Comparison of visually and mathematically constructed ^{14}C plateaus, based on Suigetsu data and INTCAL20 curve.

Bernhard Weninger, Universität zu Köln, Institute for Prehistoric Archaeology,
Weyertal 125, D-50923 Köln, Germany

This communication is focused on the presently open question whether – or not – the sequence of ^{14}C-plateaus defined by Sarnthein et al., 2020, for the Lake Suigetsu data record can likewise be identified (or not) in the INTCAL20 curve. Despite the extensive critique of the Plateau Tuning (PT) method by Bard and Heaton (2021; B&H) and detailed responses by Sarnthein and Grootes (2021; S&G), Grootes and Sarnthein (2021; G&S), it appears to me that a further open question exists, namely the (seemingly) reasonable claim by Paula Reimer (2021), that the INTCAL20 curve is '*simply too noisy*', whereas Suigetsu is '*without sufficient resolution*' to allow for a *'robust'* identification of plateaus - in either record. If confirmed, this would not necessarily inhibit an application of INTCAL20 for PT, for reasons put forward by S&G and G&S. The 'noise'-argument, however, still presents a number of caveats that persist. In particular, since INTCAL20 incorporates Suigetsu with carbonate based marine and cave records, it appears more 'secure', less 'noisy', but 'smoothed'. As apparently accepted by all participants of this discussion, in consequence the application of PT presently seems to be restricted to the use of a 'plateau master curve' solely based on the Suigetsu record (Sarnthein and Grootes, 2021).

Notwithstanding the validity of many arguments that underly the views of S&G and B&H, by chance the very same question – "*How to define a set of plateaus for a smoothed calibration curve* ?" – has recently been addressed in detail both for the Holocene by myself (Weninger, 2020) and the Last Glacial in a joint paper (Weninger and Edinborough, 2020; W&E). In brief, we developed a mathematical method for an automated derivation of the requested 'calibration-curve' plateaus. The method is based (in a sense) on amplifying the otherwise difficult to recognise shape-properties of INTCAL20-curve, whereby the curve-shape analysis is replaced by amplitude-analysis of an equivalent summed probability distribution (SPD) of calibrated ^{14}C-ages. In technical terms, based on INTCAL20 for the period 9-25 ka cal BP, a dataset with 9500 evenly distributed Gaussian ^{14}C-ages is derived, each assigned a standard deviation σ = 50 BP. The Gaussian ^{14}C-ages are summed on the ^{14}C-scale, and the resulting ^{14}C-histogram is back-calibrated from the ^{14}C-domain to the calendar time scale. The resulting SPD has widely varying amplitude. It shows a characteristic sequence of peaks and troughs, the dating and amplitude of which are a strong function both of the curve slope and of its 'wiggles'. The peak values are scaled to a maximum 'probability' p(rel) = 100 %. This maximum height is reached for plateaus 'YD' and '1' labelled by Sarnthein et al. (2020). Finally, the requested plateau boundaries are derived by a crucial gauge method. In mathematical terms, both the SPD-construction and the gauge method are related to a description of ^{14}C-calibration as Fourier Transform. The approach leads to corresponding concepts of ^{14}C-dating probability, that are derived from Quantum Theory. To avoid misunderstandings, the SPD method must not be regarded as a Fourier Transformation. (The method does *no*t redraw the calibration curve as sum of sines and cosines, but as sum of transformed Gaussians. An optical analogy is laser amplification). In a nut-shell, SPD-shape and assigned rectangular plateaus represent the same entity from the perspective of Quantum theory. Suffice to say, the approach of using a SPD record as proxy for the INTCAL20 curve shape is a non-Bayesian probability definition.

For the present discussion it may be of particular interest that a simple close-up view of the shape of the INTCAL20 calibration curve *per se* does not allow any recognition of the inborn plateau structure. The plateaus, however, exist indeed, are strong, and are easily *made visible* by means of the SPD-peaks, as detailed in W&E.

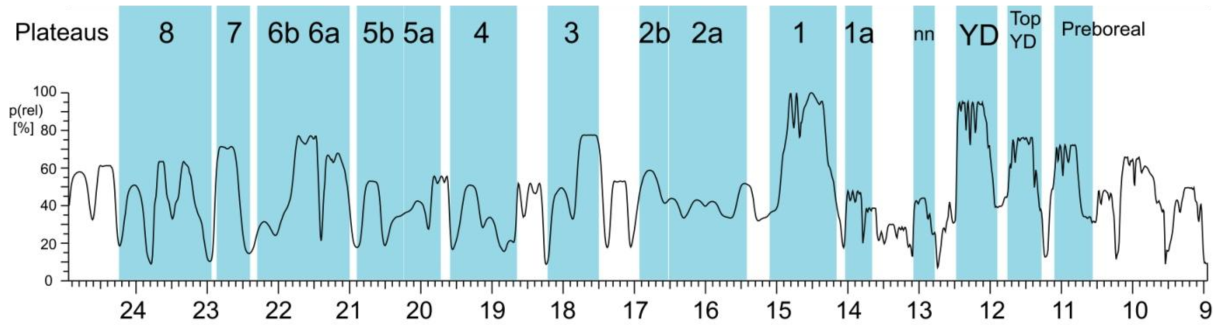

Fig. 1. Shape of INTCAL20 record compared to plateau boundary ages based on Suigetsu data.

