Features of the electric field of the atmosphere in various weather conditions

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Abstract. The article presents data on the measured series of electric field strength in the atmospheric surface layer for the period from 2010 to 2019 using the EFM550 electric field strength meter. The comparability of the influence of local (fogs, precipitation, thunderstorms, etc.) and global (cyclonic processes, solar-terrestrial communications, etc.) factors on atmospheric electric field variations is discussed. Global and local variations in the nature and dynamics of field strength for the conditions of the North Caucasus are confirmed. An analysis is made of the frequencies of the occurrence of a range of surface atmospheric electric field values. The obtained method of processing information about the repeating values of the polar atmosphere and the Earth’s atmosphere. For this purpose, a branch has been compared with a number of actual weather observations in the central part of hydrometeorology and environmental monitoring. Federal State Budgetary Institution "North Caucasus Office for Hydrometeorology and Environmental Monitoring” Roshydromet. The features of the influence of various meteorological phenomena on the state of the electric field strength were statistically described and a study was conducted to assess the influence of local phenomena - precipitation, clouds and thunderstorm activity on the change in the value of the electric field of the atmosphere in the area of the city of Nalchik.

1. Introduction

The peculiarity of electrical processes in the atmosphere is their complex nature. They are products of processes that are both endogenous and exogenous in nature. The surface layer of the atmosphere is characterized by the presence of turbulent thermodynamic exchange processes, surface sources of ionization, sources of aerosol particles associated with the occurrence of the electrode effect [1]. A separate graph includes such phenomena as natural sources of radioactive radiation, earthquakes and volcanism [2,3], as well as sources of ions of anthropogenic origin [4]. Atmospheric layers above the surface layer, in turn, are determined by global electrical processes in the upper atmosphere generated by heliogeophysical processes and galactic cosmic ray flows [5]. All this simultaneously generates local and global effects that are difficult to separate. Thus, the magnitude and direction of the ground-level electric field of the atmosphere vary widely in space and time. Global-scale effects are observed depending on the time of year and day and consist in simultaneous changes in the intensity of the electric field of the atmosphere throughout the Earth (unitary variations). At least four periods of
unitary variations are known: 11-year, annual, 27-day, and diurnal [6]. The most well-known is the daily unitary variation of the ionosphere potential, which has a morning minimum of 3-5 hours and an evening maximum of 19-20 UTS. It is assumed that unitary variations are associated with the daily course of the number of thunderstorms on the planet. Local-scale effects expressed in local variations of the field [7] are caused by features of orography and are related to weather conditions: local thunderstorm activity, snowstorms, clouds and fog, precipitation, dust, as well as the nature of air pollution by aerosol particles that have an electric charge, and other factors that cause changes in the field strength with periods ranging from fractions of a second to several hours.

The sources of the strongest fields in the troposphere are storm clouds, which are generators of electric discharges, and the field strength under them at the earth's surface reaches 104 V/m. Violation of the normal electric field occurring directly during thunderstorm activity may differ by orders of magnitude from the background values [8]. Thus, the influence of local phenomena on the change in the value of the electric field intensity of the atmosphere is extremely significant.

It can be argued that to date, the influence of local (fogs, precipitation, thunderstorms, etc.) and global (cyclonic processes, solar-terrestrial relations, etc.) factors on the daily and seasonal variations of the electric field intensity of the atmosphere has not yet been sufficiently studied.

2. Materials and methods
Collected material on registration of the electric field intensity of the atmosphere. To do this, we used information from a network of atmospheric electric field meters consisting of four EFM550 sensors that deliver information to the geophysical center at the high-Alitude geophysical Institute every half a second [9]. This network was put into operation in 2010 to provide monitoring of electrophysical phenomena in a free and disturbed atmosphere. Each digital field registration sensor is paired with hardware and software for collecting, processing and storing information. In this study, we used the values of the electric field intensity of the atmosphere from a single electric field strength meter located on the roof of the High-Mountain Geophysical Institute (Nalchik Station) building. Then the received data of the field meter were averaged over minute and three-hour intervals for the convenience of subsequent analysis.

