SEGMENTS OF ATMOSPHERIC ^{14}C CHANGE AS DERIVED FROM LATE GLACIAL AND EARLY HOLOCENE FLOATING TREE-RING SERIES

BERND KROMER,[1] MARCO SPURK,[2] SABINE REMMELE,[2] MIKE BARBETTI[3] and VLADIMIRO TONIELLO[4]

ABSTRACT. We present results of ^{14}C dating of several tree-ring series from the Late Glacial and Early Holocene, analyzed at the Heidelberg University radiocarbon laboratory. Although these are floating series, they contribute high-resolution information about the variability of atmospheric ^{14}C during those periods.

INTRODUCTION

At the Heidelberg University Radiocarbon laboratory a number of tree-ring sections and corresponding chronologies have been analyzed, covering intervals in the Late Glacial and the Early Holocene. These sections are floating, yet due to their annual resolution and the high precision of the ^{14}C analyses, they provide valuable information on temporal changes in atmospheric ^{14}C levels. Furthermore, they serve to identify intervals of anomalous ^{14}C calibration patterns.

SITES AND EPISODES STUDIED

Revine Site (14.3–15.1 ka BP)

The quarry near the lakes of Revine (Treviso, Italy) was studied in an interdisciplinary project between 1972 and 1976 by Casadoro *et al.* (1976). In the quarry more than 70 *Larix* sections were found, of which 13 were used to construct a 304-ring chronology (Corona 1984); below, we call this chronology Revine 3. Two wood samples were dated in the Hannover ^{14}C laboratory, confirming the Late Glacial age of the sequence. In 1994 we became aware of the site, which had been abandoned by that time. The remaining sections collected by us were analyzed dendrochronologically at the Hohenheim tree-ring laboratory, resulting in two more chronologies of 219 and 151 rings, respectively, named Revine 1 and Revine 2.

For the Revine chronologies we measured a sequence of ^{14}C dates. Revine 1 and 2 (Table 1) span the interval 15,150–14,750 BP. From the ^{14}C ages they appear to be coincident. Revine 3 (Table 2) covers the interval of 14,400–14,270 BP. The data of the three chronologies are plotted, in a composite plot, in Figure 1.

Based on these ^{14}C dates, the Revine *Larix* forest grew, and was ultimately buried by loamy deposits, following the last Glacial maximum. As marine ^{14}C dates place the Heinrich 1 event in the 15 ka BP range, bridging the interval between the two early chronologies and the younger one with additional findings should provide precise information on the relative $\Delta^{14}C$ change in this crucial time period.

Mid- and Late-Allerød sections

The 406-ring mid-Allerød chronology was constructed by the late Bernd Becker. The ^{14}C data (Table 3 and Fig. 2) show evidence for a *ca.* 200-yr-long ^{14}C age plateau at 11,550 BP followed by a rapid decline at younger ages.

[1]Heidelberg Academy of Sciences, Institute of Environmental Physics, INF 366, D-69120 Heidelberg, Germany
[2]Institute of Botany, University of Hohenheim 210, D-70593 Stuttgart, Germany
[3]NWG Macintosh Centre for Quaternary Dating, Madsen Building F09, University of Sydney, NSW 2006, Australia
[4]Via Settembrini 109, I-31015 Conegliano, Italy

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TABLE 1. ^{14}C dates of the Revine 1 and 2 Chronologies

Lab code (Hd-)	Chronology	Tree	Ring interval	^{14}C age (yr BP)
17685	1	50	41–60	15,143 ± 30
17871	1	56	61–80	15,087 ± 40
17193	1	50	132–155	14,978 ± 35
17676	2	103	21–40	14,848 ± 30
17873	2	103	41–60	15,054 ± 30
17875	2	103	61–80	15,009 ± 35
16802	2	103	77–83	14,812 ± 30
17854	2	101	79–99	14,736 ± 35
16801	2	101	100–120	14,766 ± 35

TABLE 2. ^{14}C Dates of the Revine 3 Chronology

Lab code (Hd-)	Ring interval	^{14}C age (yr BP)
16494	5–19	14,379 ± 30
18690	20–29	14,380 ± 30
16640	30–39	14,483 ± 30
18700	40–49	14,332 ± 30
16646	50–59	14,401 ± 30
16645	70–79	14,398 ± 25
16666	90–99	14,321 ± 30
16509	110–119	14,272 ± 30
16743	120–129	14,320 ± 30

