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New evidence of the solar Gleissberg periodicity in summer temperature over Northern Fennoscandia

Northern Fennoscandia temperature and solar activity

Many recent studies have focused on the influence of solar activity on weather and climate and the possibility of solar contribution to atmospheric processes is currently actively debated.

Northern Fennoscandia is a geographic region suitable for testing secular solar-climate relationship. This region is located:

(a) at high latitudes, in a zone in which geomagnetic rigidity cutoff is low and the infiltration of cosmic ray particles into atmosphere is facilitated,

(b) remote to areas of intensive volcanic activity, which can obscure the detection of possible solar influence .

Analyses of tree-ring based reconstructions of summer temperatures in Finnish Lapland (68–70^0 N, 20–30^0 E) have shown that their long-term changes are modulated by corresponding solar variations.

Previous reconstructions of Northern Fennoscandia temperature

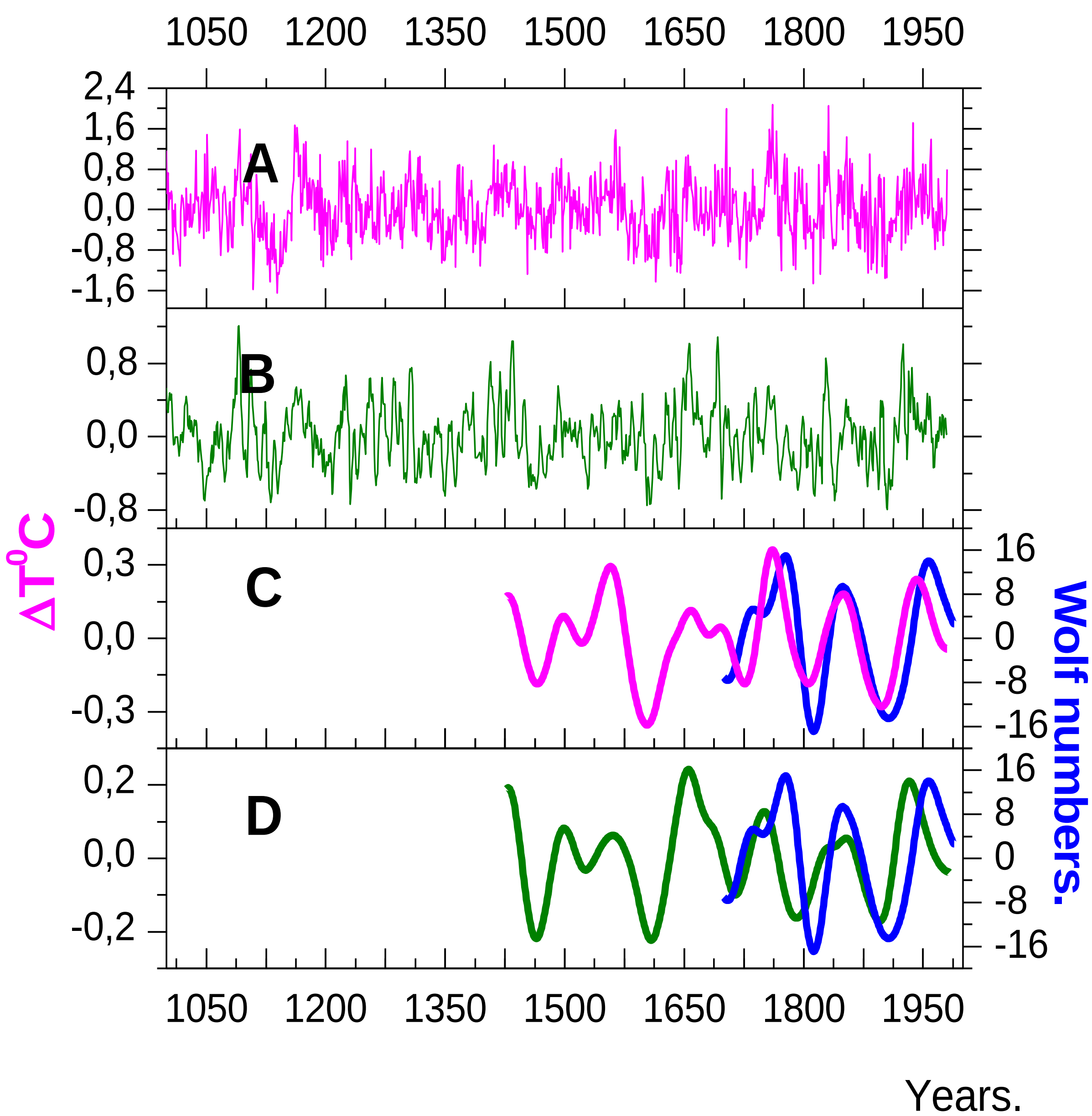


Figure 1. **A – NFT1 – reconstruction of July temperature in NF (68-70^0 N, 21-29^0 E, Lindholm and Eronen 2000);**

