

#### **Reply to Anonymous Referee #4:**

We wish to thank the reviewer for his/her comments on this manuscript. Please note that we now denote the “KPH method” as the “Green function” or “GF” method. This is to maintain consistency with other recent publications where this terminology is used. Reviewer comments are in italic.

*1) While the authors do a nice job of comparing the CCSM-based anthropogenic CO<sub>2</sub> uptake to data-based methods, they simply leave out a section on how CCSM's uptake compares to estimates derived from similar oceanographic models (e.g. the models used in OCMIP). Do all ocean-based models suffer from anthropogenic CO<sub>2</sub> uptake biases in these regions? Do the estimates of regional uptake look similar to those derived from the ocean inversion project (e.g. Mikaloff-Fletcher et al.), which uses the circulation fields from OCMIP?*

We agree that comparisons among different model-based estimates of anthropogenic carbon uptake provides useful information about different models. However, such comparisons are beyond the scope of this paper in part because detailed comparisons of different model-based estimates will be discussed elsewhere in a paper by Graven et al [in prep]. Adding such detailed inter-model comparisons to the present manuscript would greatly increase its length and change the focus of the paper. In addition, there have been previous comparisons of physical biases in the OCMIP models and their impacts on ocean carbon (Doney et al., 2004) and an examination of ventilation in the OCMIP models based on simulated CFC-11 (Dutay et al., 2002).

Graven, H.D., Gruber, N., Key, R., and Khatiwala S., Changing controls on oceanic radiocarbon: New insights on shallow-to-deep ocean exchange and anthropogenic CO<sub>2</sub> uptake [in prep].

Doney, S. C. et al. (2004), Evaluating global ocean carbon models: The importance of realistic physics, *Global Biogeochem. Cycles*, 18, GB3017, doi:10.1029/2003GB002150.

Dutay, J.C., et al., (2002), Evaluation of ocean model ventilation with CFC-11: comparison of 13 global ocean models. *Ocean Modelling*, 4: 89-120.

*2) The authors make an important point: that the uptake of anthropogenic CO<sub>2</sub> is underestimated by CCSM in the Southern Ocean and, to a lesser extent, in the North Atlantic Ocean. They briefly mention that this model-observation inconsistency is driven by the weak mixing and ventilation in the CCSM. As this seems a key result, the authors would do well to further explore it. After all, the goal here is to identify the cause of the CO<sub>2</sub> uptake bias, so that improvements can be made in future versions of the model. What does the mixing and ventilation look like in CCSM? How does it compare to*

*observations? Other models? What is the best way to correct the mixing and ventilation “problem” in this model – to go to a higher horizontal resolution? To improve the mixing parametrisations?*

Biases in mixing and ventilation in the ocean component of CCSM have been identified in previous studies that looked at differences in modeled CFC and observed CFC, which indicated biases in physical modeling (Thornton et al., 2009). The CFC biases suggest that the model has too strong ventilation near Antarctica and too weak ventilation of Antarctic intermediate and mode waters. The source of these biases in mixing and ventilation is still not fully understood and is likely the combined effect of multiple problems. Effort is underway to try to improve the model, but our main focus here is to document the impact of these biases on the uptake of anthropogenic CO<sub>2</sub>. However, part of the problem is a strong shallow bias in the Southern Ocean mixed layer depths, which reduces ventilation of the mode and intermediate waters. We have added the following text to the manuscript lines 569.

“The weak Southern Ocean ventilation is partly due to a persistent shallow bias in mixed layer depth. Along the ACC, mixed layer depths are too shallow by 20-40m during summer months, and by more than 100m in some regions during winter months. This is thought to be a result of missing processes in the model (near inertial wave and Langmuir mixing). Ongoing research is attempting to reduce this bias and improve ventilation in the Southern Ocean.”

*3) The manuscript is missing a paragraph describing the regional biases in the assumption of constant circulation for KPH. To this end, please add a column to Table 2 for Cant\_var, and comment on the regional differences between this and Cant\_const. Whilst Figure 4 demonstrates that globally integrated estimates are not biased by the constant circulation assumption, this may also be a case where large regional biases cancel each other out. Regional modelers in particular will be interested in how climate-driven circulation changes can impact anthropogenic CO2 uptake.*

We have added another column to Table 2 for Cant\_var. As shown in the Table 2, there are little differences among simulated Cant under different scenarios. This is noted in the manuscript. In this manuscript, we identified regions where the KPH/GF method may be biased and pointed out the problem in the assumption. Simulations used in this manuscript do not include some transient tracers (CFC11, CFC12, C14), which are used in the KPH/GF method. Therefore, our simulations are not capable of quantitatively calculating regional biases in the KPH/GF method.

Table 2 Regional and global distributions of  $C_{\text{ant}}$  inventories in 1994 (in PgC)

Region	$\Delta C^*$ method	Uncorrected $\Delta C^{*1}$	TTD method	KPH/GF method	CCSM $C_{\text{ant\_cnst}}$	CCSM $C_{\text{ant\_var}}$	CCSM $C_{\text{ant\_all}}$
N.Pacific	16	14	17	18	18	18	17
S.Pacific	13	12	18	16	15	14	15
N.Indian	3	3	2	2	2	2	2
S.Indian	11	9	11	11	10	10	10
N.Atlantic	22	21	24	22	18	18	18
S.Atlantic	10	8	11	8	6	6	6
Southern Ocean <sup>2</sup>	30	27	49	36	22	23	23
Global	106	94	133 <sup>3</sup>	114	92	91	93

4) Please clean-up the writing a bit in the manuscript. In particular, section 3.1 is quite challenging to read - ensure that each paragraph is anchored by a clear and concise topic sentence, and reduce the use of variable names in the writing if possible. Occasionally whilst reading, I encountered a few fairly meaningless sentences. For example, 10915, line 12 "It indicates that the bias . . . is considered." And, 10916, line 20 "The differences in these regions are mainly due to the different assumptions made in each method."

We have added some topic sentences and removed sentences above.

#### Technical corrections

10907, line 10, should read S. Ind. Ocean (>35oS) (disregard "-“ sign)

Corrected.

*10907, line 19, "Southern" is misspelled*

Corrected.

*10909, line 3, missing "the" before Southern Ocean*

Corrected.

*10909, line 9, "fall in a wide range" should read "are wide-ranging"*

Corrected.

*10910, line 7, "need" should read "needs"*

Corrected.