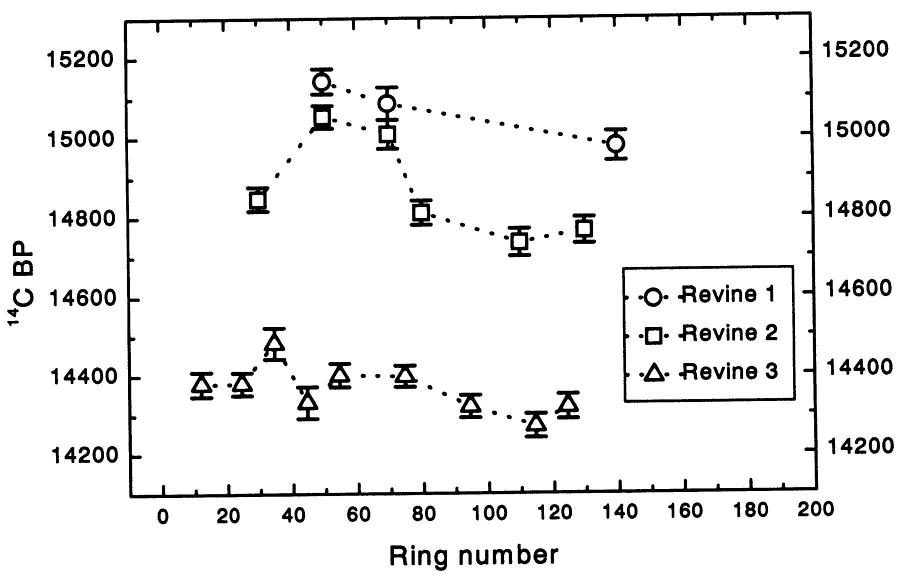

Fig. 1. ^{14}C dates of the Revine chronologies. Note that the sections are not synchronized dendrochronologically, but are plotted on a common ring scale for convenience.

TABLE 3. ^{14}C dates of the Mid-Allerød Pine Chronology (trees from the Danube, Günz and Isar rivers, southern Germany)

Lab code (Hd-)	Tree	Rings on tree	Center ring in chronology	^{14}C age (yr BP)
12068	Pfuhl 22	31–39	58	11,690 ± 24
12091	Pfuhl 22	41–44	65	11,663 ± 29
9295	Burlafingen Horn 104	28–32	82	11,622 ± 28
12092	Pfuhl 22	61–64	85	11,636 ± 31
12106	Pfuhl 22	86–89	110	11,674 ± 29
12115	Pfuhl 22	111–114	136	11,540 ± 30
12116	Pfuhl 22	136–139	160	11,569 ± 49
12151	Pfuhl 22	181–189	208	11,561 ± 37
13105	Freising 676	113–133	177	11,591 ± 30
12122	Pfuhl 22	151–159	178	11,569 ± 35
12267	Pfuhl 22	161–169	188	11,564 ± 26
16218	Pfuhl 26	200–205	202	11,570 ± 21
12151	Pfuhl 22	181–189	208	11,560 ± 37
16258	Pfuhl 26	221–225	223	11,536 ± 21
16234	Pfuhl 26	241–245	243	11,606 ± 27
16162	Pfuhl 26	261–265	263	11,516 ± 23
16227	Pfuhl 26	281–290	283	11,537 ± 27
16222	Pfuhl 26	301–310	303	11,520 ± 30
16257	Pfuhl 26	321–330	323	11,493 ± 24
16233	Pfuhl 26	361–370	363	11,379 ± 30

