

## **A modeling study of temporal and spatial $p\text{CO}_2$ variability on the biologically active and temperature-dominated Scotian Shelf**

(Editor/reviewer comments are included in black font; Responses are in blue font)

Dear Dr. Rutherford:

I am now in receipt of two reviews of your revised version. One referee (#1) has evaluated your initial (BGD) version; the other one #3 is new to this paper. Both agree that your paper has improved very much and recommended eventual publication. However, they identified some (minor) issues to be addressed. Details are given in the report below. Referee # 3 suggested to include some discussion on the role of buffering state. This echoes the need to include the Revelle sensitivity factor expressed by referee #1 during the initial submission. I agree with both referees that this may strengthen your paper, but I leave it up to you. (Your name is on the paper).

I am looking forward receiving another revision, that after inspection by me, will likely be accepted for publication. Thank you for considering Biogeosciences,

Best regards, Jack Middelburg, Associate Editor

**Response:** Thank you for your time involved with our paper. As we mentioned in our response to Referee #1 during the initial submission, discussion of buffering state/Revelle factor are outside the intended scope of our paper. Discussion of buffering capacity is of course important; however, we think adding it to our current paper would take away from our main messages and discussion. We have upcoming work which uses the same model and focuses on long-term carbonate chemistry trends, and we feel that might be a more appropriate body of work to discuss regional buffering capacity.

We have outlined below the changes we have made to address the comments from Referee #1. There were no comments/suggestions from Referee #3 in their report, but we thank them for taking the time to review our paper.

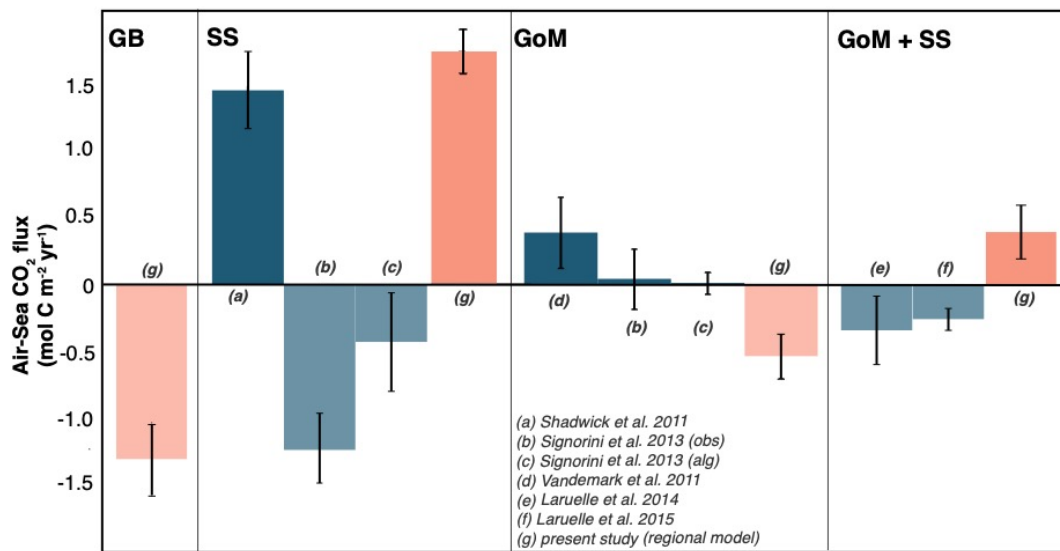
### **Suggestions from Referee #1:**

The authors did a great job with clarifying and updating the methods in this version of the manuscript. The clarification about the science questions in the text is a welcome addition as well. While the authors spend a lot of time on the discussion of Figure 9 - and rightly so - the reader is still left with questions. One important one that could be cleared up quickly in the text or in the figure is about the last panel (SS +GOM) - couldn't this also be compared to (g) the model output? Is there a reason the models would agree more with the latest round of the SOCAT products? Are the "newly" included data sets in a region that is important to

getting the direction of the regional flux correct? The addition of this detail would help clarify this disagreement and help modelers in the area understand what is needed to properly simulate this flux.

**Response:** Thank you for taking the time to review our paper again. We have addressed your remaining comments about Figure 9 as detailed below.

Firstly, we have updated Figure 9 to include a model estimate of GoM + SS to compare more directly with Laruelle et al. 2014 and Laruelle et al. 2015 (the last panel of Figure 9; see below).



Secondly, regarding the agreement of our model estimates with previous studies, we have added text (bold italics below) to hopefully answer the reader's remaining questions.

**Lines 350ff:** According to the model, the Scotian Shelf acts as a net source of CO<sub>2</sub> to the atmosphere (+1.7 ± 0.2 mol C m<sup>-2</sup> yr<sup>-1</sup>), the Gulf of Maine is a net sink of CO<sub>2</sub> (-0.5 ± 0.2 mol C m<sup>-2</sup> yr<sup>-1</sup>) and the Grand Banks act as a net sink of CO<sub>2</sub> (-1.3 ± 0.3 mol C m<sup>-2</sup> yr<sup>-1</sup>). These results are in agreement with Shadwick et al. (2014) for the Scotian Shelf, and Laruelle et al. (2014, 2015) for the Gulf of Maine. Our results disagree, however, with results from other global (Laruelle et al. 2014) and regional studies (Laruelle et al. 2015; Signorini et al. 2013; Vandemark et al. 2011). The discrepancy in reported air-sea CO<sub>2</sub> flux between these studies is partly a result of how each study defines the area of the Scotian Shelf and Gulf of Maine. For example, Laruelle et al. (2015) calculates one estimate for both the Scotian Shelf and Gulf of Maine. The shelves of eastern North America are diverse, particularly in width and circulation features, and defining

them as a single region is not representative. Additionally, the Scotian Shelf waters are strongly influenced by cold, carbon-rich Labrador Sea water, which is not the dominant endmember south of the Gulf of Maine (Loder et al. 1998, Rutherford & Fennel 2018; Fennel et al. 2019). Calculating a single flux estimate for the entirety of this dynamically diverse region is problematic and will yield a different estimate than when considering smaller and more specific regions. However, this only partially explains the difference in flux estimates.

Another reason is that the global SOCAT database was missing important regional data until recently. Signorini et al. (2013) used data from version 1.5 and Laruelle et al. (2014, 2015) used data from version 2.0 of the SOCAT database. Neither of the observational datasets used in the present study were included in SOCAT versions 1.5 and 2.0. **Error! Reference source not found.** illustrates the difference between different SOCAT versions for seasonal  $p\text{CO}_2$  on the Scotian Shelf. SOCAT v2020 has consistently higher average  $p\text{CO}_2$  values than v1.5 and v2, with at least double the number of years and a much larger number of observations going into each monthly average (on the order of 1000 to 10000 measurements in v2020 versus 100 to 1000 in v1.5 and v2). We believe that flux estimates using the updated SOCAT v2020 will agree better with our estimates and those of Shadwick et al. (2014) *since SOCAT v2020 includes more observations with higher spatial and temporal resolution to better capture the distinct seasonal cycle here. Our study, however, only focuses on the recent seasonality of  $p\text{CO}_2$ , making it difficult to distinguish if earlier SOCAT versions miss the regional dynamics solely due to low resolution of observations, or if the estimates from the different SOCAT versions are reflective of a shift in the behaviour of the shelf system. More work should therefore be done to better understand how variability on longer timescales could be affecting regional  $p\text{CO}_2$  and if that variability could also be a reason for the disagreement between the different SOCAT version.*

**No comments from Referee #3.**