Clim. Past Discuss.,
https://doi.org/10.5194/cp-2020-157-RC1, 2021

Climate of the Past Discussions

Interactive comment on "Southern Ocean bottom water cooling and ice sheet expansion during the middle Miocene climate transition" *by* Thomas J. Leutert et al.

Anonymous Referee #1

Received and published: 22 January 2021

General comments:

Leutert et al present an interesting new record of bottom water temperatures from the Kerguelen Plateau during the middle Miocene – a time of substantial ice-sheet growth and cooling. The record will be a valuable contribution to our understanding of ice volume vs temperature changes in this interval. A revised age model for ODP Site 747 is presented and seems to be robust. New benthic stable isotope data match well with existing records. The paper is overall well-written; however, I suggest a substantial overhaul of the discussion.

The stand-out feature of the new temperature record is a large, transient (∼0.8 Myr-

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long) cooling of 3-5°C during the middle Miocene climatic transition, between ∼14.5 and 13.7 Ma. The fact that cool temperatures are recorded in three consecutive intervals (each made up of ∼30 analyses) suggests it is a robust signal. Because this large cooling occurs during an interval with only a small increase in benthic δ18O, the implication is that it was accompanied by significant de-glaciation lasting ∼0.8 Myr (shown by the large decrease in bottom water δ18O). This aspect of the record (its plausibility and implications, possible mechanisms that might have caused it, whether there is any other evidence for deglaciation at this time) are not discussed in enough detail in the paper. For example, the large step decrease in bottom water δ18O at ∼14.5 Ma is barely mentioned. No clear explanation for the cooling is given (although the subsequent warming is discussed). There is very little discussion of bottom/intermediate water circulation, which water masses might have bathed the site and how this might have changed over the study interval, deep-water formation (e.g. proposed Miocene onset of Antarctic Bottom Water Formation in the Weddell Sea, Pérez et al., 2020), changes in Antarctic gateways, etc. that may have influenced the temperature record. Importantly, the reader does not know what the Miocene paleodepth of the site was and to what extent benthic forams at this site might record local versus global temperature signals. The bottom-water temperature trends at Site 747 (based on Δ47) are quite similar to those seen at Site 806 based on Mg/Ca but not other sites, which is really interesting. Is there a water mass/circulation-related explanation for this?

Specific comments:

I have a couple of suggestions to improve Figure 1: Firstly, I would use a different (more inclusive) colour scale for the temperature map, as the rainbow colour scale is now widely known to be a poor choice both for colour-blind people and also for reproduction in grayscale. Secondly, I find the plate tectonic reconstruction shown in this figure difficult to interpret, because it shows tectonic plates including ridges and continental shelves, rather than a land-sea mask or reconstructed bathymetry. I suggest that the authors use instead a paleogeographic map which

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would more clearly show the distribution of continents and oceans and the paleodepths of sites; e.g. the Scotese paleogeographic reconstruction maps (Paleomap project); Straume et al. 2020 (paleobathymetry reconstructions available at 1 Ma resolution: https://zenodo.org/record/4193576#.YAb_heB7lXh); or Cai et al 2017 (which includes digital global paleogeographic maps in the supplement, including a 14 Ma reconstruction).

Introduction

"The middle Miocene geographic position of Site 747 relative to Antarctica was similar to today"; I found this statement a bit lacking in detail on paleolatitude, setting, etc., so I suggest expanding on this. Also the paleodepth of the site is not discussed – could a shallower paleodepth contribute to the relatively warm temperatures you reconstruct compared to modern, and the relatively large changes?

The $\Delta 47$ temperature proxy is well introduced, however given that you list all the potential caveats of the Mg/Ca paleothermometer as applied to benthic foraminifera, I feel the $\Delta 47$ proxy gets off quite lightly. A brief summary of the potential impact of diagenesis (dissolution, recrystallization, and overgrowth), burial, or other known non-thermal processes on $\Delta 47$ in benthic foraminifera and their effect on reconstructed temperatures would be useful, even though you discuss this in detail later.

