Dear Editor and reviewers,
We appreciate the expert comments provided by reviewers. Below we provide a detailed point-by-point response to all these comments. The reviewers' 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. We thank the reviewers for the detailed comments and suggestions, also the time and effort that they invested into the review. We believe the revisions have strengthened the manuscript.

General Comments
The paper is motivated by the differences between the temporal evolution of ^{14}C ages and ideal ages shown in Figures 1 and 9. That ^{14}C ages are higher than ideal ages is not new (e.g. Koeve et al. 2015). There are also other models showing for the LGM higher ^{14}C ages but at the same time younger ideal ages compared to PD (e.g. Galbraith and de Lavergne 2019; see also the discussion by Skinner and Bard 2022). Apart from the introduction, ^{14}C ages are not really discussed or compared with observations. In fact, this has been done by other authors (Gu et al. 2020, Zanowski et al. 2022). The focus of Li et al. is on the discussion of simulated ideal ages. Here, a systematic problem is that there is no way to validate ideal ages with observations from the past. Therefore, the results by Li et al. may be helpful to understand the model behaviour in the C-iTRACE and iTRACE simulations, but the added value for our understanding of real marine proxy records is limited.
Respectfully, we do not agree with this comment. The scope of this modeling study is to better understand the simulated deglacial evolution of deep ocean ventilation age, focusing on the feedback mechanisms in one of the most widely used Earth system models. The focus is not model-proxy comparison, because the transient ocean simulation of the last deglaciation (C-iTRACE) have been examined in detail in Gu et al. (2020, 2021b) and Zanowski et al. (2022).

Specific comments
Figure 1 and line 75: "incredibly identical" "BwP" ages. This is indeed incredible unless further details of this unpublished approach are provided.
We thank this reviewer for the language suggestion. In the revised manuscript "incredible" is removed and this sentence now reads "This new approach of BwP age is considerably similar to the true ocean ventilation age globally" in line 82-83.

Figure 1: "BP" (= 1950 CE) should be defined somewhere (maybe near line 23)
This is clarified in revised manuscript as "all times (calendar ages) are reported in thousands of years before present (ka BP where BP indicates 1950 CE)" in line 130.

Figures 1 and 9: It would be worthwhile to include the Atlantic to facilitate the understanding of Figs. 6 and 8
Revised as suggested.

Line 56: "AABW is defined as the minimum (...) from 2°S-70°S" – does it make sense in this context to consider 2°S which is far away from the source water = ventilation regions?
The AABW transport in the manuscript is diagnosed as the minimum value in the Global Meridional Overturning Circulation (GMOC) streamfunction below 2 km. Therefore, it is reasonable to consider the abyssal ocean as far as 2° S to define overall global AABW transport.

This is clarified in the revised figure captions: "Here the GMOC intensity is diagnosed as the maximum in the GMOC streamfunction below 600 m from 33° S-60° N, and AABW is diagnosed as the minimum in the GMOC streamfunction below 2 km over 2° S-70° S".

Line 57: "ventilation time" should read "ventilation age"
Corrected.

Lines 61-62: "both the B-A and B-P age are remarkably old[er] at the LGM than the present day". This is not really the case for B-P ages shown in Fig. 1.
As shown in Figure 1, in the C-iTRACE simulation, the B-P age is approximately 1600 and 1480 years at the LGM and PD, respectively. This is clarified in revised manuscript: "First, both the B-A age and B-P age are considerably older at the LGM (~20 ka) than the preindustrial period (denoted here as the present day or PD, ~0 ka)" in line 60-61.

Line 79: There are no "true ventilation" proxies, see my comment above
We agree. In principle, radiocarbons have been considered as the best proxy for estimating the water age. However, it is still challenging to have an accurate estimation of deep ocean water age from radiocarbon (e.g. due to marine reservoir age). Therefore, the purpose of this manuscript is to provide additional model perspectives on deglacial changes in the deep ocean ventilation age and associated mechanisms. This is clarified in the manuscript: "Due to the potential challenges in radiocarbon proxies to accurately estimate the deep ocean ventilation age, we will address the second question regarding the mechanism of the deglacial evolution of the model ventilation time, in order to provide additional model perspectives on changes in the global ocean ventilation age during the last deglaciation" in line 86-89.

Line 120: "Ventilation" originally meant "oxygenation" of the deep sea; in this sense "ventilation ages" and "ideal ages" are not really the same for (chemical) oceanographers.
Indeed, these are different concepts. However, it is also common practice in modeling studies to track the water ventilation age using passive ideal age tracers, see England (1995), Galbraith and de Lavergne (2019), etc.

Figure 2 (h)-(i), lines 133 and 168: Contour lines in Fig. 2 represent the value of 0.8 but ideal ages are calculated where the percentages of AABW and NADW exceed 70%. This should be consistent (i.e., 0.8/80% or 0.7/70%)
We thank this reviewer for the suggestion. The contour lines in figure 2 are now corrected to represent the value of 0.7.

