GEOCHRONOMETRIA Vol. 25, pp 1-4, 2006 – *Journal on Methods and Applications of Absolute Chronology*

THE EFFECT OF PDF PEAKS' HEIGHT INCREASE DURING CALIBRATION OF RADIOCARBON DATE SETS

ADAM MICHCZYŃSKI and DANUTA J. MICHCZYŃSKA

Department of Radioisotopes, Institute of Physics,
Silesian University of Technology, Krzywoustego 2, 44-100 Gliwice
(e-mail: Adam.Michczynski@polsl.pl)

Key words:
RADIOCARBON,
CALIBRATION, LARGE
SET OF RADIOCARBON
DATES

Abstract: Large sets of dates are often used to construct frequency distributions to investigate variability of some events, which can follow an environmental change (eg. crystallization of speleothems depends on climatic conditions). Examples of such distributions are probability density functions (PDF) created for radiocarbon dates. In order to reach reliable conclusions concerning environmental changes, we should know how to interpret these distributions. In this study, the authors discuss the problem of a possible correlation between the presence of some high, narrow peaks in the probability density function and the shape of the calibration curve.

1. INTRODUCTION

The problem of using large sets of radiocarbon dates in environmental studies was discussed in 2003 by Michczyńska. A statistical analysis of large set of radiocarbon dates for reconstruction of paleoclimate was reported by Michczyńska and Pazdur (2004). In that paper, the authors assumed that the random character of dates is preserved in the case of large set of ^{14}C dates (large territory, different investigators interested in various scientific disciplines collecting samples). The authors constructed a Probability Density Function (PDF) by summing the probability distributions of individual ^{14}C dates after the calibration. However the shape of the constructed PDF was unexpected, because there were present high, narrow peaks (see **Fig. 1**, the lower graph). Essential changes in the shape of PDFs were expected at those time periods, where changes in the environment were important, but the appearance of such narrow peaks seemed strange. The coincidence of the localisation of high, narrow peaks of the PDF with the localisation of the border of the Holocene subdivision (Starkel, 1999; Pazdur, 2004) suggested that the presence of the mentioned peaks might be a result of the methodology of sampling. According to paper Michczyńska and Pazdur (2004): "Samples for ^{14}C dating are frequently collected only from selected horizons that are of special interest from the point of view of the investigator. Because of economic reasons only limited number of organic layers can be dated. The general rule of taking samples from places of visible sedimentation changes (e.g. from the top and bottom of the peat layer) may be the reason why samples from the border of the Holocene subdivisions are collected more frequently"

2. METHODS

In this study we would like to look carefully at the problem of the shape of PDF once more. We compared the shape of the PDF for 785 ^{14}C dates of peat samples and the shape of calibration curve. We noticed that some of the peaks of the PDF (the high, narrow ones) are corre-

