

# ***Interactive comment on “Surface-circulation change in the Southern Ocean across the Middle Eocene Climatic Optimum: inferences from dinoflagellate cysts and biomarker paleothermometry” by Margot J. Cramwinckel et al.***

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General comments This is an interesting and important study, comparing and contrasting dinocyst assemblage changes between ODP sites 1170 and 1172, one within the Australo-Antarctic Gulf and one in the SW Tasman Sea, during a time of major climate change in the middle Eocene. The study uses evidence from the assemblages to unravel the interplay of changes in ocean circulation due to tectonics and climate

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changes. Additional sites and data are used to build the case for a significant regional response to the middle Eocene climatic optimum (MECO) – in terms of changes in plankton communities, terrestrial vegetation and sea level. The interpretations are reasonable in most cases but there are a few areas where the argument is weakened by over-interpretation of what the authors admit are ambiguous data. The key areas are: the definition of the MECO at Site 1170 based on the TEX86 record, which is clearly open to interpretation; the lumping together of cosmopolitan and low/mid latitude taxa, when the latter group is the one that is best able to signal the influence of the EAC and PLC; the lack of convincing evidence for the presence of the MECO in the Latrobe-1 borehole; and the very tenuous correlation of middle Eocene transgression to a purported MECO-related glacioeustatic event.

I have made numerous comments on these and other issues at the places they occur in the text.

However, there is a hidden gem in this dataset that I'm disappointed the authors appear to have overlooked. In our warming world, we are increasingly concerned about the ways ecosystems will be adversely affected by warmer oceans and changes in ocean circulation. For dinoflagellates there is the further concern of how toxic blooms may impact coastal fisheries. The authors provide a dataset that clearly shows the MECO in this region is linked to dramatic increases in the abundance of single species, analogous to present day blooms. And intriguingly, a species of one genus dominates at Site 1170 whereas another species of the same genus dominates at 1172. Even more intriguing, both species have short-lived blooms leading up to the MECO at 1172. Much of the paper simply combines the data for these two species with their respective biogeographic groups (cosmopolitan and endemic) but these two taxa clearly dominate these groups (as shown by DCA and NMDS) and it is certainly worth considering that the rise and fall of these two species is more directly related to local watermass conditions than to current transport. I'd like to know if there is any indication of EAC or PLC influence with *E. multicornuta* removed. And I'd like to see more discussion on the

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watermass conditions that might lead to monospecific blooms of these two species.

Specific comments/Corrections by page, line:

1, 20: I see the term “Tasman Gateway” or “Tasman Seaway” has been used in the literature but it’s incorrect. The proper term is “Tasmanian Gateway”, being the gateway between Tasmania and Antarctica (see any Leg 189 publication).

1, 22: “, including the organic walled cysts of dinoflagellates (dinocysts). I’d like to see a distinction made between dinoflagellates (plankton) and dinoflagellate cysts or dinocysts (fossil remains of the plankton)

1, 23: prefer “geographic” to “spatiotemporal” (here and elsewhere)

1, 24: “geographic” here is superfluous. And is it primarily controlled by tectonism? What about the rotation of the Earth? I wonder if this simplistic separation of tectonic and climatic controls is warranted or needed in an abstract? Sentence is awkward, so how about rephrasing: “The extent to which the climatic and tectonic controls on the distribution and composition of surface currents have influence the composition of fossil assemblages ...”.

1, 26: This sentence is also a little awkward. “Indeed, the extent to which climate change affects oceanographic processes is still poorly understood”?

1, 29: Also, an awkward sentence. “trend, the Middle Eocene Climatic Optimum (MECO, ~40 Ma). This 500 kyr-long episode of global warming is unrelated to ...”

1, 31: “ocean’s”; replace “only” with “alone”

2, 1: “our new results. . .”, no hyphen between surface and ocean

2, 2: replace “southward” with “south”

2, 3: Explain how “warm temperate with paratropical elements” MECO assemblage differs from the general middle Eocene pollen assemblage?

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2, 8: change “into” to “to”

2, 13: does “intermediate-deep” mean somewhere between upper and lower deep water or is it shorthand for “intermediate and deep”, in which case this formulation is less ambiguous.

2, 15: None of these sites are close enough to the Antarctic margin to be sources of deep water and are all north of the 60S demarcation for the SO, using pmag reference frame (although noting the uncertainty).

