

Solar Activity and Its Reflection on the Dynamics of Diurnal and Seasonal States of the Atmosphere and High Mountain Landscapes

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Abstract – The solar wind has a strong influence primarily on the outer shells of the Earth (the magnetosphere and the ionosphere). As a result, it affects the potential difference between the ionosphere and the Earth's surface as well. The paper presents the results of the performed analysis of the relationships between the daily variation of the solar wind characteristics (solar wind velocity values, ion concentrations) and the electric field intensity an important experimental basis for modern research. Monitoring in the highland areas is characterized by the fact that there is almost no anthropogenic component in the formation of the electric field.

Keywords – solar wind; charged particles; flare plasma; electric field; Earth's atmosphere; electric field intensity; solar wind velocity.

I. INTRODUCTION

Solar wind is an important factor in the formation of the electric field of the atmosphere. The solar wind is a stream of charged particles (plasma) that carries away the magnetic lines of force of the Sun and flows around the Earth's magnetosphere.

You can find the electric power being received by the Earth in the solar wind using the expression:

$$I = n \cdot V \cdot S \cdot q, \quad (1)$$

where n is the concentration of particles; V is the speed, q is the elementary charge. S - the surface area of the sphere, is determined by the expression:

$$S = 4\pi R^2, \quad (2)$$

where $R \approx 300$ km is the size of the zone accessible to the solar wind particles, $q = 1,6 \cdot 10^{-19}$ C is the electron charge.

of the atmospheric surface layer. The diurnal variations of the electric field in the surface layer of the atmosphere are caused by both global and local factors. Their contribution to diurnal and seasonal variations in the electric field of the atmosphere has not been studied enough. Long-term ground-based observations of variations in the parameters of atmospheric electricity are

As it can be seen from expression (1), the amount of electric charge received by the Earth is determined by the concentration and velocity of charged solar particles. It is the upper layer of the atmosphere (i.e. the magnetosphere and the ionosphere) that takes the main effect of the solar wind.

Solar flares and different plasma outflow rates from different regions of solar surface result in the formation of interplanetary shock waves in the interplanetary space, which are characterized by a sharp jump in velocity, density and temperature. The mechanism of their formation is shown qualitatively in Figure 1. Solar activity affects highland terrains and the state of the atmosphere.

When a fast plasma flow catches up with a slower one, an arbitrary discontinuity of parameters occurs at the place of their contact, where the laws of conservation of mass, momentum and energy are not implemented. Such a discontinuity cannot exist in nature and thus disintegrates, in particular, into two shock waves and a tangential discontinuity (in the latter, the pressure and the normal velocity component are continuous). It is shown in Fig. 1a for the flare process on the Sun and in Fig. 1b, in the case when a fast stream from one region of the solar corona catches up with a slower one, flowing out of another region. The shock waves and tangential discontinuities shown in Figure 1 are carried by the solar wind over large heliocentric distances and are regularly recorded by spacecraft.

Currently, a number of countries are constantly monitoring the solar wind [1, 2].

Thus, the solar wind is a physical phenomenon, which is an important factor that must be considered not only when studying the processes occurring in the vicinity of our planet Earth, but also processes in near-earth space, as well as in the atmospheric surface layer, which affects our lives. This is due to the fact that the high-speed streams of the solar wind, flowing around the Earth, affect its magnetosphere, which is directly connected with the lower layers of the atmosphere. Such an influence is strongly dependent on the processes occurring on the Sun, since they are associated with the emergence of the solar wind itself.

$$E = \frac{V_{\text{Sun}}}{R \cdot \lambda} \quad (3)$$

where V is the potential of the ionosphere with respect to the Earth, R is the resistance of the air column under the measurement site, λ is the conductivity of air, E is the field intensity in the atmosphere.

Thus, the parameters of the atmosphere (composition, concentration and temperature of neutral and ionized particles), as well as microprocesses occurring with them, and dynamic processes of the medium should be studied in close connection to each other in order to solve the ionization balance problem in the ionosphere and control its condition.

II. METHODS AND MATERIALS

Studies of the relationship between the characteristics of the solar wind and the dynamics of the electric field of the surface layer of atmosphere have practically not been carried out, although the fact of such a connection has been noted by a number of researchers [2-5]. The main reason here is the difficulty of identifying the share of various factors (weather, anthropogenic, ionospheric, thunderstorm, etc.) that form the dynamics of the field of the surface atmosphere.