Actual observations of weather conditions registered by the Kabardino-Balkar center for Hydrometeorology and environmental monitoring, a branch of the Federal state budgetary institution "North Caucasus Department for Hydrometeorology and environmental monitoring", were used for comparison with weather events.

3. Results and discussion
During the period from 2010 to 2019, 528400560 registration of the electric field intensity of the atmosphere was performed on a single sensor EFM550 point Nalchik, after processing, a minute series of 4403338 elements and a three-hour series of 24463 elements were obtained. The duration of weather events was taken into account with accuracy to the minute according to the tables of meteorological observations.

In the course of the conducted research, a strong variability of the electrical parameters of the atmosphere under the influence of meteorological conditions was noted, even in the absence of precipitation-forming clouds [10]. The most significant disturbances of the normal electric field occur during thunderstorm activity (figure 1). All this makes it possible to use the intensity of the electric field of the atmosphere as an integral characteristic for analyzing the operational meteorological situation in the local area.

According to figure 2, we can conclude that there is seasonality during the intensity of the electric field of the atmosphere, with an observed increase in its value during the cold period of the year with peaks in January and March and a subsequent decrease to values of 60-120 V/m with the onset of the summer-autumn period. In winter, the E value is higher than in summer by an average of 50-100 V/m.

To isolate the 27-day period (figure 3) of the unitary variation, the constructed annual variation for three-hour intervals (figure 2) was processed with a median filter and subtracted from the original series.
Figure 1. Data on the minute-by-minute average electric field strength of the atmosphere from 2010-2019.

Regardless of the observation period in clear weather conditions, the field strength value ranges on average from +20 to +400 V/m and does not exceed 700 V/m, while it is almost always positive.

Figure 2. The annual variation of the obtained values of a three-hour average

Figure 3. "27-day" variation obtained after subtracting the annual component.

We selected data with clear weather for the entire observation period. According to these data, processing was performed with a division by time of year: 1,2,12 months – winter; 3,4,5 months – spring; 6,7,8 months – summer; 9,10,11 months – autumn (figure 2). A characteristic property of the daily variation of the quasi-static electric field at the Nalchik station in clear weather (wind speed no more than 6 m/s, cloud cover no higher than 3-4 points, no rain, fog, snowstorms, etc.) is the presence of a wave-like change in the values of the field strength during the illuminated time of day.
In the daily course, there is a maximum between 13-16 hours and a minimum of about 3 hours local time. For individual seasons, the form of unitary variation is preserved, but it is clearly visible that in winter the curve has a significantly greater amplitude.

Significant differences in the values of the intensity course for a complete set of data and data only for clear weather are primarily due to the presence of natural and climatic processes, such as thunderstorms, fogs, and snowfall. Precipitation leads to a significant deviation of the dynamics of the electric field from the natural course. During precipitation, the field strength can change dramatically, reaching 10,000 V/m. At the same time, clouds that produce precipitation cause irregular sharp changes in the field. [11]. During snowfall and sudden gusts of wind, there are significant jumps in the field that are characterized by: changes in the field from + 200 V/m to 10 kV/m, the duration of pulsations of field strength from 10 s to 30 min, a positive sign of field change. The paper [12] shows a good correlation (up to 0.8) between the amplitude of changes in the field strength and the intensity of snowfall.

The results of processing a number of measurements of the electric field strength of the atmosphere can be represented as the frequency distribution of the values of the field strength values for any time range. Figures 4-6 show an example of such processing.

The obtained method of processing information about the repeatability of the values of the electric field intensity of the atmosphere can also be used in the study of the peculiarities of the field intensity for various meteorological phenomena. By comparing data from weather observation tables and automatic fluxmeter measurements, we get synchronized series that can be processed in this way.

The results of the analysis of the frequency of occurrence of values of the electric field intensity of the atmosphere in the conditions of various weather events are shown in figure 7.
Figure 5. The frequency of occurrence of certain values of the electric field intensity of the atmosphere for the entire period of observations and for each of the seasons separately, the step of the rank scale was 40 V/m.

