On The Atmospheric Electric Field Fluctuations At The Periods From T=1s To T=100 Days

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ABSTRACT: This paper investigates the background level of atmospheric electric field fluctuations at the periods from T=1s to T=100 days. The data of two electrostatic flux meters (field-mill type) "Boltek-EFM-100", separated by distance of ~6 km and placed on the buildings of the Institute of Applied Physics and the Institute of Microstructures Physics at Nizhny Novgorod, were used for the analysis. Continuous records of electric field values and day average temperatures at the ground surface from June 2012 to March 2013 were analyzed. Correlative and spectral analysis methods and also spectral adaptive analysis method were used for data processing. The measurements of electric field fluctuations in July-August 2013 were made simultaneously with the measurements of the atmospheric turbulence characteristics by the microwave (8 mm wavelength) radiometer.

INTRODUCTION

One of many goals of atmospheric electricity investigations is the search of possible direct influence of solar activity on the global electric circuit (GEC) state. The correlation of GEC characteristics and quasi-periodic or sporadic solar-terrestrial physics factors could be the evidence of that influence. The current absence of such evidences means, that if direct influence of solar activity on GEC exists, it is very small and masked by self-fluctuations of GEC characteristics of troposphere origin.

The atmospheric electric field at the Earth's surface in the ideal good weather conditions is about 100 V/m) due to the potential difference between the Earth and the ionosphere and electrical conductivity of the atmosphere. The daily variation of electric field ~ 20 % , related to the power of the current generator (the number of planetary thunderstorms) during the day . This variation has a global scale and occurs everywhere at the same time , regardless of latitude and longitude. In the real conditions the electric field at the bottom of the atmosphere fluctuates locally and its spatial and temporal characteristics overlap a very wide range of values [Anisimov et.al.,2001]. Long-term periods (t $>10^4 \div 10^5$ s) are not well investigated due to difficulties with the sensors stability over long time intervals.

A possible direct effect of solar activity on the global electric circuit (GEC) is the one of the atmospheric electricity research activity . The possible correlation between characteristics of GEC and quasiperiodic or sporadic factors of solar-terrestrial physics, such as solar flares (~ 1 hour), Forbush decrease of GCR (~ 1 day), sector structure of the interplanetary magnetic field (~ 27 days) could provide a

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proof of this suggestion.

This paper is devoted to the investigations of the background level of atmospheric electric field fluctuations at very large periods (T>>1 day) and detection of the cycled relations of solar activity and GEC. The data of two electrostatic flux meters (field-mill type) “Boltek-EFM-100”, separated by distance of ~6 km and placed on the buildings of the Institute of applied physics and the Institute of microstructures physics at Nizhniy Novgorod, were used for the analysis. Continuous data records of electric field values and day average temperatures at the ground surface from June 2012 to March 2013 were analyzed. Correlative and spectral analysis methods and also spectral adaptive analysis method were used for the data processing.

MEASUREMENTS

We have measured the brightness temperature $T_я$ of convective and thunderstorm clouds. The calculated spectral density of the brightness temperature fluctuations of thunderstorm clouds in the band of frequency ~ 0.01 Hz were abnormally high compared to usual clouds. $T_я$ measurements were performed using an 8 mm radiometer. Radiometer was designed and manufactured in the IAP RAS scheme modulation radiometer direct amplification. Electric field of the thunderclouds (*E*) was measured at the Earth's surface simultaneously. Electric field measurements were performed using multiple electrostatic fluxmeter Boltek-EFM-100 (type "field mill") with the scale ± 80 kV / m, established at the Institute of Applied Physics RAS (height ~ 35 m). Also, the data of weather radar and the upper-air sounding were used.

