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Interactive comment on “Re-evaluating ^{14}C dating accuracy in deep-sea sediment archives” *by* Bryan C. Lougheed et al.

Anonymous Referee #1

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Lougheed et al. present a number of sensitivity studies on the influence of bioturbation on marine sedimentary proxy records and assess how bioturbation may bias chronological age models derived from foraminiferal radiocarbon dates. The authors specifically test the impact of bioturbation as a function of sedimentation rate, bioturbation mixed-layer depth as well as abundance variations and fragmentation of foraminifera.

In my view, this work is important and highly useful that complements and expands existing numerical tools for assessing bioturbation in marine sediments (e.g., Trauth, 2013; Dolman and Laepple, 2018) and that will help to assess possible bioturbation biases of paleo-climate proxy records, which has increasingly been found and highlighted in the last years (e.g., Costa et al., 2017; Ausín et al., 2019). However, the impact of bioturbation on marine sediment records has been known for decades, and

similarly, bioturbation models are around for a long time, as the study acknowledges. The work of Lougheed et al. may therefore seem marginal, but I consider the implementation of single-specimen simulations and the direct link to 14C calibration tools important.

The authors perform their sensitivity analyses with the new tool SEAMUS that the first author developed and presents in an accompanying paper in Geoscientific Model Developments currently in review (https://doi.org/10.5194/gmd-2019-155). This work is another useful tool for the paleoclimate community by the first author that follows a number of existing applications broadly related to the same topic, e.g., MatCal (Lougheed and Obrochta, 2016). MatCal is an integral part of SEAMUS. The paper is well structured and is written in a clear way. I therefore believe that this paper is of great interest and use to the geochronology- and paleoclimate community, and I therefore recommend publication with minor revisions.

Along with one comment of major concern, I outline some minor points of criticism below in the hope that the authors find these useful in making the study further accessible to the readership. Although I have read the accompanying paper in Geoscientific Model Developments, I haven't had the time to run SEAMUS with study-independent scenarios. I assume that SEAMUS was intensively tested and run by reviewers who have assessed the accompanying paper.

Main criticism: Most of the paper deals with best-case scenarios, in which sedimentation rate, fragmentation and bioturbation depth are held constant. This rarely applies to marine sediment cores, as acknowledged. SEAMUS offers the opportunity to test the impact of bioturbation on chronological models under a variety of scenarios with transient changes of input variables, which would more closely represent marine sediment cores. This is addressed in section 4.0, but I must say that I expected a more detailed assessment of such non-ideal and more realistic scenarios (essentially more than half a page of discussion and analyses). I hence recommend that the authors run three different simulations to give it the attention it deserves and to further highlight the power of their approach: One with the suggested step-like function in sedimentation rate, one with the suggested change in species abundance, and one with both changes. This would help to understand what process impacts the multi-modal character of the true age population the most and in what way. Furthermore, do both processes contribution equally to the offset between the AMS mean 14C age and the idealized mean 14C age, and the calibrated median age that is derived from the AMS mean age? These aspects should be discussed, in my view.

Minor comments: One key observation is that mean AMS 14C ages are generally younger than idealized mean 14C ages. The authors attribute this to the isotope mass balance effect. However, to me it seems that it must also be to some extent linked to the effect of bioturbation itself, essentially the character of the exponential pdf for true age (how extended and pointy it is), combined with character of the atmospheric calibration. I wonder whether the authors can elaborate on additional processes in case they think these may be important, or specify whether they think the isotope mass balance effect is the main driver of the observed offsets.

“Perfect” simulated sediment archive scenarios: I would argue that a “perfect” sediment core is one without and very little bioturbation (e.g., BD=1cm with high SR>10 cm). I think it is worth to rephrase to “most favorable” or “best-case“.

