Annual variation of atmospheric electricity diurnal variation maximum in Kamchatka

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Abstract. Atmospheric electric field diurnal variation measured in fair weather conditions over the ocean surface has a typical form which is called a unitary variation. It is associated with the global time and occurs simultaneously all over the planet. However, the diurnal variation, measured over the ground, depends on many local factors. The diurnal variation maximum of the electric field potential gradient, measured at Paratunka observatory, has the maximum close in time to the unitary variation maximum. In the paper we show that this maximum is determined by local conditions and is associated in time with the sunrise. The diurnal variation maximum of the electric field potential gradient, measured at Paratunka observatory in fair weather conditions, has annual variation coinciding with the annual variation of local sunrise.

1 Introduction

In fair weather conditions, a characteristic diurnal variation of the electric field potential gradient (PG) is observed over the oceans. This diurnal variation does not depend on local time and is observed simultaneously throughout the planet. It was called the unitary variation (UT variation). UT-variation is determined by thunderstorm activity all over the globe. The maximum variation is observed around 19 hours of universal time (UT) [1, 2]. Local time (LT) at Paratunka observatory is 12 hours ahead of UT. Thus, the UT variation maximum occurs durning the morning hours for the observation point. But in the morning time, besides the UT-variation, other mechanisms work as well.

At the observatories located on the continents, the effect of morning maximum is observed in PG diurnal variations [3–5]. Brown [3] explained this effect as follows. During the night, positively charged condensation nuclei are accumulated in the exchange layer of the atmosphere, and in the morning, as air temperature increases, these nuclei are transported upward as a result of turbulence and convection processes in the atmosphere. In the paper [5] the author investigated the statistical characteristics of the sunrise effect at Paratunka observatory. The work [6] gave physical explanation of this phenomenon.

Paratunka observatory is located 30 km from the Pacific coast. PG measurements can be influenced both by local and global factors. The authors set the task to find out if the morning maximum of the PG daily variation at the observatory are caused by the UT variation or by the sunrise effect.

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2 Measurement methods

Measurements of atmospheric electricity at Paratunka observatory are carried out with the Pole-2 fluxmeter. It was developed at the Voeikov Main Geophysical Observatory, Russia. Since 2016, simultaneously with the Pole-2 sensor, the measurements have been carried out with the CS110 sensor developed by Campbell Scientific, Inc., USA. The article [7] shows the identity of the measurements carried out by the both sensors. Double control of the measurements carried out by the instruments from different manufacturers increases the quality and liquidity of the data.

The electrical parameters of surface atmosphere are highly dependent on meteorological conditions at the observation site. Measurements of meteorological parameters (temperature, air pressure, wind speed and direction, precipitation level) are carried out by Davis digital weather station with 10-minute interval -. When processing the data of PG diurnal variations , the meteorological situation on the selected days is taken into account.

In Fig. 1 shows the shape-stable diurnal variations in PG under fair weather conditions. The data were processed from January 1, 2004 to November 1, 2020. The statistics included variations in fair weather conditions with a maximum after 17h local time. During the period under the study there were 300 such daily variations.

3 Main results and discussion

We made a Table with the data on the time of astronomical sunrise for the geographical point, where the Paratunka observatory is located (52.97° N; 158.25° E) , and the time of PG daily cycle maximum. Then the data were sorted in ascending order. Then approximation was carried out by the formula

$$Y = AX + B, \tag{1}$$

where X is the sunrise time in hours, Y is the PG maximum time in hours. If the coefficient A in this formula is close to zero, then the PG maximum at Paratunka observatory is determined by the UT variation. If the coefficient A is close to 1, then the PG maximum is determined by local factors. In Fig. 2, the abscissa shows the sunrise time for the observation point, and the ordinate shows the time of the PG maximum. The dots indicate the observed maxima of the PG daily variation in fair weather conditions, and the straight line shows their approximation by formula 1. As a result of the approximation, we obtained A = 0.92, B = 2.5, root-mean-square error = 0.03. The correlation coefficient is 0.9. Thus, the time of the PG daily cycle maximum shifts during the year following the time of sunrise in the region.

The physical mechanism of this phenomenon is as follows. The density of electric current in the absence of lightning sources is written as:

$$j = \lambda E + \rho V + D_t \nabla \rho, \tag{2}$$

where λ is the atmospheric electrical conductivity, the main contribution to it is made by light ions; E is the electric field strength; ρ – is the electric charge density; V is the medium hydrodynamic velocity; D_t is the turbulent diffusion coefficient. In the quasistationary case, the current density is determined by the first term and is attributed to the action of thunderstorm generators. The first term in formula 2 is responsible for the conduction current, which is determined by to the discharge current in the areas of fair weather in the global electrical circuit. After sunrise, the main contribution to the electric current density is made by the second and third terms of formula 2. As a result of turbulent heat transfer, turbulent mixing processes $(D_t \nabla \rho)$ come into action and the positive space charge, accumulated near the earth's surface
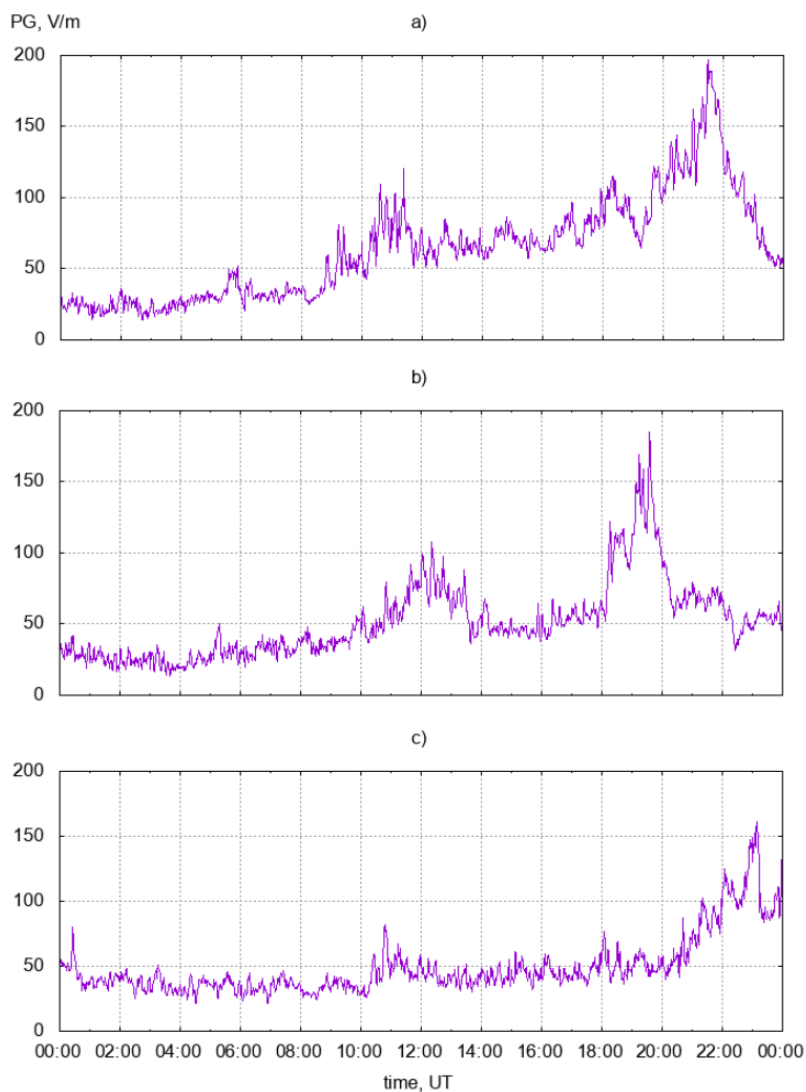
Figure 1. PG daily variations (a) for October 26, 2012, (b) for August 25, 2016, (c) for February 12, 2020.

at night, is transfered upwards (ρV) by a convective air flow . That, in its turn, leads to PG increase near the earth's surface and electric conduction current amplification. This mechanism is confirmed by experimental data. The PG daily variation with a maximum in the morning correlates with the difference in air temperatures measured at different heights [6].

To clarify the question of when a stable PG daily variation with a maximum in the morning appears, a histogram of the distribution of such days over months was made (Fig. 3). It
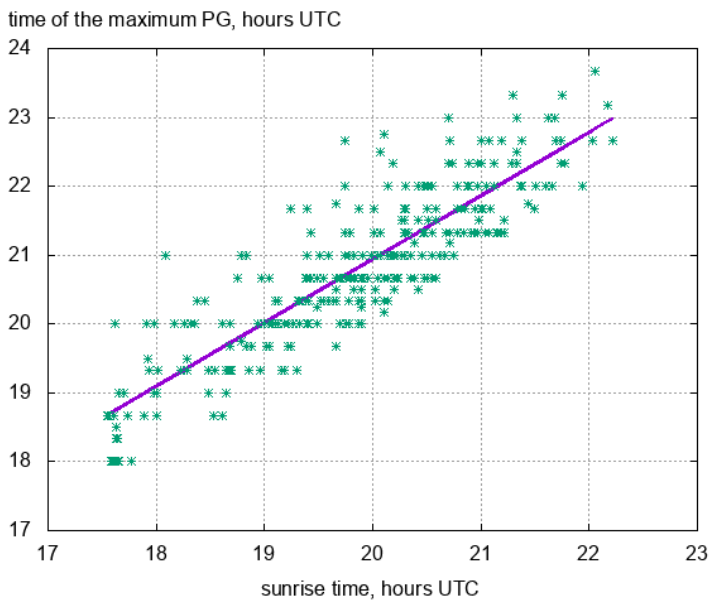
Figure 2. The stars indicate the PG daily cycle maxima. Straight line is the value linear approximation. The abscissa axis is the sunrise time, the ordinate axis is the time of the PG daily cycle maximum.

turned out that the most often the PG daily variations with maximum values in the morning hours in fair weather conditions appear in March and October.
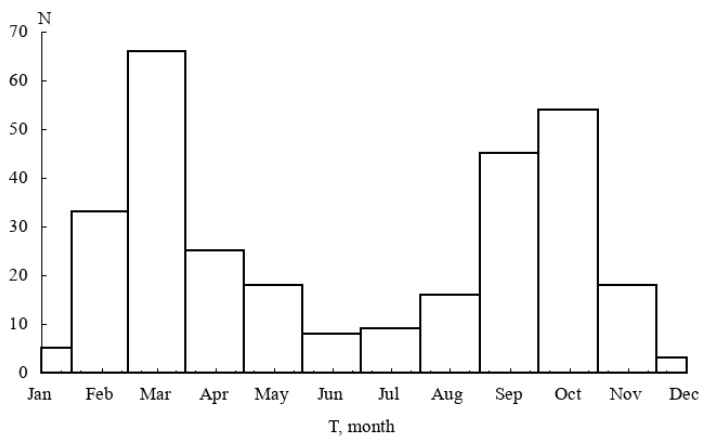

Figure 3. Histogram of the distribution of the number of days with the PG morning maximum over months.

4 Conclusions

1. In fair weather conditions, the maximum daily variation of atmospheric electricity in the surface layer is determined by the sunrise effects.

2. Most often, characteristic days with a maximum in the atmospheric electricity daily variation are observed in March and October.

Funding

Acknowledgements

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