Review of Chen et al. “Shoaled glacial AMOC despite vigorous tidal Dissipation: Vertical Stratification matters”

This is a nice result of one particular ocean model that shows only a slightly stronger LGM AMOC then present day, but more shoaled, using a stronger calculated LGM tidal mixing. Ferrari 2014, suggested that a shallower interface between North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW), as observed for the LGM, reduced mixing between the two water masses, and in turn increased deep carbon. So this study can help test our understanding of biogeochemical cycles during deglaciation in further studies that come along. The impact of the strong LGM forcing on the mechanical forcing of the AMOC is novel. It would have been nice to see further theoretical analysis on how the mixing does not impact the AMOC in the upper ocean (e.g. meridional transport based upon zonal density gradients etc.). Also I find there isn’t much effort put into describing the ocean model here and giving a more detailed description or illustration of how the ocean model actually performs against modern observations , in particular how the water masses compare and how the stratification compares in modern (see below).

L47-50: Add some more text here that there is more dissipation in the interior instead of the shelves at LGM. Removing the shelves reduces the damping of the tides and leads to increase in tidal amplitude.

L92: You might mention here that the use of ICE-6G instead of ICE-5G is suggested to reduce internal vertical mixing and would therefore suggest a further weakened AMOC (Wilmes et al 2021).

In Figure 3 (left column) I would like to see instead a vertical profile of horizontally averaged N^2 and the mean values. What mean values are used in the tide model D_IT (internal wave drag)? Are they taken from the PD and LGM simulations?

Section on Ocean Model: I would like to see more information about the ocean model described here. What is the resolution? In addition to “Figure S1 presents the horizontal resolution of the meshes for PD and LGM”. please describe it here. How does it perform with respect to the present day? Isn’t the AMOC a little weak compared with the RAPID array or other observations? How is the modern ocean forced? Does it use COREv2 AMIP type forcing? I want a better description of how the stratification compares with modern day observations. Maybe a T-S density showing different water masses in the ocean compared with modern observations (say ARGO). We don’t get a good feel from this document on how the model actually performs against modern observations, which is the most important part of the paper.

Line 115: In ocean models “K_bg is employed to manage the effects of various background mixing mechanisms”. However, the tidal mixing parameterization considers the locally dissipated energy over topography (⅓ of the total energy dissipation). The other ⅔ is dissipated in the far-field in which the background diffusivity is used to represent this. Is this correct interpretation? If so , wouldn’t this tend to underestimate the effect of the increased tidal mixing.

Therefore, there is a constant internal energy dissipation due to internal wave breaking in the far field of something of the order of Integral ( Gamma^-1 * rho * N^2 kbg) dV. Do you know how large this value is?

Line 121: Kv_tidal is dependent on N^-2 and the internal tide dissipation energy, epsilon. Epsilon is increasing at LGM , but the stratification is also increasing . I would like to see a quantitative comparison of the results produced in Figure 2 (right column) due to each component , the internal tide energy dissipation and the stratification.

L125: One of the biggest problems I have is with these Jayne et al 2009 type parameterizations is the vertical decay function F using this universal e-folding factor of 500m. Would this not tend to overestimate the internal tide mixing energy in shallow seas? But if your hypothesis is true, then the LGM surface forcing overcomes these inadequacies in the parameterization.

L133: “which resonates with the North Atlantic basin”. Do you mean that the predominant contributor , the M2 tide, has increased resonance in the North Atlantic at LGM. Isn’t this due predominantly because of the removal of the shelves at LGM and the increases of tidal mixing in the deep North Atlantic Ocean at LGM?

L135-136: So the horizontal variations of D_IT are put into FESOM in a one off setting. I assume the variations in the Brunt Vaisala frequency are taken from an LGM simulation then used to calculate the LGM tides and then the ocean model is run with these. There would presumably be some feedback between the stratification and the tide model if this were done in a proper interactive way and that the results might be different if this were done. This should be mentioned here.

L142 expand on “we apply five cycles”

L147 Also the atmospheric forcing is held fixed. A reduced AMOC would have reduced heat transport to the North Atlantic which would favour sea ice growth to some degree, even though the atmosphere tends to compensate for the lack of ocean heat transport. This would presumably affect deep water formation and stratification. The same would happen around Antarctica. This limitation should be discussed or mentioned somewhere.
This atmospheric forcing aspect is, however, mentioned briefly in the conclusions.

L160: See comments in L121 above.

L170: In PD scenarios integrating the tidal mixing…

L172 Mention Table S1 here.

Discussions:

This is a nice result and this paper should be added to the literature on the subject. In particular as the discussions conclude, the study suggests that stronger stratification significantly reduces the impact of tidal dissipation. However, in the abyssal ocean with relatively weak stratification, the pronounced tidal dissipation during the LGM notably enhances the formation of AABW.

In paleoclimate settings, increased AABW production is often associated with a colder Antarctica and increased sea ice. From Table S1, some of the increase appears to be due to the atmospheric forcing.

Maybe add a comment that since the LGM atmospheric forcing is fixed, it separates out possible effects that would occur due interactions of Southern Ocean sea ice growth on AABW formation.