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2003 – where is the negative pointer year? A case study for the NW-German low mountain ranges

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Introduction

From a climatological point of view, 2003 was one of the extremest years since the beginning of meteorological measurements. A long period of dryness and high temperatures led to extreme deficiencies in water availability in larger parts of Central Europe (Anders et al. 2004). In general, such weather conditions cause negative effects on tree growth, expressed in altered plant physiological responses (Herbst & Hormann 1998, Elling & Dittmar 2004), and consequently in narrow tree rings (Lebourgeois et al. 2005). But in respect to the record year 2003, drought resistance and resilience of European leafwood trees has been discussed controversially (Rennenberg et al. 2004, Kölling et al. 2005), especially in view of the anticipated climatic changes (Beniston & Innes 1998, Gerstengarbe & Werner 2005). As reported by Kahle (2006) radial growth of beech trees at high elevations in the Black Forest was only slightly affected by the exceptional weather conditions in the year 2003.

This recent study investigates the effects of the record year 2003 on tree-ring widths of beechs (*Fagus sylvatica*) and oaks (*Quercus petraea* and *Q. robur;* both are combined to one species) in southern regions of Nordrhein-Westfalen in West Germany. The growth responses to the weather conditions in 2003 will be compared with the responses of beeches and oaks in other extreme years of the last century by using a pointer year analysis.

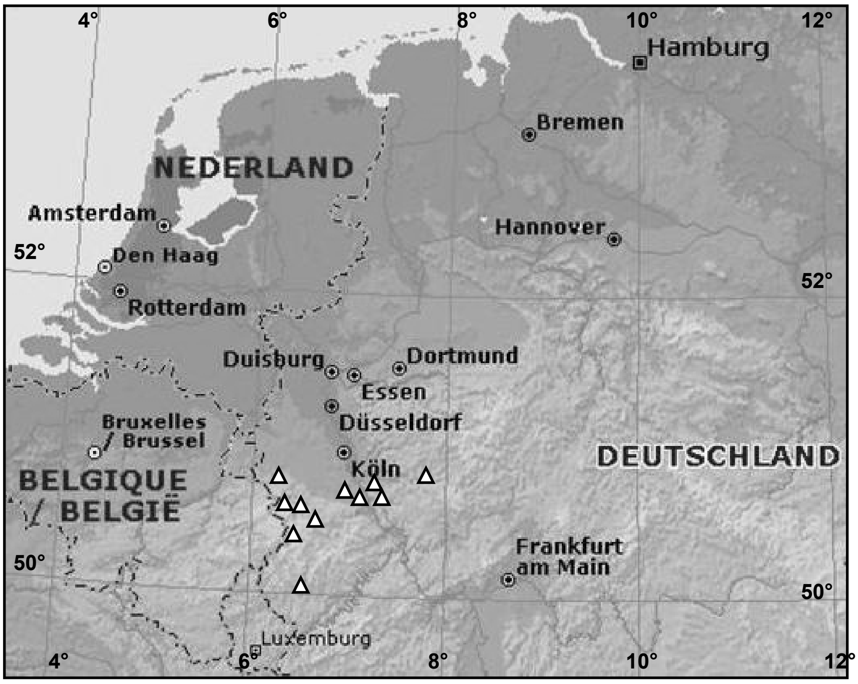

Figure 1: Map of NW-Germany with locations of dendrochronological sites. The triangles represent stands for oak and beech chronologies.

Data and methods

Dendrochronological data

The research area (Fig. 1) of the present study is located in north-western Germany between 50° to 51° N and 6° to 8° E, representing the Eifel, the so called “Köln-Bonner Bucht” with the Siebengebirge and the valley of the river Sieg in the east of Cologne. Twelve oak and 10 beech stands were selected representing the whole ecological spectrum of closed forest in the research area. The sites are located in a N-S and W-E transect covering altitudes from 100 to nearly 600 m a.s.l.. All sites consist of mature, mixed-species stands and all sampled trees belong to the crown classes ‘co-dominant’ and ‘dominant’. Table1 illustrates site topographic and dendrochronological characteristics of the 22 sampling sites.

