Dynamics of the atmospheric surface layer electricity

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ABSTRACT: Summer field ground-based campaign of aeroelectrical remote sensing observations realized in 2011-2013 years on the observation ground of Geophysical observatory "Borok" [$58^0 04'$ N and $38^0 14'$ E]. Observations were carried out in clean conditions with a low level of human-made electromagnetic disturbances and absense of industrial pollutions. Variations of electric field intensity, vertical electric current, polar atmospheric electric conductivities (formed by positive and negative atmospheric light ions), radon and thoron emanations were measured with the help of our experimental setup. Aeroelectric observations were couplied with precission meteorological measurements in the lowest part of atmospheric layer over flat ground. The main goals of provided observations were investigations of free atmosphere electrical dynamics and forming of turbulent aeroelectrical structures research.

INTRODUCTION

It is generally assumed that quasi-stationary state of the global electric circuit atmospheric region specified by permanent activity of thunderstorm generators, wich make potential difference between electrodes of concentric-spheric capacitor founded by conductive layers of lower ionosphere, ocean upper layer and Earth's crust. Electrical state of the atmosphere depends of ionosphere potential, atmospheric column resistance, vertical electric current density, electric field strength, polar electric conductivities of air, thunderstorm electrical energy lifetime and vertical profiles of these electrical quantities.[Anisimov et al, 2008; Chalmers, 1974; Anisimov, 2003; Mareev et al, 2009; Roble et al, 1986; Williams, 2009; Anisimov et al, 2014b].The sum of atmospheric electrodynamical processes includes electrical interaction both global and regional current systems, concentrated in near-ground atmospheric layer, planetary boundary layer, troposphere, middle atmosphere and different regions of ionosphere and magnetosphere [Anisimov et al, 2008]. Electrodynamics of middle latitude near-ground atmosphere forms as a sum of electrical charges separation, generation and transport physical processes in wide space-time scales range.

The goal of this work aims at dynamics of electrical field and electrical conductivity of near-ground atmosphere investigation in wide time range, including turbulent aeroelectric pulsations, self-similarity characteristics and intermittency. Research base was founded by long-term amplitude-time series, wich were given as a result of high time resolution permanent stationary and field ground-based middle latitude aeroelectrical observations.

EXPERIMENTAL SETUP AND FILED GROUND-BASED OBSERVATIONS

Precision and reliable measurement of lower atmosphere electrical quantities are necessary basis of Earth electrical environment investigations. Borok Geophysical Observatory has implemented stationary observations of air electricity since 1985. Observatory investigations aimed at solving classical tasks of atmospheric electricity (such as investigations of annual, seasonal and diurnal variations) and development of new directions connected with investigation

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of global electric circuit, interactions of geospheric shells, aeroelectrical pulsations dynamics and geomagnetic field pulsations structures.

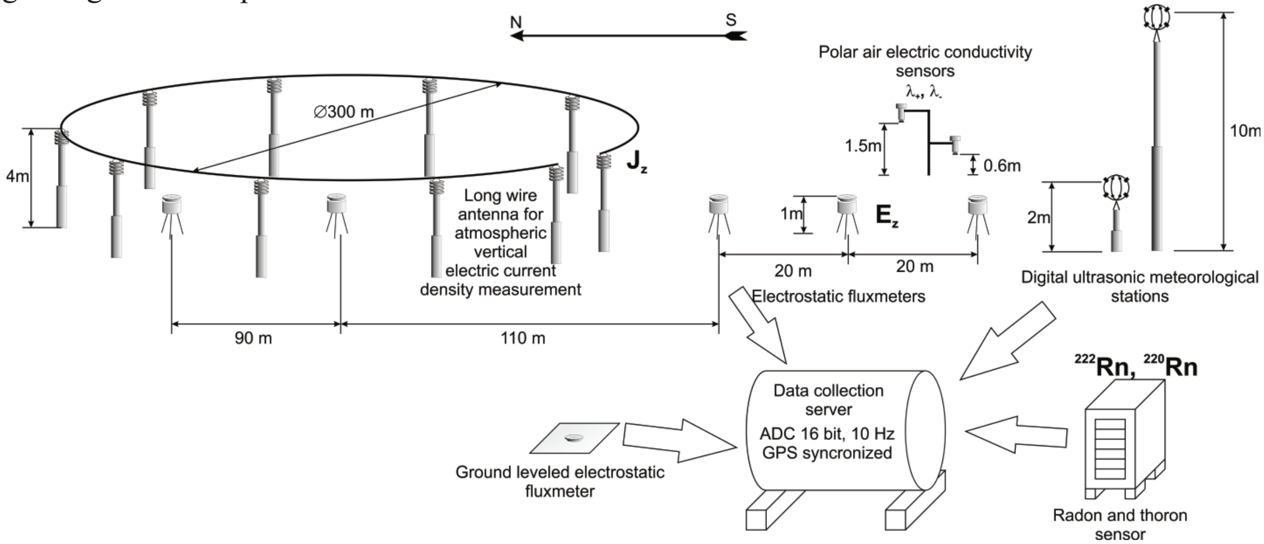

Figure 1. Experimental setup layout

Figure 1 shows the layout of experimental setup of summer seasonal observations of year 2013. Electrodynamical conditions of atmospheric surface layer were investigated by syncronous remote sensing of air electical field strength variations using electrostatic fluxmeters ("field mill"). Measurements were provided at experimental ground of Borok Geophysical Observatory IPE RAS (58°04'N; 38°14'E).

Five electric field strength sensors (electrostatic fluxmeter) were installed along a line south-north according to scheme at 1m height.One electrostatic fluxmeter was installed at a ground level for reduction ratio determination, wich was necessary to translate values of electric field strength measured at 1m height to equivalent values at the ground level. Vertical atmospheric electric current density was measured using a long-wire antenna (a current collector). The current collector represents a conductive ring of 300m in diameter mounted at insulators. Sensitivity of that current collector was not less than 0.1 pA/m^2. For the measurement of positive and negative electric air conductivities bipolar air conductivity sensors based on gerdien tube were used. Sensitivity of these sensors was not less than 0.1 fS/m, and air ion mobility range was more than 1.6 $cm^2/V{\cdot}s$. Field full-scale observations data were registered by the information collection system with 10 samples per second digitization rate.

