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Study of the electric field variation based on preliminary observations at the ENU cosmophysical complex in 2020

The atmospheric electric field E_z is the most urgent problem of study of the physics of the atmosphere and the processes occurring in it. The conducted studies show the relationship of the electric field with atmospheric processes. Monitoring its changes is necessary to solve practical problems. This article presents brief characteristics of the installation of the EFM-100 electrostatic fluxmeter of the scientific cosmophysical experimental complex at the L.N. Gumilyov Eurasian National University (ENU) and its experimental data obtained in 2020. The article presents the results of observation of atmospheric-electrical characteristics near the Earth's surface and monitoring of the electric field of the atmosphere of the city of Nur-Sultan, in particular, estimates of the variation of the electric field of the surface layer of the atmosphere during sunrise and sunset based on data obtained by the EFM-100 fluxmeter. The comparison of meteorological data with the data of the electric field strength of the atmosphere is given. The analysis of the days and months in September and October 2020, when the conditions of “good weather” were manifested, was carried out. The series of electric field data obtained at other measuring stations show the characteristic periodicity of the electric field behavior. It is established that the value of the atmospheric electric field increases during sunrise with the manifestation of the solar terminator effect. It is interesting to study the relationship between the magnitude of the electric field of the atmosphere and the intensity of the cosmic ray flux, especially in the case of Forbush effects. The data of the ENU ground-based experimental complex allows us to conduct research on the study of atmospheric physics, including atomic electricity, as well as their interaction with cosmic rays and meto-conditions.

Keywords: cosmophysical complex, electric field variation, cosmic ray flux, electrostatic fluxmeter, electric field, solar terminator, Forbush effect, monitoring.

Introduction

Cosmic rays play an important role in the processes occurring in the atmosphere that affect the climate and weather, and determine the properties of the Earth's global electrical circuit. In this regard, the study of the physical nature of secondary cosmic rays, as well as their interaction with atmospheric processes at different time scales is very important.

One of the fundamental problems in the study of atmospheric physics is atmospheric electricity. It is generally accepted that all manifestations of atmospheric electricity and its correlation with galactic cosmic rays and meteorological conditions are associated with the electric field of “good weather”.

Despite the creation of the necessary conditions for studying the physics of the phenomenon of the atmospheric electric field, the problem still remains unsolved. Meanwhile studies show its relationship with atmospheric processes. For example, it was found that the occurrence of electric charges in the atmosphere is caused by one of three sources or their combination: GCR and SCR, natural radioactive sources of soil and the formation of charges due to phase transitions in water [1].

Methodology and research methods

The atmospheric electric field is the main indicator of many geophysical processes. Observation of its changes is used to solve many practical problems. To this end in 2015 the L.N. Gumilyov Eurasian National University (ENU) in cooperation with the P.N. Lebedev Physical Institute of the Russian Academy of Sciences created a scientific cosmophysical complex [2–4] consisting of two CARPET detectors, a neutron detector and an EFM-100 electrostatic fluxmeter.

The EFM-100 electrostatic fluxmeter is designed to study atmospheric-electrical characteristics near the Earth's surface and monitor the electric field of the atmosphere. It also registers lightning discharges and is able to detect the high electric field strength that precedes the first lightning discharges.

The device operates on the principle of an electrostatic generator: in an alternating electric field, induced charges occur in the conductor. The amount of current generated by the induced charges is directly proportional to the field strength.

The structure of an electrostatic fluxmeter consists of fixed electrodes and a shielding plate that rotates over the electrodes. To rotate the plate shaft a motor powered by a direct current source is installed on the device body. When the shielding plate rotates, the measured electric field acts on the sensing elements (electrodes), after which an alternating current occurs in the circuit. In turn, the electrical circuit of the device processes alternating current. The device has an aluminum coating, the operating temperature range is from -40 to +60°C. Figure 1 shows the appearance of the installation.