Table 1: Characterisation of the dendrochronological sampling sites

subregion	location	latitude / longitude	altitude/ exposition/ inclination	code	species	length of chrono
Vulkaneifel	Holzmaar	50°07’10’’ / 6°52’30’’	430 / S / 10-20	dpe01	QUPE	1821-2004
				dpe02	FASY	1822-2004
Bonn	Kottenforst	50°42’19’’ / 7°05’21’’	170 / WSW / 8	drb01	QURO	1852-2004
	Melbtal	50°42’22’’ / 7°05’04’’	140 / W / 35-40	drb02	QURO	1802-2004
Siebengebirge	Fritschesberg	50°39’45’’ / 7°14’10’’	250 / W / 10	drb04	QURO	1860-2004
	Lohrberg S	50°40’10’’ / 7°14’58’’	375 / N / 40	drb05	FASY	1851-2004
				drb06	QURO	1847-2004
	Lohrberg N	50°40’12’’ / 7°14’46’’	340 / S / 45	drb07	QURO	1868-2004
				drb08	FASY	1850-2004
Nordeifel	Hürtgenwald	50°46’13’’ / 6°21’58’’	290 / NNW / 15	dre01	QUPE	1828-2004
				dre02	FASY	1822-2004
Rureifel	Schäferheld	50°36’35’’ / 6°27’25’’	520 / NW / 20	dre03	FASY	1823-2004
	Wiegelkammer	50°36’26’’ / 6°29’25’’	450 / E / 15	dre05	FASY	1858-2004
	Weidenauer B.	50°37’25 / 6°23’30’’	370 / NW / 40	dre09	QUPE	1808-2004
	Im Brand	50°34’14’’ / 6°21’37’’	500 / SE / 20	dre10	FASY	1817-2004
				dre11	QUPE	1834-2004
		50°34’15’’ / 6°21’49’’	470 / SSE / 30	dre12	FASY	1818-2004
Kalkeifel	Hütterbusch	50°26’27’’ / 6°33’56’’	575 / E / 5-10	dre06	QUPE	1848-2004
Hohes Venn	Kreitzberg	50°40’52’’ / 6°16’38’’	440 / NE / 0-5	dre07	QUPE	1806-2004
				dre08	FASY	1858-2004
Siegtal	Wasserfall	50°48’19’’ / 7°35’25’’	140 / SW / 40	drs02	FASY	1872-2005
	Bodenberg	50°48’49’’ / 7°35’57’’	200 / W / 35	drs03	QURO	1867-2005

For every tree, two increment cores from opposite directions were sampled at breast height. Using Lintab V measurement tables and the software package TSAPWin-Scientific version 0.53 (Rinn 2005) series of tree-ring widths with a 1/100 mm resolution were measured and averaged to tree-mean-curves. All trees are older than 130 years (last column of Tab. 1).

As Meyer (1998-1999) documented for spatial comparisons, indexation techniques which are based on a smoothing average are useful. Hence, in this study z-transformed pointer values C_z were calculated for all trees (Neuwirth 2005). This value leads to time series highlighting the anomalies against the mean radial growth for every site. Due to the high similarity of the resulting master plots between all beech sites and between all oak sites, respectively (not shown), the C_z -values were averaged for every species. In addition to the intensity of growth anomalies, only years with $C_z < -1.645$ were classified as negative pointer years. With respect to the probability density function of the standardized normal distribution, the probability for such years is lower than 5% (Neuwirth et al. 2007).

Climatological data

Temperature and precipitation values are obtained from gridded data in a spatial resolution of 10 minutes, over the time period 1901 to 2004, which were provided by the Climate Research Unit in Norwich/UK (Mitchell et al. 2004) by averaging all gridpoints of the research area. From these monthly mean curves temperature and precipitation anomalies were calculated as z-transformed residuals from the monthly mean values of the period 1961 to 1990. Thus, the resulting values are interpretable as standard deviations from the monthly mean values of the climate standard period.

