Introduction

Time variations of the electric field (strength or its potential) in the near-surface Earth's zone is one of the main sources of information for research (local, global factors) of atmospheric electricity. The electrical characteristics of the lower part of the troposphere (near-surface Earth's zone), where the majority of human activity occurs, play an important role in analysing the influence on the state of the environment of geophysical factors, as well as in monitoring climate change (e.g. Harrison, 2005) and space weather (e.g., Tinsley et al., 2007). Moreover, the understanding how the electric field changes over time is important for electrical prospecting in exploration for mineral deposits. In fair weather conditions, the average value of the intensity of the atmospheric electric field near the Earth's surface is of the order of 120 – 150 V/m over the oceans and 75 – 125 V/m over the continents and depends on the latitude of the observation point. The study of the average hourly values of the electric field obtained from the Carnegie research vessel in the Atlantic and Pacific oceans from 1909 to 1929, during fair weather, allowed the daily electric field (Carnegie's curve) to be obtained (Torreson et al., 1946). In marine and Arctic and Antarctic areas, the diurnal variation of the potential gradient (the vertical component of the strength) of the electric field basically has one maximum and one minimum, due to global thunderstorm activity. In land areas, the daily variation has the character of a double wave with two minima in periods from 4 to 6 LT (local time) and from noon to 16 LT and two maxima in periods from 7 to 10 LT and from 19 to 22 LT (Chalmers, 1967).

In the present work, daily variations in the vertical component of electric field strength during fair weather and their seasonal variability are researched in the conditions of the mid-latitude Geophysical observatory "Mikhnevo" of Sadovky Institute of Geosphere Dynamics of Russian Academy of Sciences.

Initial data

As initial data in this research, data were collected for recording the vertical component of the electric field strength at the Geophysical observatory “Mikhnevo” (54.959° N; 37.766° E) from January 2015 to December 2017. The observatory is located 85 km south of Moscow, in Mikhnevo settlement. Continuous digital recording of the electric field strength is carried out in conditions characterized by the absence of industrial and other anthropogenic pollution, as well as a low background level of electromagnetic interference. Measurements of the field strength are carried out with the help of an electrostatic fluxmeter INEP mounted on the roof of the laboratory building of the observatory. The electrostatic fluxmeter is suitable for measuring the electric current in the frequency range from 0 to 10 Hz with amplitudes from 1 to 5000 V/m with an accuracy of ± 5%. The data is recorded in UTC. The difference between universal time and time at the observation point is 3 hours: UT = LT – 3 hours. At the same time, meteorological parameters and the geomagnetic field were recorded to identify the so-called fair weather conditions, i.e. days without precipitation, thunderstorms, fogs, at a wind speed of less than 6 m / s, in the absence of cloudiness (Reiter, 1992), as well as for weak geomagnetic activity (K ≤ 3). Depending on the year, season and month, the number of selected days ranged from 2 to 9 per month.

Daily variations in the strength of the atmospheric electric field

It should be noted that the dynamics of the electric field strength in the near-surface zone of the atmosphere is formed by the non-uniform distribution of charges in the vicinity of the observation point, which in turn depends on several factors acting on different space-time scales. Therefore, in variations of the potential gradient (vertical component of the strength) of the electric field $E_z$, in fair weather conditions, it was not always easy to identify a typical daily variation. In general, the daily variation during fair weather at the observatory "Mikhnevo" showed a typical continental variation with two maxima of strength (potential gradient) of the electric field.

The averaged diurnal variations have the character of a double wave with two maxima and two minima (Figure 1). The first maximum of the electric field strength is observed between 10 and 12 LT (local time), and the second maximum at 22 LT; the corresponding minima are observed at 6 and 18
LT, respectively. The increase in the electric field strength in fair weather conduction in the morning hours and the first maximum of strength are explained by local factors, namely, the "sunrise effect" and the change in the concentration of aerosols in the near-surface zone of the atmosphere. The morning maximum ("sunrise effect") is due to the onset of convection in the boundary layer of the atmosphere with a change in its temperature and an upward charge transfer of the low-lying electrode layer and, consequently, an increase in the electric field charge (Chalmers, 1967). The presence of aerosols acting as ion recombination centres has a direct effect on the local conductivity of the atmosphere, decreasing the mobility of the ions attached to them (Harrison, Carslaw, 2003). Reduction of local conductivity under the assumption of a constant conduction current between the ionosphere and the Earth's surface leads to an increase in the potential gradient (strength) of electric field in the near-surface zone of the atmosphere in accordance with Ohm's law (Harrison, 2006). After the first maximum, the potential gradient is decreased, and eventually it reaches a minimum level at 18 LT. This is explained by the maximization of convective conditions at the end of the day, which can lead to a decrease in the concentration of aerosols near the surface of the Earth. Aerosols are transferred upward, which leads to the restoration of the ion concentration. Thus, the local conductivity increases, and then the potential gradient decreases (Serrano et al., 2006; Silva et al., 2014). The movement of aerosols gradually provides an additional reduction in the potential gradient due to a decrease in the conduction current (Harrison, Bennett, 2007). The second maximum at 22 LT and minimum at 06 LT coincide with the corresponding extreme of the Carnegie curve at 19 and 03 UT, due to the daily variations of global thunderstorm activity. However, both extremes are susceptible to local effects, which can amplify or suppress the global signal. The convective conditions maximized earlier, which caused a minimum of 18 LT, were gradually weakened, which led to an increase in the aerosol concentration near the Earth's surface and subsequently to an increase in the potential (Latha, 2003). The magnitude and concrete moment of the influence of local factors on the variation of the electric field is not easy to determine; therefore, additional variables, such as aerosol sounding, conductivity and radon emanation measurements, etc., are needed.

