labelling (ΔT versus ΔSST).

3. Results:

L. 205: How did the authors assessed the preservation? Expand or add a table in the supplementary material summarizing the ranking used. If it applies, reference it.

Preservation in samples from U1463 and U1464 was assessed in the initial reports of Expedition 356 and followed a 1-5 scoring system (1 = poor [P], 2 = moderate, 3 = good [G], 4 = very good), following the definitions from Gallagher et al., (2017a, 2017b; Expedition 356 site summaries). In the initial reports, nannofossil preservation was assessed to score 2 and 3, demonstrating moderate and in cases

good preservation. In this study, through visual inspection, we observed that good preservation was actually rare and therefore labelled the preservation for the studied interval as moderate (score 2). We will expand on the matter in L.205 and reference the score system used.

L. 228-229: Unclear to the reader. Rephrase, please.

We will rephrase this sentence and make it clearer.

L. 234-235: "NAR of Sphenolithus spp. bounced back to higher values, especially at IODP Site U1463" This is impossible to see in Figure A2. I would recommend the authors to space out the different taxa data in Figures A1 (especially in b and d) and A2 (all of them) using different Y-axes.

We will follow this suggestion and use different axes in Figures A1 and A2, in order to make the species relative abundance and NAR values more visible.

L. 241-242: Delete "As is the case for the nannofossil assemblage compositions", and change to: "Changes in NSI covary throughout the studied interval and correlate well between the two sites (Figure 4)."

We will follow this suggestion and substitute the sentence.

L. 245: change demonstrates for shows?

We will substitute this word.

L. 249. I suggest merging Figure 4 and 6.

We will follow this suggestion and merge Figure 4 and 6. To better accommodate this change, sub-sections 2.2 and 2.3 will be merged under the title: 3.2 *Nannofossil multivariate analysis*.

L. 249-250: (light blue squares)… (orange triangles)

We will add this information.

L. 255-257. I am not fully sure I understand this sentence. Are not assemblage and species composition the same? This sounds like circular thinking, but it is probably just a matter of rewording.

We will rephrase this sentence to read "*By color-coding the samples based on their age across the main time intervals of interest (5.4-5.2 Ma and after 4.6–4.4 Ma; Figure 5), we test if any of the observed changes in the abundance of dominant species were accompanied by larger shifts in the relationship between relative abundances of species in multivariate space."*

L. 278: Please use different symbols for the different sites.

We will replot this figure, using different symbols for the different sites.

L. 280: What does PP account for? I think it has not been introduced in the manuscript.

PP stands for paleoproductivity. We will introduce this term in the manuscript before using the abbreviation.

L. 285: "…Karas et al., 2011, upper…" (delete parenthesis)

The parenthesis will be deleted.

4. Discussion:

L. 326-329: Is it possible for the authors to elaborate more in these higher and lower phases?

We have described these phases in detail in section 3.2: *Nannofossil stratification index (NSI)*

"After ~4.2 Ma, this surface water stratification proxy shows higher variation with short intervals of higher values (4.2-4 Ma and 3.8-3.54 Ma), that correspond to peaks in relative abundance of Sphenolithus spp. Between 4 and 3.8 Ma, NSI demonstrates low values…"

This sentence will be written more concisely to read: "*"After ~4.2 Ma, NSI shows higher variation with short intervals of higher values (4.2-4 Ma and 3.8-3.54 Ma). These intervals correspond to peaks in relative abundance of Sphenolithus spp.*"

Additionally, in the discussion, we will elaborate more on the possible reasons that might have led to higher variability between higher and lower phases of NSI during this interval. Although the mechanism is unclear, it is interesting that higher amplitude NSI after 4.2 Ma, correlate well with higher amplitude changes observed in the temperature gradients after ~4.3 Ma. This would suggest a similar controlling mechanism to the one we are proposing in this manuscript, but in this case on shorter timescales.

L. 345: "shelf area due to…" (I would mention it in the first sentence or merge L. 344-347).

We will follow this suggestion and merge L. 344-347.

L. 360: What about a combination of two or three of the 3 proposed mechanisms? Would that be an option? If so, perhaps add a sentence.

We will add a sentence mentioning that any possible combination of the proposed mechanisms could have had similar results.

L. 371-372: "Shift" is mentioned twice in a sentence. Find a synonym.

The first "shift" will be replaced with "change".