B – NFT2 – reconstruction of April-August temperature in NF (68^0 N, 22^0 E, Briffa et al. 1990);

C – NFT1 – (magenta curve) and Wolf numbers (blue curve), both wavelet filtered in 55-147 yr band;

D – NF2 (green curve) and Wolf numbers (blue curve), both wavelet filtered in 55-147 band

Five new Northern Fennoscandia chronologies

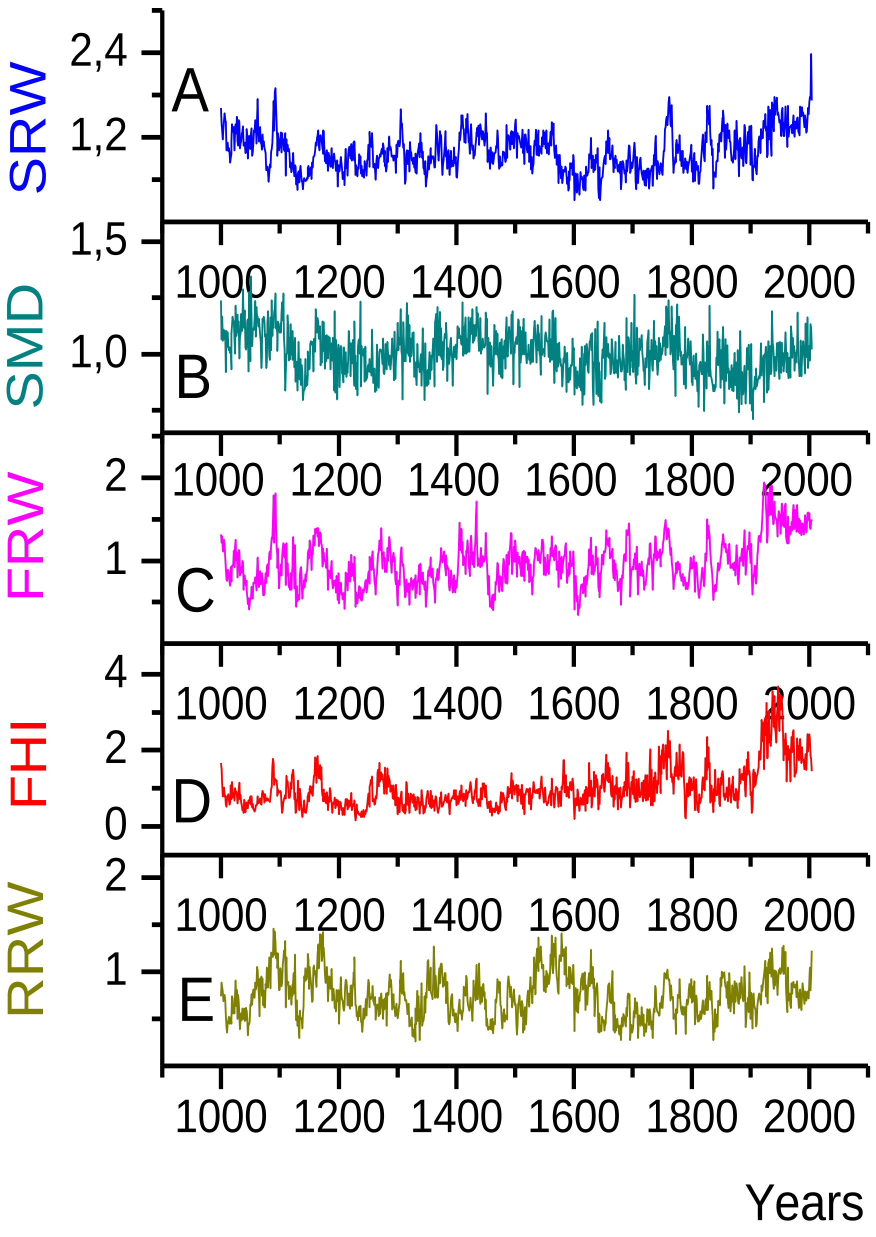


Figure 2. The five northern chronologies built using RCS

A – Swedish ring width (Grudd, 2008);

B – Swedish maximum density (Grudd, 2008);

C – Finnish ring width (Lindholm and Jalkanen, 2012);

D – Finnish height increment (Lindholm and Jalkanen, 2012);

E – Russian ring width (Kononov et al., 2009; McCarroll et al., 2013).

