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Possible solar-climate imprint in temperature proxies from the middle and high latitudes of North America

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Abstract

Five proxy temperature time series based on tree-rings and varves from the middle and high latitudes ($\varphi > 50°$) of North America were analyzed. They cover the last 3–5 centuries. It was shown that the reconstructions from Canadian Rockies (52.15° N, 117.15° W) and northeast Alaska (68.8° N, 142.3° W) correlate appreciably with Wolf number and ^{10}Be concentration in Greenland ice over long ($T > 13$ years) time scales. Correlations are weaker for the reconstruction from northwestern Canada (68.25° N, 133.33° W). Baffin Island (66.6° N, 61.3° W) and the Gulf of Alaska (49–62° N, 123–145° W) show no correlations with records of solar activity. Thus, these results indicate that solar-climatic effects have an apparent regional distribution. Possible causes of this regionality are discussed.

Keywords: Solar activity; Climate; Paleoclimatology

1. Introduction

The enduring question of the reality of a link between the Sun's activity and terrestrial climate and its possible physical mechanism is becoming increasingly important in solar-terrestrial physics. Many recent studies have focused on the influence of solar activity on climate – see e.g., De Jager (2005), Gray et al. (2010), Lockwood (2010), Engels and van Geel (2012), Moffa-Sanchez et al. (2014). Adolphi et al. (2014) found correlation between centennial variations of ^{10}Be and δ^{18}O values in Central Greenland ice during the Last Glacial Minimum (22,500–10,000 BP). In addition century-scale correlation between the Sun's activity and summer temperatures have been reported in Northern Fennoscandia (Ogurtsov et al., 2002, 2013) and North-East Siberia (Ogurtsov et al., 2015). Plausible evidence for solar influence on the climate of high-latitude regions of the Northern Hemisphere was also presented by Ogurtsov et al. (2015). The results of Ogurtsov et al. (2002a, 2013, 2015) were produced analyzing centennial-scale paleorecords.

During the last few decades more and more evidence have accumulated to support the idea that cosmic corpuscular radiation – galactic cosmic rays (GCR) and solar cosmic rays (SCR) – is a potential source of solar-induced climate variability over decadal and longer time scales (Marsh and Svensmark, 2000, 2003; Palle et al., 2004; Tinsley, 2008; Veretenenko and Ogurtsov, 2012, 2013). Marsh and Svensmark (2000, 2003) and Palle et al. (2004) showed a link between GCR and low cloudiness, Tinsley (2008) considered connections between cloudiness and global electric circuit. Some evidence for the influence

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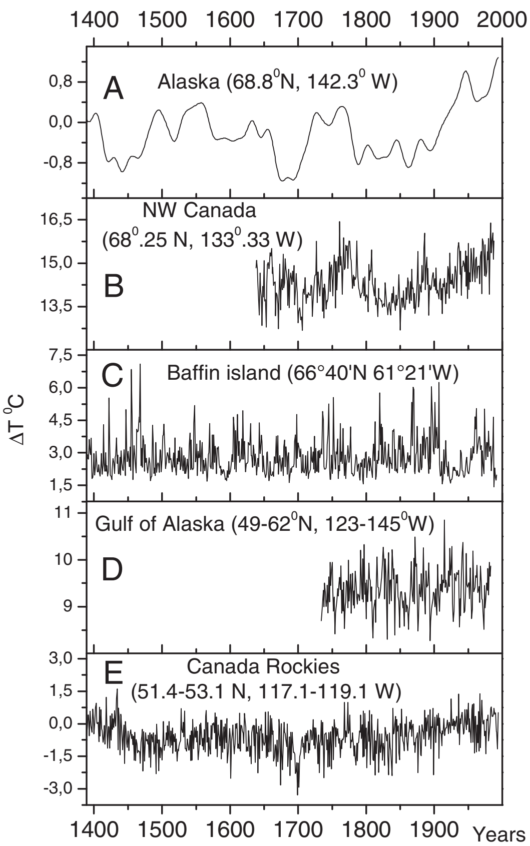