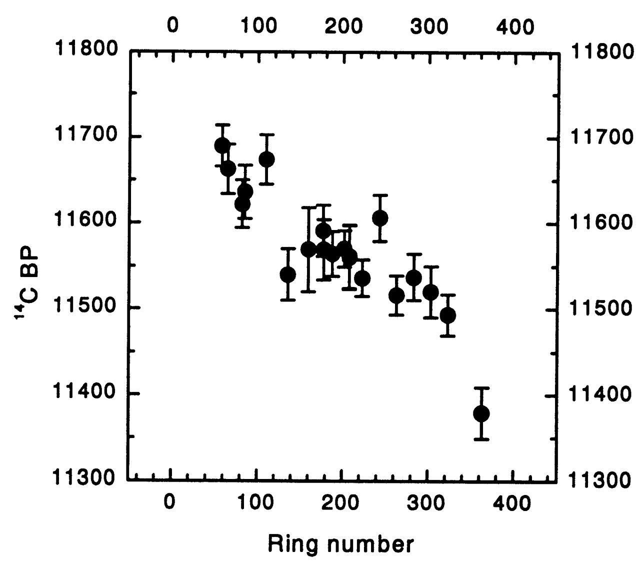

Fig. 2. ^{14}C dates of the mid-Allerød chronology

For the end of the Allerød period we have measured four tree sections recovered from quarries in southern Germany and along the river Po, which are not synchronized dendrochronologically but cover a common ^{14}C range (Table 4, Fig. 3). They document remarkably constant ^{14}C ages at 11,050 and 10,950 BP, respectively, extending over more than a century. This observation may be important with respect to the age of the Laacher eruption, as discussed next.

TABLE 4. ^{14}C Sequences of Four Late-Allerød Sections Showing a Remarkably Constant ^{14}C Age at 10,950–11,050 ^{14}C BP

Lab code (Hd-)	Ring interval	^{14}C age (yr BP)
Avigliana 9 (Dora Riparia River, Torino, Italy)		
12588	41–44	10,955 ± 28
12600	56–59	10,900 ± 30
12601	71–74	10,950 ± 32
12617	86–89	10,982 ± 38
12618	101–104	10,919 ± 31
12619	116–119	10,980 ± 27
12640	126–129	10,979 ± 33
Breitenthal 6 (Günz, southern Germany)		
17782	1–20	11,045 ± 23
17742	21–40	11,101 ± 21
17735	41–60	11,152 ± 30
17736	71–90	11,149 ± 21
Burlafingen 61 (Danube, southern Germany)		
17364	31–50	11,058 ± 22
17373	51–70	11,013 ± 25
17357	71–90	11,072 ± 22
17358	91–110	11,029 ± 33
Wörth 152 (Isar River)		
17780	1–20	11,103 ± 23
17847	21–40	11,079 ± 33
17853	51–70	11,079 ± 32
17845	71–90	11,059 ± 31

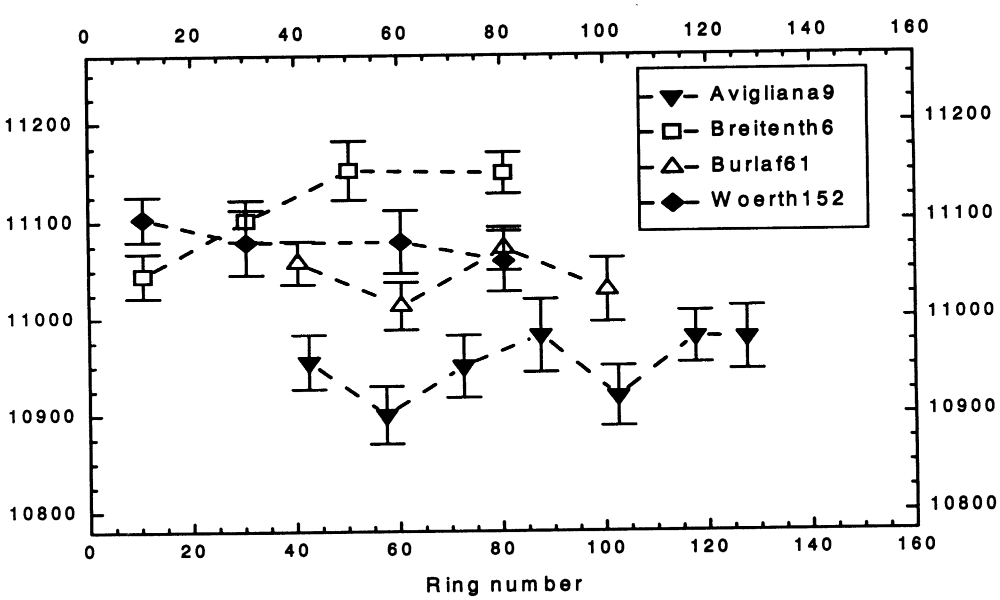

Fig. 3. ^{14}C dates of the late-Allerød sections. (Sections plotted as in Fig. 1.)

