Reply to Reviewer 2 [in square brackets]

4 June 2019

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Overview

This DeepMIP contribution outlines methods for compiling proxy land and sea temperature and CO2 data for the latest Paleocene (LP), PETM and EECO across widely distributed sites in order to provide 1) insights into controls on warm climates and 2) boundary conditions and verification data for climate models. An initial database or "atlas" is provided with the anticipation of expansion, and requirements for proxy methods and data reporting are listed. The authors have done a very nice job thoroughly explaining complex paleothermometry theory and methods for the non-expert. They offer a detailed discussion of the strengths and weaknesses of each proxy, which is expected as the author list contains many of the best experts on the proxies discussed in the paper. As I am an end user of data from many of these proxies, and not a geochemist, I am pleased to see such a complete description of each proxy. It is clear that this contribution will have the added benefit of serving as a reference for climate scientists who are not intimately familiar with the entire array of proxies.

[We greatly appreciate this positive feedback and the very thorough review]

General Comments

Building a global dataset of past climate proxy data is challenging because in the course of data collection, new proxies are developed, existing proxies are improved, and age models are refined. Especially important is the collection of raw data and original sample designations. I am pleased to see in this manuscript the importance placed on the reporting of raw clumped isotope data. This requirement should be extended to all proxy data. Since we know that proxies evolve and develop over time, the availability of raw data will allow for reanalysis and new applications should they appear. On a similar note, the authors mention that brGDGT datasets should be scrutinized for temperature plateaus, which would suggest that the calibration has saturated. This scrutiny should be applied to other proxies as well, including those calibrated to modern data sets that may not be able to estimate temperatures warmer than modern.

[The database includes all available raw data for SST proxies, GDGT-based LAT proxies and clumped isotope-based LAT proxies. For other datasets, readers are referred to the source articles. However, we agree that it is helpful to have all the raw data in a single database and we hope to include more raw data in future versions of the database. Temperature plateaus are also mentioned in relation to leaf- and pollen-based LAT estimates. Calibration saturation is not significant issue for other proxies that benefit from culturing experiments in warmer than present conditions.]

I appreciate this multi-proxy approach – collecting a diverse array of paleoenvironmental data with the goal of better understanding the climate system as a whole. This is a necessary step in developing a global temperature reconstruction and will ultimately aid in future analyses of more nuanced, regional, non-temperature reconstructions. As we have seen in other global paleoenvironmental reconstructions, paleothermometry proxies become useful in discerning other aspects of the climate system, like water column structure (e.g., thermocline depth) and ocean circulation (e.g., upwelling strength), that will be useful as the models develop and will provide

additional insight into climate dynamics. It is important to remember that these different temperature proxies record different aspects of “temperature”, (i.e., the temperature at a certain water depth or during a certain season) and are likely complementary, yet not always directly comparable.

[Good point. We have added text to indicate that we focus on SST for oxygen isotopes and Mg/Ca ratios, but have tabulated data for thermocline species and referenced sources for benthic data sets. We have also added further comment on using benthic data to infer SST in polar regions]

This DeepMIP atlas is a fantastic compilation of data and represents just the beginning of LP, PETM, and EECO paleoenvironmental global climate reconstruction. What’s next? Specifically, how will this database be used in the DeepMIP models? Are the data compiled here enough to set model boundary conditions? I believe a short statement in the conclusions addressing these questions is warranted.

[Good recommendation. We have added this statement to the conclusions.

The DeepMIP database (v. 0.1) is the first step towards a comprehensive compilation of climate proxy data for the latest Paleocene, PETM and EECO. In its current form, it improves upon pervious datasets that have been used to identify areas of agreement as well as mismatches between Paleogene climate data and climate models (e.g. Lunt et al. 2012; Huber and Caballero, 2011). With further interrogation, using methodologies similar to those of Caballero and Huber (2013), we aim to derive estimates for global mean sea surface, land surface and overall surface temperature for the three time slices, which will help to advance our understanding of climate sensitivity under high CO2 conditions. The next challenge is then to add the full range of available climate data (e.g., salinity, precipitation, humidity, seasonal variability) to the DeepMIP database. With a recent study indicating that high growth/low mitigation scenarios herald a return to early Eocene-like conditions by the end of the century (Burke et al., 2018), the goals of DeepMIP are increasingly important and timely.]

Specific Comments

In Section 6.5, briefly define C3 plants. So much detail has gone into defining the basis of the other proxies, but a simple description of why C3 plants are useful is not included.

[We’ve added the following to the text:

Plants are differentiated into three main categories based in the method by which they fix carbon: C3, C4 and CAM. C3 plants have the simplest metabolic pathway in which the isotopic fractionation from atmospheric CO2 to plant tissue has been modelled (Farquhar et al., 1982).]

