Responses in blue text

Comments from Reviewer #3

The authors compared two downscaled climate model projections to evaluate the mid-century physical and biogeochemical responses in the northwest North Atlantic shelf region. They demonstrated that the two models resulted in largely different changes in along-shelf circulation that contributed to varying patterns of warming, salinification, and increased/decreased acidification.

The manuscript is well written and, to my knowledge, cites the necessary bibliography. The methods are well described and the regional model used in the manuscript is well-validated and is adequate to answer the proposed questions.

In the manuscript, the authors show that changes in along-shelf transport in the two future scenarios are not similar. While ACM-GFLD shows a nearly 70% decrease in southwestward along-shelf transport in the Scotian shelf associated with the disappearance of Labrador Sea dye in the region, ACM-DFO shows nearly no change in transport and only a 33% decrease in LS dye. The literature demonstrates that the replacement of LS water with Slope Water does impact bottom temperature, salinity, and dissolved oxygen concentration in the shelf, particularly in the channels and deep basins of the Gulf of Maine and Gulf of St. Lawrence, which partially backs the results in the study.

While this is a robust result that advances knowledge, I think that linking short timescale changes in shelf properties solely to these changes misses one step. **For example, it is not clear to me how the different changes in ocean circulation shown in the two projections are responsible for the patterns in bottom pH.** Furthermore, why are the results for **the surface properties missing in the analysis**? It seems like **surface temperature is only briefly mentioned in lines 227-228**. I believe that the missing piece that establishes the causal relationship between changes in ocean circulation and diverging biogeochemical projections could be mitigated in one of two ways: (1) the more robust calculation of fluxes and budgets on each shelf region (GoM, SSsouth, SSnorth and GB) or (2) a **more anecdotal demonstration of this relationship, perhaps following the inflow of LS water and Slope water and the consequent changes in pH and DIC**.

Response: We thank the Reviewer for their feedback and time to prepare a thoughtful review.

In regard to surface properties, we would like to move Table S2 (which summaries total, surface and bottom changes in temperature and salinity) from the supplement into the main text in Section 3.1 (now referenced as Table 1) and will add the following sentences at line 179:

"*Resulting changes in temperature and salinity on the shelf in both future scenarios are summarized in Table 1. At the surface, temperature changes are similar in both scenarios, although ACM-DFO is slightly warmer throughout the shelf. Surface salinity changes are similar on the Scotian Shelf between the two scenarios; the magnitude of surface salinity changes is however larger on the Grand Banks and in the Gulf of Maine in ACM-GFDL.*"

Although we already comment on surface pCO_2 at lines 205ff, we would like to additionally add the following sentence at line 190 at the start of section 3.2: "*Since differences between the two future scenarios in temperature and salinity are larger in bottom waters, we focus most of our remaining analysis on comparisons of bottom water properties on the shelves*."

In response to the comment about how the different changes in ocean circulation affect the bottom pH, we will add a more anecdotal demonstration of this relationship, along the lines of the Reviewer's second suggestion. We will add the following figures and text into a third Results subsection. We will also move Figure 6 to this subsection.

"*3.3 Effects of altered water-mass composition*

The 70% decline in southwestward volume transport along the Scotian Shelf in ACM-GFDL (Figure S1) consequently results in changes to the water-mass composition on the shelf, as previously illustrated in Figure 3. With similar southwestward volume transport in ACM present-day and ACM-DFO, the water-mass composition and transit pathways are similar (Figure 2 and 3). Conversely, in ACM-GFDL with a large decline in southwestward transport of subpolar North Atlantic water, there is a large decline in both ENS and LS dye and an increase in Slp dye reaching the Scotian Shelf and Gulf of Maine. These changes result in an altered water-mass composition on the shelf system as a whole, but particularly on the Scotian Shelf and Gulf of Maine (Figure 3).

