

Reply to Anonymous Referee #1:

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.

In terms of comparing the data-based methods, there is not a lot of motivation to start with because the three methods are in agreement to first order. Yes, the methods have different strength and weaknesses, and yes, there are potentially problematic assumptions like constant disequilibrium or constant circulation. But they do not matter much. A case in point is their Figure 4: Cant-const, Cant-var, and Cant-all are nearly identical. This simply means, as had been pointed out numerous times before, that anthropogenic carbon uptake until recently is driven primarily by the air-sea pCO₂ gradient (i.e., atmospheric pCO₂).

The reviewer’s comments imply that making the constant disequilibrium assumption does not matter much. As pointed out in our manuscript, a previous study by Matsumoto and Gruber (2005) has identified the assumption of constant disequilibrium as a major source of bias in the Delta-C* method. The newly developed KPH/GF method does not make the constant disequilibrium assumption, rather it assumes that the *change* in disequilibrium is proportional to the increasing atmospheric partial pressure of CO₂, and estimates the regionally varying proportionality constant as part of the inversion. As far as we know, this assumption has not been evaluated beyond the tests in the supplementary section of the original KPH paper, which were not as comprehensive as those presented here. Our study shows that the assumption of a linear relationship between changes in air-sea disequilibrium and changes in atmospheric CO₂ as well as the assumption of constant circulation are generally valid on the global scale, and we believe that it is important to publish these results in order to establish confidence in the KPH/GF method. (see ms line 600-604, 612-613). Beyond the validity of the assumptions for global scale results, our study estimated impacts on CO₂ uptake due to both changes in circulation and changes in the natural carbon cycle. Our results revealed that the relationship between changes in the air-sea pCO₂ gradient and changes in atmospheric CO₂ concentrations are more complicated than the assumed by a linear relationship and certainly by a constant disequilibrium. Our study indicates there are regions require more attention and further study to understand the trends and variations in carbon uptake.

I would like to note also that the utility of the data-based methods in estimating future carbon uptake is very low. The reason is simply that there will be repeat hydrographic cruises. Ocean uptake will be given unambiguously by the change in carbon concentration between repeat cruises. The number of cruise lines will not be as large as during the 1990s during the era of WOCE or JGOFS but considerations have gone into selecting the lines. In addition and very importantly, using atmospheric O₂ data together with CO₂ data will be a dominant way to estimate ocean uptake of carbon in the future.

So, the statement that KPH could be used to predict future carbon inventory is not convincing. The DC, TTD, and KPH methods had very important roles to play, but their time at the forefront is now largely passed in my mind.*

We agree with the reviewer that repeated hydrographic measurements will provide a useful approach to evaluate the oceanic CO₂ uptake rates. Repeated hydrographic DIC measurements is potentially less dependent on assumptions made in data-based methods. However, this strategy may suffer from a different set of biases [Levine et al., 2008; Wanninkhof et al., 2010; Goodkin et al., 2011]. For example, the most widely used method, the extended Multiple Linear Regression (eMLR) can have large regional biases Wanninkhof et al. [2010]. Furthermore, Goodkin et al. [2011] found that secular climate changes and changes in carbonate chemistry invalidate the use of the eMLR technique over time periods beyond 2–4 decades and result in significant errors in the eMLR based estimates of oceanic anthropogenic carbon uptake. We modified the manuscript to clarify this point. (see ms lines 54-59).

Also, it will take several decades of repeat hydrographic measurements to unambiguously extract the trend in oceanic carbon uptake from the large eddy variability that will contaminate the section differences. Given the importance of CO₂ to climate, understanding the carbon cycle and predicting the trends of carbon storages are essential and require immediate attention. Therefore, we still need to develop and improve data-based methods and coupled carbon cycle-ocean circulation models. The first step of method development is detailed comparisons of different widely-used methods and understanding biases and uncertainties in these methods. It is also important to document the strengths and weaknesses of existing models to aid in their ongoing development. This manuscript tries to compare different data-based and model-based estimates of anthropogenic carbon sink in detail, including the estimate with the recently-developed KPH method, which have not been included in previous comparisons. Though the global estimates of Cant inventories from different data-based methods and the CCSM roughly fall within of the error bars of the data-based methods, the differences in regional estimates are significant. It is necessary to analyze these differences to improve the accuracy of these estimates. The fully coupled CCSM suffers from different biases and uncertainties than the ocean-only simulations used in this study. The biogeochemical-ecosystem module in the CCSM has also been modified over years [e.g. Moore and Braucher, 2008; Wang and Moore, 2011]. To the best of our knowledge, the estimates of oceanic anthropogenic carbon sink from the CCSM have not been discussed and compared with different data-based estimates. Even though our results are generally consistent with previous findings we believe that it is important to report our results. We modified the manuscript to further point out where our results are consistent with some previous findings (see ms lines 568-575).