New reconstruction of Northern Fennoscandia July temperature

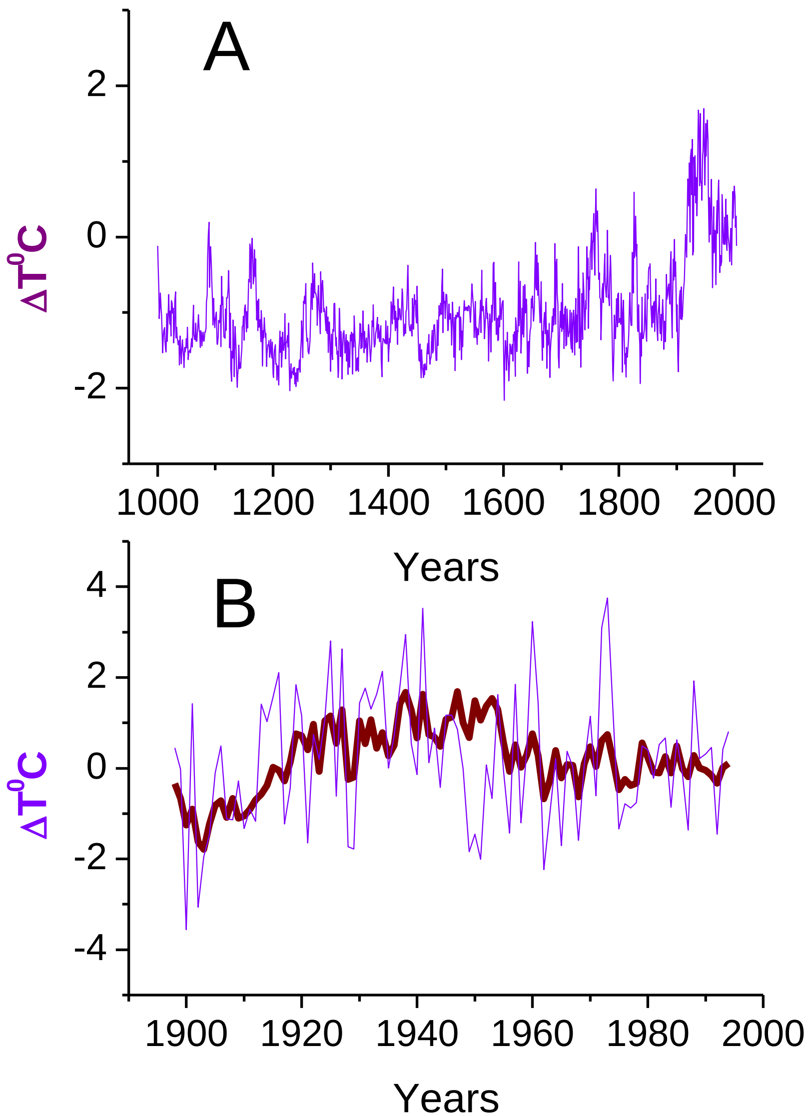


Figure 3 A – NFT3 proxy (PC1 of the five chronologies) scaled as anomalies of July temperature in Northern Fennoscandia (66°5'–70° N, 18°–33°15' E)

B – observed temperature in Northern Fennoscandia (CRUTEM4, mean July temperature of three grid boxes; broun line) and NFT3 – violet line in 1898–1994

RI between NFT3 and instrumental tempe-rature is:

0.57 over annual time scale;
0.72 over decadal time scale.

NFT3 explains 33% of annual tempera-ture variability and 52% of the decadal variability.