Altitude profiles of wind velocity and direction were registered using an acoustic dopler locator (SODAR) "VOLNA-3" from 60m to 800m height and 5m resolution. The acoustic dopler locator works permanently in the stationary measurement complex of the observatory (Figure 2). Meteorological observations were realized using two digital ultrasonic meteorological units "METEO-2H" installed on heights 2m and 10m above a ground surface. Meteorological units provide true data with 10 samples per second rate. Measurement of solar irradiance in wavelength interval from 300nm to 2800nm the Kipp&Zonen CMP3 pyranometer was used. Sensitivity of the pyranometer is 5-20 $\mu V/(W/m^2)$ and measurement range is 0-2000 W/m^2. Monitoring of radon (^{222}Rn) and thoron (^{220}Rn) volume activity was realized using seismic radon station "SRS-05". Sensitivity of the radon station is not less than $0.5{\cdot}10^{-4}$ $Bq{\cdot}s^{-1}{\cdot}m^{-3}$. Measurement range is $20\text{-}5{\cdot}10^4$ Bq/m^3. Averaging time is 30 minutes.

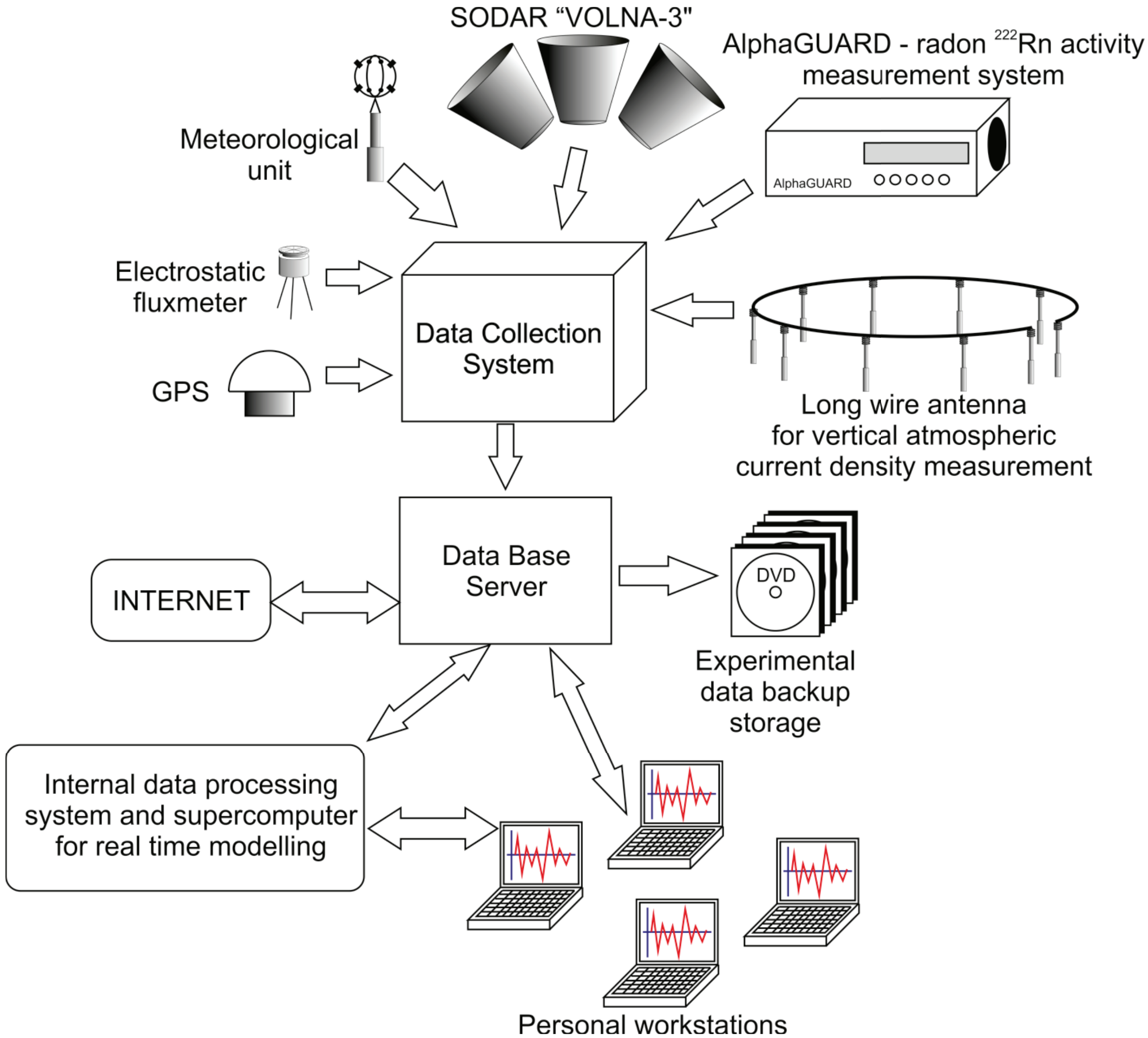

Figure 2. Scheme of the stationary permanent atmospheric electricity observation system

Figure 2 shows the scheme of the stationary permanent atmospheric electricity observation system in Borok Geophysical Observatory. The stationary observation system hardware includes an electrostatic fluxmeter, a long-wire antenna for vertical atmospheric current density measurement, the acoustic dopler locator “VOLNA-3”, the radon (^{222}Rn) monitoring system AlphaGUARD, digital ultrasonic and classical meteorological units. Meteorological units provide registration of air temperature, air humidity,atmospheric pressure, wind velocity and its direction. All the information is stored in digital form by a data collection system. The data collection system was built using precision ADCs with 16 bit and 10Hz resolution. Digital data are transmitted to the data base server, wherein automatically sorted and subjected to initial treatment for publishing on the Internet. Periodically data are stored in DVD disks as a backup. The data base server works interconnected with supercomputer, wich is using for real time modelling of aeroelectrical processes.

EXPERIMENTALDATAPROCESSINGANDANALYSISRESULTS

Figure 3 shows an example of experimental data variations from a field ground-based measurement complex.

