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HIGH-PRECISION RADIOCARBON MEASUREMENTS OF CONTEMPORANEOUS TREE-RING DATED WOOD FROM THE BRITISH ISLES AND NEW ZEALAND: AD 1850–950

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ABSTRACT. The University of Waikato, Hamilton, New Zealand and The Queen's University of Belfast, Northern Ireland radiocarbon dating laboratories have undertaken a series of high-precision measurements on decadal samples of dendrochronologically dated oak (*Quercus petraea*) from Great Britain and cedar (*Libocedrus bidwillii*) and silver pine (*Lagarostrobos colensoi*) from New Zealand. The results show an average hemispheric offset over the 900 yr of measurement of 40 ± 13 yr. This value is not constant but varies with a periodicity of about 130 yr. The Northern Hemisphere measurements confirm the validity of the Pearson et al. (1986) calibration dataset.

INTRODUCTION

The radiocarbon ages of decadal (10 yr) samples of dendrochronologically dated wood from both hemispheres spanning the AD 1850–950 interval have been measured to high-precision in the Waikato and Belfast ^{14}C laboratories. The decadal blocks of dendrochronologically dated oak (*Quercus petraea*) from the British Isles and New Zealand cedar (*Libocedrus bidwillii*) and silver pine (*Lagarostrobos colensoi)* from New Zealand were used to provide comparative measurements of the ^{14}C content of the atmosphere in both hemispheres over a 900-yr period. This data also forms the basis for a companion paper which recommends its use for calibration of Southern Hemisphere ^{14}C measurements (McCormac et al., this issue). The blocks of wood were pretreated to α-cellulose (Hoper et al. 1997) thereby removing all mobile fractions, and the ^{14}C dates for each were determined by liquid scintillation counting of benzene (Hogg et al. 1987; McCormac 1992; McCormac et al. 1993; Higham and Hogg 1997). Given that the difference in Δ^{14}C between the hemispheres was expected to be small, it was felt necessary, in experimental design, to replicate the oak, cedar, and pine measurements in both laboratories, thereby creating 2 independent measurements of the offset and, thus, negating the effects of individual laboratory bias on the value determined for the interhemispheric offset. The results show a consistent ^{14}C depletion or older ^{14}C ages in the Southern Hemisphere over the period AD 950–1850. The results given here extend the Northern/Southern hemisphere data sets from AD 1940 to 1720 presented in McCormac et al. (1998a, 1998b).

LABORATORY OFFSET

The 900 yr of data at decadal intervals allows us to determine the offset between the Waikato and Belfast laboratories with some accuracy (Table 1). The Waikato and Belfast data sets show excellent agreement with the Belfast–Waikato offset, being –4.5 yr for the British Isles oak series and –3.9 yr for the New Zealand cedar/pine series. This offset compares very favorably with previous studies, which resulted in offsets ranging from 10 to 21 yr (Table 2).

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Table 1 Offsets between Belfast and Waikato measurements for the interval AD 955–1945. σ_1 is the average standard deviation based on quoted laboratory errors and σ_2 is the observed standard deviation in the age difference. The error multiplier k = σ_2/σ_1.

Samples	Offset	s_1	s_2	k	N
Cedar/pine	–3.9 ± 2.5	25.3	23.6	0.9	100
Oak	–4.5 ± 2.6	25.9	24.3	0.9	100

Table 2 Laboratory ^{14}C offsets on identical wood

Laboratories[a]	Cal yr interval	Trees	N	Offset ± σ_{meas} (^{14}C yr)
Belfast–Seattle[a]	BC 7750–5260	German oak	181	10 ± 2
Pretoria/Groningen–Seattle[a]	BC 3910–1930	German oak	194	17 ± 2
Heidelberg–Seattle[a]	BC 7720–4080	German oak	128	21 ± 3
Heidelberg–Seattle[a]	BC 9670–8000	German pine	102	16 ± 4
Belfast–Waikato	AD 955–1945	British Isles oak	50	–4.5 ± 2.6
Belfast–Waikato	AD 955–1945	New Zealand cedar/pine	50	–3.9 ± 2.5

[a]Stuiver et al. 1998. *Radiocarbon* 40(3):1041–83, p 1045

NORTHERN HEMISPHERE MEASUREMENTS

Figure 1 shows the individual measurements from Waikato (Wk) and Belfast (UB) on decadal samples of oak from the British Isles for the period AD 950–1850 (see also Table 3). These measurements essentially repeat, at higher temporal resolution, the Pearson et al. (1986, 1993) data published in the ^{14}C special calibration issues. The evolution of the Pearson data was a result of repeated corrections, which were questioned by McCormac et al. (1995). Thus, the new data offer the opportunity to test which corrections are appropriate in light of changes made to the calibration data published by Stuiver et al. (1998) and commonly known as INTCAL98.

