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INVESTIGATION OF THE AERO-ELECTRICAL CHARACTERISTICS OF ATMOSPHERE SURFACE LAYER IN ARCTIC

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Abstract

In this study, the aero-electrical characteristics of atmosphere surface layer are considered in order to investigate the spatial structure of atmosphere currents of mechanical charge transfer in raindrops and simultaneously with air streams.

The correlation function dependence of atmospheric current antenna signals (that was obtained by the diversity technique from July to October 2006) on wind and rain meteorological data was studied. Time shifts between the atmospheric current antenna signals in dependence on the wind velocity and direction were studied.

It is shown, that during rain the current density of charge transfer by rain drops is spatially non-homogeneous on intervals approximately tens meters, and this is much more than current density of charge transfer by electrical forces. So, duringa heavy rain the signal power at 1 Hz is able to increase more than 20 dB.

During wind more than 2 m/s the time shift between signals in frequency range 0.01-0.1 Hz was found depending on the wind direction and velocity. It was caused by aero-electrical structures moving. The spatial horizontal scale of these structures were estimated as ~ 20-600 meters.

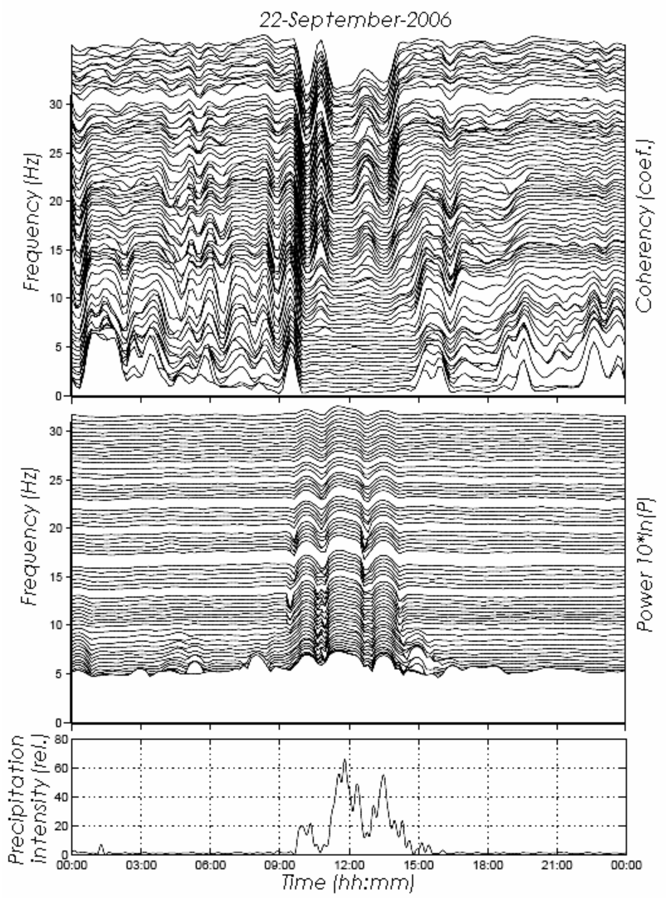

Figure 1. Coherency spectrum (top), power spectrum of electric current (middle) and rain intensity (bottom). 22 September 2006 (time UT).

Introduction

It is known, that processes of transformation of the solar energy incoming to atmosphere are accompanied by generation of different kinds of dissipative structures in wide-ranging space-time scales. At the same time, aero-electrical structures are attracting increasingly more attention as essential element of electrical energy accumulation and dissipation circuit in atmosphere (for example see [1-3]). In this connection, the study of the atmospheric current spatial inhomogeneity under any meteorological and geophysical conditions is interested. So, though there are many studies that are related to investigations of raindrop charges and precipitation currents (for example see [4-7]), the spatial structure of these currents keeps almost unstudied. Account must be taken that measuring data on atmospheric electricity in the Arctic are episodic. Some results of investigation of current statistical characteristics, which are caused by aero-electrical structures moving on surface atmosphere layer in the Kola Peninsula, are presented in this paper.

Atmospheric current under different meteorological conditions

The atmospheric currents measuring system consists of atmospheric current collector-dipole [8], geophysical data logger, synchronizer and PC with OS Linux. This system is situated at the Atmospheric polygon of the Polar Geophysical Institute (PGI) KSC RAS near Apatity city (distance from city boundaries is one and a half kilometers).

For analysis we used measuring data results under different meteorological conditions:

1. under fine weather conditions (wind velocity less 1.5 m/sec);
2. under rain and calm in air (wind velocity less 1.5-2 m/sec);
3. under windy weather without all kind precipitations.

