"SPACE CLIMATE – 5"
Session: Solar atmospheric and climate effects

Solar, volcanic and geomagnetic forcing on air–surface temperature: Geographical distribution of sensitive climate zones

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I analyze the geographical distribution of the climate response to external forcing (solar, volcanic and geomagnetic) on the periods of 11 and 22 years. As a climate characteristic I use the data of the air–surface temperature (regional data sets). The analysis is performed by the wavelet phase/coherence technique which is applied to the solar (sunspot numbers), volcanic (Dust Veil Index), geomagnetic (C_9-index) activities and the temperature data on interannual timescales for the common time interval covering most of the 20th century. Besides, I analyze the statistics of the temperature response to the solar and geomagnetic factors on the periods of 11 and 22 years for different geographical sectors. In particular, I find the existence of a combined forcing of solar and volcanic activity on the Earth temperature on the 11-year period in the second half of the 20th century over the globe, whereas a set of stations (mostly in North Atlantic) shows a coherence between solar activity and the Earth temperature on the 11-year periodicity even in absence of the combined effect; it was found that the maximal number of stations demonstrating statistically significant amplitudes of wavelet spectra corresponds to the wavelet cross-coherence between geomagnetic activity and the Earth air–surface temperature on the periods about 22 years during the time interval without intensive volcanic eruptions capable to change significantly the level of DVI_{Global}.

External factors

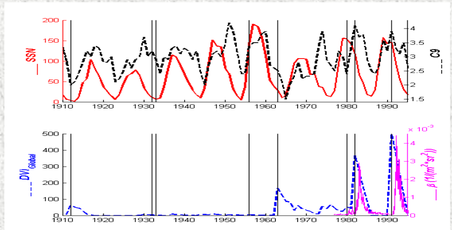

Fig.1: ***Top:*** *solar (SSN, annual) and geomagnetic (C_9, annual) activities.* ***Bottom:*** *DVI_{Global} (annual), volcanic eruptions (VEI≥5.0) and aerosol backscattering coefficients ($1/m^2sr^2$) at λ=694.3 nm.*

Two last "volcanic" peaks in DVI_{Global} coincide with decrease phases of solar activity.

Earth regional temperatures

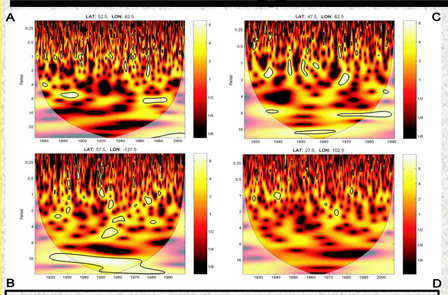

Fig.2: *Examples of wavelet spectra of temperature variations for four chosen stations.*

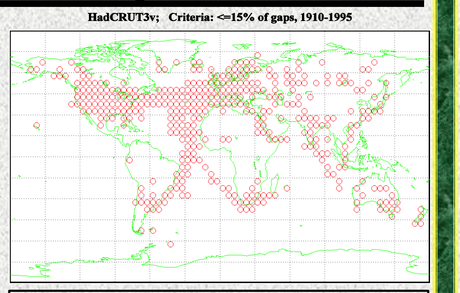

Fig.3: *Geographical location of chosen "stations".*

The stations show signals of different periods and at different time.

We analyze annual-means of air-surface regional temperature data.

Methods

Wavelet transform. This technique we used to study an evolution of observed in the data sets oscillations.

Wavelet cross coherence and phase analysis. This approach we used in the study of relations between external factors and Earth regional temperatures. This extension of wavelet analysis for two data sets allows to study an evolution of coherence and phase lag between them. Phase lags are indicated by arrows (pointing right – in phase, left – in anti-phase, straight down – first data set leads a second one by a quarter of period).

The both types of spectra were calculated using **Morlet** localized wavelet and $\omega_0=6$. Significant signals are the ones of 5% significance level against red noise background.

Solar and volcanic effects: 11-yr period

Year 1989 **was chosen to show** ***the combined forcing of the solar and volcanic activities at ~11-yr period*****. This year belongs to the time interval formed by two intensive volcanic eruptions (El Chichon, 1982; Mount Pinatubo, 1991). It provides the geographical distribution of the climate response to the solar forcing in the presence of a combined effect of solar and volcanic activities on the climate.**

