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RADIOCARBON VARIATIONS FROM TASMANIAN CONIFERS: FIRST RESULTS FROM LATE PLEISTOCENE AND HOLOCENE LOGS

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ABSTRACT. Dendrochronological studies have begun on two conifer species in the Stanley River area of western Tasmania. The chronology extends to 273 BC for Huon pine (*Lagarostrobos franklinii*) and to AD 1450 for celery-top pine (*Phyllocladus aspleniifolius*). Apart from living or recently felled trees, sections have been taken from 58 logs preserved in floodplain sediments. Two of these logs have late Pleistocene ages, centered around 13.0 and 12.7 k ^{14}C yr BP. Four logs are between 8 and 9 ka BP, and one is centered at 7.3 ka BP. The remaining logs have various ages between 6.2 ka BP and the present. ^{14}C measurements have been performed on decadal samples from the two late Pleistocene logs, providing short (260-yr) records of atmospheric ^{14}C variations when plotted against individual ring numbers. Decadal measurements on the 7300-yr-old log have been wiggle-matched with ^{14}C calibration curves from German oak and bristlecone pine. Measurements for the period, AD 1600–1800, show good agreement with northern hemisphere results, and a nearly zero offset between the hemispheres.

INTRODUCTION

Radiocarbon calibration is now well established for most of the Holocene. The differences between tree-ring ages and conventional ^{14}C ages have been determined for the last 9700 calendar yr by precision ^{14}C measurements on 10- or 20-ring samples, which are independently dated by dendrochronology (summarized by Stuiver *et al.* 1991). A small part of the difference occurs because ^{14}C ages are, by international agreement, calculated using a half-life of 5568 yr, which is known to be about 3% too short. Differences apart from this 3% reflect variations in the production rate and in the exchange of ^{14}C between oceans, atmosphere and biosphere. Most of the Holocene variation is thought to be due to changes in the production rate; the long-term peak-to-trough change is attributed to changes in the Earth's magnetic field strength, which affect the cosmic-ray flux, whereas shorter-term wiggles (with amplitudes of 100 or 200 yr) are attributed to solar modulation of the cosmic-ray flux.

Early Holocene ^{14}C data from southern Germany (Becker & Kromer 1986) are from a floating tree-ring sequence. They show short-term wiggles, such as those seen in recent millennia, and also a horizontal trend in the calibration curve with nearly constant ^{14}C ages (9600 BP) over several hundred tree rings.

Southern hemisphere measurements are essential as an independent verification, and are important because the offset from the northern hemisphere (36 yr in recent centuries; Lerman, Mook & Vogel 1970; Vogel *et al.* 1986) may have varied in earlier times due to changes in global carbon fluxes.

We began dendrochronological studies 10 years ago on two conifer species in the Stanley River area of western Tasmania (145°E, 42°S; Francey *et al.* 1984). The chronology for Huon pine (*Lagarostrobos franklinii*) has recently been extended to 273 BC. Living celery-top pine (*Phyllocladus aspleniifolius*) trees are up to 500 yr old. We sampled logs exposed in the river banks and

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excavated in floodplain sediments between 1981 and 1984, and obtained sections from 58 well-preserved logs. The oldest are two celery-top logs with late Pleistocene ages, centered around 13.0 and 12.7 k ^{14}C yr BP. Four logs are between 8 and 9 ka, and one is centered at 7.3 ka BP. The remaining logs have various ages between 6.2 ka BP and the present, but so far there are no logs between about 3.6 and 2.6 ka.

These discoveries in western Tasmania have given us an opportunity to make selected southern hemisphere comparisons with the 9.7 ka (dendroyear) span of ^{14}C records obtained from northern hemisphere bristlecone pine and European oak (Stuiver *et al.* 1991).