Decadal values of the new oak measurements were combined to form bi-decadal averages centered on the intervals used by Pearson et al. (1986, 1993). The difference between the Pearson et al. (1986) data and the new suite of 72 measurements made in Belfast is –7.5 ± 2.8 yr with the new measurements being slightly older. The Pearson et al. (1993) data, which is a corrected version of the Pearson et al. (1986) measurements, is 7.3 ± 2.7 yr different from the new measurements. Although these results are not conclusive, other evidence supports the consistency of the Pearson et al. (1986) data (van der Plicht and McCormac 1995; van der Plicht et al. 1995).

A separate set of 7 sample pairs analyzed by the Belfast lab covering the period AD 610–730 gave differences between the Pearson et al. (1986, 1993) data of –3.8 ± 7.6 and 18.5 ± 7.3, respectively. In addition, a set of 8 University of Washington measurements of Irish oak from 505 to 655 BC resulted in a 3.6 ± 5.2 yr difference from the Pearson et al. 1986 results and –10.7 ± 5.2 yr difference from the 1993 dataset (Stuiver, personal communication 2002). We would therefore suggest that future calibration data for the Northern Hemisphere incorporates Pearson et al. (1986) data for the intervals beyond the range of data presented here.

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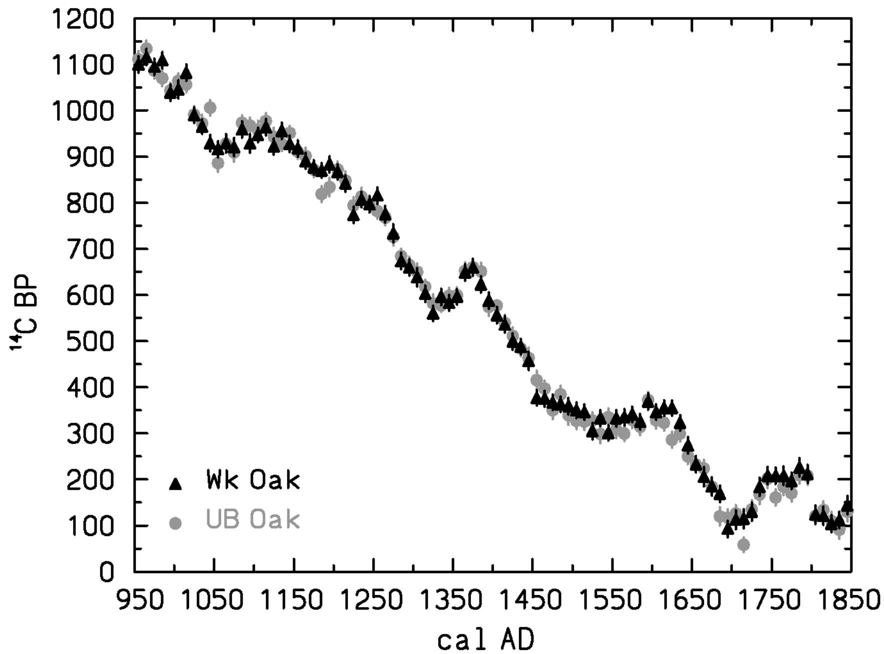

Figure 1 ^{14}C measurements on decadal samples of oak made in Queen's University of Belfast and the University of Waikato, New Zealand (AD 950–1850). AD 1855–1755 (Shane's Castle, N. Ireland); AD 1745–1505 (Sherwood Forest, England); AD 1495–1445 (Hillsborough Fort, N. Ireland); AD 1435–1325 (Toome, N. Ireland); AD 1315–1195 (Blackwater, N. Ireland); AD 1185–995 (Trim Castle, Ireland); AD 985–955 (Ballinderry, N. Ireland)