Spectrum of the new reconstruction of Northern Fennoscandia temperature

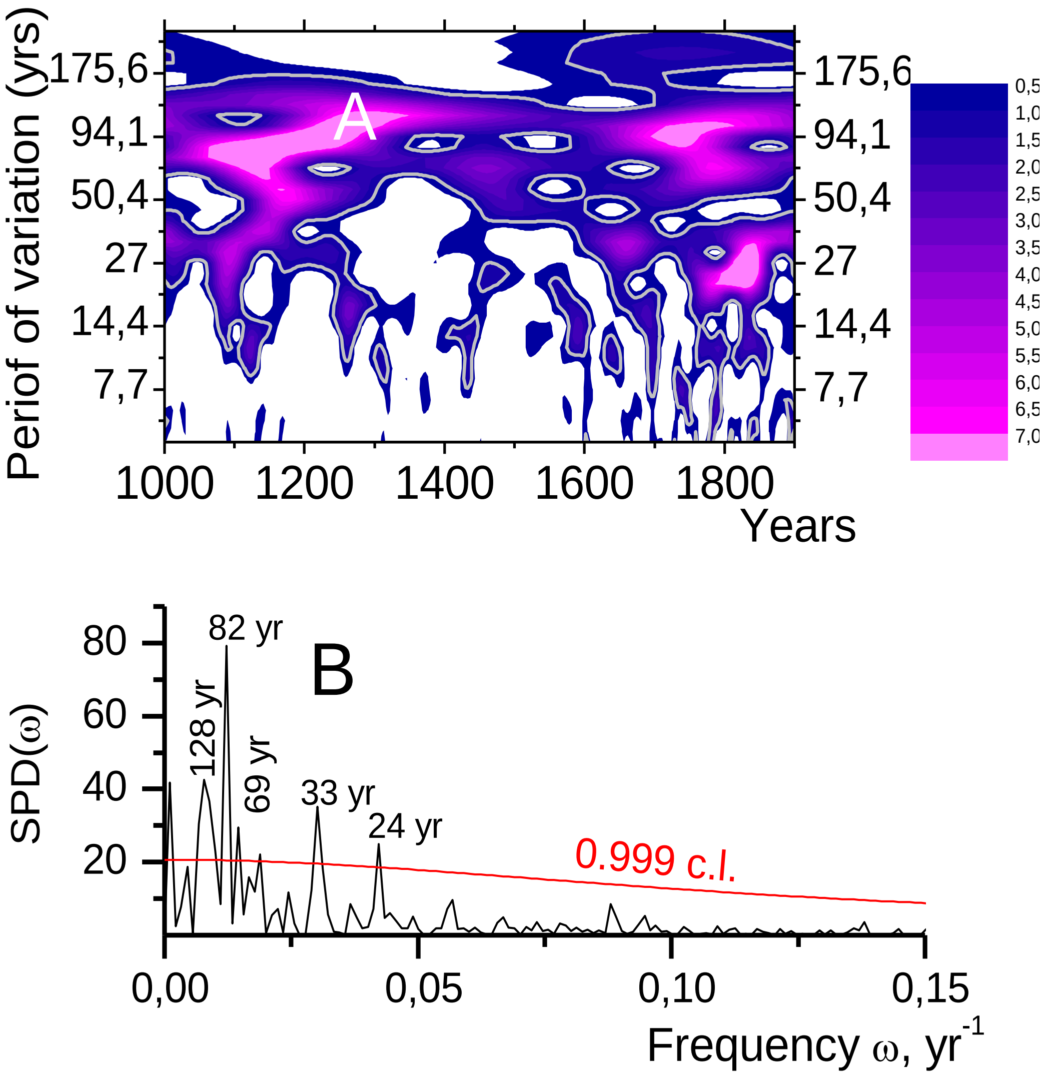


Figure 4.
A – local Morlet wavelet spectrum of NFT3 over 1000–1900. The spectrum is normalized to 0.99 confidence level calculated for a red noise with AR(1)=0.50.
B – Fourier spectrum of NFT3 for the same period with confidence level based on a red noise with AR(1) = 0.50. SPD is spectral density

Century-scale variability of Northern Fennoscandia temperature and solar activity