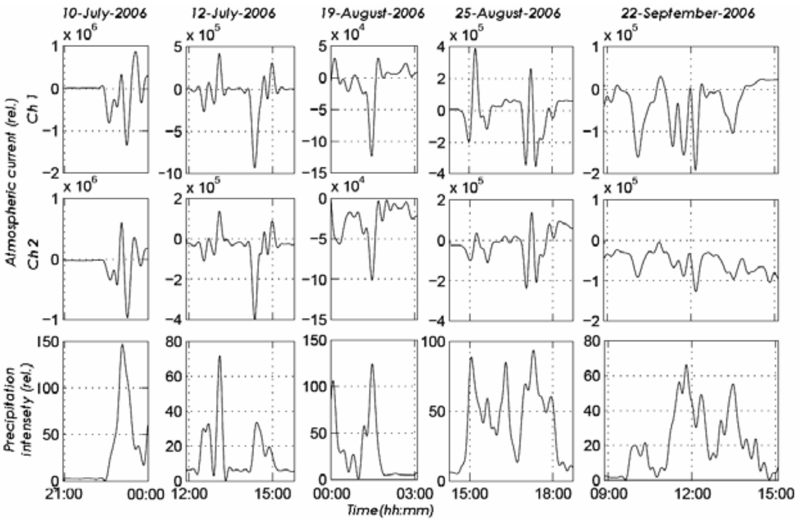

Figure 2. Low frequency rain current variations (less 0.001 Hz) and rain intensity. (The time is UT).

Weather was controlled by the atmospheric parameters measuring system, which gas been engineered in PGI [9, 10].

Fine weather current variations analysis allowed disclosing background values for the atmospheric current collector signals.

Since the high surface atmospheric layer disturbs sensitivity of current collectors, we consider the fine weather conditions as such time intervals when the wind velocity is less than 1.5 m/sec and any kind of precipitations is absent.

Usually under fine weather conditions there were observed high coherent signals (order of 0.8-0.9) from different collector's parts on frequency higher 0.001 Hz. Probably, it is caused by the global current circuit prevailing over local current sources.

For atmospheric current variations analysis during rain, 21 events were considered from July to October 2006. Obviously, mechanical transfer current is dependent on both charge transfer by raindrops and aero-electric structures transfer simultaneously with air streams. Therefore the most reliable result in rain electric current measurements could be obtain under the calm in air. Of a list of all cases that were considered only 8 cases occurred in calm in air when the wind velocity did not exceed 2 m/sec. In all cases it was found that during rain the signals from different collector's parts on frequency higher 0.001 Hz were low coherent and more powerful. For example, Figure 1 displays one of these cases occurred on 22.09.2006.This Figure displays the coherency spectrum on the top panel, the power spectrum on the middle panel and the precipitation intensity on the bottom. The intensive rain was observed from 10:00 to 15:00 UT, and the wind velocity during all day did not exceed 2 m/sec.

A sharp decrease of the signal coherency shows that charges transferred by raindrops to area each part of the collector are discriminated. Furthermore the power spectrum analysis shows that signals from different collector's parts are increased during the rain differently at different frequencies. Thus, the signal power at 1 Hz are increased more than per 20 dB, while at 25 Hz it is less than 10 dB. At the same time, the analysis of cross-covariation envelope functions showed that the time shift between signals is absent.

The analysis of the rain electric current variations from different collector's parts at frequencies less than 0.001 Hz showed similarity of their shapes. Figure 2 displays the low frequency (less than 0.001 Hz) rain current variations from different collector's parts (on top and middle) and the rainfall intensity (on bottom) for several cases. It is shown that the variation of the amplitude is directly proportional by the rainfall intensity.

However slowly-changing rainfall intensity variations can't explain faster current variations. In order to illustrate a possible mechanism of these variations we use a simple numerical model.

In numerical experiment a Poisson flow of rain drops that are fall into current collector's surface is modeled. The flow intensity is changed by Hanning function. Rain drops charge in flow is formed by Gauss distribution law with the mean charge changing as cosine function with frequency of 0.001 Hz.

The typical value of precipitation intensity (mm/h) for our region was taken from [11]. The typical value of raindrop charges was taken from [4]. Displacement current generating by charged drops passing near the wire line wasn't taken into consideration in the model. The raindrop spitting effect wasn't taken into consideration as well. These assumptions affect to quantitative estimation and do not affect to the variation shape. The modeling result is shown in Figure 3.

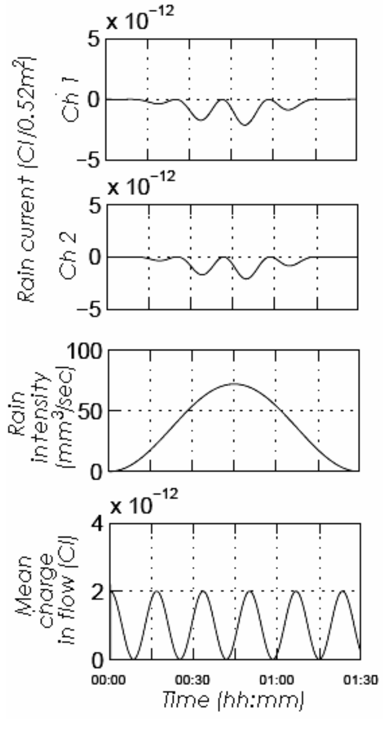

Figure 3. Rain currents (top), rain intensity (middle), rain drop mean charge in flow (bottom).