Methodology

We polished cross-sections from the logs and split them into consecutive 10-ring samples; for the innermost and outermost parts, where the rings were narrow, we took up to 60 rings per sample. For the time span, AD 1600–1800, we used five-ring samples where possible. We reduced the wood samples to about 0.5 mm particle size in a cutting mill, and prepared holocellulose following the method of Head (1979). We used standard techniques (Gupta & Polach 1985) to prepare benzene samples (4 ml). Stable carbon isotope ($^{13}C/^{12}C$) measurements were made on subsamples of the combustion CO_2 at the CSIRO Division of Atmospheric Research.

We made ^{14}C measurements using Teflon vials in a low-level Wallac Quantulus counter, usually with duplicate measurements in another counter (Wallac Rackbeta) linked to a multichannel analyzer and microcomputer system. A third counter (Packard Tri-Carb with fixed windows) was used for some measurements before February 1987, but most of the data were collected between 1987 and 1989. We calculated conventional ^{14}C ages using modern standard values derived from measurements of ANU sucrose and NBS oxalic acid, but we assumed an uncertainty of ± 0.1 or ± 0.2 counts min^{-1} for the standard, considerably larger than the typical Poisson deviation of ± 0.07 counts min^{-1} associated with an individual standard measurement. We then combined the results from the counters, weighting them inversely by variance; age differences between the counters are indicated by z-statistic values. Measurement uncertainties associated with our combined results typically range from *ca.* ± 30 yr for recent samples to *ca.* ± 60 yr for late Pleistocene samples.

Results

^{14}C results (Table 1) from the two late Pleistocene logs provide short (260-yr) records of atmospheric ^{14}C variations when plotted against individual ring numbers (Fig. 1). The variations from sample to sample are not always smooth, and may reflect a combination of experimental uncertainties (trace levels of contamination and random measurement errors). One ^{14}C result from the center of SRT-462, and two from the outermost rings of SRT-157 (probably sapwood), gave anomalously young results, which are excluded from Figure 1. The overall trend for SRT-462 is fairly flat, and the trend for SRT-157 is downward toward the outer rings. The two logs do not appear to overlap in time.

Results from the 7300-yr-old log SRT-444 (Table 2) can be compared with ^{14}C calibration curves from German oak and bristlecone pine (Fig. 2). Since SRT-444 is not dated by dendrochronology, we sought to position it by ^{14}C wiggle-matching. We estimated decadal values for German oak by a combination of averaging (for cases of multiple measurements per decade) and interpolation (for decades without data). Three of the SRT-444 values that did not correspond exactly to decadal spacing were taken as representing the nearest decadal sample. We used these smoothed values and calculated root mean square (rms) differences, moving the zero-point of the SRT-444 data in decadal steps. The minimum rms difference occurred with ring 0 of SRT-444 placed at 8260 den-

TABLE 1. Radiocarbon Dates From Stanley River Celery-Top Pine Logs, SRT-462 and SRT-157

SUA- no.	Tree-ring span years		^{13}C (‰)	Counter 1 (yr BP)	± σ	Counter 2 (yr BP)	± σ	Counter 3 (yr BP)	± σ	Combined (yr BP)	± σ	z-stat	Center ring
*SRT-462**													
5142R**	1	50	–26.5	13,134	53					13,134	53		26
5143†	51	75	–24.0	12,882	68					12,882	68		63
5144‡	76	90	–23.7	13,105	69	13,165	105			13,123	58	.48	83
5145	91	100	–23.7	13,149	69	13,121	104			13,140	57	–.22	96
5101**	70	130	–24.1	13,032	68	12,971	103			13,013	57	–.49	100
5146	101	110	–23.7	13,039	68	12,837	102			12,977	57	–1.65	106
5147	111	120	–24.0	13,065	68	13,301	97			13,143	56	1.99	116
5148	121	130	–23.4	13,174	53					13,174	53		126
5149	131	140	–23.3	12,852	67	13,018	103			12,901	56	1.35	136
5150	141	150	–23.4	13,012	53					13,012	53		146
5151	151	160	–24.2	12,764	67					12,764	67		156
5152	161	170	–24.3	13,072	69	13,036	104			13,061	57	–.29	166
5153	171	180	–24.9	13,008	53					13,008	53		176
5154	181	190	–25.1	12,825	67	12,939	103			12,859	56	.93	186
5155	191	200	–25.3	12,946	68	12,843	124			12,922	60	–.73	196
5156	201	210	–24.7	12,906	52					12,906	52		206
5157	211	220	–24.4	12,947	68	13,054	104			12,979	57	.86	216
5158†	221	257	–23.5	12,992	68					12,992	68		239
5142§	1	50	–26.8	12,195	65	12,227	98						
						Averages				13,000		.22	141

