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Synchronicity as an essential property of solar–terrestrial relations: latent components

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Abstract

It is assumed that external forcing synchronizes processes initiated by it. The concept of the synchronicity of processes is defined, based on their essential signs. The processes under study are decomposed on latent orthogonal components, which differ because of the coincidence and non-coincidence of the essential signs. The information from the original data is redistributed without distortion between these components. For computation of the components, algorithms were developed, using the Fourier transform on the basis of trigonometric functions. Theory and algorithms were applied to decompose on the components the Wolf numbers and the temperature series at 818 weather stations of the Northern Hemisphere from 1955 to 2010. By this approach, new properties of solar–terrestrial relations were revealed; the method characterizes the manifestation of the forcing and corresponds to the well-known notions of climatic processes. Therefore, the new method is informative, consistent; and it is suitable for the analysis of series under observation at this time.

> non contemplantibus nobis quae videntur sed quae non videntur quae enim
> videntur temporalia sunt quae autem non videntur aeterna sunt
> (BSV. II Corinthios 4:18)[*]

1 Introduction

On the Earth, reasoning from experience, natural and climatic processes are significantly initiated and controlled by external forcing. It has a complex structure, but the Sun is a major contributor, acting directly and adjusting the other cosmic influences. Strengthening of the Sun's magnetic field is accompanied by an increase in the number of dark areas in the chromosphere, named sunspots. A linear combination of the sunspot numbers and sunspot groups has been chosen as a comprehensive indicator of solar activity. These combinations are called the Wolf numbers, and have no physical dimensions. Astronomers have been counting spots for about 400 years.

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As a result, a unique series of instrumental data about the cosmos has been obtained. See the classical treatises by Vitinsky (1973), Chizhevsky (1976), and Shurgin (1999).

In origin and due to inadequate measurements, natural and climatic processes consist of heterogeneous components, which are not always known. Besides, the basic values now studied were chosen long ago in past centuries to meet the challenges of technological development. For processes in nature, this traditional approach is not obvious. It should be expected that investigations will have a greater effect when they consider factors that are, in a sense, immanent to the system under study.

The development of options for component and factor analysis could help to make advances in this direction; see e.g. Lyubushin (2007). These approaches are universal but formal in character. Their efficiency is directly related to the anisotropy of the cloud of points representing the state of the system being studied in a multidimensional space. In addition, the results presented by the superposition of the original values are not always amenable to meaningful interpretation; this requires empirical regularities inherent in the system.

Distinctive features of the problem to be solved are taken into account more by different variants of informal classification, based on the optimization of objective functions of an empirical nature. In such approaches, the decomposition of the original set into subsets is performed. Each subset contains as strongly as possible related elements, and the relationship between elements of different subsets must be weaker. For example, Tartakovsky et al. (2015) performed this for climate classification by iteration of the phase of temperature series.

Based on observations, we can draw conclusions about the consistency of the Sun's forcing and certain climatic processes. It is well known that the cyclic motions in the solar system are manifested in the unceasing change of seasons, in daily warming and nocturnal cooling. These changes reflect a determinism that partially characterizes the climate for a certain time interval. There are other facts concerning possible determinism or the high correlation coefficients of the intensity of cosmic rays, the radio

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flux density, and series of Wolf numbers. We refer here to the publications by Alekseev et al. (2012), Budovyj et al. (2006), Buharov (1993), and Kuklin (1984).

Discussions are underway about how climate in general and the temperature particularly are sensitive to solar variability; see, e.g., Scafetta (2014). It should agree with this author in the sense that the progress can be expected in the way of sophisticated analysis of observational data, but in terms of some basic physical principles. The classic phenomenological approach involves the formalization of empirical data. Exaggerating the observed facts, we shall have to formulate the principle: "external forcing inherently initiates and synchronizes elementary processes in the geospheres". Then we support this principle by a formal definition: "synchronicity of processes is manifested in the coincidence of their essential signs", which it is necessary to define reasonably. Thus, the synchronism is selected as an essential factor in solar–terrestrial relations.

Below we present our theory and supporting algorithms to be applied for the synchronous analysis of series of average monthly Wolf numbers and the series of average monthly temperatures measured at 818 weather stations in the Northern Hemisphere of the Earth from 1955 to 2010.

The approach presented and the results of its application for climate problems and in the field of dendrochronology were partially reflected in the publications, e.g., of Tartakovsky (2015). It should be noted that the degree of synchronicity, as information about the transition of systems to a new state, was supported algorithmically and applied to solve geophysical problems as reported by Lyubushin (2007).

In our case, the novelty is that synchronicity was constructively defined, resulting in the decomposition of the original series. This computational procedure highlights the latent essence in the measured values and provides new information about the influence of the Sun on the temperature in the atmospheric surface layer, as is presented in this paper.

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2 Selected set decomposition

Let us assume that the series of experimental data $x_{k,l}$ relate one to one to natural processes under study, which are also real and with limited energy. Here, k is the discrete argument that takes N values at a given interval of observations, and l is the number of the series and the weather station.

