Anonymous Referee #1

This manuscript analyses results from a high-resolution (1/12°) regional ocean model of the NW Atlantic forced by fluxes and boundary conditions from a lower resolution fully-coupled earth system model. Specifically, four CMIP scenarios for different future warming levels are integrated out to 2100, and the work focuses on changes to currents, surface temperature, salinity, and sea-surface height (SSH). While others have already studied the resulting future reduction to the current systems (Atlantic Meridional Overturning Circulation (AMOC) and Western Boundary Current (WBC)) for the highest warming scenario (RCP8.5 and SSP585) in fully-coupled climate models (for CMIP5, ~1° ocean models, Beadling et al., 2018; for CMIP6, ~1/4 – 1/12° ocean models, Roberts et al., 2020), the present investigation focuses on changes in the societally important near-coastal and shelf regions (Gulf of Mexico/America, West of Florida, South Atlantic Bight, Mid Atlantic Bight and Gulf of Maine), and investigates the range of possible conditions for the four different warming scenarios. These regions are found to become warmer and saltier in the future (changes which could affect the marine ecosystems) and also to have higher sea-levels. This near-coastal/ shelf focus examined across multiple future warming scenarios has not been studied before to my knowledge, and could provide useful information about future conditions for marine planners and societal uses.

However, there are two main drawbacks to the work which should be addressed before publication could be considered, as follows:

We appreciate the reviewer for their careful review of our manuscript and insightful and constructive comments. As suggested, we add a discussion regarding the potential role of the Labrador Slope Water (LSLW) in changing the ocean conditions along the Mid-Atlantic Bight (MAB). Here, we provide point-by-point responses to address each of the reviewer's comments and suggestions. Our replies are provided below in blue font for each of the general and specific comments. We believe that the revised manuscript is much improved.

Northern Inputs. The manuscript proposes (e.g. ls 41-42, 499-503) several mechanisms which may cause the changes (warming and salinification) of the coastal and shelf waters along the US South and East coasts, such as the reduced upwelling of colder and fresher waters due to the reduced flows in the Loop Current and Gulf Stream (affecting the Gulf of America/Mexico), and a northward and shoreward shift of the Gulf Stream following its separation (affecting the Mid Atlantic Bight (MAB) and Gulf of Maine (GOM)). However, it should also acknowledge the possibility of changes in the current systems which bring waters to the MAB/GOM shelf and slope region. The coastal/shelf waters here are largely derived from the inshore Labrador Current which exits the Hudson Strait, passes over the Grand Banks and then forms the Nova Scotia Current to provide cold, fresh waters to this area. In addition the (offshore) Labrador Current (with origins in the Davis Strait and West Greenland Current) flows around the Tail of the Grand Banks, and after mixing with North Atlantic Central Water, forms Labrador Slope Water which flows southwards along the shelf slopes as far as Cape Hatteras, with a core at depths of 400-600m (see New et al., 2021, and the references therein). The manuscript should acknowledge the possibility of changes in the temperature and salinity of these northern inputs as a cause of the warming and salinification here: the changes in the coastal/shelf waters imply changes in the inshore LC, and in particular the warming and salinification observed on the shelf slopes in the MAB (figure 14) at 400-600m are strongly indicative of changes the in LSLW. This possibility is briefly acknowledged in ls. 333-334 but without any evidence: more discussion of this mechanism is needed either here or, better, in the discussion section: e.g. which of the various mechanisms is actually responsible for the changes in the MAB and GOM? Also, inclusion of a figure showing changes in the near-surface properties of the Labrador Sea (which provide the head waters for the MAB and GOM areas) would be very useful.

As the reviewer pointed out, the Mid-Atlantic Bight (MAB) and the Gulf of Maine are strongly influenced by the Labrador Current and the Labrador Slope Water (LSLW). To investigate the future changes in LSLW and the associated Slope Current, we plot the vertical cross-section of the alongshore current across 30°N–41°N, 76°W–67°W in the MAB (Fig. R1). It is clear that the Slope Current is not well reproduced in MOM6-NWA12 during the historical period (1993–2020). It is much weaker compared to that in GLORYS12, and is replaced by northward flow in the upper 400m or so. Another core of southward flow appears immediately shoreward of the Gulf Stream in MOM6-NWA12. Since it is positioned away from the slope (near 73°W), it is referred to as the northern recirculation flow of the Gulf Stream.

In the future projections, the Gulf Stream weakens and its core shifts shoreward. In the SSP370 and SSP585 scenarios, the Gulf Stream core is positioned along the continental slope. Thus, both the northern recirculation flow and the Slope Current (below 600m or so) disappear in those two scenarios. Therefore, despite a large bias in the location and strength of the Slope Current in MOM6-NWS12, we can still conclude that the future warming and saltening along the MAB shown in Fig. 17 are the result of a compounding effect - reduced advection of cold, fresh Labrador Sea waters combined with the weakening and shoreward shift of the Gulf Stream.