Strategy

Because time series will be shortened at the beginning and at the end by the half of the filter-bandwidth using the Cropper-method, it is not possible to analyse the growth anomalies for the years 2003 and 2004. In case of a 5-year long bandwidth the last year for all series is 2002. Due to the advantages of a two side filter with respect to the detection and separation of different long-run behaviour (Riemer 1994), it is not reasonable, to evaluate climate forcings in pointer years by using a left-side moving average. Therefore, this study will be realized in two steps. At first, the z-transformed Cropper-values C_z for all sites is calculated for the 20th century as described above. This is followed by a pointer-year analysis where selected negative pointer years were compared with the climatic anomalies. After this, the crucial climatic events, related to the narrow tree rings, will be pointed out and classified into types of growth/climate responses for the 20th century. In a second step, the climatological situation of the year 2003 will be analysed and confronted with indexed growth chronologies for beechs and oaks for the time period from 2000 to 2004. For this, residuals against a left-side 3-year weighted moving average will be calculated. The comparision of the situation in 2003 with the types of growth/climate responses for the 20th century will give an explanation for the missing negative tree ring in 2003 especially in the beechs.

Results

Growth/climate responses in the 20th century

The calculations of pointer values as described before showed nearly the same site-related masterplots for beeches on the one hand and for oaks on the other hand. Thus, species specific masterplots were created by averageing the C_z-values of all beechs and the C_z-values of all oaks. The negative half of the combined materplot for beech and oak in the NW-German low mountain ranges is presented in figure 2a, where the ordinate represents the time scale beginning at the top with ad 1900 and ending at the bottom with ad 2000. The x-axis describes the C_z-values and ranges from 0 on the left hand to -3 on the right hand. In the 20th century beeches reacted in 9 years (1912, 1922, 1948, 1960, 1976, 1983, 1990, 1996, and 2000) with extreme negative pointer years (grey beams), while for oaks (black beams) only 8 negative pointer years (1909, 1921, 1942, 1947, 1959, 1968, 1976, and 1996) are signed (Fig. 2a). Only in the two years 1976 and 1996 (grey beams with black vertical stripes) both species show synchronous reactions.

For the interpretation of these negative pointer years comparisions with climatological anomalies in the year of tree reaction and the year before were made. Therefore, temperature (grey surfaces) and precipitation (black bars) against the monthly means of the period 1961 to 1990 are shown in figure 2b. On the right hand of the climate diagrams special anomalies, which are crucial for the narrow tree rings, are listed (Fig. 2c).

Regarding the listed interpretations for each species, three types of growth/climate responses can be classified.

Beeches have negative pointer years, if

- the growing season of the current year is cold and dry like in 1996;
- the growing season of the current year is hot and dry like in 1976 or 1983;
- the autumn of the year before was warm and dry and the end of the growing season of the current year is cold like in 1912, 1922, 1948, 1960, or 2000.

Oaks have negative pointer years, if:

- the growing season of the current year is cold and dry like in 1996;
- the autumn of the year before was cold and dry like in 1909 or 1942;
- the growing season of the current year is hot and dry like in 1921, 1947, or 1976.

Comparing the tree responses concerning only warm and dry weather conditions, beeches and oaks produce narrow rings after the same dryness periods. However, in the northwest German low mountain ranges beeches mostly react one year later than oaks like in 1921/22, 1947/48, or 1959/60. Only in 1976, both species react after a strong dryness period within the same year.

The start of the dryness period seems to be the crucial fact to explain the time-shift in growth response. In some years, the dryness period starts in February like in 1976, where for other years the dryness period starts in July or August like in 1921, 1947, or 1959. In the second case, tree-ring widths of beeches decrease not until the following growing season.