Differences in temperature, salinity and pH between these simulations are most obvious in bottom waters which are less influenced by atmospheric inputs; these differences are summarized in Figure 6. Both present-day and ACM-DFO simulations have similar bottom temperature and salinity spatial trends (Figure 6a). Temperature is coolest on the more northern part of the shelf system (Grand Banks, northern Scotian Shelf (SS_{north})) and warmest on the most southern part of the shelf system (Gulf of Maine, southern Scotian Shelf (SS_{south})). There is less spatial variability in salinity, but SS_{north} is the freshest area due to the large influence from the Gulf of St. Lawrence. SS_{south} is about 0.5 salinity units saltier than SS_{north}. In ACM-GFDL, there are larger differences in both bottom water temperature and salinity (Figure 6a). Although the same north-south trend in bottom temperature is present in ACM-GFDL, the southern shelves (SS, GoM) are over 2^{o}C warmer than at present-day and ACM-DFO. This is in contrast to surface waters where ACM-DFO is warmer throughout the shelf system than ACM-GFDL (Table 1). There are additionally large changes in bottom salinity in ACM-GFDL. While the Grand Banks become slightly fresher and the northern Scotian Shelf is relatively unchanged, the southern Scotian Shelf and Gulf of Maine both become saltier by nearly 0.5 and 0.3 units, respectively. As a result, SS_{south} is nearly 1 unit saltier and ~3^{o}C warmer than SS_{north} in ACM-GFDL versus 0.5 units saltier and 2^{o}C warmer in ACM-DFO and at present-day. The changes in temperature and salinity in bottom waters in ACM-GFDL create a larger difference between SS_{north} and SS_{south} than in the present-day simulation and ACM-DFO. This change in spatial variability is reflected in changes in bottom pH (Figure 6b).

Figure 7 further illustrates these spatial trends as they relate to changes in water-mass composition (i.e. changes to the ratio of LS+ENS to Slp dye). Values of LS+ENS:Slp less than one indicate areas that have become dominated by warm, salty slope water; conversely, areas with values greater than one are dominated by subpolar North Atlantic water. Only in ACM-GFDL are areas (GoM, SS_{south} and SS as a whole) more dominated by Slp waters. In both ACM-GFDL and ACM-DFO, all shelf areas shift towards lower LS+ENS:Slp values; however, this shift is much larger in ACM-GFDL. Larger dominance of slope water tends to correspond to warmer bottom waters (Figure 7a) throughout all simulations. Although there is less of a clear trend across all simulations in salinity (Figure 7b), regions with LS+ENS:Slp values less than one have the largest bottom water salinities. In terms of biogeochemistry, bottom DIC is relatively uniform across different water-mass compositions, and any differences in bottom DIC between the two future scenarios are small in comparison to overall increases in DIC in both ACM-DFO and ACM-GFDL from present-day (Figure 7c). Both ACM-DFO and ACM-GFDL have similar overall declines in pH throughout the system (Figure 7d), likely reflective of similar increases in bottom DIC. However, there is larger variability in bottom pH in ACM-GFDL that follows the variability of temperature and salinity associated with larger proportions of slope water."

