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Climatic variations during the last 500 years in Finnish Lapland: an approach based on the tree-rings of Scots pine

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Introduction

The tree-rings of Scots pine are sensitive to temperature changes of the summer months June and July (e.g. Hustich 1945, Mikola 1961). This is the case particularly in Lapland where temperature is clearly the minimum factor in tree growth while in Southern Finland it is precipitation. The correlation coefficient between tree-ring widths and the mean temperature in June-July may rise up to 0.70 in individual stands.

A typical pine in Lapland lives 200-300 years old, and it is easy to find over 400 years old individuals. The oldest known Scots pine tree ever found in Lapland, age 810 years, was found by professor Gustaf Sirén. Many of the small ponds and lakes of Lapland preserve submerged subfossil pines for thousands of years. This gives possibilities for examining climatic variations in tree-ring width almost to the end of the most recent Ice Age, about 10,000 years ago.

Extending climatic data to longer periods presupposes the use of proxy data, variables giving information indirectly about past climate. Tree-rings represent a reliable form of proxy data. Considered from this point of view, it is quite understandable that dendroclimatologists prefer to construct climatic models from tree-rings.

Trend studies

The research project, "Variation and trends in tree increment", is the main dendroecologically executed project at the METLA (The Finnish Forest Research Institute). Special interest is paid to studying increasing growth and its components as observed in Finnish forests during the 1900s. At least four growth components are believed to have been recognised: 1) the effect of natural climatic variation, 2) the effect of improved silviculture and changed stand structure 3) the effect of possible acidic deposition (e.g. nitrogen) and 4) the effect of possible atmospheric CO₂ concentration.

The deposition component is expected to be available only in tree-rings of the 1900s. Separating the effects of climatic, acidic deposition and CO₂ components from tree-rings is problematic, because the only possible sources of tree-ring data, the natural forests, include all these components.

Direct temperature data or data other than tree-ring data are needed for estimating the effects of climatic variation in the 1900s. The measured temperature records in Lapland span about 90 years back in time. The oldest regular temperature observations were started in 1908 in Sodankylä. The relatively short time span of measured temperature data does not enable one to make conclusions as to the causes of low-frequency oscillations in the climate. Do the present day annual climatic variations or the observed trend patterns differ in some way from those of the ancient times? Should the present phenomena be regarded as normal variation within a long time interval, or is something really happening?

Why are these kinds of studies done? Too many unfounded assumptions have been put forward as scientific facts and against the ongoing climatic phenomena. Too little attention has been paid to the information potential of long-interval time series. In order to try to place present-day growth phenomena in their proper context, for instance the unexplained increasing growth of trees of the 1900s or forecasting of future forest growth, requires that we know what kind of growth patterns there were thousands of years ago.

Once we know exactly the long-term influence of climate on tree-rings, we are also in a better position to judge more reliably the effects of environmental changes (e.g. nitrogen deposition). This also means that improvements must be made in adjusting growth models to the changing environments.

Modelling climate from tree-rings

Dendroclimatic studies at the METLA are based on nationwide tree-ring data and advanced techniques for manipulating and analysing data. A very important part is played by the climatic trend surface model developed by Ojansuu and Henttonen (1983). The data of the model originate from the Finnish Meteorological Institute. Simply the geographical coordinates in a kilometer-based grid and the altitude are needed in order to get monthly mean temperatures, monthly precipitations and annual day-degree values from the model. The system covers the years 1880-1993.

The tree-ring data can be analysed by universal statistical packages and by some dendrochronological software. The most commonly used are the DPL (Dendrochronological Program Library), the DYNACLIM software and the KINDSYS package developed by the author.

The purpose in modelling is to construct reliable local chronologies and then use them for constructing temperature maps for the last 500 years. The derived temperatures will be used for calibrating the climatic variation of the 1900s. The time span of 500 years may be too short for this kind of approach. It is, however, possible to extend the span to at least 8000 years, which gives a far more reliable reference.

The quality of the tree-ring material presupposes careful cross-dating. Data, measurement errors and missing rings cause severe problems in pinpointing the climatic signals. Because of large quantities of older and uncrossdated data, it is time-consuming to prepare them for analysis. One of the old techniques, skeleton plotting, developed by A.E. Douglas (1941), has been re-developed further by the author. A new PC-based version, using laser printer techniques, produces sharp images for easy visual cross-dating (Fig.1).

Some basic temperature models from tree-rings (transfer functions) will be presented at the conference. They are based on multiple regression, and ridge regression techniques are used for minimising the effects of multicollinearity.
Fig. 1. An example of the skeleton plot technique used in the author's KINDSYS dendro-software. The thick bars indicate minimum points in the tree-ring data. The longer the bar, the deeper is the local minimum. The years where the bars occur frequently, are most probably climatic signals in large data. Other bars may be caused by tree-specific damage. The cross-dating checking is interpreted by the position of the bars: how they hit vertically on the same year.

References


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