# DENDROCLIMATOLOGICAL RECONSTRUCTION OF THE SUMMER TEMPERATURES FOR AN ALPINE REGION

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## INTRODUCTION

In many fields of research there is an increasing interest in climate and climatic fluctuations that have occured throughout the postglacial period. But the written records of meteorological observations extend back only several decades or two or three centuries at maximum. For the pre-instrumental time, however, knowledge of the climate is still rather limited. Therefore it is necessary to try to extend the climatic records using other data available, so-called proxy data. In the catalogue of proxy climatic information, such as lake sediments, ice cores, pollen layers, historical data, and others, tree growth occupies a special position, as measurements can be assigned accurately to a particular year, tree-ring series can be developed to cover several centuries, and the ring width can vary in response to changes in climate.

## MATERIAL

We used the tree-ring widths of larch (*Larix decidua* Miller), spruce (*Picea abies* Karst.), and stone pine (*Pinus cembra* L.). The collection of the wood samples and the composition of the three tree-ring chronologies have been done by Veronika Giertz-Siebenlist (V. GIERTZ and I. GRIESSER 1975). Her work was supported by the Alpine Research Station of the

University of Innsbruck in Obergurgl/Tyrol. The chronologies are composite ones, containing tree-ring series from living trees as well as from building timber from farm houses, barns, and store houses found at heights of 1200 to 2100 meters. Whereas the stone pine chronology reaches back to 1466, the larch and spruce chronology extend as far as 1333 and 1276, respectively. The necessary climatic data have been supplied by the weather station in Vent, about 10 km from the tree sites. The records for the average monthly temperature start in 1851 and the records for the sum of the monthly precipitation go back as far as 1891 AD (I. LAUFFER 1966).

## DENDROCLIMATOLOGICAL CONCEPT

We will not go into details of the techniques but will just shortly mention the basic concept: A tree is considered a "filter", integrating and converting the annual input of external influences into a visible and measurable output in form of the width of the annual growth. Figure 1 shows, how the climate of a given year <u>t</u> effects the ring width in a tree, but not only for that same year <u>t</u>, but through effects on buds, sugar, hormones, and the growth of needles and roots also in subsequent years so that the response lags behind up to several years; because of this linkage the width of the ring in year <u>t-1</u> is also related to the ring width in year <u>t</u>. These complex relationships make the reconstruction of the climate from tree-rings rather complicated. In order to obtain an estimate for the climate in year <u>t</u> the ring widths of year <u>t</u>, <u>t+1</u> to <u>t+k</u>, and sometimes also of year <u>t-1</u> have to be taken into account.

According to H.C. FRITTS (1976) the concept of dendroclimatology is to find a linear relationship between biological variables as e.g. ring widths and a set of climatic variables using multivariate statistical procedures. To do this, one has to compute regression weights for the biological variables which give the best estimates of a climatic variable in a period of <u>n1</u> years, for which the values of the climatic variable have been measured. This period of <u>n1</u> years is called the calibration period. If a good agreement between measured and estimated values can be achieved one can use the same regression weights to compute estimates for the climatic variable in a second period of <u>n2</u> years for which measurements of the climatic variable are still available. If in this "verification period" the approximation fits equally well one can use these regression weights to estimate values for the climatic variable in a third period of <u>n3</u> years for which no measurements are available. The third period is the reconstruction period. Of course the premise is that the relationship between the biological variables and the climate did not change in the course of the three periods n1, n2, and n3.

