Responses in blue text

Comments from Reviewer #1

The authors downscaled two future climate projections to the Atlantic Canada domain to characterize the future states of the physical and biogeochemical environments. Their results show quite different outcomes of future climate states in the region. While the topic is interesting, the manuscript is mostly descriptive and speculative and does not provide much insightful new knowledge or sufficient explanations of the results. Because it is known that future climate projections can be widely different across models (hence we have CMIP), downscaled projections to a regional model being different should not be surprising. **The weakness of this manuscript, however, is the lack of robust connections showing that the changes of circulation (shelf-break currents) cause the different biogeochemical projections.** For example, **how does the changes in the shelf-break currents affects the temperature and salinity over the shelf**? Note shelf-break currents and along-shelf currents are different. Tracer released over the Labrador continental slope is expected to move along the slope and shelf-break, however, tracer concentrations from the two simulations doesn't explain the changes of physical and biogeochemical environment on the continental shelf, which seems to be the focus of this manuscript. A **more relevant analysis can be to compare the distribution of ENS tracer (on the shelf)**. To understand the causes of the simulated temperature and salinity changes, **budget calculations including the along-shelf and cross-shelf advective fluxes as well as air-sea fluxes are needed.** Otherwise, claiming shelf-break currents causing the changes is unsupported. Similarly, **how the diverging projections of temperature and salinity lead to diverging biogeochemical projections, e.g., PH and DIC, needs to be supported with actual analysis**.

Response: We thank the Reviewer for taking the time to review our manuscript. We've outlined replies to their major comments below.

Regarding connections between changes in circulation and the resulting effect on the biogeochemical projections: we would like to 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 (Figures 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 S2). 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."

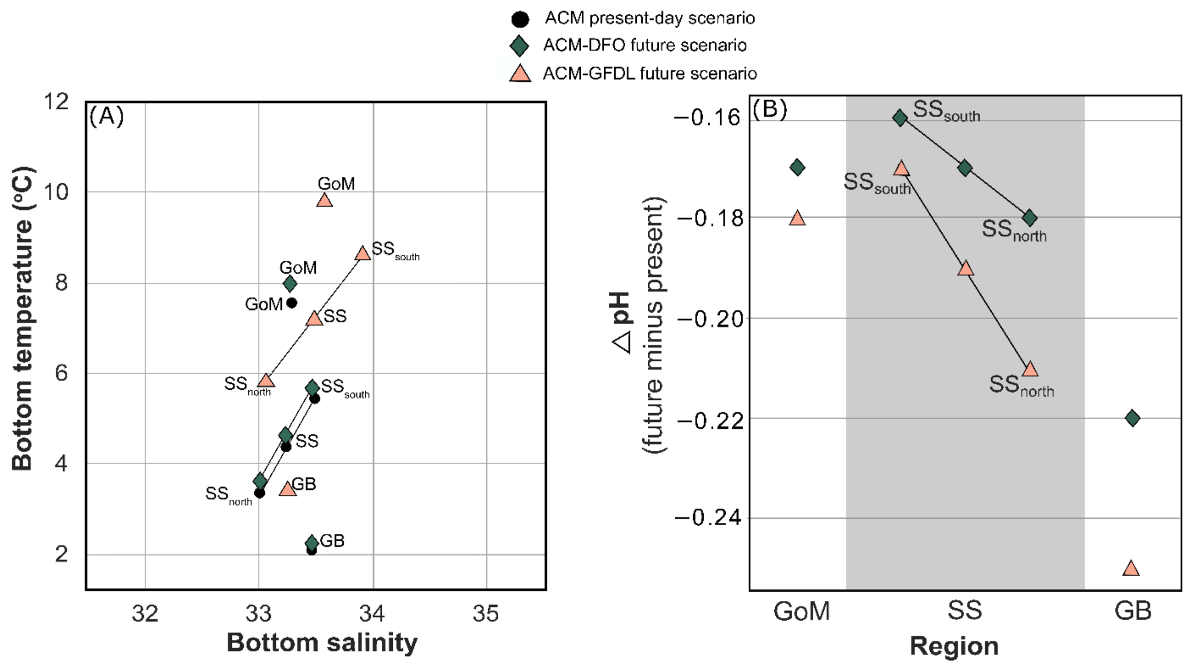

Figure 6: (A) Bottom temperature versus bottom salinity and (B) the change in bottom pH (future minus present) for the Grand Banks (GB), Scotian Shelf (SS) and Gulf of Maine (GoM). The Scotian Shelf is additionally subdivided into the northern Scotian Shelf (SS_{north}) and southern Scotian Shelf (SS_{south})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