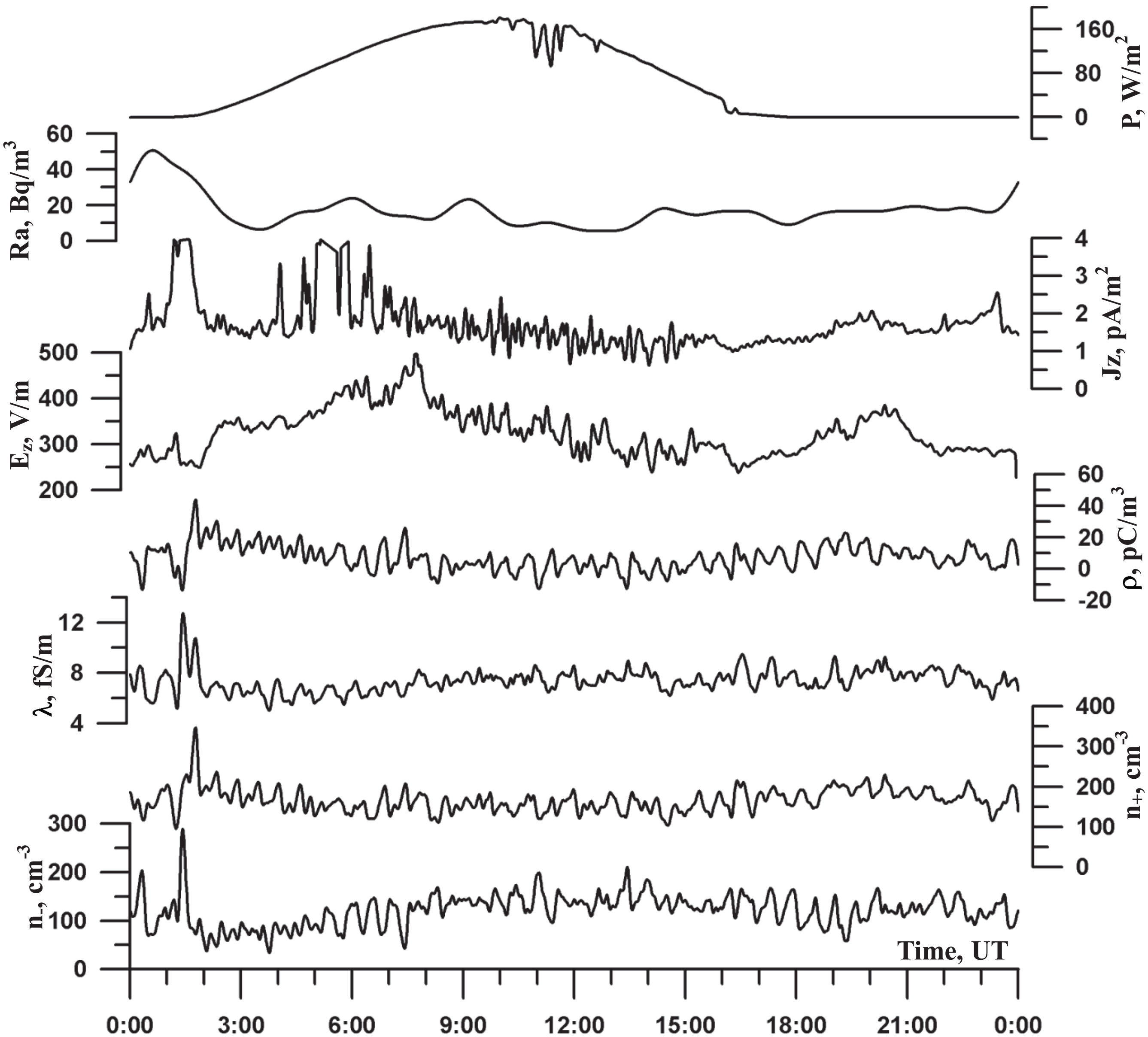

Figure 3. Variationsof light ion concentrations (n_+, n_-), air electrical conductivity (λ), space charge density (ρ), electrical field strength (E_z), vertical air electrical current density (J_z), radon ^{222}Rn activity (Ra) and solar irradiance (P). (30.07.2012). All data averaged by 30 sec.

The figure contains plots of light ion concentration, electrical air conductivity, space charge at light ions, electrical field strength, vertical electrical current density, volume radon activity and solar irradiation variations.

Figure 4 contains diurnal variations plots of space charge density concentrated on light ions for summer and winter time. Data averaged by one hour. It is shown that there is an expressed maximum at 04:00UT in space charge variations for summer time case. This time corresponds to the intensive ground surface warming by solar radiation. Average daily value of space charge density is 15 (±10) pC/m^3. At winter time ground surface was shielded by snow. In the particular case the thickness of snow cover was 50 cm.

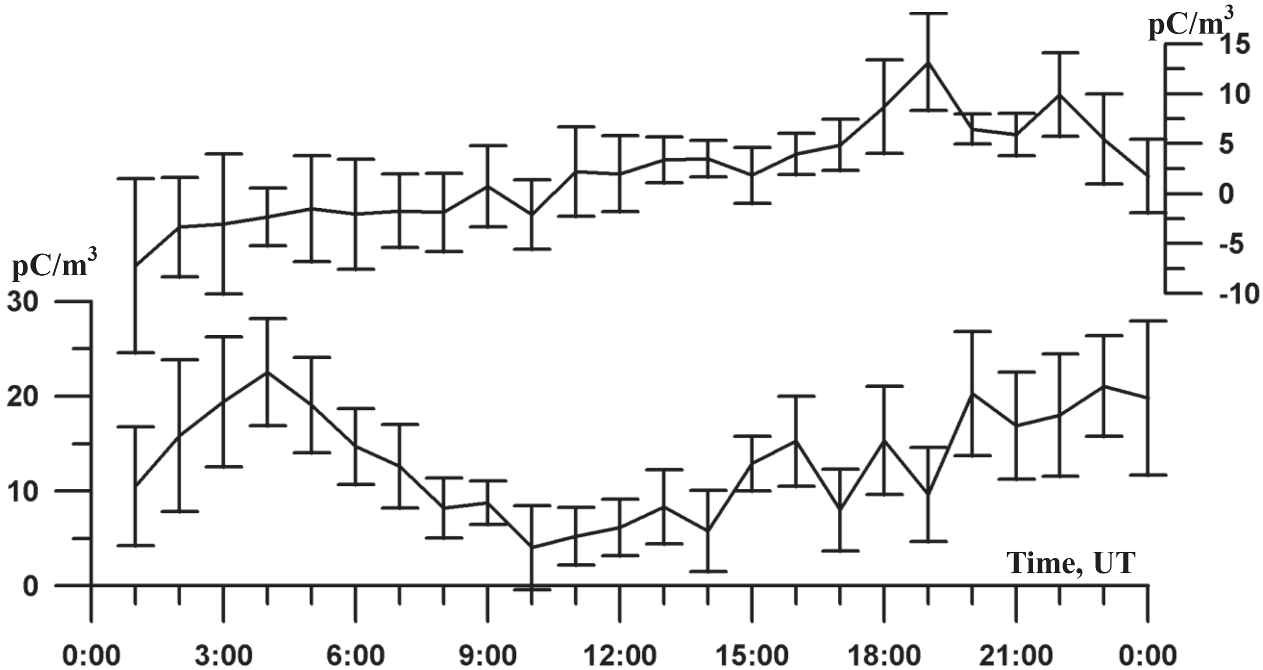

Figure 4. Daily varitations of space charge density for winter (top plot) and summer time (bottom plot) on 5,6,12,14,15,17 of December 2013 and 09,17-20,28,30 of August 2013 at Borok Observatory

A snow cover blocks radon transmission in the atmosphere and its effect to the ionization of surface atmospheric layer is greatly reduced. Average daily value of space charge density for winter time is 2 (± 10) pC/m^3.

