Solar activity cycles and climate of the Northern Hemisphere of the Earth

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The possibility of a connection between long-term variations in the Earth's climate and solar cycles is investigated using: (a) six solar activity reconstructions and (b) eight paleoreconstructions of the Northern Hemisphere temperature. It wasfound that the Earth's Northern Hemisphere temperature exhibits significant variations with periods of 86 and 190 years, close to the periods of the corresponding solar cycles of Gleissberg (century-scale variation) and Suess (bicentennial variation). However, no significant correlation was found between secular and bicentennial periodicities in climate and solar activity. Possible reasons for the weakness of the solar-climatic correlation are discussed.

Keywords: solar activity, solar paleoastrophysics, climate.

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Introduction

The Sun is the main source of energy that controls our climate system. That is why the possible influence of solar activity on the Earth's climate has been intensively studied for a long time. In recent decades, a significant amount of evidence has been collected that solar activity (SA) can affect climate both directly, by changing total solar radiation, and indirectly, by modulating the flow of galactic and solar cosmic rays [1]. However, the physical mechanism explaining the relationship between SA, space weather, and climate has not yet been clarified. Moreover, some data on the influence of SA on the climate of the Northern Hemisphere have recently been opened to question [2]. On the other hand, indications have been obtained that, at least in the climates of certain regions (North Fennoscandia, South America), there are their own internal fluctuations with periods close to the periods of solar cycles, but not related to solar cycles [3]. In this paper, we consider the possibility of natural cycles similar to solar cycles in the climate of a larger area covering the entire Northern Hemisphere.

1. Data

The following data were used:

(a) paleoreconstruction of SA [4–9] covering from 919 to over 10000 last years. These time series are shown in Fig. 1. For the next analysis they were all interpolated by years;

(b) temperature paleoreconstructions [10–17] covering last 1192−2015 years. These time series are shown in Fig. 2.

2. Results and discussion

Fourier and wavelet analyses have shown that in the spectra of all temperature series over the past 1−2 millennia

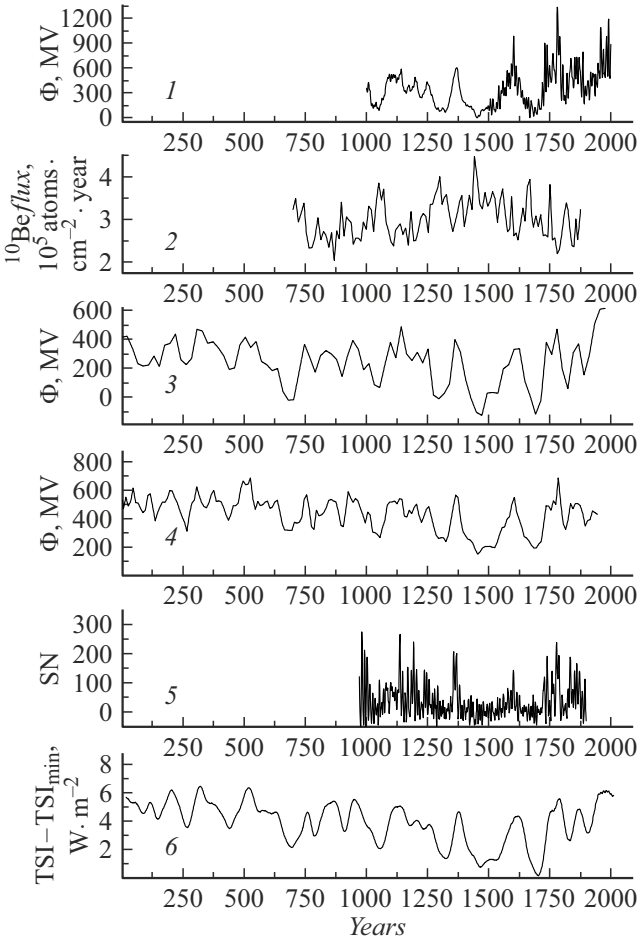

Figure 1. Solar activity indicators used in the study: *1* — solar modulation potential; [4]; *2* — concentration of ^{10}Be in Antarctic ice [5]; *3* — solar modulation potential [6]; *4* — solar modulation potential [7]; *5* — number of solar spots [8]; *6* — full solar radiation [9].

