Atmos. Chem. Phys. Discuss., 6, 6613–6626, 2006
www.atmos-chem-phys-discuss.net/6/6613/2006/

Atmospheric Chemistry and Physics Discussions

Spectral characteristics of atmospheric pressure and electric field variations under severe weather conditions at high latitudes

E. A. Kasatkina[1], O. I. Shumilov[1], Y. A. Vinogradov[2], and A. N. Vasilyev[3]

[1]Institute of North Industrial Ecology Problems, Kola Science Centre RAS, Fersmana str. 14, 184209 Apatity, Russia
[2]Kola Regional Seismological Center (KRSC) of Geophysical Survey of RAS, 184209 Apatity, Russia
[3]Polar Geophysical Institute, Kola Science Centre RAS, 184209 Apatity, Russia

Received: 8 May 2006 – Accepted: 14 June 2006 – Published: 17 July 2006

Correspondence to: E. A. Kasatkina (oleg@aprec.ru)

Abstract

The time-dependent relationships between atmospheric parameters (electric field, positive and negative conductivity, variations of atmospheric pressure) and different meteorological phenomena (rain, fogs, snowstorms, thunderstorms) were investigated through spectral analysis. These parameters were measured with help of a high-latitude computer-aided complex installed at Apatity (66.5 N, 33.4 E). The complex consists of three spaced microbarographs for measurements of atmospheric pressure variations in the range of periods from 1 s to 40 min, an instrument measuring the vertical component of the electric field, and instrument used for measurements of air conductivity and surface ozone. A computer-aided data-gathering system makes it possible to obtain information in the frequency range between 1 and 0.0001 Hz. The time-dependent frequency analysis showed that the spectral characteristics of both electric field and atmospheric pressure variations changed synchronously during severe weather conditions.

1 Introduction

As it is known short period variations of atmospheric electric field E_z are connected to various meteorological phenomena of local character (clouds, fogs, industrial aerosols, thunderstorm activity) (Chalmers, 1967; Bhartendu, 1971; Holzworth, 1981; Anisimov et al., 1994; Rycroft, 1994; Guo et al., 1996). At the same time, the appearance of atmospheric electric field and pressure pulsations can also be connected to magnetospheric disturbances at high latitudes (Holzworth, 1981; Ivanov and Semenov, 1984; Goldberg et al., 1990; Nikiforova et al., 2003). In this connection the development of new integrated methods of observation for revealing meteorological and magnetospheric sources in polar atmosphere seem to be very promising.

To this end, in Kola Science Center of RAS (Apatity, 66.5 N, 33.4 E) it was installed High-latitude computer-aided measuring complex. The complex consists of three spaced (about 300 m) microbarographs for measurements of atmospheric pressure variations in the frequency range from 0.0001 to 1 Hz, an instrument measuring the vertical component of the electric field, and instrument used for measurements of air conductivity and surface ozone, telemetry, and system for data gathering (Shumilov et al., 2002). The complex is located not far from Khibini mountains that create favourable conditions for observation of non-stationary mountain waves (Shumilov et al., 2002).

In the present paper the time-dependent relationships between atmospheric parameters (electric field, positive and negative conductivity, variations of atmospheric pressure) and different meteorological phenomena (rain, fogs, snowstorms, thunderstorms) were investigated through spectral analysis.

2 Instrument and data description

Measurements of low-frequency infrasound pressure oscillations in frequency range (0.0001–1 Hz) were carried out by means of liquid microbarographs developed by the Oboukhov Institute of Atmospheric Physics RAS (Bovsheverov et al., 1979). For determination of infrasound source spatial characteristics (azimuth, arrival time) three one-type sensors have been installed at angle tops of approximately equilateral triangle with nearly equal sides (∼300 m). In the device three wide-band filters with frequency bands 1 s–40 min, 1–40 min and 5–40 min were used. The information was transmitted with help of telemetry system consisting of two independent channels.

The complex contains also the vertical electric field measuring device “Pole-2” and conductivity measuring device “Electroprovodnost –2”. The positive and negative atmospheric electrical conductivities (λ_- and λ_+) were measured by aspirating air through two capacitor electrodes. The main idea of the method is based on the measurement of atmospheric ion current. These ions get into one of the two cylindrical capacitor electrodes. Depending on its sign. A pump is used for creation of ion stream into the cylindrical capacitor. The device permits to measure the air electrical conductivity with an absolute accuracy up to $\sim 10^{-16} \Omega^{-1}\,\mathrm{m}^{-1}$. Speed of air stream pumping is about

20 l/min, and time constant is ∼100 s. The main point of the method used in the measuring device “Pole-2” consists of transformation of the electrostatic induction constant flux into the alternating one at the surface of the receiving element. On the load that is connected with the receiving element an alternating current flow. Voltage drop on the load is proportional to E_z strength. The device has got two limits of electric field strength measurements – ±5000 V/m and ±500 V/m. The measurement accuracy is 20%.

