

Dear Editor and reviewers,

We appreciate the expert comments provided by the reviewer. Below we provide a detailed point-by-point response to all these comments. The reviewer's comments are shown in black, and our responses follow in red font. The quoted texts in the revised manuscript are in blue. Line numbers in this response reflect those in the revised manuscript unless otherwise noted.

The manuscript has been improved but there are still issues which should be amended before I could recommend its publication:

L60-61: *“First, both the B-A age and B-P age are considerably older at the LGM (~20 ka) than the preindustrial period”*

“Considerably” is rather vague and should be quantified or be removed.

Corrected

L82: *“This new approach of BwP age is considerably similar to the true ocean ventilation age globally”*

(1) The new approach is still unpublished, and Fig. 1 only shows that its results (but not that the various methods) are similar.

This is precisely what figure 1 shows, that BwP age derived using the new approach is very similar to the ideal age. The new approach itself (including the evaluation using observations) is beyond the scope of this work and the main conclusions of this work do not depend on the manuscript in review (Du et al).

(2) “Considerably” is rather vague and should be quantified or be removed.

Corrected.

(3) The “true” ocean ventilation age is the “ideal” model age (IAGE). Therefore, it would be more appropriate to rephrase, e.g., “These new BwP ages are similar to the ideal ocean ventilation tracer ages ...”

Revised as suggested. This is clarified in the revised manuscript: “This new approach of BwP age is similar to the ideal age (IAGE) globally” in line 82-83.

L194: *“dramatic bell shape”*

“Dramatic” should be removed.

Corrected.

L195-196: *“A similar bell shape pattern is also seen for the Pacific and Atlantic mean”*

There is definitely no bell shape in the Atlantic but a clear age drop near 14 ka BP.

This is now clarified in the revised manuscript: “A similar bell shape pattern is also seen for the Pacific mean (Fig. 1b)” in line 195-196.

L209-210: *“ (...) the decrease in global AABW transport aligns with the increase in global mean IAGE during the same period (14–13 ka).”* According to Fig. 1d, AABW abruptly increases between 14-13 ka BP, that is, before the age peak at 12.9 ka BP. What is the explanation for this lag?

This is now explained in the revised manuscript: “As shown in figure 1, starting from 19 ka,

the GMOC and AABW both fall rapidly and then shows a sharp recovery. When the AABW transport reaches its minimum strength at approximately 14 ka, the global mean IAGE increases towards its maximum at 12.9 ka. The lag between the AABW transport minimum at 14 ka and IAGE peak at 12.9 ka is likely because the “memory” of ocean typically last thousands of years. That is, the response time scale for the slow evolution of circulation associated with the AABW and abyssal flows can be over a thousand years. As such, the decrease in global AABW transport aligns with the increase in global mean IAGE during the same period” in line 207-212.

L274-277: “*The mean IAGE for AABW water mass increases from 836 years at the LGM to 1813 years at 14 ka due to the weakening of AABW transport, while the age of NADW increases by up to 1500 years during the period of 12–11 ka due to more NADW sinking into deeper depths in the Arctic (Fig. 2j-l), resulting in a relatively older water age for NADW and the lag of 2000 years between the maxima of Dye_NA and Dye_S (Fig. 3a-b)*”.

(1) It would be more obvious to show a time series of NADW strength which could be added to Fig 1d.

Actually, the time series of NADW is shown as GMOC in Figure 1d, which is diagnosed as the maximum in the GMOC streamfunction below 600 m from 33° S-60° N. Therefore, the main feature of the GMOC follows the upper clockwise cell mostly confined to the Atlantic sector.

(2) How is it possible that enhanced NADW production, i.e. enhanced ocean ventilation can lead to water mass ageing?

In order to avoid confusion, this sentence is now revised in Lines 280-282: “*The increased water age of NADW is attributed to a greater fraction of NADW sinking into deeper Arctic depths (Fig. 2j-l), resulting in an increased water age for NADW as distance from the formation regions increases and the lag of 2000 years between the maxima of Dye_NA and Dye_S*”.

(3) According to Fig 3b the volume of North Atlantic waters decreases between 14-12 ka. This seems to contradict more NADW sinking.

We believe the revised texts (see our response above) improves the clarity. Figure 3b shows the total volume of NADW below 1 km in the interior ocean, and it does not necessarily mean enhanced NADW production. We see how our original language could be confusing, which is now revised in Lines 280-282.

(4) I am not sure of how to interpret Fig. R3 in the author’s reply to my first review. What are the units? It appears that DYE_NA at 2 km declines before the maximum of IAGE in Fig. 3a in the paper.

The unit is percentage, similar to Gu et al. (2020). The intention of figure R3 is to show an example of more percentage of NADW water mass sinking into greater depths (up to 3.9 km) in the Arctic since 14.5 ka. As NADW water mass sinks into deeper depth, the water age of NADW generally increases with distance from the formation regions. As such, the IAGE of NADW increases to its maximum during 12 – 11 ka in figure 3a. This is now revised in Lines 280-282.

L333-334 (and L315 in the initial submission): “*The calculated southward DWBC and northward AABW DWBC are validated by the model MOCs, which are defined the same as*

in the C-iTRACE". You cannot validate model results with model results obtained with the same model and in the same simulation. If the results were not consistent something would be wrong.

This is clarified in the revised manuscript "The calculated southward DWBC and northward AABW DWBC are consistent with the model MOCs" in line 338-339. In this work, the model MOCs are calculated based on complete velocity analyses from top to bottom at numerous latitudes, while the calculated northward DWBC and northward AABW across different basins in this work are only calculated using meridional velocity at 30° S. In other words, MOCs are "ground truth" in this context, and therefore we believe the comparison is necessary to assess the accuracy of the calculations.

Reference:

Gu, S., Liu, Z., Oppo, D. W., Lynch-Stieglitz, J., Jahn, A., Zhang, J., and Wu, L.: Assessing the potential capability of reconstructing glacial Atlantic water masses and AMOC using multiple proxies in CESM, *Earth Planet. Sci. Lett.*, 541, 116294, <https://doi.org/10.1016/j.epsl.2020.116294>, 2020.