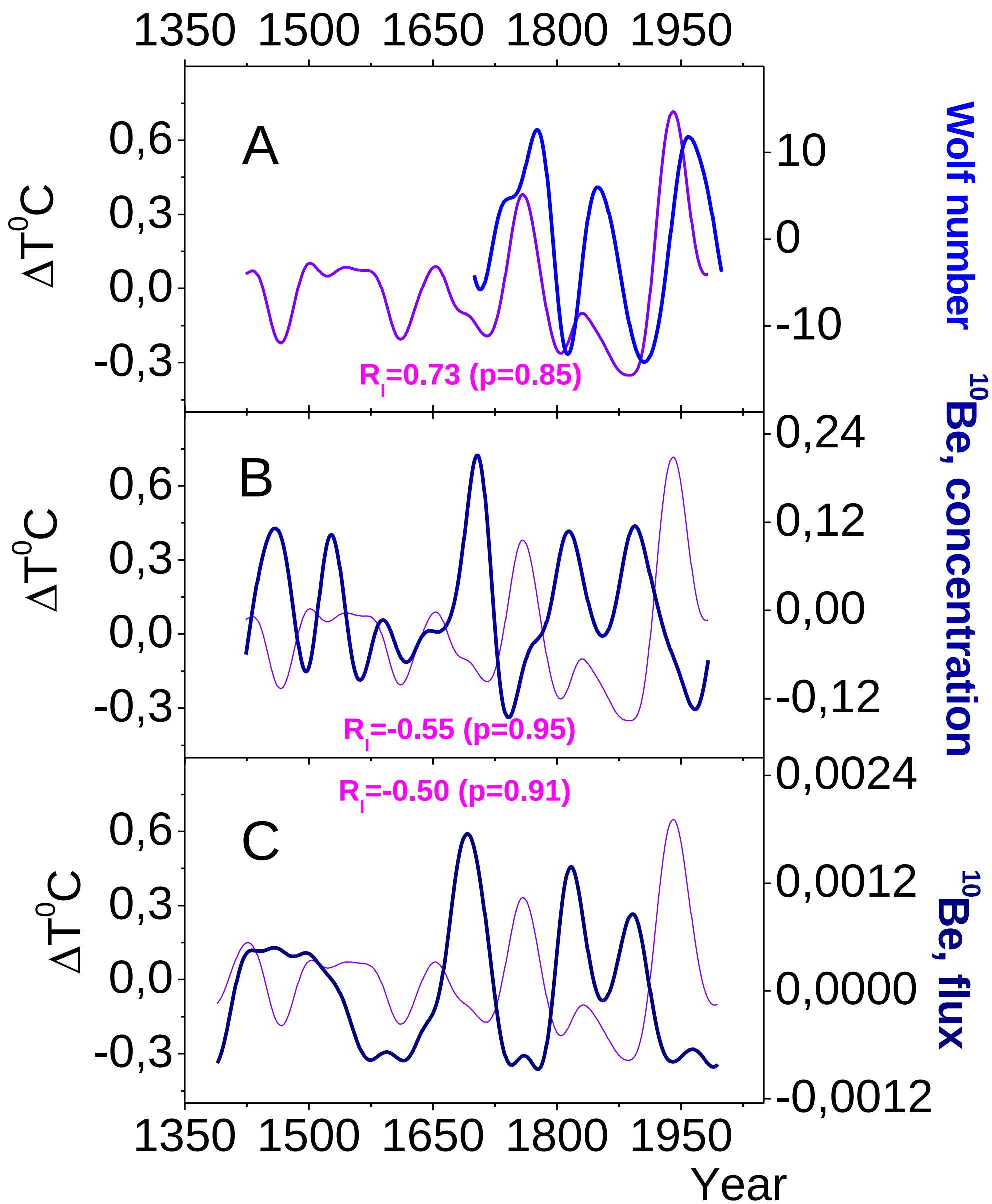


Figure 5. Time series wavelet filtered (MHAT basis) in 61–128-year band.

A – Wolf number blue curve) and NFT3 (violet curve);

B – concentration of ^{10}Be in Dye-3 core (South Greenland, 65.2^0 N, 43.8^0, W dark blue curve) and NFT3 (violet curve);

C – flux of ^{10}Be in NGRIP core (dark blue curve) and NFT3 (Central Greenland, 75.1^0 N, 42.3^0 W, violet curve).