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TABLE 1. (Continued)

SUA- no.	Tree-ring span years	^{13}C (‰)	Counter 1 (yr BP)	± σ	Counter 2 (yr BP)	± σ	Counter 3 (yr BP)	± σ	Combined (yr BP)	± σ	z-stat	Center ring
*SRT-157**												
5022**	156 205	-23.1					12,390	80				181
5028†	86 110	-26.7					12,870	90				98
5104**	1 60	-25.7	12,747	67	12,821	102			12,769	56	.61	31
5105†	61 85	-25.6	12,734	67					12,734	67		73
5106†	86 110	-25.6	12,940	68	12,815	102			12,902	57	-1.02	98
5107	111 120	-24.4	12,685	67	12,569	92			12,645	54	-1.02	116
5108	121 130	-24.6	12,682	67	12,862	124			12,723	59	1.28	126
5109	131 140	-24.7	12,600	66					12,600	66		136
5110	141 150	-24.7	12,779	67					12,779	67		146
5042	151 160	-23.6	12,593	99					12,593	99		156
5043	161 170	-22.0					12,667	118	12,667	118		166
5044	171 180	-22.7	12,792	83			12,726	113	12,769	67	-.47	176
5054	181 190	-23.3	12,692	67	12,507	98			12,633	55	-1.56	186
5136	191 200	-24.9	12,499	66	12,373	90			12,455	53	-1.13	196
5137	200 210	-25.0	12,543	66	12,464	99			12,519	55	-.66	205
5138	211 220	-25.7	12,507	66	12,622	100			12,542	55	.96	216
5139	221 235	-24.8	12,500	66	12,404	99			12,470	55	-.81	228
5111§	236 260	-25.4	11,974	64								
5175§	236 260	-24.2	10,861	59								
					Averages				12,653		-.38	149

*10–ring samples unless otherwise noted
**50– or 60–ring sample
†25– or 36–ring sample
‡15–ring sample
§rejected ^{14}C datum

