

Relationship of precipitation intensity in the form of snow with atmospheric electricity and radio-thermal radiation of the snow cover

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Abstract. Remote radiophysical methods using artificial satellites of the Earth allow to determine physical and chemical parameters of the atmosphere. For this purpose, calibration subsatellite measurements are necessary. One of the natural phenomena to be studied is precipitation in the form of snow. This paper presents the results of ground-based measurements of radio-thermal radiation of snow cover at two wavelengths 0.88 cm and 1.35 cm, as well as the results of measurements of the variation of the vertical component of the surface atmospheric electric field strength during snowfall. The measurements were made near the ice-water phase transition temperature. The research site is located in the city of Chita (Russian Federation). A strong influence of air temperature on the measured values, especially at the ice-water phase transition temperature, was found.

1 Introduction

The atmosphere has been an object of study for researchers for a long period of time. During this time, it has been possible to accumulate a lot of knowledge about the processes and phenomena that occur in the atmosphere by various methods. One of them are radiophysical methods, both active (radar) and passive (radiometric). Thus, it is possible to determine its integral characteristics (temperature, humidity) by measurements of radio-thermal radiation of the atmosphere, which is shown, for example, in [1, 2]. However, the existing radiophysical methods do not allow determining the features of atmospheric electricity (the exception is the study of lightning discharges [3, 4]), therefore, for this direction of research it is necessary to use other measurement techniques.

Knowledge of the state of the electric field is necessary to find local and global meteorological effects, which to a greater extent cause changes of electricity in the atmosphere. This is especially relevant for cities whose atmospheric air contains a large amount of pollutants.

Also, atmospheric electricity has both positive and negative effects on the human body, as well as on all biological processes occurring on Earth, so it is necessary to know about its changes in different periods of time. Such data, for example, on the variations of the vertical component of the electric field strength for the city of Chita are not available.

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The atmospheric electric field is influenced by many parameters studied in such sciences as meteorology, geophysics, etc., such as wind speed, cloudiness, precipitation, surface air pollution, etc. In this connection, more experimental data are needed, which will contribute to the expansion of knowledge in the field of the atmosphere and the processes occurring in it.

This work utilized a joint study of the intrinsic radio-thermal radiation falling on the snow surface and the vertical component of the atmospheric electric field strength of the surface layer of the atmosphere, which are currently under-lighted.

Studies of the atmospheric electric field strength under different weather conditions were performed in [5, 6]. For example, variations of the atmospheric electric field strength occur during precipitation. These values can reach 2 kV/m. In [7] daily and seasonal variations of the value of the vertical component of the atmospheric electric field strength were revealed. In [8, 9] a correlation between the electric field strength and air pollution was shown. Another example is the work [10], in which the correlation between atmospheric electricity and radio-thermal radiation of the atmosphere was established when a thunderstorm front passes over the observation site in the summer season. According to the joint data of own atmospheric thermal radiation received by radiometric receivers and changes in the values of the electric field strength of the surface layer of the atmosphere, it is possible to estimate the power of a thunderstorm front passing over the observation site.

2 The method of the experiment

Measurements of radio-thermal radiation of snow during its deposition on the surface were made at wavelengths of 1.35 cm and 0.88 cm using radiometric receivers with a sensitivity of 0.1 K at a time constant of 1 s. The vertical component of the atmospheric electric field strength was determined using an electrostatic fluxmeter, the operation of which is described in more detail in [11]. Radiometric receivers and the electrostatic fluxmeter were installed at the experimental site of the Institute of Natural Resources, Ecology and Cryology of the Siberian Branch of the Russian Academy of Sciences (INREC SB RAS) in Chita. Figure 1 shows the scheme of the experimental setup. Radiometric receivers measured the intrinsic thermal radiation of concrete, which thickness was about 15 cm. Below it the sand mixture is located. In the study region, the thickness of ground freezing is several meters and can reach 10 meters in places. This effect is related to low snow winters and low temperatures during winter time. The measurements were performed in spring time, when the temperature in the ground up to the depths of 6 meters had a negative value. The radiometers were installed at an angle of 45° relative to the vertical. Figure 1 shows the scheme of the experimental setup. The radiometers were calibrated using a black body standard and reflected thermal radiation of a cloudless atmosphere with low water vapor content from a metal sheet.