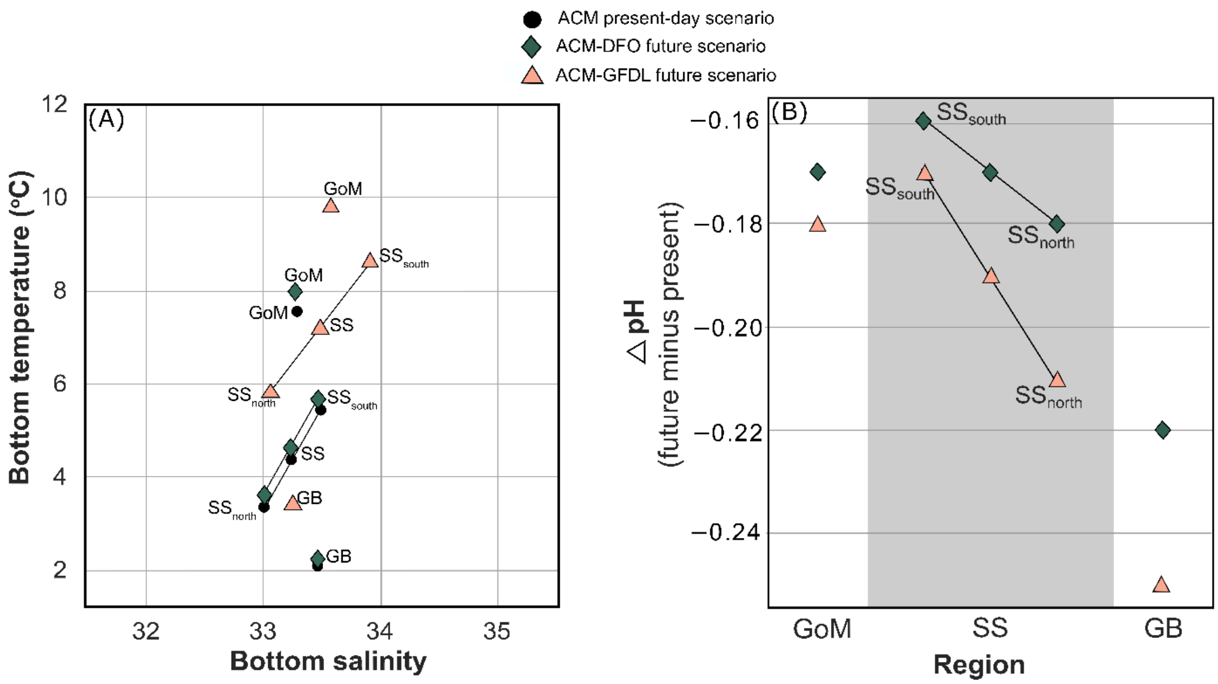

Figure 6: (A) Bottom temperature versus bottom salinity and (B) the change in bottom pH (future minus present) for the Grand Banks (GB), Scotian Shelf (SS) and Gulf of Maine (GoM). The Scotian Shelf is additionally subdivided into the northern Scotian Shelf (SS_{north}) and southern Scotian Shelf (SS_{south}) in each panel to illustrate spatial differences in each simulation.

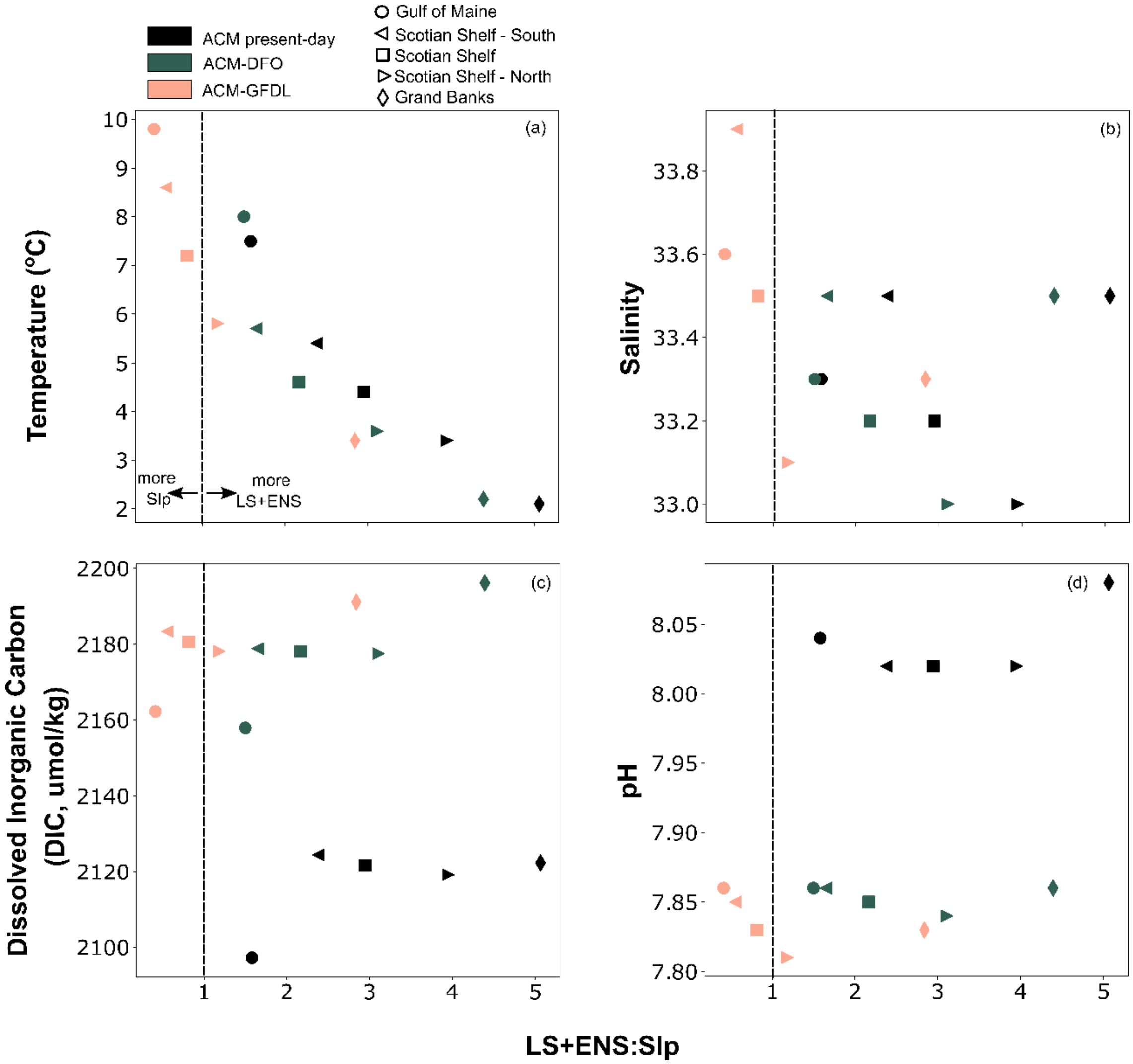

Figure 7: Effects of different LS+ENS:Slp ratios on bottom variables – (a) temperature, (b) salinity, (c) dissolved inorganic carbon, and (d) pH - in each simulation. LS+ENS:Slp ratios above 1 indicate areas that are dominated by subpolar North Atlantic waters (LS and ENS waters); ratios below 1 indicate areas that are dominated by warm, salty slope water (Slp-S and Slp-D).

