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ANOMALOUS 11-YEAR $\Delta^{14}C$ CYCLE AT HIGH LATITUDES?

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ABSTRACT. We find no evidence for an anomalously intense 11-yr cycle in $\Delta^{14}C$ at high latitudes during the period, AD 1870–1885, as reported by Fan *et al.* (1983, 1986). However, there does appear to be a regional effect within the MacKenzie River region (67°N, 130°W), with atmospheric ^{14}C depressed by 2.6 ± 0.9 ($\bar{\sigma}$) ‰ relative to the Olympic Peninsula. Such an effect would require only 5% of CO_2 in the air mass to have been derived from 5% ^{14}C-depleted soil gas CO_2. This small but apparently significant regional effect could be caused by accumulation of CO_2 within the frozen earth followed by outgassing during the spring thaw. The short growing season would enhance the effect by allowing insufficient time for global atmospheric equilibration.

INTRODUCTION

Fan *et al.* (1983, 1986) reported $\Delta^{14}C$ measurements on tree rings from the MacKenzie Delta, Canada (68°N, 130°W). In order to obtain enough wood, the authors used samples that included 2 and occasionally 3 years of growth. They conclude that their results "exhibit a 10‰ fluctuation with an 11-year periodicity anticorrelated with the solar activity cycle" (Fan *et al.* 1986: 300). This amplitude is much greater than any of the theoretical models predict for a well-mixed atmosphere (*e.g.*, see Damon, Sternberg & Radnell 1983). However, it is possible that the polar continental air mass does not completely equilibrate with other global air masses during the short growing season at high latitudes where ^{14}C production rates are greater than in lower latitudes. Thus, we decided to check the results of Fan *et al.* (1983, 1986).

METHODOLOGY

Dr. Gordon Jacoby of the Lamont-Doherty Geological Observatory made available dendrochronologically dated white spruce wood from the Grand View site, MacKenzie River area of the Northwest Territory of Canada (67°N, 130°W). Thomas Harlan of the University of Arizona Laboratory of Tree-Ring Research separated individual annual rings for the years, AD 1870–1885. We chose those years because the data of Fan *et al.* (1983, 1986) show the greatest variation during that period.

Wood from the individual years was converted to cellulose by the technique described by Linick *et al.* (1986b). After burning the cellulose to obtain purified CO_2 gas, we converted it to graphite by the catalytic reaction described by Slota *et al.* (1987). The milligram-size graphite sample was then pressed at high pressure into a cup within an aluminum "target" holder and inserted into a ten-position ion source carousel. The carousel typically contains 2 standards (NBS oxalic acid I and II), 1 background sample and 7 sample targets. We then proceeded with tandem accelerator mass spectrometer (AMS) analysis, after mounting the carousel and pumping down to below 10^{-6} torr, as described in detail by Linick *et al.* (1986a).

The analysis provides the measured ratio, $^{14}C/^{13}C$, for the samples and standards. The ratios are appropriately corrected for isotopic fractionation, and the ratio of the standards are calculated to AD 1950 (see Donahue, Linick & Jull 1990 for details). From the corrected ratios, a fraction modern is obtained, defined as

$$F = \frac{(^{14}C/^{13}C)_{sample}}{(^{14}C/^{13}C)_{STD}} \quad . \tag{1}$$

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The quantity, F, is then used in Equation 2

$$\Delta^{14}C = [Fe^{\lambda(1950-t_{cal})}-1)\ 1000. \tag{2}$$

Calculations of $\Delta^{14}C$ are based on the 5730-year half-life ($\lambda = \frac{1}{8270}$ yr^{-1}), and time is measured in calendar years.

