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Evidence for the Gleissberg solar cycle at the high-latitudes of the Northern Hemisphere

M. Ogurtsov [a,c,*], M. Lindholm [b], R. Jalkanen [b], S. Veretenenko [a,d]

[a] *A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia*
[b] *Metla, Rovaniemi Research Unit, PO Box 16, FI 96301 Rovaniemi, Finland*
[c] *Central Astronomical Observatory at Pulkovo, Russia*
[d] *St. Petersburg State University, St. Petersburg, Russia*

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Abstract

Time evolution of growing season temperatures in the Northern Hemisphere was analyzed using both wavelet and Fourier approaches. A century-scale (60–140 year) cyclicity was found in the summer temperature reconstruction from the Taymir peninsula (~72° N, ~105° E) and other high-latitude (60–70° N) regions during the time interval AD 1576–1970. This periodicity is significant and consists of two oscillation modes, 60–70 year and 120–140 year variations. In the summer temperatures from the Yamal peninsula (~70° N, ~67° E) only a shorter-term (60–70 year) variation is present. A comparison of the secular variation in the Northern Hemisphere temperature proxies with the corresponding variations in sunspot numbers and the fluxes of cosmogenic ^{10}Be in Greenland ice shows that a probable cause of this variability is the modulation of temperature by the century-scale solar cycle of Gleissberg. This is consistent with the results obtained previously for Northern Fennoscandia (67°–70° N, 19°–33° E). Thus, evidence for a connection between century-long variations in solar activity and climate was obtained for the entire boreal zone of the Northern Hemisphere.

Keywords: Solar-climate relationship; Paleoclimatology; Solar paleoastrophysics

1. Introduction

The question of the existence of a solar-climate relationship and its possible physical mechanism is highly important in geophysics. Numerous recent studies have focused on the effect of the Sun's activity on weather and climate – see e.g. De Jager (2005), Gray et al. (2010), Lockwood (2010), Engels and van Geel (2012). Strong evidence for solar influence on the climate of the North Atlantic region was obtained by Moffa-Sánchez et al. (2014). They reconstructed thermocline temperature and salinity over the North Atlantic from AD 818 to 1780 using δ^{18}O, Mg and Ca paleorecords from sediment cores. They found large and sharp centennial-scale fluctuations in temperature and salt concentrations matching with changes in solar activity (Moffa-Sánchez et al., 2014). A century-scale (55–140 year) cyclicity, likely of solar origin, is present in warm season temperatures over Finnish Lapland (68–70° N, 20–29° E) and Northern Fennoscandia (67°–70° N, 19°–33° E) during the last millennium (Ogurtsov et al., 2002a, 2013). Possible solar contribution to global warming of the last decades is a subject of active debates. Sloan and Wolfendale (2013) have concluded that changes in solar activity contribute little (only about 10%) to the increasing global temperatures observed since the middle of the 20th century, while Stauning (2014) found that the temperature curve since 2001 corresponds to decaying level of solar activity. Some other studies on solar–climate connections have also produced controversial results

* Corresponding author at: 194021, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia.

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(Svensmark et al., 2009; Calogovic et al., 2010). Moreover, in spite of some serious research efforts (see e.g. Tinsley and Deen, 1991; Marsh and Svensmark, 2000; Yu, 2002, 2004; Tinsley, 2008) a physical mechanism quantifying the connection between the Sun's activity and climate is still poorly understood. The most likely causes for the shortcomings are the following:

(a) The shortness of available empirical data sets. The longest heliogeophysical records usually cover no more than the last 100–150 years; and
(b) Spatial and temporal variability of the solar–climatic correlations (Waple et al.; 2002; Veretenenko and Ogurtsov, 2012).

It should be noted also that centennial temperature cyclicity has substantial spatial variability (Mann et al., 1995). That is why it is important to examine solar–climatic relationships over vast areas and long time intervals. In our previous work we established century-scale correlation between the Sun's activity and summer temperature at Northern Fennoscandia (Ogurtsov et al., 2002a, 2013). This region borders the North Atlantic zone where a centennial-scale solar–climatic link has been confirmed by Moffa-Sánchez et al. (2014). The present work is devoted to a search for similar connection outside the North Atlantic area.