The measurement series $T_я$ and *E* were performed for 14 days in July-August 2013. The duration of a series of continuous recording was 7-8 hours daytime. During the observation period there were 9 days of fair weather and 5 days with a strong convective clouds and associated strong perturbations of the electric field . In 2 cases, the storm clouds were accompanied by intense rainfall that has complicated the analysis of . $T_я$ measurements. These series have not been analyzed . All data were averaged over the interval 1 s due to the radiometer time constant.

The relative variations of the electric field *E* and temperature T(°K) δE=E/E_{av} and $\delta T=(T-T_{av})/T_{av}$ are presented on Figure 1, where E_{av} and T_{av} - average values for all the observations. In general, electric field sensors were consistently to temperature changes throughout the entire period. At the same time the graphics on Figure 1 clearly show the positive correlation between *E* and *T* in the summer months and negative in winter . We suggested the following simple explanation: the high summer temperatures and low winter correspond clear cloudless weather and during these periods the electric field has a higher value.

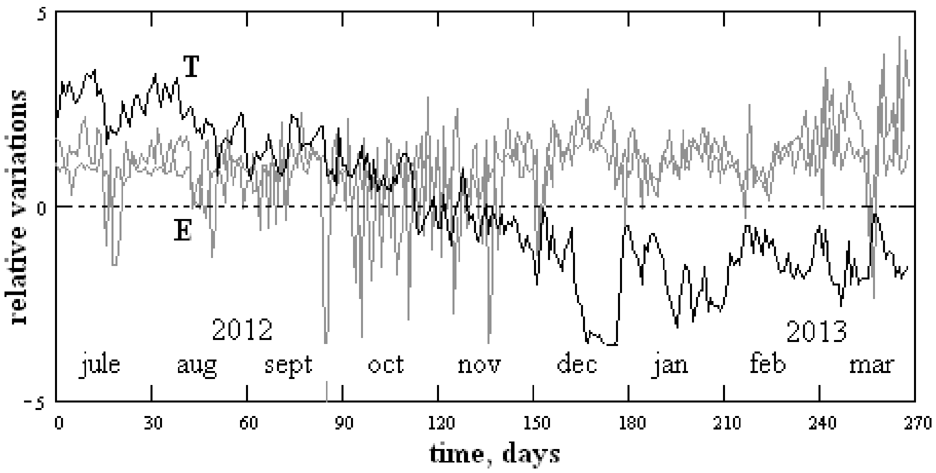

Figure 1. Relative variations of average values per night electric field (E) and temperature (T) in the period from 01.07.2012 till 31.03.2013.

Examples of simultaneous recording of the brightness temperature of clouds and their perturbations caused by the electric field are shown in Figure 2. Impulse noise in the graph E (Fig. 2-a) due to the large amount of electrical discharges (lightning).

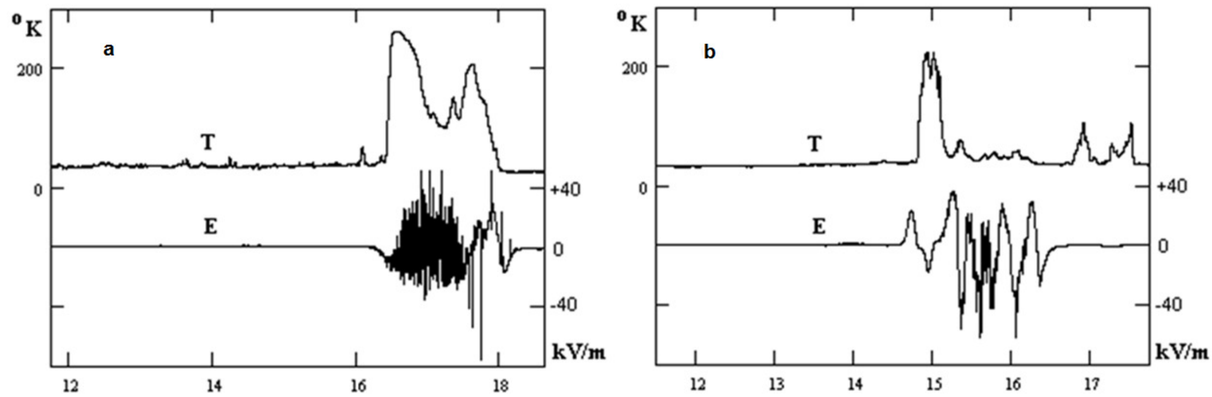

Figure 2. Variations of clouds brightness temperature and the surface electric field the due to clouds electric charges 16.07.2013 (a) and 15.08.2013 (b).

