Rebuttal to "**The sensitivity of pCO2 reconstructions in the Southern Ocean to sampling scales: a semi-idealized model sampling and reconstruction Approach**"

by Djeutchouang, Chang, Gregor, Vichi, Monteiro

## Overview of the changes

First of all, we would like to take the opportunity to thank the reviewer for the thoughtful comments and suggestions to strengthen and improve the manuscript. We have made a few changes to the manuscript, which we hope address those comments. Two main changes are (1) the greater emphasis on the caveats of including in our experiment the mixed layer depth and surface chlorophyll-a from the model; and (2) an additional quantitative analysis of the implications of the 10-day sampling period y.

In the document below, we show the response of the reviewer in bold and blue, and the response to each point in black/italics. The track changes are shown in a mark-up version of our revised manuscript in a separate file according to the "review file upload" guidelines.

## Overview

**The authors did an excellent job addressing my concerns. The paper is improved. There are just two concerns left that I am not satisfied with.**

*Thank you.*

- **The first is regarding the MLD caveat. This is not made clear enough. A well-placed clear sentence about this issue should suffice. Otherwise, you either shouldn't use MLD in the reconstruction or only predict using accurate MLD from the float data. The latter would be an interesting experiment. This criticism is also relevant to some extent to chlorophyll, as surface chlorophyll is not the same as what the satellite measures and depth resolution can also be important for this variable.**

*We thank the reviewer for this comment. Studies (such as Gregor et al., 2019; Devil-Sommer et al., 2019; Gloege et al., 2021) have found that MLD is an important driver, and so we wanted to keep the MLD as the regression metrics also pointed to a significant contribution by the MLD. However, we do recognize that using the model MLD in the reconstruction is relatively an advantage as we mentioned in the manuscript (Lines 143-45). We also acknowledge that the surface chlorophyll in the model is not the same as the surface chlorophyll that satellites measure. More specifically, the advantage of*

*including both proxy variables is that the model is providing constraints which may not be available from real-world observations. However, these advantages are relative to real-world observations, and uniform across all the sampling experiments in this study.*

- **My other remaining criticism is that I still am concerned about my previous comment: "Related to the figure 9 comment above, it seems odd to conclude the sampling need be at least daily (line 793) and that the floats should sample 1-2 days when the model output used is daily averaged. How much signal is really being aliased? Please do a more thorough time series analysis (e.g. show power spectra density to see how much variance is truly being aliased). You call into question a discrepancy with Bushinsky et al 2019. I suggest you repeat the calculation done in that paper with the model output. Since you have the model time series I suggest you be quantitative with your statements." This is important given that the abstract concludes "Wavegliders with hourly/daily resolution in pseudo-mooring mode improve on Carbon-floats (10-day period), which suggests that sampling aliases from the 10-day sampling period might have a greater negative impact on their uncertainties, biases, and reconstruction means;"**

*Thank you to the reviewer for making this suggestion. We acknowledge that there is a limitation with the model output as its fine-scale resolution might not be high enough. However, using hourly observations, Monteiro et al. (2015) did show that 1-day sampling frequency was sufficient to capture the variability so that uncertainty was minimized within a 10% uncertainty threshold in zones characterized by CO2 intra-seasonal dynamics such as the SAZ. This justifies why the 1-day model output was used and why we deem it sufficient. However, increasing the model frequency from daily to hourly would likely reveal that the uncertainty of sampling sporadically at a 10-day resolution increases uncertainty even more due to large dynamic variability and diurnal variability (Torres et al. 2021; Monteiro et al. 2015).*

- **Perhaps the answer with regards to a discrepancy with Bushinsky et al 2019 is related to your finding that "The float did well when deployed in PFZ dominated by seasonal variability which can be resolved by the 10-day sampling period but performed poorly when it was deployed in the SAZ characterized by intra-seasonal modes which cannot be resolved by the 10-day sampling period." It is possible that the discrepancy is due to location, as I believe Bushinsky et al used data from the SOFS mooring. There are many ways to be more quantitative about this issue. One suggestion is to filter (i.e. band-pass) the model output and show where in the domain pCO2 variability at frequencies higher than 10 days is a significant fraction of the total variability. This straightforward calculation is necessary to support the conclusions being drawn.**