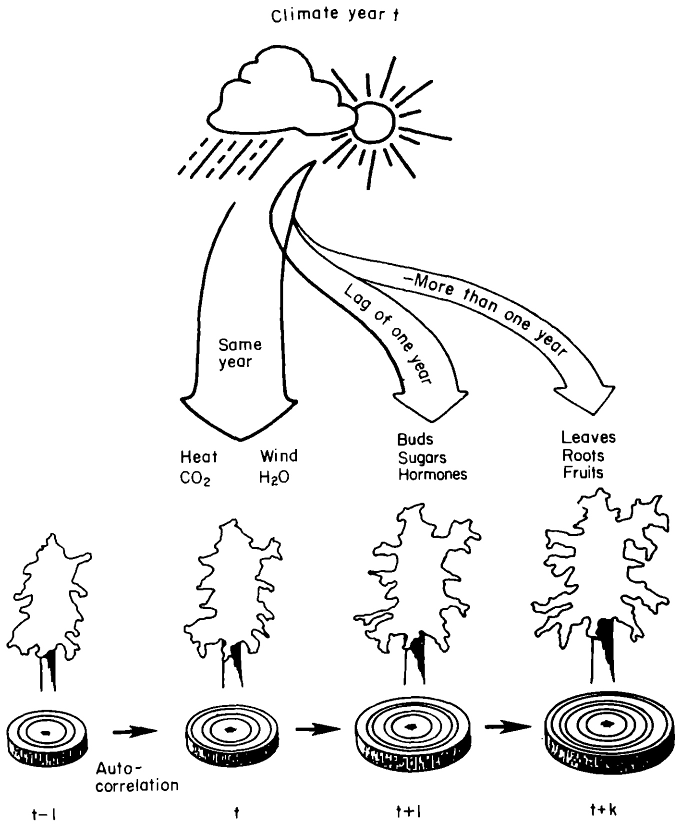

Figure 1: Effects of the climate of a given year t on the ring widths in the year t and in the following years according to H.C. Fritts (1976)

# RESULTS

In the following we would like to demonstrate the results of our own case study, based on this concept. The first step was the calculation of how the trees respond to the known climatic conditions. The effects of variation in mean temperature and total precipitation for each month from previous July to current August on the variation in ring width during the period from 1891 to 1968 are shown in figure 2. A value above zero indicates a direct relationship and a value below zero indicates an inverse relationship; the vertical lines delineate the 0.95 confidence level for each effect. Three additional variables are taken into account, namely the ring widths of the years t-1, t-2, t-3.

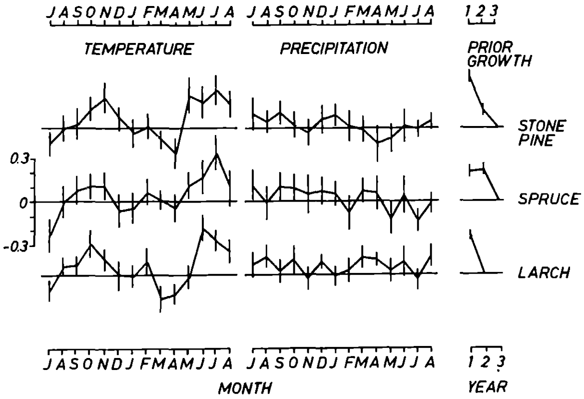

Figure 2: Response functions for ring widths of stone pine, spruce, and larch in an alpine region of Austria. The response to temperature and precipitation is given for each month from July of the year prior to growth to August of the current year. The response to the prior growth is given at lags of 1, 2, and 3 years. Temperature or precipitation in a month have significant effect on growth if the corresponding vertical line does not intersect the time axis. Temperatures in the summer of the current year show highly significant effects on growth. The patterns show the average behaviour in the period from 1891 to 1968.

The response diagrams of the three species show:

- -The temperature is of dominant importance for the growth of all three tree species, usually showing a positive effect.
- -This positive influence of temperature is obvious for the previous autumn (October and November) and the current summer (May to August).
- -There is some evidence that below-average temperatures in March and April result in wider rings.
- -The precipitation is of minor importance and does not show any common response pattern for all three species.
- -The ring widths of the year t-1 and t-2 have a positive effect on the ring width in the year t.

