RADIOCARBON, Vol 41, Nr 1, 1999, p 47–50

THE MAUNDER MINIMUM: AN INTERLABORATORY COMPARISON OF $\Delta^{14}C$ FROM AD 1688 TO AD 1710

Paul E Damon • Christopher J Eastoe

Department of Geosciences, PO Box 210077, University of Arizona, Tucson, Arizona 85721 USA

Irina B Mikheeva

AF Ioffe Institute of Physics and Technology, Russian Academy of Science, St Petersburg, Russia

ABSTRACT. Measurements on same-age tree-ring samples from proximal Ural Mountain trees by the Ioffe Institute research group and at the University of Arizona demonstrate a variance corresponding to a standard deviation of ±5.1‰ for Ioffe compared to ±2.1‰ for Tucson. There is also a calibration difference of 4.3 ± 1.2 $\bar{\sigma}$‰. Comparison of the same years measured in Seattle on wood from the Pacific Northwest shows an offset of 2.2 ± 0.5 $\bar{\sigma}$‰. This is not a calibration error, but rather is expected from the well-documented evidence for divergence and upwelling of ^{14}C-depleted CO_2 along the west coast of North America.

INTRODUCTION

Professor Grant Kocharov, head of the Astrophysics Section of the Ioffe Institute in St Petersburg, Russia, realized early the importance of radiocarbon research in obtaining information concerning paleosolar physics. Consequently, he encouraged and helped support the dendrochronological research of Professor Bitvinskas in Lithuania and a ^{14}C laboratory in Georgia. His research group also built a ^{14}C laboratory at the Ioffe Physical Technical Institute in Leningrad. Unfortunately, because they were isolated from the mainstream of ^{14}C geophysics research in the West, they were unable to participate in workshops and intercalibration studies that helped workers in the United States and Europe achieve the high precision and accuracy required in paleosolar physics research. Accordingly, Professor Kocharov supplied us with tree-ring samples from the relatively flat ^{14}C maximum resulting from the Maunder Minimum of solar activity (AD 1688–1710) for an intercomparison. The tree-ring samples from the Ural Mountains were dendrochronologically dated by Dr T T Bitvinskas of the Institute of Botany in Kaunas, Lithuania and they are the same samples measured for $\Delta^{14}C$ by Kocharov's research group (Galli et al. 1987).

RESULTS AND EVALUATION

$\Delta^{14}C$ values measured in the Laboratory of Isotope Geochemistry, the University of Arizona, are presented in Table 1 and plotted in Figure 1 along with the measurements published in Galli *et al.* (1987) and data determined at the University of Washington, Seattle, on single-year Douglas-fir tree rings (Stuiver and Braziunas 1993). Table 2 presents an intercomparison of these measurements.

We ascribe the 2.2 ± 0.5 $\bar{\sigma}$ ‰ offset between Tucson and Seattle to the west coast regional effect due to upwelling and atmospheric exchange of ^{14}C-depleted oceanic CO_2 at the divergent margin produced by the Ekman spiral (Kennett 1982; Damon et al. 1989; McCormac et al. 1995; Damon 1995; Southon and Baumgartner 1996; Stuiver and Braziunas 1998). No significant calibration offset is apparent between the Tucson and Seattle laboratories (Kalin et al. 1995; Damon et al. 1998). The 4.3 ± 1.2 $\bar{\sigma}$ ‰ offset between Ioffe and Tucson does reveal a calibration offset. The difference between the variance for both the Seattle and Tucson results ($\sigma_m^2 - \sigma_p^2$) yields a standard deviation (σ_s) of 1‰. This 1‰ σ_s is an approximation of the real variance of the signal independent of the measurement error; it may be compared to the estimate of an average amplitude of the approximately 11-yr cycle of 1.40 ± 0.16‰ for the period of time from AD 1510 to AD 1945 (Stuiver and Braziunas 1993). For the 22 yr at the flat minimum preceding the Maunder Minimum from AD 1619 to AD 1640, we obtained a variance of 3.24 yielding a σ_s of about 1.8‰ from the Stuiver and Bra-

Table 1 Results of $\Delta^{14}C$ measurements on dendrochronologically dated tree rings from AD 1688 to 1710

