Electric field measurements at mountain stations in Baksan gorge and on Cheget Peak (Elbrus region)

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Abstract. The results of long-term studies of the electric field in the atmospheric surface layer on the basis of data of continuous measurements carried out at the mountain stations located one - at the beginning of the Baksan gorge, the second – on the slope of Cheget mountain in the Elbrus region are presented. The influence of solar activity on the behavior of the electric field near the earth's surface is studied.

Introduction
The main elements of the atmospheric electricity of the surface layer are the gradient of the electric field potential, the polar conductivity of the air and the density of the vertical electric current. The set of these values determines the differential form of Ohm's law for the atmosphere. In this case, each element individually or a combination of them carries information about the processes of global or local character, occurring in the surface layer. Along with measurements of the main elements, specialized measurements of the density of the volumetric electric charge of the atmosphere, the intensity of ion formation, the concentrations of aerosol particles and the spectral characteristics of the ion composition are carried out. Additional measurements can be episodic, but it is with their help that the physically correct interpretation of the obtained data of regular observations is possible. A common task, solved on the basis of regular atmospheric-electric observations, is to obtain regime data on the electric field of the atmosphere and to identify trends in its changes. Special tasks are to study the role of global, regional and local factors in the formation of the electric field of the atmosphere; establishing relationships between electrical and meteorological quantities, determining the climatological role of atmospheric electricity, etc.

Daily variations of the electric field have two components: global and local. The role of the global component is usually a unitary variation of the ionosphere potential [1], which has a morning minimum (03h – 05h UT) and an evening maximum (19h – 20h UT). Local disturbances are determined by electrical processes in the surface layer associated with the action of the electrode effect near the earth's surface, as well as the presence of aerosol particles in the atmosphere [2]. We can assume that the continental station in the absence of significant contamination may be globally representative in the electrical respect.

Previous research
The first episodic studies of the electrical characteristics of the atmosphere in the area of Elbrus were carried out in the 30s and 50s of the last century [1]. In the period 1986 – 1988 synchronous measurements of the electric field were carried out at three mountain stations of the North Caucasus located in the Elbrus region: Cheget Peak (3040 m above sea level), Shajatmaz (2100 m) and Lower Arkhyz (2100 m) [3]. The most stable feature of the daily variations of Ez at high-altitude stations located above 2000 m is the morning minimum (01 h – 04 h UT) and the evening maximum (16 h – 22 h UT). From month to month and from station to station, only the relative values of these lows and highs change.

In the period 1989-1992 the measurements of the electric field potential gradient, conductivity of air, the ionization rate and the electrical current density were conducted by at the Peak Cheget [2]. And in 2003-2004 such atmospheric-electric observations were made at the stations Kyzburun and Peak Terskol [3]. The average amount of motes (aerosol particles) in the alpine conditions (Peak Cheget) was $5 \times 10^8$ particles in cube meter which practically does not influence electric parameters of the atmosphere. The average values of the ionization rate are 20 and 25 ion pairs/m$^3$/sec on the height of 1 m and on the surface level accordingly. Increased values of the air ionization rate in alpine regions (for example, at Voeikovo station, near Sankt-Petersburg the analogue values were 16 and 23 ion pairs/m$^3$/sec) are caused by increasing the cosmic rays intensity in alpine regions. The detailed data of atmospheric-electric observations at these stations and their analysis are given in the works [3].

**Technique and method of experiment**

The present paper analyses the data of the experimental measurements of atmospheric electric field obtained at two mountain stations in the Elbrus region, namely at the stations Peak Cheget (43°16'N, 42°30'E, 3040 m above sea level), located on the Northern slope of mount Cheget near Elbrus and Kyzburun (43°40'N, 43°27'E, 700 m above sea level), located at the beginning of the Baksan valley, 40 km from the city of Nalchik [6,7].

In our case the electric field meter EFM 550 (Vaisala) was used to record the electric field strength. In addition, for the comparative analysis of different physical and geographical conditions, the data on the electric field strength obtained in the observation points of the atmospheric electric network of Roshydromet were considered. In all points the automated measuring instruments of electric field meter "Field-2 M", worked out in the Main Geophysical Observatory (Sankt-Petersburg), are used [6].

To study the manifestation of solar-terrestrial bonds in the variations of the atmospheric electric field, the following data were used: the number of observed sunspots, the planetary index, the number of solar flares (x-ray radiation), the flow of solar radio radiation at a wavelength of 10.7 cm, (10-22 W/m$^2$). The characteristic values were obtained using geostationary operational environmental observation satellites (Geostationary Operational Environmental Satellite or GOES) GOES 15 and GOES 14 [http://tesis.lebedev.ru]. The data of measurements of the concentrations of light polar ions obtained by the counter of air ions were applied. To control the radioactivity of the atmosphere, episodic measurements of radon concentration were carried out using the AlphaGuard radiometer. The detector is a pulse ionization chamber with an active volume of 0.56 liter (alpha spectroscopy). The measurements of the equivalent dose rate of gamma radiation were carried out using a dosimeter-radiometer.

**Observation results and discussion**

Table 1 presents the results of the statistical analysis of the variations of intensity of atmospheric electric field in the mountain points of the Peak Cheget and Kyzburun for different years during the summer season. It can be noted that the average values of the atmospheric electric field vary little over the years and are close to the median value of the distribution, the range of the measured value for the summer season is wide enough and the degree of dispersion of 30-40%. In addition, the mountain
point of Cheget Peak is characterized by higher values, which is associated with the orography of the area.

