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Discussions

Interactive comment on "A high-frequency atmospheric and seawater pCO_2 data set from 14 open ocean sites using a moored autonomous system" *by* A. J. Sutton et al.

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We thank all referees for their thoughtful and constructive comments and suggestions on our manuscript "A high-frequency atmospheric and seawater pCO2 data set from 14 open ocean sites using a moored autonomous system." The revised manuscript will be much improved as a result of the careful critiques. Below we discuss the comments from C. Rödenbeck point by point including original referee comments and our responses bulleted underneath.

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Sutton and colleagues present, describe, and assess a data set of high-frequency surface carbon measurements made at various locations in the ocean over several years. Such data sets are of essential importance to any attempt to quantify and understand the role of the ocean in the gloabl carbon cycle and thus in the climate system. I clearly recommend publication of this manuscript. Find below some comments meant to help further improving the accessibility of this information.

In addition to Fig 3, a table listing the numerical coordinates of the moorings would be helpful.

– Good point. We've added a new table listing all sites and the coordinates.

p 388 line 22: Can you give the reference for this statement?

– That was an oversight that all of the reviewers pointed out. We've added references for that statement.

p 388 lines 23-26: I feel this motivation sounds weak and thereby understates the actual importance of the mooring data. Can you be more specific? Examples that come to my mind are assessment of controls on pCO2 as manifested in relationships between pCO2 and other variables at short time scales, test of parameterizations of carbon-cycle processes as used in models, or assessment of rectification effects (the effects of covariance of high-frequency variations in pCO2 and other variables on longer time scales).

– Thank you for the examples, which you are correct, highlight the importance of the mooring data. We've modified that section to include those examples and others to strengthen the motivation.

p 389 l 9-12: Can you be more specific as to whether the presented data are identical to those in SOCAT v2, or if revisions have been done meanwhile?

– They are identical and we've clarified that in the text.

p 390 l 14: Are the O2 measurements for internal diagnostic purposes only, or could they also be used in other scientific studies?

– The oxygen measurements are for diagnostic purposes, which we explain in the metadata of the mooring CO2 data sets, but we've now clarified that in the manuscript as well.

p 390 l 25: Refer the reader to Fig 2 here.

– Done.

p 391 l 10-12: How large is the non-linearity of the sensor?

– The NDIR has a non-linear response to CO2, but that response is very well characterized by the manufacturer. Licor has a function built into their firmware that accounts for the non-linear response and linearizes the output data. The linear function is calibrated prior to each atmospheric and seawater measurement with the zero (intercept) and high CO2 standard reference gas (slope). The accuracy of the linearized, calibrated output is confirmed prior to deployment by analyzing a range of intermediate CO2 standards in our laboratory.

p 392 l 1: Spell out "MBL"

– Done.

p 392 l 16: "averaged data" - specify what particular average this refers to here

– Thank you for pointing that out. In the case of the MAPCO2, this is the averaging of raw data for each xCO2 measurement as described on page 391 lines 26-29. We've clarified that in the text on page 392.

p 393 l 16: Can you comment on the rationale of the 3 _mol/mol threshold, especially why it is larger than the accuracy given in this paper?

– Based on this comment and others, we realize pre and post deployment testing in

the lab was not adequately described in the initial manuscript. The primary check of accuracy before and after deployment is a comparison to ESRL CO2 standards, typically six standards that range from zero to < 800 μmol mol-1. Systems do not leave for deployment until values are within 2 μmol mol-1 of the standards that span the typical seawater CO2 values at the mooring location. A comparison to the underway pCO2 system in the lab is then done to assess stability of the measurements over at least a week. We've modified the text to clarify this section of the methods.