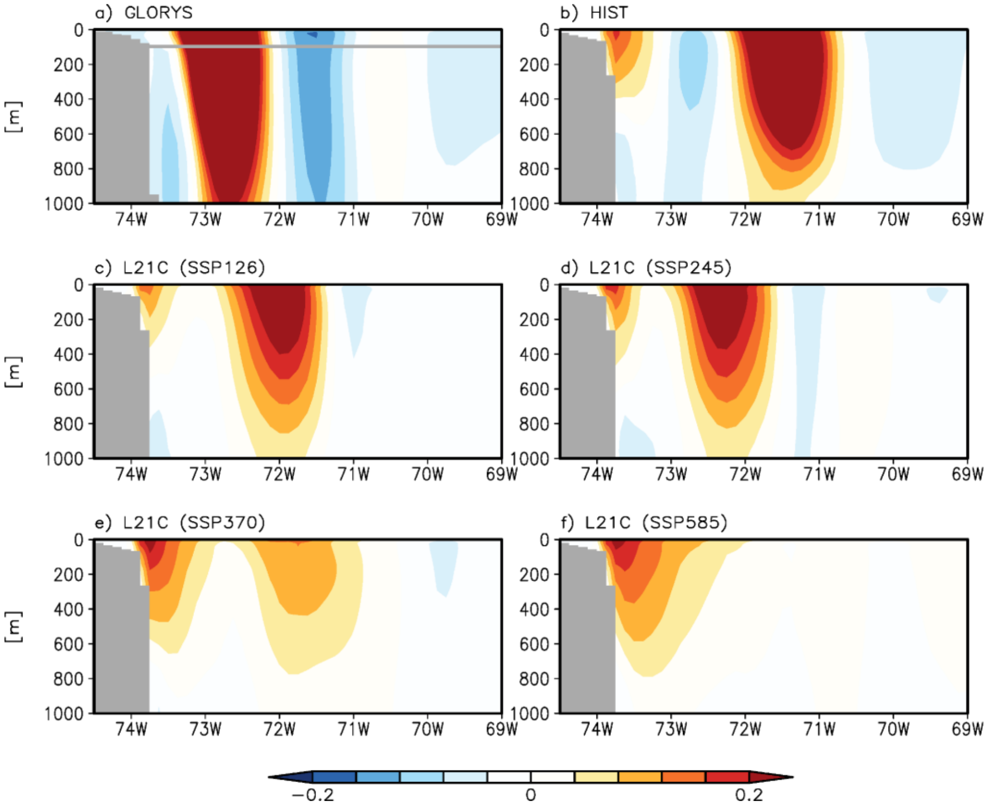

Fig. R1. (a) Vertical cross-section of the mean alongshore current across the MAB (30°N-41°N, 76°W-67°W) during the historical period (1993-2020) from GLORYS12. (b) Same as (a), but for MOM6-NWA12.

(c)-(f) Same as (b), but for the future period (2073-2100) from the (c) SSP1-2.6, (d) SSP2-4.5, (e) SSP3-7.0, and (f) SSP5-8.5 simulations, respectively.

Figure R1 is now added in the revised supplementary material. We also add the following discussion in the revised manuscript.

(L553-568) In addition, as discussed in New et al. (2021), the MAB and the Gulf of Maine are also strongly influenced by the Labrador Current and the Labrador Slope Water (LSLW). The Slope Current in MOM6-NWA12 shows a large bias in its position and the strength. More specifically, it is much weaker compared to that in GLORYS12, and is replaced by northward flow in the upper 400m or so (Supplementary Fig. 6). Another core of southward flow appears immediately shoreward of the Gulf Stream in MOM6-NWA12 . Since it is positioned away from the continental slope (near 73°W), it is referred to as the northern recirculation flow of the Gulf Stream. In the future scenarios, both the northern recirculation flow and the Slope Current (below 600m) drastically weaken. The Gulf Stream also weakens and its core shifts shoreward. In the SSP370 and SSP585 scenarios, the Gulf Stream core is positioned along the continental slope. Thus, both the northern recirculation flow and the Slope Current (below 600m or so) completely disappear in those high emission scenarios. Therefore, despite a large bias in the location and strength of the Slope Current in MOM6-NWS12, we can still conclude that the future warming and saltening in the MAB, shown in Fig. 17, are the result of a compounding effect - a weakening and shoreward shift of the Gulf Stream combined with reduced advection of cold, fresh Labrador Sea waters.

