TRACE 2008: Tree Rings in Archaeology, Climatology and Ecology, 27 - 30 April 2008, Zakopane, Poland

Climatic variation (cycles and trends) and climate predicting from tree-rings

Timonen, M.[1], Mielikäinen, K.[2], & Helama, S.[3]

1 Finnish Forest Research Institute, Rovaniemi Research Unit, PL 16, FI-96301 ROVANIEMI, FINLAND
2 Finnish Forest Research Institute, Vantaa Research Unit, PL 18, FI-01301 VANTAA, FINLAND
3 Department of Geology, University of Helsinki, Gustaf Hällstöminkatu 2 (P.O. Box 64), 00014 HELSINKI, FINLAND

Introduction. The growth of Scots pine (Pinus sylvestris L.) is highly sensitive to June-July temperatures at the Finnish pine timberline. Exceptional preservation of pine wood and its accumulation in non-oxygen muddy bottoms of ice-cold lakes have made it possible to build a 7641 years long continuous tree-ring chronology.

The characteristics of this chronology, the distribution of the samples (on both sides of the present timberline) and the strong June-July temperature connection have provided exceptional tools for dendroclimatic analysis and reconstructions.

Objectives. We discuss here three topics: 1. The "Past Timberlines" model, 2) Climatic trends during the Last Millennium and 3) Models predicting future natural climate.

Data and Methods. The "Past Timberlines" model was built by combining information from megafossil locations, lake sediments, GIS-based vegetation and climate data. Our models predicting future climate were established on tree-rings and climate data. Spectral analysis was used for identifying the most significant cycles. FFT (Fast Fourier Transformation) smoothing techniques was applied in removing high-frequency variation from the chronology. Cycle pattern analysis and duplicating techniques were used in fitting the cycle history of the past 500 years as a part of our prediction models.

Results. 1) ***A MODEL FOR THE "PAST TIMBERLINES".*** The model suggests that climate about 6000 years ago was 2.5 degrees warmer than today. More to read: check Fig.1.

2) ***CLIMATE OF LAST MILLENNIUM.*** The warmest and coldest reconstructed 250-year periods occurred AD 931-1180 and AD 1601-1850 (Fig. 5). These periods overlap with the Medieval Warm Period (MWP) and the Little Ice Age (LIA). The coldest and warmest of all reconstructed 100-year periods occurred AD 1587-1686 and AD 1895-1994, respectively. Appr. a 60-year cycle is attributable to North Atlantic thermohaline circulation (THC) during the MWP but not during the LIA.

3) ***CLIMATE PREDICTING.*** The most significant cycles in our supra-long chronology range from 30 to 95 years (30-32, 37, 47-49, 81-85 and 95 years, Fig. 2). We hypothesize that climate during the last 500 years has had a varying cyclic pattern of 60 - 95 years. Our two models predicting natural climatic variation for the rest of this century (Fig. 7) lean on this judgment.

Conclusions. Detailed picture of temperature evolution shows that MWP was a long ameliorated interval with mean temperatures warmer than temperatures during the following centuries but not warmer than during the 20th century. Cooling of climate since the MWP until the termination of the LIA follows the hemispheric trend supposedly by orbital forcing and changes in solar activity, amplification of volcanic signature years and hemispheric vegetation changes with amplifying mechanism from regional forest-limit retreat. THC further appears to be an agent behind the initiation and continuation of MWP and the mid-LIA transient warmth.

We assume in our climate prediction model that the last cycle maximums occurred in 1540, 1660, 1760, 1855 and 1925 and the minimums in 1610, 1710, 1795, 1895 and 1970. Applying the varying cycle of 80 - 95 years, the next warm cycle should peak some 2005 - 2020 and the next cool one some 2050-2065.

One should, however, note that climate is basically a *chaotic system* with a number of unknowns and uncertainties. Abrupt changes in climate and switching to alternative climate modes make it very difficult to build reliable models even in our case, i.e. predicting only future natural climate variation.