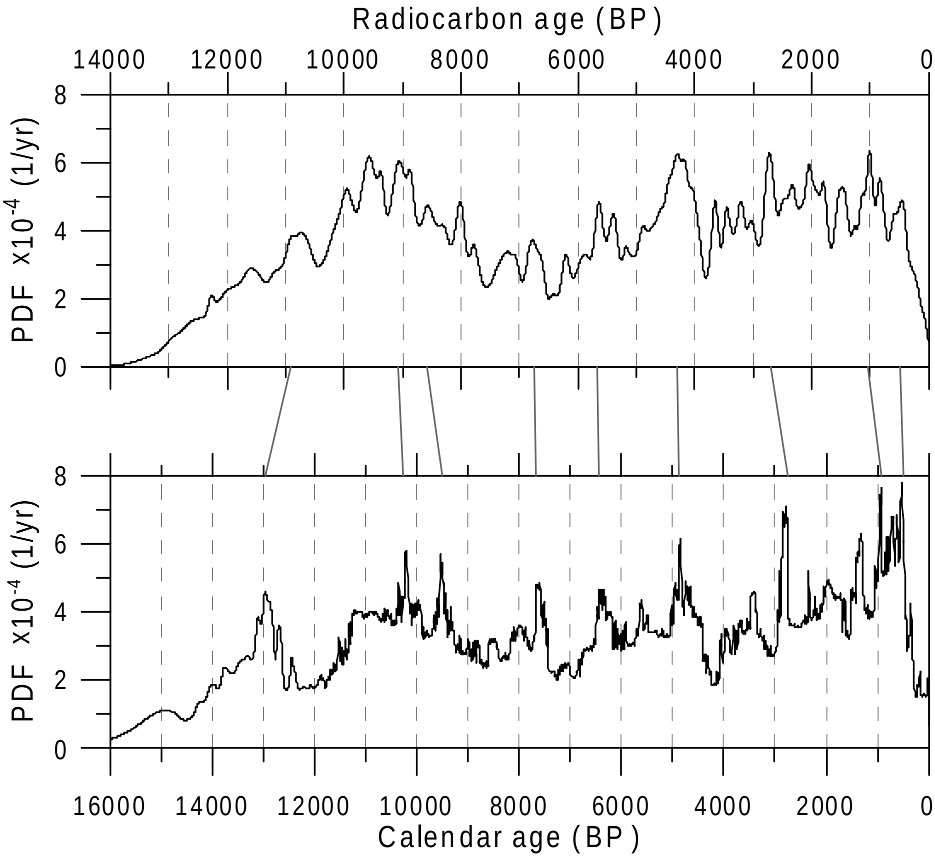

***Fig.1.** Comparison of the shapes of PDFs constructed for real 785 dates of peat samples. All peat samples come from the territory of Poland and were dated in Gliwice Radiocarbon Laboratory.*
The upper graph presents PDF constructed by summing up gaussian distributions of individual ^{14}C dates.
The lower graph also presents the PDF for the same 785 dates, but in calendar time scale. To construct this PDF, all radiocarbon dates were calibrated and the obtained individual distributions were summarised.
This PDF curve has characteristic high, narrow peaks.
The oblique strokes between the calendar and radiocarbon age axes show what radiocarbon age corresponds to the calendar age for chosen age values (where high, narrow peaks of PDF are present).

lated with the steep slope sections of the calibration curve (cf. **Fig. 2**). Moreover, such peaks do not occur in PDFs constructed for uncalibrated radiocarbon dates (cf. **Fig. 1**, upper graph) and for dates uniformly distributed on calendar time scale. This suggests that the reason for the formation of narrow peaks may be also the shape of the calibration curve. In other words, the reason of large height of some peaks in the PDF's may be the result of amplification by the calibration curve.

In order to determine the influence of the calibration curve on the shape of the PDF we conducted the following Monte Carlo experiment:

– A set of 785 calendar dates were created using random number generator. The dates were uniformly distributed on the calendar time scale in the time range 0-16 kyr BP.
– The radiocarbon date was found for each calendar date.
– We assumed that each radiocarbon date has got the same uncertainty 115 yr, equal to the mean uncertainty in the set of real 785 dates.
– The radiocarbon dates were calibrated using the calibration curve INTCAL 98 (Stuiver *et al.,* 1998) and the probability density distributions were summed in order to construct the PDF in calendar time scale. We used an updated version of the Gliwice Radiocarbon Laboratory Calibration Programme GdCALIB (Pazdur and Michczyńska, 1989; Michczyńska *et al.,* 1990). The method of constructing a PDF on the calendar timescale in our program is the same as in OxCal (Bronk Ramsey, 1995).

The results are presented in **Fig. 3** by the black line. It is evident, that we do not observe any narrow peaks characteristic for PDF of the 785 real dates (compare **Fig. 2** and **Fig. 3**).

Therefore, the peaks are not only a result of the shape of the calibration curve. They are produced by the methodology of sampling (additional samples collected from selected periods), and the calibration curve amplifies this effect and increases the height of the peaks in the PDF. We tested this hypothesis using the following simulation:

– We removed from the set of 785 random calendar dates 8 dates (1% of the set) and replaced them by 8 dates from a selected time period.
– The radiocarbon date was found for each calendar date.
– The radiocarbon dates were calibrated and probability density distributions were summed in order to construct the PDF in calendar time scale.

