

Clim. Past Discuss., referee comment RC2  
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## Comment on cp-2022-35

Anonymous Referee #2

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Referee comment on "Unraveling the mechanisms and implications of a stronger mid-Pliocene Atlantic Meridional Overturning Circulation (AMOC) in PlioMIP2" by Julia E. Weiffenbach et al., Clim. Past Discuss., <https://doi.org/10.5194/cp-2022-35-RC2>, 2022

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This study investigates the cause of the stronger AMOC in the PlioMIP2 ensemble and how Atlantic OHT and North Atlantic SSTs are influenced by this strengthening. In alignment with the findings of Otto-Bliesner et al., the authors conclude that the closure of the Bering Strait and Canadian Archipelago is the primary cause of the strengthening of the AMOC in the PlioMIP2 ensemble as it leads to a decrease in the southward freshwater transport into the Labrador Sea promoting high salinities and hence deep water formation. The authors go on to investigate the relationship between changes in the strength of the AMOC and changes in ocean heat transport. They find that AMOC driven increases in the ocean heat transport are partially compensated by a reduction of the gyre component, which helps to explain the model spread in ocean heat transport responses. I found the paper clearly written and analysis presented to be very thorough.

### Major comments

- When comparing simulated and reconstructed Pliocene SSTs Ln 110 mentions that an observational pre-industrial SST dataset is used to calculate the Pliocene minus Preindustrial SST change for the six different sites. If core top values are available they should be used rather than the pre-industrial SST dataset as using the former provides more of an apples with apples comparison and can have an impact e.g. The Haywood et al. (2020) analysis shows no Pliocene warming off California when differencing the Foley and Dowsett Uk37 records from the preindustrial SST dataset, but in Tierney et al., 2019 which differences these records from core top shows significant warming.
- In establishing the mechanism responsible for the higher North Atlantic salinities in Fig. 5 I am not 100% convinced by the analysis that led to the statement "we find no indication that the PmE freshwater flux is the driving force behind the mid-Pliocene AMOC strength increase". While the analysis provided in Section 3.2.2 is thorough and provides a case for the role of reduced freshwater transport associated with the closure of the Canadian Archipelago (0.04 Sv), I do not find the analysis in Section 3.2.3 convincing in ruling out the role of changes in the Pliocene-Preindustrial North Atlantic

surface freshwater flux. Fig. 8 shows that the MMM P-E is more negative over most of the subtropical gyre and parts of the subpolar gyre in the Pliocene simulations. This leads to more saline surface waters within the subtropical gyre (Figs. 4 & 5) that are advected into the subpolar region. Evidence of this is also seen in Fig. 6c if one takes the divergence (derivative) of the red and black lines respectively. The more rapid decline in the wind-driven northward freshwater transport (Fig. 6c, blue dashed line) is presumably due to enhanced surface evaporation due to warmer sea surface temperatures (particularly given the results of the gyre transport analysis in Section 3.4). This implies that another major cause of the higher Pliocene salinities is enhanced subtropical evaporation which is not adequately captured when using the local region defined in Fig. 8a (due to the role of advection). Therefore in addition to the closure of the Canadian Archipelago mechanism, perhaps the warmer north Atlantic SSTs due to more positive regional radiative feedbacks or forcing changes in PlioMIP2 relative to PlioMIP1 might also help explain the stronger MMM AMOC result? An ocean salinity budget such as those conducted in Emile-Geay et al., 2003 and Burls et al., 2017 provide a framework that would account for the relative roles of freshwater transport and surface freshwater flux changes. While conducting such an analysis might be beyond the scope of the current study, the authors need to either provide an analysis that rules out a significant role for surface freshwater flux changes (e.g. converting mm/day x area to a Sv change over the subtropical and subpolar regions respectively to compare with the 0.04Sv change in the freshwater transport at 65N) or discuss this caveat in their interpretation accordingly.

Emile-Geay, M. A. Cane, N. Naik, R. Seager, A. C. Clement, A. van Geen, (2003) Warren revisited: Atmospheric freshwater fluxes and "Why is no deep water formed in the North Pacific." *J. Geophys. Res. Atmos.* 108, 3178–3112

Burls, N J, A V Fedorov, D M Sigman, S L Jaccard, R Tiedemann, and G H Haug, (2017) "Active Pacific Meridional Overturning Circulation (PMOC) during the Warm Pliocene." *Science Advances* 3, 9, e1700156.

### **Minor comments and suggestions:**

Ln 30-35: When comparing the response of the AMOC in future warming scenarios with Pliocene warming one has to take into account the timescales of the mechanisms involved and if the transient or equilibrium response is being assessed e.g. the short-term stratification of the Ocean which leads to AMOC decline in 21<sup>st</sup> century in projections will weaken as heat diffuses downwards and there can be recovery as equilibrium is reached. A sentence or two acknowledging this subtlety is needed here.

Eqn 1: I suggest changing  $vT$  to  $\bar{vT}$  to indicate that this is the 100-year mean of the product of  $v$  and  $T$  as opposed to the product of the 100-year mean of  $v$  and  $T$  respectively as in equ 3. Similarly for Ln 145, change  $vT$  to  $\bar{vT}$

Ln 167-168: Are COSMOS and HadCM3 the only two model for which the total OHT is inferred from the SHF? Is the  $\bar{vT}$  save and provided for all the other models?

Figure 2 caption: I am confused about the calculation of Fig. 2b is "with respect to the average MMM North Atlantic SST (30N-70N)" supposed to be "with respect to the average MMM North Atlantic SST (30N-70N) anomaly"?

Section 3.1.2 and Fig. 3: This is for zero lag-lead and the annual times scale. The correlations between AMOC and SST could be stronger, and perhaps more similar, if the lag/lead of maximum correction for subpolar SST is shown? Also if a ten-year running mean is applied to filter out the influence of processes influencing SST associated with atmospheric noise.