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Statistical relationships between the surface air temperature anomalies and the solar and geomagnetic activity indices

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Abstract

Statistical analysis of the data series from 1856 to 2000 for the annual global and hemispheric surface air temperature anomalies is completed. Statistically significant correlations are found between global and hemispheric temperature anomalies and solar and geomagnetic indices. The temperature anomalies in the Northern and Southern hemispheres show similar statistical relations with the solar and geomagnetic indices. The cross-correlation analysis shows no statistically significant global temperature lag behind the sunspots as well as behind aa-indices. The correlation between the temperature anomalies and the geomagnetic indices is about two times higher than the correlation between the temperature anomalies and the solar indices. These results support the suggestion that the geomagnetic forcing predominates over the solar activity forcing on the global and hemispheric surface air temperatures.

Keywords: Global surface air temperature; Geomagnetic indices; Sunspots; Geomagnetic forcing

1. Introduction

Eddy (1976) draws the attention to the coincidence of Maunder's solar minimum (1645–1715) with the "Little ice age" and of Grand solar maximum (1100–1250) with the "Medieval climatic optimum". After a short period of mistrust and standstill in the 80s, the investigations of the solar activity influence on the changes of the global or hemispheric temperatures gained serious success in the last decade. Thus, the surface air temperature of the Northern hemisphere is determined to change opposite to the solar cycle length (Friis-Christensen and Lassen, 1991). In the global sea surface temperature, a temperature responding has been found to the changing solar irradiance in three separate frequency bands with periods of more than 100 years, 18–25 years and 9–13 years (White et al., 1997). The existence of a positive relation between the surface air temperature of the Northern hemisphere and the solar activity in the period 1881–1988 is shown (Georgieva, 1998). High positive correlation is found between the geomagnetic activity and the surface air temperature in Middle and Southern Europe. The same correlation in Canada is negative (Bucha and Bucha Jr., 1998). By Fourier analysis and auto-correlation analysis it is shown that the global surface air temperature anomalies display 11-year and centennial variations, overlapped on the upward temperature trend (Valev, 1998). According to many of the recent publications in the field of solar-terrestrial relationships, the solar activity forcing can substantiate a third to half of the observed global heating (Lean et al., 1995; Cliver et al., 1998; Ring et al., 2002).

2. Data and methods for statistical analysis

The purpose of the paper is to search statistical relationships between the surface air temperature anomalies and solar and geomagnetic activity indices and to compare the obtained relationships. In this work we have completed statistical analysis of the relationships between the annual

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global and hemispheric surface air temperature anomalies on the one hand and, sunspots and geomagnetic aa-indices on the other hand. We used data series compiled by the University of East Anglia (UEA) from 1856 to 2000 (Jones et al., 1986a,b). These are some of the longest and reliable instrumental series. Jones' series produce the global surface air temperature anomalies, i.e. the temperature deviations from the average temperature in the reference period 1960–1990. Since the temperature anomaly and the temperature differ by a constant, equal to the average global temperature in the reference period, we used below the shorter term 'surface air temperature'.

Waldmeir's series for sunspots numbers (Waldmeir, 1961) and Mayaud's series for geomagnetic aa-indices (Mayaud, 1972) are used. The aa-indices are obtained by geomagnetic disturbances in two antipodal observatories – one in England and the other in Australia. These two last series were selected as they are today the longest instrumental series for the solar and geomagnetic activity and match the same interval of time as the data used for the temperature deviations.

The statistical analysis of the examined data series involves Fourier analysis (FFT), linear regression and cross-correlation. The statistical reliability of the obtained correlations is evaluated by the paired-sample t-test (Schonwiese, 1985). We used annual mean values of temperature, sunspots and aa-indices for all statistical computations. We would like to underline that no filtering or smoothing procedures have applied on these values. This enables the correct and unambiguous estimation of the statistical reliability level of the already found statistical relations. Running average values are used only for visualization of the global temperature relations with the solar and geomagnetic activity indices in the last figure.