The series can be supplemented and extended by continuity to the whole real axis periodically, using an even or odd manner. For such series there exist both the discrete direct and inverse Fourier transform:

$$X_{\nu,l} = \frac{1}{N}\sum_{k=0}^{N-1} x_{k,l}\exp(-i2\pi\nu k/N), \quad x_{k,l} = \sum_{\nu=0}^{N-1} X_{\nu,l}\exp(i2\pi\nu k/N). \tag{1}$$

Here i denotes the imaginary unit, and ν is the discrete frequency. The Fourier coefficients $X_{\nu,l}$ are not complex numbers for the assumed conditions of extending the series.

Possibly related to their common origin, the similarity of the series will be significantly reduced if, for different numbers l and the same frequency ν, the Fourier coefficients $X_{\nu,l}$ take the opposite signs. Moreover, the larger the contribution that is made in the expansion by the basis functions, the greater is the violation of this genetic similarity. Conservation of the signs of the Fourier coefficients can be interpreted as a manifestation of the deterministic relationships between the series within certain limits, and the stochastic variability has an opportunity to be reflected in absolute values of these coefficients. Therefore, we define the signs of the Fourier coefficients as the essential signs, and we shall use them for implementing the synchronous analysis. Below, other reasons will be found for this choice.

For a pair of the series that characterizes the influence of the Sun and each series associated with the climatic process, we introduce the "components with coincident signs" (CS) and "components with non-coincident signs" (NS). We refer to the procedure for pairwise decomposition of the series on such latent components as “decomposition on the selected set”, hereinafter “s-decomposition”. In this case, we select the series that describes the solar activity for the entire planet. This Wolf number series s_k has the same properties in relation to the Fourier transform as the series $x_{k,l}$.

Let us obtain CS- and NS-components, $\hat{x}_{k,l}$ and $\widetilde{x}_{k,l}$ as follows:

$$\hat{x}_{k,l} = \sum_{\nu=0}^{N-1} \hat{X}_{\nu,l} \exp(i2\pi\nu k/N), \quad \hat{X}_{\nu,l} = \begin{cases} X_{\nu,l}, & \operatorname{sign} S_\nu = \operatorname{sign} X_{\nu,l} \\ 0, & \operatorname{sign} S_\nu \neq \operatorname{sign} X_{\nu,l} \end{cases};$$

$$\widetilde{x}_{k,l} = \sum_{\nu=0}^{N-1} \widetilde{X}_{\nu,l} \exp(i2\pi\nu k/N), \quad \widetilde{X}_{\nu,l} = \begin{cases} 0, & \operatorname{sign} S_\nu = \operatorname{sign} X_{\nu,l} \\ X_{\nu,l}, & \operatorname{sign} S_\nu \neq \operatorname{sign} X_{\nu,l} \end{cases}. \tag{2}$$

The result of decomposition of the selected series s_k, namely its CS- and NS-components ($\hat{s}_{k,l}$ and $\widetilde{s}_{k,l}$) depends on index l, which is individual for each series:

$$\hat{s}_{k,l} = \sum_{\nu=0}^{N-1} \hat{S}_\nu \exp(i2\pi\nu k/N), \quad \hat{S}_{\nu,l} = \begin{cases} S_\nu, & \operatorname{sign} S_\nu = \operatorname{sign} X_{\nu,l} \\ 0, & \operatorname{sign} S_\nu \neq \operatorname{sign} X_{\nu,l} \end{cases};$$

$$\widetilde{s}_{k,l} = \sum_{\nu=0}^{N-1} \widetilde{S}_\nu \exp(i2\pi\nu k/N), \quad \widetilde{S}_{\nu,l} = \begin{cases} 0, & \operatorname{sign} S_\nu = \operatorname{sign} X_{\nu,l} \\ S_\nu, & \operatorname{sign} S_\nu \neq \operatorname{sign} X_{\nu,l} \end{cases}. \tag{3}$$

These expressions describe the variable influence of solar activity across the Earth’s surface.

Note that s-decomposition leaves unchanged the original values of the Fourier coefficients $X_{\nu,l}$ and S_ν, but each coefficient falls either in the CS- or in the NS-component of the series with index l.

3 Properties of CS- and NS-components

We start from definitions (Eqs. 2 and 3); they imply the validity of the equalities:

$$x_{k,l} = \hat{x}_{k,l} + \widetilde{x}_{k,l}, \quad X_{v,l} = \hat{X}_{v,l} + \widetilde{X}_{v,l};$$
$$s_k = \hat{s}_{k,l} + \widetilde{s}_{k,l}, \quad S_v = \hat{S}_{v,l} + \widetilde{S}_{v,l}. \tag{4}$$

