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Intermittency of turbulent aeroelectric field

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ABSTRACT

On the basis of multifractal formalism with the use of a database of Borok Geophysical Observatory [58°04′ N and 38°14′ E] a complex of energy and fractal indexes of the aeroelectric field dynamics was analyzed. It is shown that in most cases the short-period (frequency band $\Delta f = 0.001$–1 Hz) aeroelectric field pulsations possess the property of self-similarity. However the intermittency of the aeroelectric field is detected inside the time intervals of transitional conditions of the lower atmosphere. Intermittency of the aeroelectric field is characterized by non-Gaussian distributions of the aeroelectric field increments, a set of the power law of a slope index of spectral density in the frequency decade 0.01–0.1 Hz, an extension of the multifractal spectrum and a deviation of the scaling exponent from a linear dependence. In conditions of unsteady stratification the aeroelectric field pulsations are monofractal and arise in consequence of a space charge transfer by locally-isotropic homogeneous turbulence.

1. Introduction

The experimental research of the short-period pulsations of aeroelectric field and current, and space charge density has allowed finding out the turbulent nature of the charged particles' mixing and a space charge transfer in the lower atmosphere. The analysis of interrelation of the energy parameters (indexes of spectrum slope β and structure function of the second order ζ_2) has revealed high degree of self-similarity of the aeroelectric pulsations in the surface layer (Anderson, 1977; Anisimov et al., 1994, 1999, 2002, 2005). Thus the difference between β and ζ_2 is distinct from the corresponding dependences for the local fields because an intensity of the aeroelectric field, being not a local value, is formed by non-uniform distribution of a space charge in a vicinity of the point of observation (Anisimov et al., 2003).

In Kolmogorov's model K41 the turbulent vortexes of each scale fill all the space homogeneously (Kolmogorov, 1941). At the same time the turbulence structure can be non-uniform, and its properties in this case are described by the cascade models (Frisch, 1995). Herewith the local disturbance of homogeneity of turbulence, where the active areas coexist with the passive (quasilaminar) simultaneously, is defined as intermittency. The intermittency is observed in hydrodynamic turbulent flows of neutral mediums and magnetized plasma and serves as the most typical property of the turbulent boundary layers (Budaev et al., 2008, 2011).

The main purpose of the work was to research of the formation of turbulent aeroelectric pulsations, to estimate the self-similarity of dynamics of aeroelectric field, and to elaborate some methods for detection of the time intervals of turbulence and intermittency in the lower atmosphere.

2. Data and methods

The digital data of Borok Geophysical Observatory [58°04′ N; 38°14′ E] were used for analyses (http://geobrk.adm.yar.ru:1352). The electrostatic fluxmeter of the “field mill” type was used as the sensor of th main component and short-period pulsations of the atmospheric electric field. The sensor had been specially designed to perform long-term precision measurements. Simultaneously the meteorological characteristics (temperature, speed and direction of wind, humidity, atmospheric pressure, and light exposure) were observed by means of an ultrasonic meteorological station. The digital registration of a data was carried out with the sampling rate of 10 Hz (Anisimov et al., 2008). Totally the data of 120

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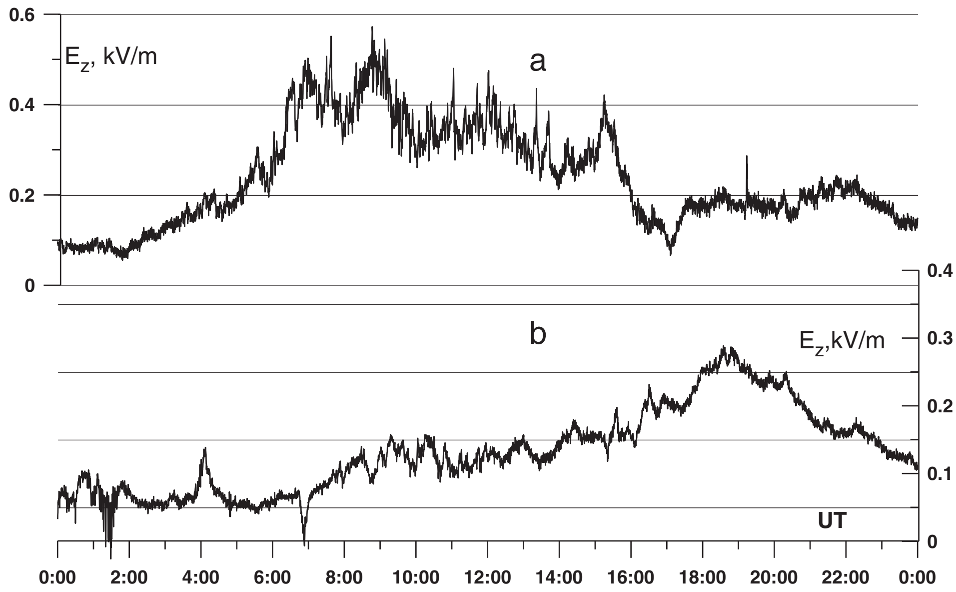

