

Interactive comment on “Trends and drivers of regional sources and sinks of carbon dioxide over the past two decades” by S. Sitch et al.

Anonymous Referee #2

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Moderate Revision

General Comments

The paper presents land and ocean carbon cycle models forced by climate reanalysis and historical atmospheric CO₂ data to quantify sources and sinks of atmospheric CO₂ over the 1990 - 2009 period. It differs from the earlier RECCAP analysis in that additional simulations were performed to separate the impact of climate variability and change from rising atmospheric CO₂. The paper is scientifically sound and analysis appropriate. However, the essential feature lacking in the paper is through comparison with previous studies. In particular, RECCAP has recently published a suite of papers in BG (which include many of the authors of this the paper) synthesising the regional carbon sources and sinks over the past several decades and these studies should form

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the baseline information to which these simulations should be compared to. Therefore, to make the paper complete and publishable a more rigorous comparison with the RECCAP studies is needed. It is not good enough to just cite them in the introduction. I want to see these studies used in the discussion as well.

In this comparison, the authors should be able to provide insight into:

1. how important are fire and land use changes on the carbon sink over the last 2 decades? The atmospheric inversions provide measurements of the net fluxes to which the simulated ocean and land fluxes can be compared to explore this issue. The discussion makes some general statements on the importance of better simulating fire and land use change but at least from the agreement of the estimated trends with the global inversion perhaps these processes are insignificant - explore and discuss this issue in more detail.

2. In the ocean, the comparison to the RECCAP should address whether using more sophisticated ocean carbon models (e.g. more complex ocean biology) changes the results from what is shown in the RECCAP studies. Further comparisons in the ocean can be should be made with recent observational synthesis such as the following references to help elucidate what key ocean carbon cycle processes are missing in the models.

Lenton et al 2012 [Lenton, A., Metzl, N., Takahashi, T., Kuchinke, M., Matear, R. J., Roy, T., Sutherland, S. C., Sweeney, C. and Tilbrook, B.: The observed evolution of oceanic pCO₂ and its drivers over the last two decades, *Global Biogeochem Cy*, 26(2), doi:10.1029/2011GB004095, 2012.]

Takahashi, T., et al. (2009), Climatological mean and decadal change in surface ocean pCO₂, and net sea-air CO₂ flux over the global oceans, *Deep Sea Res., Part II*, 56, 554–577, doi:10.1016/j.dsr2.2008.12.009.

3. The paper discusses the impact that N-limitation could have on the land carbon

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uptake but how about some comments on P-limitation? I have listed a few papers that have considered the combined impact of nutrient limitation on the land carbon uptake. P-limitation should be most important in tropical forests and savannas - do you see any indications that P limitation could be impacting the land carbon sink trend in these regions? What does it say about P limitation?

Edwards E, McCaffery S, Evans J: Phosphorus status determines biomass response to elevated CO₂ in a legume: C- 4 grass community. *Glob Change Biol* 2005, 11:1968-1981.

Wang, Y. P., Law, R. M. and Pak, B.: A global model of carbon, nitrogen and phosphorus cycles for the terrestrial biosphere, *Biogeosciences*, 7, 2261–2282, 2010.

Zhang, Q., Wang, Y. P., Matear, R. J., Pitman, A. J. and Dai, Y. J.: Nitrogen and phosphorus limitations significantly reduce future allowable CO₂ emissions, *Geophys. Res. Lett.*, doi:10.1002/2013GL058352, 2014.

In the abstract and throughout the manuscript please present the fluxes in a more consistent manner. A flux is often referred to as a sink but then given as a negative number which implies it is a source.

Minor Details

page 11 - used S_O1 and S_O2 before they were defined. page 12 - NBP is the same as net atmosphere to land co₂ flux - do you really need another variable for this process? delete it and refer to net atmosphere to land co₂ flux

page15-16 - add comparison to the RECCAP estimates of the net flux and trends

page 18 - give the estimate from Wanninkok et al 2013 line 3 to 7 - make comments on the key processes before presenting the corresponding simulations - move these statements until after the simulations are presented.

Discussion -cite the recent RECCAP analysis which include regional trend estimates.

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pg 28 line 20-25 - comment on missing P limitation in the models

pg 30. There are many general statements of the limitations of the DVGM, but from the limited quantitative assessment I see a general agreement with observations - how can you conclude the DVGMs are lacking? What do the regional reccap studies suggest? Do they provide additional evidence for need to include additional processes to improve in these models?

pg 31 line 1 - I think the figure shows very similar global trends in the ocean uptake with and without climate variability and change.

line 6 - give your estimated number for the trend so it can be compared to -0.04 PgC/y^2

line 7-13 - include the global estimate with uncertainties to help justify your statements.

Pg 32 What do the RECCAP studies conclude for the regional changes? What new information has this study provided and how do the simulated regional trends compare to ocean observations?

Pg 33, line 13 - another study you could cite. This recent paper explores the impact of climate change in an eddy resolving simulation and shows the opposite impact of climate change on ocean productivity with eddy resolution

Matear, R. J., Chamberlain, M. A., Sun, C. and Feng, M.: Climate change projection of the Tasman Sea from an Eddy-resolving Ocean Model, *J Geophys Res-Oceans*, 118(6), 2961–2976, doi:10.1002/jgrc.20202, 2013.

Pg 35 - from this study and the RECCAP studies can you comment on the role biological complexity plays in the ocean carbon uptake trends over the last 2 decades?

Pg 36, line 18-20 - not convinced that the lack of wildfires and other land disturbances was demonstrated as a key limitation of the model simulations. What observations are you using that clearly demonstrate this point? Perhaps, I just do not like this paragraph since I feel for the simulated trends over the last 2 decades that it did not emerge from

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your analysis that simplifications in the models were causing inconsistent behaviour with the limited observations. If you are either trying to extrapolate these results to the future projections or if you had better observations then some of these issues may be relevant, otherwise this paragraph is not justified.

references - missing some of the RECCAP papers cited on page 5.

table 1 - while you cite Wanninkof et al., 2013 for easier reading you could include a summary table for the ocean models too.

table 2 - a negative sink is a source - change word or sign to be consistent. it would be helpful if you made the significant trends in bold font

Label figures with a,b,c,d..

Figure 2 - there are 6 panels but only 4 are described

Figure 3 - no global trends in this figure look significant - not consistent with the information given in the text.

Figure 4 - I see no difference between the red and black trend lines - seems to disagree with the comments in the text that with climate variability and change there is a significant change in the ocean sink trend.

Figure 5 - do you need the first column since the information is shown again in the second column

Figure 6 - negative sink is a source - panel 3 has the wrong sign to be called a sink.

Figure 7- state how the onset and offset day was calculated. how did you deal with the different hemispheres?

Figure 10 - Figure 3 shows a similar trend for os1 and 2 but this plot show a clear difference (I assume W is global ocean?). The NP, EP and NAT are the 3 regions where climate variability changes the sign of the trend is there any observational data

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to support this result?

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