Search for solar periodicities in Miocene tree ring widths

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ABSTRACT

We have analysed ring-width records of two Miocene coniferous trees with an absolute age of 15–20 million years. Such data may reflect solar periodicities from the prehistoric past. Evidence for a main period of ~12.5 years has been found. This is near the present basic solar activity period of ~11 years. Other periodic components appear at 220, 150 and 53 years, respectively, which may also be related to solar variations.

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1 INTRODUCTION

The solar energy output is far from constant. Solar activity, as measured by the sunspot number, is characterized by a period of about 11 years which, remarkably, shows up also in the total energy output of the sun (Wilson and Hudson, 1988; Lean, 1991). Further pronounced periods appear at 5.5, 8.3, 9.8, 55 and 90–110 yr. ^{14}C data from tree-rings (Stuiver, 1980; Buchuladze *et al.*, 1980, Castagnoli *et al.*, 1984; Stuiver and Braziunas, 1989; Sonett and Finney, 1990) exhibit marked fluctuations on century scales as well as on decadal scales, including the 11-year cycle. The existence of such century variations caused by solar activity has confirmed from ^{10}Be ice-core data (Beer *et al.*, 1988). The sun's long-term behaviour also shows transient dynamics such as the Maunder minimum from AD 1645 to 1715 (Eddy, 1976), characterized by a striking decrease of solar activity. From the study of the auroral activity, on the other hand, there are indications that the solar cycles during the Maunder minimum show a normal periodicity (Schlamminger, 1990). New measurement methods have recently allowed deeper insight into solar variations in the last 10,000 years (cf. Stephenson and Wolfendale, 1988). The next challenge is to glean information about older epochs.

Objects which might reflect solar periodicities from the prehistorical past are sediment layers and tree-rings. Due to their short life-time, the relevant cosmogenic isotopes from those times have already decayed. Therefore, only the thickness of sediment layers and tree-rings, but not their isotopic content, can be analysed.

Although the causal connection between solar variations and growth-rings is more complex than that between solar variations and cosmogenic isotopes, several studies suggest that such connections may exist. Firstly, tree-rings have been used to reconstruct Palaeoclimates (cf. Fritts, 1976; Francis, 1986; Kumagai and Fukao, 1992). Second, evidence for solar influences on the climate has also been found on secular (cf. Stephenson and Wolfendale, 1988) as well as on the shorter 11-year timescales (e.g. Gilliland, 1981). Third, evidence for solar cycles in recent tree-ring widths has been observed, although not with strong significance (Mitchell *et al.*, 1979; Pittcock, 1979; Kocharov, 1986). This led us to investigate ring-width records of two Miocene coniferous trees with an absolute age of 15–20 Myr. The tree trunks were found in lignite mines. Since modern mining techniques make it rather unlikely that tree stumps could be detected and saved in lignite mines, specimens such as those evaluated in this work are rarely found nowadays.

The paper is organized as follows: In section 2, we introduce the data samples and comment on the excavation sites as well as the climate during the growing periods. The statistical analysis of the ring-width sequences is performed in section 3. In section 4, the results are discussed and related to known solar or climatic periods.

2 DATA SAMPLES

Both trees were identified as *Taxodioxylon gypsaceum* (GOEPP)KRÄUSEL which corresponds to the recent *Sequoia sempervirens*.

The first tree was excavated in 1955 in the mine of Piskowitz (Upper Lusatia, Germany). The 3.5 m diameter stump was analysed by U. Meier (1959), who counted 1575 rings. We used the results of her measurements for our work.

The second tree (Striegler *et al.*, 1984) was found in 1982 in the mine of Klettwitz (Lower Lusatia, Germany). This 3.2 m diameter stump originates from the first Miocene seam in the Lower Lusatia. 1089 annual rings had been counted in 1984. Due to the aerobic degradation of the wooden corpus only 217 out of the original 1089 rings could be evaluated in the present analysis. The measurement errors of the ring-widths are estimated as 0.04 mm for the Piskowitz stump and 0.07 mm for the Klettwitz stump.

The Miocene climate was considerably warmer than now. Mai (1967), by investigation of plant remains, could prove a repeated change of subtropical to temperate palaeoclimates. The average annual temperature of the floral zone, to which the Piskowitz seam belongs, is estimated as 20–23°C, and the mean annual precipitation as 2000 mm. This is definitely a subtropical climate. The seam from the Klettwitz sample belongs to a floral zone with a more temperate climate. Average annual temperatures of 17°C and mean annual precipitation of 1600 mm were characteristic for that time. For both zones, temperatures never fell below 0°C.

