

Clim. Past Discuss., author comment AC1
<https://doi.org/10.5194/cp-2021-173-AC1>, 2022
© Author(s) 2022. This work is distributed under
the Creative Commons Attribution 4.0 License.

Comment on cp-2021-173

Michael Sarnthein and Pieter M. Grootes

Author comment on "¹⁴C plateau tuning – A misleading approach or trendsetting tool for marine paleoclimate studies?" by Michael Sarnthein and Pieter M. Grootes, Clim. Past Discuss., <https://doi.org/10.5194/cp-2021-173-AC1>, 2022

Discussion contribution to Climate of the Past.

'Comment on cp-2021-173', by Edouard Bard and Timothy J. Heaton:

"¹⁴C plateau tuning – A misleading approach for marine paleoclimate studies."

Reply by Michael Sarnthein

Introduction

Though in disagreement with most arguments and objections recently raised by Bard and Heaton (B&H), we (Grootes and I) see a great chance in taking their concerns seriously, since similar reservations may also come from other colleagues in the science community. The comments below try to counter the issues of B&H with patience one-by-one.

p.1, §1 and §2. B&H refer to pitfalls of plateau tuning (PT) they had already discussed in their CP paper of B&H 2021, though not addressed in the manuscript presently under discussion for CP.

Contrariwise, the CP paper of B&H (2021) has strongly suffered from ignoring most of our detailed discussion remarks we had returned to their 17 objectives 2021 (comments of Sarnthein & Grootes, 2021). In the present comment, B&H may hopefully be able to better recognize our answers to their objections. However, it appears inappropriate now to reiterate our critical remarks on B&H statements of Feb. 2021 but focus on two key objectives, (1) the existence of atm ¹⁴C plateaus and (2) their proper reflectance in (19) ocean sediment cores.

p.1, §2. B&H refer to Skinner & Bard (2021) seeing unexplained discrepancies between local MRA estimates based on PT and that of other authors: As long as Skinner & Bard (2021) don't present any objective evidence to decide which actually was the true and which the wrong MRA estimate for a site or for closely neighbored sites under discussion, I prefer to stick to the well-defined estimates deduced by PT.

p.1, §3 and §4. B&H conclude: "Sarnthein & Grootes only consider one narrow aspect of PT – whether long atmospheric ¹⁴C-age plateaus exist and can be reliably identified. We are unfortunately unconvinced , , On the basis of the Suigetsu ¹⁴C record the authenticity of atmospheric ¹⁴C age plateau structures is now reliably confirmed by means of 3,

completely independent techniques of signal evaluation (details listed below), therefore plateaus >300 yr long are indeed regarded as robust (shorter ~250 yr is too short to be reasonably defined).

B&H demur other key PT requirements: Whether these atmospheric ¹⁴C-age plateaus transfer to the marine environment and, even if they do, whether they can be reliably identified in extremely sparse ¹⁴C samples from sediment cores , , , The transfer of atmospheric plateau signals to marine surface waters and (planktic) sediment records is broadly discussed in our synthesis paper 2020, in Grootes & Sarnthein (Feb. 2021), and now, in a graphic display of 19 sediment records, where a sampling resolution better than 50-150 yr is found adequate to identify the suite of ¹⁴C plateaus >250-300 yr long each.

B&H claim that PT was applied to sediment cores for which no independent timescale is available , ,

In contrast to the claim of B&H all results of PT were strictly reconciled (and discussed) with independent 'conventional' stratigraphic tie points of SST and planktic d¹⁸O records, and with further age markers such as ash layers for each single core record examined.

What Sarnthein and Grootes claim in their new work

p.1, §5. "We remain unclear how a reader can be confident that the hypothetical ¹⁴C-age plateaus have been identified objectively"

Based on both the ¹⁴C record of Suigetsu and that of tree rings (10 - ~15 cal ka) the suite of atmospheric plateau structures has been clearly reproduced by means of 3 independent evaluation techniques, hence is regarded robust. Either based on visual inspection or on the 1st derivative of the slope of ¹⁴C yr vs. cal yr the plateau boundaries we had inferred merge within <100 yr (Sarnthein et al., 2015) and differ from those based on the (smoothing) Bayesian spline by no more than 50 - 250 yr (Fig. 1), a difference tolerable. Different from the other two techniques, however, the Bayesian spline did not eliminate in advance up to 10 % obvious ¹⁴C age outliers that mark most ¹⁴C plateaus, hence may diffuse some plateau boundaries.

p.2, §2. This new paper therefore provides limited new insight over their review Sarnthein et al. published 2020.

