Interactive comment on "Diagnosing CO_2 fluxes in the upwelling system off the Oregon coast" by Cao et al.

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Response to the comments from Referee #1

Cao et al. apply a simple framework (OceMar) based on carbon/nitrate mass balance to semi-analytically predict CO_2 air-sea fluxes in the upwelling system off the Oregon coast. They find that they are able to represent observed fluxes in regions of the shelf that act as sinks of CO_2, but are unable to represent the source regions following the OceMar approach. Then, they add one extra assumption to the applicability of the method, namely the requirement of steady state conditions. I think the manuscript is interesting and worth of publication after some main issues are addressed.

[Response]: We are pleased that the reviewer is generally positive with our study.

I agree with Dr. Wanninkhof's comment about the overall applicability of the method and think that the manuscript would benefit from an expansion of this discussion.

[Response]: Please see our response to the comments from Dr. Wanninkhof.

Moreover, the source data the authors described (Feely et al 2008, Feely and Sabine 2011) show many more transects along the California Current System that may provide more insight into the un/applicability of OceMar in wind-driven upwelling margins (in particular, regions to the south, further away from the Columbia River). I am wondering whether the authors could incorporate some of these transects or otherwise explain their chosen focus on the Oregon region. In the latter case, they should discuss whether they would expect OceMar to work in the regions to the south and north of Oregon within the California Current System.

[Response]: We agree with the reviewer that diagnosis of additional transects would be helpful, and thus we have added in our revisions the diagnosis of Transect 6, which is off the northern California coast (Fig. R1-1 of the "Response to the comments from Dr. Rik Wanninkhof") and was also significantly influenced by intensified upwelling. This additional diagnosis generated very consistent estimations of the CO_2 flux with those of Transect 5 (Fig. R2-1), indicating that the upper waters on Transects 5 and 6 experienced nearly the same physical mixing and biogeochemical reactions. In this context, we would expect that our OceMar approach to work in other regions within the California Current system, in particular given that the physical transport and biological alterations would be more straightforward in areas without either costal upwelling or river plume.