Sea-surface height. While the results for the coastal/shelf Sea-Surface Temperature (SST) and Salinity (SSS) are interesting, the results for Sea-Surface Height (SSH) are of limited value because they only consider changes to "dynamic height" i.e. changes caused by changes in the currents (as the model has the Boussinesq approximation and cannot accommodate changes in the SSH due to warming of the water column). As the currents reduce, so does the SSH gradient across them (as expected since the SSH gradients relate to the surface geostrophic flow) meaning that the SSH to the north of the currents (on the shelf regions) generally increases and that to the southward/ oceanward side of the currents decreases. Steric sea-level changes due to the warming (and salinity change) of the water column need to be more fully discussed rather than the brief statement (ls. 473-478) about general future increases: e.g. we would need to know about the spatial structure (presumably not constant everywhere) of these changes which add to the dynamic changes presented, so that a full picture of future SSH can be formed. Perhaps a description of such spatial variability could be included based on the references in ls. 477-478. Furthermore, this lack of steric sea-level change seems to be related to their statement in ls. 222-223 that the basin-averaged SSH anomalies in the NWA12 model do not vary in time, but this should be explained more clearly.

We agree that providing a "full picture" of future coastal sea-level rise requires discussing the global mean sea level rise associated with ocean warming and glacial and ice-sheet melting along with the regional circulation-driven (i.e., dynamic) sea-level changes.. To discuss "full-picture" of coastal sea-level rise, we discuss in more detail the global mean sea level rise projection from the IPCC AR6 report in the revised manuscript.

(L516-528) Finally, we emphasize that the dynamical SSH changes described in this study would occur in addition to the global mean sea level (GMSL) rise associated with ocean warming and glacial and ice-sheet melt. As described in the methods, MOM6-NWA12 can respond to local density changes driven by local warming and freshening (e.g., Steinberg et al., 2024), GMSL rise is not directly reflected in the model simulation due to the Boussinesq approximation. Therefore, to explore the total coastal SSH change (i.e., dynamic SSH changes plus GMSL rise) in the late 21st century, the dynamic SSH changes derived from MOM6-NWA12 are combined with the GMSL change. According to the IPCC AR6 report (IPCC, 2021), the projected GMSL rise by the late 21st century relative to the historical period is 0.38 m for SSP-126, 0.47 m for SSP-245, 0.56 m for SSP-370, and 0.64 m for SSP-585, respectively. Specifically, in the SAB under the SSP-585 scenario, the dynamic sea level increase by the late 21st century (~0.2 m) accounts for nearly 25% of the total sea level increase. This highlights that the SAB could experience extreme and compounding (e.g., high tides and storm surges) coastal flooding risks in the future.

We also clarify the lack of GMSL changes in both MOM6-NWA12 and GFDL-ESM4.1 in the method section of the revised manuscript.

(L237-247) Finally, for sea level, we note that both GFDL-ESM4.1 and MOM6-NWA12 utilize the Boussinesq approximation, which conserves ocean volume. The dynamic sea level in both models can respond to local density changes driven by local warming and freshening (e.g., Steinberg et al., 2024). However, these models cannot simulate global mean sea-level (GMSL) rise caused by thermosteric expansion or added mass from ice melt (e.g., Greatbatch, 1994; Griffies and Greatbatch, 2012; Griffies et al., 2014). Furthermore, to prevent potential drifts in the basin-integrated water volume associated with the lateral open boundary conditions, we explicitly constrain the basin-averaged SSH anomaly to be zero throughout all MOM6-NWA12 simulations. Consequently, the SSH changes derived from MOM6-NWA12 strictly represent the dynamic redistribution of water mass driven by regional ocean circulation and local steric adjustments.

Minor Points

l. 148. What forcing does the ESM model provide to the NWA12 model: just air-sea luxes or lateral boundary conditions (BCs) as well? And how are the lateral BCs passed across given that the ESM uses hybrid ALE layers and the NWA uses the z* coordinate (so some interpolation should be required)?

In this study, MOM6-NWA12 uses both atmospheric fluxes and lateral boundary conditions from GFDL-ESM4 after a bias correction. ESM4 ocean model data were interpolated online from the native hybrid vertical coordinate to a z-level coordinate before being written out, and this z-level model output was then remapped online onto the z* coordinate of MOM6-NWA12 during the boundary condition updates.

To avoid any confusion, we modified the sentence describing the GFDL-ESM4 vertical coordinate in the revised manuscript (L158).

l. 157. What is the resolution of the ocean model (the atmosphere model is 1°)

GFDL-ESM4 has a nominal resolution of ½ horizontally (Dunne et al., 2020). We added the information of GFDL-ESM4 ocean model (MOM6) horizontal resolution in the revised manuscript (L158).

l. 179: this is section 2.4 not 2.5

Thank you. Fixed it.