Results

The results are given in Table 1, and plotted along with the data of Fan *et al.* (1983, 1986) and Stuiver and Quay (1981) in Figure 1. Our result at 1870 is clearly anomalous. Four targets were measured at different times over a period of about 14 months. There is no significant difference in the measurements during that time, and we have no reason to doubt the result (Table 2). We have arranged to obtain more wood to repeat the 1870 measurements and obtain measurements for the previous decade. Our other results, in per mil units, average −7.0 ± 0.7 ($\bar{\sigma}$), with any signal masked by the measurement error. The same is true for the data of Fan *et al.* that average −6.8 ± 2.6 ($\bar{\sigma}$). Except for the one datum from 1876, all of their data overlap at 1σ error with our high latitude data, and there is no significant difference between the means of the two results. However, the mean of the Stuiver and Quay Seattle data, −4.4 ± 0.3 ($\bar{\sigma}$) for the period, 1870–1885, is significantly different from our mean at the 95% confidence level. The difference between these two means is 2.6 ± 0.9 ($\bar{\sigma}$).

The question arises whether or not there is any significant variation in $\Delta^{14}C$ for the high-precision $\Delta^{14}C$ data of Stuiver and Quay. We observe that their data are lower, 3.2 ± 0.6 ($\bar{\sigma}$), during the years, 1870–1879, inclusive, than during the following years 1880–1885, inclusive, 5.2 ± 0.6 ($\bar{\sigma}$).

Table 1. Analytical data for cellulose from annual tree rings from the Grand View site, NWT (67°N, 130°W)

Date (AD)	F_m*	Poisson (σ)**	σ(N)†	N	$\Delta^{14}C$‰	$\delta^{13}C$
1870	1.0000	0.0033	0.0022	4	9.7	−22.8
1871	0.9832	0.0030	0.0050	4	−7.4	−22.7‡
1872	0.9865	0.0035	0.0037	3	−4.1	−21.8
1873	0.9824	0.0038	0.0040	3	−8.4	−22.7
1874	0.9823	0.0037	0.0017	3	−8.6	−22.7‡
1875	0.9811	0.0037	0.0023	4	−10.0	−22.7‡
1876	0.9836	0.0033	0.0055	4	−7.6	−23.1
1877	0.9868	0.0037	0.0089	3	−4.4	−22.7‡
1878	0.9836	0.0040	0.0061	4	−7.8	−21.8
1879	0.9840	0.0032	0.0038	4	−7.5	−22.7‡
1880	0.9814	0.0041	0.0023	3	−10.3	−22.7‡
1881	0.9836	0.0054	0.0085	2	−8.2	−23.1
1882	0.9874	0.0032	0.0020	4	−4.4	−22.7‡
1883	0.9810	0.0034	0.0034	3	−11.0	−22.7‡
1884	0.9873	0.0034	0.0038	3	−4.8	−23.3
1885	0.9906	0.0030	0.0012	4	−1.6	−22.7‡
					Avg ^{13}C =	−22.68‰
					1σ =	0.39‰

*Weighted average; **Counting statistics; †Standard deviation for N separate analyses; ‡Average of seven analyses