Figure 6. Analysis of the frequency of occurrence of values of the electric field intensity of the atmosphere for different seasons of the year (the total number of encountered values of this value is taken as 100 percent).

A statistical analysis of these frequency distributions is performed (figure 7). the results are shown in Table 1.
Figure 7. Analysis of frequency distributions of occurrence of atmospheric electric field intensity values for various weather events.

Table 1. Statistical characteristics of Ez series observed during weather events.

| Weather events            | Average | Median | Standard deviation | Min    | Max    |
|---------------------------|---------|--------|--------------------|--------|--------|
| No phenomena              | 180.5   | 109.6  | 229.3              | -99.4  | 2179.4 |
| rosa - dew                | 15.0    | 40.0   | 616.9              | -10202.0 | 10200.0 |
| pozem - blowing snow      | 165.9   | 79.3   | 356.6              | -782.7 | 1280.0 |
| inei - frost               | 96.0    | 80.0   | 406.4              | -10202.0 | 10200.0 |
| gled – ice                | -68.8   | 80.0   | 737.5              | -9714.7 | 1810.7 |
| gldca – sleet              | -2339.0 | -2475.9 | 567.3         | -2482.2 | 0.0     |
| dymka – haze               | 71.9    | 80.0   | 517.5              | -10202.0 | 10169.0 |
| dojd – rain                | -177.1  | -23.7  | 415.7              | -1426.6 | 1044.0 |
| liven - heavy rain         | 30.1    | 40.0   | 1361.5             | -10202.0 | 10200.0 |
| moros – drizzle            | 60.4    | 66.0   | 548.6              | -9714.7 | 4666.1 |
| msneg - snow is wet        | 271.7   | 459.7  | 624.6              | -1421.2 | 1125.0 |
| lsneg - snow showers wet   | 185.5   | 120.0  | 677.4              | -4752.3 | 5817.7 |
| sneg - snow                | 36.8    | 161.3  | 820.3              | -10202.0 | 10200.0 |
| snegl - heavy snow         | 73.3    | 109.9  | 626.4              | -7449.7 | 10200.0 |
| krsne - snow groats        | 246.9   | 160.0  | 810.2              | -10202.0 | 10200.0 |
| krled – ice groats         | -41.7   | -5.2   | 43.6               | -119.1  | -3.1   |
| zersn - snow grains        | -123.0  | 120.7  | 915.0              | -2485.2 | 1319.3 |
| igled - ice needles        | -147.5  | -143.1 | 84.5               | -316.5  | 82.7   |
| izzer - granular frost     | 60.0    | 93.5   | 556.4              | -2485.2 | 5439.3 |
| izkri - crystalline frost  | 201.9   | 160.7  | 332.8              | -965.7  | 1457.9 |
| tuman - fog                | 108.3   | 80.0   | 466.9              | -2898.7 | 3164.7 |
| tumpr - translucent fog    | 165.9   | 79.3   | 356.6              | -782.7  | 1280.0 |
| metel - general snowstorm  | -376.9  | -397.8 | 93.9               | -549.8  | -156.5 |
| mglia – haze               | 56.2    | 40.0   | 74.7               | -37.0   | 396.3  |
| zarn – lightning           | 50.8    | 80.0   | 677.4              | -10202.0 | 10200.0 |
| grad – hail                | -433.9  | 593.3  | 6458.4             | -10202.0 | 10200.0 |
| groza - tunderstorm        | 168.4   | 39.5   | 3141.1             | -10202.0 | 10200.0 |
Significant differences in the values of the intensity course for a complete data series and a sample with clear weather are primarily due to the presence of natural and climatic processes, such as thunderstorms, fogs, and snowfall, which change the measured field intensity by orders of magnitude. The main pulsations of the measured values of the electric field intensity in the summer period are associated with thunderstorm activity of clouds. Thunderstorm activity causes strong fluctuations in the electric field near the earth’s surface, which are expressed in the maximum range of pulsations in the positive and negative sides of the average value.