p 394 l 17: I'm concerned about the use of GLOBALVIEW MBL reference values to do actual corrections to the local data, given that these reference values do not contain any longitudinal variations and are also coarse in latitude. I looked at longitudinal variations of near-surface atmospheric CO2 levels as simulated by an atmospheric tracer transport model constrained by atmospheric CO2 data and SOCAT pCO2 data [TM3 with CO2 fluxes from Jena inversion s90_v3.5 with ocean prior oc_v1.2, see Rödenbeck et al (2014)] (attached figure). In the example considered (difference of 4 TAO locations from the mean over these 4 locations, 2 arbitrary years out of a longer simulation), there are longitudinal atmospheric CO2 gradients across the TAO array of up to 4 ppm (other gradients may occur elsewhere). Though this simulation may differ from the truth in the details, I expect gradients on this order to be realistic; similar gradient are also present in the TAO measurements. Thus, couldn't deviations from the MBL reference just be real? In any case, the description of the correction needs to be more specific. What is the exact criterion for correction? How exactly is it applied? Do you correct the atmospheric value only, or also the surface-ocean value?

– This issue was raised by another reviewer as well and we agree on the limitations of the GLOBALVIEWCO2-MBL data product. We did not stress enough in the initial manuscript that adjustments to the MAPCO2 data are not made based solely on MBL comparisons. When a MAPCO2 system is recovered and a new system deployed, there is typically some overlap in measurements at each location. Only in cases when there is an offset between systems at the same location, which is often corroborated

by an offset to the MBL data set as well, do we make any corrections to the MAPCO2 data. The MBL data set serves as a useful and unifying comparison data set, especially since other in situ comparison data are often lacking. As we build CO2 time series at each of these locations, we start to build an understanding of how our measurements typically compare to the MBL data set, which is an added piece of information to troubleshoot occasional offsets between deployed MAPCO2 systems. For example, winter air values measured by our MAPCO2 systems at Papa are consistently lower than MBL (Fig. 4a). We have modified the description of the MBL-MAPCO2 analysis to clarify these points.

p 397 l 12: "validation" seems too strong a word here, given that local CO2 and the MBL reference are not expected to coincide.

– We have removed "validation" from this statement.

p 398 l 5: sentence not clear to me.

– We have modified that sentence to "This includes descriptive statistics of the finalized, processed atmospheric data in addition to pre-finalized data prior to any adjustments or offsets."

p 398 l 14: Not sure about atmospheric CO2 being well mixed, see above.

– We have modified the text as described in the MBL-related comment above.

p 400 l 15: Did you mean "confidence interval"?

– We do. Thank you for alerting us to that.

p 403 l 19-21: While I agree to the message of this paragraph, this particular formulation (lines 19-21) is misunderstandable: The discrepancy of the Rödenbeck et al (2013) estimate from the TAO170W data arises because that particular location is not well-constrained from the SOCATv1.5 set, not because the calculation misses carbon upwelling in general. Also, Rödenbeck et al (2013) is not actually a "model" (in

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the sense of process simulation model) but just a "data-driven scheme" (even if some process contributions are indeed parameterized).

– That explanation is very helpful. We have modified that text as you suggest: " In a comparison between seawater pCO2 data from the TAO170W MAPCO2 and data-driven model estimates based on SOCATv1.5, Rödenbeck et al. (2013) find that seawater pCO2 estimates in the tropics are unrelated to or even opposite of the mooring observations. This discrepancy arises because that particular location is not well-constrained by the SOCATv1.5 data set. We expect the recent mooring additions to SOCATv2.0 and the open ocean MAPCO2 data set presented here to make a large impact on our efforts to model and understand the global carbon cycle in the coming years."

Tab 3: over which time period is the growth rate calculated?

– Over the period of the time series presented in Table 5 in the initial manuscript. We have clarified that in the caption.

Tab 4: "The closest MAPCO2 value in time and space" - formulation not really clear.

– That language is unclear and also unnecessary since we describe the comparisons in more detail later in that sentence, so we've removed that phrase.

Fig 3: I like very much the way of plotting the variability by size and partioned outer ring.

– Thank you.

Reference: C. Rödenbeck, D.C.E. Bakker, N. Metzl, A. Olsen, C. Sabine, N. Cassar, F. Reum, R.F. Keeling, and M. Heimann: Interannual sea-air CO2 flux variability from an observation-driven ocean mixed-layer scheme. Biogeosciences Discuss., 11, 3167-3207, doi:10.5194/bgd-11-3167-2014, 2014.

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