Response to Reviewer 1, Dr Shih-Yu Lee:

We thank Dr Shih-Yu Lee for her thoughtful and constructive comments to this manuscript.

*Please see our point-by-point responses to each of the comments below in **blue and italic,** and suggested implementations in a revised manuscript in **green**. Please note that the line numbers refer to the original preprint and will be updated in the next iteration with the revised manuscript.*

A) Experimental realism & robustness

1. Freshwater forcing magnitude, duration, and geometry: The shutdown uses 0.4 Sv for 500 yr over 50–70° N, 70–0° W (Table 2)—an idealized choice that likely exceeds plausible HE freshwater flux histories. Please (i) discuss physical plausibility versus "shock" idealization; (ii) provide a brief sensitivity or cite prior ACCESS ESM1.5 tests to hosing shape (pulsed vs ramped), duration, and release region (e.g., including/substituting the Nordic Seas or Labrador shelf). Even a short 100 yr/0.4 Sv pulse test or a reduced area hosing would help demonstrate that the non linear atmospheric reorganization at shutdown is not a by product of sustained extreme hosing.

We thank the Reviewer for this comment and understand the concerns associated with the idealized experimental set up. We will add a new section in the Discussion to elaborate this concern.

Line 486 (new Discussion section):

4.4 Robustness of the simulations

Our experimental setup was designed to assess the multi-centennial-scale impact of an AMOC shutdown and an AMOC slowdown on the climate system. The AMOC response to North Atlantic freshwater fluxes depends on both the magnitude and duration of the meltwater input. As shown in Du et al. (2025), a large, short North Atlantic freshwater pulse of 1 Sv for 5 years does not lead to significant AMOC changes, and the AMOC recovers quickly once the meltwater input is stopped. The experiments were designed to obtain a significant AMOC weakening and a shutdown with the smallest freshwater input. While this experimental setup is highly idealized and the input fluxes are significantly higher than current estimates (Zhou and McManus, 2024), it is similar to the experimental design of the recent North Atlantic Hosing Model Intercomparison Project (NaHOsMIP), in which 0.3 Sv is added in the North Atlantic for more than 100 model years to simulate the climate response to an AMOC shutdown in CMIP models (Ben-Yami et al., 2024; Diamond et al., 2025; Jackson et al., 2023).

Nevertheless, as seen in our experimental design, a pulse of 0.3 Sv for a few hundred years does not lead to an AMOC shutdown under 49ka boundary conditions. This highlights the issue of this model's sensitivity to freshwater forcing (Kageyama et al., 2013; Du et al. 2025; Saini et al., 2025a).

Given the previous experiments, with different North Atlantic meltwater input location, duration and magnitudes (Pontes & Menviel, 2024, Du et al, 2025, Saini et al., 2025), and the length of the simulations performed here (500 years), the two steps increase in meltwater input in 49ka_0.3Sv, from experiment 49ka_0.2Sv should not significantly affect the large-scale climate response, nor should the exact location of the meltwater input in the subpolar North Atlantic. A thorough study of the impact of meltwater input location on the climate response is out of scope of this study, but should be performed in the future.

2. Internal variability and sampling: Results rely on 50 yr windows. Please consider a simple signal to noise check by resampling 50 yr blocks from the control and from each experiment (or show running 30 yr means across the last 150 yr) to demonstrate that key patterns (DJF ITCZ latitude, HC strengths/widths, STR latitude, SH westerly latitude) exceed internal variability.

Thanks for the suggestion. We will add a paragraph in the new Discussion Section 4.4 (following the previous response) with a new supplementary Figure S8 to assess the statistical significance of the climate signals.

Last paragraph in the Discussion Section 4.4:

Lastly, this study uses the last 50 years of each hosing experiment to assess the climate responses. When using the 30-year running-mean values for the last 150 years in each experiment, the results are consistent with our 50-year average (Fig. S8). We note that only one model was used, and a future study could examine the linearity in multiple models.

