Biogeosciences Discussions

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Reply on RC2

Wiley Evans et al.

Author comment on "Marine CO_2 system variability along the northeast Pacific Inside Passage determined from an Alaskan ferry" by Wiley Evans et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-266-AC2, 2022

Reviewer 2:

In this paper, Evans et al. presented the full carbon system parameters along the Inside Passage of the Pacific Northwest coast of North America from November 3, 2017 to October 2, 2019. They examined their seasonal and temporal changes and discussed their controlling mechanisms, and estimated the Time of Detection. They even projected the conditions when atmospheric CO2 reaches a level that exhausts the remaining 1.5°C carbon budget. The paper is very well-written and the data will contribute to the understanding of ocean acidification status in an important region.

Thank you very much for the review of our paper. Your comments have been helpful and have improved the manuscript.

Major comments:

- Please consider adding a plot showing the internal consistency of the measurements.

We thank the reviewer for this comment. Internal consistency of the marine CO2 system is evaluated by "over-determining" the system using 3 or more distinct measurements of marine CO2 system parameters. For instance, internal consistency could be evaluated with measurements of pH, pCO2, and TCO2 made on the same seawater sample. During this study, there was never 3 distinct measurements of the marine CO2 system made; the system was never over-determined. During the first year, bottle samples were analyzed for pCO2 and TCO2 and pCO2 was continuously measured using the GO8050 on the ferry. During the second year, pH and pCO2 were both continuously measured on the ferry with no bottle samples for TCO2. Therefore, the comparison we can make requires alkalinity from an empirical relationship, which we have done and show in Supplemental Figures S2 and S3. S2 shows the comparison between alkalinity determined from the pCO2 and TCO2 measurements and alkalinity determined from a regional alkalinity-salinity relationship. S3 shows the comparison between directly measured pH and pH computed using continuous pCO2 measurements and alkalinity determined from a regional alkalinity-salinity relationship.

- [Ca2+] in the open ocean can be assumed to be conservative with salinity, which is the basis for the CO2SYS calculation. However, in the coastal ocean, especially in low salinity areas, the [Ca2+]-salinity relationship can be quite different from region to region (Dillon et al., 2020). I wonder if the authors could find any directly measured calcium data in the region, so as to improve the uncertainties of the calculated aragonite saturation states.

We thank the reviewer for this comment and agree that deviation for the global salinity/Ca^{2+} relationship is a source of uncertainty, particularly in the low-salinity, glacial melt influenced regions of southeast AK. We see this as an important next step to the work being done in southeast AK, which includes building a building a new regional algorithm for alkalinity that better captures the low salinity water in this region. We have highlighted this point in our discussion and conclusions, and now include the Beckwith et al 2019 reference, which we felt better captured the issue around riverine Ca^{2+} contribution.

- The estimation of anthropogenic CO2 levels in a coastal setup is kind of surprising. The current method to estimate anthropogenic CO2 is mainly designed for the open ocean. For the coastal ocean, pCO2 level is strongly controlled by many other processes, such as river and ground water input, eutrophication, benthic processes, etc. I'm not even sure if it is a good idea to provide such an estimate. The same goes true for the estimation of the conditions when atmospheric CO2 reaches a level that exhausts the remaining 1.5°C carbon budget.

We thank the reviewer for expressing concern regarding the estimation of anthropogenic CO2 and theoretical evaluation of the 1.5C acidification level. However, as described in our methods, the approach we use has been applied to coastal datasets (see Takeshita et al., 2015, Pacella et al., 2018, and Evans et al 2019). The reviewer is correct that multiple processes unique to the coastal ocean drive large variability in TCO2 that make evaluation of the anthropogenic CO2 signal challenging. But the approach used accounts for this variance in the delta-TCO2 disequilibria term, and makes the key assumption that this term is constant, meaning the drivers of TCO2 disequilibrium with the contemporary atmosphere are not changing over time. While this assumption may be less valid in certain regions, such as areas that have experienced an increasing eutrophication signal, the assumption appears to hold in our region based on the comparison to other recent estimates of anthropogenic CO2 content from Feely et al 2010 for the Salish Sea (Puget Sound) and from Carter et al 2019 for the coastal North Pacific surface water. The surprise for us were the low values found in areas influenced by glacial melt, which is understandable given these waters have limited ability to acquire an appreciable anthropogenic CO2 signal. We clearly state these results are theoretical and do not account for change in other drivers such as increasing temperature or changing freshwater input. We feel that inclusion of this theoretical analysis is important for evaluating the contemporary anthropogenic CO2 content, describing the degree of acidification in our region and how it varies spatially and seasonally, and for guiding experimental work on appropriate regional targets that should resemble a 1.5C warmed world.

- Please consider creating a separate section called Study site and move the current information about the site from Introduction to the new section.

Thank you for this comment. Reviewer 1 had a similar comment, and we have addressed this by adding a "Study Region" section to the manuscript.

Minor comment:

- Throughout the paper, please italicize the "p" within "pCO2".

Thank you for this comment. Italicizing the p would denote it as a mathematical operation, which is not correct in this case. We have seen this appear in the literature and believe it stems mainly from author preference. Because of this reason and the potential confusion with mathematical operation, we maintain "p"CO_2 throughout the manuscript.

- Throughout the paper, please replace "concentration" with "content", if the values are reported as per kg SW. Concentration is a term for per volume based measurements.

We have switched "concentration" for "content".

- Hydrogen ion concentration -> Total hydrogen ion content (assuming you are talking about the amount estimated based on pH on Total Scale)

We have specified "total hydrogen ion content" on Line 45 and adjusted $[H^+]$ to $[H^+]_T$ throughout the manuscript.

- Line 39: Replace "412 ppm in 2019" to "414 ppm in 2020".

We have updated this statement to reflect the 2020 value.

- Line 40: Please recheck this number. I remember it is more like 600 GtC instead of 700 GtC. I could be wrong though.

Corrected to 690+/-80 GtC as per Friedlingstein et al 2021.

- Line 41: Replace "Friedlingstein et al., 2020" with "Friedlingstein et al., 2021".

We have updated to the 2021 reference.

- Line 48: "saturation state" -> "saturation states".

We have made this correction.

- Line 48: If you choose to use the word "more", you'll better off finding a place to mention calcite?

We have edited this statement and removed the word "more".

- Line 52: For the change of aragonite saturation state, it is better to report a percentage number. After all, its baseline varies significantly across the global ocean. A change of 0.53 could mean dramatically different things in the polar region compared to the tropical region.

While we agree with the reviewer's point, we retain reporting the absolute decrease in global average aragonite saturation state as this is what is reported in the literature by Lauvset et al., 2020.

- Line 252: The uncertainty of [H+] needs a unit.

Thank you, we have added this missing unit.

- Line 258: Please specify the gridding method you used.

The description of the gridding method was adjusted to "observations were gridded by isolating and averaging data within 0.03° by 0.03° grid cells".