2. Material and methods

Two tree-ring proxy time series from subarctic Siberia and one from the high-latitudes of the Northern Hemisphere were used in this work (Fig. 1):

(a) Taimyr, Siberia (~72° N, ~105° E) warm season (May–September) temperature reconstruction based on ring width of larch collected at four sites in the Taimyr region (Jacoby et al., 2000). This time series spans AD 1575–1970.
(b) Yamal, northwest Siberia (69.5–71.0° N, 67.0–67.5° E) summer temperature reconstruction based on larch tree-ring width (Hantemirov and Shiyatov, 2002) in 2067 BC–AD 1996.
(c) Warm season temperature proxy for high-latitude (mostly 60–70° N) regions of the Northern Hemisphere (Briffa, 2000) including data from Mongolia, eastern Siberia (Yamal and Taimyr), eastern Canada, North American tree line, and northern Sweden. This time series covers time interval AD 1– 1993.

We compared these reconstructions with Wolf numbers and two records of ^{10}Be flux in ice, measured at Dye-3 core (South Greenland, 65.18° N, 43.83° W, AD 1424–1985) and in NGRIP core (North Greenland, 75.10° N, 42.32° W, AD 1389–1994) by Beer et al. (1990) and Berggren et al. (2009). Cosmogenic ^{10}Be, produced in the Earth's atmosphere by high-energy cosmic rays has for a long time

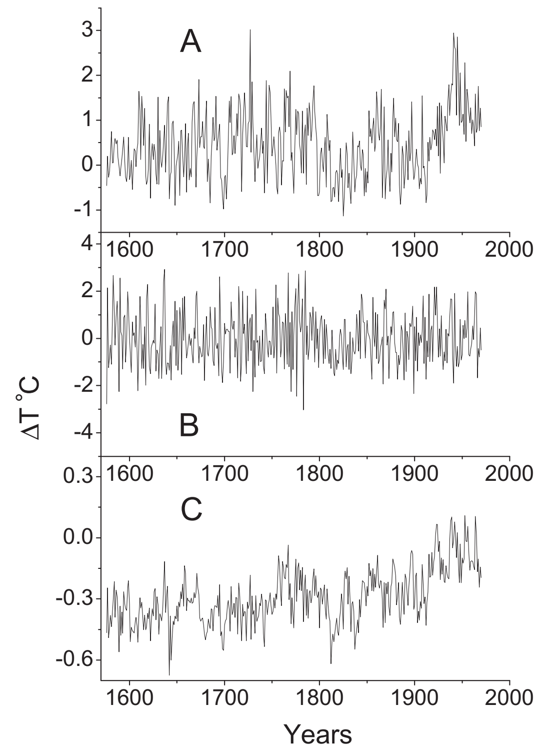

Fig. 1. Temperature reconstructions at: (A) Taimyr (Jacoby et al., 2000); (B) Yamal (Hantemirov and Shiyatov, 2002); (C) boreal belt of the Northern Hemisphere (Briffa, 2000).

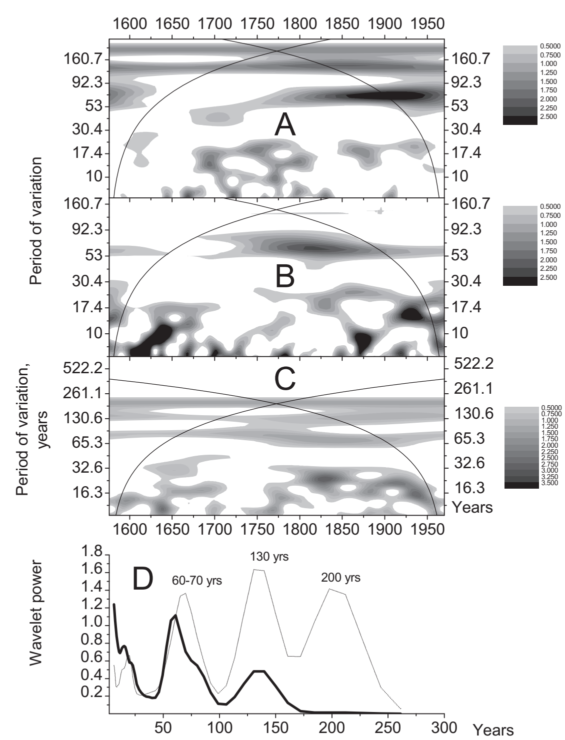

Fig. 2. (A) local Morlet wavelet spectrum of Taimyr temperature; (B) local Morlet wavelet spectrum of Yamal temperature; (C) local Morlet wavelet spectrum of growing season temperature over high-latitude zone of Northern Hemisphere; (D) global Morlet wavelet spectra of Taimyr temperature (dotted line) and Yamal temperature (solid line). All the spectra were normalized to 0.99 confidence level.