Response to Review RC2 by Andreas Schmittner

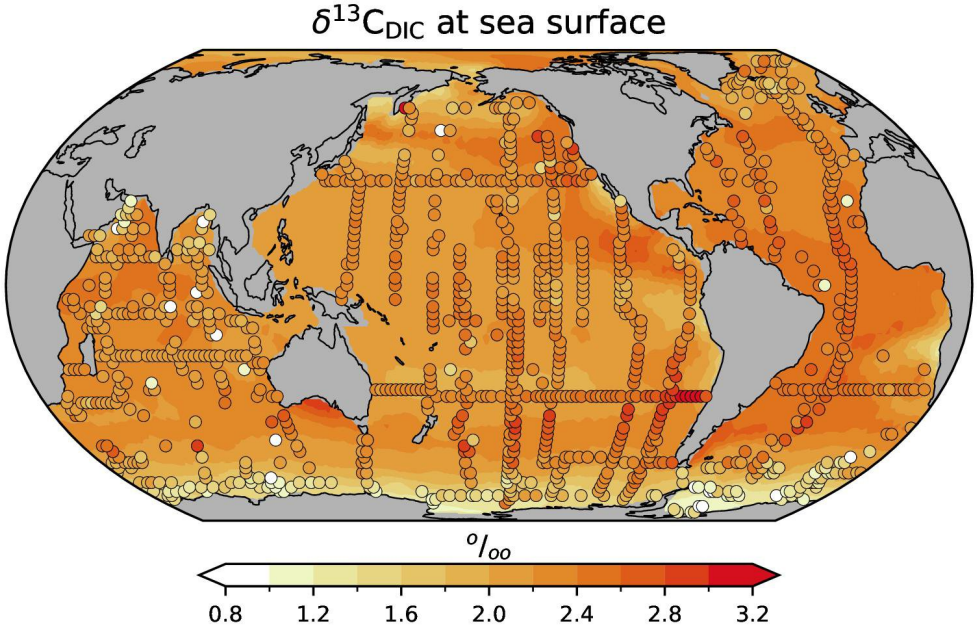
Reviewer text is in black, author replies are in blue italics.

This manuscript describes results from a new implementation of carbon isotopes in an ocean model. The paper is well written, nicely illustrated and the conclusions are backed up with the evidence provided. I only have a few minor comments and leave it to the discretion of the authors how much they want to change the manuscript.

We thank Andreas Schmittner for his constructive and friendly review and are happy to answer his comments. Corresponding manuscript changes are highlighted in blue in the revision.

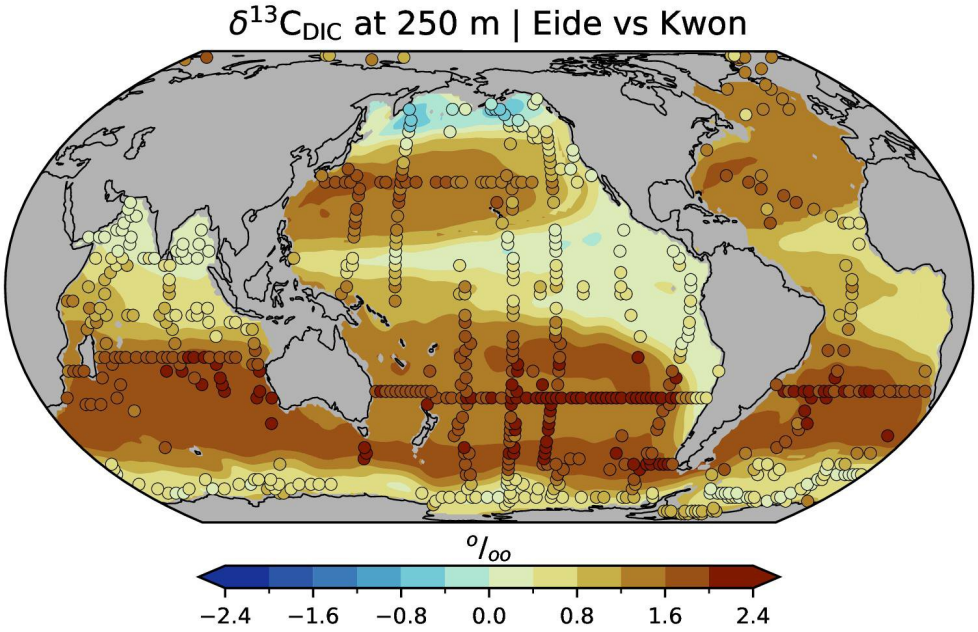
Line 197: The reconstruction by Kwon et al. (2022, https://doi.org/10.1038/s43247-022-00388-8) includes the surface and could be used to compare with the model results there.