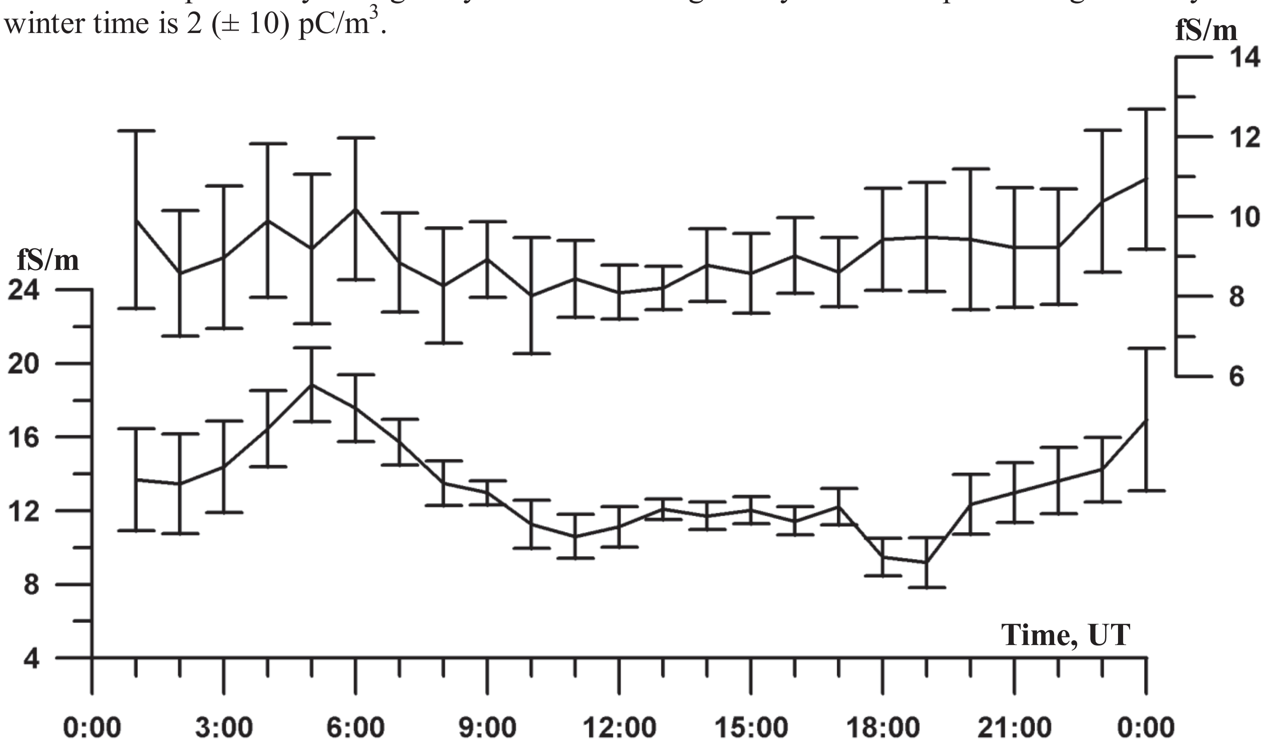

Figure 5. Daily variations of air electrical conductivity for winter (top polt) and summer time (bottom plot) on 5,6,12,14,15,17 of December 2013 and 09,17-20,28,30 of August 2013 at Borok Observatory

Figure 5 pesents diurnal variations of atmospheric surface layer electrical conductivity according to data of summer and winter seasons. It is an expressed maximum at 05:00UT in air electric conductivity variations for summer time, wich is also associated with intensive ground surfase heating by the sun. There are no expressed maximums in the diurnal variations of winter time air electric conductivity. Average daily value of air electric conductivity for summer time is 14 (±6) fS/m, and for winter time is 9 (±1.5) fS/m.

Figure 6 shows diurnal variations of atmospheric surface layer polar electric conductivities according to data of summer and winter seasons.