We carried out the above simulation twice: the first time using the time period 2750 - 2800 cal BP, where the calibration curve displays a steep slope and we observe a high, narrow peak in the PDF for the 785 real dates; and the second time using the time period 2950 - 3000 cal BP, where the calibration curve does not display a steep slope. The results are presented in **Fig. 3a** by the grey line (8 dates from the time period 2750 - 2800 cal BP) and **Fig. 3b** grey line (8 dates from the time period 2950 - 3000 cal BP). The results confirm our hypothesis: additional 8 dates for the time period, where the inclination of the calibration curve is steep, gave high, narrow peaks similar to those in the

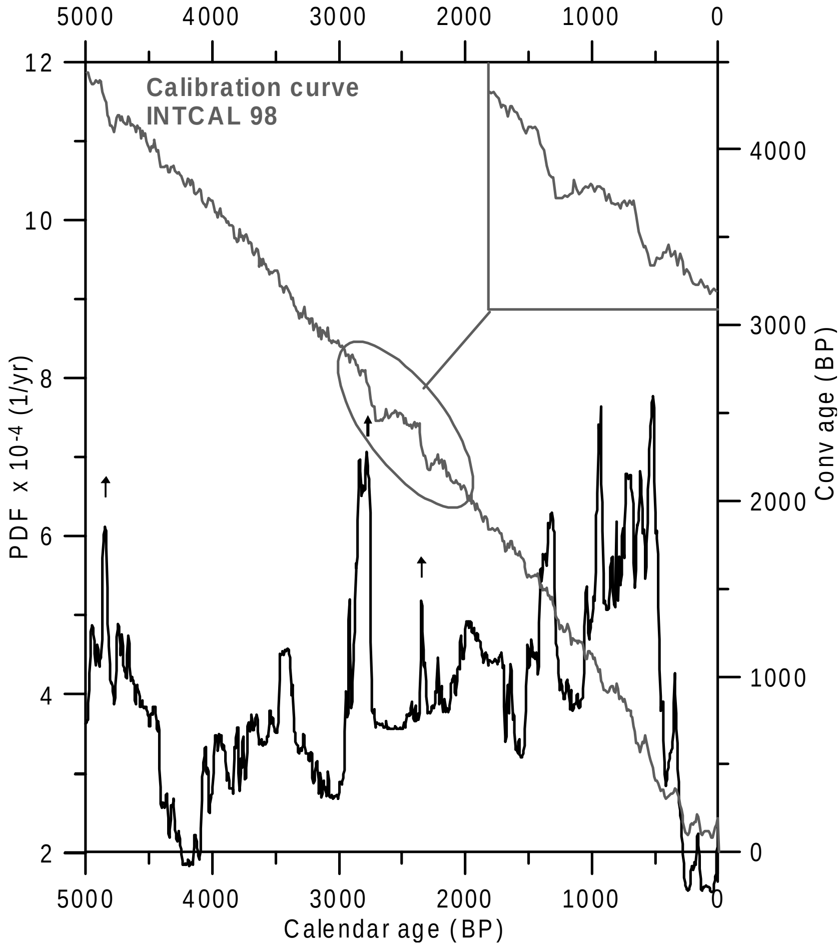

Fig.2. *The coincidence of narrow peaks in the PDF and the steep slope sections of the calibration curve suggests, that the presence of these peaks may be a result not only of the methodology of sampling, but also of the shape of the calibration curve.*

