Response to reviewer 2

(Original reviewer comments are in red, our response in black, and changes to the text highlighted yellow.)

Thank you for a thoughtful and constructive review.

Negatives- Like any modeling based analysis, the results depend on the model formulation. In this case the accuracy of the model's _13C 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 _13C 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 _13C 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 _13C) 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 _13C output makes it difficult to determine which _13C trends are more robust than others and complicates comparisons other model simulations of _13C.

We included a discussion of the effects of gas exchange and circulation/mixing in the section 6.

This conclusion depends on the accuracy of the k0 estimate (Eq. 3). Sensitivity tests with a slightly different model version than the one presented here show improvements of the δ13CDIC and Δ14CDIC simulations by using k0 = 0.253 (NRMSEs of 0.53 and 0.26) compared with k0 = 0.337 (NRMSEs of 0.56 and 0.29) supporting Sweeney et al. (2007) and Graven et al. (2012). Although we cannot exclude somewhat higher values of k0 than used here, we believe that our results will be robust for modestly faster rates of air-sea gas exchange.

and

The effect of air-sea gas exchange on δ13CDIC depends on the residence time of waters at the surface, which depends on the circulation. Likewise, the effect of biology on deep ocean δ13CDIC depends on the circulation and mixing of different water masses. In this paper we did not directly address the sensitivity of δ13CDIC on circulation and mixing in the model. This will be left for future study. The fact that the model reproduces the observed distribution of δ13CDIC and the individual effects and components reasonably well suggests that it has the balance of circulation, gas-exchange, and biology about right, but it cannot be ruled out that compensating errors lead to the right result for the wrong reason, or that other parameter combinations lead to a similarly good simulation. Thus, our results could be model dependent.

One of the major conclusions is that the equilibrium effects of air-sea gas exchange "generates meridional (_13C) gradients opposing those of biology" (8431) and "the effect of air-sea gas exchange is to reduce the biologically-imposed _13C gradients" (8442). This conclusion that gas exchange exerts an effect on _13C opposite to the biological pump is in part a result of their approach which compares the _13C 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 _13C 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 _13C is higher than that predicted at equilibrium with the atmospheric _13C and so the impact of gas exchange (depleting _13C) opposes the impact of the biological pump (enriching_13C). However, in the subarctic ocean the observed _13C 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 _13C. This approach yields a significantly different take on the roles of gas exchange and biological pump impacting _13C 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.

Thank you for raising this interesting point. In section 6 of the revised manuscript we add the following discussion addressing this issue.

It is important to note that biologically created gradients are mediated by circulation and are therefore non-local. Thinking about the effects of gas exchange and biology on local tendencies for surface waters, one may conclude that they work together in some regions, such as the sub polar oceans where both tend to increase δ13CDIC, but oppose each other in other regions, such as the subtropics, where biology tends to increase δ13CDIC whereas gas exchange tends to decrease it (Fig. 3). However, whereas photosynthesis tends to increase δ13CDIC in high latitude surface waters, the overall effect of biology is to decrease δ13CDIC there due to upwelling of isotopically light, remineralized carbon from the deep ocean (Δδ13Cbio, Fig. 3).