Climate of the Past Discussions

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Comment on cp-2020-164

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Community comment on "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" by Edouard Bard and Timothy J. Heaton, Clim. Past Discuss., https://doi.org/10.5194/cp-2020-164-CC2, 2021

Comments on

Edouard Bard and Timothy J. Heaton (B&H)

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.

Climate of the Past. Discussions

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In the fall 2019, Edouard Bard and Tim Heaton (B&H) got access to the discussion version (opened in CPD at 25-10-2019) of our paper "Plateaus and jumps in the atmospheric radiocarbon record – Potential origin and value as global age markers for glacial-to-deglacial paleoceanography, a synthesis" (Sarnthein et al., Clim. Past 16, 2020 (SA2020)). A letter to the Editor of CPD on 31-01-2020 stated they had written an extended comment to the paper but had submitted it as a research paper since it "*includes substantial material of broad interest to the community using radiocarbon in marine sediments for geochronology and paleoceanography*". This comment is now subject of our discussion. Its aim is to demonstrate that Plateau Tuning (PT) is fraught with problems and should not be used.

We thank B&H for the time and efforts they spent formulating the problems they see with the technique of ^{14}C plateau tuning. Their detailed arguments and reasoning extend far down to basic processes that may control an atmospheric and sedimentary ^{14}C record and thereby provide a base for a factual discussion of PT. Both basics and details are important when evaluating potential major-to-minor pitfalls of PT but can rarely be discussed at meetings or workshops (B&H *lines 65-69*). As stated in their letter the paper 'includes substantial material of broad interest' and many of their potential pitfalls are worth considering. Our response may help to clear various misconceptions and further explain crucial aspects of the PT method. This is important since all of us aim to find the best-possible techniques to generate proper age control of ocean sediment records and to

make an optimum use of the wealth of environmental information they contain. Below we summarize two points where B&H misconstrued PT and we advocate a different conclusion from their Fig. 3 , 5, and 6. Then we address their specific chapters and text.

Summary

Many of the 17 objections raised by B&H are based on two simple points:

- *The difficulty of reliably identifying a single ^{14}C-concentration plateau in a noisy ^{14}C sediment record and then finding its correct partner in the noisy record of atmospheric ^{14}C concentrations*

This is the subject of eight objections (2.1; 2.2; 2.5; 2.6; 3.3; 3.4 straight and part of 2.3 and 3.1).

These objections are based on *lines 40-41*, the first lines of the B&H Introduction: In line 40 the term *'a suite of'* is missing between '*tuning'*and *'hypothesized'* and in line 41 *'those that'* should be replaced by '*a suite of plateaus'*.

The problem of how to identify a plateau has been extensively considered in the development of PT. Sarnthein et al., 2007 clearly mention they '*identified a reference suite of prominent atmospheric ^{14}C "plateaus"* ', based at the time on Cariaco ODP 1002 and on U/Th dated corals and Bahama speleothem, and the identification of *'analogous series of ^{14}C plateaus in several other marine sediment cores …'*. This emphasis on suites of plateaus and suites of tie-points has been part of every PT paper including SA 2020, discussed by B&H. As B&H point out: Identifying a single plateau is very hard. Further details on meeting this set of questions are given in the companion response text of Sarnthein & Grootes (S&G).

- *The focus on ^{14}C concentration changes in the surface ocean (pla = planktic ^{14}C concentration) instead of on marine reservoir age (MRA = pla- Atm, where Atm is the contemporaneous atmospheric ^{14}C concentration).*

This leads to objections 2.3; 2.7; 2.8; 3.1 and 3.2 that basically repeats 2.3.

In a simple carbon cycle box-model (e.g. Siegenthaler et al., 1980) with a deep ocean that contains about 60 times more carbon and 50 times more radiocarbon than the atmosphere, most of the variability in ^{14}C concentration will be in the atmosphere and in its closely-connected thin ocean-atmosphere exchange layer. The focus of B&H on the surface ocean is logical, because it is easily accessible and its plankton provides our paleoenvironmental record, but MRA is the difference in ^{14}C concentration between atmosphere and surface ocean (*pla-Atm*). B&H use the Bard et al., 1997, 12-box model to calculate an attenuated and somewhat delayed response of the surface ocean to, especially rapid, atmospheric ^{14}C changes. This leads them to reject the PT derived MRA changes as "too large, too frequent, too abrupt". Their modelling addresses, however, only one facet of MRA, and a strongly attenuated *pla* signal will generate an MRA (= *pla-Atm*) signal with little attenuation. This is borne out by the effects on MRA of the ^{14}C bomb spike and Miyake events mentioned in their text. A box model, moreover, does not consider local variations in near-surface ocean mixing and ocean-atmosphere exchange, that can lead locally to large and rapid changes in *pla* and thus MRA for an unchanged atmosphere.

Fig. 3a shows the translation of the PT suite of plateaus, defined by SA2020, in the ^{14}C-age/ calendar-age domain, into the $\Delta^{14}C$/calendar age domain and compares the

translated plateau step curve with the Bayesian-spline generated Suigetsu atmospheric record. The statistically sound zig-zags of the Bayesian Suigetsu curve reveal a generally satisfactory agreement with the (green) plateaus (sections of (faster) decreasing $\Delta^{14}C$ vs. decreasing cal. age) and jumps (sections of slower decrease or increase), despite the fact that the plateaus defined by Sarnthein et al. (2015 and 2020) were based on the 2012 Suigetsu data and did not consider the most recent age corrections of Bronk Ramsey et al., (2020). The zig-zag curve does not pin the plateau slope to zero and offers another look at the position of inflection points, so far defined by the beginning and end of zero-slope plateaus. This will be further explored for PT.

The modelling exercise of 3.6 and 3.7 demonstrates how the statistical scatter of sampling and imperfect measurements may distort and mask underlying real signals. Yet, contrary to the stated conclusion, it offers hope in showing that at least two out of the three 'plateau' features of the underlying short record can indeed be found in the modelled examples. It also makes a clear point that such identification of the 'true' fine structure of a ^{14}C record is a serious research project requiring consideration of a broad range of conventional age tie points and oceanographic information and a long sequence of plateaus in order to produce reliable results. And, even then, it still needs to be checked against other independent records.