Entering the scalar product and taking into account that it is invariant with respect to the Fourier transform, then using Eqs. (2)–(4), we obtain a set of useful expressions:

$$\sum_{k=0}^{N-1} s_k \cdot x_{k,l} = (s_k, x_{k,l}) \propto (S_v, X_{v,l}),$$
$$(\hat{x}_{k,l}, \widetilde{x}_{k,l}) = (\hat{s}_{k,l}, \widetilde{s}_{k,l}) = (\hat{s}_{k,l}, \widetilde{x}_{k,l}) = (\widetilde{s}_{k,l}, \hat{x}_{k,l}) = 0,$$
$$(\hat{X}_{v,l}, \widetilde{X}_{v,l}) = (\hat{S}_{v,l}, \widetilde{S}_{v,l}) = (\hat{S}_{v,l}, \widetilde{X}_{v,l}) = (\widetilde{S}_{v,l}, \hat{X}_{v,l}) = 0; \tag{5}$$

and

$$(s_k, x_{k,l}) = (\hat{s}_{k,l}, \hat{x}_{k,l}) + (\widetilde{s}_{k,l}, \widetilde{x}_{k,l}),$$
$$(\hat{s}_{k,l}, \hat{x}_{k,l}) > 0, \quad (\widetilde{s}_{k,l}, \widetilde{x}_{k,l}) < 0. \tag{6}$$

In these expressions the summation is performed on the indices k or v, and all the series are real by construction.

Thus, the CS- and NS-components of the original series are orthogonal, resulting in the additive property of the scalar product of these components; see expressions (6).

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Let us make sure of the property of extreme correlation for the identical components of the original series. We derive an equality relating the correlation coefficients $r_l = \operatorname{corr}(s_k, x_{k,l})$, $\hat{r}_l = \operatorname{corr}(\hat{s}_{k,l}, \hat{x}_{k,l})$, and $\tilde{r}_l = \operatorname{corr}(\tilde{s}_{k,l}, \tilde{x}_{k,l})$:

$$\begin{aligned} r_l &= \operatorname{corr}\left(s_k, x_{k,l}\right) = \operatorname{corr}\left[\left(\hat{s}_{k,l} + \tilde{s}_{k,l}\right), \left(\hat{x}_{k,l} + \tilde{x}_{k,l}\right)\right] \\ &= \hat{r}_l \cdot \sqrt{\frac{\operatorname{var}\hat{s}_{k,l} \cdot \operatorname{var}\hat{x}_{k,l}}{\operatorname{var}s_k \cdot \operatorname{var}x_{k,l}}} + \tilde{r}_l \cdot \sqrt{\frac{\operatorname{var}\tilde{s}_{k,l} \cdot \operatorname{var}\tilde{x}_{k,l}}{\operatorname{var}s_k \cdot \operatorname{var}x_{k,l}}}; \\ \hat{r}_l &> 0, \quad \tilde{r}_l < 0; \end{aligned} \tag{7}$$

where the correlation coefficients and variances are calculated on the index k.

In view of expressions (6) and (7), we find:

$$r_l > 0 \Rightarrow \hat{r}_l > r_l \quad \text{alternatively, if } r_l < 0 \Rightarrow |\tilde{r}_l| > |r_l|. \tag{8}$$

From these expressions, it follows that s-decomposition extracts from a pair of series $x_{k,l}$ and s_k the components with extreme correlation for each index l: CS-components with positive correlation and NS-components with a negative one. These properties are also the reason for the choice of signs of the coefficients of the Fourier transform as the essential signs to describe the synchronicity.

Considering that the average value of a function is proportional to the value of its Fourier transform at zero frequency, we obtain the equalities for the average values:

$$\begin{aligned} &\left\langle x_{k,l}\right\rangle = \left\langle \hat{x}_{k,l}\right\rangle + \left\langle \tilde{x}_{k,l}\right\rangle, \quad X_{0,l} = \hat{X}_{0,l} + \tilde{X}_{0,l}; \\ &\left\langle s_k\right\rangle = \left\langle \hat{s}_{k,l}\right\rangle + \left\langle \tilde{s}_{k,l}\right\rangle, \quad S_0 = \hat{S}_{0,l} + \tilde{S}_{0,l}; \end{aligned} \tag{9}$$

where the summation is performed on the index k.

Bearing in mind the even continuation of the series and that the Wolf numbers s_k are always positive, we obtain the result that S_0 is real and positive. In cases where $X_{0,l} > 0$, in accordance with expressions (9) we obtain:

$$\hat{X}_{0,l} = X_{0,l}, \quad \tilde{X}_{0,l} = 0, \quad \hat{S}_{0,l} = S_0, \quad \tilde{S}_{0,l} = 0;$$

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alternatively, if $X_{0,l} < 0$, then:

$$\hat{X}_{0,l} = 0, \quad \tilde{X}_{0,l} = X_{0,l}, \quad \hat{S}_{0,l} = 0, \quad \tilde{S}_{0,l} = S_0. \tag{10}$$

It can be concluded that there are two sets of values of the index l. In one of these sets, the averages of the CS-components are equal to the average values of the original series, and the averages of the NS-components are equal to zero. In the other set of values of the index l, the CS- and NS-components are interchanged.

