Response to reviewer 3

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

Thank you for your helpful comments.

This type of approach contains, in general, non-additive 'delta' terms; meaning that the differences between the numerical model experiments may not precisely be equal to the amount 'due' to each process. This method, whereby highly idealised experiments are compared to each other to quantify the effects of different processes, is used successfully in the literature. The authors have discussed the possibility of non-additive 'delta' terms and considered the potential limitations of this in the manuscript. I think a slight re-write is needed to give more emphasis to the results being model dependent. While I agree that the model has been tuned and seems to well simulate the spatial distribution of d13C – there could be other parameter combinations in different models that would seem equally well tuned. Subject to minor alteration to increase the prominence of the model-dependence of their conclusions in the text, and the clarification of a point raised below, I support the publication of the manuscript.

Your comment on the model dependency of the results is echoed by another reviewer. We agree and acknowledge this now prominently in section 6.

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.

Specific issues:
Equations (4) and (5):
I think the details of the treatment of air-sea fluxes after Zhang et al (1995) of 13C needs some clarification in the text.
In Zhang et al (1995), epsilon_aq_g is a function of temperature. Since Zhang et al's epsilon = (alpha – 1.0)*1000 this also means that alpha_aq_g is a function of temperature. Why is the alpha_aq_g adopted here a constant, when according to Zhang et al's epsilon function, alpha should be function of sea surface temperature?

You're correct in pointing out the temperature dependency of alpha_aq_g measured by Zhang et al. However, this effect is very small (a ~0.1 permil change for a range of SSTs from 0 to 30 deg C). This is more than an order of magnitude smaller than the temperature effect on alpha_DIC_g. We note this now in section 2.1:

Here we neglect the minor temperature dependency of the isotopic fractionation factor from gaseous to aqueous CO2 ($5 \times 10^{-6}/{\circ}C$) found by Zhang et al. (1995) and approximate it as a constant $\alpha_{aq \leftarrow g} = 0.998764$ corresponding to a mean temperature of 15◦C.

Also, Zhang et al (1995) use the fractions of DIC in the forms CO2*, HCO3- and CO32- to calculate alpha_DIC_g. In this manuscript it appears this is not done – with a straight linear temperature relation given (equation 5), irrespective of the component concentrations

of DIC species.
Could the authors justify or explain these apparent differences between the full relationships of Zhang et al (1995) and their equations. It may be that I have misunderstood, but if there are approximations simplifying the full equations of Zhang et al then could these approximations be highlighted better in the text? I am not suggesting that the model is coded incorrectly, just that the text does not clarify quite how the equations/ approximations given are arrived at from the full DIC species-dependent relations in Zhang et al (1995).

Zhang et al. measured the fractionation factors of the individual carbonate species in sodium bicarbonate freshwater. They find that the individual factors cannot be used to calculate alpha_DIC_g and attribute this discrepancy to the presence of other carbonate complexes in sea water.

Here we use Zhang et al. (1995)'s direct measurements of αDIC←g in sea water (their Fig. 6), rather than their fractionation factors for the individual carbonate species measured in freshwater sodium bicarbonate solutions. Zhang et al. (1995) show that their individual fractionation factors cannot be used to calculate αDIC←g, which they attribute to the presence of other carbonate complexes in sea water.