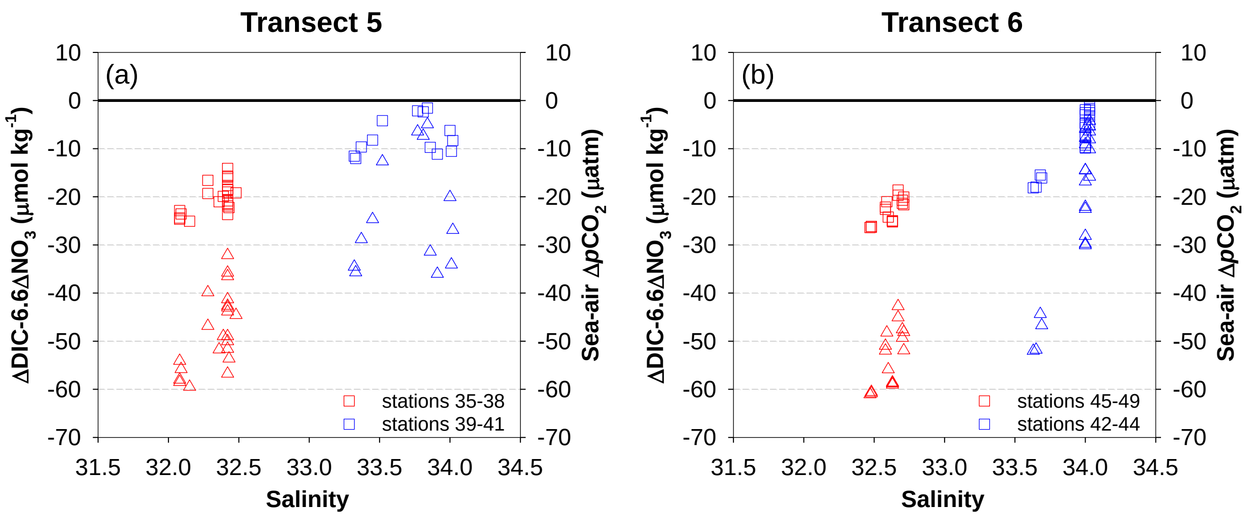

Fig. R2-1. ΔDIC−6.6ΔNO_3 (squares) and sea-air Δ*p*CO_2 (triangles) versus salinity in the surface mixed layer on Transects 5 (a) and 6 (b) off Oregon and northern California in spring/early summer 2007. The solid line indicates the *p*CO_2 equilibrium between the seawater and the atmosphere. The average ΔDIC−6.6ΔNO_3 and sea-air Δ*p*CO_2 on Transect 5 were estimated to be −20±3 μmol kg^{-1} and −48±8 μatm in the surface mixed layer of stations 35-38 (Fig. 4b). Both values were comparable to those obtained from the surface mixed layer of stations 45-49 on Transect 6 (−23±3 μmol kg^{-1} and −53±6 μatm, respectively), indicating a similar magnitude of the CO_2 sink term in offshore areas along the Oregon and northern California coast. The estimated sea surface *p*CO_2 of 342±8 μatm for Transect 5 and 337±6 μatm for Transect 6 were consistent with the field measurements of 332±12 μatm and 346±12 μatm in these regions. On the other hand, the diagnosed CO_2 flux in the nearshore with intensified upwelling was also comparable between Transects 5 and 6. However, our estimation suggested a weaker CO_2 sink or close to being in equilibrium with the combined estimated sea surface *p*CO_2 of 368±14 μatm, whereas the field measurements of ~600-1000 μatm indicated that the coastal upwelling zone should be a very strong source of CO_2 to the atmosphere.

Another suggestion would be to test the robustness of the results with respect to the choice of the carbon to nitrogen ratio. The authors could perform a sensitivity analysis where they repeat their calculations replacing the Redfield ratio by some deviations of the 6.6 value (maybe observed ranges of C:N in the region?).

[Response]: We have tested the OceMar approach with another C/N uptake ratio. Please also see our response to the comment from Dr. Wanninkhof.

Specific comments:

The abstract would benefit from a slightly more detailed explanation of the OceMar framework.

[Response]: Revised as suggested.

Also in the abstract: I found lines 15-17 a bit misleading ("we showed significant CO_2 outgassing in the nearshore regions associated with intensified upwelling and minor biological consumption: : :”). In my opinion, it reads as if the method was able to capture the outgassing, while actually the pCO_2 observations showed the outgassing and the method failed to reproduce it. Then, the authors argued for a modification to the method to address this issue.

[Response]: This sentence has been rewritten for clarity.

Page 7393, line 12-14: the region of interest is part of the California Current System. The southern part of this system has permanent upwelling-favourable winds.

[Response]: Among the entire research domain during the first NACP West Coast cruise, the most intensified upwelling was observed on Transects 5 and 6, where the subsurface water reached to the nearshore surface (see Feely et al., 2008, Figure 1). We have added the diagnosis of Transect 6 in our revisions. Please also see our response to the general comment from Referee #1.

Page 7397, lines 15-18: I’d suggest being explicit about how X^{eff} is calculated, so the reader doesn’t have to dig into Dai et al. (2013) to understand this step in the calculation. The explanation could be added as an appendix.

[Response]: The following two paragraphs in the original MS (Page 7397 Line 19-Page 7398 Line 16) had already explained how X^{eff} was calculated.

Page 7400, line ~26: why are these values not shown in figure 3?

[Response]: The estimated values of $\Delta DIC-6.6\Delta NO_3$ and sea-air ΔpCO_2 at station 25 (~82 μmol kg^{-1} and ~157 μatm, respectively) were largely different from those at other stations on Transect 4, which could not be well illustrated in a single figure. Instead, we have directly added the two values in our revisions.

We have also added a note that no values of $\Delta DIC-6.6\Delta NO_3$ and sea-air ΔpCO_2 were obtained at station 26 because the nutrient data at this station were not available.

Technical comments:
Every now and then I had problems with specific sentences that I think could be improved, e.g.:
Page 7390: lines 10-11: English here could be improved - besides, this text is part of a really long sentence, line 10 to 15!

[Response]: This sentence has been rewritten for clarity.

Page 7393: line 7: should say “broad” instead of “board”

[Response]: Modified as suggested.

Page 7394: line 18: “to quantify the conservative portion of carbon and nitrate.”? (or nitrogen nutrients, but I think the authors only use NO_3 in their calculations).

[Response]: Modified as suggested.

Page 7395: line 16: “parameters” should be replaced by “variables”

[Response]: Modified as suggested.

Reference

Feely, R. A., Sabine, C. L., Hernandez-Ayon, J. M., Ianson, D., and Hales, B.: Evidence for upwelling of corrosive “acidified” water onto the continental shelf, Science, 320, 1490-1492, 2008.