We will additionally update Lines 222ff (changes in bold italics):

"Conversely, in ACM-GFDL with the shelf-break current nearly vanishing, there is extensive bottom water warming on the shelves, in some locations by up to +5°C. ***Although one could argue that these larger increases in bottom water temperatures in ACM-GFDL could be due to atmospheric inputs, ACM-DFO actually has larger surface water warming than ACM-GFDL (Table 1). It is thus more likely that these large increases in bottom temperature are a result of higher proportions of slope water on the shelves, which is a warmer and saltier end-member (Figure S3). Slp-S and Slp-D end-members did warm slightly more in ACM-GFDL than in ACM-DFO, which is likely also contributing to bottom waters in ACM-GFDL being warmer across the shelf system."***

And lines 231-235 (changes in bold italics):

Line 231-232: "*This increased inflow* ***of warm, salty slope water amplifies the presently existing*** *disparity between the southwestern and northeastern Scotian Shelf* ***in terms of temperature and salinity*** *(Figures 6,7). With a weakened shelf-break current, the southwestern portion of the Scotian Shelf behaves more similarly to the Gulf of Maine, and the northeastern portion* ***remains more similar to Grand Banks with additional influence from the Gulf of St. Lawrence****. This north-south trend is also evident in bottom water pH (Figures 5 and 6).* ***Although the overall decline in pH is strongly dependent on increased DIC throughout the model domain and the magnitude of this decline is similar in both ACM-DFO and ACM-GFDL,*** *the weakened shelf-break current in ACM-GFDL creates localized regions* ***where increased inflow of warm, salty slope water thermodynamically dampens the acidification seen throughout the rest of the shelf system****, compared to more uniform changes to pH in ACM-DFO.*"

Specific comments:

Lines 46-50: The description of the objective of the study at this point seems redundant with the last paragraph of the Introduction. I'd suggest incorporating these sentences in the last paragraph or removing them.

Response: We will edit this appropriately.

Lines 149-151: Again, I do not think that it is necessary to repeat the objective of the study, especially in the Methods section.

Response: We will edit this appropriately.

Lines 227-228: The authors should add that surface temperature changes are not shown and air-sea CO2 flux changes are shown in Table S3.

Response: Surface temperature changes are shown in Table S2, which we will move to the main text and add reference to here along with Table S3.

Lines 263-265: Maybe it's my lack of knowledge of ecology, but it was not clear to me why Atlantic cod and snow crab would see larger habitat shifts in the southern subpopulation in a scenario with an unaltered shelf-break current.

Response: We will explain this briefly or remove it.

It seems to me like Figure 3 and Table S1 give the exact same information, so one of them can be removed (the references in the text have to be adapted accordingly).

Response: Yes, Figure 3 and Table S1 have the same information but displayed in a different way. We will remove the table from the supplement.

Figure 5: I am curious as to why the authors chose to use blue for positive and red for negative differences (especially on panel e).

Response: For panel d, we believe it makes sense to use red for the negative values since negative values mean acidification (i.e., the worsening of conditions). For panels e and f, we attach no special meaning to the color choice.

Figure 5: Why didn't the authors show the difference between ACM-DFO and ACM present, as they did for ACM-GFDL in panels C and D?

Response: We wanted to highlight the differences between the two future simulations (ACM-DFO and ACM-GFDL; panels e and f) and we felt adding another panel would crowd the figure.

Figure 6: Why didn't the authors add the present-day pH values to panel B?

Response: Our intention here is to show the difference in pH between the future and present-day values. We feel that showing the differences between the two experiments and the present-day pH values best shows the differences between the two experiments. However, in our proposed changes above, we now include pH for present-day in Figure 7.

Technical corrections:

Line 174: Reference to Figure 4 should be Figure 3.

Response: We thank the Reviewer for catching this! The figure reference will be updated.

Line 221: Reference to Figure 4 instead of Figure 5.

Response: Again, the figure reference will be updated.