If the temperature scale has the zero value, the CS- and NS-components ($\hat{x}_{k,l}$ and $\tilde{x}_{k,l}$) form on average the zones delimited by a zero-isotherm, where the weather stations with positive or negative average temperatures are located. There is one-to-one mapping of average temperatures and average values of their components. What is more, the CS- and NS-components of the Wolf numbers ($\hat{s}_{k,l}$ and $\tilde{s}_{k,l}$) are constant within the designated zones, – either zero or non-zero.

Let us look at the normalized second initial moments for the original series and their CS- and NS-components. The initial moments do not include the centering operation, i.e., the average value is kept in series; it can have a physical sense as, e.g., a positive constant component of the solar activity. Naturally, the second initial moments are positive by definition.

Let the series $\hat{x}_{k,l}$ and $\hat{s}_{k,l}$ correspond to the moments $\hat{\vartheta}_l$ and $\hat{\eta}_l$; analogously, for the series $\tilde{x}_{k,l}$ and $\tilde{s}_{k,l}$ the moments $\tilde{\vartheta}_l$ and $\tilde{\eta}_l$ are calculated, i.e.,

$$\hat{\vartheta}_l = \frac{(\hat{x}_{k,l}, \hat{x}_{k,l})}{(x_{k,l}, x_{k,l})}, \quad \tilde{\vartheta}_l = \frac{(\tilde{x}_{k,l}, \tilde{x}_{k,l})}{(x_{k,l}, x_{k,l})}, \quad \hat{\eta}_l = \frac{(\hat{s}_{k,l}, \hat{s}_{k,l})}{(s_k, s_k)}, \quad \tilde{\eta}_l = \frac{(\tilde{s}_{k,l}, \tilde{s}_{k,l})}{(s_k, s_k)}. \tag{11}$$

Taking into account the orthogonality and additivity – see expressions (5) and (6) – we find that:

$$\hat{\vartheta}_l + \tilde{\vartheta}_l = 1, \quad \hat{\eta}_l + \tilde{\eta}_l = 1. \tag{12}$$

In addition, Pearson's correlation coefficient of these moments has the properties:

$$r_2 = \mathrm{corr}\left(\hat{\eta}_l, \hat{\vartheta}_l\right) = \mathrm{corr}\left(\tilde{\eta}_l, \tilde{\vartheta}_l\right) = -\mathrm{corr}\left(\hat{\eta}_l, \tilde{\vartheta}_l\right) = -\mathrm{corr}\left(\tilde{\eta}_l, \hat{\vartheta}_l\right). \tag{13}$$

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4 Data series, consolidating grouping

We used the series of the average monthly temperatures for the calculations. These were measured at 818 weather stations of the Northern Hemisphere from 1955 to 2010. This is the most complete archive of global data on surface temperature in the public domain. The archive is updated regularly in the Met Office Hadley Centre observations datasets. For the same time interval, the series of the monthly average Wolf numbers were taken on site at the Pulkovo Observatory.

In order to consolidate homogeneous information, the original data were subdivided into monthly groups. The terms of the series for a particular month in each successive year were selected and inserted in the group without changing the original order. In total there were 12 temperature series for each of the 818 weather stations; and 12 series of Wolf numbers, which are identical at all weather stations. Each group includes 56 terms.

The discrete Fourier transform is the base algorithm of the s-decomposition. Scafetta (2014) rightly wrote about the inadmissibility of the formal application of the discrete Fourier transform and the subsequent misinterpretation of the results. Doing discrete spectral analysis, make sure that the Fourier coefficients decrease rapidly within a finite interval of definition. This problem had solved, e.g., in Tartakovsky (1993) by means of the preliminary polynomial filtering and by optimal continuation of series beyond the domain of definition.

In this case, to calculate the Fourier coefficients, the series were continued beyond the interval of definition, periodically in an even manner. Moreover, to check and eliminate the influence of the series length on the results, these series were interpolated from the original 56 up to 2^{12} samples, having been performed on the index k, i.e., on the time. The finiteness in the Fourier transform of the continued series and the compliance of both the procedures of sampling and interpolation with the sampling theorem were monitored during calculations, which were realized by means of the Mathcad package.

The designations remain the same for the newly formed series: $x_{k,l}$ and s_k. They will be referred to in the text below as the original series, unlike the series obtained by s-decomposition, i.e. the CS- and NS-components: $\hat{x}_{k,l}$ and $\hat{s}_{k,l}$, $\tilde{x}_{k,l}$ and $\tilde{s}_{k,l}$, respectively. The index k corresponds to the time, and l denotes the numbers of weather stations.

5 Results and discussion

In this section, we analyze the foregoing reasoning and its consequences. First, we note that the properties mentioned in Sect. 3 were proved computationally with machine accuracy. This makes it possible to have confidence in the quality of the developed algorithms.

In the next step, the obtained algorithms were applied to the unique observational data. Initial moments, correlation coefficients, and mean values were calculated for these series. The computed dependencies were compared as far as possible with the climate geography and are discussed below.