TABLE 2. Radiocarbon Dates From Stanley River Celery-top Pine Log, SRT-444*

SUA-	Tree rings		^{13}C	Counter 1		Counter 2		Combined			Center	Dendro
no.	span years		(‰)	yr BP	± σ	yr BP	± σ	yr BP	± σ	z-stat	ring	yr BP
5088**	307	350	−23.0	7178	48	7115	70	7158	40	−.74	329	7932
5112	301	310	−24.2	7200	48			7200	48		306	7955
5113	291	300	−24.3	7242	48	7189	83	7229	42	−.55	296	7965
5114	281	290	−24.1	7170	48	7186	70	7175	40	.19	286	7975
5115	271	280	−24.3	7130	48	7077	70	7113	40	−.62	276	7985
5116R	261	270	−24.3	7146	48	7154	70	7149	40	.09	266	7995
5117	251	260	−24.6	7003	48	7076	70	7026	40	.86	256	8005
5118	241	250	−24.5	7148	48	7247	71	7179	40	1.16	246	8015
5119	231	240	−24.8	7226	48	7087	70	7182	40	−1.64	236	8025
5120	221	230	−24.7	7221	48	7371	71	7268	40	1.75	226	8035
5121	211	220	−24.4	7253	48	7270	66	7259	39	.21	216	8045
5122	201	210	−24.9	7306	48	7385	66	7333	39	.97	206	8055
5123	191	200	−24.5	7340	48	7336	84	7339	42	−.04	196	8065
5124	181	190	−24.6	7398	49	7497	72	7429	41	1.14	186	8075
5125	171	180	−24.4	7363	49	7425	71	7383	40	.72	176	8085
5126	161	170	−25.3	7399	49	7484	72	7426	41	.98	166	8095
5127	151	160	−25.3	7337	48	7476	66	7385	39	1.70	156	8105
5128	141	150	−25.0	7240	48	7360	71	7278	40	1.40	146	8115
5129	131	140	−25.6	7398	49	7460	66	7420	39	.75	136	8125
5130	121	130	−25.4	7383	49	7363	66	7376	39	−.24	126	8135
5131	111	120	−25.1	7297	48	7398	71	7329	40	1.18	116	8145
5132	101	110	−25.0	7367	49	7479	72	7402	41	1.29	106	8155
5133†	76	100	−24.9	7317	48	7344	71	7325	40	.32	88	8172
5134†	51	75	−25.6	7389	49	7598	72	7455	41	2.40	63	8197
5135**	1	50	−25.2	7455	49	7541	72	7482	41	.99	26	8235
5116‡	261	270	−24.4	6262	48	6146	67					
						Averages		7292		.59	193	

*10-ring samples unless otherwise noted
**44- or 50-ring sample
†25-ring sample
‡rejected radiocarbon datum