DATA ANALYSIS

The analysis was based on the calculation of the spectral density function and temporal structural fluctuations of $T_я$ involving integral transform [Rytov et al., 1978]. Spectral densities were calculated for a sample length of 2^{15} seconds (~ 9 h), which is slightly greater than the length of the measurement series. Missing values were filled with zeros.

The spectral density of $T_я$ fluctuations for 8 days with good weather and normal clouds is shown on Figure.3 (a). The lower curve (thick line) corresponds to the reference clear day from 11.08.2013. One can see that the fluctuation spectrum $T_я$ consists of 2 components: high-frequency part (f> 0.01 Hz), obviously due to the turbulence of air containing water vapor in the surface layers atmosphere, and the low-frequency part (f <0.01 Hz), associated with the turbulence of the condensed phase in the atmosphere situated above the level of condensation (~ 1 km). The low frequency part of the spectrum is subject to the most significant changes depending on the nature of the weather.

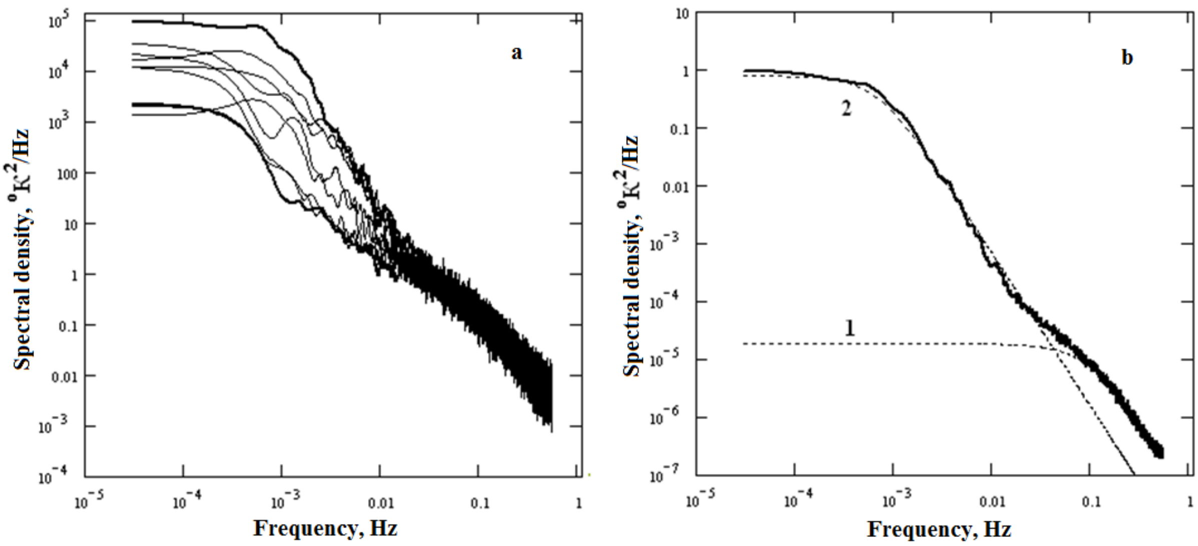

Figure 3. Fluctuation spectra of brightness temperature during periods of good weather and the usual cloud cover (a) and averaged normalized fluctuation spectrum for a typical cloud (b); dotted line - approximation based on Kolmogorov turbulence model: : 1 - $k_0V \approx 0.575$ c^{-1} and 2- $k_0V \approx 4.2{\cdot}10^{-3}$ c^{-1}.