2, 18: change “marine-based” to “sea” and, no, they are not supported by estimates for land temperatures from NLR approaches, which are in general closer to the modelled temperatures (add Pancost et al. 2013), so SST estimates are 5-10C warmer than models and LAT estimates.

2, 21: add comma after processes

2, 22: remove parentheses around global

2, 31: plural “changes”. Lord Howe Rise is part of Zealandia so rephrase: “submerged parts of NW Zealandia. . .”

3, 1: that’s a lot of potential effects but rather speculative. Suggest you keep it simple. “. . . should have affected ocean circulation in the region with likely impacts for global heat transport and climate.”

3, 4: change “of” to “from”

3, 5: Change “Southern Ocean” to “SO”.

3, 6: Rephrase: “. . . endemism are characteristic of a diverse range of fossil groups . . .” (circum-Antarctic is tautological when you’ve already said Southern Ocean)

3, 9: here is where I’d prefer you to use “dinoflagellates”. If you use cysts here, you really also need to use frustules for diatoms and tests for forams and rads. Personally,

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I don't think you need to use "dinocyst" at all, but certainly should not be used when you are talking about plankton as opposed to assemblages in sediment.

3, 12: Query use of "cosmopolitan". This is unconventional usage. Cosmopolitan means found everywhere, so hard to see why this group signals the influence of the PLC or EAC.

3, 13: NZ is not in the Tasman Sea. It is east of it.

3, 26: change "biogeographical patterns" to "biogeography"

3, 27: why the "cf."?

3, 28: Why is "orbital scale" mentioned? Is it relevant? Why the "cf."?

3, 32: Why is deep ocean warming described as "transient" and surface-water warming described as "widespread"

3, 34: be a little more specific than "global perturbations"

4, 2: low-latitude and cosmopolitan are not the same thing.

4, 3: change "outstanding" to "unresolved"

4,5: Sentences in this paragraph from "In addition . . ." to end of paragraph should come before the description of the dinocyst assemblages. These sentences are part of the general description of the MECO.

4, 8: The two factors mentioned do not "imply" a volcanic explanation. Revise this sentence and provide a reference for the volcanic carbon hypothesis.

4, 11: Last sentence of paragraph is poorly worded. Revise.

4, 25: Revise: "in the 2–3 km-deep and 50 km-wide Ninene Basin".

5, 18: Delete "interval"; no hyphen between shallow and marine, as for 5, 21.

5, 31: Sentence doesn't make sense. What covers the unconformity and overlies basal

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Nirranda Group?

5, 32: “Latrobe-1 borehole”

6, 2: change “overlying” to “underlying”; What’s the age of the Dilwyn Fm?

6, 11: Elsewhere in text it is referred to as Hampden section. Be consistent. Why no mention of the work on the rest of the Eocene / Paleogene section (e.g. Morgans, 2009; Hollis, et al., 2012; Inglis et al., 2015)

6, 12: missing comma after “. . .E)”

6, 13: “end-member” is not the right word. How about “analysed to identify influences from the TC or EAC in the middle Eocene prior to the MECO”.

6, 28: lower case “s” for section.

7, 2: 50 and 90 are normally seen as too few for robust statistical analysis.

7, 5: and identified to what taxonomic level?

7, 14, 16: Key problem issue for this paper. Definition of “cosmopolitan” is ambiguous and not in line with convention: cosmopolitan = found everywhere. I recommend you use only low and mid-latitude taxa as your guide to PLC and EAC influence.

7, 27: Again, ambiguous terminology. Your example is not of a taxon with unknown biogeographic affinities, but with conflicting biogeographic affinities.

9, 7: What is meant by “spatial”? Lateral? Geographic might be a better term.

9, 24: U is not a direct proxy for TOC.

9, 26: Change “like” to “As with”.

10, 2: Change “for” to “of”.

10, 5: Change “dinocysts” to “assemblage”

10, 7: Can low salinity be consistent with low BIT?

10, 9: Change “most dominant” to “most abundant”.

10, 12: Differentiate cosmopolitan from low/mid latitude.

10, 13: What does “a.o.” mean?

10, 20: delete “at this site”; redundant.

10, 23: Provide error values for SST estimates and show on Fig. 3.