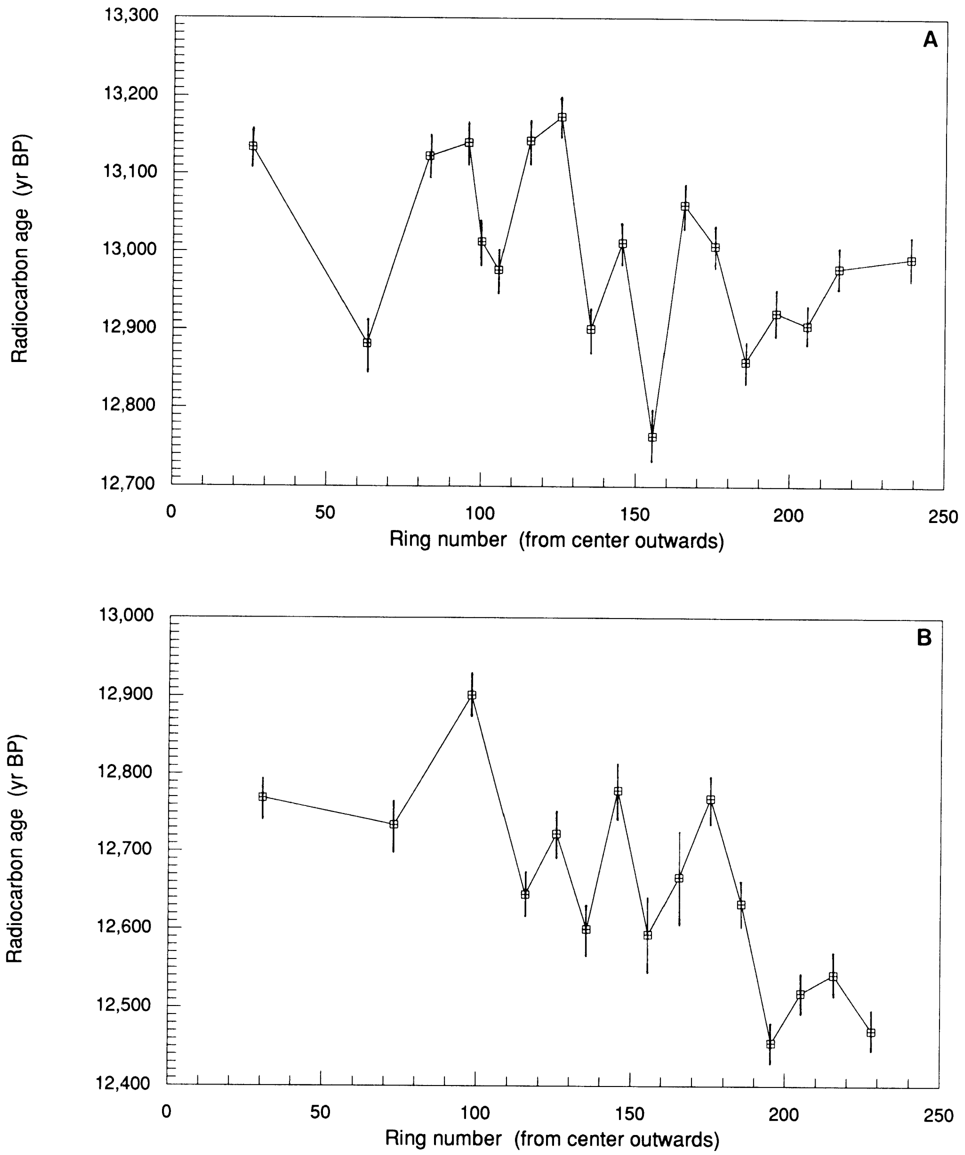

Fig. 1. ^{14}C ages from Stanley River celery-top pine logs, SRT-462 (A) and SRT-157 (B). The data are combined results from measurements in two liquid scintillation counters.

droyears BP. At that position, the SRT-444 data were an average of 14 yr younger than the oak data, with an rms difference of 61 yr. We also examined the robustness of the fit by adding or subtracting an arbitrary 50 or 100 yr to all the SRT-444 ^{14}C data, but did not find a better fit. The bristlecone pine data covered only part of the region of interest, and was insufficient to allow a formal fitting procedure.

Results for the period, AD 1600–1800 (SRT-31B and SRT-225 in Table 3), indicated small systematic differences between the counters. The results from Counter 3 (measured 1986/87) were generally older than those from Counter 1, whereas the results from Counter 2 (measured 1987/88)

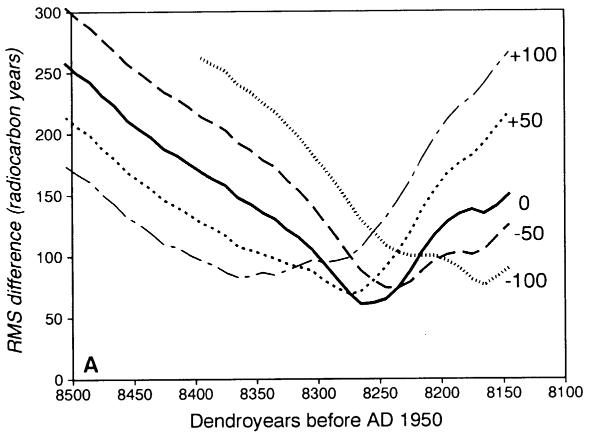

Fig. 2A. Rms differences between the ^{14}C ages measured for SRT-444 and a smoothed (decadal) representation of the German oak data. The minimum difference occurs when ring 0 of SRT-444 is placed at 8260 yr BP. Adding or subtracting an arbitrary 50 or 100 yr to all the SRT-444 ^{14}C data gives a poorer fit between the data sets.