Averaged curve is shown in Figure 3-b. The spatial spectrum of the turbulent density fluctuations in the Kolmogorov turbulence mode is described by [Rytov et al., 1978]:

$$F(k) \sim \left(k_0^2 + k^2\right)^{-11/6} \qquad (1)$$

where k_0- wave number corresponding to the turbulence outer scale of turbulenc. Neglecting radiation pattern width of the radiometer the spectral density frequency dependence of fluctuations can be obtained in the form:

$$G_T(\omega) \sim \left(k_0^2V^2 + \omega^2\right)^{-4/3} \qquad (2)$$

where V - transverse to the RP wind speed demolition. In the so-called inertial range at $\omega >> k_0V$ we have

$$G_T(\omega) \sim \omega^{-8/3}. \quad (3)$$

On the Figure 3-b a dotted line approximation in the framework of this model is shown. The experimental spectral density is $(k_0V)_{LF} \approx 4.2{\cdot}10^{-3}$ s^{-1} и $(k_0V)_{HF} \approx 0.575$ s^{-1} for low frequency (LF) and high frequency (HF) parts of the spectrum respectively. Amount thus calculated LF and HF parts of the spectrum with the corresponding normalization coefficient almost exactly coincides with the experimental curve (not shown on Figure 3-b).

The spectra of fluctuations $T_я$ of normal cloud and the spectral density of fluctuations for 2 electrically active clouds are presented Figure 4-a. The electrically active and thunderclouds $T_я$ fluctuation spectrum is broadened towards the higher frequencies . The ratio of the spectral densities of fluctuations $T_я$ for thunderclouds and ordinary clouds, is shown in Figure 4-b. It clearly shows an anomalous enhancement of fluctuations in periods of ~ 2 min. Assuming the wind velocity at altitudes demolition of ~ 1 km (from upper-air sounding data) $V \approx 5$ m/s we obtained that it corresponds to a spatial scale of inhomogeneities about 0.6 km .