Alkenones are not among the SST proxies discussed here, presumably because they are not terribly useful during these time intervals. TEX86 is recommended as a good proxy for when alkenones are not present or are outside their calibration range, and this would be a good place to mention that alkenones are scarce before 40 Ma (as is mentioned later) and that they saturate at temperatures below those expected during these warm intervals. Alkenones are, however, listed as a CO2 proxy, though no alkenone-based CO2 estimates are included in Supplementary Data File 8, possibly because none exist prior to the middle Eocene. Are alkenones included here because they could be a

useful CO2 proxy if they were found in LP, PETM and EECO sediments? What is the likelihood of this? Also, Supplementary Data File 8 is not listed in the text or in the supplementary contents in Supplementary Data File 1.

[We have added a section on alkenones as SST proxies, and discussed their potential for future early Eocene paleotemperature and paleo-CO2 reconstructions.]

In Supplementary Data File 3, please better define "Setting" on the cover sheet. Are these water depths in meters? Are they modern or paleodepths? If "Setting" is the same as "Environment" on the following sheets, please use the same terminology.

[Corrected]

Also, please explain the 2.5, 50 and 97.5 columns. I assume these are percentiles? What do the shaded cells of different colors mean? Please make any changes and explanations consistent across all data tables.

[Colours and columns are now defined.]

Technical Corrections

Please look at these pages/lines more closely for minor mistakes. I've suggested corrections below.
4/5: Paleogne - Paleogene [*done*]

9/12: foraminifer - foraminifera [*done*]

9/15: undertake - undertaken [*done*]

9/17: biasin - bias in [*done*]

11/2: are - is [*done*]

11/22: allows - allow [*done*]

17/11: foraminifera - foraminiferal [*done*]

17/34: semi-quantitatively - semi-quantitative [*done*]

20/10: includes - include [*done*]

24/13: TEX86 (needs subscripts) [*done*]

24/15: in for - for (delete "in") [*done*]

26/24: pShouteroxy - proxy [*done*]

31/12: 28C - 28◦C [*done*]

33/4: results - result [*done*]

33/11: 25 - 25◦C [*done*]

35/9,9,14: Ma - Myrs [*done, but changed to "my", which is the abbreviation used earlier*]

40/29: are - is [*done*]

42/31: delete "from a single" [*done*]

43/15: C3 (not subscript) [*done*]

47:27: missing a parenthesis [*done*]

49/30: 20◦ - 20◦C [*done*]

50/18: sample – sampled [*done*]

Check the proper order of references. Some are ordered by year after the first author; others are ordered alphabetically by second author. Please also check for consistent punctuation in and around citation parentheses in the text.

[All corrected]

Should Farquhar et al. (1982) on page 44, line 18 be cited as Farquhar and Sharkey (1982)? Should Goericke et al. (1994) on page 37, line 16 be cited as Goericke and Fry (1994)? Zeebe (2007) is cited once in the text on page 12, line 33, but two Zeebe (2007) references are listed. Which one is correct?

[All corrected and added Farquar et al. (1982) to refs]

Check the following references for correct usage of a and b designations: Eagle et al., 2013 a and b Edgar et al., 2013 b Evans et al., 2018 a and b Schouten et al., 2013 a and b Sluijs et al., 2007 a and b

[All checked and corrected]

The following citations appear in the manuscript text but not in the References section:

- Bains et al., 1999: p91, l4 (Figure 2 caption) [*added*]
- Crouch et al, in prep: p92, l6 (Figure 3 caption) [*added*]
- D'Hondt and Zachos, 1993: p10, l7 [*corrected to D'Hondt et al., 1994*]
- Gradstein et al., 2004: p95, l7 (Figure 6 caption) [*added*]
- Huff et al., 2003: p30, l25 [*added*]
- Kennett and Stott, 1991: p91, l4 (Figure 2 caption) [*added*]
- Liu et al., 2009: p23, l25 [*added*]
- Lauretano et al., 2016: p90, l4 (Figure 1 caption) [*corrected to 2015*]
- Royer et al., 2005: p30, l25 [*added*]
- Si and Aubry, 2018: p8, l16 [*added*]
- Thomas et al., 2002: p91, l4 (Figure 2 caption) [*added*]
- Thompson et al., 2015: p32, l13 [*added*]
- Torsvik et al., 2012: p96, l4 (Figure 7 caption) [*added*]

- Urey, 1984: p8, l12 [*corrected to 1951*]

The following references appeared in the References section but not in the manuscript text:

- D'Hondt et al., 1994 [*see above, added to MS*]
- Roij et al., 2016 [*deleted*]
- Sluijs et al., 2008 [*deleted*]
- Sluijs et al., 2009 [*deleted*]
- Wilke et al., 2006 [*deleted*]