Analysis of the week current tension of the electric field of the atmosphere for the territory of the CBD according to the network of four sensors EFM550

M Ch Zalikhanov¹, S I Shagin², A A Adzhieva³

¹High-Mountain Geophysical Institute (Russian Federation)
²Kabardino-Balkarian State University (Russian Federation)
³Kabardino-Balkarian State Agricultural Univ (Russian Federation)

E-mail: aida-adzhieva@mail.ru

Abstract. The article presents the results of a week of simultaneous measurements by four EFM 550 sensors of the electric field strength for points located in the plain of the piedmont and mountainous parts of the Kabardino-Balkarian Republic. The high role of local meteorological conditions in the formation of the surface atmospheric electric field is noted.

Introduction
In the atmosphere there are constant oscillations of the electric field, resulting from the accumulation of negative charges in some and positive - in other layers. The redistribution of heavy and light particles leads to the accumulation of space charges of different signs in different places. The characteristics of the electric field of the atmosphere — the field strength and its potential — also depend on the distribution of the conductivity of the atmosphere and, consequently, on meteorological factors: fogs, clouds, precipitation, blizzards, dust and atmospheric ionization, volcanic eruptions, etc. The electric field strength can change dramatically, especially with the rapid movement of air masses along with particles of water and dust vertically. The magnitude and direction of the surface electric field of the atmosphere varies widely in space and time and depends on weather conditions, orography of the area, season, day, classical and turbulent electrode effects, radon activity in the subsurface air and other factors. The electric field of the atmosphere depends on the shape of the relief - it increases around the protruding elements of the landscape, buildings, high-altitude masts and weakens in the depressions of the relief, on city streets, etc. The field strength can reach hundreds of thousands of volts per meter. At a critical voltage, discharges appear - lightning between the clouds or between the cloud and the Earth. The current in the discharge is up to 70 kA, the duration is about 1 ms, the discharge power can be up to 10⁶ kV.

Studies in clear weather have shown that there is a stationary electric field at the surface of the Earth with an average intensity of about 130 V/m. Earth at the same time has a negative charge of about -3⋅10⁵ C, and the atmosphere as a whole is positively charged. The field strength is greatest in mid-latitudes, and decreases towards the poles and the equator. With a height, the field strength decreases and at a height of 10 km does not exceed several volts per meter. Only near the surface of the Earth in the mixing layer with a thickness of 300-3000 m, where aerosols accumulate, can the field intensity increase with height. Above the mixing layer, the tension of the field decreases with height.
according to the exponential law. The potential difference between the Earth and the ionosphere is 200-250 kV.

The field strength also changes over time: along with local diurnal and annual variations, global daily and annual variations in the intensity of the atmospheric field are synchronous for all items, so-called unitary variations that are associated with changes in the earth’s electrical charge, while local with changes in the magnitude and distribution of the height of the bulk electric charges in the atmosphere in the area.

The global component is usually a unitary variation in the potential of the ionosphere, having a morning minimum of 3-5 hours and an evening maximum of 19-20 UTS. The unitary variation is good at observing over the oceans [1]. With the appropriate selection and processing of data series for a large number of non-polar stations, a curve is also obtained that agrees well with the unitary variation curve [1, 3, 5]. Local perturbations are determined by electrical processes in the surface layer associated with the effect of the electrode effect near the surface of the earth, and, in particular, the presence of aerosol particles in the atmosphere [5].

The surface layer of the atmosphere is characterized by the presence of turbulent exchange processes, surface sources of ionization (radioactivity), sources of aerosol particles. The non-stationarity of turbulent thermodynamic processes is expressed as the dependence of the turbulent exchange coefficient on time, which has a diurnal variation. This leads to non-stationary electric processes in the surface layer during the day, manifested in a change with time of the electric field intensity and electrical conductivity of air in the surface layer. On the other hand, temporal variations of electrical characteristics in the surface layer may be due to the non-stationarity of electric fields and currents above the surface layer, in particular, determined by global electrical processes in the upper atmosphere.

Electricity clear weather is inextricably linked with thunderstorm electricity and is part of a distributed current loop - the global atmospheric electrical circuit (GEC).