Kultti, S., Mikkola, K., Virtanen, T., Timonen, M. & Eronen, M. 2006. Past changes in the Scots pine forest line and climate in Finnish Lapland: a study based on megafossils, lake sediments, and GIS-based vegetation and climate data. The Holocene 16(3): 381-391.
Check also Kultti et.al. 2003: Past changes in the Scots pine treeline and climate in Finnish Lapland - evidence from pine megafossils and lake sediments. http://lustiag.pp.fi/PastTimberlines.pdf

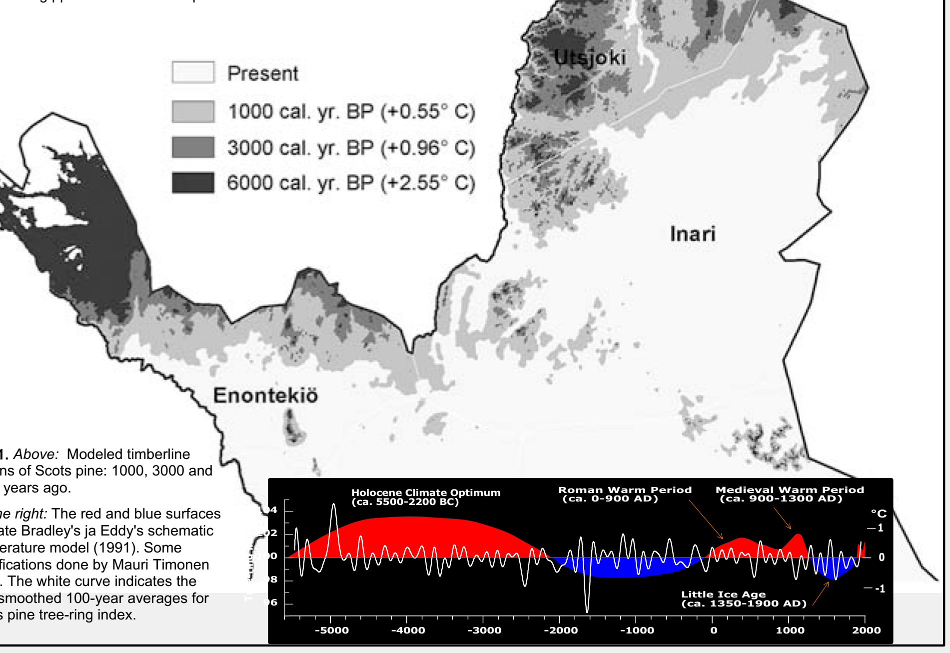
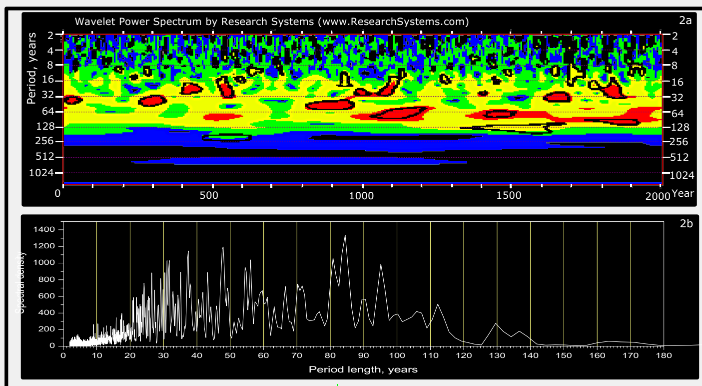


Fig. 1. *Above:* Modeled timberline regions of Scots pine: 1000, 3000 and 6000 years ago.

On the right: The red and blue surfaces indicate Bradley's ja Eddy's schematic temperature model (1991). Some modifications done by Mauri Timonen 2007. The white curve indicates the FFT smoothed 100-year averages for Scots pine tree-ring index.



The tree-ring index for the last 2000 years was analyzed by the Wavelet Power Spectrum (**Fig 2a).** Red color shows the most significant cycles. Climate cyclicity seems to have become more stable during the last 600-700 years.

Spectral density analysis for the whole 7641-yr timberline pine chronology exposes several cycles (**Fig 2b**). The strongest of all is an 84-yr cycle.

The Wavelet Power Spectrum for the last half millennium suggests that cycle length varies between 60 and 95 years. We assume this to be caused by climatic variations and having a connection to solar activity and the North Atlantic thermohaline circulation patterns.