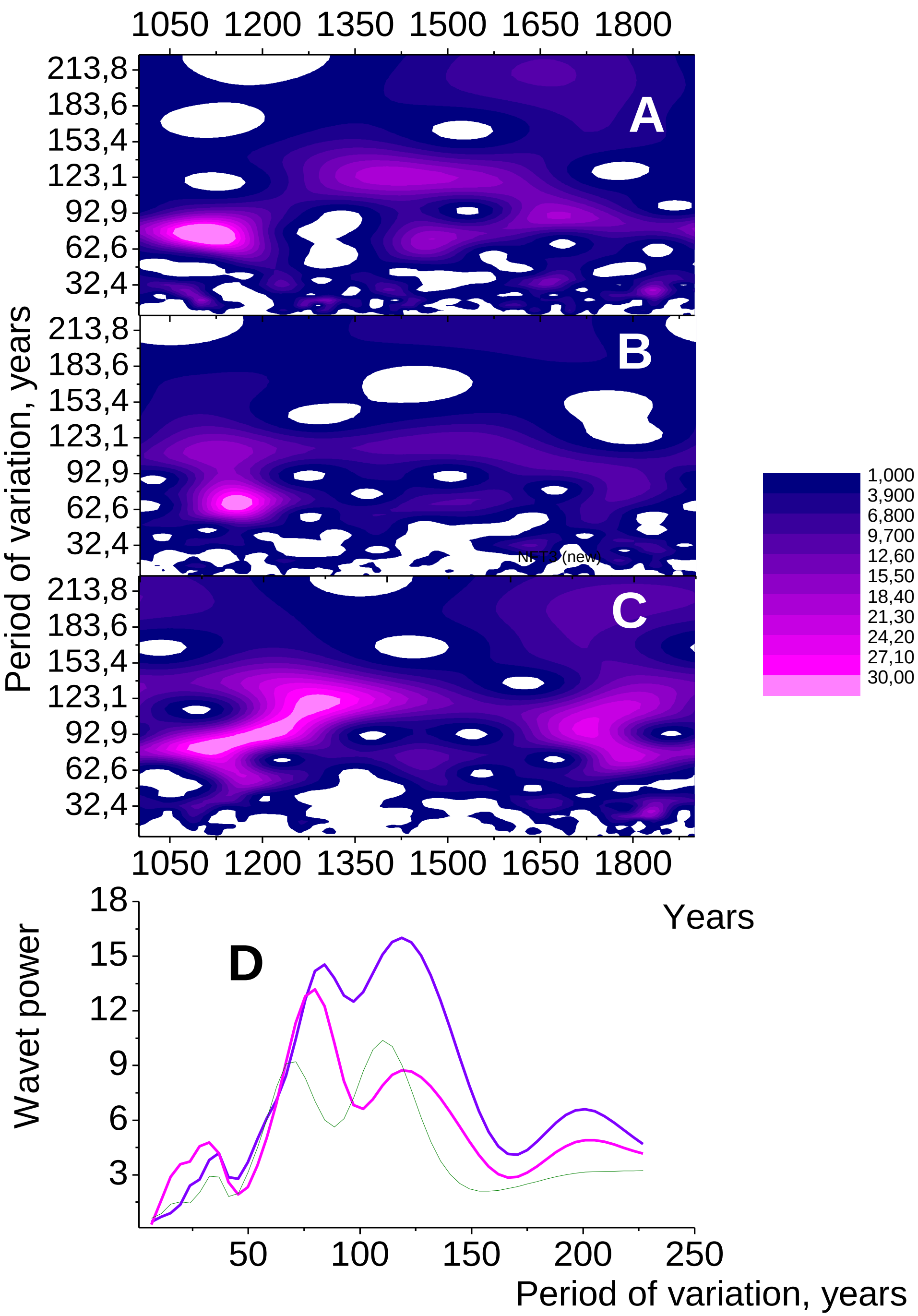


Figure 6.

A – local Morlet wavelet spectrum of NFT1.

B – local Morlet wavelet spectrum of NFT2.