**Figure 1** Average daily variation of the vertical component of the electric field in fair weather conditions at the Geophysical observatory "Mikhnevo" for the period from January 2015 to December 2017. Error bars indicate the standard deviation in each hour.

In present research a positive correlation (Pearson correlation coefficient 0.765) between the average daily variation at the observatory "Mikhnevo" and the unitary variation (the Carnegie curve (Harrison, 2013)) is established, although the differences exist because of the strong differences in the measurement sites (the observatory is located on the mid-latitude Russian platform, Carnegie "were performed in the northern and central part of the Pacific Ocean). Nevertheless, the minimum values of about 02 - 03 UT at both sites are in good agreement and correspond to low global thunderstorm activity. In addition, the maximum value of potential gradient (vertical component of the strength) of the electric field $E_z$ in both curves is recorded at about 19 - 21 UT. The key difference between the two curves is the second maximum observed around 07 - 09 UT (10 - 12 LT), which does not correspond to the shape of the Carnegie curve.
Seasonal variations in the intensity of the atmospheric electric field

In winter, the daily values of potential gradient (vertical component of the strength) of the electric field $E_z$ are lower compared to the summer period, and the spring and autumn values are between them. The potential gradient at the high-latitude Norwegian station "Karasok" (Adlerman, Williams, 1996) and at the observatory "Wise" in the Mediterranean desert (Yaniv et al., 2016) and the global thunderstorm activity in the Northern Hemisphere have a similar seasonal dependence (Cecil et al., 2014). The seasonal dependence of the electric field potential gradient obtained in the present study is in agreement with the results of the analysis of data obtained at the observatory "Vostok" (Antarctica) and seasonal variations of the global current or Schumann resonances measured at the observatory "Nagycenk" (Hungary) (Corney et al., 2003).

It should be noted that the winter maximum in the potential gradient of the electric field in the Northern Hemisphere, first is established by Lord Kelvin in 1860 and subsequently confirmed in the course of scientific expeditions on the vessels "Carnegie" and "Maud" (Parkinson, Torrason, 1931) and measurements of the electric field at 60 continental observatories (Paramonov, 1950), does not correspond to modern concepts of global thunderstorm activity (Mezuman et al., 2014) and on seasonal variations of meteorological parameters and the ionospheric potential (Williams, 1994). It was suggested that the incorrect conclusions about the seasonal variations in the gradient of the electric field potential could be brought about by the fact that the analysis (Parkinson, Torrason, 1931) was based on a small sample, only 82 days (out of 1248 days of observations of the seventh cruise of the Carnegie's science vessel), of which summer days were only 7. Repeated analysis with inclusion of data from other cruises made it possible to more accurately determine the seasonal change in the electric field potential gradient, with the maximum of the electric field potential gradient in the summer months of the Northern Hemisphere coinciding with the maximum in global thunderstorm activity (Adlerman, Williams, 1996; Harrison, 2013).

Conclusion

The present research the results of observations of variations in the vertical component of the Earth's electric field strength at the Geophysical observatory "Mikhnevo" of Sadovsky Institute of Geosphere Dynamics of Russian Academy of Sciences (Moscow Region, Mikhnevo settlement) from January 2015 to December 2017 are analysed. The average daily variation in fair weather conditions showed a typical continental double wave variation with the first maximum between 10 and 12 LT and the second maximum at 22 LT. The first maximum is probably due to local factors, in particular, the "sunrise effect" and the change in the concentration of aerosols in the near-surface layer of the atmosphere. The second maximum is explained by global factors, since the time of its occurrence coincides with the maximum of the Carnegie curve. A positive correlation is established between the averaged diurnal variation at the observatory "Mikhnevo" and the unitary variation (Carnegie's curve). In winter, daily values during fair weather are lower compared to the summer period, and spring and autumn values are between them.

To determine the magnitude and the specific moment of local factors influence on the formation of temporal variations in the vertical component of the strength (potential gradient) of the electric field, more detailed analysis is required involving additional data, in particular, measuring the variation of electrical conductivity in the Earth's atmosphere, aerosol sounding, etc.

References


