Relation of Atmosphere Surface Pressure Fluctuations with Geomagnetic and Cosmic Factors

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We present results of the digital spectral analysis of the time series containing the daily samples of the atmosphere surface pressure measured at Saratov city from Jan 1, 1995 to Dec 31, 1999. We calculated also cross correlation functions between the pressure fluctuations and the planetary geomagnetic indices, $A_p$ and $C_p$, and cross correlation function between these fluctuations and the cosmic-ray intensity. Two peaks detected in the calculated power spectrum are related, probably, with the atmosphere tidal waves. The relation of the pressure fluctuations with the $A_p$ index of the geomagnetic activity is statistically insignificant. The cross correlation function between the pressure fluctuations and the $C_p$ index has the maximal value $0.044 \pm 0.023$ at the pressure time delay $4^d$. The statistically significant negative correlation is discovered between the surface pressure fluctuations and the cosmic-ray intensity. The cross correlation function has two minima: at the zero time delay with the value $-0.068 \pm 0.023$, and at the pressure time delay $12^d$ with the value $-0.087 \pm 0.023$. The negative correlation between the pressure and the cosmic-ray intensity is observed at the pressure time delay as long as $17^d$ and can be explained by the so-called condensation mechanism of an interaction of the cosmic rays with the atmosphere.

1. Introduction

The problem of an investigation of the influence of cosmic factors on the Earth’s atmosphere attracts the attention of many researchers. Among these factors there are tidal interactions with the Moon and the Sun as well as the
nutational motion of the Earth’s rotation axis and the proper nutation of the Earth (motion of the pole) [1]. Cosmic rays of solar and galactic origin also interact with the atmosphere. The fluxes of these cosmic rays depend on a state of the Earth’s magnetosphere and, as a consequence, on the solar activity [2]. The aim of our current study is the investigation of possible relation of the atmosphere surface pressure fluctuations with geomagnetic and cosmic factors using the digital spectral analysis of time series and the cross correlation functions calculations.

2. Observational data

We examined the time series containing the daily samples of the atmosphere surface pressure measured by the mercury barometer at Saratov city (51°.5 N; 46°.0 E; \( h = 80 \text{ m} \)) from Jan 1, 1995 to Dec 31, 1999 at 12 hours of third time zone. As a first stage, we subtracted from the pressure samples the main annual harmonic with the period equal to the tropical year (365.2422). The amplitude \( A = 5.36 \text{ hPa} \) and the phase \( \phi = 1.44 \text{ rad} \) of this harmonic have been determined by fitting to the time series a sinusoid using the least squares method.

Cosmic rays are not registered at Saratov city. However the flux of galactic cosmic rays of high energies which can to penetrate in atmosphere down to the sea level has a high correlation at different points of some region. Therefore we used the daily data on cosmic rays measured at Apatity station. The cosmic-ray flux samples have been filtered by the moving average digital filter using the averaging interval time length 200 \( d \).

The data on \( A_p \) and \( C_p \) planetary geomagnetic indices accepted from the Space Physics Interactive Data Resource (http://spidr.ngdc.noaa.gov/).

3. Calculation and analysis of power spectrum

We used for the spectral analysis of the time series containing the daily samples of atmosphere surface pressure with subtracted main annual harmonic the classical version of the power spectrum estimation based on calculation of the Fourier transform of an autocorrelation function with the Tukey’s spectral window [3]. The maximal time delay of the autocorrelation function
was chosen $450^d$. In this case the number of degrees of freedom equal to 11, and the half-power bandwidth is 0.00296 cycles per day. The upper frequency boundary of the calculated spectrum was chosen 0.10 cycles per day.

Several well-defined peaks there are in the power spectrum. We adopted for periods of feasible harmonics which correspond to these peaks to be equal to the periods of peak maximal points and the error of the estimation of a period to be determined by a value of the half-power bandwidth. Two peaks with the periods $29^d.9 \pm 2^d.7$ and $16^d.4 \pm 0^d.8$, probably, are the tidal harmonics $M_m(27^d.55)$ and $M_f(13^d.66)$, respectively [1]. The peaks with periods $45^d.4 \pm 6^d.1$ and $11^d.8 \pm 0^d.4$, probably, are related with the modes of proper atmosphere oscillations [4].

4. Investigation of correlation between surface pressure and geomagnetic activity

We calculated cross correlation functions between the pressure fluctuations and the planetary geomagnetic indices $A_p$ and $C_p$ for different time delays of the pressure measured in integer days numbers. The relation of the pressure fluctuations with the $A_p$ index of geomagnetic activity is statistically insignificant. The cross correlation function between the pressure fluctuations and the $C_p$ index has a maximum value $0.044 \pm 0.023$ at the pressure time delay $4^d$. This result is in a good accordance with the data of Mustel et al. [5].

It is clear that the magnetic field of the Earth not affect directly on the atmosphere air. A relation of atmosphere parameters variations with the geomagnetic activity is a consequence of its relation with factors of the solar activity including the X-ray and the UV-radiation of solar flares, the solar cosmic rays, and the modulation of a galactic cosmic-ray flux. Therefore it is interest to examine a relation of the pressure fluctuations with the primary factors of the solar activity.

5. Investigation of correlation between surface pressure and cosmic-ray intensity

According to the modern conception, the main canal of the solar activity influence on the Earth’s troposphere is a modulation of the flux of
galactic cosmic rays of high energies which can to penetrate in atmosphere down to the sea level [2]. Investigations of correlations between the atmosphere characteristics and the cosmic-ray intensity can potentially elucidate the mechanism of an interaction of cosmic rays with the Earth’s atmosphere.

We calculated the cross correlation function between the pressure fluctuations and the cosmic-ray intensity. The values of this function are negative and small enough, but mostly are statistically significant. The cross correlation function has two minima: at the zero time delay (apparently, a moment of the Forbush decreases in cosmic-ray intensity) with the value $-0.068 \pm 0.023$, and at the pressure time delay $12^d$ with the value $-0.087 \pm 0.023$. The negative correlation between the pressure and the cosmic-ray intensity is observed at the pressure time delay as long as $17^d$. This result is in a good accordence with the data of Grigor’ev et al. [6], who studied the variation of surface pressure after the Forbush decreases of cosmic-ray intensity at Yakutsk city using the epoch superposition method. These authors have found that the response of the pressure variations to the Forbush decreases has on average duration $13^d$ and amplitude $+2$ hPa, respectively.

The negative correlation between the surface pressure and the cosmic-ray intensity can be explained by the so-called condensation mechanism of an interaction of cosmic rays with the atmosphere air. Cosmic rays can produce hygroscopic clusters in the lower atmosphere through ionization. This must result in a certain increase and decrease in pressure if the cosmic-ray intensity decreases and increases, respectively.

It is interesting that negative correlation between the surface pressure and the cosmic-ray intensity exists also for negative pressure time delays down to $-5^d$. This effect can be connected partly with the finite duration of the Forbush decrease. Another explanation of the forward negative correlation is an influence of a microwave radiation of solar flares. This radiation also can produce the water molecular clusters in the lower layers of the atmosphere [7].

References

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