SIMILARITIES BETWEEN TREE-RING CHRONOLOGIES IN GERMANY AND NEPĀL: AN ANALYSIS OF LONG-TERM FLUCTUATIONS

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Dendrochronology describes tree-ring widths as a result of climatic (precipitation, temperature) and non-climatic influences (site factors, genetic constellations). In order to enhance the dating selectivity it is common practice in laboratories to standardize the raw data (HUBER, 1943; ECKSTEIN & BAUCH, 1969; BAILLIE & PILCHER, 1973; FRITTS, 1976; SCHMIDT & ANIOL, 1978; HOLLSTEIN, 1980). This emphasizes the yearly changes and reduces site differences and long-term trends in ring widths. By this technique a continuous oak chronology of Germany reaching back to 8021 BC has been established (e.g. BECKER, 1993) which allows the precise dating of oak trees with extremely low statistical errors. By regional climate differences the extent of validity of tree-ring calenders is limited. Therefore separate regional chronologies e.g. of North-, West-, and South Germany were established. After there experiences the idea of "teleconnection" e.g. between trees from Scandinavia and North America, published in 1935 (DEGEER, 1935), was not accepted.

In the following we present chronologies of oak, pine, and fir trees from different climate zones. Using raw data (instead of indexed values) of tree-ring widths we find significant similarities between growth trends over unexpectedly long distances (SCHMIDT & GRUHLE, 1995).

Tree-ring chronologies of Germany

We first demonstrate the advantage of using raw data instead of indexed values for tree-ring growth, when comparing trees of different species from different regions. When using indexed values there is no correlation between *Quercus robur* (ECKSTEIN, personal communication) from North Germany (1376-1972 AD) and *Abies alba* (BECKER & GIERTZ-SIEBENLIST, 1970) from South Germany (1376-1961). We obtain a correlation coefficient $r = 0.09$ and t-value = 2.3 (Student-test). The raw data values however clearly indicate similarity ($r = 0.47$, $t = 13.1$) at the synchronous position.

Tree-ring chronologies of Germany and Asia

Surprisingly, a high similarity can also be found both for oaks and firs from Germany (ECKSTEIN, personal communication; DELORME, 1973; BECKER & GIERTZ-SIEBENLIST, 1970) when compared with pines from Asia (Nepāl, SCHMIDT, 1992-93), Karakorum (WINIGER, ESPER, personal communication). Fig. 1A shows a long-term trend to higher growth (1650-1850 AD) and to lower growth (1850-1990 AD). The tests commonly used in dendrochronology confirm the similarity already visible in the raw data. In Fig. 1B, C the cross correlation curves are plotted against the shift from -300y to +300y in 1y steps. The synchronous position (shift = 0) e.g. the correlation coefficient and t-value between Nepāl pines and German fir are $r = 0.68$, $t = 18.2$.

Tree-ring chronologies and sunspot numbers

Similarities are also evident between tree-ring growth and solar activity for oaks from Germany (raw-data), pines from Asia (raw-data), and pines from California (indexed values). The Californian data of *Pinus ponderosa* contain 7 site chronologies and the data of *Pinus jeffreyi* represent the data of 12 site chronologies (HOLMES, ADAMS, FRITTS, 1986).

To avoid interference with the 11y solar cycle, the sunspot numbers and tree-ring values are smoothed by a gliding 10y interval (Fig. 2). In the synchronous position a significant (negative) correlation can be seen in connection with a second negative peak when shifted by + 85....90y (sun earlier than trees). Over the entire shift range of -180y and +180y the curves of the Californian and German trees show a remarkable similarity, related to sunspot numbers.

Sunspot numbers and temperature

Correspondingly, there is a significant increase of the correlation coefficient between sunspot and temperature values of England (MANLEY, 1974) and Switzerland (PFISTER, 1988) at the synchronous position. This is also visible e.g. of the US temperature data from San Francisco, Denver, and Washington. The high correlation at a shift of 87/88y and 170y may indicate the Gleissberg period (Fig. 3A).

Precipitation (water level) and temperature

We have chosen the yearly mean water level of the river Rhine at Cologne as representing the integrated rainfall in the region between Switzerland and West Germany. The strong anticorrelation between Rhine water level and different European and North American temperature series indicates the general importance of water level data for climate studies (Fig. 3B).

Precipitation (water level) and tree-rings

As shown in Fig. 3C, the long-term water level fluctuations correlate strongly with tree-ring growth trends in Germany and Asia.