SUIGETSU: Plateau names and blue-shaded areas, according to Sarnthein and Grootes (2020: Tab.1)
Method: visual inspection of Suigetsu data.
INTCAL20: Summed Calibrated Probability Distribution (SPD) of 9500 model Gaussian ^{14}C-ages (identical σ=50 BP).
Method: In descriptive terms, the input uniform sample sequence is folded by INTCAL20 to produce a characteristic sequence of peaks and troughs. The SPD-peaks represent the flat regions of the calibration curve.The troughs represent the steep regions. In mathematical terms, the SPD is a Fourier Transform of INTCAL20 (W&E).

As illustrated in Fig. 1, the SPD peaks clearly serve as proxy for plateaus potentially existing in the INTCAL20 record. Of course the plateaus could also be - *qua method* - wrongly established in both records. But the method is promising. Many SPD-peaks are entirely consistent with the independently established plateaus of Sarnthein et al., (2020) (blue shades). With increasing cal. age, these are the peaks/plateaus named Preboreal, TopYD, YD, nn, 1a, 1, 7, and 8 (lump of three peaks). Other plateaus (6b, 6a, 5b, 5a, 4, 3, 2a and 2b) certainly only show (what archaeologists might term) 'restricted similarities', although with interesting deviations. Beyond the question at which ages the two methods lead to *'well-fitting' or 'not well-fitting'* plateaus, it is of further interest that plateaus may exist at ages previously unrecognised (e.g. ~17.2 ka, ~19.7 ka cal BP). In different words, we now have the chance not only to differentiate between 'plateaus' and 'noise', but may further refine the existing plateau definitions. We can furthermore learn how to quantify (from the new perspective of SPD) some possibly underlying physical and oceanographic variables that have controlled the origin of plateaus, perhaps in combination with further studies towards the newly developed concepts of probability theory that are derived from Quantum physics.

Conclusion

Given the overall good agreement between the visually-defined Suigetsu plateau-sequence and the mathematically-derived INTCAL20-based plateau-sequence (Fig. 1), the critique on the PT-method by B&H may appear unnecessarily restrictive, especially when seen in relation to actually promising further PT-research, now underway.

References

Bard, E. and Heaton, T. J.: On the tuning of plateaus in atmospheric and oceanic ^{14}C records to derive calendar chronologies of deep-sea cores and records of ^{14}C marine reservoir age changes, Clim. Past Discuss. [preprint], https://doi.org/10.5194/cp-2020-164, in review, 2021.

Grootes, P.M. and Sarnthein, M., 2021. Comments on Eduard Bard and Timothy J. Heaton (B&H). Climate of the Past. Discussions, submitted 17 Feb 2021.

Reimer, P. J., Austin, W. E. N., Bard, E., et al.: The INTCAL20 northern hemisphere radiocarbon calibration curve (0–55 cal kBP), Radiocarbon, 62, 725–757, https://doi.org/10.1017/RDC.2020.41, 2020.

Michael Sarnthein, Kevin Küssner, Pieter M. Grootes, Blanca Ausin, Timothy Eglinton, Juan Muglia, Raimund Muscheler, and Gordon Schlolaut: Plateaus and jumps in the atmospheric radiocarbon record – potential origin and value as global age markers for glacial-to-deglacial paleoceanography, a synthesis. Clim. Past, 16, 2547–2571, https://doi.org/10.5194/cp-16-2547-2020, 2020a.

Michael Sarnthein and Pieter M. Grootes., 2021. Response to the Preprint of E.Bard and T.J.Heaton (B&H), Climate of the Past. Discussions, submitted 16 Feb 2021

Weninger, Bernhard. 2020. Barcode seriation and concepts of Gauge Theory. The ^{14}C-Chronology of Starčevo, LBK, and early Vinča. Quaternary International Volumes 560–561, 20 September 2020, Pages 20-37. https://doi.org/10.1016/j.quaint.2020.04.031

Weninger, Bernhard. and Edinborough, Kevan. Bayesian ^{14}C-rationality, Heisenberg Uncertainty, and Fourier Transform**.** Documenta Praehistorica 47:536-559, 2020.