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Interactive comment on "Southern Ocean as a constrain to reduce uncertainty in future ocean carbon sinks" *by* A. Kessler and J. Tjiputra

Anonymous Referee #1

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Kessler and Tjiputra present their analysis of present day and end of century carbon fluxes in the Southern Ocean based on an ensemble of CMIP5 Earth System Models and the RCP8.5 emission scenario. The authors identify a substantial spread between the different models and an observation-based estimate. The authors further identify a link between present day flux estimates and the cumulative uptake over the next century, hence in order to more accurately estimate future developments, we need to reduce the present day uncertainties. Finally, the authors attribute the model spread to variations of the seasonal cycle and its drivers.

The Southern Ocean plays a key role in the uptake and storage of CO2 as well as the uptake of heat but to-date we still deal with large uncertainties when it comes to the processes governing the variable uptake of CO2 in this basin. This uncertainty in

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both model and observation-based estimates of the sea surface CO2 (for observation-based estimates see e.g. Rödenbeck et al. 2015) can be largely attributed to the lack of observations to constrain current models. I believe this paper adds a valuable contribution to our current understanding and it makes a strong pledge on why we should continue to monitor the Southern Ocean in order to get more accurate future projections of the Southern Ocean and global ocean carbon sink. I do believe this paper and its results are valuable to the community, hence I can recommend it for publication after some minor comments are addressed.

Minor comments:

Throughout the text the authors refer to the gridded pCO2 dataset as “observations” (e.g. abstract line 2). This is technically not correct since the pCO2 dataset is derived from a statistical model. A more accurate description would be “observation-based”

In the introduction I am missing a link to some previous studies in the Southern Ocean. E.g. Le Quéré et al. 2007 argue for a saturation of the Southern Ocean carbon sink which is expected to continue throughout the century, whereas the authors show that CMIP models agree that the Southern Ocean continues to take up CO2.

Introduction page 2647 lines 5-6: This is very minor, but there are more recent references by the Global Carbon Project reporting the fraction of the emitted CO2 taken up by the ocean.

Introduction page 2647 lines 12-24: I believe you should add some references here

Introduction page 2648 lines 13-23: I believe this part should be in the results section.

Methods page 2650 line 19: The co2sys software tool for matlab should be referenced as van Heuven et al. 2011

Methods page 2654 lines 11-12: “... both metrics, the CMIP5 models have linear relationships ...” - I dont believe you can argue for a linear relationship based on Figure 2a, whereas it is more clear for figure 2b.

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Methods page 2654 lines 9-15: I believe this belongs to the results section.

Methods page 2654 lines 18-20: “The regional distribution is defined according to the low-, mid- and high-latitudes, motivated by the large-scale difference in carbon uptake mechanisms occurring in these regions” - While I am not concerned by the regional division I do disagree with the argument provided by the authors here. E.g the 45S line is actually cutting more or less exactly through one of the main CO2 uptake regions, hence processes a few degrees north and south of these lines are the same.

Results page 2656 line 1: Lenton et al 2013 compare inversion estimates, model estimates and an observation-based estimate from Takahashi et al 2009. Please explain which estimate from Lenton et al. 2013 has been used for the comparison.

Results page 2660 lines 15-19: the authors do not explicitly rank the G1 and G2 groups, but based on the comparison of the seasonal cycle in the text and the agreement with the mechanisms explained in Takahashi et al 2002, I am inclined to rank G1 models higher than G2 models. This could be a user recommendation for future research in the Southern Ocean.

Results, general: There is an inconsistency regarding the sign of the fluxes. Before the seasonal cycle analysis, the authors use positive numbers for ocean uptake fluxes(see figures 1-5), whereas for the seasonal cycles analysis (Figures 6-7 and text) outgassing fluxes are positive. Please adjust for consistency.

Discussions page 2665 lines 26-29: the interannual variations in the air-sea flux do not necessary effect the seasonal cycle, unless the interannual variations are of seasonal nature. A good reference for this is Hauck et al 2013.

Page 2663 line 11: “seasonality” change to seasonal

page 2663 lines 12 and 13: remove “compared to” and “total seasonal cycle”

page 2661 line 19: sectors of THE SO

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page 2665 line 24: change "... in the SO is non-negligible." to " . . . in the SO are non -negligible."

Figure 8 caption: observations are represented by gray lines and markers, not black.

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