A new method of analysing long-term growth trends in tree-rings, the mobility

The interpretation of these results are difficult because the analyse of long-term growth trends in raw data chronologies is faced with the problem of not knowing the exact individual, endogenom components (e.g. juvenil growth with high fluctuation in ring-width, decrease of ring-width with increasing diameter or senescence), and site conditions.

For this reason we have developed a new method of analysing long-term patterns in tree-rings which is not dependent on the absolut values of the ring-widths. Instead of using common procedures of indexing we analyse growth fluctuation by measuring the so-called "mobility" of tree-ring growth.

Method

The mobility-index (MI) is a measure of width-changes (up or down) from one year to the next. To enhance the signal we calculate the MI-values for groups of four successive years. The sequence "up-down-up" or "down-up-down" represent the strongest possible growth change in any 4-year interval. These sequences are given the highest weight. Sequences of "down-down-down" or "up-up-up" are given with the lowest weight. The MI-values are calculated as averages for intervals of 10 years, which glide over the entire chronology. Each MI-value is allocated to the youngest year and represents the fluctuation of the preceeding 10 years.

Mobility Index

The calculated MI-values were obtained using the equation:

$$MI\,(j) = [\,C/(M-1)\,]\ [\sum_{m} \{ F\,(k)\,(|D1\,(j)| + |D2\,(j)| + |D3\,(j)|)/3 \}]\text{, with}$$

$m = 1,\dots,M$
M = gliding interval of M data points (here $M = 10$)
$C/(M-1)$ = amplitude normalizing term, C = arbitrary constant
$X\,(j)$ = set of N data, $j = 1 \dots N$
$D1\,(j) = X\,(j+m) - X\,(j+m-1)$
$D2\,(j) = X\,(j+m+1) - X\,(j+m)$
$D3\,(j) = X\,(j+m+2) - X\,(j+m+1)$, $D1\,(j)$ to $D3\,(j)$ are the differences in the data range $X\,(1) \dots X\,(N-M+1)$
$F\,(k)$ = weighting factor, $k = 1 \dots 5$ according to the mobility (fluctuation) strength between D1, D2 and D3. $F = 1$ without mobility, $F = 5$ for highest mobility (up-down-up, e. g.)

We found a significant positive correlation between tree-ring width and mobility of all tested regional chronologies of Germany, Switzerland, and Nepāl, despite different species and different climate zones (e.g. Fig 4, 5).

In order to understand this phenomenon biologically we tested the long-term record of yearly mean temperature from Central England (MANLEY, 1973) and its calculated MI-values, and the long-term records of annual mean "thermo-and hygro-indices" from Switzerland (PFISTER, 1988) with their MI-values. There is, however, no significant correlation. Nor do the varve chronologies (2500 years) of Poland (GOSLAR, personal communication), and the varve MI-values show any significant similarity. On the other hand, a close correlation can be found between sunspot numbers and sunspot mobility (Fig. 6).

Result

The observed high correlation between tree-ring growth and growth-mobility, sunspot numbers and sunspot-mobility is an indication that long-term growth trends are influenced by changes in solar radiation.

A long-distance similarity can be observed between tree-ring widths (raw data) over the last 500 years in Europe and Asia.

The long-term trends before and after 1850 are summarized in the following table.

Period	ring width	water level	temperature	sunspots
1650-1850 AD	increase	increase	decrease	decrease
1850-1990 AD	decrease	decrease	increase	increase

USED DATA

Temperature data (yearly mean):
San Francisco: 1872-1990, Denver: 1873-1990, Washington: 1862-1990.

Water level data (yearly mean):
River Rhein at Köln, 1817-1990. Bundesanstalt für Gewässerkunde, Koblenz.
Sunspot numbers (yearly data) 1749-1992, official Zürich values.