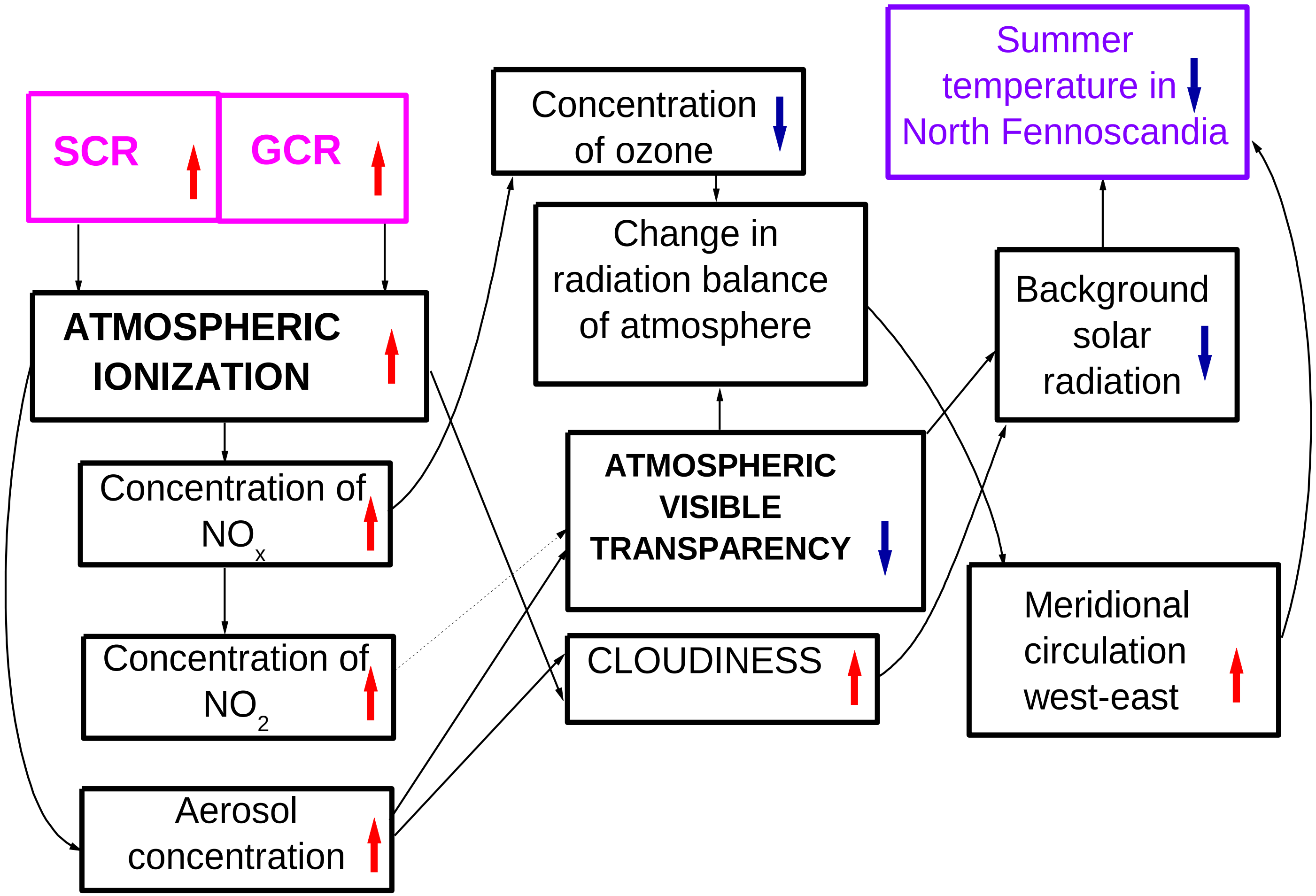
C – local Morlet wavelet spectrum of NFT3.

D – global Morlet wavelet spectra of NFT1 (violet curve), NFT2 – (green curve), NFT3 – (magenta curve).

All the spectra are normalized by variance.

RCS method captures low frequency variability in tree growth (temperature signal) better than the standardization methods (negative exponential and linear regression lines) used in previous reconstructions.

Possible mechanism of a century-scale link between solar activity and summer temperature in Northern Fennoscandia



CONCLUSION

Analyses of the northern summer temperature proxy NFT3 showed that:

1) a century-type (55–140-year) periodicity is well preserved in the data. This periodicity is highly significant and has a bi-modal structure, i.e. it consists of two oscillation modes, 55–100-year and 100–140-year variations.

2) The century-long variation in NFT3 shows fairly significant correlation with the corresponding Gleissberg cyclicity in:

(a) sunspot number (positive correlation) over AD 1700-1994;

(b) beryllium record from South Greenland (negative correlation) over AD 1424–1983;

(c) beryllium record from Central Greenland (negative correlation) over AD 1389–1990.