Fig. 2 caption: l. 918 insert (b) and (c) for the SSS and current speed panels.

We added them in the Fig.2 caption. Thank you.

Fig. 5 caption. l.s 954-955: (a) is for Yucatan, (b) for the Florida Current: the caption has these the wrong way around.

Thank you. Fixed them.

l. 325: “scenarios” not “scenario” better.

Changed.

l.s 335-337: insert latitudes and longitudes of the centres of the regions of minimum surface warming to make things clearer.

We added the longitude/latitude information of minimum surface warming.

l.s 338-340: could the region of minimum SST increase South of Gulf Stream in fig 6e be due to the reduced GS strength (fig 7j, i.e. bringing less heat transport) as well as to its northward shift?

Under high emission scenarios (i.e., SSP370 and SSP585), the Worthington Gyre (Worthington, 1976)—a recirculation gyre located south of the Gulf Stream near 35°N, 73°W—almost completely disappears due to the weakening of the Gulf Stream (Figs. 9d and 9e), leading to a reduction in heat convergence to the region. Therefore, as the reviewer indicates, the weakened Gulf Stream is the primary driver of the minimal future SST increase observed south of the Gulf Stream, where the Worthington Gyre was located during the historical period.

We changed this in the revised manuscript.

(L389-391) “The regions of minimal SST warming appear to be linked to the reduced Gulf Stream or the reduced Loop Current, implying a reduction in ocean heat convergence to these regions (Figs. 6e and 6j).”

l.s 359-360: could refer to Beadling et al. 2018 and Roberts et al. 2019 here in connection with reductions in the WBC system.

We added the references (L388-389).

l. 1001: fig 8 caption: remove "The vertical dotted lines" at the end.

The end of the sentence is missing. Thank you for pointing it out. We changed the Figure 9 caption (originally Figure 8). "The vertical dotted lines indicate the historical and future averaging periods."

l. 383 etc. There are several references to the slowdown of the AMOC but a figure of this only appears in the Supplementary material. Please insert this figure (S6) in the main manuscript somewhere near here. This is important because the AMOC is NOT the same as the WBC system, e.g. McCarthy et al., 2015. This also means that in l. 426, refer to the new AMOC figure rather than to figure S6.

We added McCarthy et al. (2015) as a reference (L301) and moved former Figure S6 from the supplement to the main manuscript as Figure 10.

Fig 10 caption: say the years are e.g. model years - 2000.

To avoid confusion, we changed figure 13 (originally Figure 10) caption and added description.

"Fig. 13. Spatially averaged sea level changes (cm) from historical period (1993-2020) in (a) the northern Gulf of America, (b) West Florida shelf, (c) the South Atlantic Bight, (d) the Middle Atlantic Bight, and (e) the Gulf of Maine under the SSP-126 (blue bars), SSP-245 (green bars), SSP-370 (orange bars) and SSP-585 (red bars) simulations. The dynamic sea level changes are spatially averaged over the shelf regions below 200 m depth (brown-colored area in the maps). The years on the x-axis represent the center of a 20-year averaging period (e.g., the value for 2030 represents the average from 2021 to 2040). "

l. 423: after "begins to emerge" insert "after 2070".

We added it.

Fig. 12: it would be good to include density changes here as well as the dynamically important quantity: lighter water on the western side of the channel would be consistent with lower (geostrophic) flows through the Florida Straits.

Fig. R2 shows the vertical cross-section of mean density in the east coast of Florida (26.5°N, 79.7°W–78.0°W) during the historical period and its future changes under four SSP scenarios. During the historical period, the isopycnals strongly tilt upward toward the Florida coast (Fig. R2a), supporting a strong northward geostrophic flow. However, the future projections show a pronounced negative density anomaly (i.e., lighter water) emerging precisely around 200 m depth along the coast (Fig. R2b-e). This localized density reduction results in a flattening of the isopycnals, indicating an increasingly stable water column along the coast. Consequently, this flattening of the isopycnals weakens the cross-stream horizontal density gradient, thereby reducing northward volume transport in the Florida Straits.

We added the Fig. R2 in the supplementary and discussed it in the revised manuscript.

(L493-497) “A distinct decrease in density (i.e., lighter water) emerges on the western side of the Florida Current around 200 m depth (Supplementary Fig. S5). This localized density reduction reflects a relaxation, or flattening, of the upward-tilted isopycnals along the Florida coast. Consequently, this flattening of the isopycnals weakens the cross-stream horizontal density gradient, thereby reducing northward volume transport in the Florida Straits.”