In the data gathering system seven channels were used. The first three ones gained information from microbarograph sensors with a polling frequency of five times per second. The next four channels transformed signals with a polling frequency of ten times per second from both the electric field and conductivity sensors. As a result a diurnal data file was formed and then transferred into the data storage.

3 Results and discussion

3.1 Rain

An example of E_z and electrical conductivity variations during a rain on 28 June 2002 is given in Fig. 1. The rain period was observed between 14:00 and 16:00 UT. After some break the rain was again detected near 18:00 UT, when E_z value decreased up to background value. In the case the rain seemed to cause charge sink that was formed in the lower part of thunderstorm cloud. Figure 2 shows a time-dependent (dynamical) spectrum of E_z variations for the event considered. It was computed by the windowed discrete-time Fourier transform of a signal using a sliding window (Rabiner and Schafer, 1978). It is seen that E_z was accompanied by the appearance of oscillations with periods T>1 min. After the rain start at ∼18:00 UT E_z variations disappeared.

3.2 Thunderstorm

An event of rather strong thunderstorm accompanied lightning has been detected on 29 June 2002. Note that thunderstorms with lightnings are very seldom behind the polar circle (not more than two-three per year). This day the strong thunderstorm with lightnings started between 13:10–13:20 UT. At the moment considerable variations of E_z with amplitudes ~10 kV/m and sign changes were detected (see Fig. 3b). Figure 4 demonstrates a dynamical spectrum of E_z and atmospheric pressure variations during thunderstorm. It is clearly seen that E_z with periods T>1 min coincide with thunderstorm activity beginning (see Fig. 4a). Strong jumps in the pressure variations were measured practically simultaneously with E_z changes after thunderstorm start (Figs. 3a, 4b). A lot of papers are devoted to infrasound generation by lightning discharges (Balashandran, 1979; Grigorjev and Dokuchaev, 1981).

It should be pointed out that high-frequency component of atmospheric pressure variations (2 min<T<6 min) temporally coinciding with the start and development of thunderstorm activity appeared at the background of already existing slow variations of pressure with T>6 min, that are probably related to the connection and propagation of mountain lee waves (Shumilov et al., 2002). The result obtained coincides with data given in works (Balashandran, 1979; Grigorjev and Dokuchaev, 1981) where the possibility of infrasound and internal gravity wave generation by lightning discharge is considered.

3.3 Fog

Figure 5 shows the measured atmospheric pressure P, vertical electric field E_z and electrical conductivity variations during a fog on 3 December 2001. On the day the air temperature was stable (−5°C), any precipitation was absent, and a weak wind flew. Approximately at 06:00 UT a strong fog started to develop (visibility was less than 50 m at the moment). The fog then existed up to 22:00 UT. Since the time of the fog formation (06:00 UT) a slow increase in E_z took place and lasted up to midday hours

(see Fig. 5b). Maximal values of E_z reached 1 kV/m that exceeded nearly by one order the background values and agreed with experimental data and theoretical estimates (Bott et al., 1990). In the evening, when the fog scattered, electric field decreased, but still exceeded the background value by two-three times. Air electrical conductivity decreased at the time (see Fig. 5c). It was noted on conductivity drop during a fog by Chalmers (1967). The increase of E_z and decrease of electrical conductivity during the fog formation seemed to be connected to the aerosol condensation growth in the air and attachment of the light ions to the aerosol particles.

Together with start of considerable changes in electric field some changes in atmospheric pressure were also detected (decrease of the variation amplitude and appearance of high-frequency component (see Fig. 5a). According to Figs. 6a, b, the dynamical spectra of electric field (a) and atmospheric pressure (b) demonstrate a noise burst in a wide-frequency band at ~08:00 UT. It is seen from Fig. 6a that this effect is not so noticeably expressed in E_z spectrum which consists of equally spaced frequency bands with a width of ~0.005 Hz. The noise burst disappeared after the fog vanished. Probably the pressure fluctuations were related to formation of stretched “aeroelectrical” structures filled in a turbulent gas in fog conditions (Anisimov et al., 1994).

4 Conclusions

The time-dependent spectral analysis of atmospheric pressure and electric field variations under severe weather conditions (rain, fog, thunderstorm) showed that the frequency characteristics of both parameters changed practically synchronously.