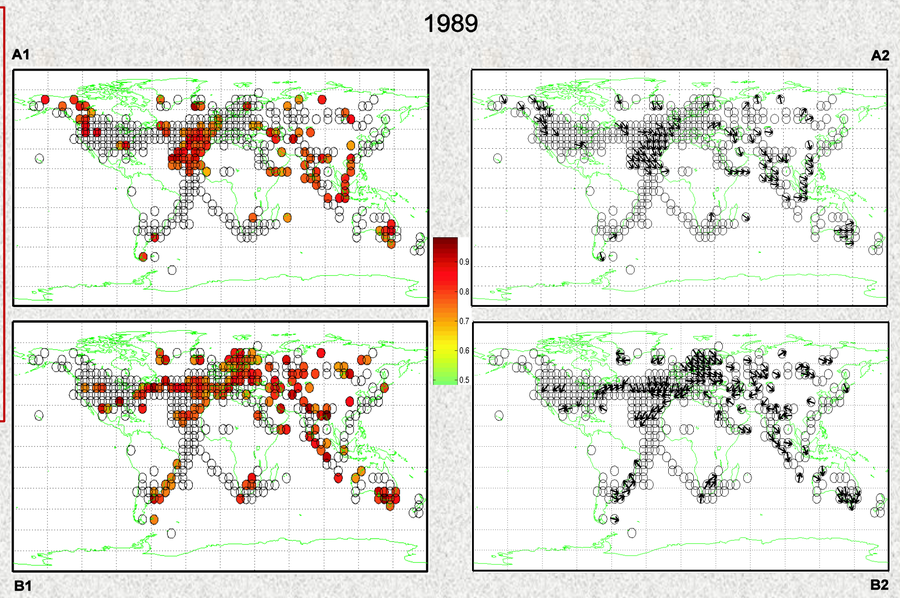

Fig.4: *Stations demonstrating statistically significant wavelet cross-coherence amplitudes for the year 1989 on the quasi-11-year periodicity: SSN and the air–surface temperature (A1), DVI_{Global} and the air–surface temperature (B1). The values of phase lags are shown in the panels A2 and B2, correspondingly.*

Some statistics

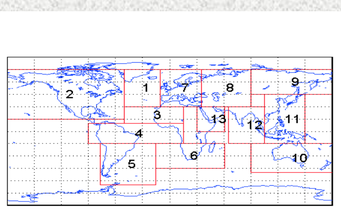

Fig.7: *Geographical zones chosen for statistical analysis of wavelet cross coherence between the external factors and the air–surface temperature.*

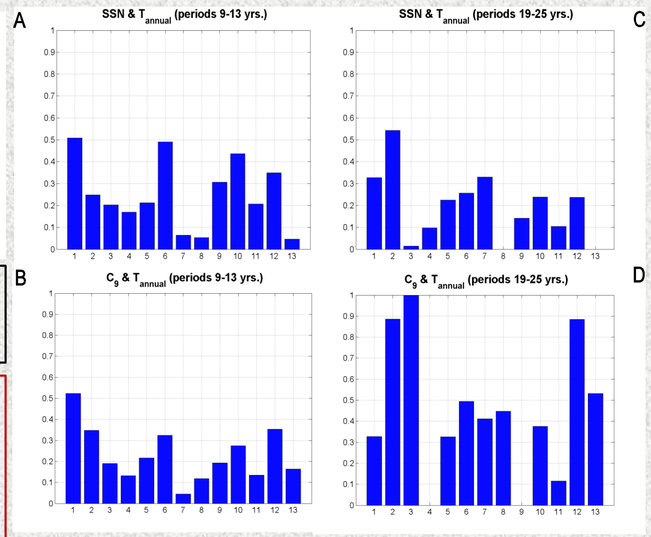

Fig.8: *Histograms of the relative quantity of stations (per number of stations in a zone, per year) where statistically significant values of amplitudes of wavelet cross-coherence between the external factors and the air–surface temperature are observed: (A) SSN, 11-yr period; (B) C_9, 11-yr period; (C) SSN, 22-yr period; (D) C_9, 22-yr period.*

The mostly widespread response is to geomagnetic activity at 22-yr period. The zones mostly sensitive to the solar and geomagnetic forcing at 11-yr period — North Atlantic, North Africa, Australia, Hindostan; to the geomagnetic forcing at 22-yr period — North America, North-West Africa, Hindostan.

