

## ***Interactive comment on “Early westward flow across the Tasman Gateway” by W. P. Sijp et al.***

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Received and published: 29 January 2016

### **Response to Review 2 of “Early westward flow across the Tasman Gateway” by Sijp et al.**

Reviewer comments are in *italic*. This response contains revised and new figures, uploaded to the site.

*This paper provides a good example of applying paleoclimate model simulations to evaluate a hypothesis based on empirical paleoclimate data, in this case that shallow opening of the Tasman Gateway in the early Eocene led to westward flow across the gateway. This study shows that under specific paleogeographic conditions such flow is consistent with ocean circulation models. While not especially groundbreaking, this*

C3082

*study does add to our understanding of how the opening of southern hemisphere gateways influenced climate change in the Eocene.*

*Overall, I found the results and analysis to be sound and well described. However, section 3.2 (Temperature changes in response to gateway opening) is unsatisfying. In this section the authors point out that they observe no SST cooling during opening of the Tasman Gateway, in contradiction of the earlier findings of Bijl et al. The authors then discuss alternative model experiments where deep sinking in the Ross Sea is suppressed, where cooling is observed. However, these alternative model experiments are not discussed elsewhere in the manuscript, the results are not shown in any figure, and there are no citations to other work with similar studies. I think if the authors are going to include these alternative experiments they need to document them much more closely. They should be discussed in the methods (with more details on the model set up), the results should be shown in a figure, and previous studies with similar experiments should be cited. Otherwise, these alternative model experiments should be left out, and the authors should simply state that the model results are not consistent with the paleoceanographic data in terms of an SST response to gateway opening.*

We now remove all reference to the alternative experiments with Ross Sea sinking suppressed, and simply state that our model does not show significant cooling upon gateway opening. Our reasons for doing this, in addition to responding to the reviewer comment, are that we feel these additional experiments were also somewhat artificial in nature. They required a rather high local fresh water flux that may be difficult to justify, and the simulation did not constitute a natural unforced equilibrium of the model. The original intention of these alternative simulations was to find out under what conditions an AAG cooling response to shallow TG opening could be expected.

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Specifically, the intention of these alternative simulations was to see whether deep sinking suppression could produce sufficiently cooler conditions in the Ross Sea, so as to yield AAG cooling upon TG opening. However, although Bijl et al., 2013 shows that the gradual Myr cooling started time-equivalent to opening of the TG, the direct cooling effect of TG opening is minor. This is because proxy data suggest that SSTs were similarly warm on both sides of the TG before opening. This is in fact in agreement with our standard simulations presented in the paper, and attempts to obtain alternative scenarios by forcing the model to obtain a temperature difference across the TG would serve little purpose as this would be contrary to proxy findings.

In response to this reviewer comment, we include an additional new figure 7 showing the SSTs for TG closed in our standard experiments, having (a) DP closed and (b) DP open (just before the old figure 7 showing the SST difference in response to TG opening).

We also add the following text at the beginning of section 3.2 on page 5032:

“Sea surface temperatures close to Antarctica have similar values of 10 to 12 degrees C on both sides of the TG when the TG is closed and DP is open or closed (Figure 7).”

And change the original beginning of this section to:

“As a result, although a westward flow emerges from the Ross Sea to the AAG (see above), the opening of the TG in our model configuration where the DP remains closed leads to no significant sea surface temperature cooling (Fig. 8).”

C3084

*Otherwise, I have minor comments and suggestions outlined below. There are a number of instances where typos or grammatical issues complicate the understanding, so the authors should take care to proofread the article before publication.*

We have conducted further proof reading.

*Title: This title is very broad, and makes it sound like this paper provides empirical evidence for “early westward flow. . .”. I would suggest changing the title to more accurately reflecting the study, such as “Model simulations of early westward flow. . .”*

We now change this title to “Model simulations of early westward flow across the Tasman Gateway”.

*P 5022 Line 21: add i.e. before “the ACC. . .”*

We changed this.

*P 5024 Line 8: add “and” between Kennett citations.*

Done.

*P 5025 L 8: “must have occurred south”- meaning unclear*

We change this to: “Eastward flow through the Tasman Gateway would be expected to bring the low-latitude species from the Australian margin into the SW Pacific Ocean.

C3085

This is contrary to their findings, therefore, they hypothesize that the throughflow must have occurred south, perhaps within the reach of the easterlies, allowing the throughflow of the taxa present in the Ross Sea that consistently dominate the westward flow along Antarctica, the Eocene Antarctic Counter Current. ”

*L 12: This sentence is poorly constructed.*

We change this to:

“Organic biomarker proxy records for paleotemperature of the sea surface and the air temperature were derived from the same sedimentary archives as the oceanographic reconstructions. They show that the opening of the Tasmanian Gateway coincided with surface water and air temperature cooling of several degrees (2–4 degs), of which the Antarctic hinterland cooled the most (4 degs).”