5.1 Correlations of solar activity and temperature data

The correlation coefficients of the temperature and Wolf number series and their components (r_l, $\hat{r}_l$, and $\tilde{r}_l$) are calculated monthly from 1955 to 2010 and for each of the 818 weather stations. We obtained 9816 values of correlation coefficients, with dependences shown in Fig. 1. The coefficients varied in the ranges: $\hat{r} \in [0.902, 0.165]$, $\tilde{r} \in [-0.933, -0.183]$, $r \in [0.497, -0.519]$. In 85 % of cases $|r| < 0.2$ and r never reaches the values $\hat{r}$ and $\tilde{r}$ for each month and each weather station, as follows from expressions (6)–(8).

Figure 1 shows that the fluctuations of $\hat{r}$ and $\tilde{r}$ mostly occur around the levels ±0.5, but with a certain trend and modulation associated with the course of r. We found no

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evident dependences of r, $\hat{r}$, and $\tilde{r}$ on geographic coordinates, altitude, and the mean temperature of the month.

Coefficients $\hat{r}$ and $\tilde{r}$ show the presence of an evident and unambiguous relationship between $\hat{s}_{k,l}$ and $\hat{x}_{k,l}$, $\tilde{s}_{k,l}$ and $\tilde{x}_{k,l}$. In most cases, these coefficients are significant according to Fisher's test with a probability of at least 0.95 for the small sample used.

Positive correlations of CS-components and negative correlations of NS-components characterize their opposite effect in the geosystem. The consequence of this is a small correlation coefficient r of the original series of Wolf numbers and temperatures.

5.2 Distributions over the temperature intervals

Figure 2 shows the histograms of the original temperature series, their CS- and NS-components for each month from the years studied. The temperature partitioning interval was equal to 1 °C. The total number of samples from the interpolated series was 838 450. Due to this, in the histograms all intervals were filled, with none missed.

For each month, it was discovered that over a long and continuous range of positive temperatures the histogram of the original temperature series coincides with the histogram of CS-components. Moreover, in July and August there is coincidence in the whole range of the temperature changes. For each month there is also a continuous range of negative temperatures, where the histogram of NS-components coincides with the histogram of the original temperature series, excepting the range about ±3 °C. The normalized rms-difference of the histograms does not exceed 3–4 % along the range matching.

For all the months at zero temperature, there is a sharp peak of the histogram of the NS-components. The Wolf numbers are always positive; there are also dominant positive average values of the original temperature series. In these conditions, according to the definition (Eqs. 2 and 3) and to the property (Eqs. 10), it appears that the most frequent values of the NS-components are near to zero.

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In the histograms of the CS-components, the peak at zero is less noticeable, and is absent from June to September for the above reasons; i.e., a negative average temperature is less frequent than a positive one in the whole sample of 818 series.

Thus, the CS- and NS-components of the temperature series have a quite clear physical meaning – the distribution of the components on temperature intervals coincides with the same distribution of the original temperature within the above-mentioned ranges.

The temperatures from weather stations at different locations can fall into the same interval of the histogram by construction. From this, it follows that the observed properties of the histograms are not local and relate to the whole temperature field of the Northern Hemisphere that is formed under the influence of the Sun. How these properties are realized for each weather station separately, it is a subject for further research?

5.3 Second initial moments of the Sun's activity components

The monthly progress of the second initial moments $\hat{\eta}_l$ (Eq. 12) is shown in Fig. 3. There are two clearly delimited ranges of changes with a width of about 30 %. The initial moments of 400 stations (orange, green, and blue colours in Fig. 2) take the upper range throughout the year. The moments of all remaining 418 stations (black colour in Fig. 2) are in the upper range only in July and August. In the cold season, by location, the moments of these stations are located in the lower range.

Let us consider the location of these 400 stations. Among them are 31 stations located in the zone of influence of the warm North Atlantic Flow (Table A1). This moves in the northern part of the Atlantic Ocean and is an extension of the Gulf Stream. The next 11 stations are located on the North-West Coast of America (Table A2) under the influence of the North Pacific warm flow. Off the coast of North-West Canada and South Alaska, this flow turns into the Alaska Flow. The remaining 358 stations are located from 0.5 to 50° N, in the tropical and subtropical zone.

Throughout the year, a steady flow of solar energy can occur by direct heating of the Earth's surface and atmosphere according to climate zone, as well as by a steady heat transfer. Conceivably, in this case, the transfer is related to the warm ocean flow from the South to the North. Interestingly, the annual course of the second initial moments of CS-components of Wolf numbers $\hat{\eta}_l$ displays in Fig. 3 the current geography of the climate. At the same time, a latent property is revealed – the reallocation of the incoming energy in two ranges, the width and the distance between which is about 30 % of the possible changes.

5.4 Collation of the average temperatures and the initial second moments

There are two types of dependencies of moments $\hat{\eta}_l$ for weather stations, as shown in Fig. 4. In July and August, these dependencies are continuous, whereas for all other months there are jumps up in size from 27 % in January to 39 % in May. The average temperatures also experience upward jumps at the same points, changing their signs from minus to plus. The points of the jumps move with the weather station location for different months. Thus the ascending ordering of the second initial moments corresponds to the ordering of the mean monthly temperatures in accordance with their signs.