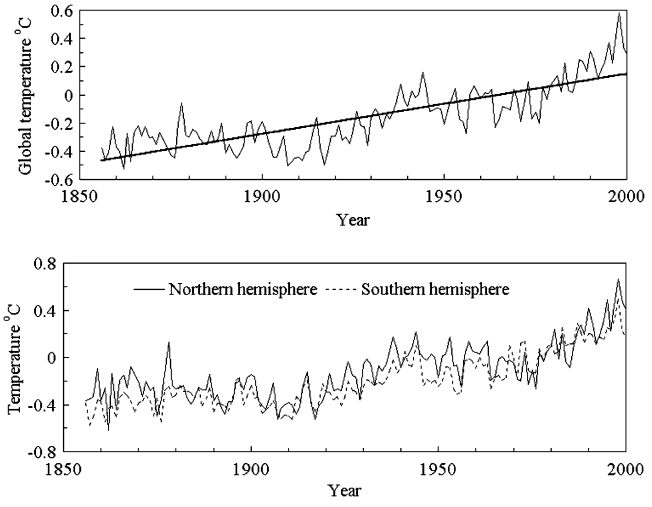

Fig. 1. Annual global surface air temperature and the trend (top panel) and, the Northern and Southern hemispheric surface air temperatures (bottom panel). A sharp trend in the last two decades, mainly a result of the greenhouse forcing, weakens correlations.

3. Results

The annual global temperatures from 1856 to 2000 are shown in Fig. 1 (top). As mentioned above, a part of the rising trend results from the greenhouse global warming and, another part is a result from the solar and geomagnetic forcing. The annual temperatures of the Northern and Southern hemispheres have similar long-term variations (Fig. 1 (bottom)) and they closely correlate ($r = 0.87$). A spectral analysis (FFT) of the global temperature is completed after removing the trend. By this approach a spectral analysis of the sunspots and aa-indices is completed. The Fourier spectra are shown in Fig. 2. Decadal and long-term (low-frequency) components with various amplitudes are observed in the three spectra. The

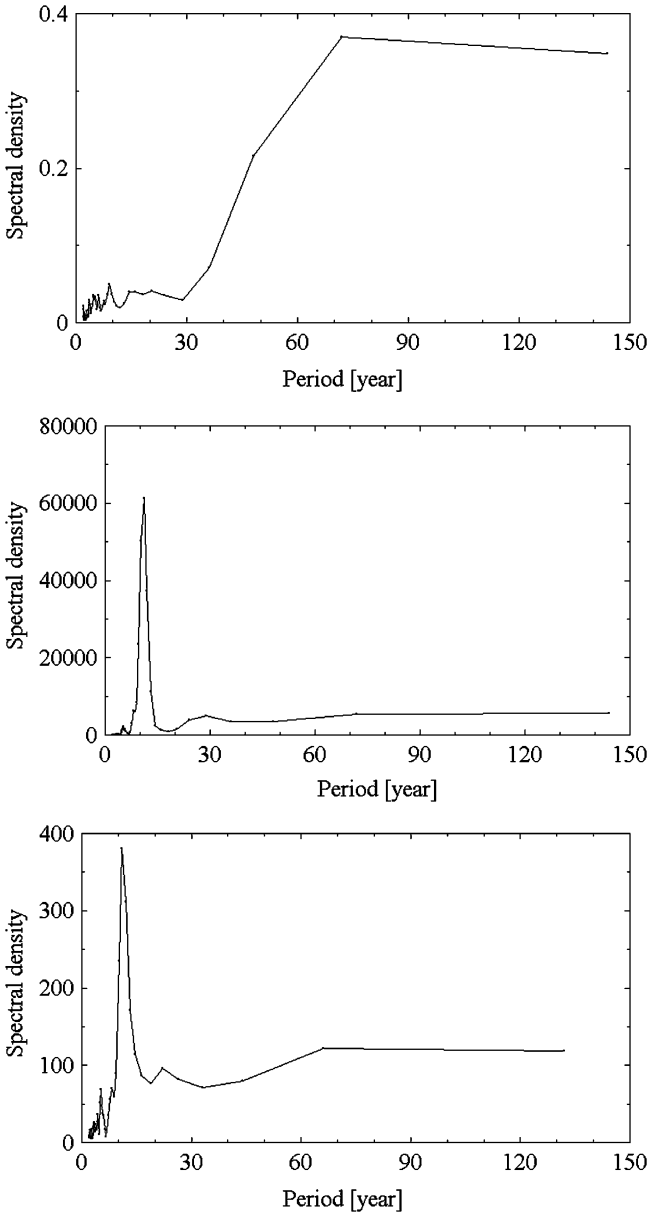

Fig. 2. Spectral densities of the global surface air temperature (top panel), sunspots (middle panel), and geomagnetic aa-indices (bottom panel).