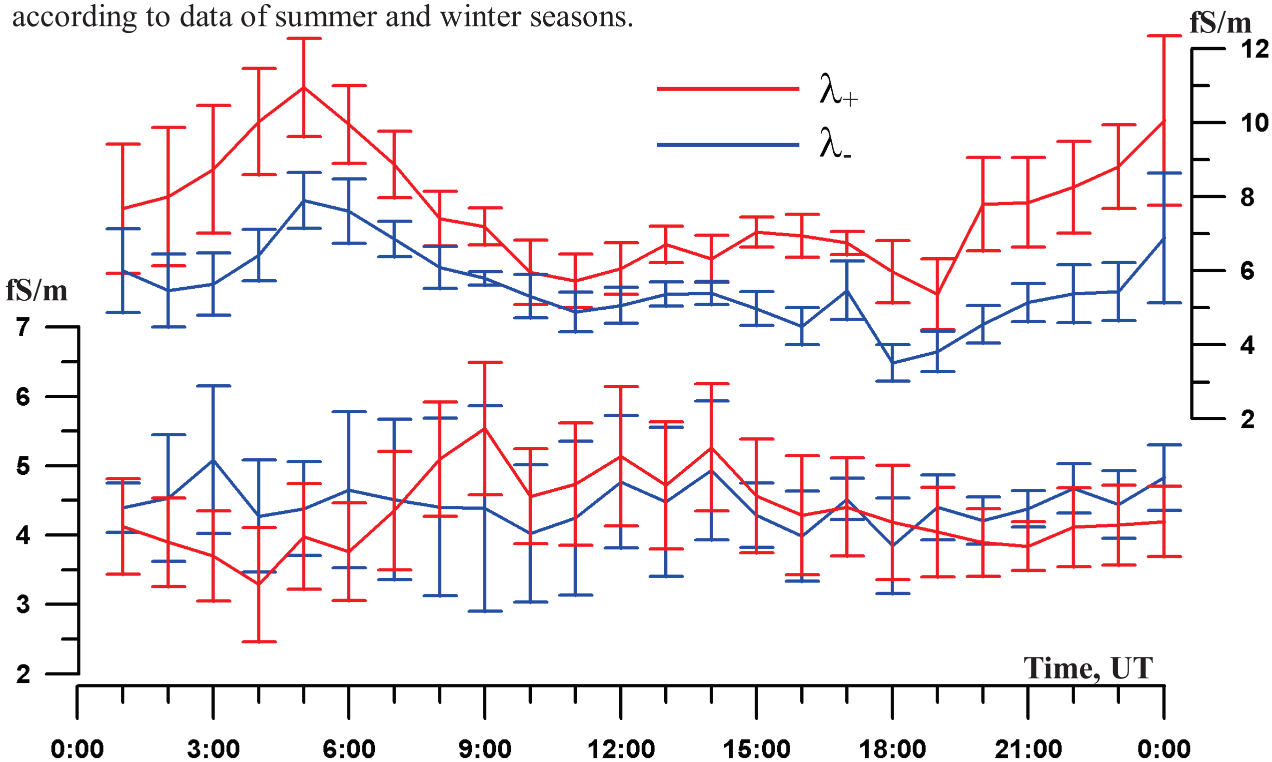

Figure 6. Diurnal variations of polar air electric conductivities for summer (top plot) and winter (bottom plot) time on 5,6,12,14,15,17 of December 2013 and 09,17-20,28,30 of August 2013 at Borok Observatory

Decay of radioactive gases from the blowes of the earth is the main factor of atmospheric surface layer ionization [Smirnov, 1992]. Radon (^{222}Rn) and thoron (^{220}Rn) emanations are major factors of atmospheric surface layer ionization. Variations of radon volume activity near ground surface show significant correlation with air electrical conductivity at 0.6m height. Correlation quotient between ^{222}Rn volume activity and λ on average is 0.6 for time averaging of 30 minutes. For time averaging of 3 hours mean value of correlation quotient is 0.9.

Figure 7 presents diurnal variations of air electric conductivity (λ) and radon volume activity (^{222}Rn) according to data from 09, 17-20, 28, 30 of August 2013. There was a maximum value of ^{222}Rn volume activity at night time, and minimum during day time.

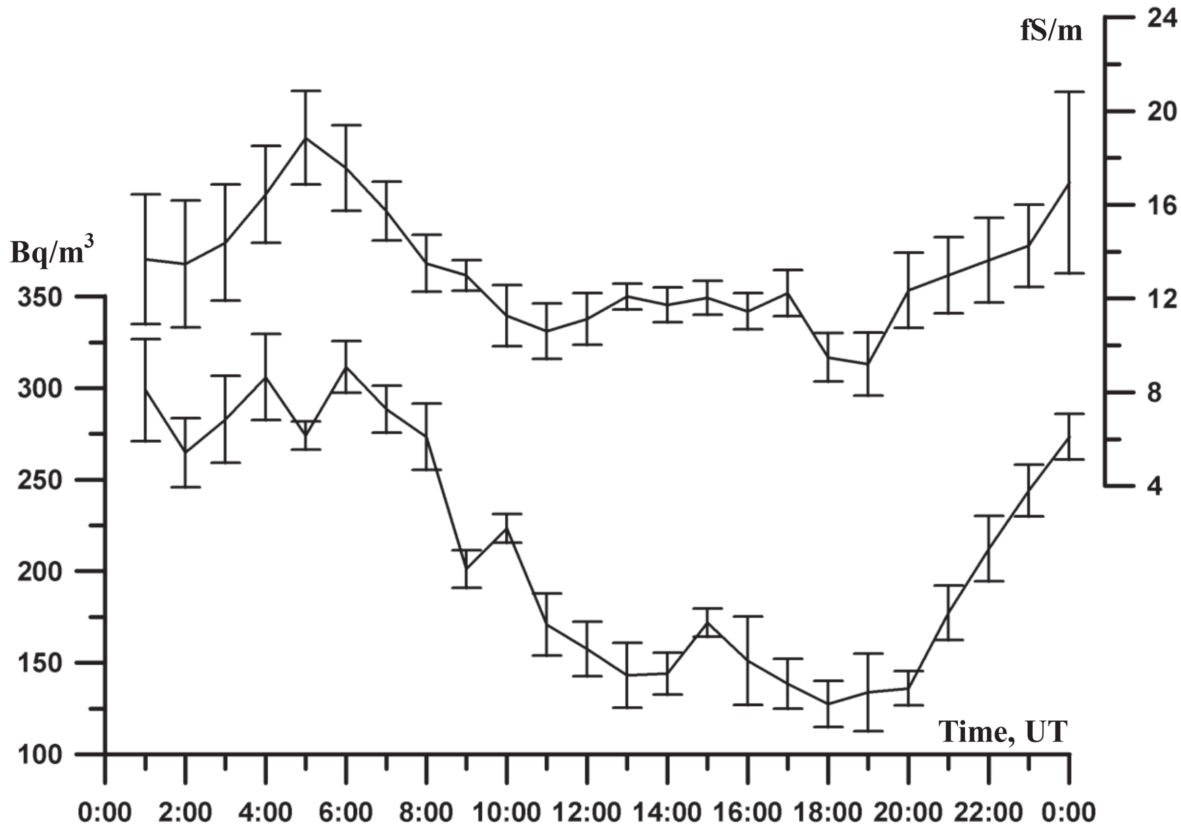

Figure 7. Diurnalvariationsof ^{222}Rn activity (bottom plot) and electric air conductivity (top plot) on 09,17-20,28,30 of August 2013 at Borok Observatory