Year	$\Delta^{14}C$ (‰)	$\delta^{13}C$ (‰)
1688	16.1 ± 1.9	−22.7
1690	14.4 ± 1.9	−22.2
1691	16.9 ± 1.9	−22.5
1692	15.6 ± 1.8	−22.2
1693	16.7 ± 1.8	−21.9
1694	15.9 ± 1.8	−22.2
1695	14.0 ± 1.7	−22.1
1696	18.6 ± 1.8	−22.1
1697	16.8 ± 1.8	−22.5
1698	15.1 ± 1.8	−22.2
1699	19.9 ± 2.0	−22.7
1701	19.8 ± 1.7	−22.7
1702	18.7 ± 1.8	−22.3
1703	16.9 ± 1.7	−23.0
1704	20.4 ± 1.8	−22.8
1705	17.0 ± 2.0	−21.8
1706	20.0 ± 1.7	−22.0
1707	19.4 ± 2.1	−22.2
1708	18.3 ± 1.8	−22.3
1710	13.8 ± 1.8	−21.8

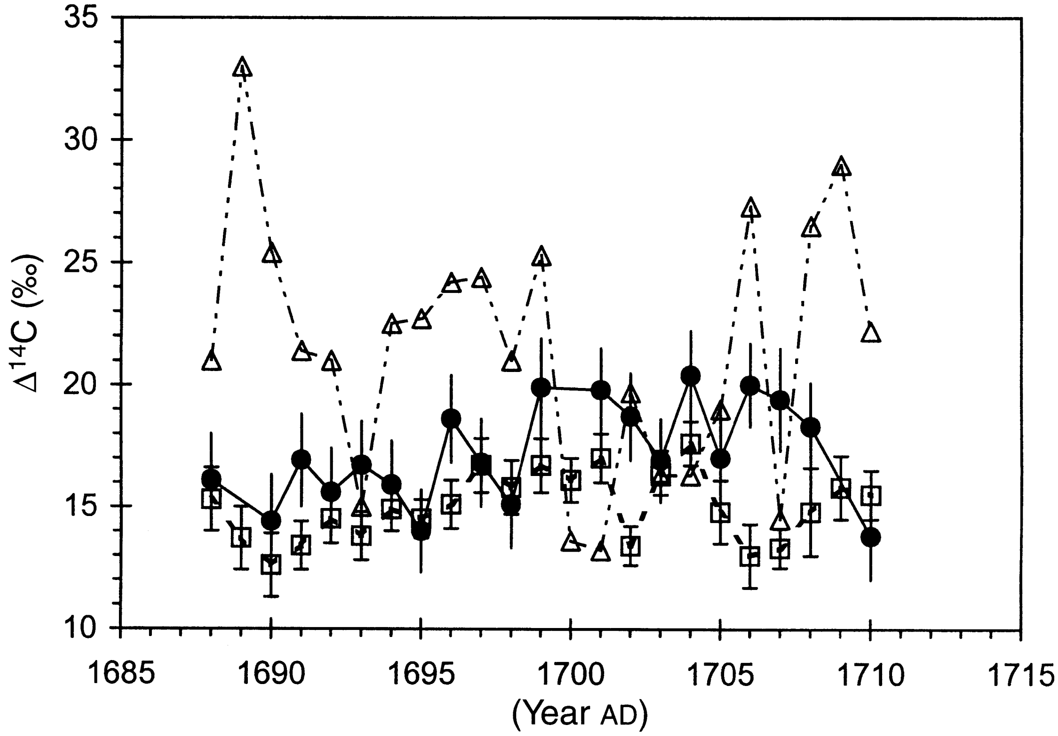

Figure 1 The results of $\Delta^{14}C$ measurements in tree-rings of 1688–1700 AD according to the present work (●); Stuiver and Braziunas (1993) (□); Galli et al. (1987) (△).

https://doi.org/10.1017/S0033822200019329 Published online by Cambridge University Press

Table 2 Intercomparison of measurements on single-year tree rings for the interval AD 1688–1710

	Ioffe (1) (‰)	Tucson (2) (‰)	Seattle (3) (‰)
$\bar{\chi}$	21.5	17.2	15.0
σ_m	5.1	2.1	1.4
σ_p	?	1.8	1.1

$\bar{\chi}$ = mean value; σ_m = measured; σ_p = average Poisson counting precision
(1) Galli *et al* 1987; (2) this paper; (3) Stuiver and Braziunas 1993

ziunas (1993) data. The lower σ_s during the Maunder Minimum is compatible with the presence of the 22-yr cycle and suppression of the 11-yr cycle (Peristykh and Damon 1998) as suggested by Vasiliev and Kocharov (1983).