11, 8: “Precarious” is the wrong word, but a good choice nevertheless, because the whole interpretation of this section is precarious due to the subjective way the SST record has been interpreted. This is only one possible interpretation. Another is that the warming at 670 m precedes the MECO and perhaps can be correlated with the broad peak around 440 m at 1172. Thus, the MECO is the interval between 5570 and 600 m at 1170. This shorter duration is consistent with the biostrat and would mean that the cyst accumulation rate is not so untenably high. Both options should be considered.

11, 16: Poorly worded. “sufficient numbers of dinocysts were encountered for counts of 50-100 specimens to be undertaken. Other marine palynomorphs such as prasino-phytes and acritarchs, were rare/common(?)”

11, 31: Revise sentence beginning “Furthermore...” to “Cycadopites ... are also present but rare.

12, 1. Simultaneously is the wrong word. Delete. The abundance of Dilwynites, Protea... also decrease towards the top of the borehole.

12, 17. Very poorly worded but crucial sentence. The FO of this species is said to be at 40 Ma. When is the LO? It can only be used to define the MECO if it's restricted to the MECO. I conclude from the biostrat presented that the interval may include the MECO but equally may be younger (anywhere between 40 to 35.95 Ma).

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12, 24: Differentiate cosmopolitan from low/mid latitude taxa.

12, 29: Which species help to constrain the age? And revise to “this 4 m-thick interval within the section”.

13, 6: Use of “records” implies plural, meaning more than just the Hampden section. Are there data from other NZ sections?

13, 10: What is meant by “60degS front”? Do you mean the polar front? What evidence is presented for it lying north of the gateway?

13, 12: This SST range excludes the high SSTs in the MECO and possible MECO intervals. Why?

13,14: Surely we are not interested in mantle-based paleolatitudes, which are not linked to the Earth’s spin axis. Restrict discussion to the uncertainty on the pmag reconstruction.

13, 19. This is a key part of the argument, so needs a stronger word than “may”. How about “is more likely to”

13, 20. This is an observation, so replace “suggest” with “find”, but I suggest you drop the word “transported”, which is interpretation.

13, 21: “transported” is similarly redundant here - “southward reach of the warm EAC...”

13, 24: “Additionally” is not needed.

14, 1: This is an interesting finding, and should be investigated further (see general comments)

14, 7: This statement further serves to highlight why it would be helpful to differentiate cosmopolitan from low/mid latitude taxa

14, 15: You don’t explain how this species responded and consequently miss the op-

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portunity of expanding on a major discovery: mono-specific blooms of different species of Enneadocysta during the MECO at Sites 1170 and 1172 warrants more discussion.

14, 26: This section is based on the so-called “precarious” use of the SST record to define the EECO at 1170. The alternative correlation noted above also needs to be considered. Note too that the MECO has not been identified for sure on the Otway Basin and is not described at Hampden.

15, 18: Again, a stronger word than “might” is needed here: “most likely”?

15, 25: “production OF dinoflagellate prey . . .”

16, 3: Again “seem” is too weak a word. If there is evidence, specify it.

16, 4: Repetition. Replace “sporomorph record at” with “assemblages in”

16, 10: Numerous terms introduced here, either for the first time or with limited context: Wilson Bluff, Latrobe unconformity, Lutetian gap, Khirthar transgression. Consider which ones are actually needed for the argument and explain them more fully.

16, 28. Highly tenuous to suggest a short-lived event like the MECO could be linked to such a large- scale change in base level, accommodation space. A more fruitful approach may be to consider the longer-term climate shift from EECO to MECO, where significant cooling is inferred for early middle Eocene and the MECO is seen in the context of generally warmer conditions in the later middle Eocene (e.g. Pekar et al. 2005)

17, 15 and 18: STR and ETP are areas of ocean floor not localities, so the plankton communities are found “on” them not “at” them.

17, 20: Difficult to reconcile, but you suggest it may be related to the nature of pre-existing assemblages. Something on this idea needs to be added to the conclusions.

17, 21: This conclusion is contingent upon age model assumptions.

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17, 25: Correlation with the MECO is uncertain.

17, 26: SLR link to MECO is too speculative. Is there evidence for SLF after the MECO?

#### References:

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Pekar, S. F., Hucks, A., Fuller, M., and Li, S., 2005, Glacioeustatic changes in the early and middle Eocene (51-42 Ma); shallow-water stratigraphy from ODP Leg 189 Site 1171 (South Tasman Rise) and deep-sea  $\delta^{18}\text{O}$  records: *Geological Society of America Bulletin*, v. 117, no. 7-8, p. 1081-1093.

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