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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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Dear Julia Gottschalk,

Thank you for interest in our manuscript, your encouraging words and for your contribution to the discussion forum of this manuscript.

Indeed, when analysing for the rare radioisotope 14C on such small samples, one must be vigilant for any possibility of modern 14C contamination, as pointed out in the publications you have cited in your short comment: Brown and Southon (1997); Hua

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et al. (2004). Those publications specifically refer to possible contamination during the graphitisation process, which we did not use. The method which we use involves acidifying sample carbonate to sample CO2 in He-flushed, sealed septa vials for direct measurement in the MICADAS AMS (e.g. Wacker et al., 2013). This method has much smaller sample mass requirements than the graphitisation process, meaning that it is possible to measure much smaller sample masses on the AMS. However, we agree that the general principle of small sample masses being relatively more susceptible to contamination of course applies, just that the mass threshold is much lower than in the case of graphitisation. We measured IAEA-C1 standard powder, as well as single Eemian (i.e. assumed 14C "blank") foraminifera from the same species and sediment core. The masses of these blank foraminifera samples (min: 12.8 μg C, max: 24.0 μg C, mean: 19.0 μg C) were of similar range to that of the foraminifera used for the study (min: 8.4 μg C, max: 47.2 μg C, mean: 19.8 μg C). Procedural blank foraminifera values ranged between $\sim$31,000 and $\sim$41,000 14C yr BP and were generally not as good as those for IAEA-C1 material. There was no correlation between sample mass and 14C value, neither in the case of the IAEA-C1 material nor the blank forams.

The specific blank correction value used was F14C = 0.0095 $\pm$ 0.00203 ($\sim$37500 14C yr BP). This blank value, along with its uncertainty, was applied using the BATS software (Wacker et al., 2010). For a smaller, second run of samples (ETH-74XX) it was possible to use a much lower blank (F14C = 0.0033 $\pm$ 0.00101).

You are correct that the variability of process blanks and the reduced measurement sensitivity reduce, for now, for now, the ability to precisely measure older samples. Moreover, as you suggest, the variation also reduces the precision somewhat on younger dates (e.g., in the <20,000 14C yr BP range). Compared to a constant blank value of 37,500 14C yr, variable blank values between $\sim$31,000 and $\sim$41,000 14C yr would affect 14C ages of Holocene samples (i.e. the bulk of our samples) by between $\sim$0.9% and $\sim$3.5%, thus increasing uncertainty. Due to the relatively poorer counting statistics inherent in 14C dating single forams, our reported 14C dates already have

quite a low precision (between 1% and 4%) anyway. Moreover, the uncertainties associated with 14C reservoir age reduce chronological precision by a further 7.5% on average. Therefore, the variation in blank value is not significant in determining the quantified PDSM in T86-10P (which is on the order of thousands of years). In general, dating single forams sacrifices precision to gain accuracy. Such an approach is especially useful in sediment cores with high PDSM and/or very low SAR, where large multi-specimen samples would yield a good 14C signal with low error, but all information regarding the large intra-sample 14C age heterogeneity would be lost.

Pre-treatment options for single forams is something that we are continually looking into. It is our intention that in future, a routine and (automated) prep system for single foraminifera will be developed, with the ability to carry out preatreatment online and split gaseously into stable isotope and 14C fractions. However, this depends on access to project funding.

Thank you also for pointing out that no information is provided regarding sample size (i.e. mass) in the supplemental table. We agree that this information should definitely be provided in the case of our study, as we detail new methods. We will include information regarding sample ug C as reported by the MICADAS AMS in the supplemental table. You might note that some of the larger sample masses with 14C data have no corresponding stable isotope data. In principle it should have been possible to also report stable isotope data for these larger samples, but we suffered a failed IRMS run at another laboratory (not at our affiliation institutions).

Once again, thank you for your interest in our manuscript and specifically your helpful comments requesting more information about the blank correction process. We will better highlight this process (as explained above) in the updated version of the manuscript, which will certainly serve to significantly improve the reader experience.

On behalf of the co-authors, kind regards,

Bryan Lougheed

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