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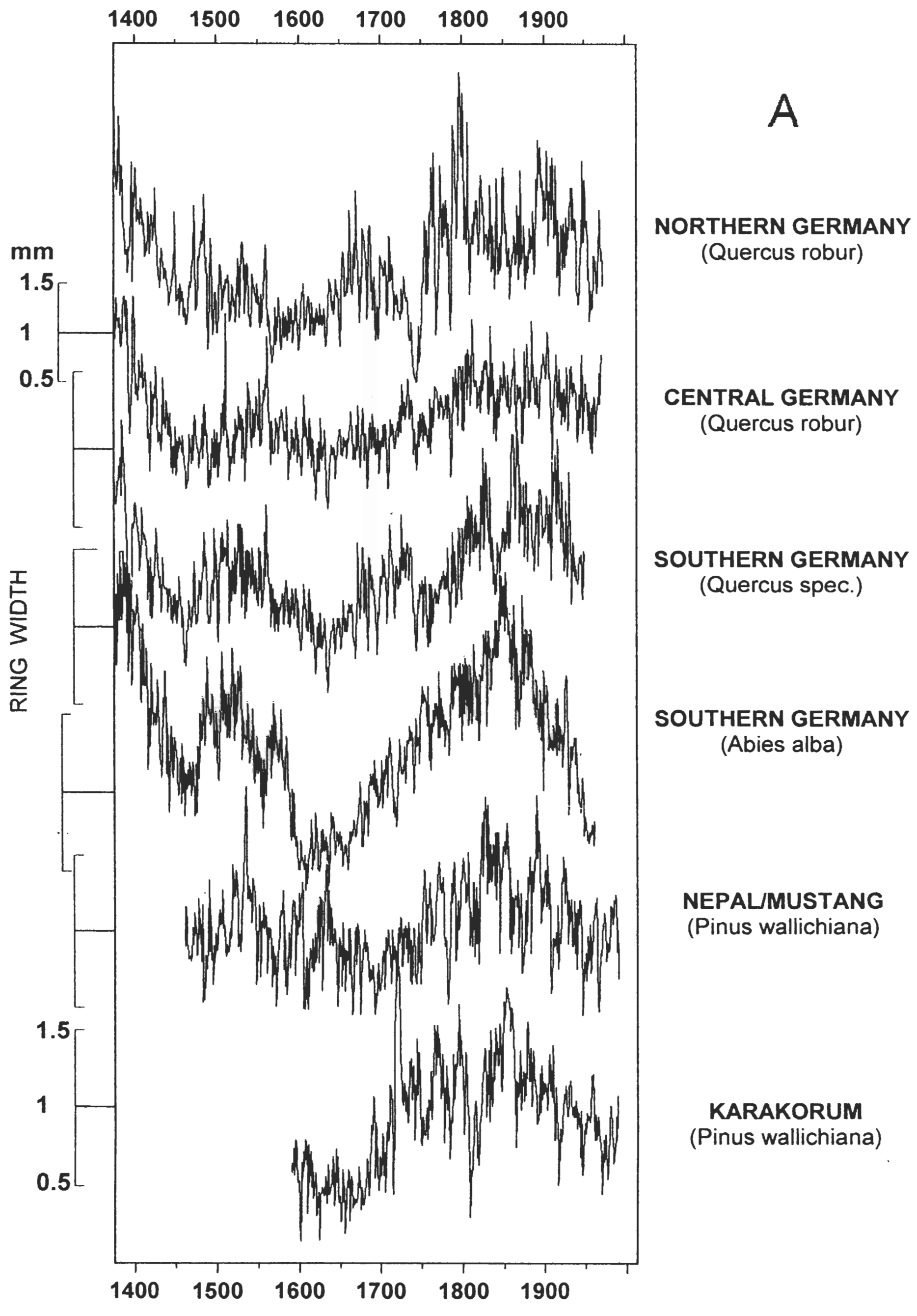

Fig. 1A: Tree-ring chronologies (raw data) from Germany, Nepāl and Karakorum.