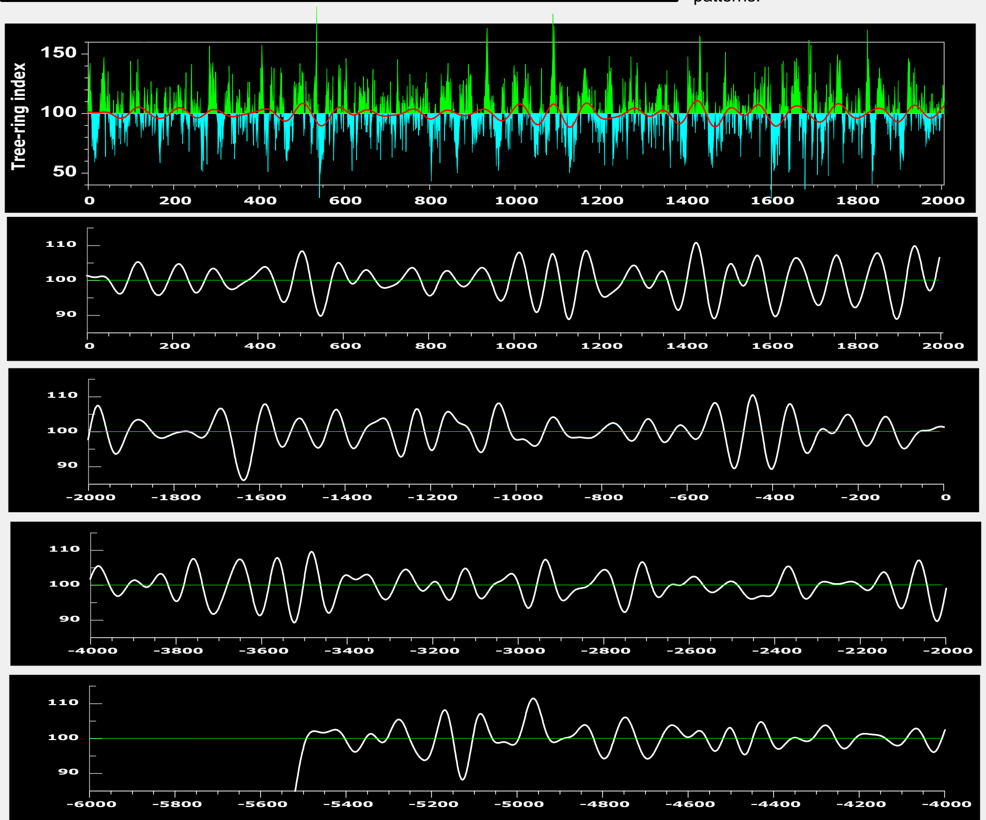


Fig.3. 50-yr FFT smoothing visualises the 80-95-yr cyclicity in the tree-ring chronology.

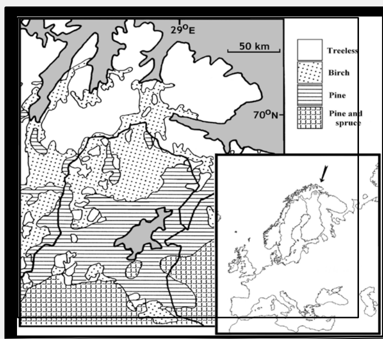


Fig. 4. Finnish timberline region (figure with horizontal lines) is close to Arctic and Atlantic Oceans.
Geographical location and prevailing southwestern winds explain why Finnish timberline pine is sensitive to climate patterns occurring especially in the North Atlantic Ocean.
The study material was collected on the north side of Lake Inarijärvi, where the oldest pine megafossils were found.