SOUTHERN HEMISPHERE MEASUREMENTS

Figure 2 shows the individual measurements from Waikato and Belfast on decadal samples of cedar and silver pine covering the period AD 950–1850. These follow closely the temporal variations of the oak measurements (Figure 1) and show again a very high degree of agreement between the measurements made in the 2 laboratories. Because of the limited age range of available cedar, it was necessary to change species to silver pine at AD 1405. The cedar trees grew in 2 sites in the middle of the North Island of New Zealand (rings AD 1401–1720, Takapari Forest Park, 40°04′S, 175°59′E; rings AD 1721–1850, Hihitahi Forest Park, 39°32′S, 175°44′E), while the silver pines grew on the west coast of the South Island (Oroko Swamp, 43°14′S, 170°17′E). Knox and McFadgen (2001) claim there is a statistical difference between the North Island cedar data given in McCormac et al. (1998a) and the South Island matai data given in Sparks et al. (1995) and, furthermore, suggest that the differences might be the result of either geographic location or proximity to the intermittently active volcano, Ruapehu. We consider it unlikely that volcanic emissions have affected the ^{14}C content of the cedar wood (Rubin et al. 1987; Bruns et al. 1980), as Hihitahi Forest Park is 32 km away, and Takapari Forest Park is 94 km away from the volcano. We have checked the consistency in $\Delta^{14}C$ between silver pine and Takapari Forest Park cedar by dating 5 wood samples of the same dendrochronological age from both species. The results are shown in Table 4. The weighted mean difference between the 2 species is 9.4 ± 7.6 yr based on 10 sample pairs. Using the student-t test for paired samples, there is no difference between the measurements for cedar and silver pine at the 95% confidence level.

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Table 3 Measurements on decadal samples of wood from the British Isles and New Zealand. Uncertainties include both counting statistics and sample preparation. Cedar and pine measurements (C/P) have been averaged over the interval AD 1405–1445. The SH offset is calculated from the average of the difference in the New Zealand and British Isles measurements for each laboratory.