Unfortunately, Kwon et al. (2022) do not provide gridded data and their reconstruction has spatial gaps. We think that the horizontal resolution of our model setup is too coarse for a robust comparison with local observations / reconstructions. Therefore, we stick to the rather smooth, remapped reconstruction by Eide et al. (2017). For the sake of completeness, we show preindustrial $\delta^{13}C_{DIC}$ simulated for surface water with the corresponding values by Kwon et al. (2022; dots). This figure will also be included into the Appendix of the revision (new Fig. A6) and briefly discussed in L215-217.



New Figure A6. *Preindustrial $\delta^{13}C_{DIC}$ of surface water at about 18 m depth. Shaded areas: Simulation CC, filled circles: Reconstructed values by Kwon et al. (2022).*

The simulation results are largely in line with the reconstructed values by Kwon et al. The model results appear to be lower than the Kwon data in the South Pacific. However, Kwon's reconstruction also exhibits higher $\delta^{13}C_{DIC}$ values than Eide et al. in the Southern hemisphere thermocline and intermediate which can be seen the figure below and which is also discussed by Kwon et al. (2022):



Preindustrial $\delta^{13}C_{DIC}$ of seawater at 250 m depth. Shaded areas: Reconstruction by Eide et al. (2017), filled circles: Reconstructed values by Kwon et al. (2022).

Line 218: The decomposition by Broecker and Maier-Reimer (1992) is problematic as it ignores the effect of differences in preformed $\delta^{13}C$ and PO_4. Interior ocean $\delta^{13}C$ and PO_4 include preformed components. For $\delta^{13}C$ the preformed component is impacted by air-sea gas exchange, whereas for PO_4 it isn't. Thus $\delta^{13}C_{BIO}$ is not equal to $\delta^{13}C_{rem}$ (which doesn't include a preformed component). $\delta^{13}C_{BIO}$ doesn't include the correct biological preformed component of $\delta^{13}C$ either since it was calculated using PO_4. In other words, this decomposition, although widely used, is pretty much useless to understand $\delta^{13}C$.

See our next response.

Line 223: Since $\delta^{13}C_{BIO}$ (as calculated following Broecker and Maier-Reimer, 1992) includes effects of air-sea gas exchange (from preformed $\delta^{13}C$), $\delta^{13}C_{AS}$ includes effects of biology.

We agree that $\delta^{13}C_{BIO}$ and $\delta^{13}C_{AS}$ should not be confused with remineralized and preformed $\delta^{13}C$ and mention this in the revision in L249-251. The dependence of $\delta^{13}C_{AS}$ from biological effects was already mentioned in the submission (now in L264-265). As mentioned in our response to Review #1, the comparison of simulated $\delta^{13}C_{BIO}$ and $\delta^{13}C_{AS}$ with the values reconstructed by Eide et al. is primarily intended as a tentative validation with further datasets in addition to $\delta^{13}C_{DIC}$ but not as a quantitative analysis of the contributions of different drivers to $\delta^{13}C_{DIC}$. This is clarified in the revision in L253-259.

Line 247: Why not run model with Suess effect included for a proper comparison to observations? Suess effect can be expected to decrease $\delta^{13}C_{POC}$ by about 2 permil (e.g. Fig. 8 Schmittner et al., 2013). What is the global difference (model-obs)?

The global RMS difference between modelled and observed $\delta^{13}C_{POC}$ is 2.6‰ which is mentioned in the revision at L278. The difference is higher than what could be expected from the Suess effect only. We think that a rigid analysis of this issue should deserve a dedicated separate study which, in addition to higher

spatial resolution, should involve more sophisticated climate forcing, anthropogenic ^{14}C, and maybe further anthropogenic ocean ventilation tracers.