L. 420-470. The reference Stuut et al. (2019) (https://doi.org/10.1029/2019GL083035) could be useful in the section 4.3 from the discussion because that study (in the continental margin of NW Australia) covers the last 5.3 Ma.

We will add this reference in the beginning of the paragraph, as part of the overall paleoclimatic regime in the continental margin of NW Australia during the early Pliocene before we focus on paleoproductivity and paleoecology matters.

L. 423: Make sure PP is introduced before (not just in the figure captions), I guess the first time is in L. 67.

We will make sure that this abbreviation is introduced in the text.

L. 478: Trilobatus sacculifer

We will write the full name of the genus.

L. 534-547: Figures A1 and A2. I already mentioned it, but I think it is difficult to see the data in some of the plots from these figure (especially if you print it in black and white). I would suggest using different Y axis.

As mentioned earlier, we will follow the suggestion of giving the plots some space, by modifying the y-axis.

When referring to a specific taxa, please add the symbol in the caption on top of the colour, as it was done for example in Figure C1. E.g., (<5µm Reticulofenestra and <3µm Gephyrocapsa; green circles).That will help colour-blind readers.

We will follow this suggestion.

Also, I would probably include them as main figures (not as appendix), but this is up to the authors.

We will consider this suggestion, although we think that the figures contain a lot of information (as you probably already noticed), which are not all presented in detail in the main manuscript and would be tangential to the main focus of this manuscript. We would like to keep a "grouping-oriented" strategy by focusing mainly on dominant species and ratios between them. Yet, we want to show all (raw) data that is included in the CA and Shannon-index calculations for transparency and for those seeking more details, in the supplement.

L. 537: Rather than error bars, I would use "shaded areas"

Good point. We will use the term "shaded areas".

L. 545: 15%; Bordiga … (delete parenthesis).

We will delete this parenthesis.

In Figs. B1 and C1 the symbols of the legend do not match with the ones in the plot.

Good observation, thanks. We will correct the symbols so that they match the plot.

References:

There are several typos in the reference list. I spotted few, but the authors need to carefully check all the references.

L. 589: 2.45 Ma (space missing)

L. 594: (80-.)., (revise, something is missing here)

L. 595: K.-H.

L.598: CO_2 (subscript)

L. 606: 7(May) Double check

L. 614: Holloway

L. 626: 925, and… (delete comma?)

L.631: (August) Double check

L. 633: (80-.)., (revise, something is missing here)

L. 653: ,, (delete one comma) (February) Double check

L. 657: Species names' in italics

L. 665-666: Add doi

L. 672: PAST

L. 675: CO_2 (subscript)

L. 684-686: Add doi

L. 693-694: Add doi

L. 695: Nye, H. .: (delete one dot)

L. 707-714: B-Th, B. –. T. or B. T.? The name of the main author is written in 3 different ways.

L. 756: Page numbers or number of pages?

L. 769: (80-.)., (revise, something is missing here)

We thank the reviewer for taking the time to identify these typos. The references will be revised accordingly.

References

De Vleeschouwer, D., et al., 2019. Stepwise weakening of the Pliocene Leeuwin Current. Geophys. Res. Lett. 46, 8310–8319.

Gallagher, S.J., et al., 2017. Site U1463. In Gallagher, S.J., Fulthorpe, C.S., Bogus, K., and the Expedition 356 Scientists, Indonesian Throughflow. Proceedings of the International Ocean Discovery Program, 356: College Station, TX (International Ocean Discovery Program).

Gallagher, S.J., et al., 2017. Site U1464. In Gallagher, S.J., Fulthorpe, C.S., Bogus, K., and the Expedition 356 Scientists, Indonesian Throughflow. Proceedings of the International Ocean Discovery Program, 356: College Station, TX (International Ocean Discovery Program).

Petrick, B., et al., 2019. Glacial Indonesian Throughflow weakening across the Mid-Pleistocene Climatic Transition. Sci. Rep. 9, 16995.

Smith, M., et al., 2013. Comparison of $U^{k'}_{37}$, TEX_{86} and LDI temperature proxies for reconstruction of South-East Australian Ocean temperatures. Org. Geochem. 64, 94–104.

Smith, R.A., et al., 2020. Plio-Pleistocene Indonesian Throughflow variability drove Eastern Indian Ocean sea surface temperatures. Paleoceanogr. Paleoclimatol. 35, e2020PA003872.