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BRIEF COMMUNICATIONS

Solar Activity Effect on Atmospheric Processes. Autoregressive Analysis of Precipitation Cycles

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Abstract—Spectral and autoregressive analysis was performed on the data of the measurements of solar activity and atmospheric precipitation in different regions of the Earth. It is shown that for reliability of the derived probability correlations between the processes under study, the measured cosmic ray intensity must be taken into account. This result agrees with the model of the solar activity action upon the lower atmosphere, proposed by Pudovkin and Raspopov.

INTRODUCTION

Oscillations of the terrestrial climate are of a polycyclic character [1–5]. The cycles have a duration of 2–3 years (quasi-biennial cycle), 5–7, 10–12, 20–23, and 80–90 years. As was shown in [2], the 11-year cycle, which is predominant in the sunspot cycle and has great amplitude, but in meteoprocesses, is pronounced weaker and is usually second to the 22-23-year cycles. Moreover, in a series of works, the presence of statistically valuable variations with a duration of 3–4, 7–8, 12–13, and 17–33 months, has been revealed in geophysical data. Both climatologic and hydrologic variations, and the variations of other characteristics (cosmic ray intensity, medical–biological parameters [3]) are related to identical processes in interplanetary space and on the Sun: powerful interplanetary shock waves, solar flares, high-speed streams in the solar wind, the sectorial structure of the interplanetary magnetic field, etc.

It should be noted that spectral analysis of hydrometeorological data has already been carried out earlier [4, 5]. The distinctive property of the present work, as compared to previous studies, is the use of new qualitative statistical and calculative approaches to reveal interrelations between the processes and the elaborated original scheme of modeling a mechanism for the interaction of heliophysical and geophysical processes [6].

The assumption seems to be that the parameters describing atmospheric processes can be presented as a sum of their preceding values, i.e., in a form of autoregressive model [7]. In this case, the new data are used for the updated model, and an opportunity arises to predict the level a step forward.

Methods of elaborating the prognostic models were described in detail in [7], and we will consider here only its practical application. As a result of studies into the temperature and hydrologic parameters [8], the autoregressive model was developed, which predicted an error of a level in the Chudskoe lake for the next year on the order of 42% (for the order of ARMA model equal to 8). The question arose of the sufficiency of the parameters used, i.e., the proper water level in the lake, solar activity and temperature. After including the data on cosmic rays [9], it appeared to be possible to lower the error to 35%. The analysis of possible mechanisms for oscillations in the lake levels showed that one should use some additional meteorological parameters, in particular, the measurements of atmospheric precipitation levels, and then we were faced with the question of the character of these variations.

The measurements of precipitations in Russia, Estonia and Lithuania from 1910 to 1992, together with the data on solar activity (sunspot area S), were used for the analysis. The autoregressive spectral methods [6, 7] were applied in these studies parallel to examining correlations between solar activity and oscillations of the precipitation levels in each of the regions; control correlations between the precipitation oscillations were also examined in pairs of different regions. The calculations of spectral characteristics were carried out both from mean monthly values and from the average annual ones; this method provided the possibility of estimating oscillations of the precipitation levels and their correlation in a wide frequency range. The correlation and cross-correlation functions for both processes demonstrate a satisfactory coincidence in their dynamics. The spectra of each of the processes are also quite similar Figs. 1a–1d display the presence of identical identified peaks and confirm the assumption of the identity of both processes.

In this case the periods on the order of 1 year and, possibly of 3 months over the whole data sets, are related to solar activity; this is confirmed by the results