The statistical results are supported by biological research. A number of scientists have pointed out the importance of summer temperature for the growth of trees in high altitudes (e.g. Z. BEDNARZ 1976, W. TRANQUILLINI 1976, F.H. SCHWEINGRUBER, O.U. BRÄKER, E. SCHÄR 1979, O. HEIKKINEN 1980) because a warm summer is favourable to high net photosynthesis. The carry-over effect of the prevailing living conditions in one year to the growth in one or more following years, proven statistically in our case study, has also been found in empirical biological studies. This means that the effects of an unusually cool or warm summer on growth are smoothed over several years, presumably by the retention of the needles and by the development of the cuticle which is to prevent a desiccation damage in the subsequent winter (M.N. BAIG, W. TRANQUILLINI, W.M. HAVRANAK 1974).

From the response diagrams it is evident that in the ring width a rather high amount of information on summer temperature is stored which we have tried to extract for the reconstruction of summer temperature records as far as tree-ring series are available. We calculated the estimates for the temperatures of June and July for year t using the ring widths of larch, spruce, and stone pine of the years t, t+1, t+2, and t+3. The result is shown in figure 3. The total period covered by tree-ring series from 1471 to 1968 has been subdivided into three parts of different length:

- -the calibration period from 1968 to 1891
- -the verification period from 1890 to 1851
- -the reconstruction period from 1850 to 1471.

In addition to the reconstructed annual values of summer temperature the low frequency fluctuations of summer temperature have been calculated and plotted; below average values are plotted in black.

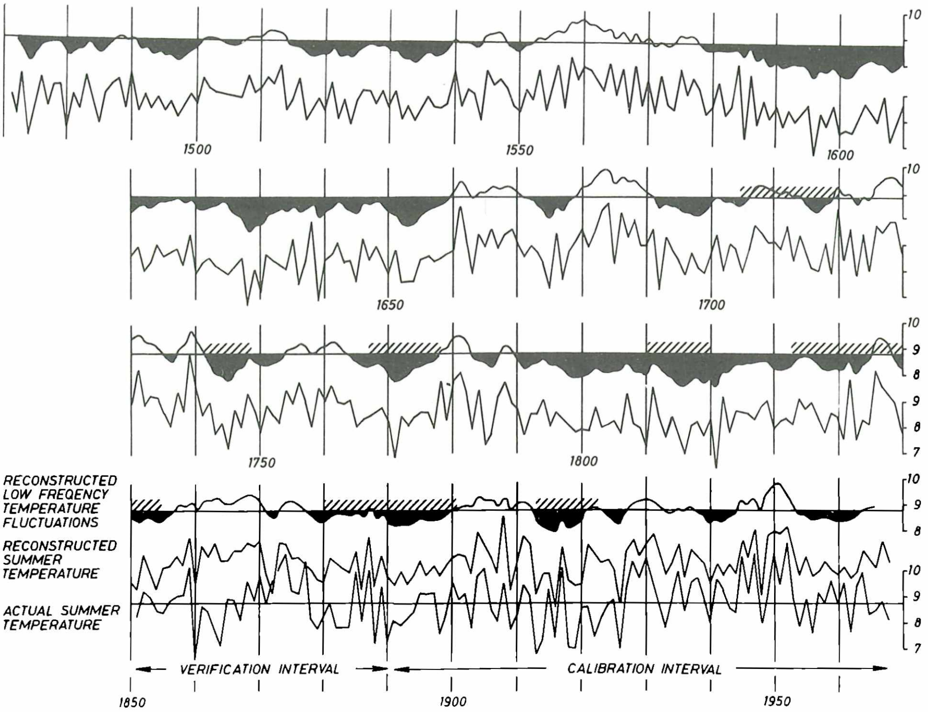

Figure 3: Reconstructed summer temperatures and their low frequency fluctuations from 1471 to 1968. The horizontal axis delineates the average summer temperature of the instrumental period from 1851 to 1968. For the instrumental period the actual summer temperatures are represented in the lowermost curve. In this period the reconstructed values are shifted against the actual to allow an easy comparison. An area between the curve of the low frequency fluctuations and the axis is blackened if the temperatures are below average. Known glacial advances are indicated by hatching.