Section 2.2. It needs to be specified what fraction of the total number of foraminifera has been picked by the simulations, maybe simply by inserting “with a fraction set by the operator”. I would expect that this fraction matters for the magnitude of offset between AMS mean 14C age and whole-sample/idealized 14C age. I think it is worth highlighting that this fraction in reality changes as the abundance of (well-preserved) foraminifera changes in sediment cores, and that this would affect the observations (in what way?).

Line 155: it is unclear what is meant with “samples nearing the blank value”. I would argue that samples with a 14C age of 45 kyr BP have a much larger analytical uncertainty

(>200 yr). Please clarify.

Line 204-207: Do you mean that the AMS 14C age diverges from the idealized mean 14C age? I am confused here that an offset diverges from something. Please clarify.

Line 208: I think it would help to specify the following “for each discrete depth FROM THE ARTIFICALLY PICKED SAMPLES”, because simulated AMS mean and idealized mean 14C age are introduced here for the first time.

Line 250: Rephrase to express that the true median age is lower than the calibrated mean age, as “offset” can be both negative and positive.

Line 258: I would recommend to add “throughout the sedimentation history of a sediment archive, MUCH MORE EFFICIENTLY THAN YOUNG FORAMINIFERA DOWNWARDS”

Line 286: I agree that a sample is 14C-dead when it is older than the blank, but shouldn’t it be declared 14C-dead when within 2-sigma of the blank too (Stuiver and Polach, 1977). If the authors agree, I’d recommend clarification of this sentence.

Line 323-326: I am surprised that the offsets around 11 kyr are emphasized, although they occur throughout the simulation, with a similar or larger magnitude. Please revise.

Typos: Line 176: remove “it that” Line 215: remove “much” Line 223: space missing between idealized and mean Line 230: remove “of” Line 280: add “of” at the end of line Line 297: remove “4” Line 302: insert “that” after “this effect is” Line 334: remove both “/” Figure caption 1, 3 and 5: change “i.e” into “i.e.” or “i.e.,” ; 14 in “14C” should be superscript; I am also somewhat confused by the (what seems to me an inconsistent) use of “mean 14C age” and “idealized”, in particular with regards to how panel a is labelled. Shouldn’t it say in the last sentences: “on the y-axis the corresponding 14C age distribution of the single specimens (with the blue diamond corresponding to the AMS mean 14C age). [. . .] The pink normal distribution on the y-axis represents the IDEALISED 14C AGE UNCERTAINTY of the single specimens, where the pink square corresponds to the expected IDEALISED MEAN 14C age." This may seem marginal but it would help to keep the terminology consistent across figure caption and figure labels.

References: Ausín, B., Haghipour, N., Wacker, L., Voelker, A.H.L., 2019. Radiocarbon Age Offsets Between Two Surface Dwelling Planktonic Foraminifera Species During Abrupt Climate Events in the SW Iberian Margin Paleoceanography and Paleoclimatology. Paleoceanogr. Paleoclimatology 34, 63–78. https://doi.org/10.1029/2018PA003490 Costa, K.M., McManus, J.F., Anderson, R.F., 2017. Radiocarbon and stable isotope evidence for changes in sediment mixing in the North Pacific over the past 30 kyr. Radiocarbon 1–23. https://doi.org/10.1017/RDC.2017.91 Dolman, A.M., Laepple, T., 2018. Sedproxy: A forward model for sediment-archived climate proxies. Clim. Past 14 (12), 1851–1868. https://doi.org/10.5194/cp-14-1851-2018 Lougheed, B.C., Obrochta, S.P., 2016. MatCal: Open Source Bayesian 14C Age Calibration in Matlab. J. Open Res. Softw. 4, 1–4. https://doi.org/10.5334/jors.130 Stuiver, M., Polach, H.A., 1977. Discussion: Reporting of 14C data. Radiocarbon 19 (03), 355–363. https://doi.org/10.1017/S0033822200003672 Trauth, M.H., 2013. TURBO2: A MATLAB simulation to study the effects of bioturbation on paleoceanographic time series. Comput. Geosci. 61, 1–10. https://doi.org/10.1016/j.cageo.2013.05.003

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