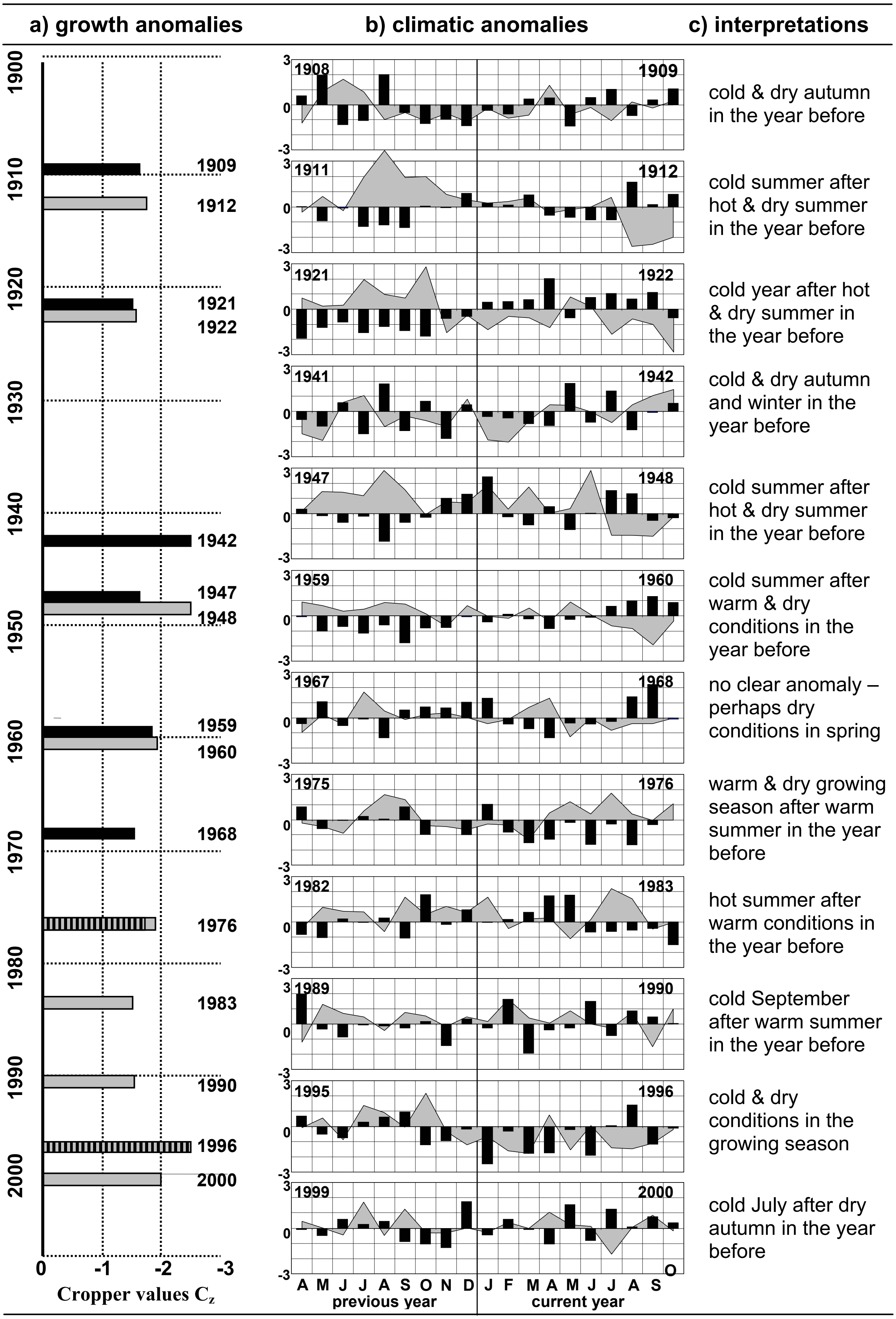

Figure 2: (a) Negative growth anomalies for beech (grey) and oak (black) from 1901 to 2000, (b) corresponding temperature (grey) and precipitation (black) anomalies shown as z-transformed deviations from the monthly long-term means, and (c) interpretations.

Climate and growth conditions in 2003/04

Climatic anomalies in the research area from April 2003 to October 2004 are shown in figure 3a. From June to September 2003 the monthly temperature means were approximately 1σ higher than the corresponding means of the reference period 1961 to 1990.