The obtained results note onto the validity of investigation of atmospheric parameter variations at high latitudes with help of the integrated methods measuring several quasi-independent atmospheric parameters simultaneously. This approach seems to permit us to create not contradicting scheme of physical processes in atmosphere.

Acknowledgements. This research was supported by the Russian Foundation for Basic Research (grant N 05-04-97528) and by the Regional Scientific Program of Murmansk region.

References

Anisimov, S. V., Bakastov, S. S., and Mareev, E. A.: Spatiotemporal structures of electric field and space charge in the surface atmospheric layer, J. Geophys. Res., 99, 10 603–10 610, 1994.

Balashandran, N. K.: Infrasonic signals from thunder, J. Geophys. Res., 84, 1135–1145, 1979.

Bhartendu, S.: Relation of the atmospheric potential gradient with meteorological elements: Cross power spectral analysis, Pure Appl. Geophys., 88, 210–227, 1971.

Bott, A., Sievers, U., and Zdunkovski, W.: A radiation fog model with detailed treatment of the interaction between radiate transfer and fog microphysics, J. Atmos. Sci., 47, 2153–2166, 1990.

Bovsheverov, B. V., Grachev, A. I., Lomadze, C. O., and Matveev, A. K.: Liquid microbqrograph, Izv. AN SSSR. (in Russian), Phys. Atmos. Ocean, 15, 1215–1218, 1979.

Chalmers, J. A.: Atmospheric electricity, Tarrytown, NY, Pergamon, 195 pp., 1967.

Goldberg, R. A., Croskey, C. L., Hale, L. C., Mitchell, J. D., and Barcus, J. R.: Electrodynamic response of the middle atmosphere to auroral pulsations, J. Atmos. Terr. Phys., 52, 1067–1084, 1990.

Grigorjev, G. I. and Dokuchaev, V. P.: Infrasound and internal gravity waves under thunderstorm discharges in atmosphere, Izv. AN SSSR. (in Russian), Phys. Atmos. Ocean, 17, 690–697, 1981.

Guo, Y., Barthakur, N. N., and Bhartendu, S.: The spectral relationships between atmospheric electrical conductivity and air pollution in urban conditions, J. Geophys. Res., 101, 6971–6977, 1996.

Holzworth, R. H.: High latitude stratospheric electrical measurements in fair and foul weather under various solar conditions, J. Atmos. Terr. Phys., 43, 1115–1125, 1981.

Ivanov, K. G. and Semenov, I. H.: Appearance of low-frequency pressure fluctuations at the earth surface during magnetospheric substorms, Geomagnetism and Aeronomy (in Russian), 24, 857–858, 1984.

Nikiforova, N. N., Kleimenova, N. G., Kozyreva, O. V., Kubitski, M., and Michnowski, S.: Influ-

ence of auroral-latitude precipitations of energetic electrons on variations in the atmospheric electric field at polar latitudes (Spitsbergen Archipelago), Geomagnetism and Aeronomy (in Russian and English), 43, 29–36, 2003.

Rabiner, L. R., and Schafer, R. W.: Digital Processing of Speech Signals, Englewood Cliffs, NJ, Prentice Hall, 1978.

Rycroft, M. J.: Some effects in the middle atmosphere due to lightning, J. Atmos. Terr. Phys., 56, 343–348, 1994.

Shumilov, O. I., Kasatkina, E. A., Tereshchenko, E. D., Vasilyev, A. N., and Raspopov, O. M.: Atmospheric pressure variations in the region of lee waves near the Khibini massif, Izv RAN. (in Russian and English), Phys. Atmos. Ocean, 38, 471–475, 2002.