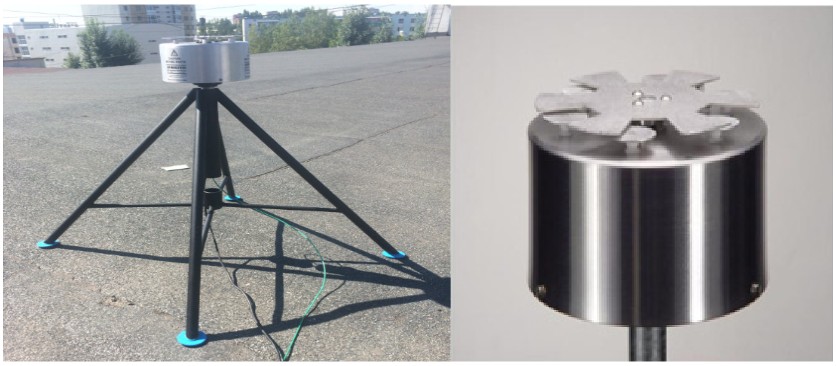


Figure 1. External view of the EFM-100 and its installation at ENU

With the help of the software the data is displayed graphically (Figure 2) on a computer and daily files are formed in the output: a data file for recording the electric field strength.

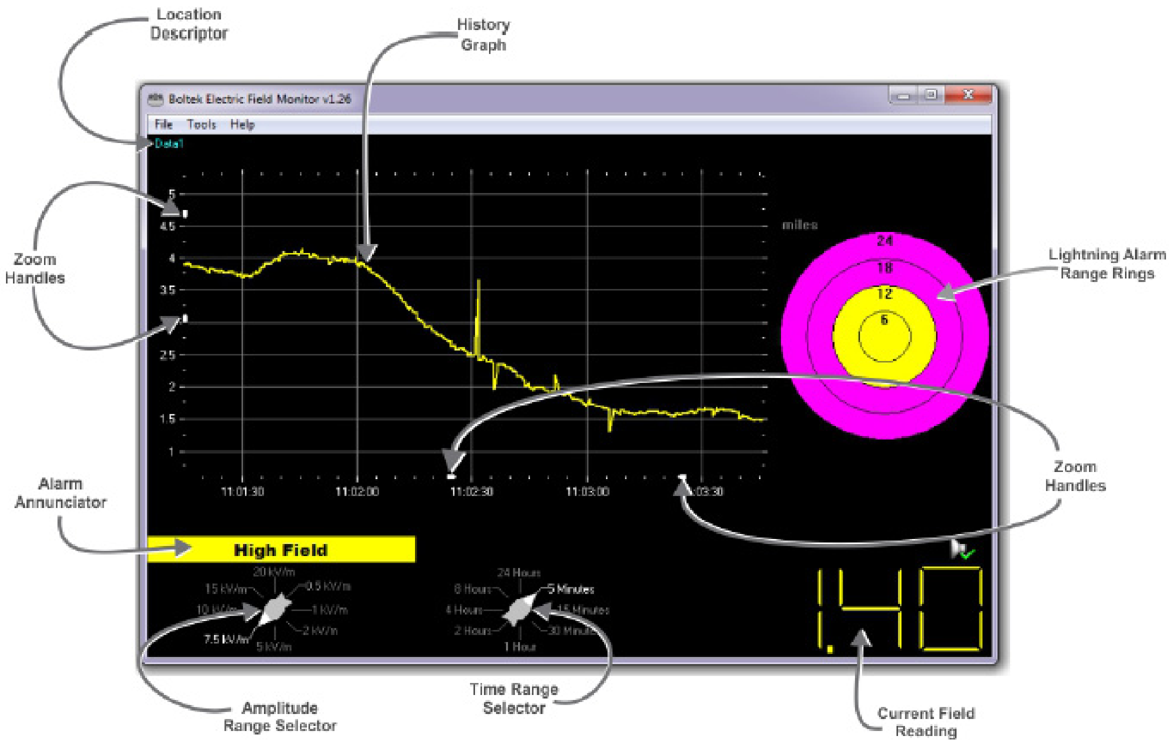


Figure 2. EFM-100 Software Display

Discussion

Thunderstorm detection is achievable with the EFM-100, a means of detecting electromagnetic radiation from lightning discharges. Observation of the electric field of the atmosphere allows solving the problems of storm warning both independently and in combination with meteorological installations. The equipment uses special software Electric Field Monitor and provides online data on the situation of the electric field of the atmosphere and the strength of the electric field in a two-dimensional display with the ability to detect lightning discharges within a radius of 38 km.

