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Interactive Comment

Interactive comment on "Revisiting the absolute calibration of the Greenland ice-core age-scales" *by* L. Skinner

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Lucas Skinner on Revisiting the absolute calibration of the Greenland ice-core age-scales

The author is perfectly right with his statements about the ultimate importance of precise chronology in most fields of paleoclimatology and paleoceanography. In particular, we need precise ages for a proper understanding of the processes controlling climate change, which frequently can be only deduced from proper phase relationships. We all fully endorse that 8220;the worst error we can make is to entrench and generalise a precise stratigraphical relationship on the basis of erroneous age assignments8220;.

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Interactive Discussion

Discussion Paper

To shortly inform the outside reader not permanently involved with the various age scales here discussed, we have to deal in this discussion of paleoceanographic ages with four different groups of age-scales. (1) The absolute (i.e., calendar, astronomňical) age-scale is deduced from tree ring counts back to 14 200 years and from annual-layer counts in Greenland ice cores for the interval back to 60 000 years B.P. (Svensson et al., 2008), now scrutinized in L. Skinner8217;s article. (2) Past atmospheric radiocarbon (14C) ages as measured from wood chunks are not equal to 14C ages deduced from a radiocarbon half life, but deviate from modern atmospheric 14C by irregular changes in 916;14C. (3) 8220;Raw8220;, uncorrected marine 14C dates of surface water are measured on corals and planktic foraminifera. (4) The difference between atmospheric 14C ages and coeval 14C ages of surface water is referred to as 14C reservoir age. Pre-bomb 14C ages of modern surface waters show a global average of 400 years and vary between 250 and almost 1300 years to the south of New Zealand (Stuiver and Braziunas, 1993). Reservoir ages are a complex result of different factors such as ocean-atmosphere gas exchange, the time past since a last thourough mixing of surface waters with atmospheric CO2 (for intermediate and deep waters), the admixture of upwelled old deep and intermediate waters to the surface ocean, and the sealing of a sea surface by sea ice.

The highly interesting and well composed paper of L. Skinner, obviously a sceptics of the quality of annual layer counting in ice cores, is mainly concerned with potential inconsistencies in the absolute age scale recently deduced with great care and clear definition of uncertainties for Greenland Ice Core Chronology 2005 (IGCC05; Svensson et al., 2006, 2008). Instead, he promotes an ice core chronology published by Shackleton et al. (2004) (8220;SFCP048220;), which is based on a bundle of correlations of millennial-scale climate signals in Iberian Margin sediment cores to coeval signals in Greenland ice cores and to U/Th-based age control points. In particular, Skinner is not prepared to accept the large temporal and spatial variability of 14C reservoir ages of surface waters along the Iberian Margin, which results from adopting GICC05 as age scale for the paleoceanographic records from the Iberian Margin.

CPD

4, S370–S375, 2008

However, I see various serious pitfalls in the reasoning of Skinner8217;s paper.

(1) Indeed, there are six different ice core-based chronologies that compete. Howňever, only three of them are actually based on careful annual-layer counting, GICC05, the chronology of ice core GISP2 (Meese et al., 1997; with an estimated error of 2

(2) The age-scale SFCP04 favoured by Skinner is based on a correlation of joint millennial-scale climate signals in four Iberian margin cores with the paleoclimatic dataset of the Cariaco Basin (Hughen et al., 2006), which is linked to the Hulu speleothem uranium-series age-scale (Wang, Y.C. et al., 2004), named 8220;Huli-aco8220; chronostratigraphy. Also, SFCP04 is compared with numerous paired U/Th and 14C dates of corals (Fairbanks et al., 2005). However, a closer inspection of the alignment of climate signals from the Iberian Margin to those from the 8220;Huli-aco8220; climate record (Fig. 3 in Skinner, 2008) reveals different qualities of signal match. Most climate oscillations match from 17-27/29 ka (except for a 600-year deviation near 24 ka) and from 37.5-50 ka. However, the fit is more laborious from 27-37.5 ka, here leading to a high uncertainty in the SFCP04 age-scale of 14C dates from Iberian margin cores, reaching 500-1000 years, unmentioned by Skinner.