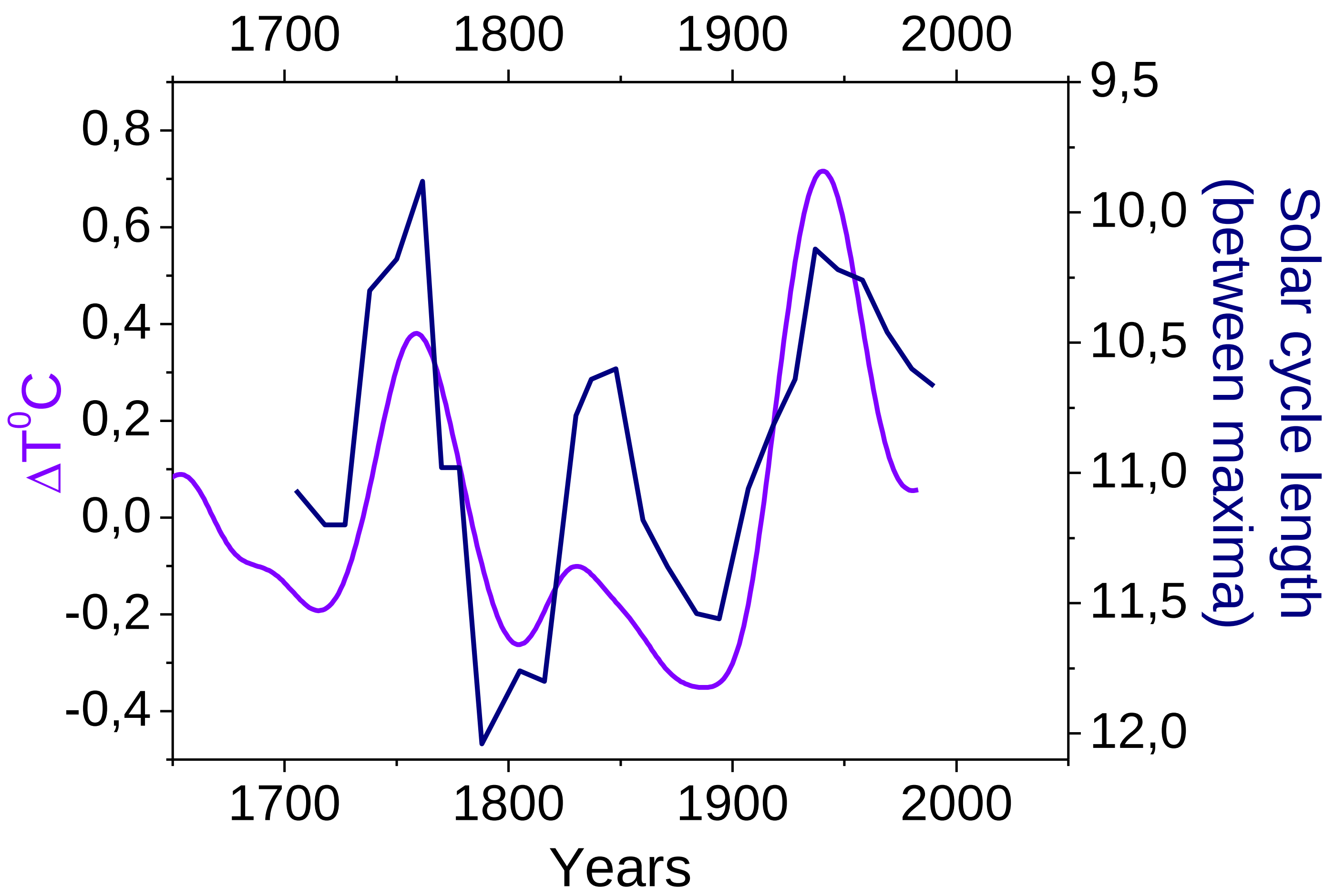
Thus the reality of a link between long-term changes in solar activity and climate in Fennoscandia has been confirmed by means of the new and expanded experimental data.

The obtained results testify advantage of the RCS method of standardization, which captures low frequency variability in tree growth.

- A mathematical representation of the modified negative exponential option for ringwidth standardization is as follows (Fritts 1976, p. 263):
- $wt \sim a*\exp(-bt)+k$
- where wt is ring width at year t, a is ring-width at year zero (if k is negligible), b is the slope of the decrease in ring width (hence, the ‘‘concavity’’ of the curve), and k is the minimum ring width, which is asymptotically approximated for large values of t.

- This approach scales ring measurements by comparison against an expectation of growth for the appropriate age of ring for that type of tree in that region (Briffa et al. 1992a). The tree-ring measurements acquired from multiple trees in one area are aligned by ring age (years from pith), and the arithmetic means of ring width for each ring age are calculated. The curve created from the mean of ring width for each ring age is smoothed by using a suitable mathematical smoothing function (Briffa et al. 1992; Esper et al. 2003; Melvin et al. 2007) to create smoothly varying RCS curve values for each ring age. In a simple application of RCS, each ring measurement is divided by the RCS curve value for the appropriate ring age to create a tree index

- At each site, annual shoot growth was obtained by measuring the distance between successive terminal bud scars along the main stem


1700
1800
1900
2000
0,8
0,6
0,4
0,2
0,0
-0,2
-0,4
ΔT^0C
9,5
10,0
10,5
11,0
11,5
12,0
Solar cycle length
(between maxima)
Years