Year AD	Wk C/P (^{14}C BP)	δ^{13}C (‰)	Wk oak (^{14}C BP)	δ^{13}C (‰)	Qub C/P (^{14}C BP)	δ^{13}C (‰)	Qub oak (^{14}C BP)	δ^{13}C (‰)	SH offset (^{14}C yr)
955	1162 ± 18	–21.5	1100 ± 18	–25.8	1191 ± 20	–22.1	1111 ± 18	–25.9	71 ± 19
965	1166 ± 18	–21.9	1116 ± 18	–25.1	1169 ± 19	–21.9	1134 ± 18	–26.0	43 ± 18
975	1157 ± 18	–22.0	1095 ± 18	–25.3	1149 ± 17	–22.3	1086 ± 17	–25.6	63 ± 18
985	1165 ± 18	–21.7	1109 ± 18	–25.6	1119 ± 17	–21.9	1070 ± 17	–26.3	52 ± 18
995	1051 ± 18	–22.1	1039 ± 18	–23.5	1105 ± 19	–22.1	1043 ± 17	–24.3	37 ± 18
1005	1073 ± 20	–21.5	1046 ± 20	–23.2	1090 ± 17	–21.7	1064 ± 17	–24.4	26 ± 19
1015	1098 ± 18	–22.0	1082 ± 18	–22.9	1104 ± 17	–22.3	1056 ± 17	–24.6	33 ± 18
1025	1024 ± 17	–21.7	990 ± 17	–23.3	1072 ± 19	–22.1	991 ± 19	–23.2	55 ± 18
1035	1008 ± 16	–21.9	965 ± 16	–23.3	1018 ± 19	–22.1	972 ± 19	–23.6	44 ± 18
1045	1001 ± 17	–21.9	929 ± 18	–23.4	1017 ± 17	–22.2	1006 ± 17	–23.8	41 ± 17
1055	964 ± 20	–21.9	916 ± 18	–23.9	919 ± 19	–22.4	886 ± 19	–24.4	40 ± 19
1065	971 ± 20	–21.8	929 ± 20	–23.9	983 ± 20	–22.1	928 ± 20	–24.6	49 ± 20
1075	949 ± 20	–21.8	921 ± 20	–23.7	956 ± 20	–22.1	909 ± 20	–23.8	38 ± 20
1085	996 ± 20	–22.2	959 ± 18	–23.9	1001 ± 17	–22.1	973 ± 17	–23.8	32 ± 18
1095	1003 ± 20	–21.9	929 ± 20	–23.8	1019 ± 18	–22.4	967 ± 18	–24.1	62 ± 19
1105	1001 ± 15	–22.1	947 ± 16	–23.3	1000 ± 18	–22.2	958 ± 20	–24.1	49 ± 17
1115	977 ± 18	–21.9	964 ± 18	–23.3	1001 ± 19	–21.9	977 ± 18	–24.1	18 ± 18
1125	982 ± 20	–21.6	922 ± 18	–23.4	1022 ± 18	–21.9	943 ± 20	–23.6	70 ± 19
1135	971 ± 18	–21.5	956 ± 18	–25.0	1008 ± 16	–21.7	928 ± 16	–25.0	51 ± 17
1145	966 ± 18	–21.8	928 ± 18	–25.4	996 ± 16	–22.1	951 ± 16	–25.8	42 ± 17
1155	961 ± 18	–22.0	918 ± 18	–25.5	937 ± 16	–22.8	911 ± 16	–25.5	34 ± 17
1165	927 ± 17	–22.1	891 ± 17	–26.0	906 ± 18	–22.6	901 ± 18	–25.6	21 ± 18
1175	931 ± 16	–22.0	877 ± 16	–25.4	950 ± 17	–22.4	872 ± 17	–25.5	65 ± 17
1185	912 ± 16	–22.0	870 ± 16	–24.1	887 ± 17	–22.2	819 ± 17	–25.0	54 ± 17
1195	930 ± 18	–22.2	883 ± 18	–26.7	867 ± 20	–22.6	834 ± 20	–27.1	41 ± 19
1205	913 ± 17	–22.0	867 ± 17	–26.5	896 ± 18	–22.7	872 ± 18	–26.7	36 ± 18
1215	883 ± 18	–21.9	842 ± 18	–26.7	883 ± 20	–22.4	848 ± 20	–26.6	38 ± 19
1225	843 ± 18	–21.7	774 ± 18	–26.1	846 ± 18	–22.1	794 ± 18	–26.6	61 ± 18
1235	820 ± 17	–21.5	807 ± 17	–26.9	818 ± 20	–22.1	813 ± 20	–26.9	10 ± 19
1245	849 ± 17	–22.0	797 ± 18	–26.3	795 ± 19	–22.4	797 ± 18	–26.8	26 ± 18
1255	848 ± 18	–21.3	816 ± 18	–26.0	838 ± 17	–21.6	782 ± 17	–26.5	45 ± 18
1265	811 ± 18	–21.5	775 ± 18	–26.1	850 ± 17	–21.8	768 ± 17	–26.7	60 ± 18
1275	781 ± 20	–21.7	734 ± 20	–26.3	809 ± 19	–21.7	726 ± 19	–26.2	66 ± 20
1285	755 ± 18	–21.8	674 ± 18	–26.4	753 ± 20	–21.6	684 ± 16	–26.8	75 ± 18
1295	722 ± 18	–21.8	660 ± 18	–26.4	722 ± 18	–21.7	665 ± 18	–26.5	60 ± 18
1305	707 ± 18	–21.8	639 ± 20	–26.0	678 ± 18	–21.6	650 ± 18	–26.2	47 ± 19
1315	693 ± 18	–21.6	603 ± 18	–26.4	695 ± 14	–21.8	618 ± 15	–26.3	82 ± 16
1325	632 ± 18	–21.5	560 ± 17	–26.2	646 ± 18	–22.0	582 ± 20	–26.4	68 ± 18
1335	632 ± 18	–21.1	596 ± 18	–26.1	649 ± 18	–21.4	577 ± 14	–27.0	56 ± 17
1345	658 ± 17	–21.6	583 ± 17	–26.6	638 ± 17	–21.8	598 ± 17	–26.4	58 ± 17
1355	675 ± 17	–21.2	596 ± 17	–26.6	686 ± 17	–21.2	599 ± 18	–26.3	83 ± 17
1365	707 ± 18	–21.3	649 ± 18	–26.6	708 ± 18	–21.2	652 ± 19	–26.5	57 ± 18
1375	710 ± 18	–21.8	660 ± 18	–26.4	722 ± 19	–21.4	660 ± 19	–26.2	56 ± 19
1385	676 ± 18	–21.3	623 ± 18	–26.3	669 ± 19	–21.5	651 ± 19	–26.3	36 ± 19
1395	624 ± 18	–21.4	588 ± 18	–26.4	629 ± 21	–21.9	574 ± 19	–26.4	44 ± 19
1405	592 ± 13	–22.1/ –21.3	556 ± 18	–26.0	583 ± 13	–22.2/– 21.1	577 ± 12	–25.1	18 ± 14
1415	552 ± 13	–22.1/ –21.4	536 ± 18	–25.9	574 ± 12	–22.1/– 21.5	539 ± 18	–26.0	26 ± 16