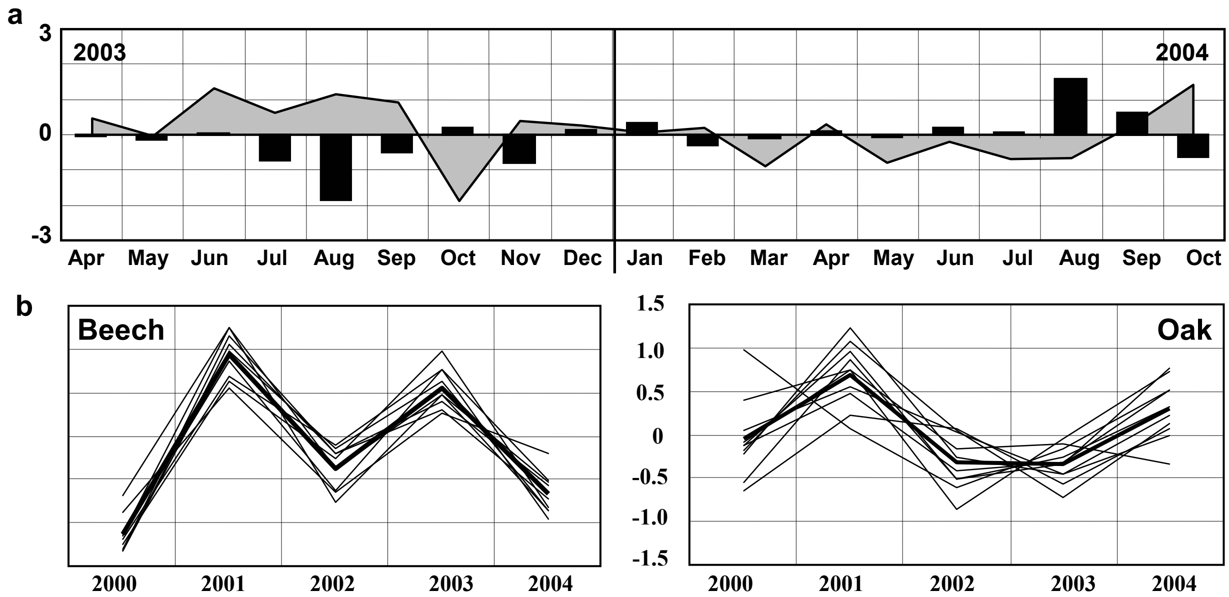

Figure 3: The a) temperature (grey) and precipitation (black) anomalies 2003/04 and b) the growth anomalies from 2000 to 2004 illustrated as residuals against a 3-year left-side weighted moving average for beechs (left) and oaks (right) in the NW-German low mountain ranges.

However, during the spring and June of 2003, the precipitation sums nearly reached the values of the reference period. First, in July (-0.8σ) and especially in August (-1.9σ) they stayed clearly behind the reference values. Therefore, the strong dryness period in 2003 began not before July and persisted until September, followed by a cold October. In 2004, the whole growing season was characterized by temperatures slightly below the reference values and precipitation sums near by the values from the reference period 1961 to 1990.

The indexed growth chronologies, illustrated as residuals against a 3-year left-side weighted moving average, for beeches and oaks from 2000 to 2004 are shown in figure 3b. For the years 2000 until 2002 both species have synchronous radial increments. After a wide tree ring in 2001, beeches and oaks show a weak growth depression in 2002 with tree-ring widths slighly below the moving average. In the following years both species reacted with contrary growth behaviour. While oak tree rings in 2003 remained on the level of 2002 or became slightly smaller, beeches produced wide tree rings in 2003. In contrast to the oaks, which showed increasing tree-ring widths in 2004, beeches had narrow tree rings at all locations. But the growth depression was not strong enough to reach a negative pointer year (z-values from -0.5 to 1.0).

Weather conditions in 2003/04 are characterized by a strong dryness in the late summer, and therefore they are comparable to 1921/22, 1947/48, and with limitations to 1959/60 (Fig. 2b).

Conclusions

Beeches and oaks in the NW-German low mountain ranges have similar numbers of negative pointer years in the 20th century. But only in two years (1976 and 1996) both species show synchronal reactions. Whereas in 1996 a cold and dry growing season was responsible for narrow tree rings, in 1976 from April to August temperatures above average and precipitation below average caused the growth depressions.

In respect to dryness conditions, growth/climate responses of beeches and oaks in NW-German low mountain ranges can be devided into three types:

- narrow tree-ring widths as a response to dryness at the end of the growing season in the year before (valid for beech only);
- narrow tree-ring widths as response to dryness during the whole growing season (valid for beechs and oaks);
- narrow tree-ring widths as a response to dryness in the summer of the current year (valid for oaks only).

In the research area the dryness period of 2003 persisted especially from July to September, which is comparable to periods in 1921/22, 1947/48, and 1959/60. The response of the oaks to these weather conditions was a weak growth depression in 2003. Beeches reacted with a unique but weak negative growth depression in 2004. In fact, in NW-German low-mountain ranges 2003 is no negative pointer year.

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