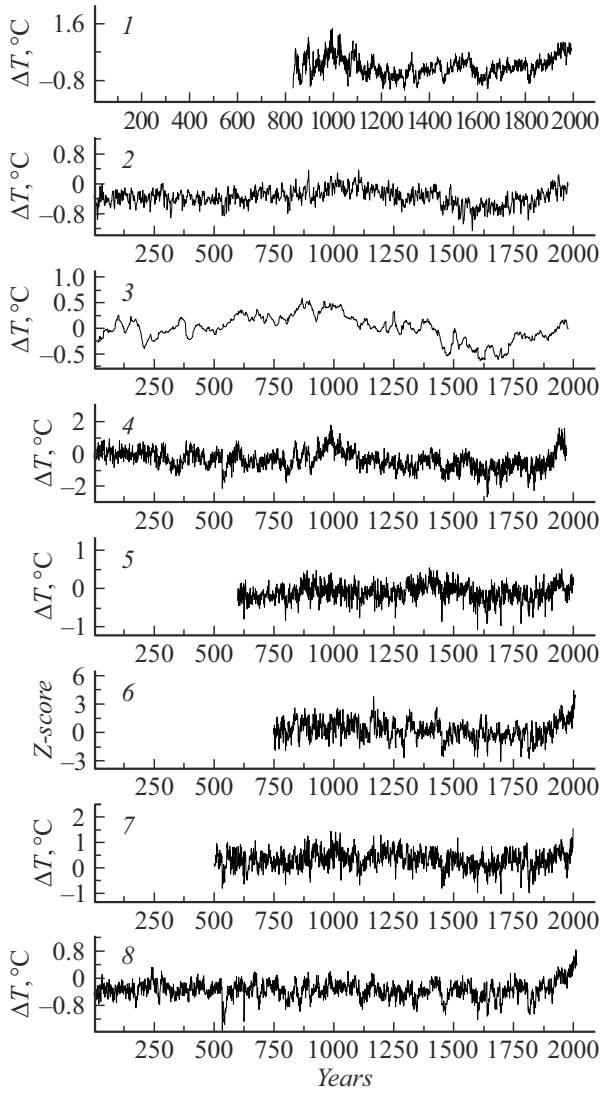

Figure 2. Graphic reconstruction of temperature variations in the Northern hemisphere used in this paper: *1* — tree-ring reconstruction from paper [10]; *2* — multi-reconstruction from paper [11]; *3* — multi-reconstruction not using tree-ring data [12]; *4* — multi-reconstruction from paper [13]; *5* — tree-ring reconstruction from paper [14]; *6* — tree-ring reconstruction from paper [15], normalized to zero average and unit dispersion; *7* — tree-ring reconstruction from paper [16]; *8* — tree-ring reconstruction from paper [17].

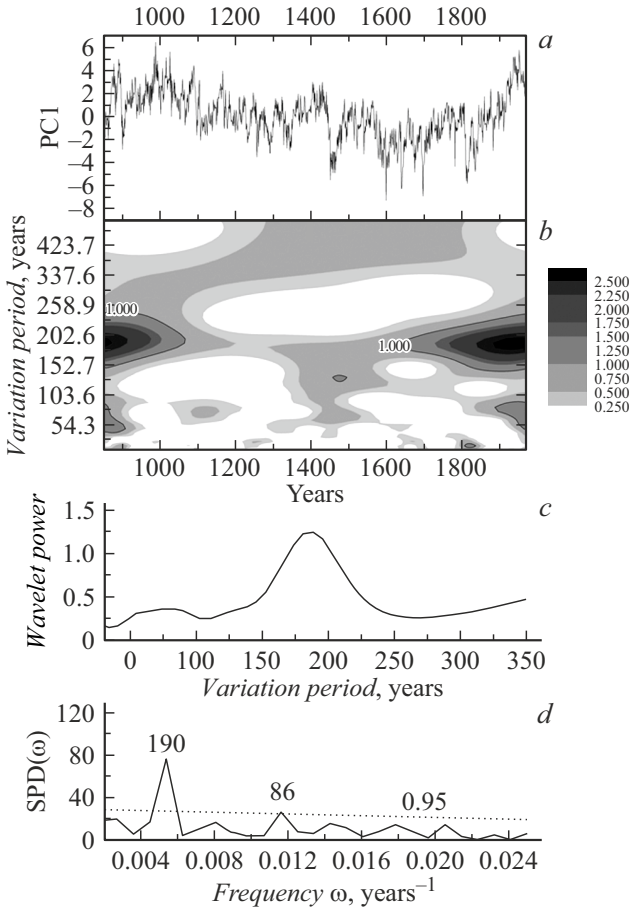

Figure 3. *a* — first major component of eight temperature series; *b* — local wavelet spectrum PC1 normalized to confidence level of 0.95; *c* — global wavelet spectrum PC1 normalized to confidence level of 0.95; *d* — Fourier spectrum PC1, dashed line — confidence level 0.95.

there have been fluctuations with periods of about 100 years and 180–270 years, close to the periods of the Gleissberg (quasi-secular) and Suess solar cycles (quasi-two centuries old). This conclusion can be illustrated in Fig. 3, which shows the first main component PC1 of the eight temperature series shown in Fig. 1, restoring 55% of their total dispersion, and thus identifying and reflecting the most common fluctuations inherent in these time series. As we may see from Fig. 3, the first spectrum PC1 has peak at 86 years and powerful peak at 189 years.

Correlation analysis of the series filtered in the centennial and bicentennial frequency bands showed, however, that these temperature variations do not correlate with the corresponding cycles of solar activity, with the exception of the 200-year periodicity in series Esper et al. [10]. Only series [10], wavelet filtered in the range of 186–259 years, correlates with the main component (filtered similarly to the first component) of the six solar reconstructions with a coefficient of -0.72 (confidence level $p = 0.03$). All other correlation coefficients lie within the range of -0.47–0.42 and their significance does not reach 0.10. The reasons for the weakness of the solar-climatic correlation can be: (a) non-linearity of the relationship between temperature and solar activity, (b) distortion of the solar signal by fluctuations in volcanic activity [18], (c) distortion of the solar signal by internal oscillations present in the climate system [3], (d) Inaccuracies of climate reconstructions.

Conclusions

A statistical analysis of eight temperature paleoreconstructions of the Northern Hemisphere, covering the last 1–2 millennia, showed that there are significant variations

in their spectra with periods of 86 and 190 years. However, their correlations with the corresponding SA cycles turned out to be weak. This may mean the presence of a natural quasi-two-century variation in the climate of Northern Hemisphere that is not related to solar activity. Such frequency can significantly distort the solar signal and make it difficult to detect it.

Conflict of interest

The author declares that he has no conflict of interest.

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