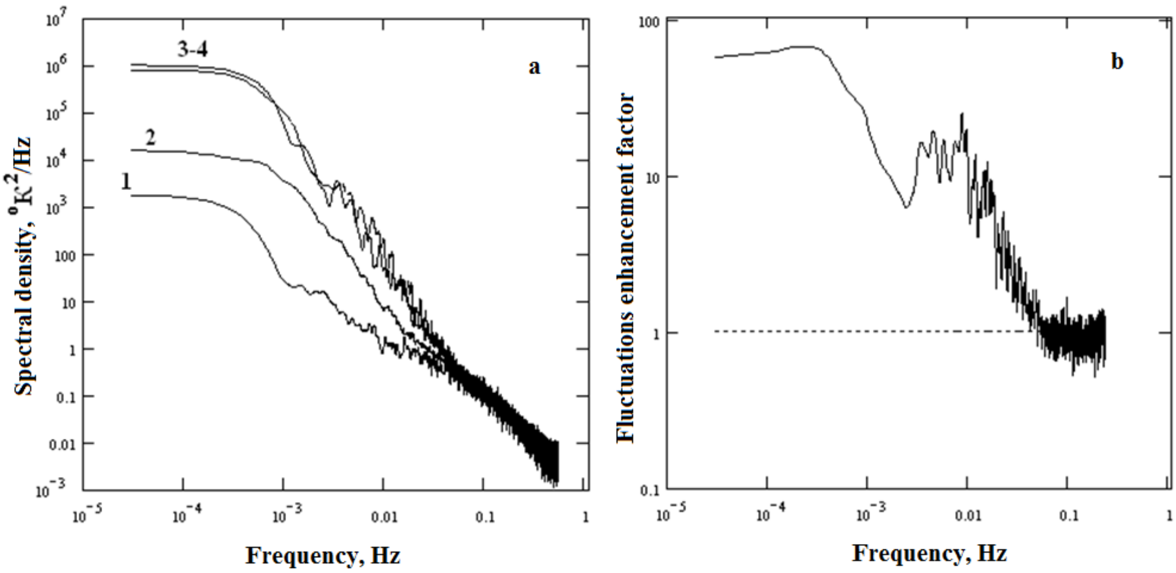

Figure 4. Fluctuation spectra of the brightness temperature of clouds of different type (s): 1 - reference range on a clear day, the 11.08.2013, 2 - average spectrum of normal cloud (see Figure 3-b), 3-4 - spectra of electrically active clouds 17.07.2013 and 15.08.2013, the city, as well as the enhancement factor of the spectral density of fluctuations of the brightness temperature of the electrically active clouds in relation to the usual cloud cover (b).

The overall the spectral density of δE and δT fluctuations during the very long periods is shown of Figure 5. We use the direct FFT with a rectangular time window length 2t = 269 days (the entire period of observation) . This leads to a smoothing and averaging the spectral density function $g(\omega)=\sin(\omega t)/\omega t$. The approximation of spectra gives% $E_\omega^2 \sim \omega^{-0.511}$ and $T_\omega^2 \sim \omega^{-1.427}$. For the short period (February 2013) the spectral density we obtained that in periods of ~ 24 hours changes the slope of the spectrum in the direction of increasing the spectral index.

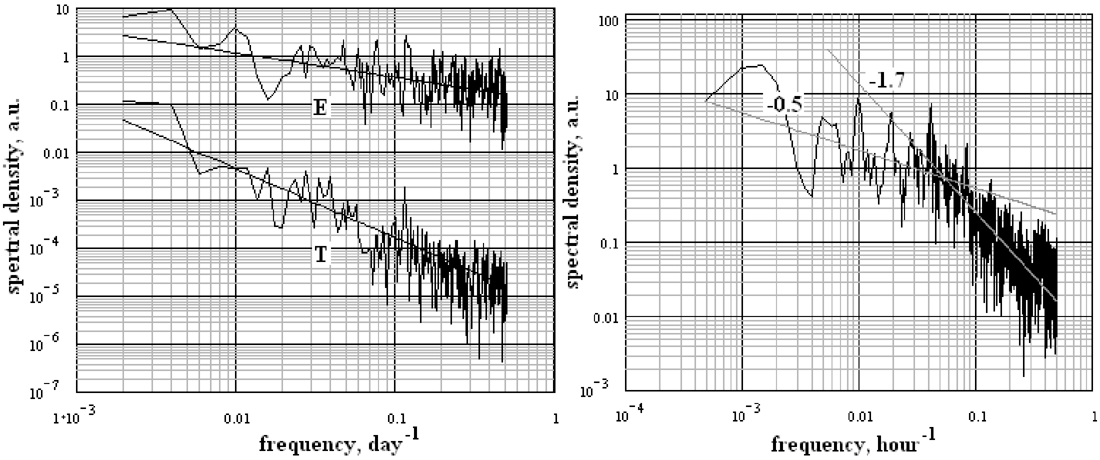

Figure 5. Spectral density of fluctuations of average per day values of the electric field (E) and temperature (T) in the range of 31.03.2013÷ 1.07.2012, the (left) and average hourly values of the electric field in the range of 01/02/2013 29.02÷ 2013 .

For periods $t > 1$ day the spectral density dependency on the frequency significantly weaker than for short-period fluctuations of the spectra *E*, where $n \approx 2.7$ [Anisimov et.al.,2001]. It is obviously connected with the changing nature of atmospheric turbulence and laws redistribution of electric charges in the troposphere in the time domain.