*L 14: How are the Antarctic hinterland temperatures known? Is this based on MBT/CBT temperatures? If so it is fairly uncertain what location is reflected in those temperatures. More detail on this claim is needed. Also, error estimates on the temperature changes are needed.*

We agree that “hinterland temperatures” is not a very specific term. Three proxies for air temperature are used on the marine sediments offshore Wilkes Land, based on vegetation composition and their nearest-living-relative temperature requirements (Pross et al., Nature 2012), one organic geochemical proxy based on soil bacteria (Weijers et al., 2007; Pross et al., 2012) and one mineralogical proxy on the temperature dependency of weathering products (Passchier et al., 2013). The latter is likely from further inland than the presumably coastal temperature reconstructions from the

C3086

vegetation and soil.

*P 5026 L22: How were the depths for the two gateways chosen? And why are they different? It seems like these depths could be quite important for the results of the study. More background on why they were chosen, and what evidence supports these choices, is needed.*

The depth of the gateways were chosen so as to be shallow, but still allow the coarse resolution model to simulate oceanic throughflow. The real ocean would produce currents at shallower depths that the model can not reproduce. However, running the model with somewhat deeper gaps does not give substantially different results. We refer to Sijp and England 2005 for an extensive study on the effect of gateway depth on global climate.

*P 5030 L 17: Cut the word eventually.*

We cut this word.

*P 5030: It would be better to be quantitative about the tracer studies in the text. What does enhanced mean quantitatively? What about limited?*

We change “locally enhanced tracer concentrations” on line 22 of page 5030 to the mathematically precise term “local maximum in tracer concentration”, and add that this maximum is X, Y percent of the global maximum Z. The word “limited” on line 26 refers to lower latitude taxa remaining geographically limited to the west of the TG according to Bijl et al. (2013). We now replace “limited” by “geographically constrained”.

C3087

*P 5031 L 19: "none of that" is vague- it would be good to be more specific.*

This part of the sentence refers to time, and we agree it is unclear. We replace "and none of that is seen before" by "and not earlier."

*L 29: I think if the authors are confident in this result they should extend the analysis, and state that it provides evidence for a later opening of the Drake Passage.*

We are confident of the results. We note that strictly speaking, either Drake Passage was closed or there were very significant obstructions upstream or downstream obstructions near the DP.

To indicate confidence, we replace "suggests" on line 27 with "indicates".

A further analysis is provided on page 5033, and here we replace line 17:

"As said, our results do not strictly dictate an absence of flow through the DP, but rather suggest that the results of (Bijl et al., 2013), and their inference of an Antarctic Counter Current, are point to severe obstructions to a wide and deep flow through DP and nearby areas at similar latitudes."

with a stronger statement containing the above "caveats":

"Our results, and those of Bijl et al. (2013), indicate a later opening of the DP.

C3088

Alternative to DP closure, we raise the question (for future research) whether a similar effect could have been achieved from severe obstructions to a wide and deep flow through the DP and nearby areas at similar latitudes, a possibility not explored in our model experiments."

*P 5034 L 17: "Build" should be built*

We replace "build" with "built"

*Figure 1: It should be made clear what negative and positive values indicate (i.e. westward or eastward flow). Also, I think it is confusing and misleading to have different scales on all of the color bars. I would strongly suggest making them uniform in this and other plots.*

We add to the end of the figure caption: "Positive values indicate eastward flow, negative values indicate westward flow."

*Figures 5 and 6: It would be helpful to have the two different sources have different color schemes to better differentiate them. Also, as above, the color bars should have the same scale in each panel (i.e. they should all go from 0 to 15).*

We have now assigned the same scales to all the color bars in figures 5 and 6. We have also used different color schemes for the different source regions, orange indicating warmer water species and blue indicating cooler water species.

The tracer snapshots were taken at different times since their release for different

C3089

figure panels, resulting in different color bar scales. We have now calibrated all experiments by showing each experiment at the same time since tracer release, namely 5 years. We now add to sentence 5 on p11, after “ellipse”: “We examine a snapshot taken 5 years after tracer release.”, and add this to the figure captions as well.

*Figure 7: I think the last sentence of the caption is mislabeled here. Based on both the text and the figure, I think it should say there is cooling to the east of Australia when the DP is open.*

Correct, thank you for noticing this mistake. We now change the sentence to:

“The opening of the TG leads to a maximum of around 4.0 degrees C localized surface ocean cooling to the west of Australia upon opening the TG only when DP is open.”