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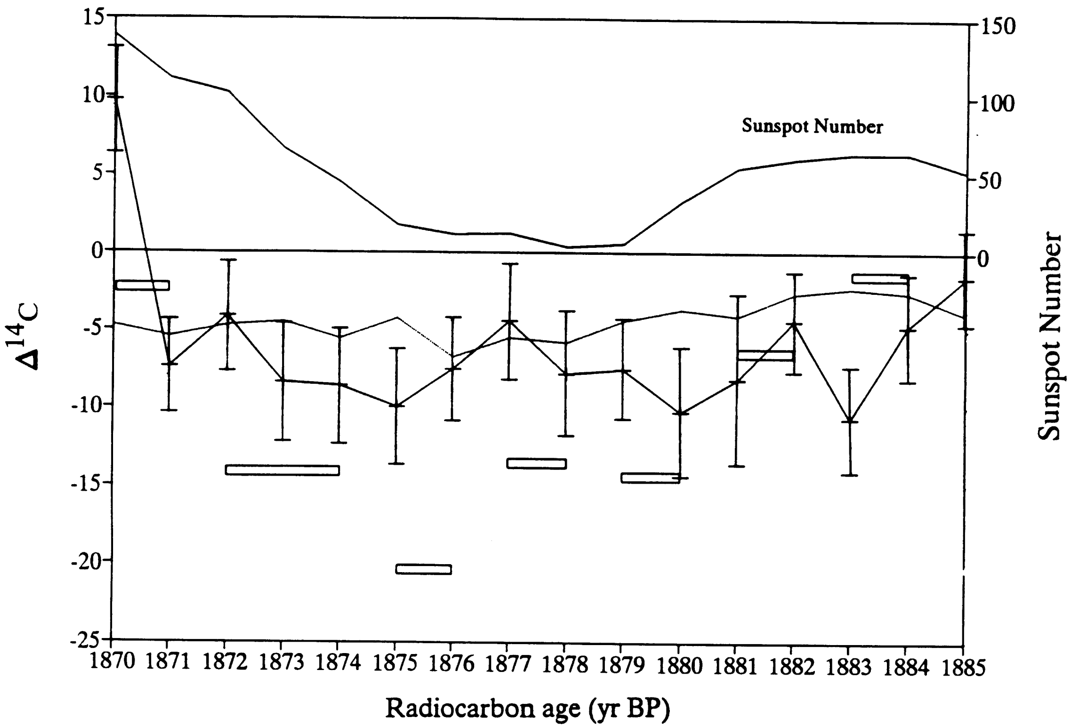

Fig. 1. $\Delta^{14}C$ data for MacKenzie River samples (67–68°N, 130°W) compared with high-precision data from the Olympic Peninsula. + = this work; ▭ = Fan *et al.* (1983, 1986); — = Olympic Peninsula data of Stuiver and Quay (1981). Sunspot number is shown for comparison.

TABLE 2. Fraction modern, F_m, for the anomalous result for AD 1870 cellulose

Date of analysis	Fm	Poisson (σ)
7/27/89	1.0006	0.0068
9/18/90	1.0067	0.0081
10/02/90	0.9974	0.0061
10/03/90	1.0057	0.0058
Weighted average	1.0000	0.0033

The difference, 2.0 ± 0.8 ($\bar{\sigma}$), is significant at the 95% confidence level. This variation is consistent in amplitude, but not in phase with expectation for solar modulation of the galactic cosmic-ray flux, assuming a well-mixed troposphere (Damon, Sternberg & Radnell 1983). Such small variations can be due to various factors, including the tendency for solar and galactic cosmic rays to be anticorrelated (Lingenfelter & Ramaty 1970; Damon, Cheng & Linick 1989).

CONCLUSION AND DISCUSSION

The following conclusions seem to be warranted by the data:

1. There is no evidence for an anomalously intense 11-year cycle at high latitudes in the MacKenzie River area during the time period, AD 1870–1885.
2. There is a difference of 2.6 ± 0.9 ($\bar{\sigma}$) between $\Delta^{14}C$ values from the Olympic peninsula

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samples and the high-latitude samples.

3. It is necessary to make more measurements to verify the existence of our anomalously high $\Delta^{14}C$ measurement at 1870.

We suggest that the regional effect may be due to accumulation of ^{14}C-depleted CO_2 within the frozen earth under the snow blanket and release into the atmosphere during the spring thaw. Such an effect has been observed for radon in Ontario, Canada (Jonasson & Dyck 1978). Messerschmidt (1933) attributed high atmospheric concentrations of radon in April and May, to the spring thaw in Germany. Dörr and Münnich (1986) measured seasonal ^{14}C variations in soil CO_2 in a beech/spruce forest in the Rhine Valley, Germany. They found a 10% reduction in $\Delta^{14}C$ values for soil gas collected during the winter, as compared with summertime values. The effect observed for the MacKenzie Delta could be produced if 5% of atmospheric CO_2 had been derived from 5%-depleted soil gas CO_2. The effect would be enhanced by the short growing season at high latitudes and continuing thawing of the frozen tundra during that time.

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