4. Conclusion
The peculiarities of changes in the electric field intensity of the atmosphere in Nalchik in 2010-2018 were monitored. The results of the analysis for the study of periods of unitary variation of the electric field strength at the sensor installation site (FGBI HMGI, Nalchik) are obtained. Graphs of fluctuations of the electric field in clear weather conditions and taking into account various weather events are constructed. An analysis of the frequency of occurrence of the values of the studied time series is performed.

Combining the data of electric field registration and weather conditions to identify the role of meteorological phenomena in daily and annual variations in the electric field intensity, it can be concluded that the daily course of the values of the electric field intensity of the atmosphere can serve as an object of separation of global and local factors of atmospheric electricity.

Even in clear weather conditions, the data obtained are significantly influenced by meteorological factors, the degree of air ionization, the presence of aerosol particles in the atmosphere, etc. In this regard, on the one hand, it is necessary to search for places suitable for monitoring the electric field of the atmosphere, on the other hand, it is necessary to develop theoretical models describing non-stationary electrical processes in the surface layer.

Further research will focus on the study of surface layer tension in a larger number of points in the Foothill zone of the KBR, synchronous measurement of meteorological conditions using automatic weather equipment, lightning direction-finding data of the LS8000 lightning discharge system, and measurement of radar characteristics of cloud cover using DMRL-C.

References
[1] Boldyrev A I, Vyazilov A E, Ivanov V N et al. 2016 A highly sensitive field mill for registering weak and strong variations of the electric-field intensity of the Earth’s atmosphere Instrum Exp Tech 59 pp 740–748 doi: 10.1134/S0020441216040151
[2] Anisimov S V, Galichchenko S V, Afinogenov K V 2016 Radon transport and the formation of the electrical state of the atmospheric boundary layer Fundamental and Applied Hydrophysics vol. 9 Issue 4 pp 7-14
[3] Smirnov S E et al. 2017 Effects of strong earthquakes in variations of electrical and meteorological parameters of the near-surface atmosphere in Kamchatka region //Geomagnetism and Aeronomy vol 57 issue 5 pp 610-617
[4] Spivak A A, Riabova S A, Kharlamov V A 2019 The Electric Field in the Surface Atmosphere of the Megapolis of Moscow Geomagnetism and Aeronomy vol 59 issue 4 pp 467-478
[5] Morozov V N, Sokolenko L G, Zaitedtninov B G 2018 Global electric circuit in the atmosphere: theoretical models and experimental data Proceedings of the Main Geophysical Observatory named after A I Voeikova 589 pp 98-113
[6] Anisimov S V, Mareev E A 2008 Geographical exploration of the global electrical circuit. Earth Physics 10 pp 8 – 18
[7] Adzhiev A Kh, Kalov H M 2012 The study of the electric field strength of the atmosphere in the city of Nalchik, according to the electric field meter EFM550 VII All-Russian Conference on Atmospheric Electricity. (Collection of works Main Geophysical Observatory named after A I Voeikova) pp 101 – 103
[8] Adzhiev A K, Shapovalov A V, Shapovalov V A, Stasenko V N 2016 Atmospheric electric field strength and thunderstorms in the North Caucasus Russian Meteorology and Hydrology pp 186-192 doi:10.3103/S1068373916030031

[9] Adzhiev A H., Kuliyev D D., Abshaev M T., Bolgov Yu V., Mashukov Kh H 2013 Hardware and Software complex for monitoring the electrical intensity of the surface layer of the atmosphere News KBNC RAN 2(52) pp. 49-56

[10] Adzhieva A A, Shapovalov V A, Mashukov I Kh 2017 Local sensing of atmospheric electric field around nalachik city // Proceedings of SPIE - The International Society for Optical Engineering 14. "Advanced Environmental, Chemical, and Biological Sensing Technologies XIV" 2017 pp 102150W

[11] Adzhiev A Kh, Daurova Z A 2015 Diurnal variations of the electric field of the atmosphere during weather and climate changes //Proceedings of the second all-Russian conference global electric circuit, Borok 5-9 October 2015 pp 16-17

[12] Adzhiev A H, Markandrew L M 2015 Variations of the atmospheric electric field during snowfalls and snowstorms //Proceedings of the second all-Russian conference global electric circuit, Borok 5-9 October 2015 pp 18-19