Variations of atmospheric electric characteristics in the troposphere and stratosphere

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The sensing of the electric conductivity of the atmosphere, the electric field strength, and the vertical conduction current was carried out at some stations in Japan in 1966–1971. More than 600 balloon launches are considered. Annual and diurnal variations and vertical profiles of electric characteristics are presented, and the relation of electric characteristics to atmospheric cloudiness and pressure is analyzed.

Main problem of atmospheric electricity measurements on the ground and in free atmosphere is determination of relations between global and local generators of electric charges, and, hence, electric field in the atmosphere.

The relation between local and global atmospheric electric characteristics is expressed as

$$U / R = E\lambda,$$

where U is the potential of high atmospheric layers relative to the ground, R is the total resistance of the atmospheric column, E and λ are the electric field strength and the electric conductivity of air, respectively.

Observations of E and λ near the ground surface fail to explain the reasons of their variations. They can be related both to global effects leading to a change of the potential of high layers and to change of the total resistance of atmosphere (for example, under the effect of ionization by cosmic rays), they can be caused by local effects (different meteorological phenomena and anthropogenic factors) as well. The global characteristics (U and R) cannot be measured directly. They are determined through integration of the measured $E(h)$ and $\lambda(h)$:

$$U_h = \int_0^H E(h)\mathrm{d}h; \; R_h = \int_0^H \mathrm{d}h / \lambda(h),$$

where H is the height of the upper boundary of sensing, and h is the current coordinate.

The parameters U and R, calculated in that way, depend on the local conditions in the lower atmospheric layers, and they do not reflect global processes. At the same time, the interest to these parameters is caused by the fact, that they are principal in the existing models of electric processes.

In this work, we use data of the World Data Center (WDC) on the electric field strength, electric conductivity of air at different heights, and the vertical current of the conductivity.[1–4]

The database including the cloudiness data and the NCER / NCAP Reanalysis data on atmospheric pressure (the height in geopotential decameters and the atmospheric pressure reduced to the sea level) was created based on the results of sensing. The data of radiosensing of the atmospheric electric parameters obtained at the stations of Kagoshima, Sapporo, Tateno, Hashijojima in Japan and Syowa in Antarctica are involved in the WDC materials. The measured parameters were the following: the electric field strength, vertical current of conductivity, and the conductivity of air. The geopotential data obtained at the station Weissenau in South Germany are contained in WDC collections.

All data on the potential of the atmosphere in Weissenau are shown in Fig. 1. The mean value over the entire period of observations is 282 kV, and that over the period of joint measurements from 1966 to 1971 is 284 kV. From the data of Japanese stations over 1966–1971, this value makes 308 kV.

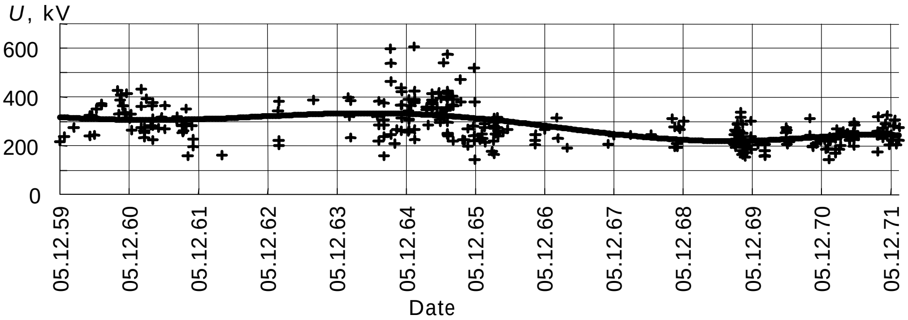

Fig. 1. Difference of the ground–atmosphere potentials at Weissenau.

Note that the spectrum of the potential values is very wide. They can essentially vary even during a day.

Distributions of E and λ over all balloon launches are shown in Fig. 2. The distribution are constructed for heights of 5, 10, 15, 20, 25, and 30 km for all cases of balloon launches at Japan stations, because they are situated quite close to each other, and the height of their locations is changed insignificantly.