CONCLUSION

$\Delta^{14}C$ measurements on same-age samples measured under the direction of Professor Kocharov and also measured at the University of Arizona demonstrate a greater variance for the Ioffe Institute results, corresponding to a standard deviation of ±5.1‰ (σ_m) compared to the Tucson results of ±2.1‰ (σ_m). Konstantinov et al. (1997) also concluded, in explaining the differences in data series, that the experimental errors of the Soviet data are much greater than ±3‰. The Tucson–Ioffe calibration offset is 4.3 ± 1.2 $\bar{\sigma}$ ‰. We ascribe an offset between Tucson measurements and Seattle measurements of 2.2 ± 0.5 $\bar{\sigma}$ ‰ to divergence and upwelling of ^{14}C-depleted CO_2 along the west coast of North America. This divergence is caused by the wind-driven Ekman Transport and ocean currents diverted by coriolis force that result in the Ekman Spiral and west coast divergence and upwelling. The high-precision results from Seattle and Tucson also demonstrate a flat $\Delta^{14}C$ maximum corresponding to the Maunder Minimum, with variance and standard deviation around ±1‰.

ACKNOWLEDGMENTS

We greatly appreciate Professor Grant Kocharov of the Ioffe Institute in St Petersburg for making available the Ural Mountain tree rings that made this study possible. This work was supported by NSF Grant ATM-9520135 and the state of Arizona.

REFERENCES

Damon PE. 1995. A note concerning "Location-dependent differences in the ^{14}C content of wood" by McCormac et al. *Radiocarbon* 37(2):829–30.

Damon PE, Cheng S, Linick TW. 1989. Fine and hyperfine structure in the spectrum of secular variations of atmospheric ^{14}C. *Radiocarbon* 31(3):704–18.

Damon PE, Eastoe CJ, Hughes MK, Kalin RM, Long A, Peristykh AN. 1998. Secular variation of $\Delta^{14}C$ during the Medieval Solar Maximum: a progress report. *Radiocarbon* 40(1):343–350.

Galli M, Castagnoli CC, Attolini MR, Cechini S, Nanni T, Kocharov GE, Mikheeva IB, Bitvinskas TT, Konstantinov AN, Metskhvarishvili RYa. 1987. A 400-year ^{14}C record: 11-year and longer cycles. In: Chudakov E, editor. *Proceedings of the 20th International Cosmic Ray Conference, Moscow;* Vol 4. Moscow: Nauka. p 280–3.

Kalin RM, McCormac FG, Damon PE, Eastoe CJ, Long A. 1995. Intercomparison of high-precision ^{14}C measurements at the University of Arizona radiocarbon laboratory. *Radiocarbon* 37(1):33–8.

Kennett JP. 1982. *Marine geology.* Englewood Cliffs (NJ): Prentice Hall. 813 p.

Konstantinov AN, Krasiljschikov AM, Lazarev VE, Mikheeva IB. 1997. On the variation of ^{14}C in the Earth's atmosphere in the last 400 years. *Izvestiia Akademii Nauk, seriia fizicheskaia* 61(6):1242–8 (in Russian).

McCormac FG, Baillie MGL, Pilcher JR, Kalin RM. 1995. Location-dependent differences in the ^{14}C content of wood. *Radiocarbon* 37(2):395–407.

Peristykh AN, Damon PE. 1998. Modulation of atmospheric ^{14}C concentration by the solar wind and irradiance components of the Hale and Schwabe solar cycles. *Solar Physics* 177(1/2):343–55.

Southon JR, Baumgartner TA. 1996. A long-term record of upwelling from the Santa Barbara basin, Southern California. *Radiocarbon* 38(1):114.

Stuiver M, Braziunas TF. 1993. Sun, ocean, climate and atmospheric CO_2: an evaluation of causal and spectral relationships: *Holocene* 3(4):289–305.

Stuiver M, Braziunas TF. 1998. Anthropogenic and solar components of hemispheric ^{14}C. *Geophysical Research Letters* 25(3): 329–32.

Vasiliev VA and Kocharov GE. 1983. On the solar activity dynamics during the Maunder Minimum. In: Kocharov GE, editor. *Trudy XIII Leningradskogo Seminara po Kosmofizike* (Proceedings of the XIII Leningrad Seminar on Space Physics). Leningrad: Nauka. p 75–100 (in Russian).