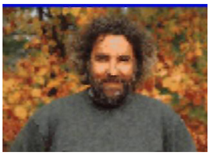
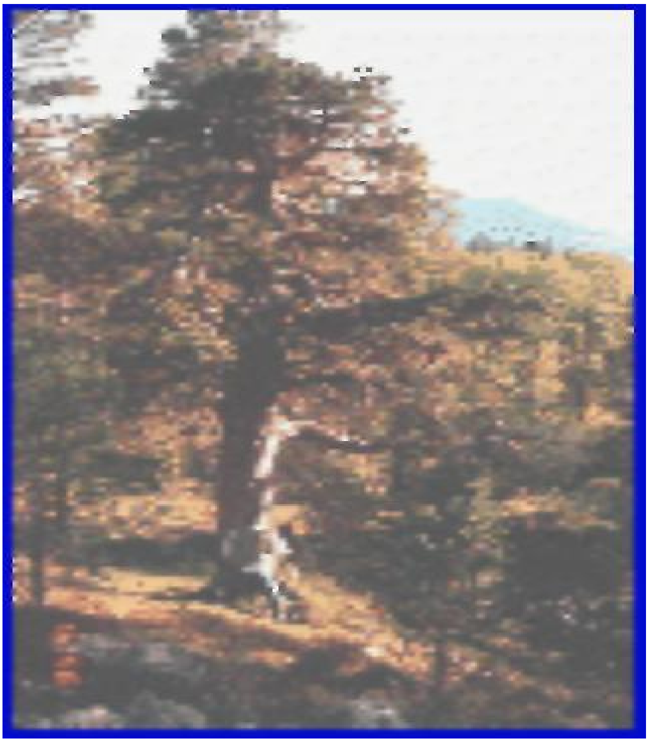
Trees as indicators of climate change

(http://www.cru.uea.ac.uk/cru/annrep94/trees/)

by Dr Keith Briffa



In many areas of the world where there is a strong seasonality in either temperature or rainfall, many species of trees form clear annual growth rings around their circumference. As more and more rings grow over the lifetime of these trees they form a record of year-by-year changes in climate, often stretching across hundreds and sometimes thousands of years. These records are the primary resource of the science of *dendroclimatology* - the study of the relationships between climate and tree-growth parameters and their use in the reconstruction of past climates.



Old scots pine trees growing north of the Arctic Circle in northwest Sweden record the evidence of past changes in summer temperatures in the varying widths and densities of their annual rings

At a few locations in the world, instrumental records of climate variables such as temperature or precipitation, reach back several hundred years. Over much of the world's well-populated land masses, however, there are extensive records only for a century or so. In many large and more remote regions such as northern Russia or northern Canada only a very sparse network of climate stations exists and most of their records span only a few decades. Our knowledge of `natural' climate variability is limited by the shortness of these records.

Small diameter cores being taken from 400-year old pines

Tree rings are one important source of what are called proxy-climate indicators or palaeoclimate data. Tree-ring data, such as ring widths or measures of ring density, hold a special place among such palaeoclimate records because they provide information which is annually resolved, continuous and, importantly, they provide climate information which is dated to the precise year. Extracting this information, however, is not straightforward.

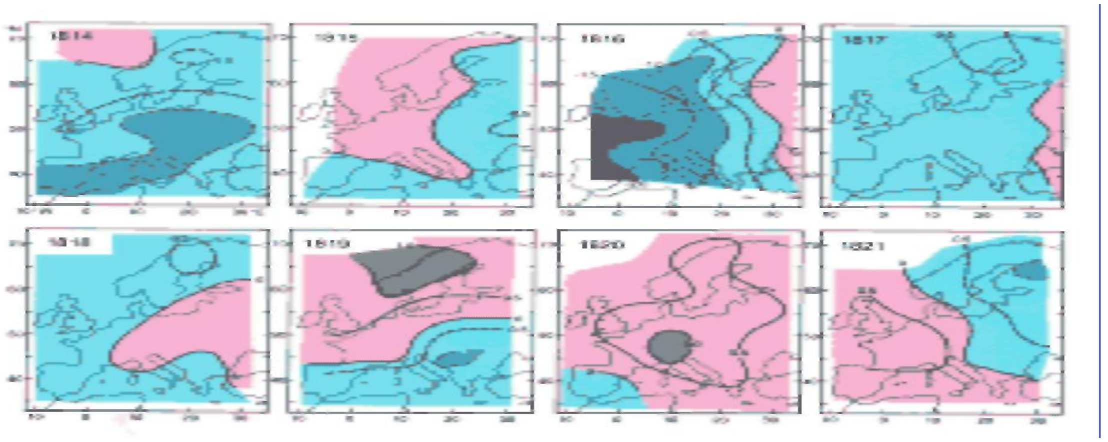
Tree growth is actually controlled by a complicated mix of climate-related factors. These include soil and air temperatures, soil moisture conditions, sunshine, wind etc. The size and density of cells within different parts of the annual growth ring, and the width of the ring itself, vary according to how the combination of all these climate factors change throughout the growing season. To complicate matters further, tree growth in one year is influenced to varying degrees by the nature of growth in one or more previous years and even by the climate conditions that prevailed outside the growing season. Ring growth over a number of years is also affected by non-climate-related factors that include tree age, competition from other plants, soil fertility, attacks by herbivorous insects and even changes in the composition of the atmosphere. It is the task of the dendroclimatologist to try to identify and separate these various influences in an effort to isolate information about some particular aspect of changing climate.