The method of controlling the electric field of the atmosphere under the action of the solar wind, developed at High-mountain Geophysical Institute, is based on recording the electrical characteristics of the atmosphere, at an altitude of 3 thousand meters above sea level, in an ecologically unpolluted area (Cheget peak in Elbrus region), while simultaneously monitoring weather phenomena in the study area.

Due to the uniqueness of the station location, it is possible to study the relationship of the upper layers of atmosphere with the surface layer through the global electric current circuit, as well as to control the upper layers of the atmosphere and the state of the ionosphere.

In addition, it is possible, given the high-altitude location of the station, to monitor changes in the Earth's field at different values of the solar wind velocity and ion concentration. Studies of many atmospheric-electrical phenomena and the implementation of the proposed task are possible only at background monitoring stations, where there are no effects of local anthropogenic changes.

The aim of this work is to identify the role of solar wind factors in the dynamics of daily and seasonal variations of the electric field in the surface layer of atmosphere.

Studies of diurnal variations of the atmospheric electric field at various values of the solar wind velocity and ion concentration were performed at the CHEget high-altitude station (height 3100 m). The high-altitude location of the station allowed us to exclude the contribution of anthropogenic factors in the dynamics of the electric field intensity. The meteorological control of the study area allowed us to distinguish days with "convenient" weather.

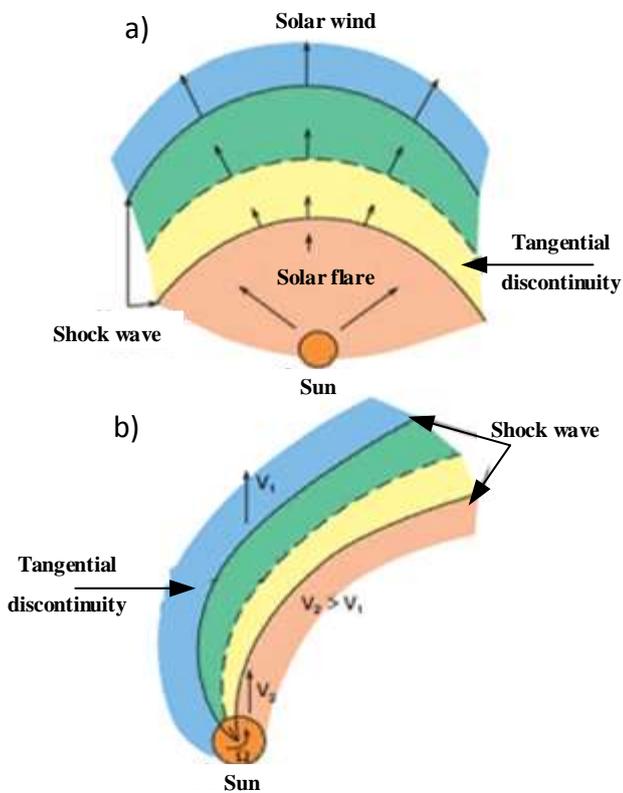


Fig. 1. a - the tangential gap separates the solar wind, perturbed by the external shock wave, from the flare plasma, perturbed by the internal shock wave; b - a qualitative picture of the structure of the flow arising in the solar wind in the case when a faster flow from one region of the solar surface catches up with a slower one flowing out of another region. Ω is the angular velocity of rotation of the Sun.

Table 1 presents a fragment of the data of the solar wind velocity and ion concentration from the database [1].

TABLE I. VALUES OF THE SOLAR WIND VELOCITY V AND ION CONCENTRATION N FOR AUGUST 2016.

<i>One-time</i>	<i>Average in a day</i>	<i>One-time</i>	<i>Average in a day</i>
328.6	334	3.5	3
401.1	386	0.1	9.4
552.8	497	1.4	3.6
545.2	581	2.9	1.8
670.9	624	1.8	1.4
602.3	602	2.4	1.5
500.7	548	2.5	1.9
493.6	477	4.1	3.4
608.7	571	1.4	2.4
613.7	630	0.9	1
590.2	595	2.6	1.5
495.7	544	1.6	1.6
422.2	454	2.8	1.7
360.2	403	2.9	3.7
278.2	318	2.3	3.1
336	302	4.2	5.5
384.1	378	3.6	3.9
355.3	365	3.5	3.5
357.1	346	2.1	2.8
291.6	321	2	2.7
408.1	364	5.9	7.1
370.3	395	3.5	4
508.6	390	5	7.5
544	527	1.5	2.9
498.6	532	2.5	2.7
458.9	456	3.3	3.7
425.8	420	4.4	3.7
371.8	374	12.1	5.3
344.8	343	11.9	9.1
452.2	419	6.8	6.4
429.2	430	6.6	5.1