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Year AD	Wk C/P (^{14}C BP)	δ^{13}C (‰)	Wk oak (^{14}C BP)	δ^{13}C (‰)	Qub C/P (^{14}C BP)	δ^{13}C (‰)	Qub oak (^{14}C BP)	δ^{13}C (‰)	SH offset (^{14}C yr)
1425	543 ± 13	−22.0/ −21.4	499 ± 18	−25.7	547 ± 13	−22.3/ −21.7	511 ± 19	−26.0	40 ± 16
1435	524 ± 13	−22.2/ −21.3	488 ± 17	−26.0	526 ± 12	−22.2/ −21.6	484 ± 17	−26.2	39 ± 15
1445	492 ± 13	−22.0/ −21.1	457 ± 20	−26.6	506 ± 13	−22.0/ 21.6	463 ± 23	−26.2	38 ± 18
1455	455 ± 17	−21.9	377 ± 17	−26.1	455 ± 17	−23.0	415 ± 21	−25.8	61 ± 18
1465	408 ± 17	−22.0	375 ± 17	−25.7	409 ± 17	−22.2	397 ± 18	−25.8	23 ± 17
1475	435 ± 18	−21.5	367 ± 17	−25.3	424 ± 20	−23.1	350 ± 19	−25.1	71 ± 19
1485	405 ± 17	−21.8	363 ± 17	−25.0	402 ± 17	−22.3	384 ± 20	−25.4	31 ± 18
1495	401 ± 18	−22.1	359 ± 18	−25.4	417 ± 18	−22.7	339 ± 21	−25.6	59 ± 19
1505	380 ± 17	−22.0	350 ± 17	−24.6	374 ± 18	−22.3	327 ± 18	−24.7	38 ± 18
1515	338 ± 17	−21.9	346 ± 17	−25.0	349 ± 18	−22.1	325 ± 18	−24.9	7 ± 18
1525	352 ± 17	−21.7	305 ± 18	−24.9	336 ± 18	−22.1	328 ± 18	−25.3	28 ± 18
1535	362 ± 17	−21.5	333 ± 17	−24.8	317 ± 19	−22.1	298 ± 19	−24.8	25 ± 18
1545	359 ± 18	−21.5	301 ± 17	−24.6	344 ± 19	−22.4	335 ± 19	−25.3	36 ± 18
1555	361 ± 18	−21.4	333 ± 18	−24.8	368 ± 18	−21.6	308 ± 18	−25.4	44 ± 18
1565	348 ± 18	−21.0	335 ± 18	−24.8	355 ± 16	−21.1	299 ± 16	−25.1	37 ± 17
1575	381 ± 17	−20.8	341 ± 17	−25.0	335 ± 18	−21.0	329 ± 18	−25.2	24 ± 18
1585	380 ± 17	−20.8	325 ± 17	−24.5	344 ± 19	−20.8	314 ± 18	−24.9	44 ± 18
1595	397 ± 17	−20.7	369 ± 18	−24.7	377 ± 19	−21.1	372 ± 18	−24.5	17 ± 18
1605	414 ± 17	−20.5	346 ± 17	−24.8	391 ± 18	−21.1	328 ± 18	−24.9	66 ± 18
1615	391 ± 17	−20.8	355 ± 17	−24.9	378 ± 18	−21.0	323 ± 17	−25.1	45 ± 17
1625	369 ± 17	−20.7	355 ± 17	−25.3	323 ± 17	−21.1	286 ± 17	−25.3	26 ± 17
1635	350 ± 17	−20.5	323 ± 17	−25.1	303 ± 17	−20.8	299 ± 17	−25.2	16 ± 17
1645	311 ± 18	−20.8	274 ± 18	−24.9	284 ± 17	−20.8	250 ± 17	−25.6	35 ± 18
1655	260 ± 18	−20.8	233 ± 18	−24.8	238 ± 16	−21.0	232 ± 17	−25.3	16 ± 17
1665	237 ± 18	−20.2	206 ± 21	−24.7	261 ± 16	−20.6	224 ± 19	−24.9	34 ± 19
1675	212 ± 18	−20.0	185 ± 20	−24.6	205 ± 17	−20.7	184 ± 20	−25.7	24 ± 19
1685	198 ± 18	−20.0	169 ± 18	−25.0	188 ± 21	−20.4	120 ± 20	−25.7	46 ± 19
1695	147 ± 18	−20.1	93 ± 18	−25.7	167 ± 20	−20.8	117 ± 19	−25.8	52 ± 19
1705	155 ± 21	−19.9	113 ± 21	−24.9	136 ± 20	−20.4	126 ± 19	−25.4	25 ± 20
1715	122 ± 17	−20.5	115 ± 21	−24.6	129 ± 16	−21.0	58 ± 16	−25.1	45 ± 18
1725	162 ± 20	−19.7	130 ± 20	−24.5	135 ± 19	−20.7	135 ± 20	−25.2	16 ± 20
1735	213 ± 19	−19.7	184 ± 20	−24.5	194 ± 20	−20.2	167 ± 21	−25.8	28 ± 20
1745	232 ± 19	−19.8	208 ± 19	−24.5	224 ± 19	−20.4	201 ± 20	−25.2	24 ± 19
1755	224 ± 18	−19.8	208 ± 18	−23.8	249 ± 19	−20.5	161 ± 18	−24.6	51 ± 18
1765	248 ± 20	−19.8	208 ± 20	−23.6	203 ± 18	−20.5	184 ± 18	−23.8	28 ± 19
1775	218 ± 19	−19.5	197 ± 18	−23.5	192 ± 18	−20.3	170 ± 18	−24.2	22 ± 18
1785	246 ± 19	−19.8	226 ± 20	−23.3	234 ± 18	−20.2	209 ± 18	−23.6	23 ± 19
1795	242 ± 20	−20.0	212 ± 20	−23.6	230 ± 18	−20.5	208 ± 20	−23.7	26 ± 20
1805	176 ± 19	−19.7	124 ± 20	−24.0	164 ± 19	−20.2	121 ± 19	−23.8	47 ± 19
1815	129 ± 20	−19.9	121 ± 20	−23.2	154 ± 19	−20.3	134 ± 19	−23.7	14 ± 20
1825	140 ± 20	−20.1	104 ± 19	−23.4	151 ± 19	−20.9	110 ± 20	−21.9	39 ± 20
1835	141 ± 18	−19.7	112 ± 18	−23.5	159 ± 20	−20.4	91 ± 20	−23.9	46 ± 19
1845	165 ± 20	−19.8	144 ± 20	−23.9	146 ± 20	−20.2	130 ± 21	−24.5	19 ± 20