Solar effect: 11-yr period

Year 1935 **was chosen to show** ***the solar activity effect at ~11-yr period in absence of an additional intensive volcanic impact*****. This is a year in the middle of the time interval with DVI_{Global} close to zero, when the combined effect of solar and volcanic activities on the climate is absent. The analysis of this interval allows to find the geographical zones which are more sensitive to the forcing of the 11-yr solar cyclicity in the absence of other intensive factors such as intensive volcanic eruptions.**

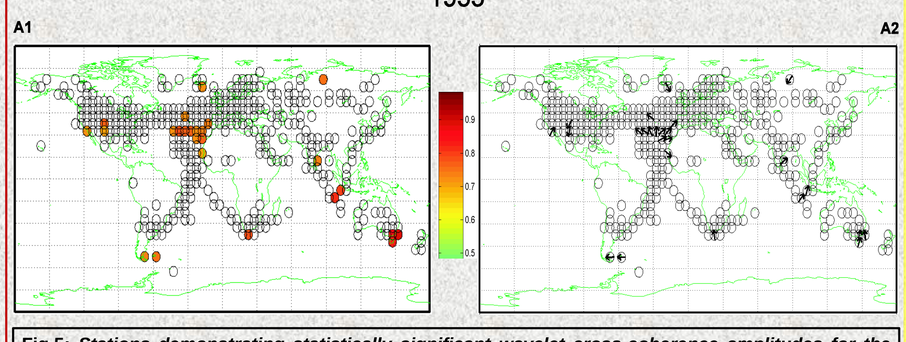

Fig.5: *Stations demonstrating statistically significant wavelet cross-coherence amplitudes for the year 1935 on the quasi-11-year periodicity between SSN and the air–surface temperature A1. The values of phase lags are shown in the panel A2.*

Solar and geomagnetic effects: 22-yr period

Year 1949 **was chosen to show** ***the solar and geomagnetic activity influence at 22-yr period*****. This year corresponds to the middle of the interval without intensive volcanic eruptions.**

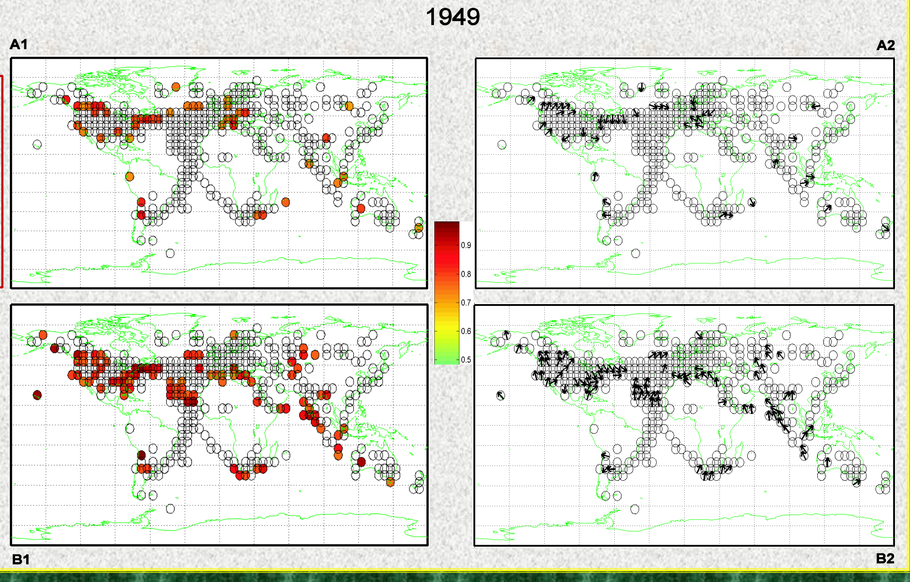

Fig.6: *Stations demonstrating statistically significant wavelet cross-coherence amplitudes for the year 1949 on the quasi-22-year periodicity: SSN and the air–surface temperature (A1), the C_9-index of geomagnetic activity and the air–surface temperature (B1). The values of phase lags are shown in the panels A2 and B2, correspondingly.*

Conclusions

1. **There are many stations over the globe with statistically significant amplitudes of wavelet cross-coherence between solar activity (SSN) and the air–surface temperature data on about 11-year periodicity during the last quarter of the 20th century, which can be explained by a combined effect of the solar and volcanic forcing;**

2. **there is a set of stations, mostly in the North Atlantic, demonstrating statistically significant amplitudes of wavelet cross-coherence between solar activity (SSN) and the air–surface temperature data at about 11-year periodicity in the middle of the 20th century in the absence of the combined effect of intensive volcanic and solar activities;**

3. **the climate zones which are mostly sensitive to external (solar and geomagnetic) forcing, are allocated as follows: sensitive to the solar and geomagnetic forcing at 11-year periodicity — North Atlantic, North Africa, Australia, Hindostan; sensitive to the geomagnetic forcing at 22-year periodicity — North America, North-West Africa, Hindostan;**

4. **the maximal number of stations with statistically significant amplitudes corresponds to the wavelet cross-coherence between the (C_9)-index of geomagnetic activity and the air–surface temperature variations on the periods about 22 years during the time interval without intensive volcanic eruptions capable to change significantly the level of DVI_{Global}.**

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