Indeed, our recent, IntCal20-based revision of the age tie points and MRA for 19 marine data sets did not aim for any new results but just for a more accurate age control, crucial for any proper correlation to other marine and/or non-marine paleoclimate records.

Lack of independence between Lake Suigetsu and Hulu Cave Chronologies

p.2, §3 and top of §4. , , , , the updated Suigetsu calendar age chronology , , , , is not independent of the Hulu Cave ¹⁴C record.

Various aspects of the Suigetsu calendar age chronology and their link to that of Hulu Cave and various caveats were broadly discussed in our synthesis 2020, thus won't need to be repeated in this comment.

p.2, §4 – §6. (an admonition concerning our Fig. 4, not "Fig .3") , , , , one must be extremely careful not to overstate one's confidence that similarities in the two records after tuning provide robust and repeated evidence for the simultaneous presence of ¹⁴C-age plateaus

Indeed, our Fig. 4 won't serve for overstating the confidence in the similarity of ¹⁴C

plateau structures found in Suigetsu and Hulu records, but just highlights the lack of discrepancies. As broadly discussed in 2020, we are fully aware, and more so than other authors, that both the timing of Hulu and the correlated Suigetsu records don't present a purely atmospheric signal but hide away in part major, in part minor potential shifts in the Dead Carbon Fraction (DCF) of the Hulu stalagmite, short-term shifts yet unknown.

Variation in Atmospheric ^{14}C levels

p.2, §7. and p.3, §1-2 and §3. B&H 2022 address a crucial issue in questioning the Suigetsu-based evidence for a long "staircase" of ^{14}C -age plateaus 15 – 30 cal ka per analogy to that found in the tree ring record 0 – ~15 cal. ka, i.e., the problem of reliably separating short-term wiggles (e.g., 100 yr and less) from actual plateau-style trend inversions in $D^{14}\text{C}$ extending over about 300 – 1200 yr.

- B&H may have overlooked in our approach that medium-term atmospheric ^{14}C variations, in particular ^{14}C jumps are clearly identified and reproduced with just a minor degree of subjectivity (chosen width of Kernel window) by means of the 1st derivative of ^{14}C yr vs cal yr we employ.
- This approach that helps us "to see the wood for the trees", a sincere problem to some colleagues, a problem also reflected in B&H Fig. 1. PT does not intend to compete with IntCal in creating a novel age calibration program but just aims for a centennial-scale raster of atmospheric ^{14}C structures suitable for global age correlation.
- Interesting to note that the length of ^{14}C plateaus and the extent of ^{14}C jumps have changed significantly over different regimes of glacial-to-deglacial climate: Plateaus up to 1000 yr long covered ~80% of the peak glacial and early deglacial period 30–14 cal. ka (as outlined by B&H 2021). From ~14–8.6 cal ka, the plateau length dropped to several hundred years (our Fig. 3 and Sarnthein & Werner, 2018). Later on, Holocene plateaus rarely exceeded >250 yr, except for a single case near 2.5 cal ka ("Hallstatt" plateau).
- The potential origin of the variable length of ^{14}C plateau structures was broadly discussed by Sarnthein et al. (2020) in the context of changes in oceanography and the global carbon cycle, that were more prominent prior to 14 cal. ka than during the Holocene.

Updating of hypothesized ^{14}C -age plateaus

p.4, §4. B&H found parts of Fig. 1 incompatible with data listed in Table 1.

Indeed, the base level of plateau 7 in Fig. 1 had unfortunately suffered from a plotting error and had to be lifted from 480 to 494‰ $D^{14}\text{C}$. Thanks to the advice of B&H the compatibility of plateau 7 has now gained a lot. Conversely, Table 1 rightly puts the end of plateau 10a to 25.96 cal. ka as plotted in Fig. 1, consistent with the record of the Bayesian spline, different from an age of 25.65 cal. ka suggested by B&H.

p.4, §5 and §6 and p.5, Fig. 2b. B&H claim that the suite of ^{14}C -age plateaus was physically unreasonable, especially, the suite of massive and instantaneous $D^{14}\text{C}$ jumps suggested by means of visual inspection.