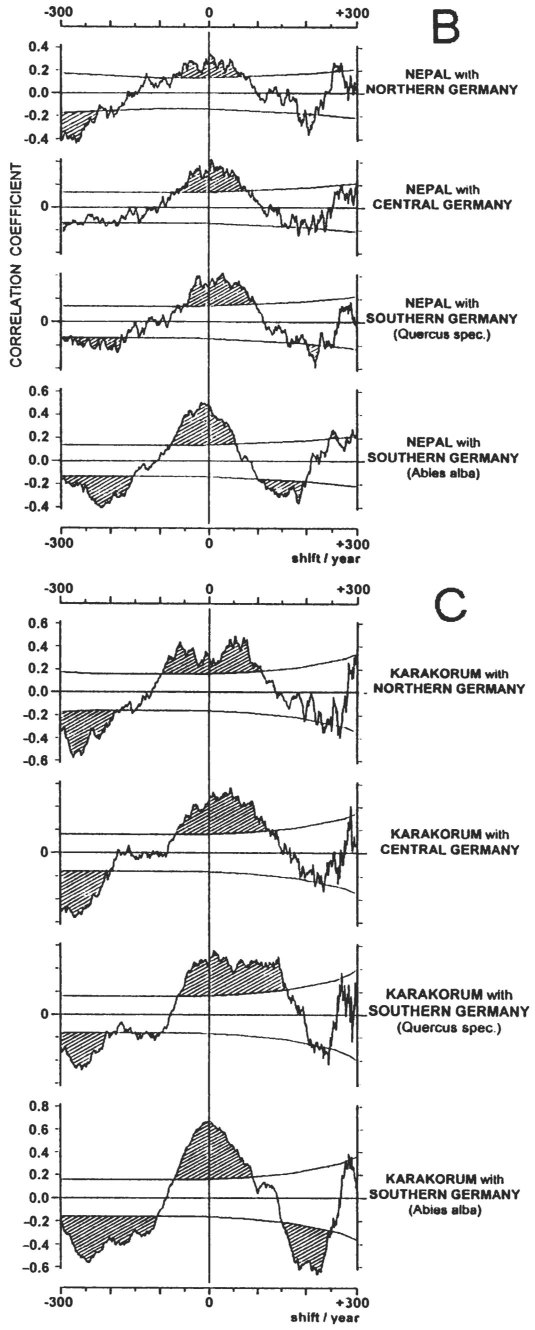

Fig. 1B,C: Correlation against the shift between the chronologies of Fig. 1A: Nepāl and Germany (B) and Karakorum and Germany (C). The flat lines indicate the confidence limit 99.0% for exceeding correlation values.

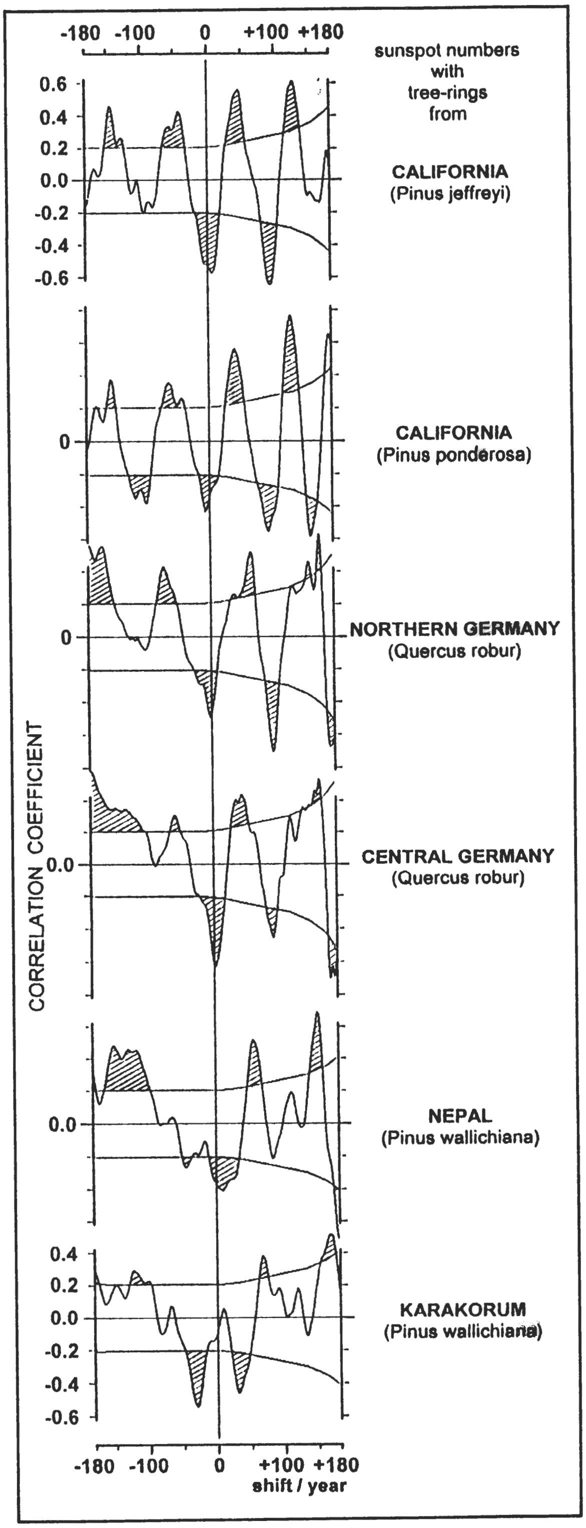

Fig. 2: Correlations against shift of sunspot numbers (1749-1993) with the tree-rings from California, Germany, Nepāl and Karakorum. Confidence level 99.0%. The data sets are smoothed by a 10-y gliding average.