The dynamics of the electric field of the surface layer of atmosphere is formed by the imposition of disturbances of local origin on the global variations of the electric field. The unitary variation of the electric field, representing synchronous changes in the whole of the Earth (minimum - 4-5 hours and maximum 19-20 hours), resulting from changes in the potential of the ionosphere, is one of the proofs of the existence of a global generator of the atmospheric electric field, related to, first of all, the thunderstorm activity of the equatorial zone of the globe [6, 7]. The contribution of a thunderstorm generator to maintaining the electric potential of the ionosphere is approximately 70% (the potential of the earth's surface is considered to be equal to zero). Another part of the potential of

the ionosphere, determined by cosmic factors (20–30% contribution), is the interaction of the solar wind with the earth's magnetosphere and tidal influence on the ionosphere from the Sun and the Moon (magnetospheric generator, ionospheric dynamo), depends on the geographical coordinates of the observation points, as occupy a limited area [8, 9].

Along with thunderstorm and magnetosphere-ionospheric generators, a certain contribution to the variations of the electric field is made by a convective current generator, which contributes about 10% to the ionospheric potential acting in the atmospheric boundary layer [10-12].

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The global and local characteristics of the atmospheric electric field are interrelated and are the dynamic parameters of the global electrical circuit (GEC), the current loop formed by the conducting layers of the ionosphere and the earth's surface and closing them with an electrically conducting atmosphere. Theoretical papers on the functioning of the GEC deal with the processes of the establishment and dissipation of the atmospheric electric field depending on the behavior of the source, in the role of which the ionospheric potential acts. As a result of the modelling, it has been established that there can be a phase shift between fluctuations of the current density in the atmosphere and the potential of the ionosphere due to differences in the values of electrical conductivity in different regions of the globe.

To measure the daily variations in the atmospheric electric field intensity, we used a hardware-software complex that measures the values of the atmospheric electric field intensity at the CHEget peak and transmits them to the central server. The hardware-software complex for measuring the values of the atmospheric electric field intensity in the area of the command and control center CHEget and transmitting them to the central server consists of three components.



Fig. 2. a) - Appearance of the sensor of the atmospheric electric field meter EFM550; b) - The sensor head of the electric field meter.

1. The atmospheric field intensity meter EFM 550 (production of Vaisala).
2. The block of transmission of the values of the atmospheric electric field intensity (production of Russia).

3. The program of processing and visualization of variations in the intensity of the electric field of the atmosphere (GRAF) (production of the FSBI High-mountain Geophysical Institute, Russia).

Vaisala's EFM550 electric field meter measures the atmospheric electrification. Data on atmospheric electrification can be used to warn of thunderstorm danger (Fig. 2).

III. RESULTS

To identify the role of cosmic weather in the daily and seasonal dynamics of the electric field of the surface layer of atmosphere, the following values were used: the flow velocity and concentration of ions, which reflect the splash changes in $V, \text{ km/s}$ $E, \text{ kV/m}$ and thus reflect the properties of the solar wind striking the Earth. The consequences of the action of solar-terrestrial relations can have an auxiliary, and sometimes decisive, effect on the dynamics of daily and seasonal variations in the field of the surface layer of atmosphere. These splash changes in solar activity lead to abrupt changes in the solar wind velocity and ion concentration, Fig. 3.