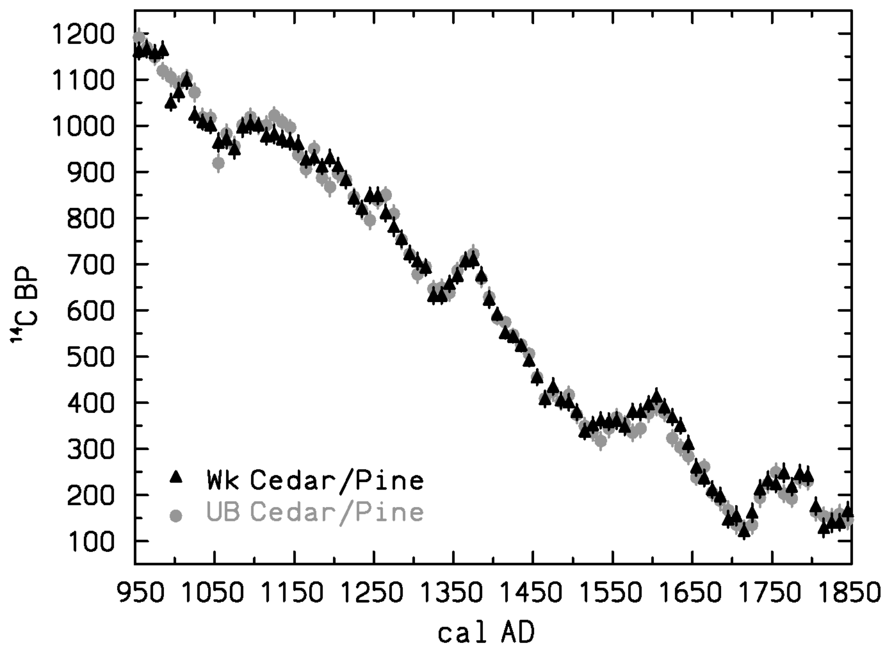

Figure 2 ^{14}C measurements on decadal samples of cedar and silver pine made in Queen's University of Belfast and the University of Waikato, New Zealand; (cedar AD 1405–1855; Hihitahi & Takapari Forest Parks, North Island, New Zealand; silver pine AD 955–1455, Oroko Swamp, South Island, New Zealand)

