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Biogeosciences Discussions

Interactive comment on "A model study on the sensitivity of surface ocean CO_2 pressure with respect to the CO_2 gas exchange rate" *by* P. Landschützer et al.

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The authors would like to thank referee#1 for the useful comments.

Referee#1: In general, the comment of referee#1 states that the paper does not provide sufficient substance for a full publication. Referee#1 is missing novel concepts, ideas, tools or data and points out that substantial conclusions are not reached and including ocean circulation changes would improve the study.

Response by authors: The focus of the paper is to investigate the effect of locally increasing wind speeds on the sea surface pCO2 and air-sea gas fluxes of CO2. While existing studies (p10799, lines 9-21) conclude that CO2 fluxes substantially alter with

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changing wind patterns due to circulation changes, our study is focused on the effect of increasing wind speeds on the gas transfer velocity alone. If we were to include changes in the ocean circulation, it would be problematic to identify the gas exchange effect alone due to the non-linearity of the model system. We conclude that wind driven changes (as presented in the literature) in the global gas uptake mainly result from circulation changes, because our results show that changing the gas transfer velocity alone does not substantially change the global fluxes. At the moment a newer version of the MICOM-HAMOCC model is emerging, and it is therefore not possible to re-do the same model runs and to include changes in the ocean circulation with the identical model code and initial conditions as used for this manuscript. Also this former model version which had been used for our manuscript was running on a supercomputer with shared memory architecture (openMP). The respective supercomputer is not available any more unfortunately. In order to nevertheless follow the wish of the referee we further add on the innovation part of the manuscript. We suggest including an analysis on the ocean carbon storage changes with respect to the presented sensitivity studies in the revised manuscript. This will offer an additional new inside into the impact of gas transfer velocities on the mode of carbon cycling. . As our results in the manuscript show that global changes in pCO2 and annual fluxes are low (with respect to all sensitivity runs), we now want to investigate in addition changes in the column inventory of the total CO2 and explore the effect of an enhanced gas transfer over the 52 years of model integration.

Referee#1: Title: Maybe replace “ocean CO2 pressure” with partial pressure of CO2 (pCO2) on the ocean

Response by authors: We have now revised the title to “A model study on the sensitivity of the partial pressure of CO2 (pCO2) on the surface ocean with respect to the CO2 gas exchange rate”.

Referee#1: Abstract 1.Which are the controlling factors?

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Response by authors: In the revised manuscript, we have clarified the sentence to: “Rising CO2 concentrations in the atmosphere and a changing climate are expected to alter the air-sea CO2 ïňĆux through changes in the gas exchange parameters, such as gas solubility or gas transfer rate.”

Referee#1: Abstract 2. On what base has the gas exchange rate been increased by 44%?

Response by authors: this number is based on increasing wind speeds of 20%. The quadratic relationship between U and k leads to an increasing exchange rate of 44%.

Referee#1: Abstract 3. Line 11-15: Is that something new?

Response by authors: To the authors’ best knowledge, there is no study that looks at the effect of global CO2 fluxes to regional perturbation of wind speed or gas transfer coefficient. The closest study we found is by Eden&Oschlies (2006), which looks at the sensitivity of the North Atlantic CO2 gas exchange to different gas exchange formulation in their model.

Referee#1: Abstract 4. an accurate quantiïňĄcation of the gas transfer velocity ...provides a potential source to enhance model predictions” this is correct, however, the study does not include an accurate quantiïňĄcation of the gas transfer velocity.

Response by authors: We have now revised the statement from “An accurate quantification of the gas transfer velocity. . .” to “The study suggests that uncertainty in the gas transfer variable in the model can attribute to the model-data bias, especially with respect to the pCO2 and air-sea CO2 flux variables”

Referee#1: Text 5.p.10798 Line 24-26 correct but what controls the gas concentration difference?

Response by authors: We have revised the sentence to: “The exchange process is controlled by the gas concentration difference between the atmosphere and the ocean surface layer due to the equilibrium state between the ocean circulation and the bio-

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geochemical state of the ocean. The gas flux further depends . . .”

Referee#1: Text 6. p.10799. 6/7 what has the poleward shift to do with k?

Response by the authors: The poleward shift of the winds as well as the strengthening of the westerly winds is predicted by some studies (as stated in the Introduction Section). We acknowledge that a shift in the westerly winds leads to changes in the gas transfer velocities, which is dependent on the wind surface stress. We included this additional information in the revised manuscript.

