Author's response to Anonymous Referee #1

Original reviewer's comments are inserted in black, Author Replies (AR) are added in blue, and Changes made to the Manuscript (CM) are finally listed in grey, whereby line numbers refer to the fully revised version of the manuscript.

General Comments:

The authors use the NEMO ocean model to carry out a set of simulations that have 1/4 degree horizontal resolution across the entire globe, as well as some which feature AGRIF nests to achieve 1/20 degree horizontal resolution within the Atlantic Ocean. These simulations are then compared against observations that span the North and South Atlantic Ocean. Observed AMOC transports at multiple locations are compared against the model output, identifying certain features. The authors find that surface freshwater restoring influences the AMOC transport. The manuscript is well thought out, covers a much larger expanse of the Atlantic than we normally read about in AMOC-related articles, and provides a lot of information that modellers, observationalists, and climate scientists may find useful.
AR: We thank you for your kind reply and constructive criticism below which helped to improve the manuscript.

Specific Comments:

- L135-137: Is this free/no slip change for both the parent and nest, or just the nest? If only the nest, I'm curious why no-slip isn't included everywhere in the nest as it helps generate eddies. Perhaps include some text in the manuscript on why only use a small region with no-slip.

  AR: One of the major achievements in NEMO was the implementation of an energy-enstrophy conserving momentum advection scheme in combination with partial cells. However, as shown for ORCA025 by Penduff et al. (2007), the use of no-slip sidewall boundary conditions cancelled most of the improvements. The following developments with ORCA025 and subsequent high-resolution nests like VIKING20X were usually continued with free-slip boundary conditions. During the development of VIKING20X, we performed sensitivity experiments which confirmed the better performance of, e.g. the circulation in the Northwest Corner, with free-slip conditions. However, it was also noticed that the generation of Irminger Rings was only possible through no-slip conditions in the region of the West Greenland Current (Rieck et al., 2019). This only applies to the nest. The motivation of these choices is now included in the text.

  CM (L.136-140): Horizontal sidewall boundary conditions are formulated as free-slip, which was demonstrated as an optimal choice in ORCA025 to benefit from the energy-enstrophy conserving momentum advection scheme in combination with partial cells (Penduff et al., 2007). Sensitivity tests during the development of VIKING20X confirmed that free-slip is also the preferred option at higher resolution. In contrast, the generation of West Greenland Current eddies were shown to work best with no-slip conditions (in the nest) which motivated its use in a region around Cape Desolation (Rieck et al., 2019).

- L150: I find it intriguing that the spatial multiplier is 5 between ORCA025 and VIKING20x, but you were able to get away with a time multiplier of 3. I always thought AGRIF required the same spatial/temporal multiplier even though you set it. I might have to try this later. No response needed here, I just wanted to express I learned something.

AR: Technically, AGRIF does not require a fixed ratio of spatio and temporal refinements. The choice of the time step depends on fulfilling the CFL Criterion in the respective grid. For global grids the largest possible timestep is usually determined by the smallest (usually most poleward) grid cell. If a nested domain is not directly placed at high latitudes, the timestep can usually be chosen larger than the grid refinement would suggest.

- L229-236: It isn't clear what the INATL20-JRA-long simulation will provide. Assessing nested boundary condition issues is useful, but this simulation has different restoring, slip conditions, and tides. Please provide more justification here on why this simulation is included, particularly in reference to any anticipated AMOC changes suspected due to nested boundary conditions.

  AR: We are aware that the INALT20-JRA-long simulation is not a systematic sensitivity experiment. Due to the fact that the southern boundary of the high-resolution nest in VIKING20X cuts right through e.g. the Cape Basin where most of the variability has an origin south and east of it, we wanted to explore the impact of the nest extension and the lack of properly represented eddies outside on the mesoscale and interannual variability in its direct vicinity. For both scales, the differences in the numerical setting are less important. In the new version, we have justified the inclusion of the INALT20-JRA-long simulation as follows:

  CM (L.240-243): Owing to the differences in the numerical setting, we concentrate the comparison to the influence of the Agulhas Current system and the Malvinas confluence region on the mesoscale and interannual variability. Both are represented in VIKING20X only on the coarser host grid but are part of the nested high-resolution region in INALT20.

- Figure 9: The spatial area of the MLD is much different between these runs. But I don't see how their MLD volume (d) is so similar. This is addressed in L403-413, but I still have an issue with the MLD plots, I would have expected to see a larger change in fig 9d. Perhaps it is because the spatial max MLD is plotted. Perhaps try plotting a mean of the annual max MLD?

  AR: The colour shading in Fig. 9a-c does indeed show long-term (1980-2009) mean of the annual maximum MLD. The MLD structure is quite similar in both ORCA025 and VIKING20X. Details in depth and horizontal pattern obviously compensate, so that, under the same forcing, it results in similar total volume. This is already mentioned in the text:

  CM (L.416-419): While the resolution seems to determine the general spatial structure, the forcing and other model specific settings impact the intensity and temporal variability of deep convection. During the first 15 years, i.e., until the mid 1970s, the MLD_a volume in the depicted domain (Fig. 9d) shows nearly the same magnitude and temporal variability for all simulations. (notably, the overall mixed layer volume in the ORCA025 simulations is not systematically larger than in the VIKING20X simulations).

- L355: Any suggestion why this pathway is not seen in your simulations?

  AR: Thank you for pointing that out. Indeed, this was an inconsistent comparison between Lagrangian water mass spreading focusing on the path of the NADW towards the Indian Ocean (Van Sebille et al., 2012) and overall horizontal velocities (here). In an experiment using Lagrangian particles we can identify a similar path towards the Indian Ocean as in Van Sebille et al. (2012).

  CM (L.359-363): A zonal band of slightly elevated speed between 20° S and 25° S indicates the flow of NADW water described by Van Sebille et al. (2012) which could also be identified in our simulations by Lagrangian experiments (here not shown).

Technical corrections:

- Figure 2c- My PDF viewer shows horizontal white lines on the AVISO figure, but they are only over land and do not make the figure difficult to view.

  AR: Thank you for this hint. We updated Figure 2, eliminating the white lines.

CM: Figure 2 was updated.

- L21-22: Grammar issue clouds this sentence.

  AR: We agree and have changed the sentence to:

  CM (L.22-23): In contrast to its importance, the AMOC and its past evolution is most difficult to obtain and to quantify.

- L23: 'The RAPID array at 26.5N is ...'

  AR: Has been changed.

- L120: I'm not sure what an 'eddy-present' configuration is. Do you mean eddy-permitting or eddy-resolving? It isn't clear here or in the later parts of the manuscript

  AR: The terms "eddy-present" and "eddy-rich" follow recent nomenclature (e.g. Hewitt et al., 2020) replacing "eddy-permitting" and "eddy-resolving" by more unambiguous terms.

- L386-389: awkward sentence that could use a rewrite.

  AR: We agree and have rewritten accordingly:

  CM (L.400-402): In the subpolar North Atlantic, further deepwater is generated and added to the NADW. Owing to strong wintertime heat loss, in particular through strong and cold winds, the Labrador and Irminger Seas are regions of deepwater formation. Deep convection provides a lighter, upper component to the NADW (in contrast to the overflows forming lower NADW).

- L618: extra space before a period.

  AR: Has been changed.

- L639: 'Only Besides' is confusing, seems like the authors meant to write 'Besides...' and forgot to remove 'Only'.

  AR: That is correct, "Only" was removed

- L676: bit awkward "... does equal the one ..."

  AR: Has been changed:

  CM (L.693-694): for VIKING20X-JRA-long the NBUC trend is equal to the AMOC trend,

References

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