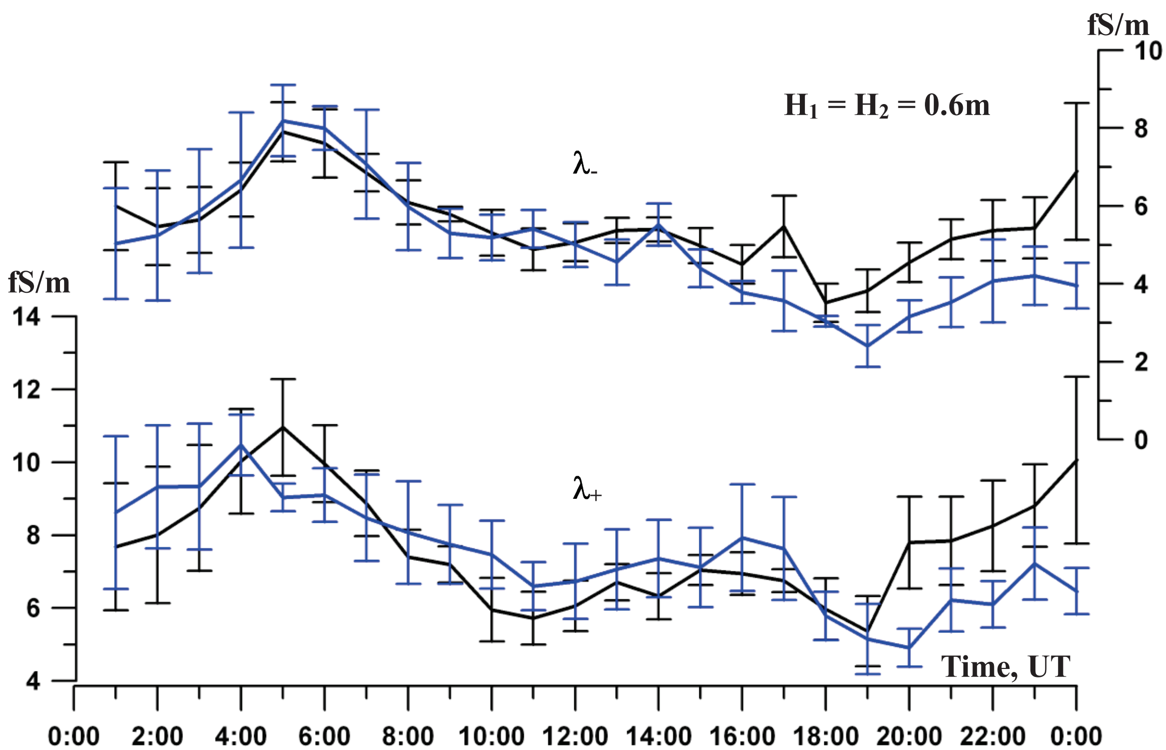

Figure 8. Diurnal variations of polar electric air conductivities at 0.6m height above the ground surface on 09,17-20,28,30 of August 2013 at Borok Observatory

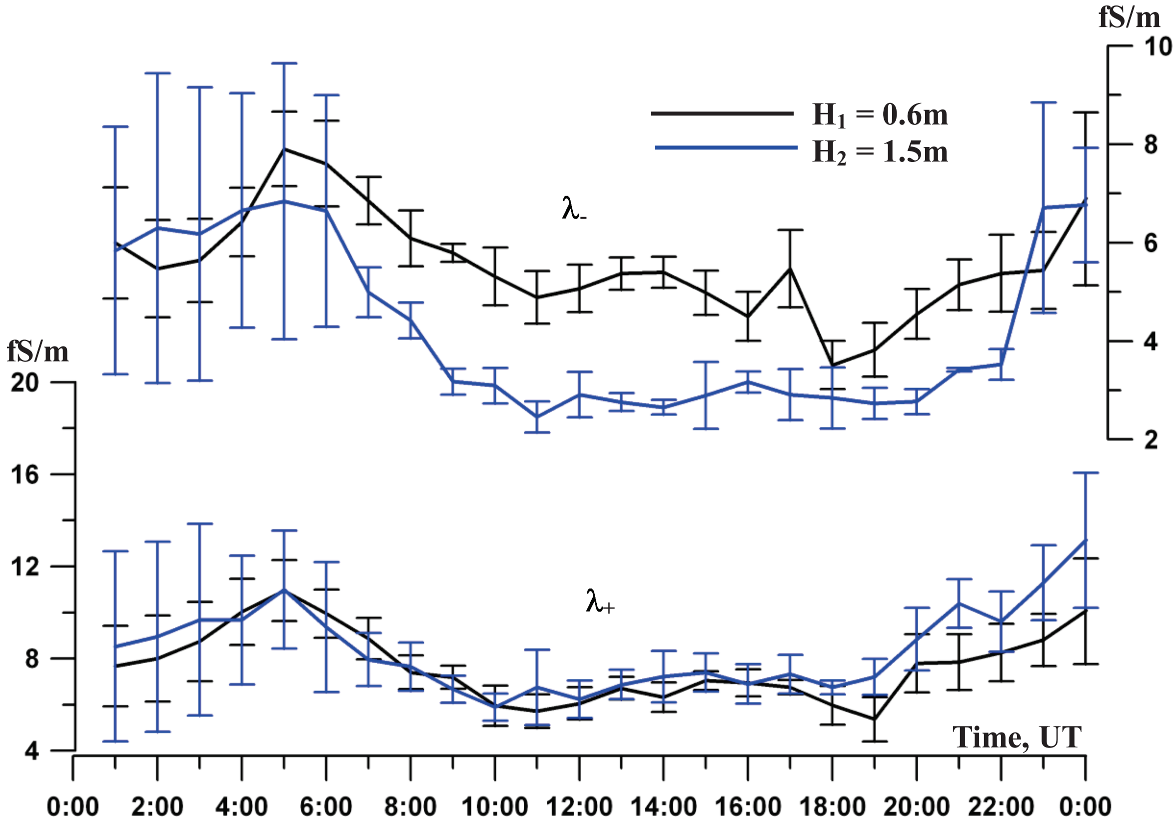

Figure 9. Diurnal variations of polar electric air conductivities at 0.6m (black plot) and 1.5m (blue plot) heights above the ground surface on 09,17-20,28,30 of August 2013 at Borok Observatory

During summer field ground-based observations of year 2013 synchronous measurements of polar air electric conductivities variations at heights 0.6m and 1.5m above the ground surface were provided. Initially both of the sensors were placed at 0.6m above the ground surface and at a distance of 1m from each other. Figure 8 shows diurnal variations of polar air electric conductivities registered by the sensors wich were installed at 0.6m height. Correlation quotient between data froms sensors is 0.96. At the next stage, one of the sensors has been raised to a height 1.5m, and the second sensor was at height 0.6m. Figure 9 presents diurnal variations of polar air electric conductivities at heights 0.6m and 1.5m. It is shown that air electric conductivities at night time at such heights have about absolute values, however at day time negative air electric conductivity at height 1.5m is two times less, than the same air conductivity at height 0.6m.Presumably this is due to the influence of turbulent convection and activity arising from the ground and atmosphere warming by the sun, such situation is typical only for periods of fair weather conditions.