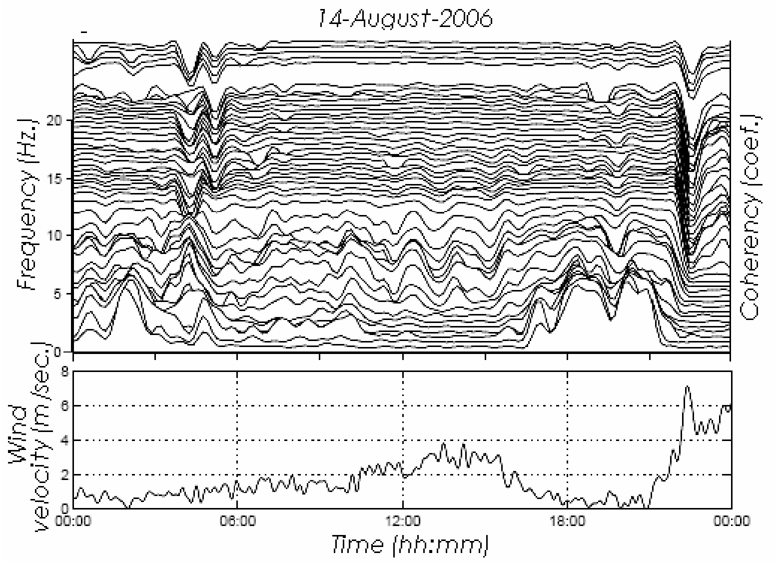

Figure 4. Coherency spectrum (top) and wind velocity (bottom). 14 August 2006. (The time is UT).

Comparison of modeling results and current variations in Figure 2 showed that changed charge distribution function is able to explain the faster current variations.

Thus the conclusion that the probability density function of the rain drops charge does not vary for individual cloud, but often differs for different clouds, was obtained by the data processing and numerical results. Probably, the constancy of the probability density function for individual cloud is explained by strong ascending airs that are typical for rain clouds [11].

For atmospheric current variations dependence on the wind direction and velocity the analysis of 24 cases when wind velocity exceed 1.5 m/sec during time intervals more 1 hour were performed. For example, Figure 4 displays one of these cases occurred on 14.08.2006. The Figure displays coherency spectrum on the top panel and the wind velocity on the bottom. The Figure shows that frequency range with low correlation is depended on the wind velocity directly.

Obviously there is the time shift between different collector's parts caused by mechanical transfer eclectic charge with air streams. Cross-covariation function envelopes are calculated for time shift value estimation. For example, Figure 5 displays calculation results for the case of 14.08.2006. This Figure displays cross-covariation functions in frequency ranges (from up to down): 0-0.01 Hz, 0.01-0.1 Hz, 0.1-1 Hz, 1-15 Hz. From 10:00 to 16:00 the wind direction was south-south-east, from 22:00 to 24:00 it was nord-west.

Time shift approximately 15 seconds in frequency range 0.01-0.1 Hz is seen in Figure 5. It is observed in time interval from 10:00 to 16:00 under the south-south-east wind direction and is caused by aero-electric structures that are moved by wind near the collector. During the wind with nord-west direction the time shift isn't observed. In frequency range 0.1-15 Hz chaotic positions of cross-covariation function envelope maximums are observed under the wind velocity more 2 m/s independently on wind direction. It is caused by surface layer turbulence.

Since the time shift between signals from different collector's parts was observed in the frequency range 0.01 - 01 Hz with wind velocities of 2 – 6 m/sec, the maximal horizontal size of aero-electric structures, which caused the time sifts, was equal to product of current variation periods and wind velocities. The estimation obtained in this way shows, that aero-electric structures horizontal scale is 20-600