Figure 3 (a): What is the reason of the lag of ~2 kyears between the maxima of DYE_NA and DYE_S?
The maxima of DYE_S is due to the weakening of AABW transport, and the maxima of DYE_NA is due to NADW water masses sinking into deeper depth in the Arctic region. This is now clarified in the revised manuscript "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)" in line 274-277.

Line 193: "decrease in AABW transport and increase in IAGE during the same period (14-13 ka)" is at odds with Figure 1

This statement is actually consistent with Figure 1. Between 14 and 13 ka, the decrease in the global AABW transport (blue line in Figure 1D) corresponds to an increase in the global mean IAGE (black line in Figure 1A). We see how our original language could be confusing, which is now clarified in the revised manuscript: "This bell shaped deglacial evolution of global IAGE aligns with similar transport evolutions of the residual GMOC and global AABW (Fig. 1d, Fig. 2d-f) as well as the AABW% in dye tracer from the Southern Ocean (Fig. 3, Fig. 2g-i). Here, the GMOC is diagnosed as the maximum in the GMOC streamfunction below 600 m from 33° S-60° N and, therefore, the main feature of the GMOC follows the upper clockwise cell mostly confined to the Atlantic sector. Since the abyssal ocean is predominately filled by AABW, the evolution of IAGE corresponds more closely to the AABW intensity than GMOC as shown in figure 1 that the decrease in global AABW transport aligns with the increase in global mean IAGE during the same period (14–13 ka)" in line 203-210.

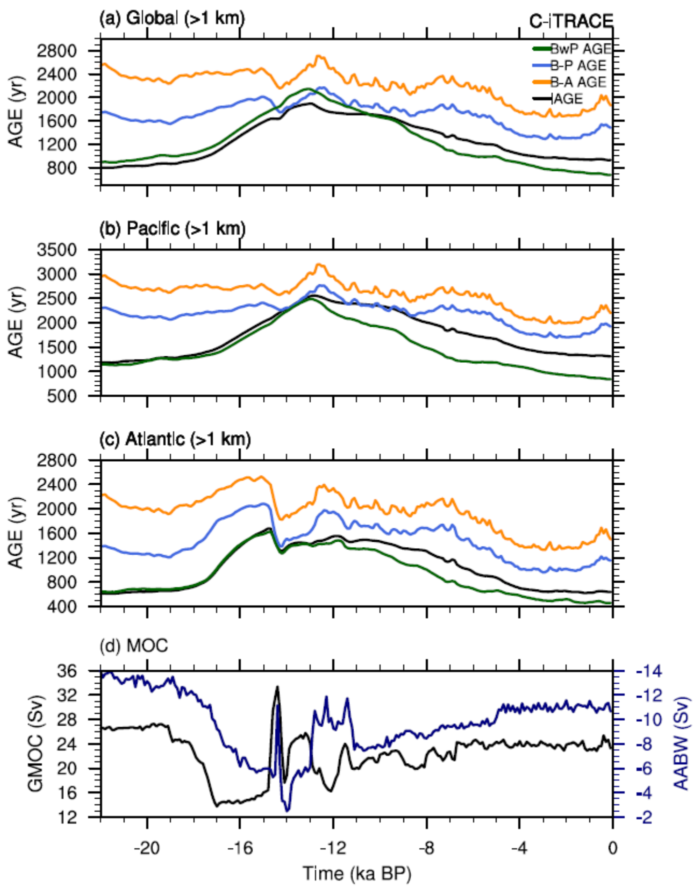

Figure R1 Time evolutions in the C-iTRACE: (a) The global mean ideal age (IAGE; black), benthic-atmosphere $\Delta^{14}C$ age (B-A age; yellow), benthic-planktonic $\Delta^{14}C$ age (B-P age; blue), and weighted benthic-planktonic $\Delta^{14}C$ age (BwP age; green) averaged below 1 km. (b) The Pacific mean IAGE (black), B-A age (yellow), B-P age (blue), and BwP age (green) averaged below 1 km. (c) The Atlantic mean IAGE (black), B-A age (yellow), B-P age (blue), and BwP age (green) averaged below 1 km. (d) The Global Meridional Overturning Streamfunction (GMOC; black) and Antarctic Bottom Water strength (AABW; navy). Here the GMOC intensity is diagnosed as the maximum in the GMOC streamfunction below 500 m from 33° S-60° N, and AABW is diagnosed as the minimum in the GMOC streamfunction below 2 km over 2° S-70° S.

Figure 4: The changes would become more obvious if the ages were scaled to values at 0 ka BP (i.e., if age anomalies were shown)
Revised as suggested.

Figure 4 / line 199: As the Pacific is connected with the Indian Ocean south of the equator, the Indo-Pacific MOC should be considered instead of the PMOC
Revised as suggested.

Figure 6, 7, 8, 11, 12, 13: Units are missing
Corrected.

