Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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Journal of Physics: Conference Series 1697 (2020) 012007 doi:10.1088/1742-6596/1697/1/012007

Possible influence of solar and astronomical factors on a climate of Northern Fennoscandia

M G Ogurtsov[1], S V Veretenenko[1], S Helama[2], R Jalkanen[2] and M Lindholm[2]

[1]Ioffe Institute, Politekhnicheskaya 26, St Petersburg 194021, Russia
[2]Natural Resources Institute Finland, Rovaniemi, Finland

maxim.ogurtsov@mail.ioffe.ru

Abstract. Eleven proxy records of Northern Fennoscandia and North Atlantic climate variability were analyzed. Correlation of climatic records with (a) a quasi 11-year solar cycle of Schwabe, (b) a quasi 22-year solar cycle of Heil, (c) a quasi 20-year planetary-tidal cycle, related to wobbling of the Sun around the baricenter of the solar system, has been studied. A weak but stable and statistically significant correlation between the climatic proxies of Northern Fennoscandia and a double solar cycle was found to be present through the AD 1700–2000. No evidence of a connection between climatic records and both solar Schwabe cycle and quasi 20-year astronomic cycle were found. Possible physical mechanisms behind the revealed effect are discussed.

1. Introduction

Northern Fennoscandia (NF) is a geographic region quite appropriate for testing solar-climate relationship. This region is located at high latitudes i.e. in a zone (a) in which geomagnetic rigidity cutoff is low and the infiltration of cosmic ray particles into atmosphere is facilitated, (b) affected by stratospheric polar vortex which is likely to play an important role in transfer of the impacts of solar activity on atmospheric circulation patterns [1, 2], (c) remote to areas of intensive anthropogenic activity. In fact, there are multiple studies demonstrating potential connections between the solar forcing and climate of NF climate variability [3-6]. Despite of these findings, the solar signals were not confirmed by McCarroll et al. [7] who found no clear link between reconstructed total solar irradiance and NF summer temperature (NFST), at least before AD 1600. Moreover, Scafetta [8] proposed a ca 20-year planetary-tidal cycle, related to wobbling of the Sun around the baricenter (center of mass) of the solar system that could also be a factor affecting the terrestrial climate at time scales confusingly mimicking those of the Hale (quasi 22-year) solar cycle. These results suggest a need for a more thorough study of the NFST variability and its potential connection to extraterrestrial factors, at time scales relevant to periodicities of both the solar and astronomical forcing mechanisms. This work represents such an analysis. We concentrate on solar and astronomical forcing data and those of NF and North Atlantic (NA) climate records on decadal and bi-decadal scales in order to reveal any connections between the solar/astronomical forcing on climatic variability on time scales relevant to (a) the Schwabe solar cycle (ca 11 years), (b) the Hale solar cycle (ca 22 years) and (c) that of the Sun's wobbling i.e. astronomical cycle (ca 20 years), by means of the up-to-date NF and NA climatic proxy records.

2. Data

Proxy records in two categories were analysed: (a) the reconstructions of NF climate variability (b) the reconstructions of the large-scale ocean and atmospheric circulation indices representative of wide areas of North Atlantic, including the index series of the sea surface temperature in North Atlantic (NASST), North-Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO). The NAO is a measure of the difference in the sea level pressure between the Azores High Icelandic the Low and which, in turn, affects the atmospheric circulation over the NA and the NF region. The AMO is determined as a low-frequency mode of the North Atlantic (0–60 °N, 7.5–75° W) sea surface temperature (SST).

Table 1. A list of proxy records used in this analysis.