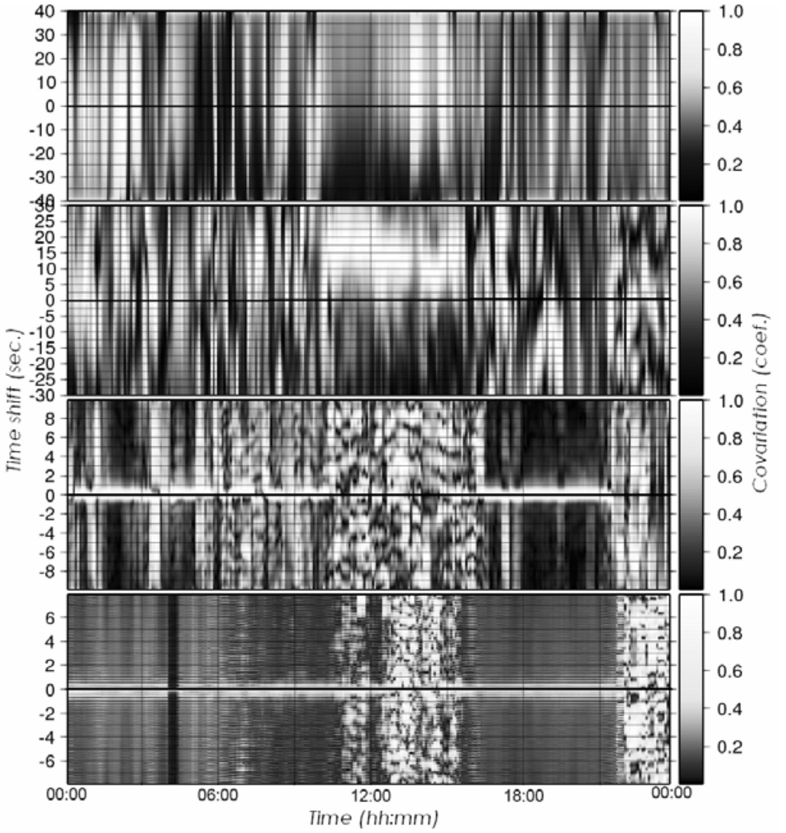

Figure 5. Cross-covariation analyses results for case 14 August 2006. (Frequency ranges from up to down: 0÷0.01 Hz, 0.01÷0.1 Hz, 0.1÷1 Hz, 1÷15 Hz).

meters. These values are in agreement with values obtained by measurements in the mid-latitude geophysical observatory "Borok" [2,3].

Conclusions

On the basis of the statistical analysis of atmospheric current variations observed on Kola Peninsula (Apatity polygon) using collector – dipole we conclude that:

- The probability density function of the rain drops charge does not vary for individual cloud, but often differs for different clouds.
- There is the time shift between signals in different collector's parts caused by aero-electric structures that are moving by wind near the collector. The horizontal scale of the aero-electric structures is estimated as 20-600 meters.

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References

1. Anisimov S.V., E.A.Mareev and S.S.Bakastov. On the generation and evolution of aeroelectrical structures in the surface layer. // J. Geophys. Res., 1999, v.104, 14359-14367.

2. Anisimov S.V., E.A. Mareev, N.M. Shikhova, and E.M. Dmitriev. Universal spectra of electric field pulsations in the atmosphere. // Geophysical research letters, 2002: v.29, 2217-2220.

3. S. V. Anisimov, N. M. Shikhova, E. A. Mareev, and M. V. Shatalina. Structure Functions and Spectra of Turbulent Fluctuations in the Aeroelectric Field. // Izvestiya, Atmospheric and Oceanic Physics Vol. 39, No. 6, 2003, p. 690 -704.

4. Чалмерс Дж. А., Атмосферное электричество. Пер. с англ. Л.: Гидрометеоиздат, 1974. 419 с.

5. Selvam M.A., G.K. Manohar, L.T. Khemani, Bh.V. Ramana Murty., 1977: Characteristics of Raindrop Charge and Associated Electric Field in Different Types of Rain. // Journal of Atmospheric Sciences v.34, Nov. (1791-1796).

6. Aspinall W.P., 1972: Mechanical-Transfer Currents of Atmospheric Electricity. // JGR v.77, №18. (3196-3203).

7. Cobb W.E., B.B. Philips, P.A. Allee., 1967: Note on mountain-top measurements of atmospheric electricity in northwestern United States. // Monthly Weather Review v.95, №12. Dec. (912-916).

8. Ролдугин В.К., 2002: Об измерении атмосферных токов при помощи сетчатого коллектора. // Техника и методика геофизического эксперимента. Сборник научных трудов ПГИ КНЦ РАН. Изд.КНЦ РАН. Апатиты. 2002. С.154-164

9. Першаков Л.А. Автоматическая метеорологическая станция. // Техника и методика геофизического эксперимента. Сборник научных трудов ПГИ КНЦ РАН. Изд.КНЦ РАН. Апатиты. 2002. С.90-101.

10. Першаков Л.А. Устройство для обнаружения и регистрации интенсивности метеоосадков. // Техника и методика геофизического эксперимента. Сборник научных трудов ПГИ КНЦ РАН. Изд.КНЦ РАН. Апатиты. 2002. С.102-107.

11. Матвеев Л.Т. Физика атмосферы. СПб.: Гидрометеоиздат, 2000. 777 с.