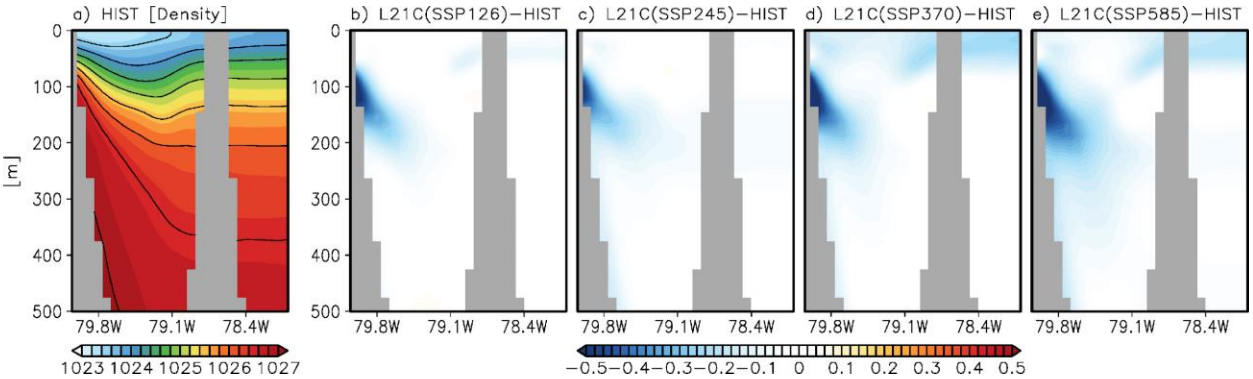

Fig. R2. (a) The vertical cross-sections of the mean density in the east coast of Florida (26.5 °N, 79.7°W-78.0°W) during the historical period (1993-2020). The difference in density between the future and historical periods from (b) SSP-126, (c) SSP-245, (d) SSP-370, and (e) SSP-585 simulations, respectively.

l.s. 514-516: “Further analysis indicates that the weakening of the Florida Current accompanies a substantial reduction of upwelling of cold and fresh subsurface water to the continental slope and shelf region.” – where is this further analysis??

This refers to Figure 15 (originally Fig. 12), which shows the vertical cross-section of ocean conditions off the east coast of Florida. For clarity, we have revised the sentence in the manuscript.

(L580-582) “Further analysis, shown in Fig. 15, indicates that the weakening of the Florida Current accompanies a substantial reduction of upwelling of cold and fresh subsurface water to the continental slope and shelf region.”

References

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Ross, A. C., Stock, C. A., Koul, V., Delworth, T. L., Lu, F., Wittenberg, A., and Alexander, M. A.: Dynamically downscaled seasonal ocean forecasts for North American east coast ecosystems, Ocean Science, 20, 1631–1656, https://doi.org/10.5194/os-20-1631-2024, 2024.

Anonymous Referee #2

The manuscript presents results from downscaling four projections under SSP scenarios computed by the 1 degree GFDL earth system model to a 1/12 degree MOM6 regional model of the western North Atlantic. The authors find significant scenario dependence for SST and SSS but much less dependence for currents and sea level change. They attribute the lower sensitivity to a delayed response. Current and sea level changes are connected with the AMOC decline simulated by the parent 1 degree GFDL model. The presented findings are consistent with Saba et al. (2026) but the present study offers results for different realistic scenarios.

The inter comparison between low and high-resolution model results of the historical mean state is quite extensive given that NAW12 is not a new configuration and has been evaluated before by Ross et al. (2023/24). One could easily save some figures particularly since most of the outcome is expected, well documented progress when moving from 1 degree to 1/12 degree. Instead, the dependence of the changes on the resolution should be more the focus of the paper, to discuss in what way enhanced resolution leads to different projections. Therefore I suggest to move the evaluation into the supplement and the results from global climate model out of the supplement. In that process the discussion of the biases can be condensed and the differences of the projections enhanced.

We appreciate the reviewer for insightful and constructive comments. Here, we provide point-by-point responses to address each of the reviewer's comments and suggestions. Our replies are provided below in blue font for each of the general and specific comments. We believe that the revised manuscript is now better organized and improved.