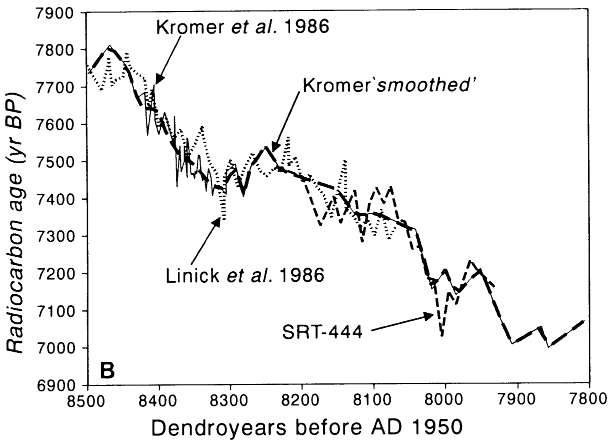

Fig. 2B. ^{14}C ages from Stanley River celery-top pine log, SRT-444 (--); combined results from two counters. The measurements are compared with data from the unified German oak series with ring 0 placed at 7230 BC, *i.e.*, 9179 BP (Kromer *et al.* 1986; —) and a smoothed representation of the German oak data (— —). SRT-444 is shown with ring 0 placed at 8260 yr BP, which gives the best match to the German oak data. Bristlecone pine data from the USA (Linick *et al.* 1986; IIII) are also shown.

were younger. The results from Counter 1 alone are therefore used in Figure 3, where they show good agreement with the high-precision decadal data of Stuiver and Becker (1986). There are no significant differences in phase or amplitude of the variations. However, our data are, on average, slightly younger than the corresponding northern hemisphere data, and not older by *ca.* 36 yr, as would be expected from other comparisons of northern and southern hemisphere wood (Lerman, Mook & Vogel 1970; Vogel *et al.* 1986). Since the northern and southern hemisphere measurements were made in different laboratories, we considered the possibility of an error in the modern standard determination in our laboratory. Thus, two of our pretreated wood samples were sent to Seattle for measurement; those results coincide with northern hemisphere data (Fig. 3).

Discussion and Conclusion

Comparisons of conventional ^{14}C ages with results from other dating methods provide data on ^{14}C calibration for the late Pleistocene. Uranium-thorium data have been published by Bard *et al.* (1990); varve data by Stuiver (1971) and Stuiver *et al.* (1986); and summaries of thermoluminescence data were given by Barbetti (1980) and Aitken (1987). These data are summarized in Figure 4.

TABLE 3. Radiocarbon Dates From Stanley River Huon Pine Trees, SRT-31B, SRT-40 and SRT-225*

SUA- no.	Tree ring span yr AD		^{13}C (‰)	Counter 1 yr BP	± σ	Counter 2 yr BP	± σ	Counter 3 yr BP	± σ	Combined yr BP	± σ	z-stat	Dendro yr AD
SRT-31B													
5047	1610	1614	-22.5	342	50			405	55	371	37	.85	1612
5048	1615	1619	-22.7	399	50			414	57	406	38	.20	1617
5049	1620	1624	-23.0	329	50			388	58	354	38	.77	1622
5050	1625	1629	-22.5	311	50			376	57	339	38	.86	1627
5051	1630	1634	-22.7	313	50			384	57	344	38	.94	1632
5052	1635	1639	-22.5	273	50			264	56	269	37	−.12	1637
5056	1640	1644	-23.1	320	35	303	61			316	30	−.24	1642
5057	1645	1649	-21.9	258	35	180	55			236	30	−1.20	1647
5058	1650	1654	-23.0	258	33	274	53			262	28	.26	1652
5059	1655	1659	-22.4	166	34	167	55			166	29	.02	1657
5060	1660	1664	-22.8	158	34	197	55			169	29	.60	1662
5061	1665	1669	-24.6	144	34	154	55			147	29	.15	1667
5062**	1670	1694	-25.4	120	34	126	53			122	29	.10	1682
5063†	1695	1704	-25.2	72	34	10	61			57	30	−.89	1700
5064†	1705	1714	-25.8	88	34	21	55			69	29	−1.04	1710
5065†	1715	1724	-25.9	142	34	87	61			129	30	−.79	1720
5066†	1725	1734	-25.8	102	34	29	55			82	29	−1.13	1730
5067†	1735	1744	-24.7	158	34	116	55			146	29	−.65	1740
5068†	1745	1754	-24.8	191	34	153	61			182	30	−.54	1750
5069†	1755	1764	-25.2	158	34	143	55			154	29	−.23	1760
5070†	1765	1774	-25.1	163	34	69	61			141	30	−1.35	1770
5071	1775	1779	-24.9	118	34	104	55			114	29	−.22	1777
5072	1780	1784	-24.5	175	34	63	55			144	29	−1.73	1782
5073	1785	1789	-23.9	209	34	75	55			172	29	−2.07	1787
5074	1790	1794	-24.3	230	34	145	55			206	29	−1.31	1792
5075	1795	1799	-24.5	174	34	144	55			166	29	−.46	1797
5076	1800	1804	-24.8	99	34	120	55			105	29	.32	1802