3 SPECTRAL ANALYSIS

In the present study, two techniques for spectral analysis have been applied: the straightforward periodogram method (also called Fast Fourier Transform spectrum FFT), and the Maximum Entropy Method, MEM (Haykin, 1983). As the periodogram is not in general a consistent estimator of the power spectrum, the FFT spectra have been smoothed in order to obtain reliable estimates. The MEM provides superior spectral resolution and a better low-frequency response compared to other methods, but due to the nonlinearity of MEM it is difficult to judge the significance of peaks in MEM spectra directly. Hence, another concept based on a so-called objective criterion is applied to test whether a periodic component is significant (Kurths *et al.*, 1988). Additionally, long-term trends in the ring sequences are removed by subtracting 5th-order polynomials, and the detrended data are smoothed by replacing them by their 3- or even 5-term simple moving averages.

Figure 1a shows the Piskowitz record reduced to its 5-point averages for better visibility. The FFT spectrum of the high-pass filtered record is shown in Fig. 1b. Following the Kolmogorov–Smirnov test, the three dominant peaks at 5.6, 12.7 and 16.9 yr make the sequence non-random with a confidence level of >99%. A raw estimate of the statistical significance of the peak at 12.7 yr can be obtained by means of an analysis of the spectral density values in the neighbourhood of the peak. An extrapolation of the distribution of their heights yields an expectation value of 0.01 cases for the 12.7-yr-value (0.83). Normalized to all

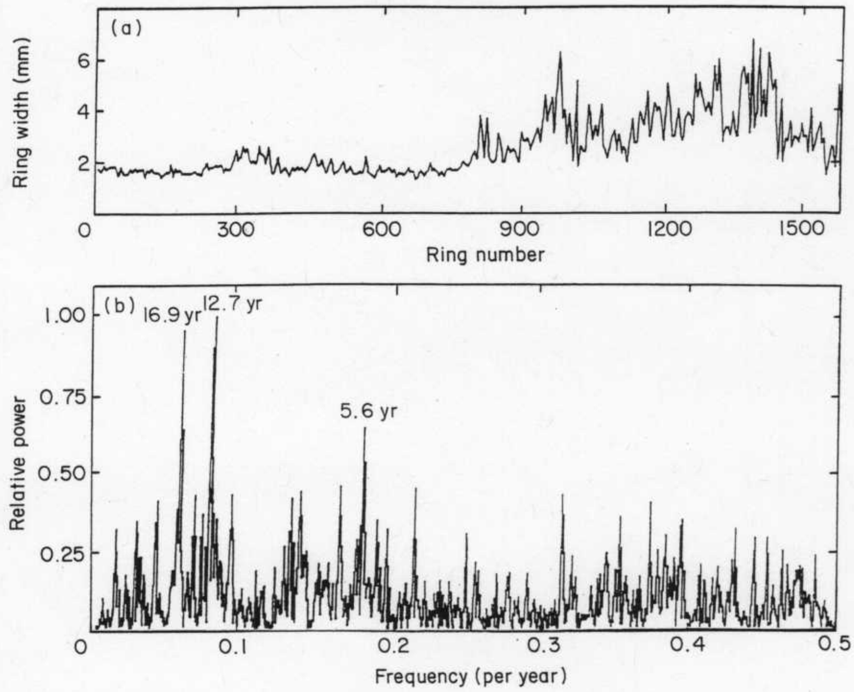

Fig. 1. *Piskowitz tree: (a) Width sequence (5-ring averages), (b) FFT power spectrum of the high-pass filtered width sequence.*

770 values of the periodogram, this translates to a confidence limit of 97%.

A change in the variability occurs after about 800 years, possibly due to environmental influences (cf. Fig. 1a). Therefore, in addition, we have analysed the first part (rings 1–770) and the second part (rings 850–1575), separately.

In the range below 20 years, the MEM power spectrum of part I exhibits only one peak at 17.1 years (Fig. 2a). Further peaks are observed at 49, 150 and 220 yr, appearing also in part II (Fig. 2b

Table 1. Periods found in the ring-width sequences (in years). Significant periods are marked by +.

Klettwitz record		Piskowitz record			
		part I		part II	
FFT	MEM	FFT	MEM	FFT	MEM
—	—	—	440	—	440
—	—	—	220+	—	220+
—	—	—	150	—	150+
—	50+	—	49+	—	53+
—	—	14.8/18.6	17.1+	16.9+	17.1+
12.4+	12.8+	—	—	12.7+	12.6+
8.2	8.4	—	—	—	—
—	—	—	—	7.1	7.2
5.7+	5.5+	—	—	5.6+	5.6+