Laacher See Eruption

The Laacher See Tephra (LST) is an important late-Allerød time marker for central and northern Europe. Its ^{14}C age has been determined repeatedly, leading to a range of 11,300–11,000 BP (Hajdas *et al.* 1995). We attempted to narrow this range by dating wood sections buried in the tephra close to the site of the eruption (at a maximum distance of several kilometers). We collected samples of branches of cherry (*Prunus padus*) embedded in the Brohltal tephra ("trass"), and we obtained sections of poplar trees excavated from the tephra at Kruft, close to the Allerød base of the tephra. The Kruft sections were analyzed dendrochronologically at the Hohenheim laboratory and cut into decadal samples. The (charred) sections had 50–60 rings with bark preserved.

The ^{14}C results are summarized in Table 5. The results clearly show two groups of data: the Brohltal samples have dates in the 11,225 BP range, whereas the sections of Kruft cluster at 11,060 BP with a narrow range of <40 yr. The same ^{14}C age range was obtained from wood fragments collected close to Leipzig, Germany and submitted by A. Hiller, which come from strata immediately above and below the LST.

TABLE 5. Laach Eruption, ^{14}C dates of Ring Sections from Buried Trees and Branches

Lab code (Hd-)	Name	Rings/position	^{14}C age (yr BP)
17900	Brohltal 1/4	1–38	11,277 ± 26
17100	Brohltal 1a	*ca.* 50 rings	11,206 ± 20
17145	Brohltal 3a	*ca.* 50 rings	11,223 ± 22
17101	Brohltal 5b	*ca.* 50 rings	11,121 ± 28
18648	Kruft 1	31–40	11,037 ± 27
19098	Kruft 9	1–20	11,063 ± 30
19092	Kruft 9	21–30	11,066 ± 28
18622	Kruft 9	31–40	11,073 ± 33
19037	Kruft 9	41–50	11,075 ± 28
18438	Kruft 8	Outermost rings	11,065 ± 22
17132	Kru - 16*	Below LST	11,055 ± 23
17131	Kru - 18C*	Above LST	11,058 ± 22

*Submitted by A. Hiller, Leipzig

We interpret the age difference as a result of the familiar "old wood" problem, *i.e.*, the Brohltal samples may have been dead for several decades before the time of the eruption. If the 11,060 ^{14}C yr age range is part of a ^{14}C age plateau as observed above, we may expect to find strongly sloping ^{14}C ages prior to this range, which would explain the rather wide range of LST ^{14}C ages found in the literature.

Interhemispheric ^{14}C Gradient in the Early Holocene

The atmospheric ^{14}C offset between the Northern and Southern Hemisphere is of considerable interest for atmospheric and ocean circulation studies as well as for isotope constraints on the global carbon cycle (Braziunas, Fung and Stuiver 1995). The interhemispheric ^{14}C offset may have been considerably lower in the past than what is observed today (*ca.* 40 yr) (Barbetti *et al.* 1992; Sparks *et al.* 1995). We attempted to obtain information on the relative change of the north-south ^{14}C offset by wiggle-matching a floating Tasmanian pine section to the Hohenheim German oak and pine chronologies. The idea was that the length of the section (457 rings) should be sufficient to wiggle-match it to the German oak chronology, even with the added degree of freedom caused by a possible variability of the north-south gradient.

The ^{14}C data for the Huon pine (SRT 416) are tabulated in Table 6. For the wiggle-match only a small window exists, due to the ^{14}C age inversion at the oldest rings of the Huon pine. The placement best matching the overall structure is shown in Figure 4. It is apparent that the result is compatible with an interhemispheric gradient of several decades for most of the common range of the data sets, yet at the time of peak atmospheric ^{14}C activity, corresponding to the apparent ^{14}C age inversion at 10,100 cal BP, the north-south offset seems to have vanished. This conclusion is not affected by the uncertainty in the wiggle-match, as any other placement would still result in identical ^{14}C ages in the two hemispheres for this period.