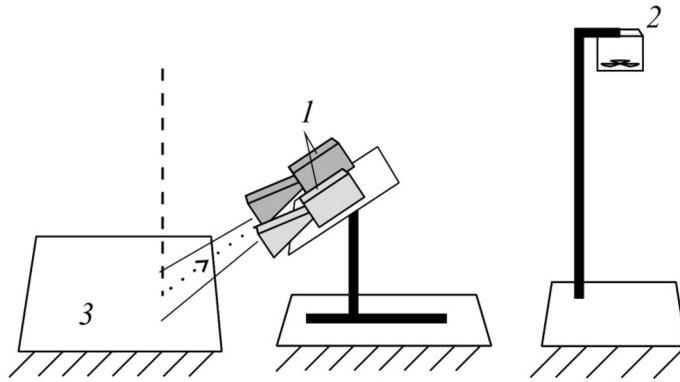


Fig. 1. Scheme of the experimental setup (1 - radiometric receivers; 2 - electrostatic fluxmeter; 3 - concrete platform).

3 Results and discussion

Two time intervals were selected to examine the effect of snowfall on the surface radio-thermal radiation and on the values of the atmospheric electric field strength: from March 13 to 14 and from March 21 to 22, 2023. During these time intervals, snowfall occurred at temperatures of $-5\text{ }^{\circ}\text{C}$ and $0\text{ }^{\circ}\text{C}$, respectively. Figure 2 shows the obtained results of the effect of snowfall on the radio brightness temperature of the object and on the vertical component of the electric field strength in the surface layer of the atmosphere.

At snowfall from March 13 to 14, the values of electric field strength (E) decrease by $10\text{...}20\text{ V/m}$. On the plots of the values of radio brightness temperature (T_b) at the wavelengths (λ) of 0.88 cm and 1.35 cm , variations of radio brightness temperature characterizing the radio-thermal radiation power are observed, which is related to the initial period of precipitation time. When the thin intermediate layer of snow lying on the semi-infinite layer increases, interference is observed as a result of the reflection of electromagnetic waves from the upper layer of snow and the interface of media (snow - concrete). The intensity of precipitation on this day was low and for the entire selected observation time interval the snow thickness amounted to a value of about 1 cm . After midnight, there was a sharp jump in the electric field intensity, up to 100 V/m . During this period of time there was an increase in the intensity of snowfall. This fact is characterized by the change in the frequency of the interference pattern from time. It should be noted that the value of the electric field decreased on average due to the increase in absolute air humidity.

During snowfall from March 21 to 22, the values of electric field strength increased and reached about 700 V/m (Figure 2b), which is explained by the high intensity of precipitation. Figures 2d and 2f show the values of radio brightness temperature at wavelengths of 0.88 cm and 1.35 cm . At the onset of snowfall, there is a sharp decrease in T_b , which is due to the appearance of a relatively thin layer of water formed by the melting of the falling snow on the surface of the concrete. The high intensity of precipitation is evidenced by the interference pattern of radio-thermal radiation with increasing values of T_b .

The difference in the behavior of the electric field strength values is explained by the intensity of snowfall and ambient air temperature. In general, the atmospheric electric field depends on the conductivity of the atmosphere. With increasing humidity, increasing concentration of particles, dust, fogs the conductivity of the atmosphere increases. Under the influence of technogenic impact on the atmosphere of cities, the conductivity of the atmosphere in general decreases. Increase in humidity of the atmosphere leads to a decrease in aerosol particles, which indicates that under the influence of water vapor in the atmosphere

can occur not only an increase in the value of the atmospheric electric field, but also its decrease. However, there is a complexity of the influence of the phase transition on the values of the electric field strength.