Table 4 ^{14}C measurements on the overlap between cedar and silver pine (AD 1405–1455)

Year	Lab	Cedar ^{14}C BP			Silver pine ^{14}C BP			Difference		
1405	Wk	584	±	16	602	±	16	18	±	22.6
1415	Wk	550	±	16	554	±	16	4	±	22.6
1425	Wk	549	±	16	537	±	16	−12	±	22.6
1435	Wk	515	±	16	533	±	16	18	±	22.6
1445	Wk	477	±	16	506	±	16	29	±	22.6
1405	UB	577	±	21	587	±	17	10	±	27.0
1415	UB	569	±	17	580	±	18	11	±	24.8
1425	UB	553	±	17	538	±	20	−15	±	26.2
1435	UB	519	±	17	533	±	17	14	±	24.0
1445	UB	500	±	17	513	±	20	13	±	26.2

The combined measurements from the 2 laboratories on wood from the Southern and Northern Hemispheres are shown in Figure 3. The fact that the Southern Hemisphere measurements give older dates is clearly visible. The average value for the hemispheric offset over the 900 yr of measurement is 40 ± 13 yr. However, careful analysis shows that this value is not constant through time, but varies with a periodicity of about 130 yr. McCormac et al. (this issue), deals more thoroughly with this and make specific recommendations for the use of the data to calibrate ^{14}C ages.

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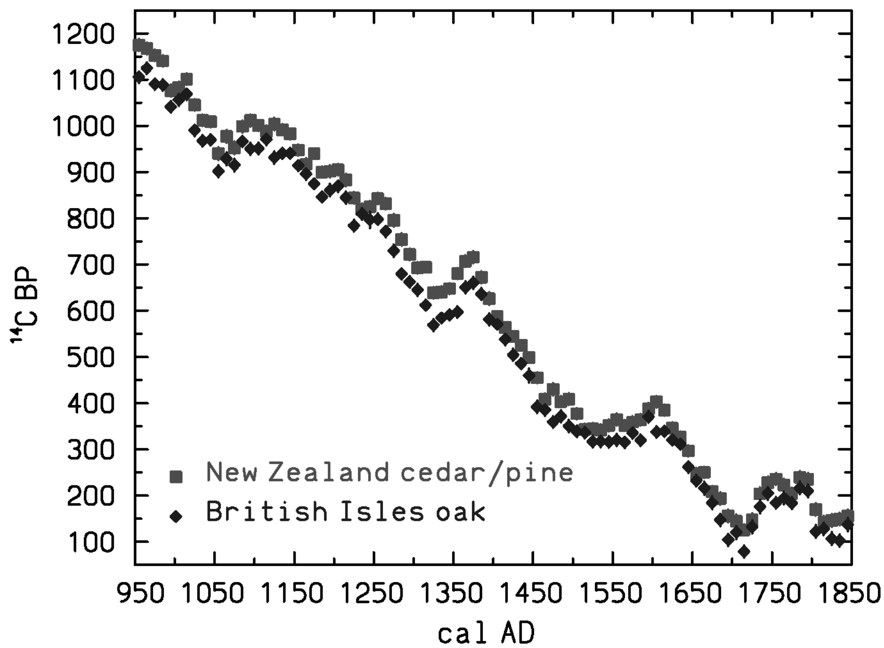

Figure 3 Comparison of combined ^{14}C dates of Southern and Northern Hemisphere wood measured by QUB and Waikato

CONCLUSIONS

Two sets of ^{14}C measurements on decadal samples of oak, cedar, and silver pine are presented covering the period AD 950–1850. The offset between the Waikato and Belfast laboratories is significantly lower than corresponding offsets presented in other studies. The Northern Hemisphere measurements confirm the validity of the Pearson et al. (1986) data and suggest its use in future calibration work.

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