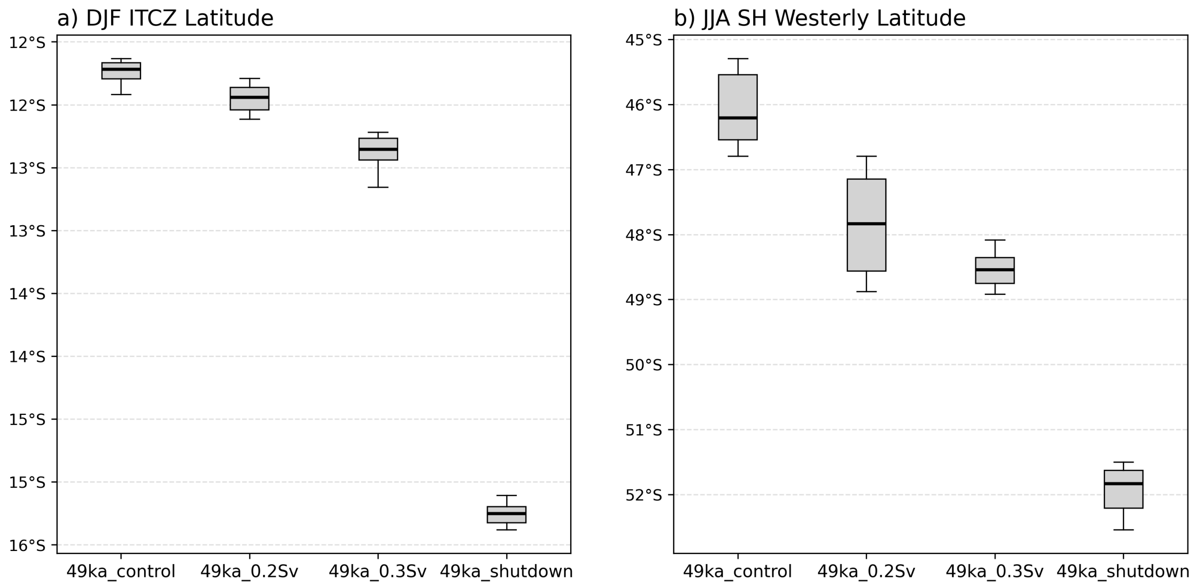

Figure S8: Box plot of 30-year means across the last 150 years for a) DJF ITCZ latitudes, and b) JJA SH westerly wind latitude in each experiment. Within each box, the thick line inside the box represents the median value (50th percentile) of each group; the top and bottom of the box shows the 25th and 75th percentile, respectively; the whiskers show 10th to 90th percentile.

B) Mechanistic clarity/suggestion

5. Energetics of the ITCZ shift: Since the story hinges on interhemispheric energy transport compensation, would it be possible to exam TOA energy transport decomposition (DJF/JJA) that connects the ~1 PW reduction in NH ocean heat transport at 30° N to the southward DJF ITCZ jump in shutdown. Even a zonal mean cross equatorial energy flux figure would make the mechanism crisper.

Thanks for the suggestion. We will add a new supplementary Figure S3 to illustrate the zonal-mean atmospheric heat transport to aid the discussion of the energetic mechanism of ITCZ shift in Section 3.1.

Lines 210-213 (Section 3.1):

In response to an AMOC shutdown (Fig. 2d), a significant precipitation reduction is simulated to the north of the equator while the precipitation is greatly enhanced to the south, extending from the Atlantic to every ocean basin, indicating a southward shift of the mean ITCZ position. The atmospheric cross-equatorial heat transport increases (Fig. S3) to partially compensate for the reduced ocean heat transport (Fig. S3), pushing the ITCZ southwards towards the warmer hemisphere.

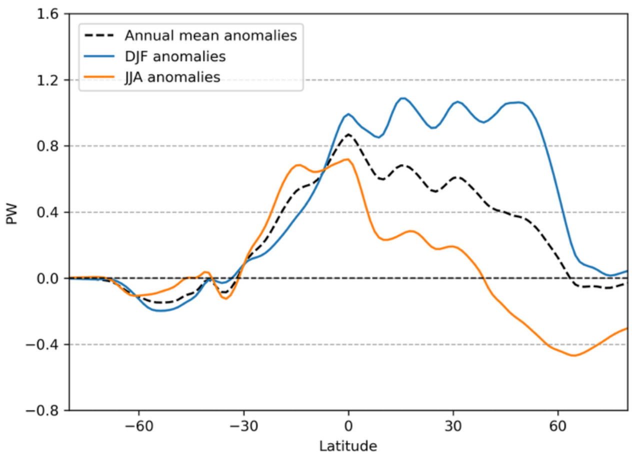

Figure S3: 49ka_shutdown - 49ka_control anomalies for annual mean, DJF, and JJA zonally averaged northward atmospheric heat transport (PW).