Figure 3 shows a comparison of the data on variations in the atmospheric electric field strength obtained using the EFM-100 electrostatic fluxmeter of the cosmophysical complex of the L.N. Gumilyov ENU with meteorological data from the city of Nur-Sultan in August 2020.

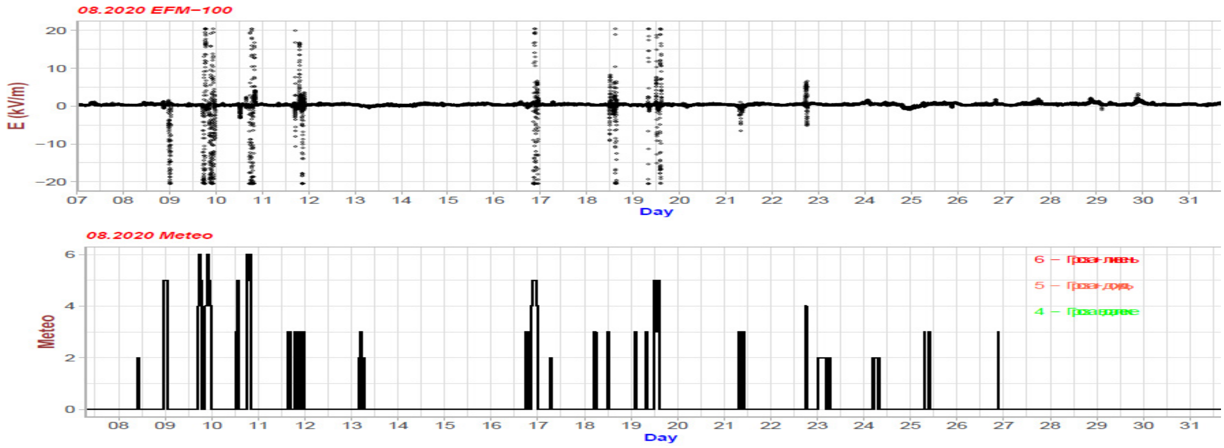
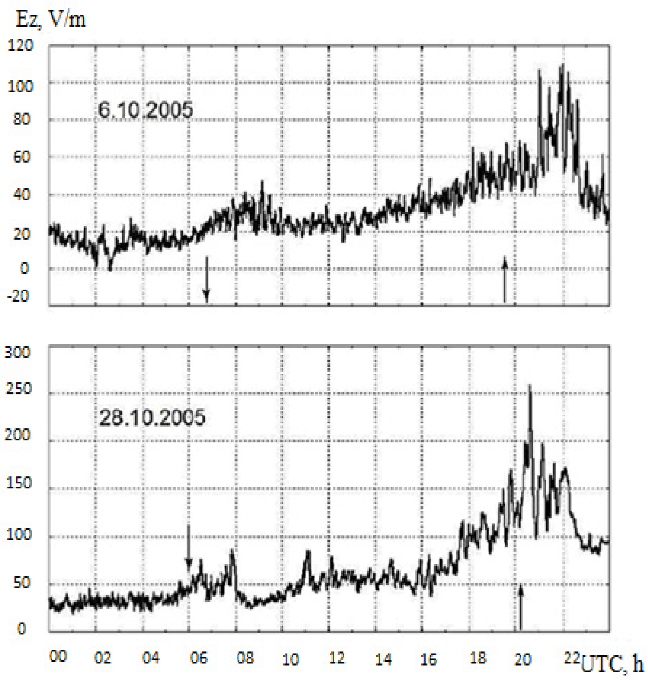


Figure 3. Comparison of the electric field variation data (upper graph) with meteorological data (lower graph) in August 2020

As you can see, the value of the electric field strength created as a result of the potential difference during a rain or thunderstorm reaches hundreds of V/m or several kV/m. Thunderstorms are usually traced with a sudden change in the field value near the earth's surface.

The results of these typical diurnal variations in the gradient of the electric field potential under “good weather” conditions based on observations at other stations are presented below with arrows corresponding to the times of sunrise and sunset (Figure 4).



Note: the standard time of the Paratunka GO is 12 hours ahead of UT.

Figure 4. Typical diurnal variations in the gradient of the electric field potential in good weather conditions. Arrows up — time of sunrise, down — time of sunset.

