



## Towards a mechanistic interpretation of $\delta^{13}\text{C}$ : modelling calcification in benthic foraminifera and its application to palaeoceanographic model scenarios

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The proxy  $\delta^{13}\text{C}$  as derived from benthic foraminifera shells is widely used by palaeoceanographers to reconstruct past water masses. A mechanistic description of the biogeochemical processes involved in forming the benthic foraminiferal  $\delta^{13}\text{C}$  signal, however, is still lacking.

We are using a reaction-diffusion model for calcification in benthic foraminifera, coupled to a combined global ocean and a carbon cycle circulation model, in order to describe the formation of foraminiferal shell  $\delta^{13}\text{C}$  more mechanistically. The coupled models are then applied to a present-day control run and different glacial ocean circulation scenarios.

Our results suggest that the effect of temperature on  $\delta^{13}\text{C}$  in benthic foraminiferal shells is more pronounced than previously thought: high (low) temperatures result in higher (lower) shell  $\delta^{13}\text{C}$  values when compared to the  $\delta^{13}\text{C}$  value of dissolved inorganic carbon (DIC) in the same location. Additionally, we find that the modelled respiration rate modulates benthic shell  $\delta^{13}\text{C}$  values: higher (lower) respiration rates cause a marked depletion (enrichment) of shell  $\delta^{13}\text{C}$ . Crucially, for the standard respiration rate all scenarios result in shell  $\delta^{13}\text{C}$  values that are lower by  $\geq 0.2\text{\textperthousand}$  compared to the corresponding  $\delta^{13}\text{C}$  of the surrounding DIC.

Importantly, the changes in modelled  $\delta^{13}\text{C}$  induced by changes in temperature and respiration rate are in the same order of magnitude as the differences in  $\delta^{13}\text{C}$  between the present-day/Late Holocene and the LGM. Given these uncertainties, the distribution of LGM water masses based on reconstructions of  $\delta^{13}\text{C}$  is less well constrained than previously thought: both a shoaled Atlantic meridional overturning circulation as well as one that is close to the present-day circulation can be reconciled within the uncertainties.