1. Moving "3.1 Model validation for the historical period" to supplementary

As the reviewer pointed out, Ross et al. (2023) have already described the performance of MOM6-NWA12 compared to various reanalyses and observations. However, the results from Ross et al. (2023) are based on hindcast simulations driven by atmospheric reanalysis and GLORYS as surface forcing and boundary conditions during the historical period. On the other hand, our NWA12 were forced by bias-corrected atmospheric and oceanic outputs from GFDL-ESM4. Therefore, we need to confirm that NWA12, when forced by bias-corrected GFDL-ESM4 outputs, realistically captures the time-mean ocean states and circulations, which is a crucial necessary step in this study. In addition, Ross et al. (2023) did not validate the transports of the Western Boundary Current (WBC) system (i.e., the Yucatan Current, Florida Current, Antilles Current, and Deep Western Boundary Current), which are key components modulating sea level along the US South and East Coasts. Therefore, we would like to keep Section 3.1 in the main text. To address the reviewer's suggestion to consolidate figures, we combined Figs. 1 and 2 (i.e., the mean from GLORYS and biases from ESM4 and NWA12) and moved the original Fig. 2 (i.e., the mean from ESM4 and NWA12) to the supplementary material.

2. Adding the GFDL-ESM results to the main figures.

We agree with the reviewer on this comment. The addition of the future projection results derived from the parent model (i.e., GFDL-ESM4) is important for discussing the differences between the parent model and the child model (i.e., MOM6-NWA12) and improves the manuscript. Therefore, we moved Figures S4, S5, and S6 from the supplement to the main manuscript as Figures 7, 8, and 12, respectively.

Details

Line 44-45 Are these implication part of the investigations of the manuscript? I did not find much about it that would deserve being mentioned in the abstract.

We removed this part in the revised manuscript.

Line 148-150 I assume ESM4 is run under the same 4 scenarios as NWA12. Where are those runs described and how does ESM4 compare to other climate models in climate sensitivity. A littel bit more information should be provided here.

Meehl et al. (2020) noted that GFDL-ESM4 has a relatively low equilibrium climate sensitivity (ECS, 2.6 K) compared to the multi-model mean (3.7 K) of 68 participating CMIP6 models. This result is consistent with previous studies (e.g., Dunne et al., 2020; Sentman et al., 2026). We addressed this in the revised manuscript.

(L162-164) "It is noted that the equilibrium climate sensitivity (ECS) of GFDL-ESM4 is approximately 2.6 K, which is at the lower end of the sensitivity range for CMIP6 models (Dunne et al., 2020; Meehl et al., 2020; Sentman et al., 2026)."

Line 196-200 Not clear what the difference between the method here and the previous method is. For instance Liu et al. 2012 also corrected with the difference between the climatologies. Alexander et al. however used the differences between the mean. I don't understand how this would assume that the climate variability remains the same as in the historical period. Correcting with mean or climatology does not constrain the climate variability.

As the reviewer pointed out, our methods are fundamentally similar to those previous studies (Liu et al., 2012, Alexander et al., 2020, and Shin and Alexander, 2020). They all applied a climatological mean bias correction. However, Alexander et al. (2020) used interpolated daily values from the monthly outputs of a control simulation, which was forced by reanalysis during the historical period. Liu et al., (2012) used daily atmospheric forcings extracted from a reanalysis product and then added them to monthly CMIP surface forcing fields. Both methods derived high-frequency atmospheric forcings from the historical period, and then added them to monthly forcing fields to force future projection simulations with an assumption that high-frequency atmospheric variability in the future remains the same as in the observed historical period (i.e., fixed high-frequency atmospheric variability). In contrast, we use bias-corrected 3-hourly and daily atmospheric forcings derived directly from GFDL-ESM4. Therefore, the high-frequency atmospheric variability comes from GFDL-ESM4. This means that the model results in our study consider the future modeled high-frequency atmospheric variability, which is different from the previous studies.

To avoid confusion, we modified the corresponding text in the revised manuscript.

(L214-226) "It is noted that our 'Delta method' shares similarities with approaches from previous studies (Liu et al., 2012; 2015; Alexander et al., 2020; Shin and Alexander, 2020; Pozo-Buil et al., 2021), which replace model climatology with reanalysis climatology to reduce mean biases. However, our method fundamentally differs in its treatment of high-frequency atmospheric forcing. While those previous studies utilized high-frequency atmospheric forcing (i.e., daily time scales) from historical reanalysis datasets for future projections—thereby assuming that high-frequency forcing remains unchanged in the future—we retained the model-generated high-frequency atmospheric variability (e.g., 3-hourly and daily). We took this approach to ensure more consistent climate projections, recognizing that weather and climate are interdependent. Indeed, not only does weather depend strongly on low-frequency variability (e.g., weather conditions during the different phases of ENSO are substantially different), but also weather statistics can substantially change under future climate conditions (e.g., Cheng et al., 2012; Jeong and Sushama, 2019).“

Line 204-206 This argument is not convincing. Jackson and Wood do not really assess runoff uncertainty and Giuntoli argued that hydrological models add uncertainty in addition to the contribution of GCMs. Following just the latter argument you may also disregard the GCM contribution. If there is not meaningful signal and only uncertainty is added, projected runoff could be neglected. But I doubt that there is not meaningful runoff signal, since sea level projections nowadays include contributions from glacial and ice sheet melt and a clear positive trend in river discharge is visible already now (https://doi.org/10.5194/hess-28-2179-2024). So, neglecting the runoff contribution is likely to reduce realism rather than uncertainty.