Reconstructed variable (Reference)	Region	Type of proxy data	Period	Abbrevi-ation
Mean regional July temperature (Lindholm and Eronen [9])	Northern Fennoscandia (68–70° N, 20–29° E)	TRW	AD 8–1991	NF_LE00
Mean regional July temperature (Ogurtsov et al. [10])	Northern Fennoscandia (67°–70° N, 19°–33° E)	TRW, MXD, THI	AD 1000–2004	NF_O13
Mean regional July temperature (Helama et al. [11])	Northern Fennoscandia (66.4°–70.8° N, 14.0°–35.3° E)	TRW, P	5500 BC–AD 2005	NF_H12
July–August temperature (Kononov et al. [12])	Russia, Khibiny Low Mountains 67.4°N, 33.15° E	TRW	AD 1630–1840	R_K09
Mid-summer temperature (Lindholm and Jalkanen	Finland, Laanila site (68.45°–68.5°N, 27.25–27.4°E), Sodankylä site (67.2° N, 26.6° E)	TRW	AD 745–2007	F1_LJ12
Mid-summer temperature (Lindholm and Jalkanen, [13])	Finland, Laanila site (68.45°–68.5°N, 27.25–27.4°E), Sodankylä site (67.2° N, 26.6° E)	THI	AD 745–2007	F2_LJ12
April–August temperature (Grudd [14])	Sweden, Torneträsk site (68.2°–68.3°N, 19.4°–19.8° E)	TRW	AD 500–2004	S1_G08 S2_G08
July–August average daily sunshine hours (Gagen et al. [15])	Finland, Laanila site 68°3 N, 27°3 E	δ^{3}C	AD 886–2001	SH_G11
Sea surface temperature, SST (Gray et al. [16])	North Atlantic (0–70° N)	TRW	AD 1567–1990	SST_G04
Atlantic Multidecadal Oscillation, AMO	North Atlantic (0–70° N)	MP	AD 500–2006	AMO_M09

(Mann et al. [17])				
Summer North-Atlantic Oscillation, SNAO (Folland et al. [18])	North Atlantic, Azores, Iceland	I, TRW	AD 1706-1976	SNAO_F09

A new improved version of the instrumental record of sunspot number (SN) (SILSO [19, 20]) was used as an indicator of solar activity changes. In order to isolate the quasi 11-year Schwabe cycle from the SN record, long-term (periods longer than 28 years) variations were removed from the SN time series by means of the Fourier filter (Fig. 1A). In order to isolate the quasi 22-year Hale cycle from the original sunspot record, we constructed an alternate double solar cycle (odd 11-year cycles were considered as positive and even ones as negative), in addition we remove long-term changes in that series (S_N^{22}, Fig. 1B). The distance of the Sun from the baricenter of solar system, calculated by Okhlopkov [21] over the AD 1700–2050 period (Fig. 1C), was used as an indicator of of the possible planetary-tidal influence on the terrestrial conditions

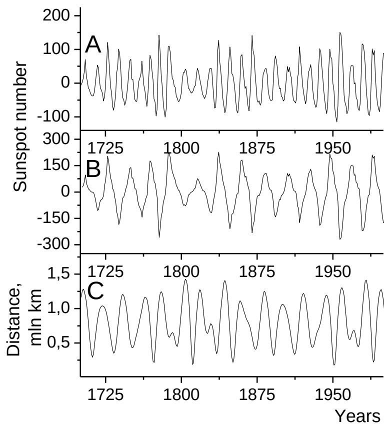

Figure 1. A – the 11-year solar cycle of Schwabe S_N^{11} . C – the 22-year double solar cycle S_N^{22} . D – the distance of the Sun from the center of mass of solar system (scanned and digitized from Okhlopkov [21]).

3. Results

In order to test the correspondence between the solar/astronomical forcing data and the different climatic proxy records, the coefficients of linear (Pearson) correlation were calculated and the statistical significance of each of the calculated correlation was estimated using a random-phase test through 2000 Monte Carlo simulations. Linear correlations between the solar/astronomical forcing data and NF and NA climatic records were calculated for each of the time-series (Table 2).

Table 2. Correlation coefficients between the solar/astronomical forcing data and the climatic records over the AD 1700–2000 period.

