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Interactive comment on "Biology and air–sea gas exchange controls on the distribution of carbon isotope ratios (δ^{13}C) in the ocean" *by* A. Schmittner et al.

Anonymous Referee #2

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The paper discusses the results of a model simulation of the δ13C of dissolved inorganic carbon (DIC) in the ocean. The authors separate the impacts of the biological pump and air-sea gas exchange on the spatial distribution of δ13C by running several model simulations with a range of conditions. They compare the model simulations with del13C observations.

Positives- This model analysis of δ13C is one of the most thorough to date. The authors perform a range of model sensitivity experiments to isolate impacts of the biological pump and gas exchange. They come to some important conclusions. First, that the biological pump exerts dominate control versus gas exchange on the ocean distribution of δ13C. Second, that the non-uniform ocean δ13C decrease resulting from anthro-

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pogenic CO2 uptake has reduced both surface and depth gradients in δ13C compared to pre-industrial times. Third, the model simulations yield δ13C values that are reasonably close to observations in the surface ocean (after accounting for anthropogenic change) and deep sea which one could interpret as the model having about the right balance between biological pump, gas exchange and circulation characteristics of the ocean. Of particular note, is the discussion of the importance of preformed δ13C (and nutrients, etc.) on the observed spatial variability of δ13C in the ocean, which generally is under appreciated. The results of this study improve our understanding of the factors controlling δ13C distribution in the ocean and thus should improve the use of δ13C as a tracer of the ocean's carbon cycle both in the modern and paleo ocean.

Negatives- Like any modeling based analysis, the results depend on the model formulation. In this case the accuracy of the model's δ13C output depends on the accuracy of the model's ecosystem, gas exchange parameterization and circulation/mixing scheme. The latter factor is not discussed in the paper despite its impact being significant. For example, the impact of gas exchange on surface δ13C depends not only on the gas exchange rate but also the residence time of water in the surface ocean, which in turn depends on the strength of the Ekman and geostrophic transports, upwelling/downwelling rates, mixed layer depth, eddy mixing, etc. Likewise in the deep sea, the δ13C depends not only on in-situ respiration but on deep sea ventilation rates and the relative strength of northern and southern deep water end members (and their preformed δ13C) which depends on the strength, for example, of the meridional overturning circulation. Unfortunately, one can't easily determine the sensitivity of the model output to changes in circulation strength as one can to changes in the gas exchange rate or biological pump. Furthermore, the model dependence of the δ13C output makes it difficult to determine which δ13C trends are more robust than others and complicates comparisons other model simulations of δ13C.

One of the major conclusions is that the equilibrium effects of air-sea gas exchange "generates meridional (δ13C) gradients opposing those of biology" (8431) and "the effect of air-sea gas exchange is to reduce the biologically-imposed δ13C gradients" (8442). This conclusion that gas exchange exerts an effect on δ13C opposite to the biological pump is in part a result of their approach which compares the δ13C output of two model experiments, one with no biology to one with no gas exchange (Fig. 4). However, one could take a different approach and compare the impacts of air-sea gas exchange and the biological pump on the δ13C in the surface ocean currently observed (with the anthropogenic effect) or (estimated) for a pre-industrial ocean. In this case one finds that in the tropical/subtropical surface ocean the observed δ13C is higher than that predicted at equilibrium with the atmospheric δ13C and so the impact of gas exchange (depleting δ13C) opposes the impact of the biological pump (enriching δ13C). However, in the subarctic ocean the observed δ13C is lower than that expected at equilibrium with the atmosphere and thus in this region both gas exchange and the biological pump are enriching the δ13C. This approach yields a significantly different take on the roles of gas exchange and biological pump impacting δ13C in the surface ocean with these processes working together in some regions and opposing each other in other regions. It would be worth having the authors discuss this alternate look at the interplay between gas exchange and biological pump in the paper.

I would have liked to seen some property-property plots to compare observations and model output. For example, δ13C vs DIC or δ13C vs PO4 trends in the surface ocean and deep sea. Are model slopes and scatter similar to observations? How sensitive are the slopes to model parameters (gas exchange rates, biological pump, etc.)? Can these relationships be used to evaluate model performance?

Overall- I like the paper. The authors present a systematic model-based evaluation of the impact of the biological pump and gas exchange on spatial distributions of δ13C in the ocean. Given the increase in δ13C data from WOCE and CLIVAR programs this type of analysis is clearly needed. They conclude that the biological pump dominates the δ13C distribution in the ocean and that the δ13C changes resulting from anthropogenic CO2 uptake have significantly altered δ13C gradients from pre-industrial times.

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Interactive Comment

These are important points. The results are model dependent and thus it's difficult to evaluate the robustness of their conclusions until other models are used to simulate δ13C. In the meantime, the author's analysis has identified some important findings on processes controlling δ13C in the ocean which will help the community utilize δ13C as a tracer of the ocean's carbon cycle in the modern and paleo ocean.

I strongly recommend publishing the paper.

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