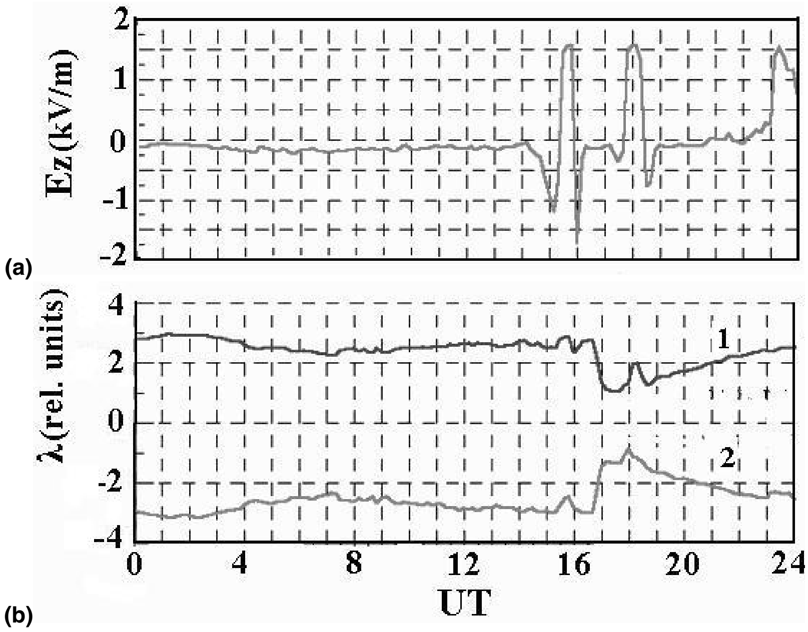

Fig. 1. The variations of atmospheric electric parameters (1 min averaged) on 28 June 2002 (rain conditions) at Apatity (66.5 N, 33.4 E): **(a)** vertical electric field E_z, **(b)** positive λ_+ (curve 1) and negative λ_- (curve 2) electrical conductivity.

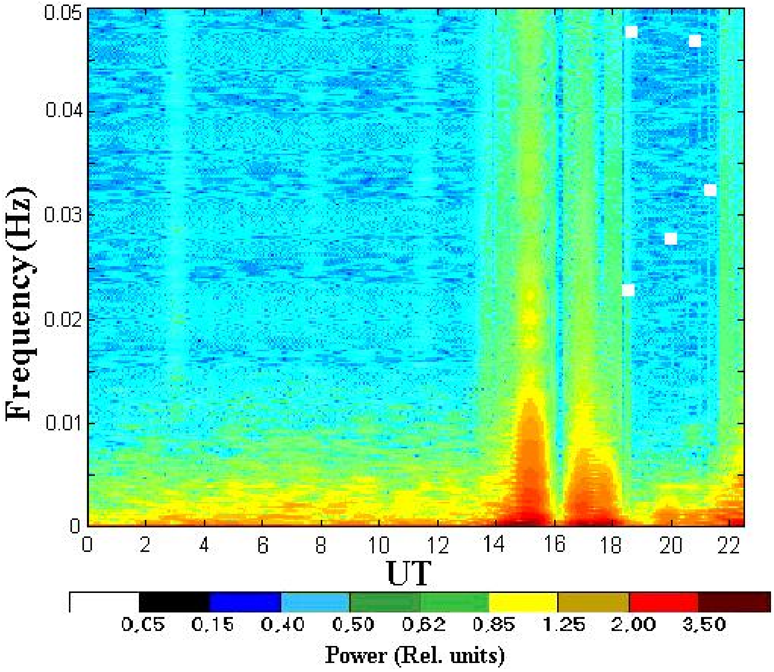

Fig. 2. The dynamical spectrum of E_z variations during a rain on 28 June 2002 with sampling frequency of 0.1 Hz.

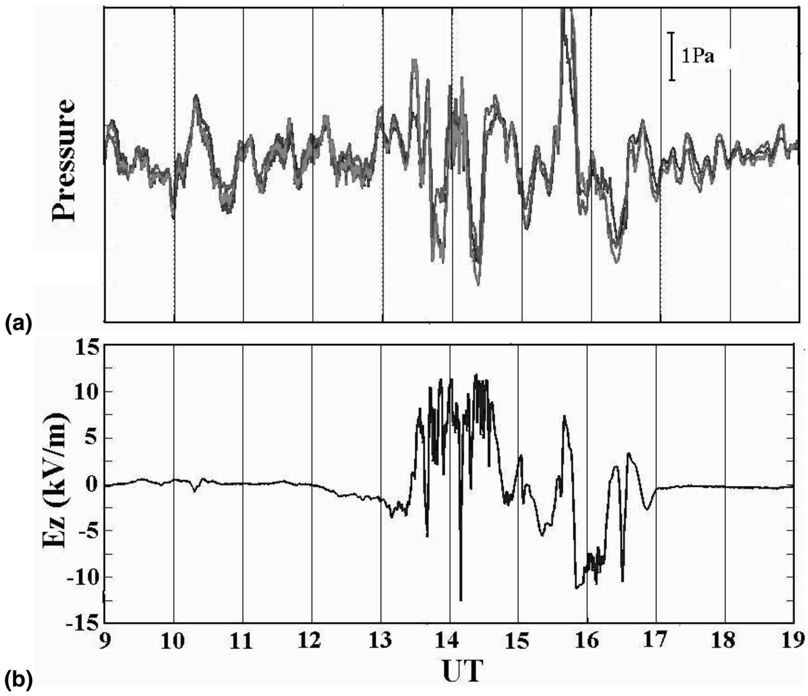

Fig. 3. The variations of atmospheric pressure **(a)** and vertical electric field E_z **(b)** (10 s averaged) on 29 June 2002 at 09:00 UT to 19:00 UT (thunderstorm conditions).