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TABLE 3. (Continued)

SUA-no.	Tree ring span yr AD		^{13}C (‰)	Counter 1 yr BP	± σ	Counter 2 yr BP	± σ	Counter 3 yr BP	± σ	Combined yr BP	± σ	z-stat	Dendro yr AD
SRT-40													
5077‡	1350	1399	-21.5	566	35	524	55			554	30	−.64	1375
SRT-225													
5085†	1601	1610	-24.6	358	35	297	55			340	30	−.94	1606
5086†	1611	1620	-24.7	294	35	359	55			313	30	1.00	1616
SRT-31B (Stuiver, personal communication 1992)													
†	1660	1664		208	14								1662
	1765	1774		174	15								1770

*5-ring sample unless otherwise noted
**25-ring sample
†10-ring sample
‡50-ring sample

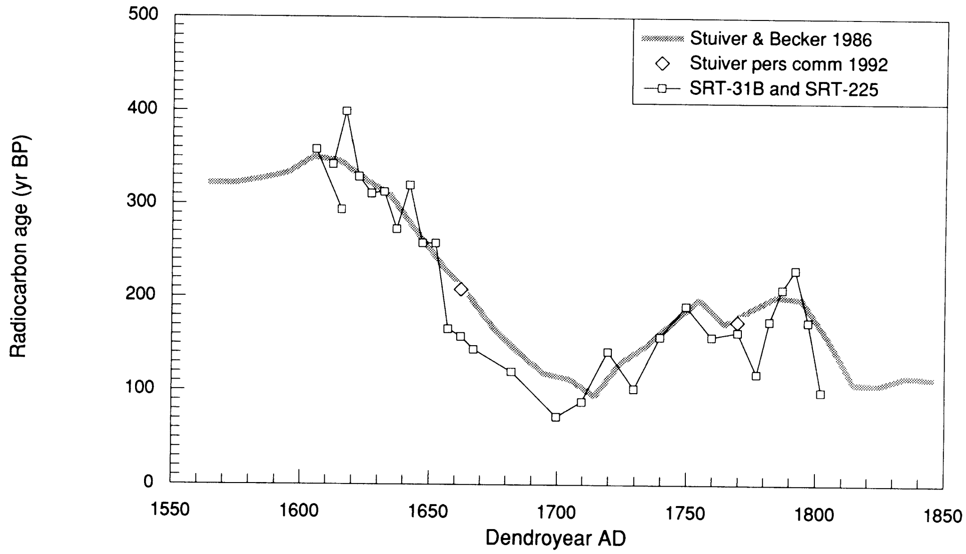

Fig. 3. ^{14}C ages from Stanley River Huon pine trees, SRT-31B and SRT-225, for the period AD 1600–1800; Counter 1 data only. The results are compared with the high-precision decadal curve of Stuiver and Becker (1986). Two measurements were made on our samples by Minze Stuiver (◇).

