Answer to RC1

We thank the reviewer for this overall positive feedback and insightful comments. Below, we provide individual answers to each comment, along with planned modifications of the manuscript.

This study investigates the role of (1) GIS and WAIS meltwater forcing rate, (2) stochastic noise on meltwater forcing, on AMOC collapse using a 5-box conceptual AMOC model. The paper is technically sound and confirms the idea that the WAIS has a stabilizing effect on the AMOC (proposed by previous studies) even under the influence of forcing rate and noise.

The paper is worthy of publication in ESD, however additional analysis/revisions are needed. Please see the comments below.

Additional analysis with realistic meltwater flux forcing: I propose an additional analysis/discussion on the AMOC collapse at the realistic range of forcing parameters (Eq (1) and Eq (2)). First, please provide a realistic range of the forcing parameters in the context of a palaeoclimate event (e.g., MWP-1A) or future climate change (e.g., CMIP6 SSP5-8.5 scenario). Then, discuss the AMOC collapse behavior at this realistic range of meltwater flux. If this specific past/future event is not applicable to the forcing scenario used in this paper (which assumes full melting of GIS and WAIS), I suggest performing an additional experiment. This would provide practical insights into the AMOC collapse in the past/future. Also, it would shore up a weakness of the paper (the weakness of using a highly idealized model with conceptual forcing).

Reply: our manuscript focuses on the qualitative aspects of rate and noise-induced effects on the AMOC stability. However, it is motivated by future climate change and, as such, we ensured that the different forcing parameters used were consistent with Armstrong McKay et al. (2022), the most comprehensive and up-to-date reference regarding future tipping events. In this paper, a most likely scenario is also provided, wherein the GIS collapses in 10,000 years and the WAIS in 2,000 years. In our deterministic model, such a GIS forcing is far from being strong enough to result in an AMOC tipping. Therefore, in this most likely scenario, the AMOC remains stable independently of the applied WAIS meltwater flux.

In our paper, a collapse duration of 1,000 years for the GIS was used in the deterministic case, which is the lower limit of the range of 1,000 to 13,000 years proposed by Armstrong McKay et al. (2022). Hence, as suggested around line 110, this must be interpreted as a worst case scenario. This is further motivated by Aschwanden et al. (2019), where a high emission scenario (extended RCP8.5) yields a collapse of the GIS at the millennial timescale. In such a scenario, all the range of plausible WAIS tipping points are exceeded in less than a century, resulting in a negligible time delay between the two ice sheet tipping events (i.e. $\Delta t \approx 0$). Therefore, in this worst case scenario, a collapse duration of WAIS of approximately 500 to 1,200 years results in a stabilization of the AMOC (Fig. 2a). Such considerations can also be made in the stochastic experiments, although in terms of the probability of AMOC collapse.

While it is true that those results could also provide insight into paleoclimatic events (e.g. MWP-1A), we did not discuss such aspects as the conceptual AMOC model of Cimatoribus, Drijfhout, and Dijkstra (2014) is built and parametrised to represent a present-day AMOC. As such, we prefer to avoid speculating in this direction.

Changes in text: discussion relating our results to future climate change will be added.

Line 80: The authors consider the time delay between FN (representative of GIS collapse) and FS (representative of WIS collapse) forcing as a key parameter of the AMOC experiment. What is the physical motivation for setting a time delay between them? What is a realistic range of time delay in the context of palaeoclimate and future climate change?

Reply: given the uncertainty on both ice sheet tipping points and the uncertainty in future climate warming trajectories, a wide range of delays between ice sheet tipping events is in principle possible.

For example, considering a global warming scenario in which global temperature increases from 1.1°C to 3.0°C above preindustrial level in 1,500 years, the WAIS would begin to collapse 1,500 years after the GIS if their respective tipping points are at 3.0°C and 1.1°C. Conversely, if those tipping points are inverted, the WAIS would begin to collapse 1,500 years before the GIS.

Changes in text: the motivation for considering varying time delays (and tipping timescales) will be clarified.

Section 3: Please show the figure that shows together the case of WAIS included and the non-included case for the AMOC collapse (time series would be good). The WAIS-induced stabilization effect is an important key message of this paper, so the direct comparison of these two cases will improve the presentation of the paper (the current version of the figure set is not friendly to readers who are not familiar with the low-order AMOC modelling and dynamical systems theory).