Fig. 1. Daily variations of aeroelectric field at Borok Observatory: a) July 11, 2008; b) February 3, 2012.

continuous daily series have been analyzed from the observation seasons 2007–2011.

The typical examples of daily dynamics of aeroelectric field in the "fair weather" conditions (absence of precipitation, wind speed no more than 2 m/s, cloudiness no more than 5 balls) are presented in Fig. 1. For summer seasons the daily variation of the aeroelectric field (Fig. 1) is connected with a daily trend of the major meteorological parameters. For the period of the developed convection (near local midday — 08:00 UT) the amplitude of short-period aeroelectric pulsations (ΔE_z) is insignificant, and the small-scale components of pulsations are homogeneous. During the winter seasons the daily aeroelectric field variation is manifested more weakly; however, the amplitude of the short-period aeroelectric pulsations is increased and comparable with the amplitude of pulsations in the conditions of high humidity or fog (Anisimov et al., 2005). As a whole, the daily summer trend of the aeroelectric field is defined by the convective generator effect (Morozov, 2006). For the winter seasons the daily trend of the aeroelectric field is conformed to the unitary variation.

For revealing of ΔE_z scaling properties the degree of self-similarity and homogeneity of turbulent aeroelectric pulsations was estimated. For every twenty-minute interval of ΔE_z daily files within scales ($5 < t_2 - t_1 < 200$) seconds, the relation

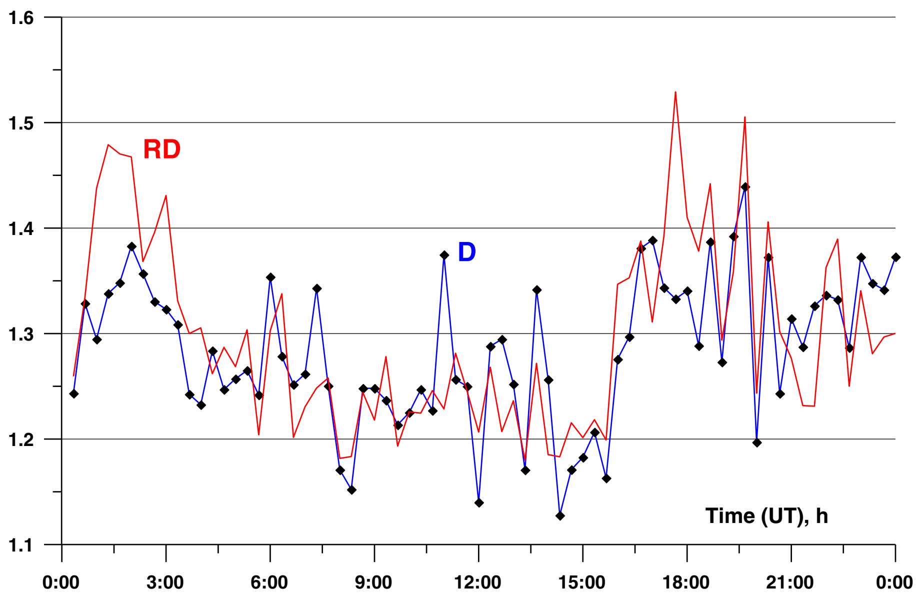

Fig. 2. Dynamics of the regularization dimension (RD) and the fractal dimension (D) of turbulent aeroelectric pulsations on August 9, 2009 at Borok Observatory.