The GICC05 and SFCP04 age-scales and the coral-based 14C ages partially result in 916;14C differences that exceed 2008240; equal to >2000 years, which Skinner (2008; Fig. 2; with a GRIP age-scale version unfortunately unspecified) invoked as evidence for inconsistencies in the GICC05 chronology. Nevertheless, these differences neither accumulate (as result of an increasing number of possibly lost annual layers) nor occur uniformly over the last 50 ka. The 916;14C values of all three chronologies show a close match back to 26 ka. The interval from 26-29 ka cannot be used for comparňison, because it is not covered by ice core ages from both chronologies, likewise the intervals at 31-32.5 ka and 36-38 ka. From 38 ka back to 50 ka, 916;14C values for GICC05 and SFCP04 again match closely, whereas the coral-based chronology strongly deviates from both age-scales toward younger atmospheric 14C ages and thus may present the actual problem. Skinner8217;s statement (p. 796) about 8220;very good agreement with available radiocarbon calibration datasets, including both the coral datasets of Bard et al. (1998) and Fairbanks et al. (2005)8221; is thus incorrect, at least for part of the time. Furthermore, an agreement between corals and Cariaco implies the assumption of a constant reservoir age, made for both age-scales. If this is incorrect, but variations are roughly similar for both, it won180;t affect their difference. In summary, the apparent discrepancies between GICC05- and SFCP04-based 916;14C values at 26-38 ka appear little substantiated, if not neglectible in view of both the outlined troubleňsome correlation of the SFCP04 and Cariaco records, the lack of coeval age control points over large parts of the interval under discussion, and the ignored potential independent variations of local reservoir ages.

(3) Skinner (2008; Fig. 3) sees a major problem in employing the GICC05 age-scale to the stratigraphy of Iberian Margin cores, because GICC05 ages result in reservoir ages of 800-1700 years prior to 22 ka, thus implying extremely radiocarbon-depleted surface waters at mid-latitudes during last glacial times. However, the proviso of Skinner that glacial reservoir ages ages on the Iberian Margin have little deviated from an average of 830 years (in contrast to individual values varying between 200 and 1500 years; Fig. 3) appears little substantiated, such as the proviso of Shackleton et al. (2004) that glacial reservoir have remained constant near to 500 years. Skinner does not consider the possibility of truly variable reservoir ages, ignores any fine structure in the record, and tries to match something highly variable to an almost arbitrary constant value.

On the other hand, high reservoir ages of 800-1700 years match perfectly results which were recently deduced from an approach named 14C plateau tuning (Sarnthein et al., 2007), an approach is likewise using the 8220;Huliaco8220; age-scale. Yet, these results imply a large-scale spatial and temporal variability of reservoir ages of surface waters over glacial Termination IA. For example, reservoir ages of 2200-2500 years were found for sea ice-sealed surface waters of the Icelandic Sea during peak glacial times and Heinrich 1. Moreover, Waelbroeck et al. (2001) concluded on reservoir ages of 1200-1900 for the central North Atlantic to the west of the Azores. Finally, the

Iberian Margin is well known for abundant upwelling of oldish interňmediate waters, which necessarily induce a major 14C depletion of surface waters. Since upwelling intensity has increased during glacial times (Abrantes et al., many papers, e.g., 2002), reservoir ages have increased accordingly.

In summary, we may feel relaxed and accept for good reasons the GICC05 chronology as best age-scale presently available, because it reproduces closely two age-scales counted independently in ice cores GISP2 and GRIP (Hammer, 1997) for the last 42 ka. In addition, we need to accept that 14C reservoir ages of surface waters have been subject to substantial (small-scale) spatial and temporal changes, with local maximum values near 2500 years. Accordingly we find that 14C chronologies obtained from a single small-scale ocean region such as the Iberian Margin may be biased by dominant local ocean processes such as the upwelling of oldish intermediate waters and thus cannot be generalized. Finally, we need to define for marine sediment records of the last 60 ka a number of age control points independent of 14C dating with an uncertainty of 300 years and better, such as GICC05 chronology has recently tried to constrain the Mono Lake and Laschamp geomagnetic events. However, their present age uncertainty still requires further reduction.

P.S.: The remark of disappearing layers in an ice core (p. 799, l. 18,19) is incorrect. If the layer did exist in the firn (erosion may remove surface deposition, if average accumulation is low), then the isotopes and gases may diffuse so their annual signal disappears, but dust and, generally, chemistry will stay in place.

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CPD

4, S370–S375, 2008

Interactive Comment

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CPD

4, S370–S375, 2008

Interactive Comment