**Table 1.** Statistical indicators of experimental distributions of the electric field (V/m) of the atmosphere at the stations of Peak Cheget and Kyzburun

| Observation site | Peak Cheget | Kyzburun |
|------------------|-------------|----------|
| **Year**         | 2012        | 2013     | 2014 | 2015 | 2016 | 2012 | 2013 | 2016 |
| Average          | 651         | 694      | 630  | 650  | 622  | 247  | 267  | 210  |
| Standard error   | 7           | 13       | 8    | 14   | 10   | 4    | 3    | 3    |
| Median           | 649         | 720      | 600  | 635  | 618  | 250  | 253  | 195  |
| Coefficient of variation | 32% | 33% | 37% | 32% | 26% | 33% | 29% | 35% |

Figure 1 shows typical variations of the electric field (gradient potential \( V' \)) of the surface layer of the atmosphere "good weather" with a minute averaging during the day for the winter and summer months at the Alpine station. In the winter season, the values of the atmospheric electric field during the day change little relative to the average. In summer, the daily maximum is manifested in variations against the background of a large spread of values in the daytime.

![Figure 1](image)

**Figure 1.** Variations of atmospheric electric field (\( V' \)):
1 - February, 2 - August; Peak Cheget, 2014

The daily course of the atmospheric electric field of the surface layer in the summer months in the mountain observation points is characterized by a pronounced maximum in (12h -15h UT) and a minimum in (05h – 08h UT). The maximum is in the daytime local time, which seems to be due to the action of the convective generator.

Figure 2 shows the average daily variations in the atmospheric electric field in relative values. The diurnal changes for the summer period have a good degree of consistency for both the two mountain observation points and the Carnegie curve reflecting the unitary variation. The coefficients of pair correlation of the data sets received as follows: Peak Cheget-Kyzburun – 0,79; Peak Cheget-curve Carnegie 0,73, Kyzburun-curve Carnegie – 0,53. The results obtained are in good agreement with the results of earlier studies in 1989-1992 and 2003-2005 [4,5].
The meteorological conditions at the mountain observation points are characterized by low air temperatures, as well as by a small variation between day and night values and high humidity. Table 2 shows the average values of meteorological parameters of the surface atmosphere in the summer months for the mountain peak Cheget.

![Graph](image)

**Figure 2.** Average daily variation of the electric field in the atmospheric surface layer (in % of the mean value), June-August 2014, 2016: 1 - Peak Cheget, 2 – Kyzburun

**Table 2.** Average day and night values of meteorological characteristics, Peak Cheget, 2016

|       | Temperature, °C | Wind speed, m/s | Relative humidity, % |
|-------|-----------------|-----------------|----------------------|
| Day   | 10.9            | 3               | 66                   |
| Night | 7.4             | 2.2             | 77                   |

In the conditions of small aerosol pollution of air in mountain conditions the volume charge created by aero ions in a surface layer of the atmosphere is the reason of local variations of an electric field. Concentrations of air ions for high-altitude points have consistently high values, and daily changes do not have a pronounced course characteristic of continental stations. The average concentrations of polar air ions obtained at the mountain station Peak Cheget are: 800-900 cm$^{-3}$ for positive and 500-700 cm$^{-3}$ for negative air ions. The atmosphere in mountain conditions is characterized by low level of radioactive α-radiation (radon concentration is less than 30 Bq/m$^3$) and increased level of γ-radiation in comparison with flat areas (equivalent dose rate of 0.25 µSv/h) [6,7,8].

To identify solar-terrestrial connections in the atmospheric electric field, the following data were used: the number of observed sunspots, the planetary index, the number of solar flares (x-rays) of different power classes. It should be noted that the processes of spotting and flash activity (number and power of flashes) are interconnected. And also the influence of powerful class X flashes on the geomagnetic field of the Earth is observed, the characteristic of perturbations of which is the planetary index (Ap-index).

Figure 3 shows the average daily variations in the intensity of the atmospheric electric field of the surface layer and the number of flashes of class C, M and X, with the power of x-ray flashes (W/m$^3$): C – 10-6, M – 10-5, X – 10-4.

An integral characteristic of the presence and intensity of solar flares is the flash activity index, determined from 0 to 10. In [9] it is indicated that the increase in the number of sunspots and solar radiation flux at a wavelength of 10.7 cm leads to a decrease in the electric field strength of the surface layer of the atmosphere.
Figure 4 shows the dependence of the atmospheric electric field near the earth's surface on the value of the flash activity index for two mountain points. It is possible to note the increase in the values of the electric field in the amplification of solar flare activity, and for Kyzburun this dependence is more significant.

**Figure 3.** Average daily variations of the electric field of the surface layer of the atmosphere and the number of solar flares, Cheget Peak, 2014

**Figure 4.** Regression of atmospheric electric field on the index of flare activity: 1 – Kyzburun, 2 – Peak Cheget

**Summary**

The results of the studies allow us to conclude that the high-altitude stations located in the Elbrus region, most of the time globally representative and can be recommended for monitoring the electric field of the atmosphere at the global and regional levels. At the same time, alpine stations can be used to assess and control anthropogenic impact on the atmosphere. The connection of the parameters of
solar activity with the electric field confirms the previously stated hypothesis about atmospheric
electricity as a possible mechanism for the implementation of solar-terrestrial relations

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