Fig. 1. Temperature reconstructions at: A – northeastern Alaska (Anchukaitis et al., 2013); B – northwestern Canada (Szeicz and MacDonald, 1995); C – Baffin Island, Canada (Moore et al., 2001); D – Gulf of Alaska (Schweingruber et al., 1993); E – Canadian Rockies (Luckman and Wilson, 2005).

of GCR on regional temperature in south Brazil were found by Frigo et al. (2013). Furthermore Veretenenko and Ogurtsov (2012, 2013) showed a relationship between GCR and stratospheric polar vortex. Ogurtsov (2007) proposed that long-term variations of both SCR and GCR influence century-scale changes of global climate. In addition Lam et al. (2013) demonstrated an influence of the interplanetary magnetic field B_y on mid-latitude surface pressure. However, despite intensive efforts a physical model quantifying the relationship between solar activity, space weather and climate is still largely missing. Moreover, some studies on solar-climate connection (Friis-Christensen and Lassen, 1991; Marsh and Svensmark, 2000, 2003; Svensmark et al., 2009) are even contradicted and questioned by others (Damon and Laut, 2004; Sloan and Wolfendale, 2008; Calogovic et al., 2010). Currently the influence of solar activity on atmospheric transparency via changes of the atmosphere ionization seems to be the most promising alternative mechanism for a the solar-climatic link.

In the present work we continue to study long-term (periods longer than 10–20 years) correlations between the Sun's activity and climate of the Northern Hemisphere focusing now on possible solar-climatic connection over the North American continent. One of the main difficulties in solar-climate research is the shortness of the majority of experimental data sets. Since the available empirical data series are rather short – usually they cover no more than the last 100–150 years – we used up-to-date temperature proxies. It should be noted that some scientists doubt the Sun's ability to significantly affect the Earth's climate (Pittock, 2009). In addition, e.g., according to Mann et al. (1995) climate can vary naturally at multi-decadal and centennial time scales.

2. Materials and methods

Five temperature proxies (from trees and sediments) from the middle and high latitudes ($\varphi > 50°$) of North America were used (Fig. 1):

(a) July–August temperatures reconstructed in northeastern Alaska (Firth River valley, 68.8° N, 142.3° W) based on latewood density data (Anchukaitis et al., 2013). This time series covers time interval AD 1073–2002.
(b) June–July temperatures reconstructed in northwestern Canada (68.25° N, 133.33° W) using tree-ring data (Szeicz and MacDonald, 1995). This series spans AD 1638–1988.
(c) Summer temperatures reconstructed at Donard Lake, Baffin Island, Canada (66.6° N, 61.3° W) based on laminae thickness in sediments (Moore et al., 2001). This record covers time interval AD 752–1992.
(d) Warm season (April–September) dendroclimatic reconstruction from the Gulf of Alaska (49–62° N, 123–145° W) (Schweingruber et al., 1993). The series from ring-widths and latewood densities spans AD 1734–1983.
(e) Summer (May–August) maximum temperature reconstruction from Canadian Rockies (52.15° N, 117.15° W) (Luckman and Wilson, 2005), which covers time interval AD 950–1994.

The proxy time series were compared with Wolf numbers and a record of ^{10}Be flux in ice, measured in NGRIP core (North Greenland, 75.10° N, 42.32° W, AD 1389–1994) by Berggren et al. (2009) using correlation analysis. Wolf number reflects magnetic activity of the Sun directly. It starts only at AD 1700. Cosmogenic ^{10}Be produced in the Earth's atmosphere by high-energy cosmic rays is effectively modulated by solar activity. It is deposited in polar ice and serves an indirect indicator of the Sun's activity. Cosmogenic beryllium has been successfully applied for a long time as a reliable proxy of solar activity (see Usoskin, 2013). Annually resolved ^{10}Be records cover time intervals of 5–6 centuries. For further analysis all the data sets were smoothed by 13 years. We used smoothing by 13 years moving averages in order to suppress the 11-year variation and to retain longer-term variability.