Lines 245-252 (Section 3.2.1):

In response to an AMOC weakening, the annual mean ITCZ position shifts southwards towards the warmer hemisphere in all simulations (Fig. 2d-2f), generating the cross-equatorial atmospheric energy transport (Hadley Cell) to partially compensate for the reduced oceanic heat transport. This drives alterations in the strength and width of the HC. Notably, the atmospheric compensation is highly seasonal. In the HS simulation, the TOA energy transport in DJF season reaches ~1.05 PW at 30 °N, while ~0.19 PW in JJA (Fig. S3) to compensate for the ~1 PW annual reduction in the North Atlantic ocean heat transport. This leads to more pronounced changes in DJF season in the HC and ITCZ responses.

Lines 490-491 (Conclusion):

Due to AMOC shutdown, a pronounced southward shift of the DJF ITCZ is simulated, associated with stronger DJF atmospheric compensation for the reduced NH ocean heat transport than in JJA. This asymmetric atmospheric response leads to a strengthened northern winter (DJF) HC and weakened southern wintertime (JJA) HC, influencing the seasonal climate response in the tropical and subtropical regions.

6. Southern Ocean/sea-ice feedbacks: You note notable SAT cooling near the Ross/Weddell sectors and stronger SH westerlies in shutdown (Fig. 2a; Fig. 7). The argument will be more comprehensive to show how wind/ice/ocean coupling amplifies the SH response.

Thanks for the suggestion. We will add a statement in Section 3.2.3 to demonstrate the impact of the high southern latitude cooling on the westerlies.

Line 326 (add to the end of the paragraph):

The strengthening of the westerlies is driven by an enhanced meridional temperature gradient in the Southern Ocean due to high-latitude cooling near the Ross/Weddell sectors (Fig. S4).

7. Basin contrasts in SH westerlies: The Atlantic sector behaves differently from the Pacific/Indian in slowdowns; shutdown realigns them (Fig. 7). Would be good to clarify why the Atlantic deviates.

Thanks for the suggestion. This is due to the stronger and clearer temperature response in the Atlantic basin that leads to changes in the SH westerlies. Since the AMOC reductions in the slowdown experiments are small, the temperature response is limited to the Atlantic basin, which leads to larger changes in the SH westerlies in the Atlantic basin compared to the others where there is little change in the interhemispheric temperature gradient.

We will add more discussion in the corresponding Section 3.2.3.

Line 334 (add to the end of the paragraph):

This may be due to the stronger interhemispheric temperature gradient change in the Atlantic Ocean in the slowdown simulations compared with the other ocean basins.

8. Carbon cycle configuration and outputs: ACCESS ESM1.5 includes an interactive carbon cycle, and the author discuss potential CO_2 links via SH westerlies (p. 22). Please state whether carbon was prognostic or prescribed here and, if active, showing simulated air–sea CO_2 flux (Southern Ocean sectors), DIC/alkalinity, and atmospheric CO_2 response will be of great interest.

While for the radiative forcing, atmospheric CO_2 is kept constant at 284.3 ppm, the model also includes a prognostic atmospheric CO_2 tracer. However, this research question is the focus of other studies (e.g. Willeit et al., 2025), and it is out of scope of the topic of the manuscript. This question is explored by another PhD student in our group.

Reference:

Willeit, M., Ganopolski, A., Kaufhold, C., Dalmonech, D., Liu, B., and Ilyina, T.: Earth system response to Heinrich events explained by a bipolar convection seesaw, Nat. Geosci., 18, 1159–1166, https://doi.org/10.1038/s41561-025-01814-0, 2025.