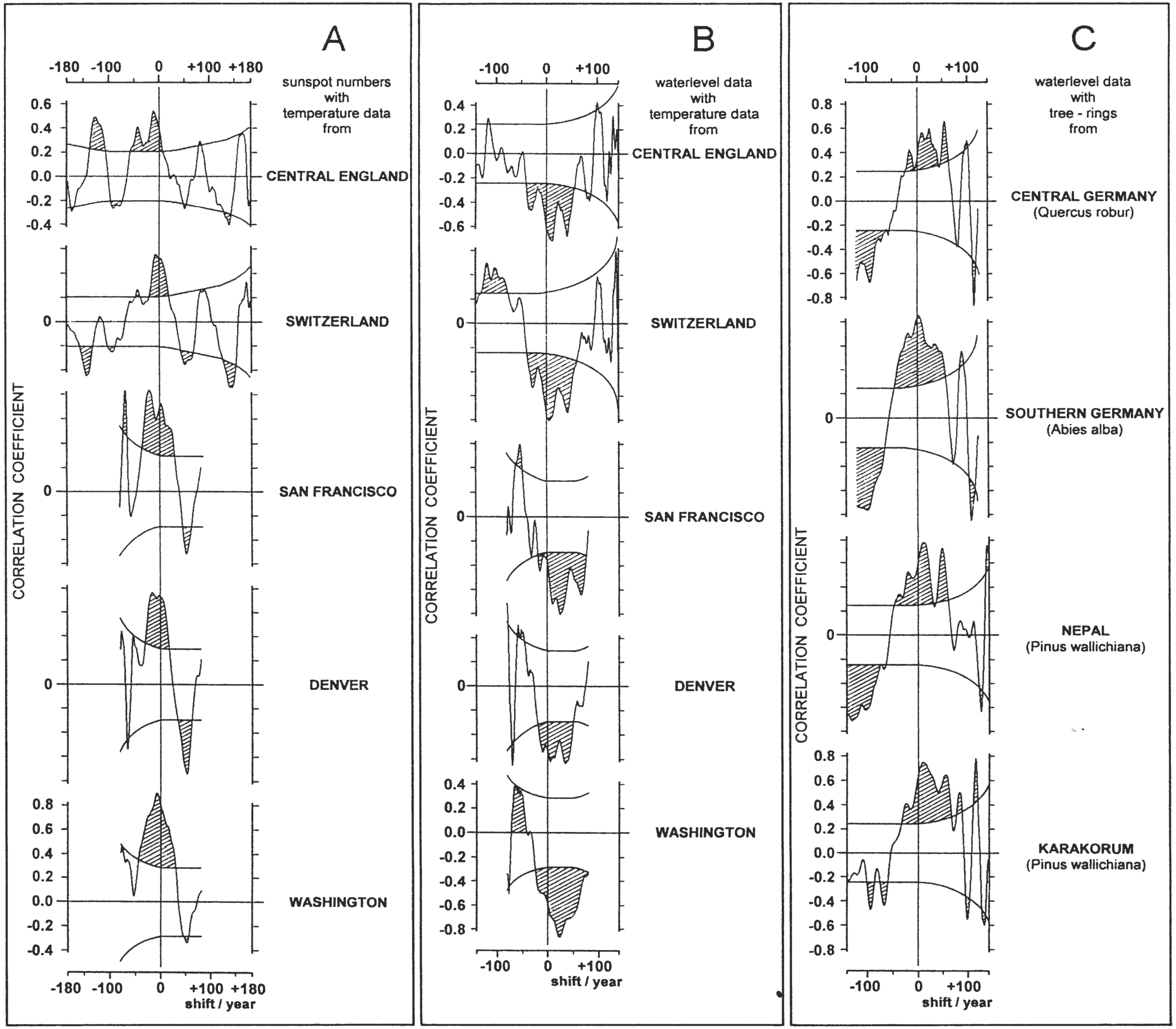

Fig. 3: Correlations against shift of sunspot numbers with temperature data from Europe and USA (A), against shift of waterlevel data (river Rhine) with temperature data (B) and with tree-rings from Germany and Asia (C). Confidence level 99.0%. The data sets are smoothed by a 10-y gliding average.

