Solar signal in climate change: cross wavelet and EMD analysis of time-series

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Long-term climate time-series and solar proxies are studied using wavelet transforms and Empirical Mode Decomposition method. Cross wavelet techniques is applied to examine coherence and phase relationships between various time-series on interannual scale and to find the solar signal in climate data. Time-frequency patterns reveal synchronous quasi-periodicities and the global origin of some climatic oscillations. Patterns display also transient correlations and non-linear impact of solar activity on climate. Geographical regions and periodic patterns of significant solar impact on climate are allocated. The last 20 years since 1990's demonstrate unusual high-sensitivity of climate response to solar output: this result is discussed in connection with the problem of unprecedented high level of sunspot activity and climate warm in the late 30th century.

1. Introduction

The purposes of this research are:
1) to investigate the change in climate time-series (some instrumental and reconstructed data) on interannual time scale;
2) to find the solar signal in climate data;
3) if it exists, to find the time periods and regions of climate sensitivity to solar signal.

2. Method of the paper

1) Empirical mode decomposition, wavelet & cross wavelet (with solar activity) analysis of annual (smoothed by 5 points) data;
2) reconstructed instrumental climate-variables, wavelet & cross wavelet (with solar activity) analysis of annual (unsmoothed by 5 points) data;
3) reconstructed instrumental climate-variables, wavelet & cross wavelet analysis of annual (unsmoothed by 5 points) data;
4) reconstructed instrumental climate-variables, wavelet & cross wavelet analysis of annual (unsmoothed by 5 points) data obtained by Empirical Mode Decomposition method.

3. Experimental data

In this research the instrumental air temperature datasets for Stockholm, St.Petersburg and Central England were studied.

Also the climate proxy (T, NAO, SOI) discussed in the paper of Jones & Mann (2000) were used. The length of data sets varies from 300 to 2000 years.

Pace data was transformed by different methods based on the information kept in cores, ice cores and documentary. Here we investigate the annual climate data smoothed by Moving Average Smoothing (MAS) method by 5 points as well as unsmoothed core.

As an indicator of solar activity we choose the Wolf number index (from KGS database http://www.ngdc.noaa.gov). As above, we study smoothed and unsmoothed annual data.

The results of wavelet and cross wavelet (with Wolf numbers, 5-year smoothed data) analysis for such climate proxies (also 5-year smoothed data) as air temperature, NAO and SOI are presented. Here one can see the temperature figures for four different regions: Polar Urals, Central Europe, Western North America and Tasmania. One can see the 11-year signal, which appears differently in the different regions. From the comparison with the corresponding cross wavelet spectra one can suggest that the signal can be seen better in the polar and coast-line regions. From the comparison with the wavelet spectra of Wolf numbers one can remark that the 11-year signal is stronger during the periods of high solar activity. The signal in Central Europe (continental zone), where the coherence between the temperature and Wolf numbers is weak, can sometimes be observed during the same periods (for example, 1930-1970). So, the 11-year signal can be observed in the second half of the 20th century and sometimes in the past – probably it is related to the high level of solar activity. It is suggested to filter the original unsmoothed data with Empirical Mode Decomposition (EMD) method and to investigate the wavelet and the cross wavelet with the unsmoothed data of Wolf numbers spectra of EMD-components.

4. Conclusions

As a result of the investigation the following conclusions can be made:

4. The ~11-year signal in instrumental and reconstructed data;
5. The signal is not linear: it can be observed in different regions in different periods;
8. The signal is more stable in northern regions;
10. The responses to the signal can be observed not only in north or ocean regions, but also on the continents in the periods of the high level solar activity.
12. In the considered instrumental temperature data the ~11-year signal is observed to be more explicit since 1925-1930-th years.

References