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Climate of the Past
Discussions

Interactive comment on "Moving beyond the age-depth model paradigm in deep sea palaeoclimate archives: dual radiocarbon and stable isotope analysis on single foraminifera" *by* Bryan C. Lougheed et al.

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We agree with the authors that the effects of post-depositional sediment mixing (PDSM), i.e. bioturbation, are important to consider and are hidden by conventional dating methods that measure a single 14C value from a sample containing many discrete specimens. As the number of distinct, e.g. forams, required for a 14C sample decreases – the question of how representative these few individuals will be of the layer

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from which they were recovered becomes increasingly important. This uncertainty will not be measured unless multiple replicate samples are dated from the same sediment layer. By taking this to the extreme and dating individual forams, Lougheed et al are able to directly estimate the standard deviation in age of individuals recovered from the same 1 cm sediment layer atÂă4670 14C years. Widespread use of individual dating would enable a much more robust consideration of the effects of bioturbation on proxy records. In fact, by using a particularly large species of foram, they take this one stage further, and perform 14C dating on just half of each foram test, allowing d18O to be measured on the remaining half. This removes the need for depth-age modelling altogether and we agree that this is indeed a very exciting possibility that will open up regions of low sedimentation rate to proxy climate reconstruction with high temporal resolution.

Lougheed et al also simulate sediment cores for a range of sediment accumulation rates and a large number of PDSM intensities. The PDSM is modelled by applying Gaussian noise to the position of forams in the sediment cores with a range of standard deviations. Their figure 4 shows the results of the simulation. Using the observed sediment accumulation rate of 2.2 cm/ka, they estimate the standard deviation of movement required in order to obtain a SD of age of 4670 14C years as approximately 6 cm. We note that in the region of the observed sediment accumulation rate for this core, the contour line for a SD of $\sim$ 5000 14C years is more or less parallel to the PDSM axis and therefore there is little power to constrain the strength of PDSM. Also, if a constant sedimentation rate is assumed, then is the SD in depth not simply the SD in time (4670 years) scaled by the sedimentation rate, i.e. 4670 * (2.2 / 1000) = 10.274 cm?

We think this paper could be improved by instead considering a well established physical model of bioturbation in which there is a well-mixed surface layer of sediment of a fixed depth (Berger & Heath, 1968). Assuming a constant sedimentation rate, and a fixed mixing depth, the time integrated solution to this simple model predicts that the ages of material at a given depth follow an exponential distribution (Berger & Heath, 1968). The scale parameter of this exponential distribution is simply the mixed layer depth divided by the sedimentation rate (alternatively parameterised by rate = 1/scale). Both the mean and the standard deviation of the exponential distribution are equal to the scale, and so the ratio of the mixed depth and sedimentation rate give a prediction of the standard deviation of ages according to this model. Using a typical mixing depth of 10 cm (Boudreau, 1998) and the observed sedimentation rate of 2.2 cm/ka, we obtain a standard deviation of 10 / (2.2 / 1000) = 4545 14C years, remarkably close to the 4670 14C years from the simulation.

We noticed one other potential error. In figure 2, the calibrated ages in panel B appear to be about $\frac{1}{2}$ the 14C ages in panel A, whereas calibrated ages should be older than their 14C ages (but not by 2x).

Berger, W. H., & Heath, G. R. (1968). Vertical mixing in pelagic sediments. Journal of Marine Research, 26(2), 134–143. Boudreau, B. P. (1998). Mean mixed depth of sediments: The wherefore and the why. Limnology and Oceanography, 524–526.

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