The same properties are apparent in both Figs. 3 and 4. In the January panel (Fig. 4, black bars) to the left of the jump, in the negative temperature zone, are located 418 stations. The remaining 400 stations are to the right of the jump, i.e., in the positive temperature zone, across the whole year (Fig. 4, orange bars). In Fig. 3, the second initial moments of these 400 stations are located in the upper range (orange colour) and throughout the year also. The distance between ranges varies with the size of the jump in the course of the year in Fig. 3, including the zero distance in July and August.

During the course of the year, the stations gradually move from the left to the right zone excepting July and August Within this period, the left zone is not revealed. Then the reverse process begins, ending in December This month, based on the number of stations in zones, is similar to February, and March is similar to November This

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similarity is reduced in an April–October pair, and then further between May and September.

The jumps of the average temperature from negative to positive occur due to natural causes. On the contrary, solar activity s_k, characterized by Wolf numbers, is the same for all weather stations, and contains no visible jumps. They appear only because of s-decomposition, depending on the location of the weather stations. The correlation coefficients of the second initial moments and the average temperatures at weather stations are given in Table 1, from which it is clear that they are determined by these jumps.

Thus, obtained as a result of s-decomposition, the second initial moments $\hat{\eta}_l$ and $\tilde{\eta}_l$, given in Eqs. (11) and (12), change consistently with the average temperatures in terms of the correlation coefficients. The primary cause is an abrupt change at the boundary between the positive and negative temperatures. For this reason, the relationship between CS-components can be interpreted as an energy inflow from the Sun, and between the NS-components as an energy outflow.

6 Conclusions

This work is based, as a consequence of experience, on the hypothesis that synchronicity is an essential feature of solar–terrestrial relations. The Sun's external forcing initiates climatic processes on the Earth and should therefore be manifested in the similarity of their essential signs. Solar activity is characterized by the Wolf numbers and is considered as an integral indicator of forcing. Use is made of the orthogonal CS- and NS-components of Wolf numbers and the processes under study that differ in the coincidence and non-coincidence of their essential signs. These components are the latent essence of the phenomenon, and between them the information from the original data is redistributed without any distortion. To calculate these components, algorithms based on the Fourier transform were developed.

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The theory is applied to decompose the Wolf numbers and temperature series from 818 weather stations of the Northern Hemisphere from 1955 to 2010. We obtained the following results.

The CS- or NS-components of the Wolf numbers and temperature series have significant correlation coefficients in the range from weak to strong values for small samples, typical for the minimum period of stability of the climate.

The histograms of the original temperature series coincide with the histograms of their components over long continuous ranges of temperatures, excluding the range of about ±3 °C.

The second initial moments of the CS-components of the Wolf numbers display the climate geography, and fall into two ranges, the width and the distance between which is about 30 % of the possible changes.

The relationship between the CS-components of the Wolf numbers and temperature series can be interpreted as an inflow of energy from the Sun, and between the NS-component – as an energy outflow. The distribution of the inflow and outflow of solar energy over the weather stations undergoes jumps from about 27 % in January to 39 % in May, excluding July and August.

This new approach is informative; it describes the manifestation of the forcing and corresponds to the known concepts of natural and climatic processes. It deserves wide application and the search for other matches or mismatches. The results are convincing that the things, "which are seen"*, sometimes do not reflect the essence of the phenomenon; it may be helpful to look at latent things, "which are not seen"* and are novel at least.

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Table 1. Monthly progress of the correlation coefficients of the second initial moments $\hat{\eta}_l$ and the average temperatures at weather stations; the sample size is 818; see Fig. 4.

Months											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0.812	0.779	0.719	0.657	0.387	0.148	−0.050	−0.002	0.386	0.615	0.778	0.778

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Table A1. Weather stations from the zone of influence of the warm North Atlantic Flow.

#	Synoptic index	Latitude ° N	Longitude °	Country
1	7015	50.6	3.1	France
2	6447	50.8	4.4	Belgium
3	10 469	51.3	12.4	Germany
4	10 410	51.4	7.0	Germany
5	3955	51.9	−8.5	Ireland
6	10 361	52.1	11.6	Germany
7	6260	52.1	5.2	Netherlands
8	10 338	52.5	9.7	Germany
9	10 384	52.5	13.4	Germany
10	3962	52.7	−8.9	Ireland
11	3377	53.2	−0.5	England
12	3302	53.3	−4.5	England
13	3969	53.4	−6.3	Ireland
14	10 147	53.6	10.0	Germany
15	10 184	54.1	13.5	Germany
16	10 170	54.2	12.1	Germany
17	10 035	54.5	9.6	Germany
18	3917	54.7	−6.2	Ireland
19	3162	55.3	−3.2	England
20	3980	55.4	−7.3	Ireland
21	6186	55.7	12.5	Denmark
22	3100	56.5	−6.9	England
23	3091	57.2	−2.2	England
24	3026	58.2	−6.3	England
25	1415	58.9	5.6	Norway
26	3005	60.1	−1.2	England
27	1317	60.4	5.3	Norway
28	6011	62.0	−6.8	Denmark
29	1212	62.9	6.5	Norway
30	4018	63.1	−22.6	Iceland
31	4082	64.3	−15.2	Iceland

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Table A2. Weather stations of the North-West Coast of America.

