

Interactive comment on “Air-sea CO₂ fluxes in the East China Sea based on multiple-year underway observations” by X. Guo et al.

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Response to Referee #1

General comments

This paper reports an extensive set of seasonal underway $p\text{CO}_2$ and ancillary data for the East China Sea for 24 cruises over 2006-2011. The authors use these data to constrain seasonal variability in $p\text{CO}_2$ in five spatial zones and to calculate the total CO₂ sink for the East China Sea. This work is valuable, both in providing a robust estimate of the CO₂ sink for this large marginal sea in the context of its biogeochemistry and physical circulation, and in making a large contribution to the global set of $p\text{CO}_2$ data for marginal seas. The work was conducted using standard methods, and the conclusions are well supported by the data. The paper is also well written. I have only minor suggestions for improvement, mainly questions for clarification and suggestions for clearer presentation.

[Response] [We thank the positive comments from the reviewer.](#)

Specific comments and questions

p. 5133, line 16: “increasing trend” in air $p\text{CO}_2$. Given the large seasonal variability and sporadic sampling, a five-year time series is not really long enough to demonstrate an increasing trend in atmospheric $p\text{CO}_2$. The comparison with the Mauna Loa time series does draw the eye upward, but without it, it would be difficult to interpret a secular increase from these data. If I had only the red dots, I might draw a horizontal line through the data all the way to June 2009 and then another, higher one through the 2010 and 2011 data. This plot is not important for the rest of the interpretation in the paper, but perhaps

it would be better to say that the data were “not inconsistent with the global increase in atmospheric $p\text{CO}_2$,” rather than that they showed an “increasing trend.”

[Response] We agreed with the reviewer and have revised the MS accordingly.

p.5134 lines 26-29. Why is the intra-seasonal variation within Zone 1 so much smaller in fall than in the other seasons? Are there transitions within the other seasons that might have been sampled at different phases during different cruises, or is there predictable, domain-wide upwelling in autumn?

[Response] We note that this intra-seasonal variation of $<10 \mu\text{atm}$ excluded the data collected during the October 2006 cruise which was substantially different from typical fall cruises as explained in our original MS. We contend that small variability might be a general feature of this domain in fall when cooling and stronger monsoon than summer break the water column stratification. As a result, the CO_2 -enriched bottom water mixes upwards to the surface and eventually releases to the atmosphere. According to the literature, there was no upwelling in this area in fall. Unfortunately, we have had no cruise observations during the transition between summer and fall.

p.5137, line 2. Insert range of values observed by Zhai and Dai for comparison.

[Response] Accepted and revised as suggested.

p.5137, lines 10-22. Leave most of these numbers in the tables and just report ranges in the text; it is hard to take in so many numbers in the middle of a paragraph. The values might be better presented as a bar graph.

[Response] Accepted and revised as suggested.

p.5137, line 19: “more than twice the global average for ocean margins.” Return to this point in the Discussion and explain (or speculate) why this sea takes up so much more CO_2 than do other marginal seas.

[Response] Accepted and revised as suggested. In Section 5.2, we have elaborated the discussion.

p.5138, lines 3-13. Present your own new work first, before bringing in the work of other authors for context.

[Response] Accepted and revised as suggested.

p.5138, lines 17-24. Explain $NpCO_2$ more clearly - its meaning, calculation and use.

[Response] Accepted and revised as suggested. We added the explanation in the section of "Data processing" of our revised MS.

p.5138, line 25 and Figures 8 and 9: "no trend with SST." It looks as if there might be a trend in some seasons, even if not for the dataset as a whole. This is worth exploring.

[Response] Accepted and revised as suggested. We have described these features in the revised MS.

p.5141, lines 13-14: "low in winter (2.1 fold), high in spring (2-3 fold)." These ratios are essentially the same. Why is one "low" and the other "high?"

[Response] We have revised as "The intra-seasonal variation in the CO_2 fluxes was generally low in winter (typically <2 fold variations), but it was very high in summer (4 to 6 fold) and spring (2 to 3 fold)". In winter, the intra-seasonal variation was 1.2-1.4 folds except in Domain 1 where it was 2.1 fold.

p.5142-51243: anomalous results in October 2006 and December 2010. I think that the October 2006 results should be included in the average, since the anomalous values were the result of a natural bloom, which might reasonably be expected to occur again from time to time. In contrast, I agree with the authors' decision to exclude December 2010, since the anomalous values in that case likely resulted from a change in the timing of the winter cruise. That does call into question the use of 2010 as a reference year, however. Was December 2010 included in the calculation of the reference conditions?