## CONCLUSIONS

It is easy to see that the reconstructed summer temperatures give a good representation of the actual temperatures in the verification period. Now the question arises how reliable the reconstructed temperature fluctuations are for the time before a verification has been possible on the basis of actually measured values, that is before 1850. At the moment our only approach is to check the periods of below-average summer temperatures against the more or less known intervalls of glacial advances and decreases (B. MESSERLI, P. MESSERLI, C. PFISTER, H.T. ZUMBUHL 1978). The period from the late 16th century through the middle of the 19th century constitutes the so-called "little ice age", characterized by long-lasting periods of below-average temperatures. But even within those periods the summer of single years may occasionally be warmer than average summers.

There are historically known glacial advances in the Alps as indicated in figure 3 by hatching from 1913 to 1925, from 1880 to 1903, from 1810 to 1855, and from 1768 to 1780. The period from 1855 to 1880 is reported as an extreme glacial retreat throughout the Alps. In the time before 1770 there was an advance beginning presumably about 1705 and reaching its culmination about 1720, and possibly another one about 1743. Around 1600 a long period of maximum length of the glaciers is reported.

In summarizing, the reconstructed summer temperatures for the site around Obergurgl show a good correspondence with the historically known or estimated glacier movements. Therefore, the radial growth of trees could be of help in the study of past variations of climate, particularly for the period before 1750. More detailed research is planned in cooperation with scientists of other disciplines.

## SUMMARY

The analysis of tree-rings of spruce, larch, and stone pine from an alpine site in Austria shows a promising response of the annual growth to the temperature during the vegetation period. On the basis of this relationship a statistical model is built, which permits a reconstruction of the summer temperatures in pre-instrumental time using tree-ring chronologies of modern conifers and building timber.

## ZUSAMMENFASSUNG

Die dendroklimatologische Analyse von Fichten, Lärchen und Zirben aus den Ötztaler Alpen/Österreich ergab eine deutliche Reaktion des radialen Jahreszuwachses auf die Temperatur während der Vegetationsperiode. Aufgrund dieser Beziehung wurde ein statistisches Modell entwickelt, mit dem Sommertemperaturen in der Vergangenheit unter Verwendung von Jahrringchronologien von lebenden Bäumen und von Bauholz rekonstruiert wurden.

# LITERATURE

BAIG, M.N., TRANQUILLINI, W. und HAVRANAK, W.M., 1974: Cuticuläre Transpiration von Picea abies- und Pinus cembra-Zweigen aus verschiedener Seehöhe und ihre Bedeutung für die winterliche Austrocknung der Bäume an der alpinen Waldgrenze. Cbl. ges. Forstwesen, vol. 91, pp. 195-211.

BEDNARZ, Z., 1976: Wplyw klimatu na zmiennosc szerokosci slojow rocznych limby (Pinus cembra L.) w Tatrach. Acta Agraria et Silvestria, vol. 16, pp. 17-34.

FRITTS, H.C., 1976: Tree Rings and Climate. London, New York, San Francisco, 567 p.

GIERTZ, V. and GRIESSER, I., 1975: Dendrochronologie. Tiroler Heimatblätter, vol. 3, pp. 94-100.

HEIKKINEN, O., 1980: Mountain pine radial growth and the forest limit zone in Gadmental, the Swiss Alps. Fennia, vol. 158, pp. 1-14.

LAUFFER, I., 1966: Klima von Vent. Diss. Univ. Innsbruck.

MESSERLI, B., MESSERLI, P., PFISTER, C. and ZUMBUHL, H.T., 1978: Fluctuations of climate and glaciers in the Bernese Oberland, Switzerland, and their geoecological significance, 1600 to 1975. Arctic and Alpine Research, vol. 10, pp. 247-260.

SCHWEINGRUBER, F.H., BRÄKER, O.U., and SCHÄR, E., 1979: Dendroclimatic studies on conifers from central Europe and Great Britain. Boreas, vol. 8, pp. 427-452.

TRANQUILLINI, W., 1976: Water relations and alpine timberline. Ecological Studies. Analysis and Synthesis, vol. 19, pp. 473-491.

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