Referee#1: Text 7. Lines 28/29 What is the physical basis for increasing k only in those regions? Response by authors: Based on studies of increasing strength of the westerly winds regions G02 and G03 have been chosen. As the model suggests both of these regions are net uptake regions with high specific transfer rates. G04 in contrast was chosen because it is a net supersaturated region and because of the low specific gas transfer rate. In addition, some studies (as stated in the Introduction Section), have shown that future climate change would influence the wind strength (e.g., in the Southern Ocean), hence may affect the regional CO2 gas exchange. The idea to look at each of the regions separately is to see how sensitive the global CO2 fluxes are to changes of the wind speeds in a specific region.

Referee#1: Text 8. P 10802 line 1, what does quantitatively correct parametrization mean?

Response by the authors: We now revised “Previous research focused on the quantitatively correct parameterizations of the gas transfer velocity...” to “Previous research, based on wind tunnel studies and tracer experiments, mainly focused on constraining the gas transfer velocity as a function of the wind speed”

Referee#1: Text 9.17/18 Again, rationale for the 44%. Would it not make more sense to do a general senitivity study, consistent increases and decreases with specific response on the carbon cycle? If this is supposed to be representative for potential future

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changes in wind, why not change the wind???

Response by the authors: Please see authors response to referees comments Abstract 2 and general comments

Referee#1: Text 10.Lines 23-25 are repetitive, this has been stated already in the same paragraph

Response by the authors: We have removed the statement "The high specific gas transfer rates in these areas are caused by the influence of the strong westerly winds and the high gas solubilities due to the low sea surface temperatures." in the revised manuscript

Referee#1: Text 11.Page 10804: I don't think the result that increased gas exchange velocities increase the gas fluxes justifies a scientific publication.

Response by the authors: Please see authors' response on general comments and to referees comment Abstract 3.

Referee#1: Text 12.Page 10804/805 It is also to be expected that this intensifies the intra-annual signal and that the signal is weaker in the equatorial band, which as I understand has been chosen because of its lower gas exchange velocities ???!!!

Response by the authors: We find that (p10805 lines6-10): "In the high latitudes it (perturbation of the surface pCO2) results in less uptake or increased outgassing in months of low air-sea disequilibrium, whereas the effect of the increased gas transfer rate dominates in months where the air sea disequilibrium is high." We find the opposite of this effect in the equatorial band (due to its supersaturated nature): The perturbation of the surface pCO2 is decreasing the gas fluxes (less outgassing) in months where the air-sea disequilibrium is low. But again: the effect of the increased gas transfer rate dominates in months where the air-sea disequilibrium is higher. Therefore the results show in all 3 cases stronger seasonal amplitudes (although the magnitude in the equatorial band is lower than in the high latitudes), which was a-priori not expected.

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We have included this additional information in the revised manuscript.

Referee#1: Text 13.Page 10805 lines 14-18 Again, what is the physical basis for increasing k only in that specific region?

Response by the authors: Please see authors' response to referees comment text 7.

Referee#1: Text 14. P10807 line 6/7 which sensitivity experiment? Response by authors: We now revised "... model predictions are best between 20S-20N and get improved by the sensitivity run." to "... model predictions are best between 20S-20N and get improved by sensitivity run G04." Referee#1: Text 15.Line14/15 "largest model data discrepancies" this has already been mentioned several times - can be removed

Response by authors: We changed "The pCO2 RMSE and the AAE again show the largest model data discrepancies 40–60 S, whilst the errors are in general smaller between 40–60N than between 20 S–20N" to "The errors in the sea surface pCO2 are in general smaller between 40–60N than between 20 S–20N"

Referee#1: Text 16.p10808 line 2. What means "on the long run" in this context? Response by authors: "on the long run" in this context means for the entire simulation length (1948-2009). We now revised "... on the long run" to "...during the entire time period" Referee#1: Text 17.Lines 7-9 Where does this result come from? If this was the reason to do this study, it should be mentioned earlier and could be discussed in more detail. This might actually strengthen the paper.

Response by the authors: Please see authors' response to the referee's general comments.

Referee#1: Text 18.P 10808 line 23 Local model.....benefit from including these effects Why not include them, then?

Response by authors: It is one of our findings that local enhancements of the gas transfer rate by 44% can improve local model outputs compared to observation data. We therefore conclude that other local effects (e.g. bubbles) might have the potential

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to improve local predictions as well. We therefore recommend including them in future studies.

Technical corrections for text and figures suggested by referee#1 are now included in the revised manuscript.

Interactive comment on Biogeosciences Discuss., 8, 10797, 2011.