[Response] In the section of Results, we excluded the October 2006 cruise in calculating the CO_2 flux. However, in the Discussion (Section 5.2), we did compare and discuss the seasonal and annual average CO_2 fluxes with and without the data from this October 2006 cruise. We fully agreed that the low pCO_2 in October 2006 was a result of a natural

bloom, but fall blooms are rather atypical in the region to our best knowledge.

The December 2010 cruise has no influence on the calculation of values in the reference year (please also refer to our response to Review #2).

p.5144, lines 8-12. Future work will probably not need to be as comprehensive as this study. Now that this study has illustrated the range of values and the degree of variability in different locations and at different seasons, future sampling could concentrate on those seasons and locations where the variability is greatest or the mechanisms controlling $p\text{CO}_2$ the least understood. It would be worthwhile to say that here, instead of just saying that future work must reduce the error from undersampling.

[Response] The suggestion has been well taken. We have revised as “High-frequency observations in the seasons and/or locations with largest variability and/or with poor understanding in the mechanisms controlling $p\text{CO}_2$ are clearly needed to reduce the error from undersampling so as to further improve the estimates of CO_2 fluxes”.

Figure 1. Note non-linear depth scale for colour bar.

[Response] Accepted and revised as suggested.

Figure 3. Darken zone boundary lines. They are hard to see, especially in the NW corner, where the colours change. Enlarge the whole figure to clarify labels.

[Response] Accepted and revised as suggested.

Figure 4. Clarify the timescale. Add more month labels, or add vertical lines to mark every January 1 or in some other way make it easier for readers to associate the variations in SST and SSS with the month or season. Also, plot labels (A,B) are uppercase, while in the caption they are lowercase (a,b).

[Response] Accepted and revised as suggested. We added vertical lines to show the months. We changed “a” and “b” to “A” and “B”.

Figure 5. Same comment about the timescale as for Figure 4.

[Response] Accepted and revised as suggested. We added vertical lines to show the

months.

Figure 6. This is a very useful figure that captures both the mean and the variability. Explain in the caption why October 2006 and December 2010 are treated differently from the other seasons in the figure, and whether December 2010 was included in the calculation of the 2010 reference year.

[Response] Accepted and revised as suggested. We have explained why we excluded the data from the October 2006 and November 2010 cruises in the caption of Fig 6 in the revised MS. The abnormal $p\text{CO}_2$ in December 2011 cruise has no influence on the values corrected to the reference year (Please also see our response above).

Figures 8 and 9. See comments above about possible relationships with SSS and SST one season at a time.

[Response] Accepted and revised as suggested. We have revised in Section 5.1.

Figure 10. It looks as if there could be a quantifiable relationship between NpCO_2 and chl in zone 3 for all seasons at once. It seems odd that the chlorophyll is highest in fall in Zone 4 in one year. Is that value correct?

[Response] (1) NpCO_2 decreased linearly with Chl a in Domain III, but there was not such quantifiable relationship in other domains. (2) We checked the data. There were two stations with high Chl- a ($2.0 \mu\text{g L}^{-1}$) in Domain IV in fall. At both stations, $p\text{CO}_2$ was $338 \mu\text{atm}$, and dissolved oxygen was slightly oversaturated (101-103%). Therefore, the high Chl- a values were reasonable.

References

Takahashi, T., Sutherland, S.C., Wanninkhof, R., Sweeney, C., Feely, R.A., Chipman, D.W., Hales, B., Friederich, G., Chavez, F., Sabine, C., Watson, A., Bakker, D.C.E., Schuster, U., Metzl, N., Yoshikawa-Inoue, H., Ishii, M., Midorikawa, T., Nojiri, Y., Kortzinger, A., Steinhoff, T., Hoppema, M., Olafsson, J., Arnarson, T.S., Tilbrook, B., Johannessen, T., Olsen, A., Bellerby, R., Wong, C.S., Delille, B., Bates, N.R. and de Baar, H.J.W., 2009. Climatological mean and decadal change in surface

ocean $p\text{CO}_2$, and net sea-air CO_2 flux over the global oceans. *Deep-Sea Research II*, 56 (8-10): 554-577.