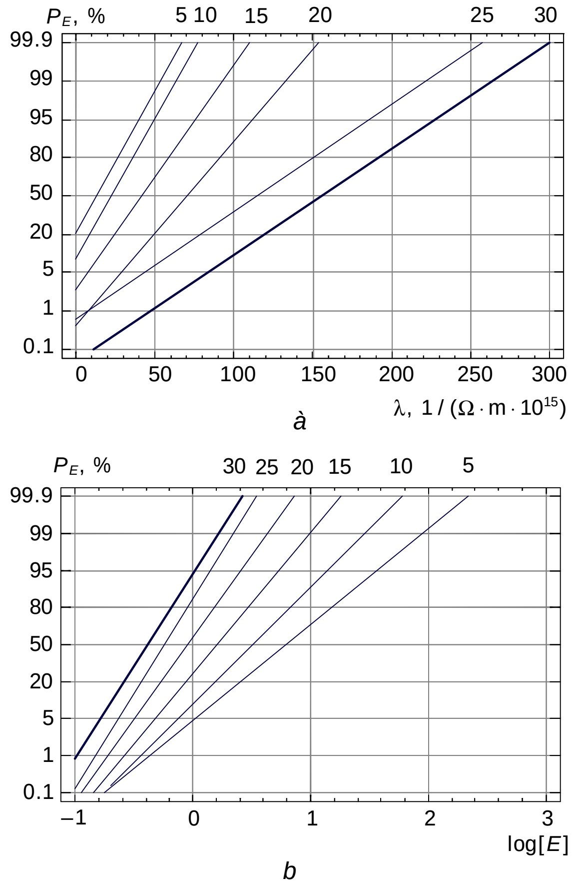

Fig. 2. Height distributions of λ (*a*) and E (*b*).

Annual behavior of the electric conductivity of air at all heights over Japan has a very complicated shape. The main maximum is observed in August–September, and the main minimum is in April–May. It is difficult to judge about the daily λ, because the fixed time of sensing was 0, 6, and 12 a.m., and 6 p.m. GMT. However, the values of conductivity have a maximum at 6 a.m. (3 p.m. of zone time), and the amplitude of the diurnal behavior is 40–50% at all heights. Annual behavior of the conductivity current essentially depends on the height in the atmosphere and has a main maximum in October–November, and a minimum in March. Annual variations of the field strength have the amplitude of about 40% with a main maximum in October–November and minimum in March–April. The maximum in the diurnal behavior of the field strength and the potential falls on the evening hours GMT.

Analysis of E values at different cloud amount and different cloud layers shows that the vertical profile of the strength up to the height of 10 km strongly depends on the cloud amount. Cloudiness, especially the low-level clouds, strongly decreases the resistance of the atmospheric column. The mean profiles of the electric field strength at different cloud amounts of the low-level cloudiness are shown in Fig. 3.

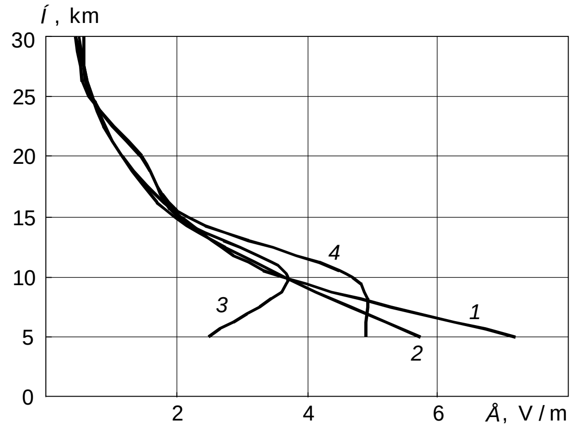

Fig. 3. Mean profiles of E at various cloudiness: 0 (*1*); 1–5 (*2*); 5–10 low-level cloud amount (*3*); 5–10 total cloud amount (*4*).

The variation coefficients of the E values at the height of 5 km at cloud amount of 5–10 are 3.2, and at the height of 20 km they are 1.23. The variation coefficients at heights of 5 and 20 km at cloud amount of 0–5 are 1.7 and 0.6, respectively.

Comparison of the sensing data on electric parameters and heights of isobaric surfaces shows their sufficiently close correlation. The air conductivity at a height of 30 km correlates with the height of isobaric surfaces from 500 to 150 hPa with the coefficient of 0.5. Negative correlation is observed between the heights of isobaric surfaces and the air conductivity at heights of 10–15 km. The field strength at a height of 30 km correlates with the heights of isobaric surfaces with the coefficient of –0.47. Such dependences can be explained by ionization action of cosmic rays and the effect of the atmospheric pressure on their intensity.

References

1. *Results of Observations of Atmospheric Electricity. World Network* (Gl. Geofiz. Obs., Leningrad, 1971), 50 pp.
2. *Materials of Observations of the Strength of Electric Field of the Atmosphere at Different Heights from the Data of Sounding in 1966–1971* (Gl. Geofiz. Obs., Leningrad, 1973), Part 1, 112 pp.
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