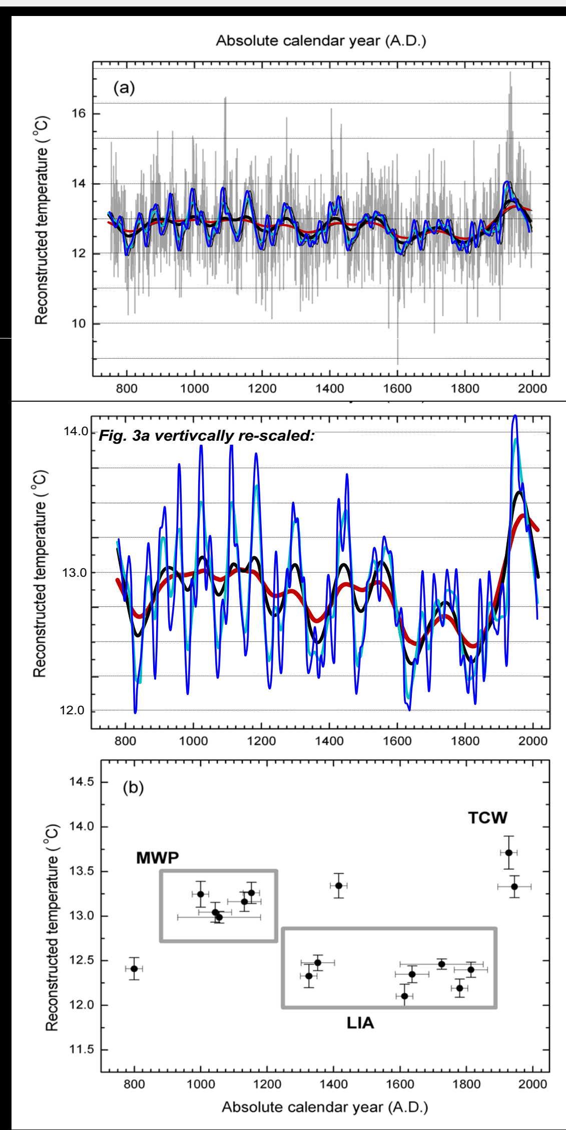


Fig. 5 (Right). Climatic evolution of the past millennium through Medieval Warm Period (MWP), Little Ice Age (LIA) and Twentieth Century Warmth (TCW). Reconstructed temperature variability depicts total variations (grey line), superposed by decadal, multi-decadal, centennial and multi-centennial variations (a). The anomalous climate phases were quantified by four warmest and coolest 50-year periods, three warmest and coolest 100-year periods and the warmest and coolest 250-year periods. Horizontal bars indicate the duration of the period, vertical bars indicate the standard errors about the period mean (b).

Reference: Helama S., Timonen M., Holopainen J., Ogurtsov M.G., Mielikäinen K., Eronen M., Lindholm M. & Meriläinen J. (submitted). Imprints of Medieval Warm Period, Little Ice Age and twentieth century warmth in proxy-based temperature reconstruction at high latitudes of Europe.

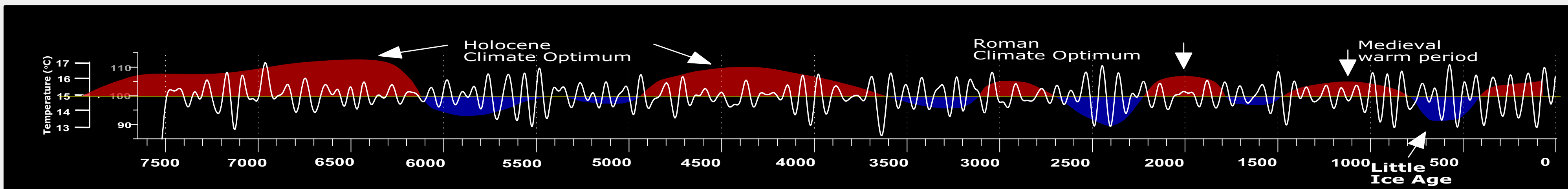


Fig. 6. The red-blue curve: average near-surface temperatures of the Northern Hemisphere during the past 11 000 years (red-blue modified from Dansgaard et al., 1969, and Schönwiese, 1995). The white curve: 50-yr FFT smoothing on the tree-ring index of the Finnish 7638-yr supralong pine chronology.

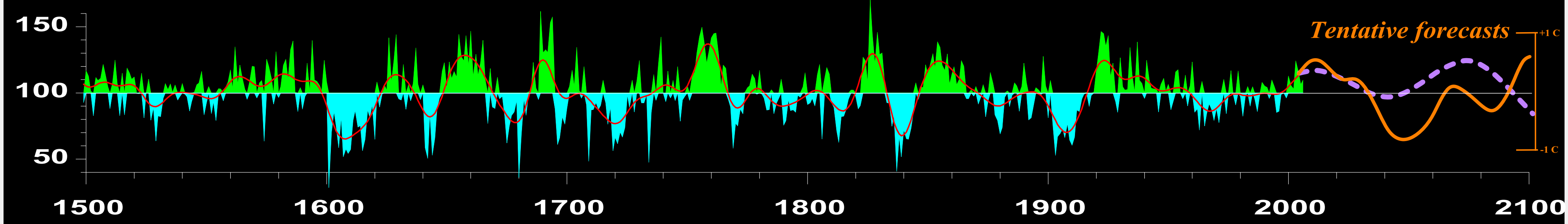


Fig. 7. The green-blue curve indicates annual growth variation of Scots pine at the Finnish timberline. The red curve is an 11-yr FFT smoothed index. The orange (11-yr FFT) and violet (50-yr FFT) smoothed curves show two tentative tree-ring index developments for the rest of this century. It can also be considered as a proxy estimate for future natural climate development in Northern Finland (human effect not included!).