ON THE SOLAR ACTIVITY AND EARTH ATMOSPHERE LARGE-SCALE VORTICAL PROCESSES COUPLING

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Abstract

The analysis of solar activity (SA) influence on large-scale vortical processes in the Earth atmosphere (for example, tropical depressions, typhoons and hurricanes) is the important part of natural hazards and Earth climate change research. In particular, the mutual correlation functions of solar activity (SA) characteristics and tropical cyclogenesis (LVP) intensity are studied, the spectra of SA and LVP are compared and so on.

In the present paper the correlation coupling between Wolf numbers W(t) characterizing solar activity intensity with large-scale vortical perturbations (LVP) amount T(t) occurring in the Earth atmosphere is considered. In the Fig.1 the graphs of W(t), T(t) are shown for the time interval from 1983 up to 1998 years. A single point of these curves give the number of events during month period. So 192 points in the each data set were used. According to Fig.1 the behavior of oscillating functions W(t), T(t) is different, for example, the growth of W(t) not always accompanied by the T(t) increase, the peaks of these functions have different position on t and so on. So far as W(t), T(t) oscillate the mutual correlation function $Cr(n)$ was calculated where n is the temporal shift in months. Let us determine the averaging W and T values on the data sets taken $<T>=\left(\frac{1}{192}\right)\sum_j T_j$, $<V>=\left(\frac{1}{192}\right)\sum_j V_j$, where $V_j = 0.02W_j$, and dispersions of temporal sequences considered $\sigma_t^2 = \left(\frac{1}{192}\right)\sum_j \left(T_j - <T>\right)^2$, $\sigma_V^2 = \left(\frac{1}{192}\right)\sum_j \left(V_j - <V>\right)^2$, $0 \le j \le 191$. The mutual correlation function is determined by

$$Cr(n) = \frac{1}{192}\sum_{j=0}^{191-n}\left(T_{j+n} - \langle T \rangle\right)\cdot\left(V_{j+n} - \langle V \rangle\right), \quad n = 0,1.....N/2 \quad (1)$$

The plot of $Cr(n)$ is presented in Fig.1b and it shows the absence of clear correlation between fluctuations $\delta T_j = T_j - \langle T \rangle$ and $\delta V_j = V_j - \langle V \rangle$. For example, there are wide intervals of anti-correlations. The maximum of the first positive correlation in behavior of considered events W(t), T(t) corresponds to temporal shift of the order of 6 days. Variable trends X_j for the function V_j and Y_j for T_j one are shown in Fig.2a. The mutual correlation function $Crf(n)$ of W and T fluctuations near these trends $\delta V_j = V_j - X_j$, $\delta T_j = T_j - Y_j$ is presented in Fig.2b. It is clear that relationship of LVP with SA has a complicated nature. So the consecutive mathematical model of relationship between the solar activity and large-scale vortical processes in the Earth atmosphere must take into account a number factors of principle like large-scale instability triggering, the large vortices generation, nonlinear stabilization of instabilities, perturbations dissipative decay, the ration between typical periods of subsystems variability (SA and LVP). According to this we develop the oscillator x(t) model allowing to explain the observable features of T(t)-W(t) correlations. The basic equation is written like this

$$x_{tt} + \nu x_t + \omega_o^2 x = f(t) \quad (2)$$

where ν, ω_o - are the friction coefficient and oscillator frequency respectively. It is supposed also that $f(t) = 0$, $x(t) = 0$ for $t \le 0$. The solution of (2) is determined by formula

$$x(t) = \frac{1}{\omega_1}\int_0^t d\tau f(t-\tau)\exp(-\nu\tau)\sin(\omega_1\tau), \quad t > 0 \quad (3)$$

Here $\omega_1^2 = \omega_o^2 - \nu^2$. Let us take T to be the temporal step so $t_k = Tk$, where k = 0, 1 ..... (N -1). From the expression (3) relationship of $x_k = x(t_k)$ with $f_j = f(t_j)$ follows as ($B = T/\omega_1$)

$$x_k = B\sum_{j=0}^{k} f_{k-j}\exp(-\delta j)\sin(\gamma j) \quad (4)$$

where the following denotes are introduced $\delta = \nu T$, $\gamma = \omega_1 T$. The external force we take as the sum of two dispersed impulses

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\begin{aligned}
& f_k = A_1 D_1(k)\sin\Psi_1(k) + A_2 D_2(k)\sin\Psi_2(k) \\
& \Psi_1(k) = \Omega_1(k-m) - \varphi_1, \quad \Psi_2(k) = \Omega_2(k-s) - \varphi_2 \\
& D_1(k) = 1/\left[1 + (k-m)^2/\tau_1^2\right], \quad D_2(k) = 1/\left[1 + (k-s)^2/\tau_2^2\right], \\
& 0 < m, s < (N-1)
\end{aligned}
\tag{5}
$$