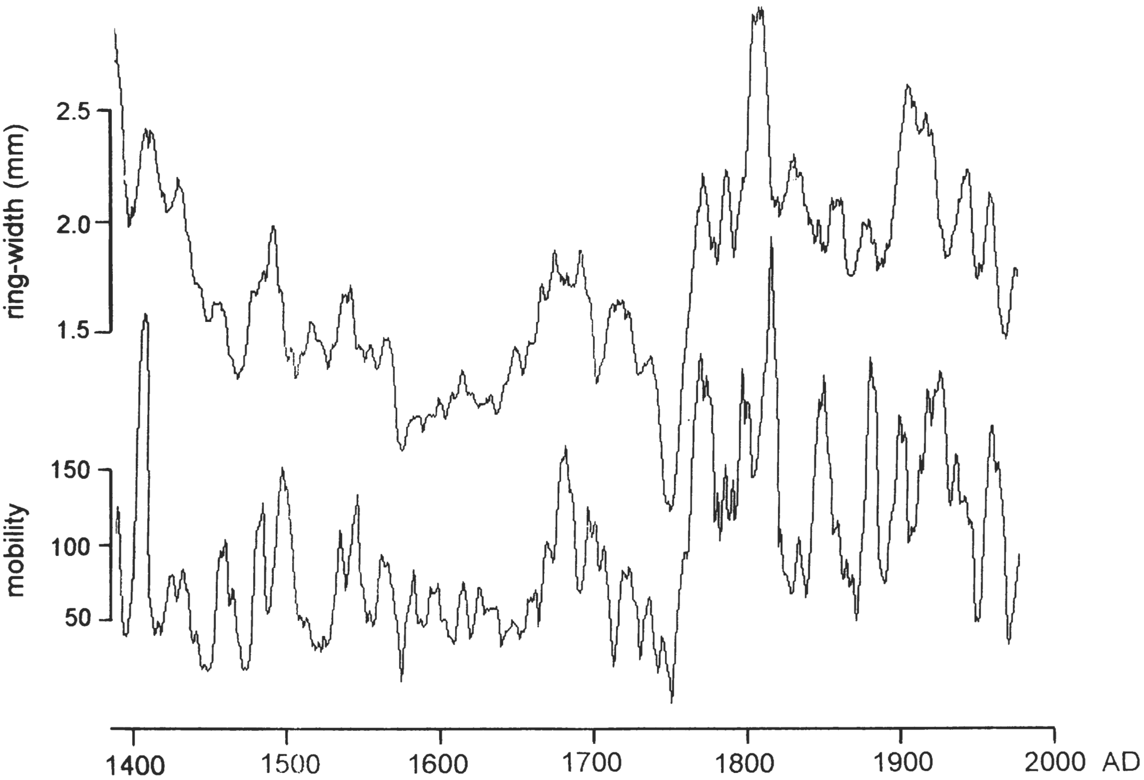

Fig. 4: Tree-ring calendar North Germany (*Quercus robur*, 10-y gliding average of the raw data) and the MI-values (10-y gliding average of the mobility-indices). Correlaton coefficient r = 0.64, t-value =17.8.