Figure 10 shows forming of aeroelectrical structures in space charge density concentrated at light ions and electric field strength[Anisimov et al, 2014a].

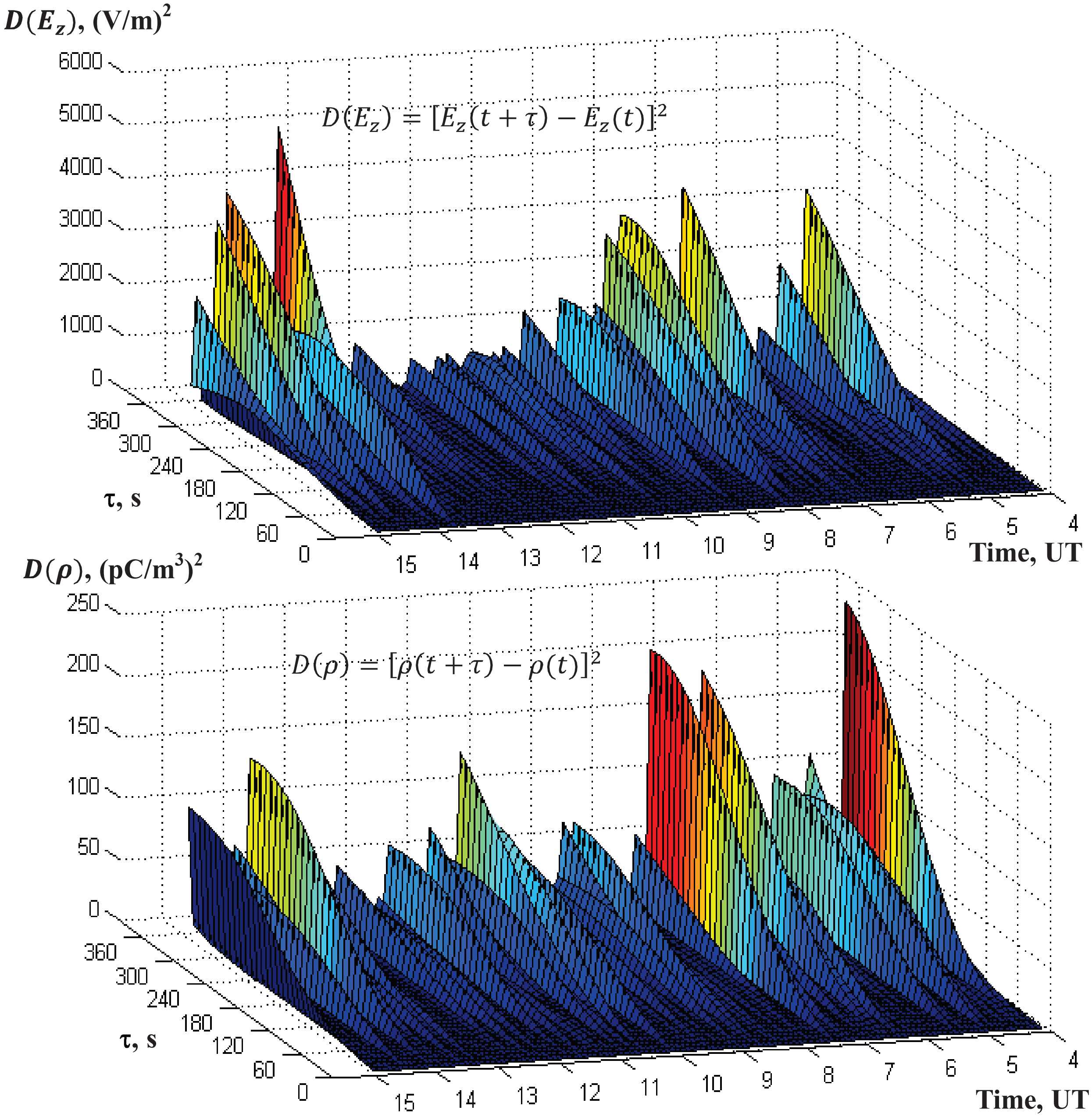

Figure 10. Structures inelectrical field strength (top plot) and space charge density (bottom plot) on 28.07.2012 at Borok Observatory.

Figure 11 shows variations spectral density of space charge, concentrated at light ions. Time interval at 24 hours with 1 second meaning was choosen for calculation. It is shown that space charge density spectra is self-similar. The power of spectra decay is close to (-1.6).