The plots of the external force f_x and excited by it oscillations x_x are given in the Fig.3a for the case of parameters choice $\delta = 0.01$, $\gamma = \pi/19$, $\Omega_1 = \pi/41$, $\Omega_2 = \pi/107$, $A_1 = 1$, $A_2 = 0.7$, $\tau_1 = 40$, $\tau_2 = 90$, m = 400, s = 990 , $\varphi_1 = 0$, $\varphi_2 = \pi/3$. In this case the oscillator frequency γ is significantly larger of the external force frequencies Ω_1 , Ω_2 and we see the strong correlation between f(t) and x(t) behaviors. For the intermediate case $\gamma = \pi/95$, $\Omega_1 = \pi/41$, $\Omega_2 = \pi/107$ and unchanged other parameters, when the oscillator frequency value is placed between the external force frequencies Ω_1 , Ω_2 , the plots of f_x and x_x are presented in the Fig.3b. It is seen from this figure the anti-correlation of functions x_x and f_x at the time t < 700. But at the time t>700 the clear correlated behaviors of oscillator displacement x_x and force f_x are occurred f_x. The case presented in the Fig.3a corresponds to the non-inertial approximation in the equation (2): $x(t) \approx f(t)/\omega_o^2$. The mutual correlation functions for the both cases are shown in Fig.4a and Fig.4b respectively. Their comparison indicates that for the second case the level of mutual correlation x_x and f_x is less essentially.

Thus on the basis of the simple model considered it is possible to understand the complicated behavior of mutual x_x - f_x correlations in the dependence on ratio between oscillator frequency and external force frequencies.

From the analysis given above it is seen the necessity to develop model of LVP-intensity based on the differentiable functions. Such model allows, for example, describe correctly the phase space of LVP-intensity and to improve our understanding of possible correlation relationships between large-scale vortical processes in the Earth atmosphere and solar activity variation, to study further the physical mechanisms of solar-terrestrial relationships realization in the large-scale atmosphere dynamics [1].

Let us consider the LVP-intensity in the North-East part of Pacific Ocean for the August-October season of 1998 year. During the period 53 events (tropical depressions, storms and cyclons occurred). Take into account that the each event with its ordering number k had the development period of duration ε_k, the quasi-stationary phase $a_k \le t \le b_k$ and the decay stage with duration τ_k. The development stage we approximate by the function

$$p_k(t) = 0.5(1 + (t - a_k)/\left[\varepsilon_k^2 + (t - a_k)^2\right]^{1/2}$$

where t , a_k , b_k , ε_k - are measured in days. The decay stage of large-scale perturbation is approximated by the following function

$$g_k(t) = 0.5(1 + (b_k - t)/\left[\tau_k^2 + (t - b_k)^2\right]^{1/2}.$$

Therefore, the life cycle of single LVP with number k is described by the function $f_k(t) = p_k(t) \cdot g_k(t)$, shown in Fig.5a. Now the cyclogenesis intensity may be determined like this $T(t) = \sum_k f_k(t)$, where $1 \le k \le 53$. The plot of intensity T(t) for the chosen season is given in Fig.5b. It is important that we have the analytical formula for LVP-intensity in the form of differentiable functions. This allows us to study the phase plane (T, Q), where Q(t) = dT / dt or in the discrete form we obtain now $Q_j = (T_{j+1} - T_j)/\Delta t$, where Δt is the temporal step so $t_{j+1} = t_j + \Delta t$.

The phase plane $\left(T_j, Q_j\right)$ is shown in the Fig.6 for the entire season considered and in some time intervals. These figures indicate the complicated structure of phase plane studied. In particular, if we try to develop the oscillator model driven by the external force [2] (for example, suppose $f_j = V_j$), to describe this plane then it is necessary to take into account the dissipation, the variable oscillator parameters like its frequency, a nonlinearity and so on which must determined by the background temperature, pressure, winds fields in the ocean-atmosphere system. The criterion of usefulness such model may be the correspondence of LVP-intensity profile T(t) obtained to the experimental data existed. Such model is under development now. It is necessary to note also that besides the solar-terrestrial relationships there are the external factors influence on the LVP in the Earth Atmosphere, for example, cosmic rays. лучи.

CONCLUSIONS

1. It was considered the correlation relationships between the large-scale vortical processes intensity occurred in the Earth atmosphere (the set on independent events) and the solar activity variations characterized by the Wolf numbers. The complicated dynamics of these correlations is explained

on the basis of oscillator model under influence of the external force and the ratio between the force frequencies and oscillator one is taken into account.

2. The analytical approximation of LVP-intensity based on the differentiable functions is developed and it is applied to the analysis of active cyclogenesis season August-October 1998 year for the North-East part of Pacific Ocean. The complicated structure of LVP-intensity phase plane is obtained. The approximation by the oscillator model beside the dissipation must take into account the variable system parameters like oscillator frequency and possible the system nonlinearity. The parameters variability corresponds naturally the non-stationary background fields under LVP-development.

References

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