Time- series	Reference	Variations with c.l. ≥0.95	R_l^{11}	R_l^{22}	R_l^{20}

S1_G08	Grudd [14]	22.3	–0.06	**-0.29** (3, *0.998*)	0.10 (2, *0.76*)
S2_G08	Grudd [14]		0.03	**-0.16** (2, *0.993*)	0.10 (2, *0.81*)
F1_LJ12	Lindholm and Jalkanen [12]	24.3, 11.6	–0.02	**-0.20** (2, *0.984*)	0.05 (1)
F2_LJ12	Lindholm and Jalkanen [13]		0.06	–0.07 (0)	0.02 (0)
R_K09	Kononov et al [12]	25.6	0.05	**–0.23** (2, *0.992*)	0.06 (4)
NF_H12	Helama et al. [11]		–0.02	**–0.14** (2, *0.980*)	0.05 (2)
NF_LE00*	Lindholm and Eronen [9]	24.4	0.07	**–0.16** (2, *0.982*)	0.08 (2)
NF_O13	Ogurtsov et al. [10]		0.05	**–0.14** (2, *0.978*)	0.03 (1)
SH_G11*	Gagen et al. [15]	21.3, 16.0, 13.4	0.08	0.14 (1, *0.811*)	0.05 (1)
SST_G04*	Grey et al. [16]		0.05	**-0.16** (3, *0.955*)	–0.07 (2, *0.71*)
AMO_M09*	Mann et al. [17]		-0.03	–0.16 (2, *0.814*)	–0.08 (3, *0.59*)
SNAO_F09*	Folland et al. [18]		-0.06	–0.09 (0, *0.64*)	–0.05 (0)

Rl^{11} – is the coefficient of correlation between the climatic records and the quasi 11-year Schwabe component of solar forcing, Rl^{22} – is corresponding correlation between the climatic records and the quasi 22-year Hale component of solar forcing, Rl^{20} – is the correlation between the climatic records and the astronomical forcing data indicative of the wobbling of the Sun. The correlation coefficients with the significance exceeding 0.95, are shown with large font size. Phase shifts (forcing data leading the NFST data) in years are shown in brackets and the significance – in italics in brackets.* – correlation was calculated over the AD 1700-1990 period.

It was resulted for the AD 1700–2000 period (Table 2) that:

(a) there is no significant correlation between climatic records and solar forcing data at periodicities relevant to Schwabe cycle.

(b) There is no significant correlation between climatic records and astronomical forcing data at periodicities relevant to quasi 20-year cycle.

(c) There is no significant correlation between NAO and solar/astronomical forcing data.

(d) Importantly there is a weak, statistically significant (the confidence level exceeding the 0.95 level) negative correlation data at periodicities relevant to the Hale cycle and seven of the nine NFST records as well as between the solar forcing at corresponding periodicities and the NA sea surface temperature.

4. Conclusion

Our analyses reveal weak but statistically significant negative correlation between the quasi 22-year Hale solar magnetic cycle and the NFST and NASST reconstructions over the AD 1700–2000 period. This shows clear evidence to link the Northern Fennoscandian climate and the Sun's activity obtained here over the short time scales in addition to the evidence, previously found at century-scale [3,4] and millennial-scale [6]. These findings reinforce the views that the solar activity have likely played an essential role in affecting the history of climate in North Atlantic and Northern Fennoscandian regions. Galactic cosmic ray (GCR) intensity is a potential physical agent to mediate the solar signal into the climate variability. Indeed, the GCR intensity variations come with 22-year periodicity, as the GCRs are sensitive to changes in the polarity of the Sun's magnetic field. Another potential agent of solar influence on climate may be the geomagnetic activity which is associated with solar wind disturbances and also shows a roughly 22-year periodicity [22]. No evidence to link and the planetary-induced gravitational perturbations in solar system and the climate variability in NF and NA regions were obtained.

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