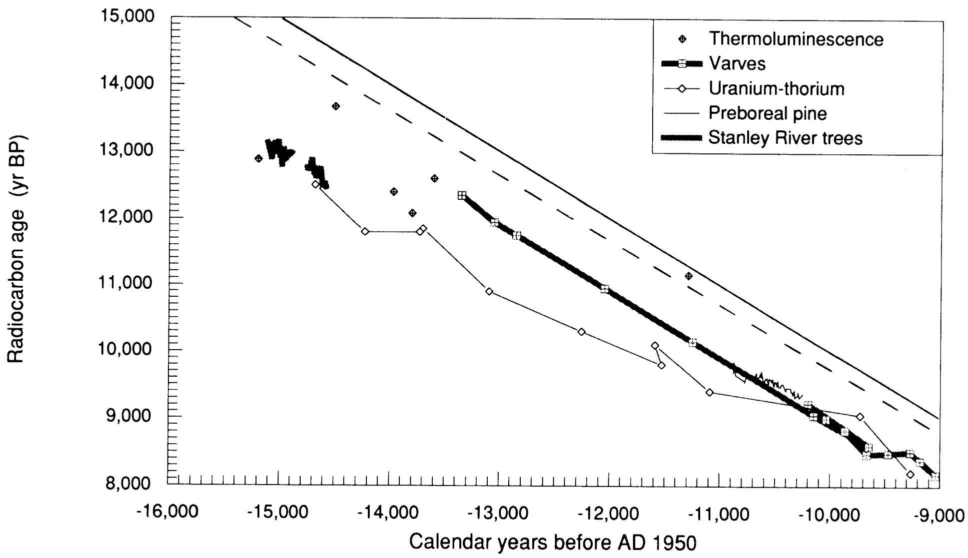

Fig. 4. Comparison of conventional ^{14}C ages with other dating methods for part of the late Pleistocene and early Holocene. The solid line would be the ideal relationship if conventional ^{14}C ages were always equal to true ages, and the dashed line shows the deviation expected for the 5568-yr half-life. The U-Th data are from Bard *et al.* (1990), the varve data from Stuiver (1971) and Stuiver *et al.* (1986), and the TL data from Barbetti (1980) and Aitken (1987). ^{14}C data from southern Germany (Becker & Kromer 1986) are from a floating Preboreal tree-ring sequence, shown here on the assumption that the ^{14}C ages are, on average, 1 ka too young (*i.e.*, ring 0 for the Preboreal pine is tentatively placed at 9031 BC or 10,980 BP). The Stanley River data from SRT-462 and SRT-157 are shown here on the assumption that ^{14}C ages are 2 ka too young.

Virtually all data indicate that ^{14}C ages are younger than true ages during the late Pleistocene, with probable differences ranging from 2.6 ka at 15 ka BP to 0.9 ka at 10 ka BP (Stuiver *et al.* 1991).

^{14}C data from the Stanley River and from German Preboreal pine (Fig. 4) show trend changes on a time scale of 1 or 2 centuries, such as those seen throughout the Holocene. The Preboreal data also show a plateau in the calibration curve with nearly constant ^{14}C ages (9600 BP) over several centuries in early Holocene time.

Tasmanian ^{14}C data from SRT-444 have been wiggle-matched with German oak data. With ring 0 of the oak data at 7230 BC (Kromer *et al.* 1986), our match places ring 0 of SRT-444 at 8260 dendroyears BP. With that match, our data appear to be slightly, but not significantly, younger than the northern hemisphere data.

Our data from the southern hemisphere for the period, AD 1600–1800, also indicate little or no offset in ^{14}C concentration when compared with northern hemisphere data. These minimal apparent offsets, at around 8.1 k dendroyears BP, and again, in recent centuries, would provide an important constraint on global carbon models if confirmed by further measurements.

Detailed intercomparisons with other laboratories are being planned, and it should be possible eventually to estimate precisely the offset between the northern and southern hemispheres during early and mid-Holocene time.

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