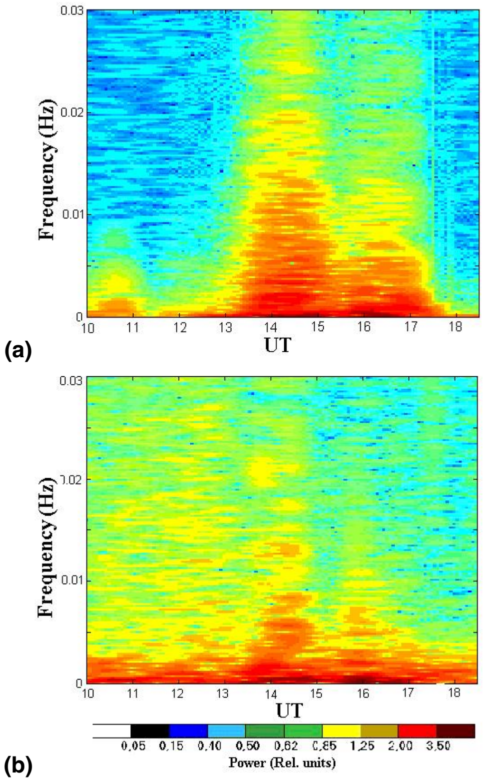

Fig. 4. Common spectral characteristics in electric field **(a)** and atmospheric pressure during a thunderstorm on 29 June 2002. Spectrograms were calculated with sampling frequency of 0.1 Hz.

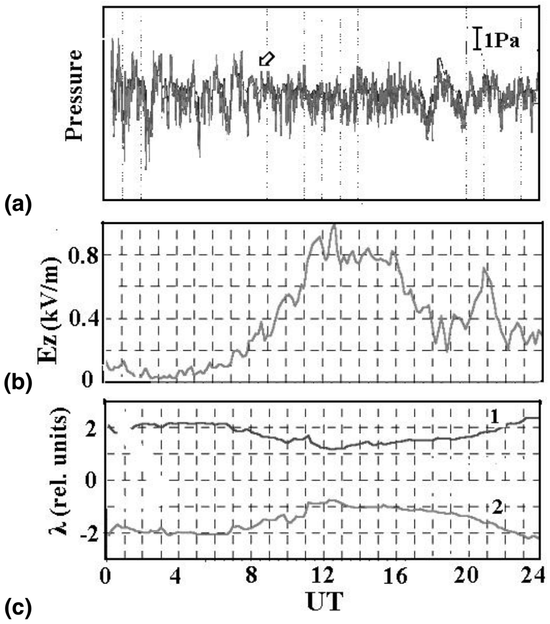

Fig. 5. The variations of atmospheric parameters (1 min averaged) on 3 December 2001 (fog conditions): **(a)** atmospheric pressure, **(b)** vertical electric field E_z, **(c)** positive λ_+ (curve 1) and negative λ_- (curve 2) electrical conductivity. Arrow shows the appearance of high frequency component in pressure variations.

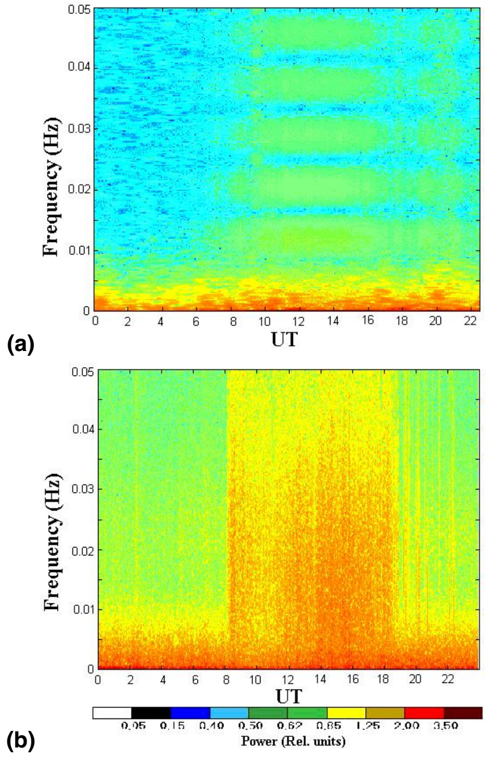

Fig. 6. The same as in Fig. 4, but during a fog on 3 December 2001.