The physical reason for the formation of GEC in the atmosphere is the sharp increase in air conductivity with height. Near the surface of the Earth, the air conductivity is very low and amounts to $(2-3) \cdot 10^{-14} \text{S/m}$, which corresponds to a concentration of light ions of about $10^3 \text{cm}^{-3}$. With an increase in altitude due to an increase in the level of ionization determined by galactic cosmic rays to 40 km, and higher by the ultraviolet and x-rays of the sun, conductivity increases almost exponentially with a characteristic scale of 6 km. Already at the height of the D-layer of the ionosphere (about 80 km), it increases by more than 10 orders of magnitude compared with the troposphere. The conductivity of the earth in the surface layer (and even more so the water in the ocean) also exceeds the conductivity of the atmospheric boundary layer by 10–12 orders of magnitude. Thus, constantly functioning thunderstorm generators are concentrated in a fairly narrow weakly conducting layer between the earth’s surface and the ionosphere.

Small discharges also occur in the atmosphere, which, in combination with high-power discharges, create significant interference to radio communications. Electrostatic discharges can damage electronics and cause fires, especially for flammable substances.

One of the special problems of atmospheric electricity is the study of electric field variations in the atmospheric surface layer of global and local origin. Experimental solution of this problem requires a long series of observations. In addition, even in conditions of “good weather” (wind speed not exceeding 6 m/s, cloudiness not higher than 3-4 points, no rain, fog, blizzards, etc.), the obtained data are significantly affected by meteorological factors, the degree 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.

**Methods and research materials**

To monitor electrophysical phenomena in the free and disturbed atmosphere by measuring the local electric field in the monitoring center of the geophysical situation over the southern region of the
Russian Federation at the FSBI «High Mountain Geophysical Institute» a hardware-software complex was created that includes: measuring the intensity of the electric field of the atmosphere EFM550 by “Vaisala” (Finland) and software for solving problems of measuring, transmitting and visualizing the values of the electric field of the atmosphere [6, 9].

The complex has been operating since 2010, 4 EFM550 electric field meters were installed in the atmosphere, they were installed in Nalchik, Cheget Peak, Kyzburun and Urvan, (Figure 1). Each of them is associated with a personal computer, on whose hard disk the values of the electric field strength of the atmosphere are recorded.

![Figure 1. Placement of sensors for electric field meters in the atmosphere EFM550](image)

Electrostatic fluxmeters EFM-100 [3]. The EFM-100 and its upgraded version of the EFM-100M allow not only to detect lightning discharges, but also to determine the state of high electric field intensity preceding the first lightning discharges. The electric field resulting from the potential difference arising during a thunderstorm reaches voltages of the order of hundreds of V/m or even units of kV/m. Lightning can be detected by a sudden simultaneous change in the vertical and horizontal components of this field near the earth’s surface.

The operation of the device is based on the principle of operation of an electrostatic generator. It consists in the fact that when a conductor is introduced into an alternating electric field, a movement of induced charges occurs in it, and the amount of current generated by the moving charges is proportional to the change in field strength. Structurally, an electrostatic fluxmeter consists of stationary measuring electrodes and a shielding plate rotating above them. The shielding plate has six sectoral notches of the same shape, placed symmetrically around the circumference, the middle line of each sector has an angle of 60° with the average lines of its neighboring sectors. The engine mounted on the housing base turns the shaft with a horizontal shielding plate mounted on it, the rotation speed is controlled by the rotation speed stabilization unit. To minimize the level of interference introduced into highly sensitive input circuits, the flat design of a brushless motor powered from a constant current source is used. The field conversion is carried out mechanically due to the rotation of the blades, resembling the wings of a windmill. When the shielding plate is rotated, the sensitive elements are periodically shielded from the action of the measured electric field, as a result of which a rapidly changing alternating current arises in the circuit connecting the measuring plate to the ground, which is processed by the electrical circuit of the device.

Data from four meters of the atmospheric electric field intensity is fed to a server designed to store the data of the atmospheric electric field strength values.

The frequency of measurements of the values of the electric field intensity of the atmosphere is 2 Hz.
Data processing results

The size and direction of the surface electric field of the atmosphere varies widely in space and time and depends on weather conditions, orography of the area, time of year, day and other factors [1, 3–5].

Figure 2 shows the weekly course of the atmospheric electric field strength on June 25, 2014 to July 1, 2014, according to four sensors — an electric field meter in the atmosphere of the EFM550.