Reply: we thank the reviewer for this valuable suggestion.

Changes in text: it will be implemented in the manuscript, along with some explanatory text.

Limitation of the conceptual model: The 5-box AMOC model used in this study does not consider the AMOC impact on the WAIS melt. The model considers only a one-way influence from the WAIS melt to the AMOC. However, as the authors explained in the introduction, the collapse of AMOC would increase the Southern Hemisphere temperature and accelerate the WAIS melt, while decreasing the Northern Hemisphere temperature and decelerating the GIS melt. The discussion of this missing physics (which may be very important) should be explained in the paper (probably in Section 6).

Reply: our experiments are based on meltwater forcing trajectories which have been simplified into parabolas, solely defined by their duration in time and initiation time, independently of the AMOC dynamics. While this does not allow for implementing such feedbacks, some of their impact can be discussed in light of our results as follows.

On one hand, cooling of the North Pole tends to inhibit a GIS tipping event, which renders an AMOC collapse less likely. On the other hand, warming of the southern ocean implies an earlier and/or faster WAIS collapse. Especially, it would result in an earlier maximum of the WAIS meltwater flux, implying a shift of the Δt_{max} forcing parameter towards negative values. In the deterministic experiment, we found that $\Delta t_{\text{max}} \approx -150$ years is optimal to result in an AMOC stabilization. Hence, the consequences of this feedback are more nuanced, as it may facilitate or inhibit AMOC tipping if it drives Δt_{max} away from or towards this optimal value, respectively.

Changes in text: discussion of those feedbacks will be added.

L203: Which numerical scheme for stochastic differential equations is used to solve the weak noise case?

Reply: the algorithm SOSRI was used. It is a stability-optimized adaptive integration algorithm for sotchastic differential equations, best described in Chris Rackauckas and Nie (2020). It is implemented in the Julia package DifferentialEquations.jl (Christopher Rackauckas and Nie, 2017), which was used throughout the study.

Changes in text: description of numerical methods and tools will be added.

Abstract: The key results of the paper are summarized too much in the abstract, and do not give an immediate answer to the question likely to arise from the title (so, what is the role of the forcing rate and noise?). Please revise it.

Reply: the answer provided by this manuscript is that both rate and noise-induced effects have substantial impact on which ice sheet collapse trajectories may or not result in an AMOC tipping.

Changes in text: we will rework the abstract to make this clearer.

References

Armstrong McKay, David I. et al. (Sept. 2022). "Exceeding 1.5°C global warming could trigger multiple climate tipping points". In: *Science* 377(6611). Publisher: American Association for the Advancement of Science, eabn7950. DOI: 10.1126/science.abn7950. URL: https://www.science.org/doi/10.1126/science.abn7950 (visited on 10/07/2022).

Aschwanden, Andy et al. (June 2019). "Contribution of the Greenland Ice Sheet to sea level over the next millennium". In: *Science Advances* 5(6). Publisher: American Association for the Advancement of Science, eaav9396. DOI: 10.1126/sciadv.aav9396. URL: https://www.science.org/doi/10.1126/sciadv.aav9396 (visited on 03/22/2024).

Cimatoribus, Andrea A., Sybren S. Drijfhout, and Henk A. Dijkstra (Jan. 2014). "Meridional overturning circulation: stability and ocean feedbacks in a box model". en. In: *Climate Dynamics* 42(1), pp. 311–328. ISSN: 1432-0894. DOI: 10.1007/s00382-012-1576-9. URL: https://doi.org/10.1007/s00382-012-1576-9 (visited on 10/07/2022).

Rackauckas, Chris and Qing Nie (Sept. 2020). "Stability-Optimized High Order Methods and Stiffness Detection for Pathwise Stiff Stochastic Differential Equations". In: *2020 IEEE High Performance Extreme Computing Conference (HPEC)*. ISSN: 2643-1971, pp. 1–8. DOI: 10.1109/HPEC43674.2020.9286178. URL: https://ieeexplore.ieee.org/document/9286178 (visited on 03/25/2024).

Rackauckas, Christopher and Qing Nie (2017). "Differentialequations.jl–a performant and feature-rich ecosystem for solving differential equations in julia". In: *Journal of Open Research Software* 5(1), p. 15.