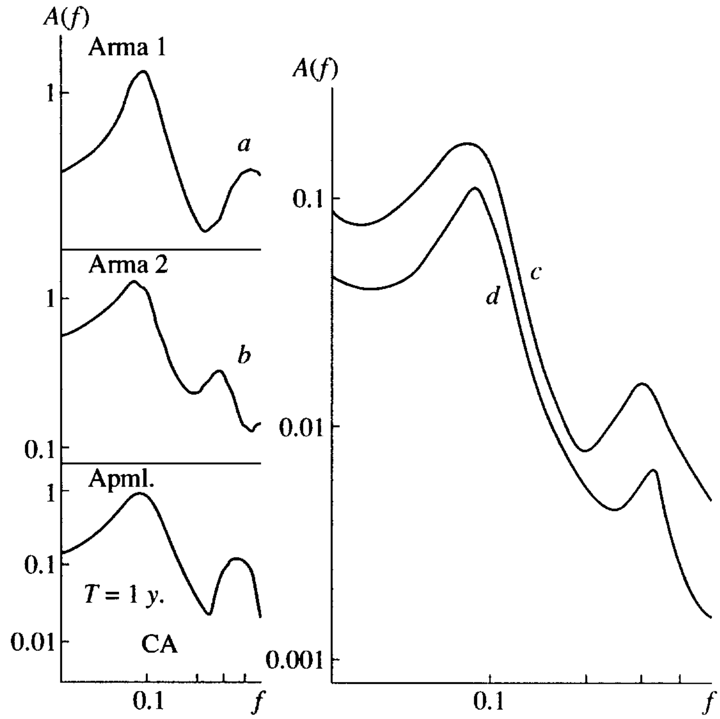

Fig. 1. Spectral characteristics of precipitation in (*a*) Lithuania and (*b*) Russia during the years 1982–1992 together with mutual ARMA-spectra for precipitation and solar activity for (*c*) Lithuania and (*d*) Russia.

of ARMA spectral analysis [6] for mean monthly value of the solar activity and oscillations of precipitation level in Estonia and Lithuania.

The autoregressive analysis of the average annual values of oscillations of the precipitation intensity was carried out in a similar way (Fig. 2). Calculations of the amplitude spectra (a) and the coherence spectra (b) showed the presence of both the 11-year component and the quasi-biennial wave in the analyzed data. The results obtained are in good agreement with similar calculations for the temperature [7] and the lake levels [8]. Moreover, the results are concordant with the results of the analysis of the mean wind velocity in the energy-active zones [5] and therefore fit the general pattern of the relevance of atmospheric processes to solar activity.

Calculations based on the average annual data on solar activity and the temperature in different points yield similar results, they reliably identify the temperature oscillations with periods on the order of 2–4 and 9–11 years associated with similar oscillations in the solar activity.

The dynamics of oscillations is also identical, while the (9–11) yearly oscillations are present continuously, oscillations with periods of 2–4 years are of a more random character, but this fact also agrees with a behavior of similar oscillations of the solar activity. In this case the phase spectra demonstrate delays of the temperature variations and agree with the results of studying the solar activity effect on geophysical and hydrological processes [9, 10].

A comparison of spectral characteristics of atmospheric parameters with similar spectra of galactic and solar cosmic rays [11–14] demonstrates a good agreement not only in the frequency domain but in phase also

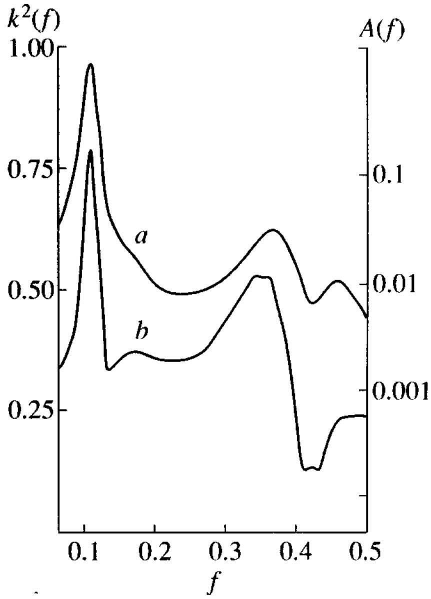

Fig. 2. Amplitude ARMA-spectrum (*a*) and coherence spectrum (*b*) for the level of precipitation and solar activity during the years 1910–1992.

(during 1952–1992 the variations with periods of 3–5 months, 1 year, 2–4 and 11 years were observed in cosmic rays, which were coincident with the solar activity variations and oscillations of precipitations during the same period).

On the basis of the relationships obtained, an autoregressive model was constructed of the type

$$Z_t = \sum_{i=1}^{t-k} \alpha_{t-i} Z_{t-i} + \sum_{i=1}^{t-l} \beta_{t-i} Y_{t-i} + \sum_{i=1}^{t-m} \gamma_{t-i} X_{t-i} + \xi_t,$$

where Z_{t-i}, Y_{t-i}, and X_{t-i} are current data on precipitation level, solar activity and intensity of cosmic rays; Z_t is a parameter for the prognosis; α_{t-i}, β_{t-i}, and γ_{t-i} are the autoregression coefficients; ξ_t is the residual noise level minimized in the process of calculation.

The inclusion of the data on the intensity of cosmic rays (ICR), as a parameter, substantially improves the model accuracy, the error in Z_t is then lowered from 42 to 26%.

CONCLUSION

As a result of the calculations performed, a probable correlation between the processes on the Sun and in the terrestrial atmosphere has been found; in this case, the analysis of the behavior of a delay between atmospheric processes and the solar activity, demonstrates the presence of time intervals from 12 to 36 months between all the atmospheric processes, that agrees with the results of calculations based on the other methods.

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