*We thank the reviewer for this good suggestion, which we implemented below. While we have not directly applied a low band-pass filter, we used instead a 10-day rolling mean, which in this instance may be a simpler and more transparent way to achieve the objective of the low band-pass filter.*

*The aim of the 10-day rolling mean is to eliminate or weaken all the frequencies higher than the 10-day mode of variability. We took this into consideration in the revised version of the manuscript.*

*Specifically, in order to be more comprehensive while providing a more quantitative characterization of our findings, an additional analysis was conducted on the 10-day modes of variability. We thus took the difference of this 10-day rolling mean from the daily model output, which would give us the < 10-day modes of variability while its root-mean-squared error (RMSE) would give us a statistical understanding of what the uncertainty might be if we sampled at a 10-day rate. This approach is actually similar to what Mazloff et al. (2018) did in their study but they applied a 90-day rolling mean.*

*In this approach, the hypothesis is that by weakening the < 10-day modes of variability, we should be able to show a significant improvement in the RMSE for the 10-day sampling mode. Our analysis resulted in an average of 2.53 µatm in the SAZ and 1.71 µatm in the PFZ. The study domain map of the RMSEs is shown in Fig. 1 (on this note) which also shows a significantly high uncertainty in the SAZ.*

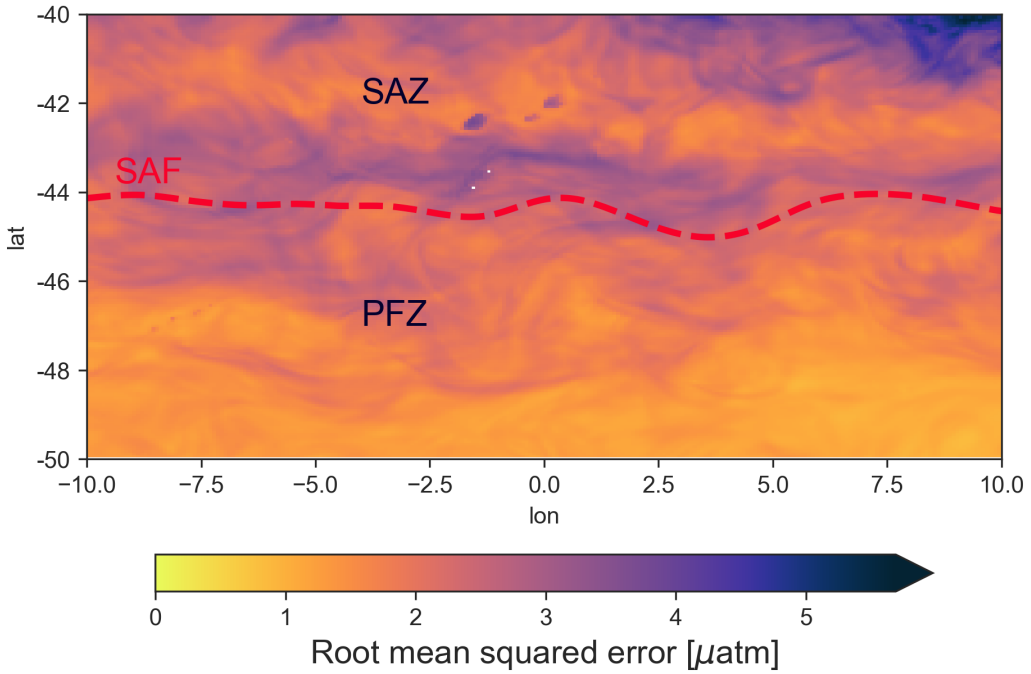


***Figure 1:*** *The RMSE map of the difference of the 10-day rolling mean (i.e., low-pass filtered pCO2 where the duration is set to 10 days) from the daily model pCO2 in the study domain divided by the Sub-Antarctic Front (SAF, red dashed line) into two sub-domains: the Sub-Antarctic Zone (SAZ) and the Polar Frontal Zone (PFZ).*

*These results show a dramatic decrease in the RMSE relative to the 1-day analysis, highlighting thus the important contribution made by the < 10-day modes of variability from the daily model output. This map (Fig. 1, on this note) confirms the sensitivity of the RMSE of 10-day sampling reconstruction to the presence or absence of synoptic variability, which was also highlighted in Monteiro et al. (2015).*