Line 235-236: "isopycnals (...) at 30°S exhibit minimal changes below 3.4 km" – this is at odds with what can be seen in Figs. 2 and 5
The calculation of AABW DWBC actually has nothing to do with Figure 2. Contours in figure 2 are zonal mean potential density, while contours in figure 5 are zonal potential density at 30° S which are essentially all flat below 3.4 km. Therefore, the AABW transport are calculated at 30° S using the basin wide integrated volume transport below 3.4 km.

Line 242: "The calculated northward AABW DWBC transport aligns exceptionally well the transport of model abyssal upper cell in each basin (Fig. 6g-h, Fig. 7g-h)". Do you mean "abyssal cell", "upper cell" or "abyssal and upper cell"? I don't get that from Figs. 6 and 7.
Indeed. This is now clarified in revised manuscript: "The calculated northward AABW DWBC transport aligns exceptionally well with the transport of model abyssal cell in each basin" in 259-260.

Line 255: Why is the (ideal) ventilation age of AABW typically much older than the age of NADW?
This is now elaborated in the revised manuscript: "Note that the ventilation age of AABW water mass is typically much older than the age of NADW (Fig. 3). This is because the NADW water mass characterizes the southward branch of the upper cell confined to the Atlantic sector, which is interconnected with AABW and thermocline ventilation, leading to relatively short residence times through the ocean interior" in line 271-274.

Line 258-259: "more NADW sinking into deeper depths in the Arctic" – this is not in line with Fig. 3 (b) where the volume of DYE_NA remains almost constant.
There is actually a slight increase of volume of Dye_NA in figure 3b, although the volume of NADW is about 8 times smaller than the volume of AABW. Figure R2 shows that the global concentration of Dye_NA at 2 km during the 20ka, 16 ka, 14.5 ka, 12.9 ka, and 0ka, respectively. It clearly shows more NADW water mass in the Arctic since 14.5 ka and therefore the ventilation age of NADW gets older during the period of 14.5-10 ka in figure 3a.

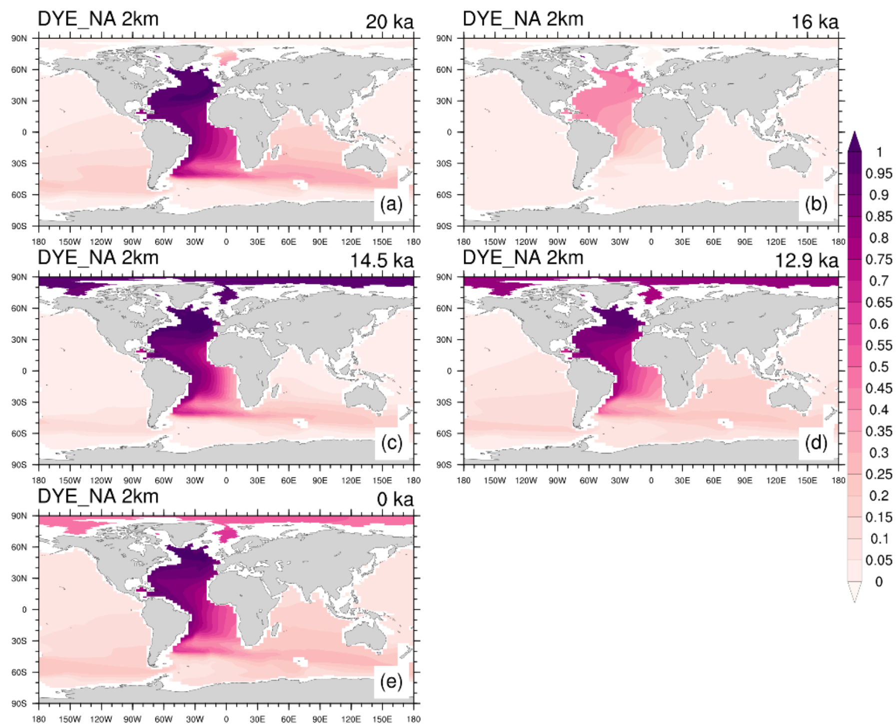

Figure R2 Global distribution of Dye_NA concentrations at 20 ka, 16 ka, 14.5 ka, 12.9 ka, and 0 ka, respectively.

Line 315: "The calculated southward DWBC and northward AABW DWBC are validated by the model MOCs" – this is a tautology

The model MOCs here are direct diagnostic output from simulations, and by comparing the calculated transport of DWBCs using meridional velocity with model MOCs, we are able to access the accuracy and reliability of the calculations as well as main temporal features of DWBCs transports. Therefore, it is our opinion that it is necessary to verify the calculated DWBC with the model MOCs.

Line 349: See my comment concerning line 75

Revised as suggested. Reference is added in the revised manuscript.

References:

England, M. H. (1995). The age of water and ventilation timescales in a global ocean. *Journal of Physical Oceanography*, *25*, 2756–2777.