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Towards a mechanistic interpretation of δ13C: modelling calcification in benthic foraminifera and its application to palaeoceanographic model scenarios

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The proxy δ13C 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 δ13C 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 δ13C 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 δ13C in benthic foraminiferal shells is more pronounced than previously thought: high (low) temperatures result in higher (lower) shell δ13C values when compared to the δ13C value of dissolved inorganic carbon (DIC) in the same location. Additionally, we find that the modelled respiration rate modulates benthic shell δ13C values: higher (lower) respiration rates cause a marked depletion (enrichment) of shell δ13C. Crucially, for the standard respiration rate all scenarios result in shell δ13C values that are lower by $\geq 0.2‰$ compared to the corresponding δ13C of the surrounding DIC.
Importantly, the changes in modelled δ13C induced by changes in temperature and respiration rate are in the same order of magnitude as the differences in δ13C between the present-day/Late Holocene and the LGM. Given these uncertainties, the distribution of LGM water masses based on reconstructions of δ13C 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.