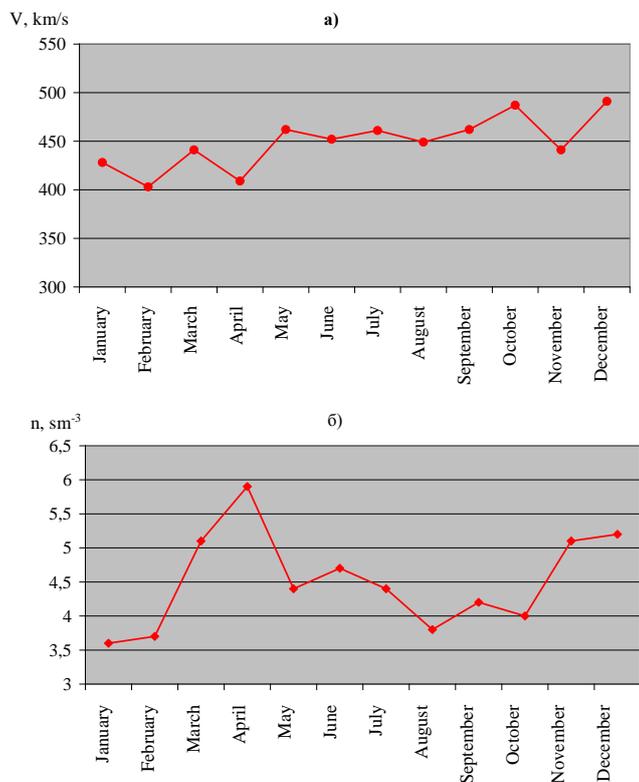


Fig. 3. Monthly mean values of the solar wind velocity (a) and proton concentration (b) for 2016.

We conducted comparative analysis of the daily variation of the solar wind velocity v , ion concentration n and the electric field strength of the surface atmosphere E and determined their correlation relationships.

The present work gives some preliminary results. The analysis of the relationship between the daily variation of the solar wind velocity v , ion concentration n and the electric field strength of the surface atmosphere E showed that there are days

with good correlations between the specified parameters (the correlation coefficient E and n is 0.57 (Fig. 4) and days with weak correlations (the correlation coefficient E and n is equal to 0.44 (Fig. 5).

It should be noted that, during a given period of time, we have found no clear correlation between the solar wind velocity and the ion density

A separate analysis of the relationship between the values of the solar wind velocity v with the electric field intensity of the surface atmosphere E and the ion concentration n with the electric field intensity of the surface atmosphere E showed a larger correlation between E and n .

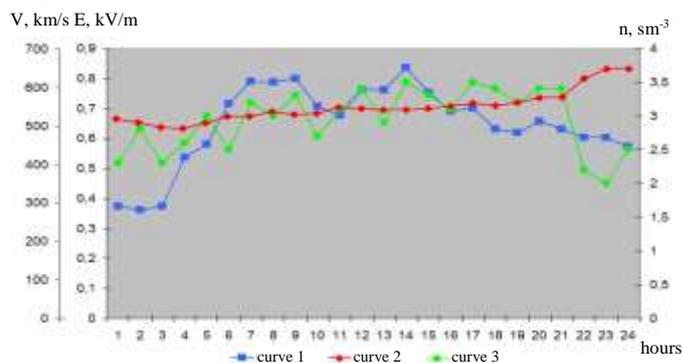


Fig. 4. The daily variation of the field intensity values (curve 1), the solar wind velocity values (curve 2), and the ion density (curve 3) for July 14, 2016.

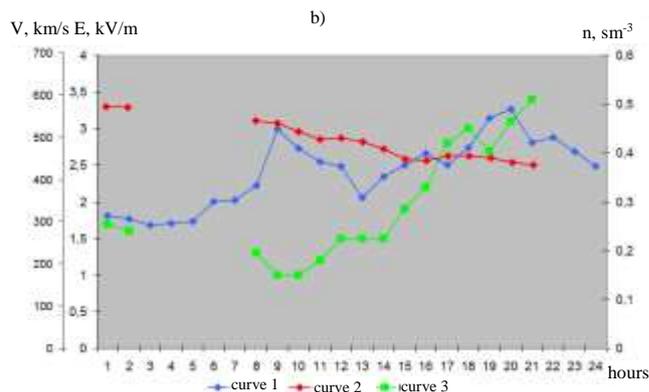


Fig. 5. The daily variation of the field intensity values (curve 1), the solar wind velocity values (curve 2), and the ion density (curve 3) for October 19, 2016.

IV. CONCLUSION

In this paper, we revealed the presence of a correlation relationship between the characteristics of the solar wind and the values of the electric field intensity at the high-altitude station.

An analysis of a limited number of data E , V , and n makes it possible to note that an increase in the values of v and n leads to an increase in the average daily values of the electric field gradient of the surface atmosphere as compared to the mean multiyear values of the "good weather" field.

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