Above the present limit of modern pine growth are numerous lakes, today surrounded only by birch. Many of these lakes contain the remains of pines that grew here when summers were warmer than today.

By sampling selected trees in carefully chosen locations it is possible to simplify the identification of specific climate information. For example, trees growing at high latitudes or high altitudes are most sensitive to changing temperatures while the growth of trees in semi arid environments responds strongly to changing soil water conditions and so provides information on precipitation.

Information about the past growth of trees is simply acquired by taking small-diameter radial cores which do not injure the tree. These are mounted, prepared and the ring widths measured and stored. By carefully comparing, correctly aligning and then averaging the yearly growth measurements from many trees in an area, a *chronology* can be constructed which reaches, unbroken, from the present back to the earliest growth years of the oldest trees. In special situations, matching a chronology with overlapping series of measurements from dead trees, perhaps preserved in old buildings or naturally in river gravels, peat bogs or lakes, enables chronologies to be extended backwards, sometimes for thousands of years, even though the individual trees that make up the chronology may have lived for only a few hundred years.

A sample of a well-preserved subfossil pine trunk recovered from a northern Swedish lake. This tree grew about 6000 years ago

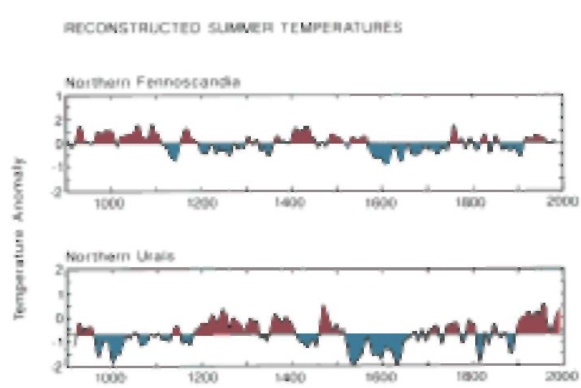


Where networks of tree-ring data are available, detailed year-by-year maps of climate can be reconstructed. This example shows summer temperature patterns (anomalies from the 1951-70 mean) over western Europe during the late 1810s and early 1820s. Long single-site records and spatial patterns of changing climate conditions are particularly valuable for studying the natural mechanisms of climate change that operate independently of possible interference brought about by the human race

By statistically comparing tree-ring chronologies with modern climate records, equations can be developed which can be used in conjunction with the tree-ring data to reconstruct past climate values, with a degree of confidence that depends on the strength of the tree- growth/climate link and the statistical quality of the chronology back in time.

During the last two decades, the Climatic Research Unit (CRU) has developed numerous tree- ring chronologies and worked on a number of fundamental aspects of the statistical methodology of dendroclimatology. A range of projects have been undertaken, using different types of tree-ring data, either to reconstruct past climate or to explore possible changes in other environmental conditions.

In recent years it has been in the area of climate reconstruction that the CRU has concentrated its efforts and produced a range of results that include regional average records of summer temperatures, extending over more than 1000 years, in both Northern Fennoscandia and the northern Urals and detailed spatial maps of temperatures for several centuries across northwest Europe, the western United States and northern North America.



By comparing modern climate and tree-ring records, equations can be developed that allow long tree-ring chronologies to be used for estimating past climate variability, sometimes over thousands of years. Two summer temperature records are show here, one representing northern Fennoscandia and the other the area of the Polar Ural Mountains in Siberia. The data are smoothed to accentuate decadal and longer-timescale variations

The major project currently underway involves the coordination of an international collaboration between tree-ring researchers from 15 institutions in 9 countries. This work is funded by the European Community Environment Programme. Its long-term goals include the reconstruction of spatial patterns of summer temperatures across the whole of northern Eurasia during several recent centuries and investigation of the evidence for various forcing mechanisms such as volcanic activity, solar variability or changes in the oceanic circulation of the North Atlantic and Arctic Oceans. This work is drawing heavily on a close collaboration with Dr Fritz **Schweingruber** at the Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland; Dr Stepan **Shiyatov**, Institute of Plant and Animal Ecology, Ural Branch of the Russian Academy of Sciences, Ekaterinburg, Russia; and Dr Eugene **Vaganov**, Institute of Forest, Krasnoyarsk, Russia. They are providing much of the primary chronology data from a network of sites across northern Russia, all of which are being analysed to provide densitometric information at Dr Schweingruber's laboratory. At special locations in Sweden and Finland, the project has produced continuous temperature-representative chronologies stretching across the whole of the last 2000 years. Subfossil wood preserved in lakes in these regions will eventually allow us to extend these series to more than 7000 years. The project is also examining evidence of climate variability contained in similarly long oak-ring-width chronologies in west central Europe and exploring the strength of climate control over isotopic variations in different elements of oak tree rings from Ireland, Finland and the United Kingdom.

Much of the work in dendroclimatology at the CRU has and continues to involve significant collaboration between colleagues within the Unit and abroad. Besides the current project described above the CRU is at present working on joint tree-ring research with other institutions in both North and South America, Russia and New Zealand. The continued success of our work in this area will be dependent on the strength of our links with these and other tree ring workers around the world.