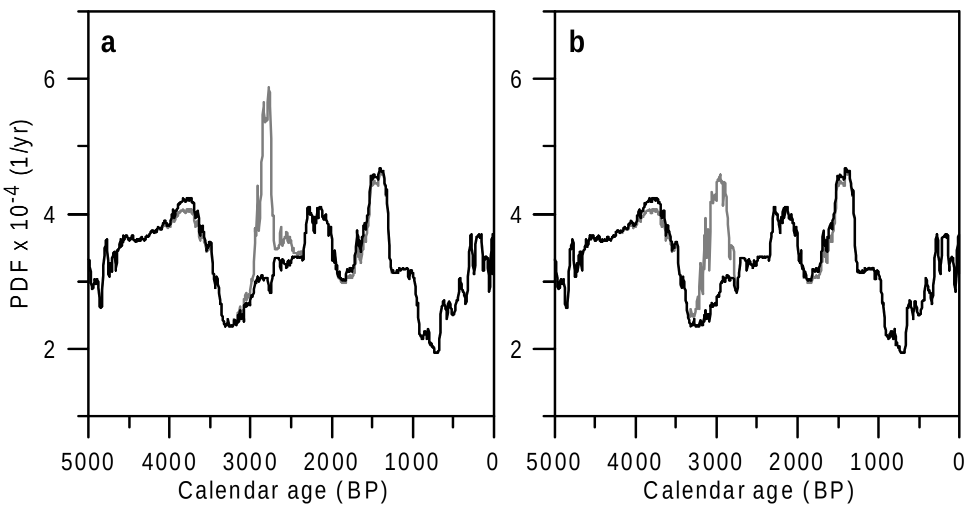

Fig.3. *Part (0-5000 cal yr BP) of the Probability Density Function (PDF) constructed for 785 randomly generated calendar dates is presented as the black line.*
a. *Replacing of 8 random dates by 8 dates from the time range 2750-2800 (section of steep slope of the calibration curve) results in a rapid increase of the value of PDF - grey line. The shape of the generated peak is very similar to that of the peak in the real PDF (cf.* ***Fig. 1.****, lower part).*
b. *Replacing of 8 random dates by 8 dates from time range 2950-3000 does not result in such rapid increase of the value of PDF - grey line.*

PDF of the 785 real dates (cf. **Fig. 3** and the lower part of **Fig. 2**), whereas the peak produced by 8 dates for the time period with a small inclination of the calibration curve is distinctly lower. **Figs 4a** and **b** show the probability density function constructed using the same sets of dates as **Figs 3a** and **b**, but using uncalibrated radiocarbon dates. The effect of the peaks' height increase does not occur here and both peaks (for the time period 2750 - 2800 cal BP and 2950-3000 cal BP) have a similar height.

3. CONCLUSIONS

The results of the experiments confirm our hypothesis. Additional 8 dates in the time period, where the inclination of the calibration curve is steep, gave a high, narrow peak similar to that in the PDF of 785 real dates (see **Fig. 3** and **2**), whereas the peak produced by 8 dates in the time period with a small inclination of the calibration curve is distinctly lower. **Fig. 4** shows the PDF con-

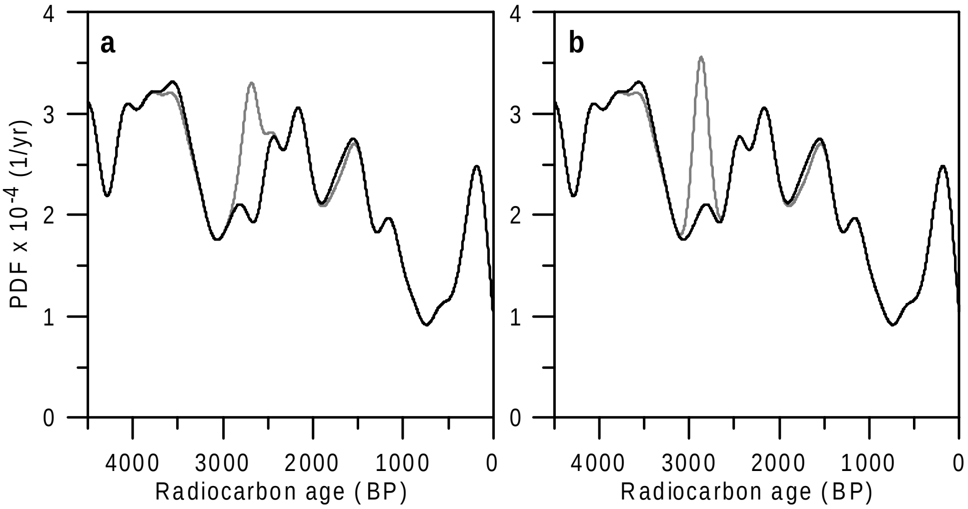

Fig 4a *and* ***b.*** *The same as* ***Figs 3a*** *and* ***b****, but for radiocarbon time scale. The effect of peaks' height increase does not occur here and both peaks (for the time period 2750-2800 cal BP and 2950-3000 cal BP) have a similar height.*

structed using the same sets of dates as **Fig. 3**, but using uncalibrated radiocarbon dates. The effect of peaks' height increase does not occur here and both peaks (for the time period 2750 - 2800 cal BP and 2950 - 3000 cal BP) have a similar height.

The shape of the calibration curve influences the shape of PDFs to a considerable degree.

The high, narrow peaks of the PDFs are produced both by preferential sampling and through the influence of the calibration curve shape. The steep slope sections of the calibration curve work as an amplifier and increase the height of the PDF.

ACKNOWLEDGEMENTS

This study was carried out within project CD-3/RMF-1/2003 (EVK2-CT-2002-80008) and BW/RMF-1/2006.

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