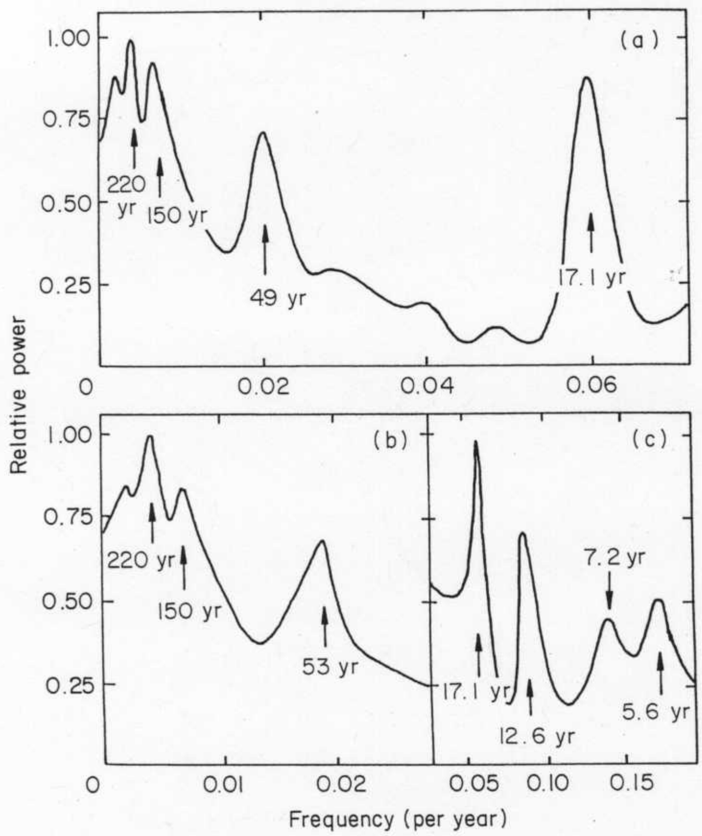

Fig. 2. *MEM power spectrum of the detrended width record of the Piskowitz sample: (a) part I, after 5-year smoothing of the width record, (b) part II, after 5-year smoothing of the width record, (c) part II, without smoothing of the width record.*

and c). Additionally, however, part II shows several peaks below 20 years, namely at 17.1, 12.6, 7.2 and 5.6 yr, respectively.

Figure 3a shows the width sequence of the Klettwitz trunk. The spectral estimates given by the MEM and the FFT (Fig. 3b, 3c) agree with what has been found for the Piskowitz sample. Both methods consistently yield pronounced peaks at 12.4/12.8, 5.7/5.5 yr (FFT/MEM). Assuming a white noise background for the detrended sequence, the Kolmogorov–Smirnov test yields a chance of less than 3% for the random appearance of a peak such as that found at 12.5 yr.

4 DISCUSSION AND SUMMARY

The statistical analysis of two ring-width records from Miocene trees exhibits several hidden periodic components (see Table 1). Surprisingly, most of these periods may be related to recent sunspot variations.

From the longer Piskowitz record we get information on the period range from century scales to a few years. Although the Kettwitz record consists of only 217 rings, it yields an independent insight into decadal scales. Note that this length is only slightly below the record of Wolf sunspot numbers (244 yr).

The following periods are of particular interest:

1 The strongest peak occurs, in both trees, around 12.5 yr in approximative agreement with the present basic solar cycle of about 11 years. Although it does not appear significantly in the power spectra of part I of the Piskowitz sample, careful inspection shows, that in the first 300 years as well as at the end of part I there is some activity near 12.5 yr. Conversely, in the middle of part II, the 12.5-yr period nearly disappears. These effects might indicate events similar to the Maunder-, Spörer- and Wolf-minima in the present millenium. Note on the other hand that these grand minima lasted no longer than 100 years. Therefore, climatic changes may be another explanation for this finding in the Piskowitz record. Due to the strong noise component of the sequences, we do not want to draw further conclusions here. In particular, it is (unfortunately) impossible to study this period in the tree-ring records in more detail, as was proposed for the sunspot numbers (Wilson, 1984), because our records consist of a complex mixing of several periodic components. The main period is not as outstanding as in the case of sunspot numbers.

2 The very long periods visible in the Piskowitz record can be related to century-scale solar oscillations as found in atmospheric ^{14}C; e.g. a fundamental oscillatory mode of the sun with a 420-yr period has been identified from a MEM analysis of a 9600-yr ^{14}C chronology (Stuiver and Braziunas, 1989).

Moreover, their spectrum reveals several harmonics, the strongest being centred at 218 and 143 yr, respectively. Sonett and Finney (1990) found a marked period of 209 yr in radiocarbon. These results seem to be in good agreement with our periods at 150, 220 and – only slightly indicated – 440 years. We do not see an indication of the Gleissberg cycle at 90–110 yr (Gleissberg and Damboldt, 1979). Instead, all our data show periods of about 50 years. This period in sunspot sequences is revealed as a 'shoulder' of the Gleissberg peak (Cohen and Lintz, 1974; Wittmann, 1978). In accordance with our results, in $\delta^{18}O$ and thermoluminescence data from AD 1181 to 1808, the 50-yr period is stronger than any neighbouring period, and the 90-year cycle seems to be absent (Castagnoli *et al.*, 1984).

3 The period of about 17 yr in the Piskowitz sequence, on the one hand, could be related to the weak 16.3-yr period seen in sunspot spectra (Wittmann, 1978; Vitinsky *et al.*, 1986) and the spectrum of aurorae between 6877 BD and AD 1000 (Attolini *et al.*, 1988).

4 Finally, we want to mention the period at 5.5 yr which is known from recent sunspot and climate data (Vitinsky *et al.*, 1986).