Thank you for pointing this out. We agree that the Jackson and Wood study was not particularly relevant to our study. So we removed the references in the revised manuscript. Müller et al. (2024), as mentioned by the reviewer, showed that even though global river discharge driven by climate change exhibits a clear positive trend, the projected river discharge changes in our regional model domain (i.e., the southern and eastern US seaboards) are insignificant and uncertain during the first half of the 21st century (Figs. 4 and 6 in Muller et al., 2024). We believe this justifies our decision not to consider future changes in river runoff in our regional ocean model. The potential effects of a wider range of possible runoff changes towards the end of the century is a very important topic to explore but it is beyond the scope of the present study. To address this, we changed the main text in the revised manuscript.

(L178-185) Although global river discharge driven by climate change exhibits a clear positive trend, the projected changes in river discharge in our regional model domain (i.e., the southern and eastern US seaboards) are insignificant and uncertain during the first half of the 21st century (Muller et al., 2024). Therefore, we did not consider future changes in runoff in this single-model downscaling and instead applied the daily mean climatology (1993–2020) of GloFAS river runoff data for the entire simulation period (1950–2100). As a result, the potential effects of regional runoff change on nearshore salinity and sea level are not addressed in this study.

Line 216-223 You may want to mention other components that are not included in the sea level projections, particularly since you refer to this information in the conclusions.

The MOM6 cannot simulate the basin-averaged sea level changes since this model utilizes a Boussinesq approximation. Therefore, we addressed this limitation in GFDL-ESM4.1 and MOM6-NWA12 in the method section of the revised manuscript.

(L237-246) Finally, for sea level, we note that both GFDL-ESM4.1 and MOM6-NWA12 utilize the Boussinesq approximation, which conserves ocean volume. The dynamic sea level in both models can respond to local density changes driven by local warming and freshening (e.g., Steinberg et al., 2024). However, these models cannot simulate global mean sea-level (GMSL) rise caused by thermosteric expansion or added mass from ice melt (e.g., Greatbatch, 1994; Griffies and Greatbatch, 2012; Griffies et al., 2014). Furthermore, to prevent potential drifts in the basin-integrated water volume associated with the lateral open boundary conditions, we explicitly constrain the basin-averaged SSH anomaly to be zero throughout all MOM6-NWA12 simulations. Consequently, the SSH changes derived from MOM6-NWA12 strictly represent the dynamic redistribution of water mass driven by regional ocean circulation and local steric adjustments.

Line 241-242 I think it is mostly broader, I am not sure if I see the shift away from the coast.

We agree that the Gulf Stream (GS) in GFDL-ESM4.1 is broader than in GLORYS12. However, Supplementary Fig. S1 shows the historical mean (1993–2020) position of the GS, defined by the 15°C isotherm at 200 m depth, in GLORYS12, GFDL-ESM4.1, and MOM6-NWA12. This figure shows that the GS in GFDL-ESM4.1 is shifted slightly further offshore along the South Atlantic Bight compared to its position in GLORYS12. To clarify this, we now explicitly reference Supplementary Fig. S1 in this section of the revised manuscript.

(L267-269) “In addition, ESM4.1’s Gulf Stream along the South Atlantic Bight (SAB) is weaker, broader and slightly shifted away from the US East Coast compared to that in GLORYS12 (Supplementary Fig. S2).”

Line 315-319 What are "these regions" over which the temperature change was calculated?

In this context, “these regions” refers to the areas of the maximum SST warming around the MAB and the Gulf of Maine (35°N–42°N, 75°W–60°W). To clarify this, we added the longitude/latitude information to the revised manuscript.

(L343-345) “Warming in these regions around the MAB and the Gulf of Maine (35°N–42°N, 75°W–60°W) is reduced to ~3°C, ~2°C and ~1°C in SSP-370, SSP-245 and SSP-126, respectively (Fig. 5b-d).”

Line 360-363 These two statements seem to contradict each other. Fig.7 is from the end of the century and I believe to see gradual differences. I suggest to point to the gradual differences visible in Fig.7 but then also to the surprisingly similar development until 2070 seen in Fig. 8. Additionaly mention here when the scenario forcings start to differ, because later you use an argument of delayed response that requires the reader to know until when scenarios were still similar.