![Figure 2](image)

**Figure 2.** The distribution of the average electric field intensity of the atmosphere in clear weather conditions according to EFM 550 sensors

The effects of the local scale for variations in the electric field are determined, among other things, by the meteorological conditions characteristic of the area [2, 7]: clouds, precipitation, fog, blizzards, dust storms cause a change in field strength with periods ranging from fractions of a second to several hours. In general, there is a close relationship between field strength and meteorological elements. Figure 3 shows how during thunderstorms the electric field changes over a wide range and can change direction to the opposite, but this occurs in a small area, directly under the thunderstorm cell and for a short time.
The exchange processes in the surface layer of the atmosphere are non-stationary due to the dependence of the heating of the atmosphere and the horizontal wind speed on time. During the day, this can lead to a change in the stratification of the surface layer and, accordingly, the space-time distribution of the ions.

**Table 1.** The distribution of the average electric field strength of the atmosphere according to the data from the sensors of the field strength meters EFM 550

| Data       | Cheget 3034 m | Kyzburun 705 m | Nalchik 536 m | Urvan 302 m |
|------------|---------------|----------------|---------------|-------------|
| 2014.06.25 | 640,224       | 54,599         | 37,577        | 104,839     |
| 2014.06.26 | 502,868       | 91,408         | 37,019        | 93,731      |
| 2014.06.27 | 470,585       | 74,181         | 66,069        | 97,971      |
| 2014.06.28 | 466,601       | -0,023         | 24,301        | 50,66       |
| 2014.06.29 | 385,645       | 6,415          | 23,663        | 59,348      |
| 2014.06.30 | 688,704       | 20,819         | 40            | 60,567      |
| 2014.07.01 | 554,583       | 35,253         | 35,065        | 89,593      |

The height of the location of the electric field strength meters is given in Table 1. You can trace the dependence of the average field strength on the height of the terrain. Although it should be said that the readings of field gauges are largely due to local features and weather conditions.

For data processing, the authors developed specialized software [8].
Summary
In the course of the conducted research, the strong variability of atmospheric-electrical quantities under the influence of meteorological conditions was noted, even in the absence of sediment-forming clouds. The most significant violations of the normal electric field occur during thunderstorm activity. All this allows the use of the electric field intensity of the atmosphere as an integral characteristic for the analysis of the operational meteorological situation in the local area.

References
[1] Anisimov S V, Shikhova N M, Mareev E A, Shatalina M V 2003 Structures and Spectra of Turbulent Pulsations of the Aeroelectric Field (Izvestiya AN. Physics of the atmosphere and the ocean) 39 (6) 765–780.
[2] Boldyrev A S, Boldyreva K A, Kupovy G V, Pestov D A, Pestova O V, Redin A A 2013 On the issue of monitoring the electric field of the atmosphere according to ground-based observations (Modern problems of science and education) 6 875-884.
[3] Imyanitov I M, Shifrin K S 1962 The current state of atmospheric electricity research (Successes of Physical Sciences) 76 (4) 593-642.
[4] Kashleva L V 2008 Atmospheric electricity (SPb., RSHU) p. 116.
[5] Kupov G V 1998 Electrical space charge in the surface layer (News of the Southern Federal University. Technical science) 3 134.
[6] Mashukov I Kh, Adzhieva A A, Shapovalov V A 2017 Study of the characteristics of the electric field strength in the surface layer from measurements of the EFM550 sensor network (Third All-Russian Conference “Global Electrical Circuit” Borok September 25 – 29) 51-52.
[7] Shapovalov V A, Adzhieva A A 2012 Analysis of the time series of meteorological parameters and their prediction in the mezorayon (Proceedings of the KBSC RAN) 1 (45) 32-37.
[8] Shapovalov V A, Mashukov I Kh 2017 Certificate of state registration of computer programs (AEFM-DM-2017 software for processing and visualization of atmospheric measurement data. № 2018618300 dated 07/11/2018).
[9] Adzhieva, A A, Shapovalov V A, Mashukov I Kh 2017 Local Sensing of Atmospheric Electric Field around Nalchik City. Advanced Environmental (Chemical, and Biological Sensing Technologies XIV, Proc. of SPIE Vol. 10215, 102150W (May 3, 2017) DOI: 10.1117/12.2279940.