Conversely, the overwhelming consistency of trends inferred for the Suigetsu atmospheric ^{14}C record on the basis of three independent evaluation techniques (our Fig. 1) provides strong support in favor of the authenticity of the "rung ladder" of ^{14}C plateau and jump structures over peak glacial to deglacial times.

This authenticity of ^{14}C plateau structures is not impaired by a comparison with the IntCal20 record (B&H, Fig. 2b), where the structures are largely lost for the following reasons:

The IntCal20 record aims for a maximum in robustness of ^{14}C -age calibration being based on averaging, hence smoothing a broad variety of the different terrestrial and marine ^{14}C records employed, many of them presenting an only indirect record of atmospheric D^{14}C where unknown changes in MRA and DCF are ignored. Inversely, the purely atmospheric Suigetsu record is less well resolved, only indirectly dated, and less well age calibrated than IntCal20, but capable to display the primary suite of structures preserved in the raw ^{14}C record, hence less suited for any fine-scale age calibration at estimates <50–100 yr.

Transferral of atmospheric ^{14}C variations to the ocean

p.5, §3. B&H dispute the reproducibility of plateau identification in marine sediments. s

We are pleased to give once more some guidance already published (but ignored by B&H).

The objectivity of identification of a plateau suite is regarded robust as it is supported by (1) the use of the 1st derivative in all ^{14}C records to separate small-scale noise (extending over less than ~ 100 yr) from major long-term shifts (>300 yr) in the ^{14}C -age trend, (2) a strict alignment of the age scale derived by PT with that of independent but paired conventional age tie points of d^{18}O , SST, and other sediment records such as ash layers, (3) a frank discussion of alternative plateau alignments where questionable, (4) a detailed discussion of each PT-based time scale with scales published for neighbor sites in an ocean basin (as being displayed in the primary papers on PT records published).

B&H demur the sparsity of marine ^{14}C records suited for PT because of short-term changes in sedimentation rate and MRA complicating the practice of PT.

This problem is linked to the costly efforts of high-resolution PT for sediment cores with strictly hemipelagic bulk sedimentation rates $>10\text{--}20$ cm/ky as suggested by conventional means of stratigraphy, excluding cores with turbidites. Though surprises in age assignment are found inevitable and only resolved by means of the package of tests listed above.

p.5, last § and p.6, §1. B&H question the ground-truthing of short-term changes of sedimentation rate and hiatuses by independent lines of evidence.

Different from this suspicion hiatuses and other major changes in sedimentation rate were independently confirmed in most PT-dated core sections by means of visual inspection and high-resolution photography of sediment sections and studies of the sediment composition.

Ground-truthing of ^{14}C plateaus is also achieved by (1) plateaus lengths exceeding $>10\text{--}20$ cm, in part >50 cm thick, densely sampled hemipelagic sediment sections, (2) by characteristic internal structures in the suite of atmospheric plateaus 27-10 cal ka clearly reproduced in a sediment section, (3) by a match with conventional stratigraphic tie points such as DO event 1.

p.6, §2. B&H evoke the potential signal alteration by bioturbation and other sediment mixing processes.

A detailed response is given in our recent article under discussion (L.149–160).

p.6, §3–§5. Minor issues in the critique uttered by B&H

p.6, §3. B&H bemoan changes in the plateau assignment of ^{14}C plateaus for four Pacific records, results finally stored under Küssner et al. (2020) in the PANGAEA database.

Such changes between the initial submission of a manuscript and its last state are

common and a legitimate result of scientific discussions amongst different coauthors on the best-possible plateau assignment, the final results of which were included into both the PANGAEA database (2020) and the paper of Küssner et al., 2020 (though unfortunately rejected). Likewise, subsequent comments of coauthors cited by B&H present a legitimate private, though scientifically untested opinion of these authors.

p.6, §4. B&H contest the direct match of marine ¹⁴C records to those of the atmosphere.