Methods/Results & Discussion: I think it would be clearer if the Results and Discussion were separated.

Age model: I would move the Age Model section up so that it follows the Site Details section. In addition, an age-depth plot for Site 747 (in the supplement if necessary) showing all of the different tie points used (magnetostratigraphy, isotope-based, biostratigraphy) and the described hiatus would be very useful. Is the assumption that Site 806 sedimentation rates were constant and similar either side of the orbitally-tuned record between 14.1 and 13.3 Ma supported by shipboard magnetostratigraphic and biostratigraphic datums? I would verify this if you have not already, especially given

that this is the record that has the most similar trends to your new record. With this assumption, the comparison is not very robust. Presumably the original publication of the Mg/Ca record had age constraints that covered the whole interval? The calculation of uncertainties should be briefly described, rather than just referring to the supplement of another paper.

“Results from adjacent samples are pooled to achieve this number of measurements” Please be more precise about how many adjacent 2-cm samples were pooled together (mean, min, max depth/age intervals over which results were averaged). Samples were run on two different machines, but as far as I can see we cannot tell from the figures which data were run on which machine. It might be useful to colour code data points in Figure S3 to show that there are no machine offsets. Are the cited external reproducibilities for both of these machines? As a side note, I feel like Figure S3a should be shown in the main text (maybe as a top panel in Fig. 3), as it shows the raw data upon which all your subsequent data averaging and interpretations are based.

Fig. 3: horizontal solid lines: averaging intervals; it is not clear to me why the points are not plotted in the middle of the averaging intervals. Is the age of the points weighted towards the highest data density? Why was a 400-kyr moving window approach used rather than a Gaussian-Weighted Filtering approach, as in Modestou et al 2020? I am not sure which method is most appropriate, but the Gaussian-Weighted Filtering approach does seem to smooth out the small-scale features noted by the authors to be caused by scatter in measurements. Add an error bar for Mg/ca-based temperatures. On Figures 2 and 3, it would be helpful to highlight the middle Miocene climatic optimum and transition intervals, and also the hiatus.

Line 192 – again please specify how large/variable the intervals over which data were averaged are in the text. “We note that small-scale features in the moving average curves are likely caused by the scatter in the underlying individual $\Delta 47$ measurements, and should not be interpreted as real climate signals” For clarity, please quantify small-scale (<X °C) in this sentence. Lines 200-203 (and throughout the results and discus-

sion): I suggest citing temperature confidence intervals (± x°C at x CI) when describing absolute values, this will help to emphasise which trends are significant given the large error bars on Δ47 temperatures (e.g. a 3-5°C cooling is larger than 68% CI). Line 218: How do the recalculated bottom-water temperatures from Site 761 compare to the originally published values? Line 229: What artefacts could result from comparing a low-resolution record of discrete samples (each representing maybe 1-2000 years, without knowing if it is a glacial or an interglacial) with a record where each sample integrates hundreds of thousands of years? Line 269: do the authors have any suggestions as to how to investigate this? Line 288: include d18Obw errors in the text. "For the later MCO (15.6–13.9 Ma), our estimates of δ18Obw range from around -0.3 ‰ to 0.7 ‰' This statement doesn't really adequately describe the large step changes in reconstructed bottom water δ18Obw at ~14.5 Ma and 13.7 Ma. Line 294: due to their temporal resolution and also due to averaging of many samples probably mixing glacial and interglacial climate states. Line 326: what was the interpretation of this change in vertical gradient?

Reference:

Pérez, Lara F., Yasmina M. Martos, Marga García, Michael E. Weber, Maureen E. Raymo, Trevor Williams, Fernando Bohoyo et al. "Miocene to present oceanographic variability in the Scotia Sea and Antarctic ice sheets dynamics: Insight from revised seismic-stratigraphy following IODP Expedition 382." Earth and Planetary Science Letters 553 (2020): 116657.

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