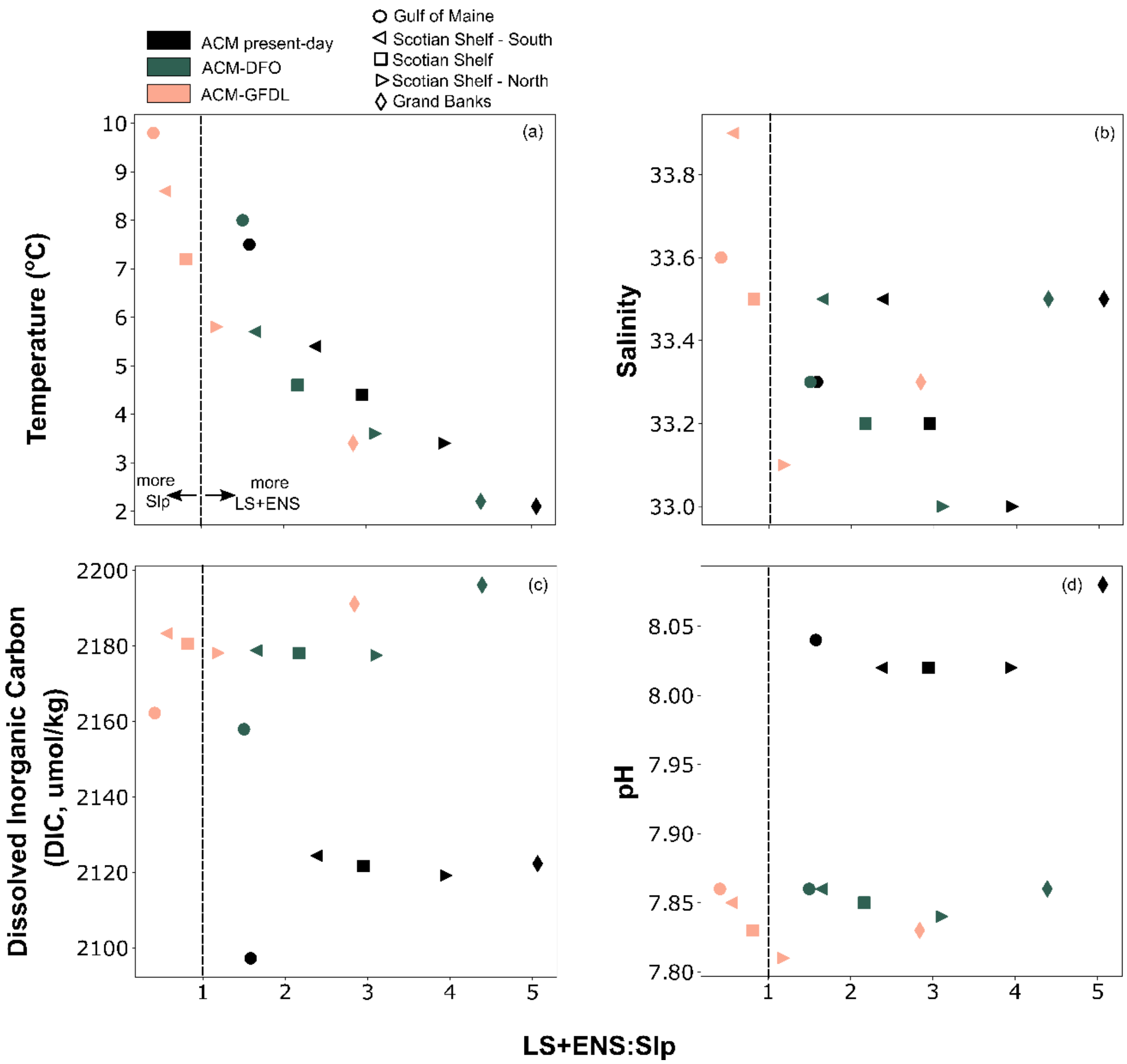

Figure 7: Effects of different LS+ENS:Slp ratios on bottom variables – (a) temperature, (b) salinity, (c) dissolved inorganic carbon, and (d) pH - in each simulation. LS+ENS:Slp ratios above 1 indicate areas that are dominated by subpolar North Atlantic waters (LS and ENS waters); ratios below 1 indicate 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 S2). 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."*

Regarding the distribution of ENS tracer vs LS tracer: We chose to display distributions of the LS tracer in Figure 2 as this dye tracer highlights the shelfbreak current (or lack thereof) best. The ENS tracer is more representative of the along-shelf transport on the inner shelf, which is not the intended purpose of Figure 2. Changes in ENS dye is included in the dye tracer mass fractions shown in Figure 3, which includes the fraction of ENS and LS dye on Grand Banks, Scotian Shelf and Gulf of Maine.

Other comments:

Line 18: "*Our results illustrate that a wide range of outcomes is possible for continental margins*" This is extrapolation and unsupported.

Response: We would like to update this sentence to read: "*Our results* ***suggest*** *that a wide range of outcomes is possible for continental margins …"*

Line 61: "*Future projections indicate a significant decline in SC strength over the next century potentially accelerating warming and deoxygenation (Saba et al. 2015, Claret et al. 2018).*" Isn't the projection of SC strength model-dependent, as mentioned in the abstract?

Response: We have updated this sentence to read: "***Some*** future projections indicate a significant decline in SC strength…"

Line 231: "*This localized increased inflow creates an even larger disparity between the southwestern and northeastern Scotian Shelf than what is currently present*". Localized increase inflow is not shown. This statement (and the paragraph) is unsupported.

Response: Increased inflow is indeed shown in Figure S2 where we show that there is a larger concentration of Slp-D dye in the deep basins along the Halifax transect in both scenarios, but particularly so in the ACM-GFDL scenario. This figure additionally shows that there is a large decrease in LS dye along the shelf break of the Scotian Shelf. Additionally, the changes outlined above in response to the Reviewer's first comments should address their concern about whether there is a disparity between SS_{south} and SS_{north}, and how this relates to changes in water-mass composition.