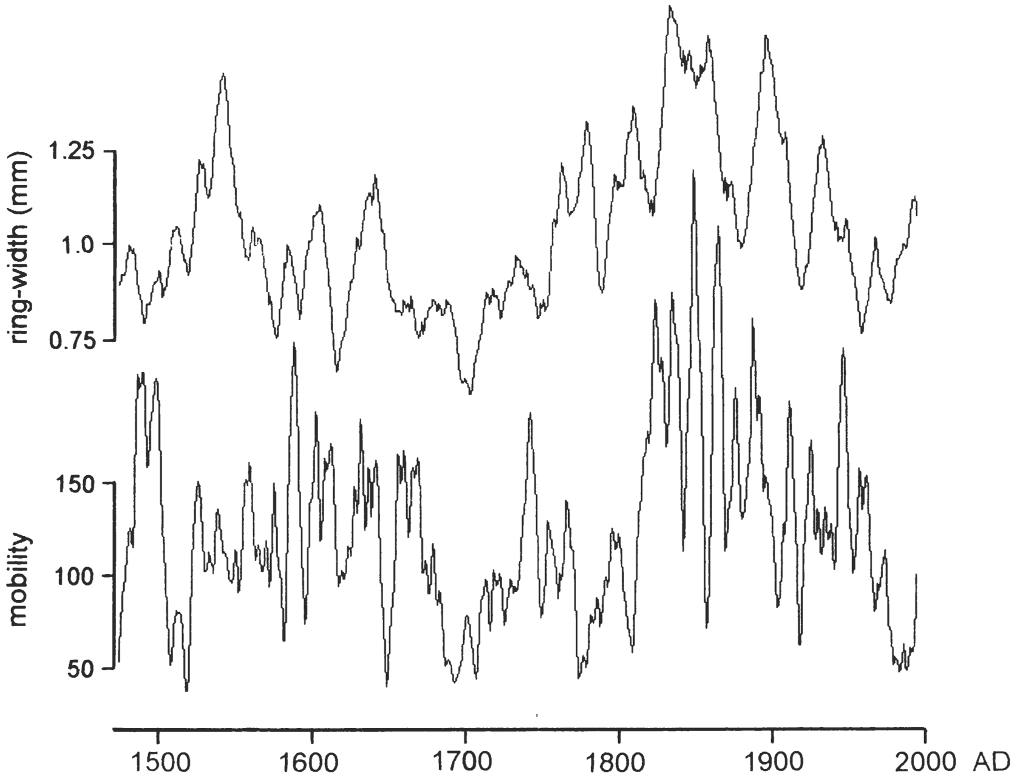

Fig. 5: Tree-ring calendar Mustāṅ/Nepāl (*Pinus wallichiana*, 10-y gliding average of the raw data) and the MI-values (10-y gliding average of the mobility-indices). Correlation coefficient r = 0.36, t = 7.8.

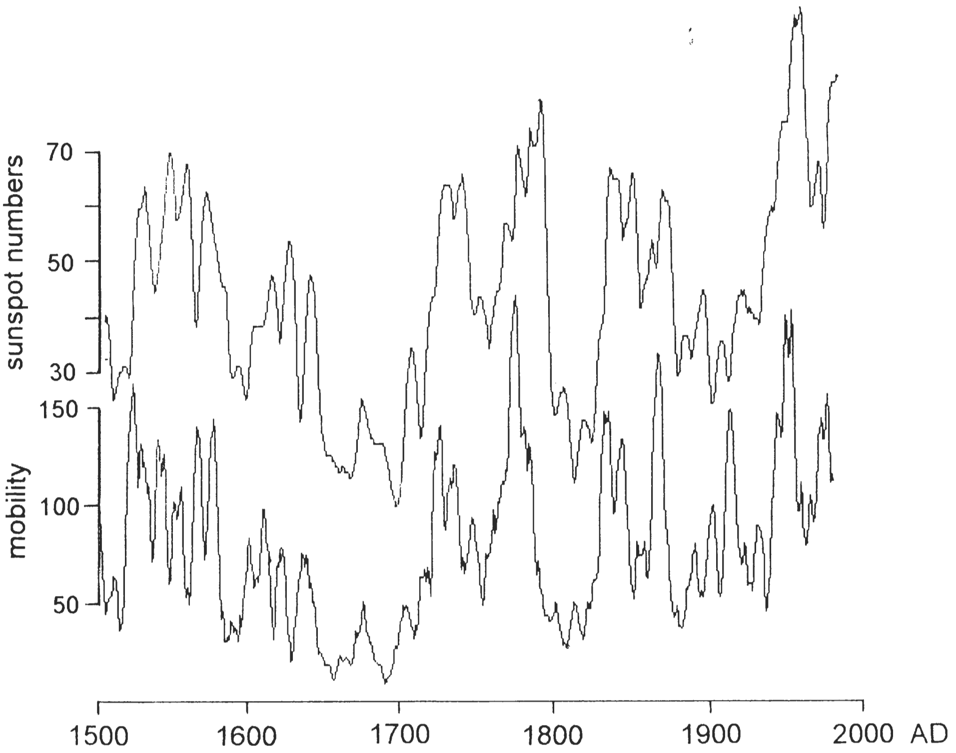

Fig. 6: Sunspot numbers (10-y gliding average) and the Ml-values (10-y gliding average of the mobility-indices). Correlation coefficient r = 0.84, t-value = 30.