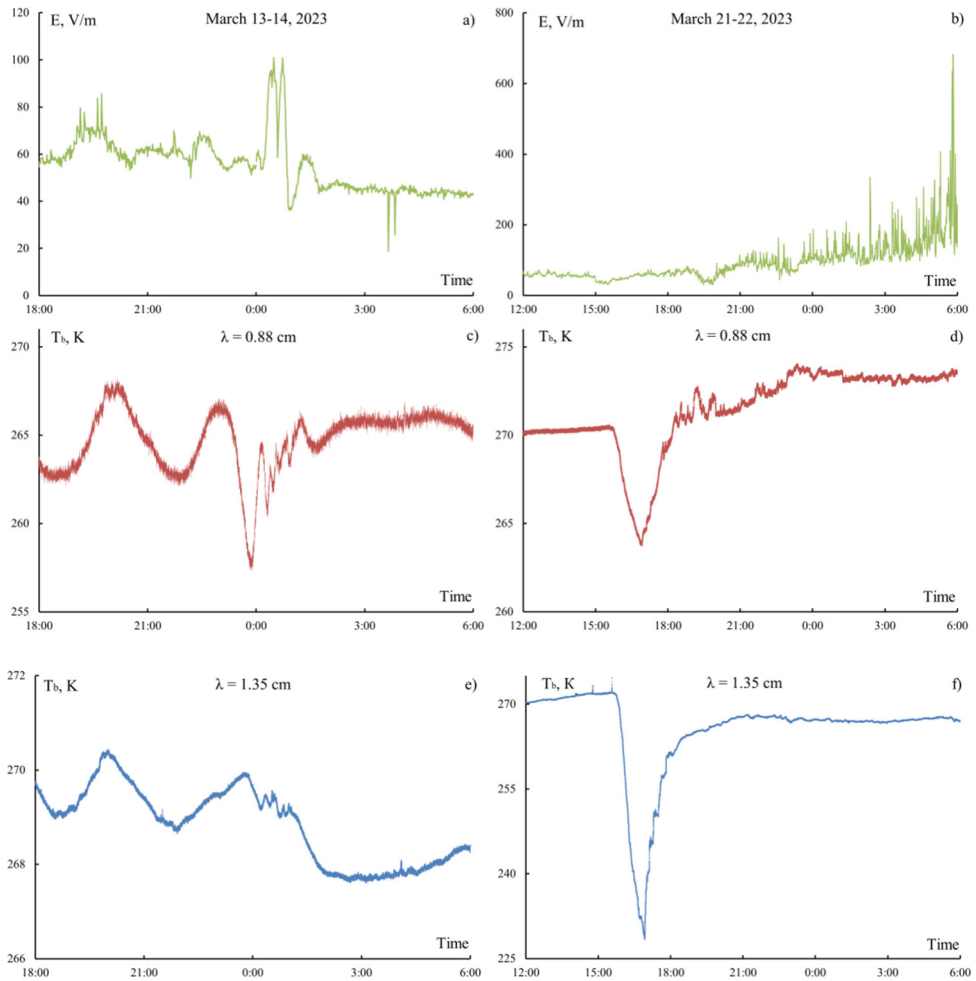


Fig. 2. Plots of a,b) - surface layer atmospheric electric field strength and radio brightness temperature at wavelength: c,d) 0.88 cm; e,f) 1.35 cm. Local time.

4 Conclusion

Thus, during precipitation in the form of snow, strong variations of the intensity of the vertical component of the electric field in the surface layer occur. They depend on many factors, in particular, on the intensity of snow precipitation and ambient temperature. As for the radio-thermal radiation power of a snow cover of relatively small thickness, the interference of radio brightness temperature is observed, depending on the value of the snow layer thickness. At the water-ice phase transition temperature, the values of the radio-IR temperature of the snow cover and the reflected radiation of the atmosphere sharply decrease due to the formation of a thin water layer. The interference also practically disappears when the thickness of the snowfall layer changes.

These results will be of interest to specialists in the field of geoecology and meteorology in the processing of satellite radiometry data.

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