TABLE 6. ^{14}C Series of the Huon Pine SRT 416

Lab code (Hd-)	Ring start	Ring end	^{14}C age (yr BP)	$\delta^{13}C$
18300	1	20	8834 ± 32	-25.51
18341	20	30	8807 ± 24	-26.05
18177	30	40	8896 ± 28	-25.73
18221	40	50	8852 ± 25	-25.78
18875	50	60	8901 ± 21	-26.86
18876	60	70	8971 ± 20	-26.84
18877	70	80	8984 ± 23	-26.12
18890	80	90	8992 ± 38	-25.96
18896	90	100	8956 ± 22	-26.13
18928	100	110	8852 ± 38	-25.95
18929	110	120	8982 ± 18	-25.41
18983	140	150	8969 ± 25	-25.10
18992	160	170	8945 ± 21	-24.37
18964	210	220	8916 ± 19	-24.59
18884	220	230	8879 ± 21	-23.83
18991	230	240	8876 ± 19	-23.47
18959	240	250	8836 ± 24	-23.42
18988	280	290	8931 ± 19	-22.47
18672	300	310	8850 ± 21	-24.46
18697	310	320	8870 ± 21	-24.33
18677	320	330	8846 ± 20	-24.54
18680	330	340	8846 ± 20	-24.03
18695	340	350	8861 ± 20	-24.10
18839	350	360	8830 ± 24	-24.03
18833	360	370	8738 ± 19	-23.84
18844	370	380	8759 ± 23	-23.66
18699	380	390	8771 ± 19	-23.40
18696	390	400	8792 ± 21	-23.34
18636	400	410	8803 ± 22	-23.22
18342	410	420	8785 ± 21	-23.05
18227	420	430	8692 ± 21	-22.92
18229	430	440	8763 ± 20	-23.19

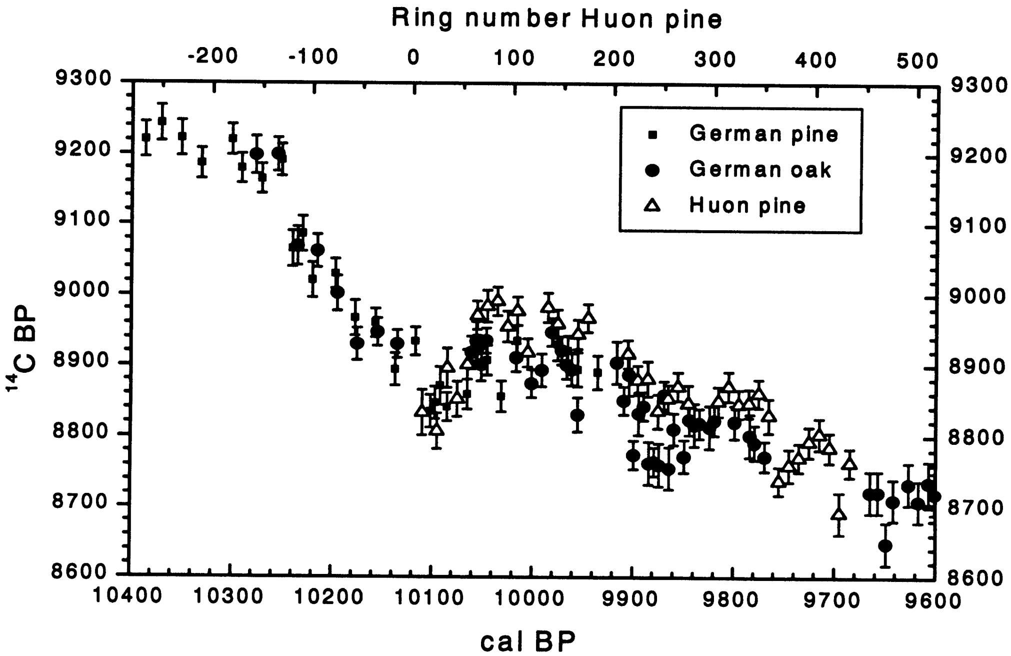

Fig. 4. ^{14}C series obtained from the floating Huon pine SRT416, compared to the German oak and pine chronologies. The best match is obtained when ring 1 of SRT416 is set to 10,120 cal BP. The interhemispheric offset seems to vanish around 10,100 cal BP.

Conclusion

^{14}C series from tree-ring sections, even when floating, can provide high-resolution information about the variability of the atmospheric ^{14}C level. We hope that these sections, when combined with other sections in this age range, will ultimately help in the reconstruction of the Late Glacial and early Holocene ^{14}C pattern.

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