Thank you for pointing it out. As the reviewer suggested, we revised the sentences to point out these differences at the end of the century (Fig. 6, originally Fig.7) and highlighted the similar changes across all scenarios until around 2070 (Fig. 9, originally Fig. 8).

(L389-393) “These scenario-dependent differences in the reduction in surface current are clearly shown by the late 21st century (Fig. 6). To further explore volume transport by the WBCs system, we examine the temporal changes in the volume transport in the Florida Current, Yucatan Current, Antilles Current, and the Deep Western Boundary Current (DWBC), as shown in Fig. 9.”

(L417-428) “Similarly, the time series of volume transports in the WBCs system shows a similar rate of decline across all four SSP scenarios until approximately 2070 (Fig. 9). The insensitivity of Northwestern Atlantic WBCs to emission scenarios before 2070s is consistent with the AMOC decline in GFDL-ESM4.1, which is the major contributor to the modulation of the Atlantic WBCs system (Fig. 10). Previous studies (e.g., Weijer et al., 2020; Baker et al., 2023) found that the rate of AMOC weakening derived from most CMIP6 models shows limited sensitivity to emission scenarios prior to around 2070, consistent with GFDL-ESM4.1. It is important to note that the greenhouse gas forcings for the CMIP6 SSP scenarios begin to diverge after the historical period (~2014), with separation in their radiative forcing pathways emerging by the mid-21st century. The results that WBC volume transports and AMOC remain relatively insensitive to these diverging emissions scenarios for several decades provides critical evidence for a delayed ocean response to greenhouse gas forcing.”

Line 373-366 Is the reduction really significant given the error bars? Given the error bar it is probably more appropriate to say that the Antilles Current disappears (no significant mean transport).

Agreed. We toned down this in the revised manuscript.

(L405-406) “This suggests that the Antilles Current may disappear (nearly zero mean transport) after around 2080 (Fig. 9c)”

Line 383 Point to Fig. S6 already here

Added.

Line 368-388 Do the lateral boundary conditions make NWA12 entirely a slave of the ESM4.1 for AMOC? You may want say something about this.

As mentioned in the previous reply, we added the following sentence to address this point in the revised manuscript.

(L419-421) “The insensitivity of Northwestern Atlantic WBCs to emission scenarios before 2070s is consistent with the AMOC decline in GFDL-ESM4.1, which is the major contributor to the modulation of the Atlantic WBCs system (Fig. 10).”

Line 398-399 not shown?

This refers to Fig. 11 (originally Fig. 9).

Line 405-406 How much is AMOC vs gyre weakening? Although ultimately as Yin et al. (2010) suggested the AMOC may be the origin of the changes, it would be useful to mention changes in the barotropic circulation of the subtropical gyre (stream function). because it seems that the transport change directly associated with AMOC weakening can account only for a fraction (<50% from the numbers reported on page 18 and the AMOC decline Fig.S6) of the reduced transports.

The rate of WBC volume transport reduction in MOM6-NWA12 cannot be directly compared with the rate of AMOC weakening in GFDL-ESM4.1 because they are not two-way coupled. Additionally, due to the Orlanski's radiation open boundary conditions (Orlanski, 1976) employed in MOM6-NWA12, the volume transports across the open boundaries do not exactly match between the two models. Therefore, it is quite difficult for us to reconcile the aforementioned difference between the two models.

Similarly, since MOM6-NWA12 is a regional model with open boundaries, the stream function values in the eastern open boundary, which are required to integrate the barotropic volume transport, cannot be determined. Therefore, we are unable to compute the barotropic streamfunction for the MOM6-NWA12 domain. This limitation is briefly discussed in the revised manuscript, pointing out that the gyre circulation could potentially contribute to the changes in the WBCs volume transport.

(L442-445) "It is noted that the gyre circulation change potentially contributes to the changes in WBC volume transport. However, since MOM6-NWA12 is a regional model with open boundaries, we are unable to explore the barotropic streamfunction for the regional domain."

Line 454-455 How does geostrophic adjustment weakens upwelling. Isn't it more just the flattening of the isopynals.

This sentence is now revised.

(L493-497) A distinct decrease in density (i.e., lighter water) emerges on the western side of the Florida Current around 200 m depth (Supplementary Fig. S5). This localized density reduction reflects a relaxation, or flattening, of the upward-tilted isopycnals along the Florida coast. Consequently, this flattening of the isopycnals weakens the cross-stream horizontal density gradient, thereby reducing northward volume transport in the Florida Straits. Due to reduced bottom Ekman transport and a relaxation, or a flattening, of the upward-tilted isopycnals associated with a weakened Gulf Stream, upwelling decreases along the continental slope and shelf, limiting the supply of cold and relatively fresh subsurface water from underneath the Gulf Stream.

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