The structure time function is an informative characteristic of describe the atmospheric turbulence is [Rytov, 1976] :

$$D_X(\tau) = \left\langle \left| X(t+\tau) - X(t) \right|^2 \right\rangle, \qquad (4)$$

where the angle brackets denote averaging, *X* - the parameter of investigation. Figure 6 shows the calculated structure functions for normalized *E* and *T*. The average squared difference of temperature in spaced times growing up to intervals of ~ 0.5 years , which is explained by seasonal course of *T*. For the electric field structure function is almost saturated at intervals of <1 day. A similar saturation effect of the structure function for the electrical path length of radio waves in the atmosphere cm/dm - also on intervals range ~ 10^4-10^5 s should be noticed [Esepkina et.al., 1973]. Apparently, the statistical characteristics of the electric field fluctuations reflect the properties of atmospheric turbulence not only in short periods (and local spatial patterns) [Anisimov et.al., 2001] , but in periods of more than one day (and spatial scales greater than 100 km) .

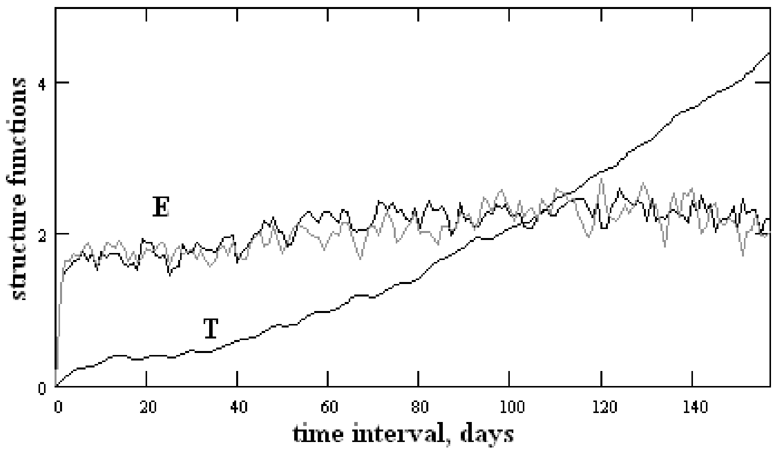

Figure 6. Temporary structure functions $D(\tau)$ of normalized values of the electric field (E) and temperature (T) in the period from 07.01.2012 till 31.03.2013.

CONCLUSIONS

Spectral density of brightness temperature fluctuations consists of RF components in periods of good weather due to the turbulence of the air mass in the atmospheric boundary layer and LF components associated with turbulent motions in droplet clouds at a height of ~ 1 km. The frequency dependence of the two components is consistent with the Kolmogorov spectrum of turbulence.

The spectral density of $T_я$ fluctuations of thunderclouds can be located in a limited band around f ~ 0.01 Hz with a higher level of fluctuations.

Taking into account the data of the microwave radiometer, two turbulent layers, affecting the electric field fluctuations at the ground surface, have been identified: 1) the near-surface layer (0-300 m) with turbulent inhomogeneities of heavy ions (aeroelectric structures) and 2) the upper layer over the condensation level (~1 km), with turbulent inhomogeneities of electrically charged droplets. Contribution of these layers, including the cases of thunderstorm occurrence, into the electric field fluctuations at the ground surface and statistical signatures of fluctuations were investigated.

At the sufficiently large periods 1-100 days the spectral density of electric field fluctuations may be described by the power law with index -0.5; the root-mean-square deviation (in the large frequency band) is ~40% from the average E-field value. A smooth frequency dependence of field fluctuations spectral density is analogous to the frequency dependence of atmospheric turbulence spectral density, for which the respective structure function reaches saturation at these time intervals.

Strong direct correlation between flux meters data and temperature were not obtained. Spectral density of temperature fluctuations falls down by power law with index -1.7 (~5/3), i.e. more quickly, than for electric field fluctuations. At the same time, in some narrow bands the quasi-periodic correlated disturbances of E and T exist, which are evidently related to characteristic times of air mass transportation and which independently affect on the both parameters analyzed.

ACKNOWLEDGMENTS

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