MRA and the quality of ¹⁴C signal transfer depend on the time lags between surface ocean (habitat of planktic foraminifers, in particular of near-surface dwellers) and atmosphere, values that depend on regional mixing and lateral advection of surface waters. Only a minor portion of the time lags can be covered by simple box models listed by B&H. In case the time lag between ¹⁴C signals in local surface waters and global atmosphere may be as large as 20 years and more, the objection to PT was hardly relevant, since the error range of PT-based age tie points is far larger (up to 50-100 yr). Grootes & Sarnthein displayed a more extensive reasoning in their contribution of the discussion of the paper of B&H (2021).

p.6, §5. B&H postulate that the benthic ¹⁴C record of South China Sea site GIK17940 should actually resemble the ¹⁴C plateau structures, since the water column has been largely mixed down to 2 km depth.

In part this postulate may indeed be realistic (Fig. S6), far more than B&H may have recognized when inspecting Fig. S6. A perfect plateau structure, however, fails because of the insufficient sampling resolution of benthic ¹⁴C ages and an ocean mixing intensity that still was somewhat erratic over the long time range studied both in terms of intensity and potential changes of ocean water masses admixed.

Summary

By means of their critical remarks B&H provided a great and highly appreciated opportunity to explain in more detail a number of ongoing questions on the reasoning of PT, in our previous explanations perhaps not sufficiently spelled out and/or specified. One may now expect that a number of readers will try to reproduce more easily the solid base of PT and will employ it as a trendsetting tool for their marine paleoclimate studies.

References

*Bard, E. and Heaton, T.J.: On the tuning of plateaus in atmospheric and oceanic ¹⁴C records to derive calendar chronologies of deep-sea cores and records of ¹⁴C marine reservoir age changes. *Climate of the Past*, 17, 1701–1725.*

<https://doi.org/10.5194/cp-17-1701-2021>

*Grootes, P.M. and Sarnthein, M.: Community comment on "On the tuning of plateaus in atmospheric and oceanic C records to derive calendar chronologies of deep-sea cores and records of C marine reservoir age changes" by Edouard Bard and Timothy J. Heaton, *Clim. Past Discuss.*, <https://doi.org/10.5194/cp-2020-164-CC2>, 2021.*

*Küssner, K., Sarnthein, M., Michel, E., Mollenhauer, G., Siani, G., and Tiedemann, R.: Glacial-to-deglacial reservoir ages of surface waters in the southern South Pacific. *PANGAEA*, <https://doi.org/10.1594/PANGAEA.922671>, 2020.*

*Küssner, K., Sarnthein, M., Michel, E., Mollenhauer, G., Siani, G., and Tiedemann, R.: Glacial-to-deglacial reservoir ages of surface waters in the southern South Pacific. *Paleoceanography and Paleoclimate*, 47 ms-pp. (2020, rejected)*

Sarnthein, M. and Grootes, P. M.: Community comment on "On the tuning of plateaus in atmospheric and oceanic C records to derive calendar chronologies of deep-sea cores and records of C marine reservoir age changes" by Edouard Bard and Timothy J. Heaton, *Clim. Past Discuss.*, <https://doi.org/10.5194/cp-2020-164-CC1>, 2021.

Sarnthein, M., Kußner, K., Grootes, P.M., Ausin, B., Eglinton, T., Muglia, J., Muscheler, R., Scholaut, G. Plateaus and jumps in the atmospheric radiocarbon record – Potential origin and value as global age markers for glacial-to-deglacial paleoceanography, a synthesis. *Climate of the Past*, 16, 2547–2571, doi: 10.5194/cp-16-2547-2020, 2020.

Sarnthein, M. and Werner, K.: Early Holocene planktic foraminifers record species specific ¹⁴C reservoir ages in Arctic Gateway, *Marine Micropaleontology*, 135, 45-55.

DOI:10.1016/j.marmicro.2017.07.002, 2018.

Skinner, L.C. & Bard, E.: Radiocarbon as a dating tool in paleoceanography, *Review in Geophysics*, 60, e2020RG000720, doi.org/10.1029/2020RG000720, 2022.