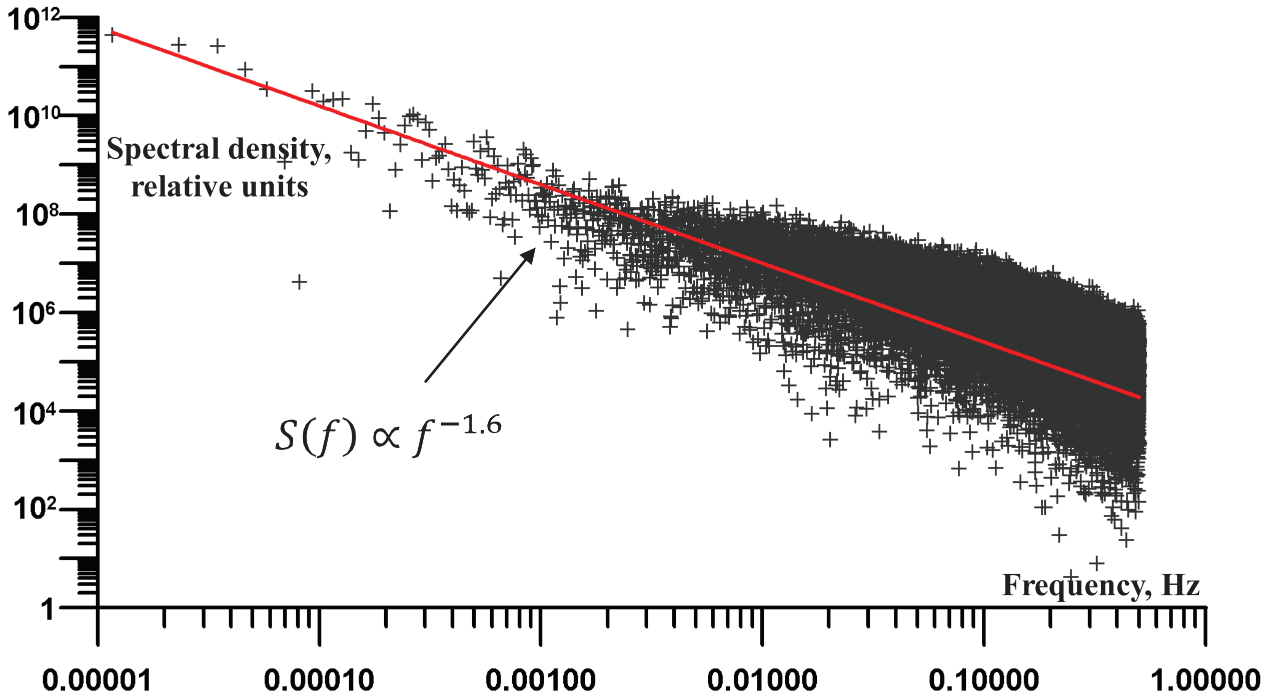

Figure 11. Spectral density of space charge variations on 09.08.2013 at Borok Observatory.

Spectral density of space charge variations is presented at Figure 12. The power of spectra decay for period from 10 to 500 seconds are close to -5/3. The power of spectra decay for period from 2 to 10 seconds is different at day and night conditions. At daytime power of spectra decay for this period is mostly close to -5/3. But at nighttime power of spectra decay varies from -1.9 to -3.1.

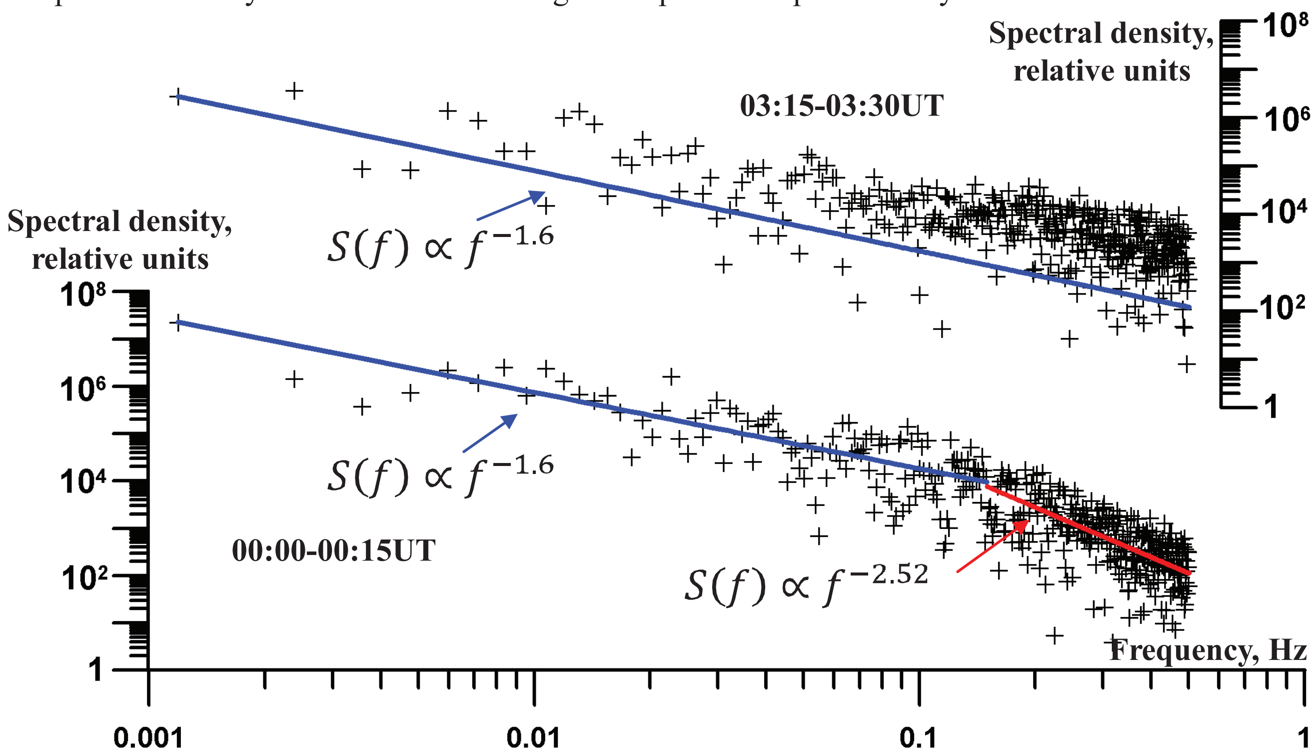

Figure 12. Spectral density of space charge for day and night on 03.08.2012 at Borok Observatory.

CONCLUSIONS

Thus, the results of statistical processing of amplitude-time series obtained during ground aeroelectric observations of 2011-2013 years (performed at midlatitude Borok observatory and included observations of electrical field strength, light ion concentration and atmospheric surface layer electrical conductivity) suggest that:

- Light ion concentration changes during the day. At night time when turbulence is suppressed by stable stratification light ion concentration mainly more than at day time. This can be explained by accumulation of radioactive gases and their progenynear the ground surface due to weak convection.
- There is maximum of space charge density concentrated at light ions during sunrise. More intensive forming of middle and heavy ions fractions due to hydratation and clusterization at surface warming and water vaporization conditions is a possible reason of light ions total positive charge growth at morning hours [Smirnov, 2010]. Hydrate complexes concentration growth causes asymmetric electrical charge redistribution between ion fractions and negative charge gaining by heavy fraction [Smirnov, 2010].
- Presence of coherent aeroelectrical structures is a typical feature of turbulent aeroelectrical pulsations and space charge density [Anisimov et al, 2014a, Anisimov et al, 2014b].
- Light air ion concentration variations and space charge density are connected with radon activity variations [Anisimov et al, 2013].
- Space charge density variations spectra is self-similar. The power of spectra decay for period interval from 10 to 10000 seconds is close to -5/3. The power of spectra decay for period from 2 to 10 seconds is different at day and night conditions. At day time the power of spectra decay for this period is mostly close to -5/3. But at night time the power of spectra decay varies from -1.9 to -3.1. [Anisimov et al, 2013]

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