#	Synoptic index	Latitude ° N	Longitude °	Country
1	72 594	40.8	−124.2	USA
2	72 597	42.4	−122.9	USA
3	72 698	45.6	−122.6	USA
4	72 688	45.7	−118.8	USA
5	72 791	46.2	−123.9	USA
6	72 792	47.1	−122.9	USA
7	72 793	47.5	−122.3	USA
8	71 894	49.4	−126.6	Canada
9	71 109	50.7	−127.4	Canada
10	71 101	53.3	−131.8	Canada
11	70 398	55.0	−131.6	Alaska

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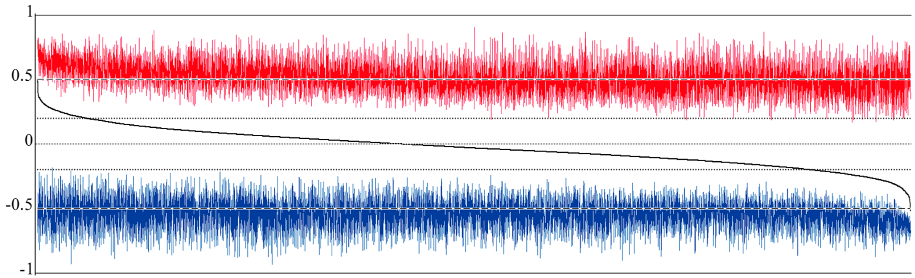

Figure 1. Correlation coefficients of Wolf numbers and temperature series, of their CS- and NS-components. Red colour denotes $\hat{r}$, blue denotes $\widetilde{r}$, and black line is r. All correlation coefficients are ordered with r, which range in descending order along the abscissa. Each value corresponds to one of the temperature series from 818 in each of 12 months for 56 years. In total there are 9816 points along the abscissa. Dotted lines designate corridor ±0.2.

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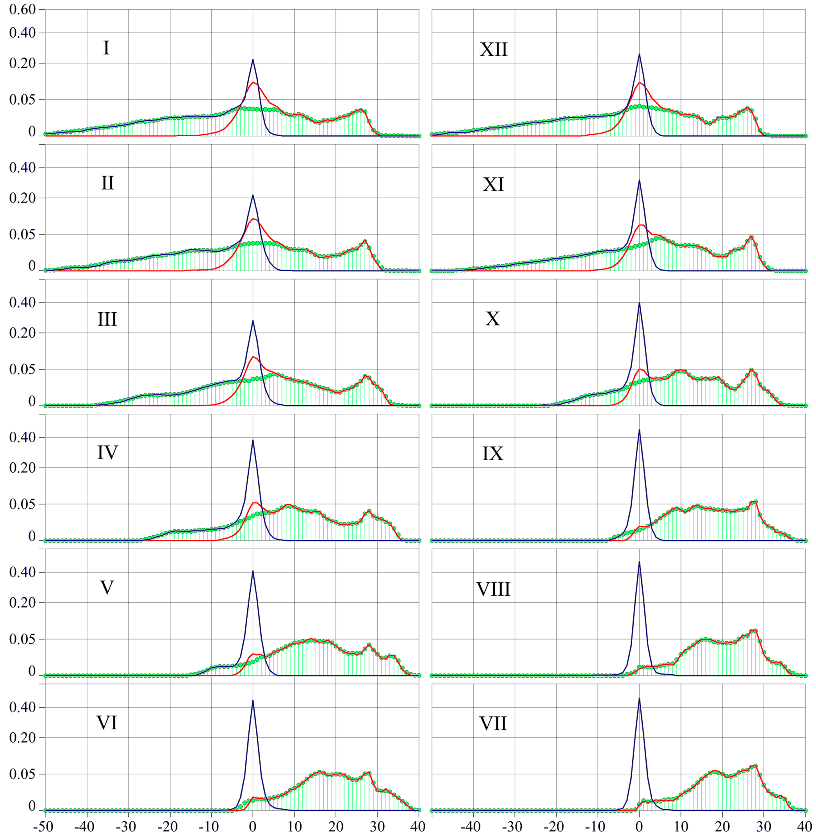

Figure 2. Histograms of the temperature series. Green circles and lining denote histograms of the average temperatures; red lines are histograms of CS-components; black lines denote the histograms of NS-components. The normalized rms-difference of histograms does not exceed 3–4 % along range matching. The relative frequencies on ordinate are in the power scale with exponent equal to 1/2. Interval partitioning on the abscissa is equal to 1 °C. Months are indicated by Roman numerals in all panels.

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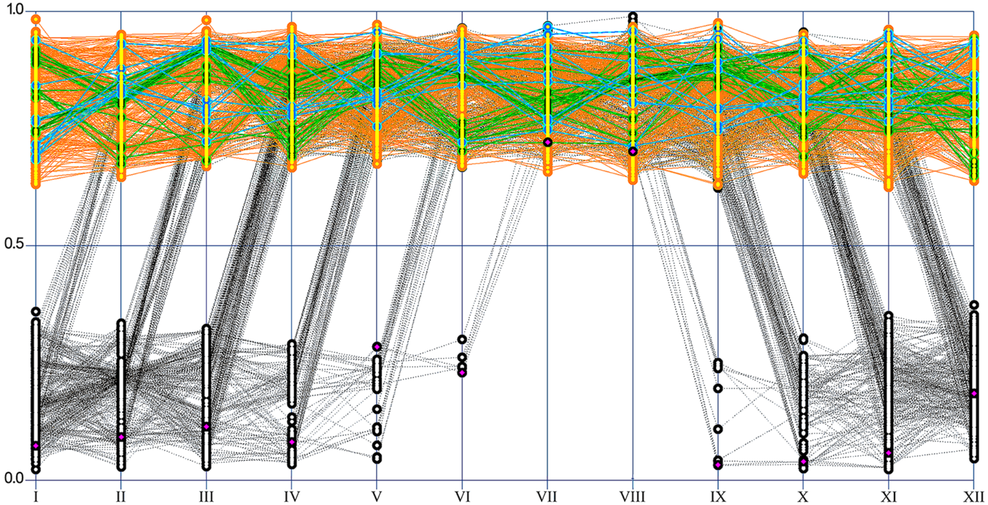

Figure 3. Normalized second initial moments of CS-components of Wolf numbers from 1955 to 2010 at weather stations. Yellow and orange colours denote 358 stations from 0.5 to 50° N; green marks 31 stations in the North Atlantic from 50.6 to 64.3° N; blue marks 11 stations of North-West Coast of America from 40.8 to 55° N; black denotes 418 stations that do not coincide with the previous ones, from 50 to 80° N; black circles with red center are the most northerly weather station at 80.6° N, synoptic index 20 046. Months are indicated by Roman numerals along the abscissa.

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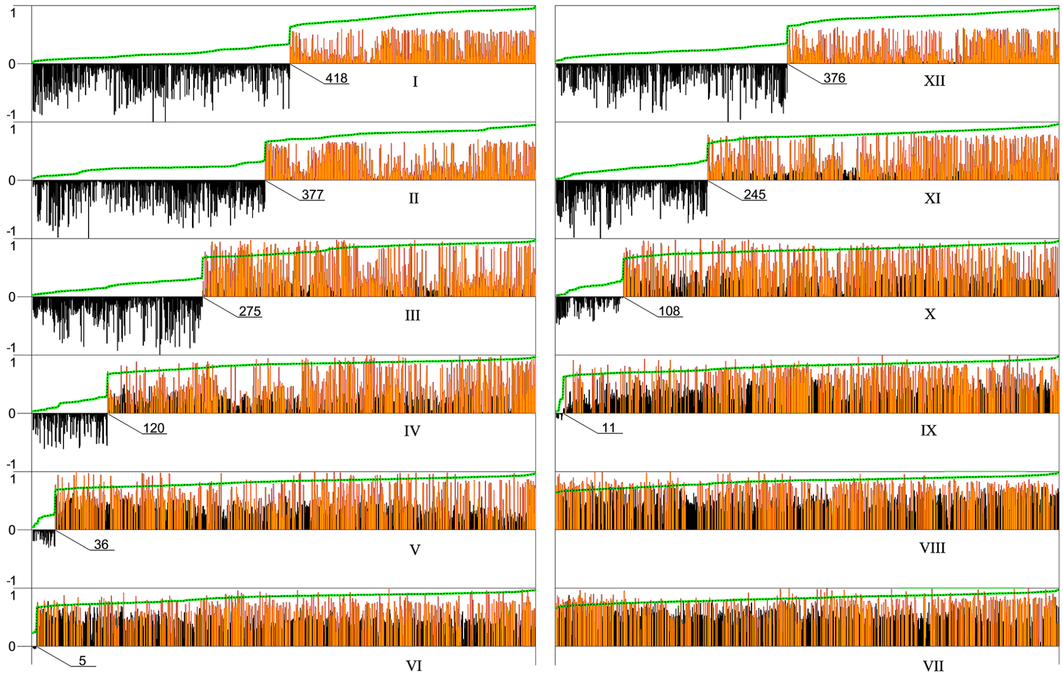

Figure 4. Normalized average monthly temperatures for 56 years at 818 weather stations in the Northern Hemisphere: black bars denote the polar and temperate zone; orange bars denote tropical and subtropical zone; green lines are moments $\hat{\eta}_l$ ranged in ascending order independently for each month. Each point of the abscissa corresponds to one of the weather stations. The numbers of stations in the range of negative temperatures is shown on callouts. Months are indicated by Roman numerals in all panels.

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