In turn, the experimental data obtained with the EFM-100 electrostatic fluxmeter of the LN Gumilyov ENU cosmophysical complex with different time variations (Figures 5, 6) of the electrostatic field for “good days” shows the regularity of its behavior.

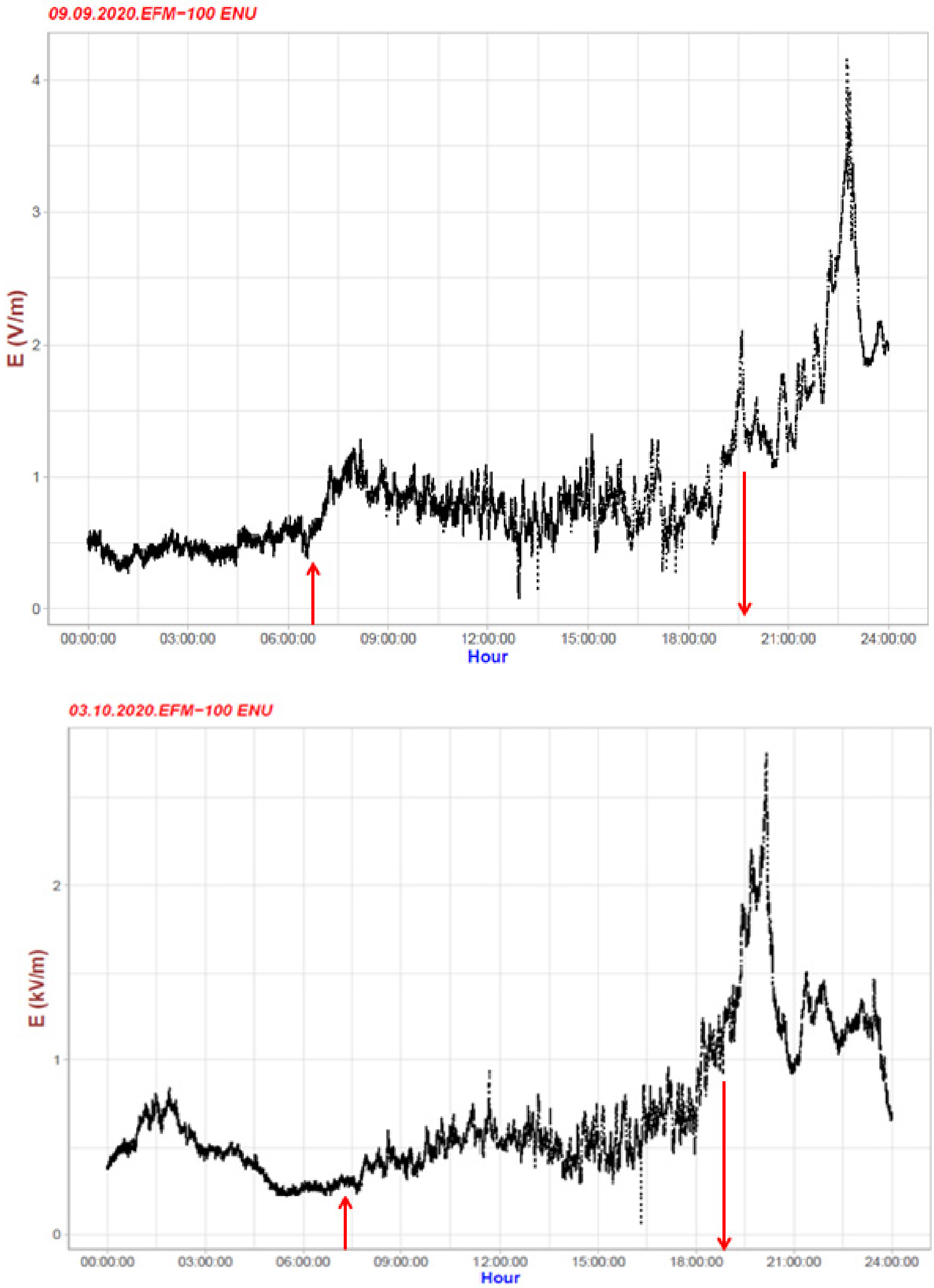


Figure 5. Daily variations of the electric field according to the ENU complex for “good days” (upper graph — 09.09.2020, lower graph — 03.10.2020), Arrows up — time of sunrise, down — time of sunset

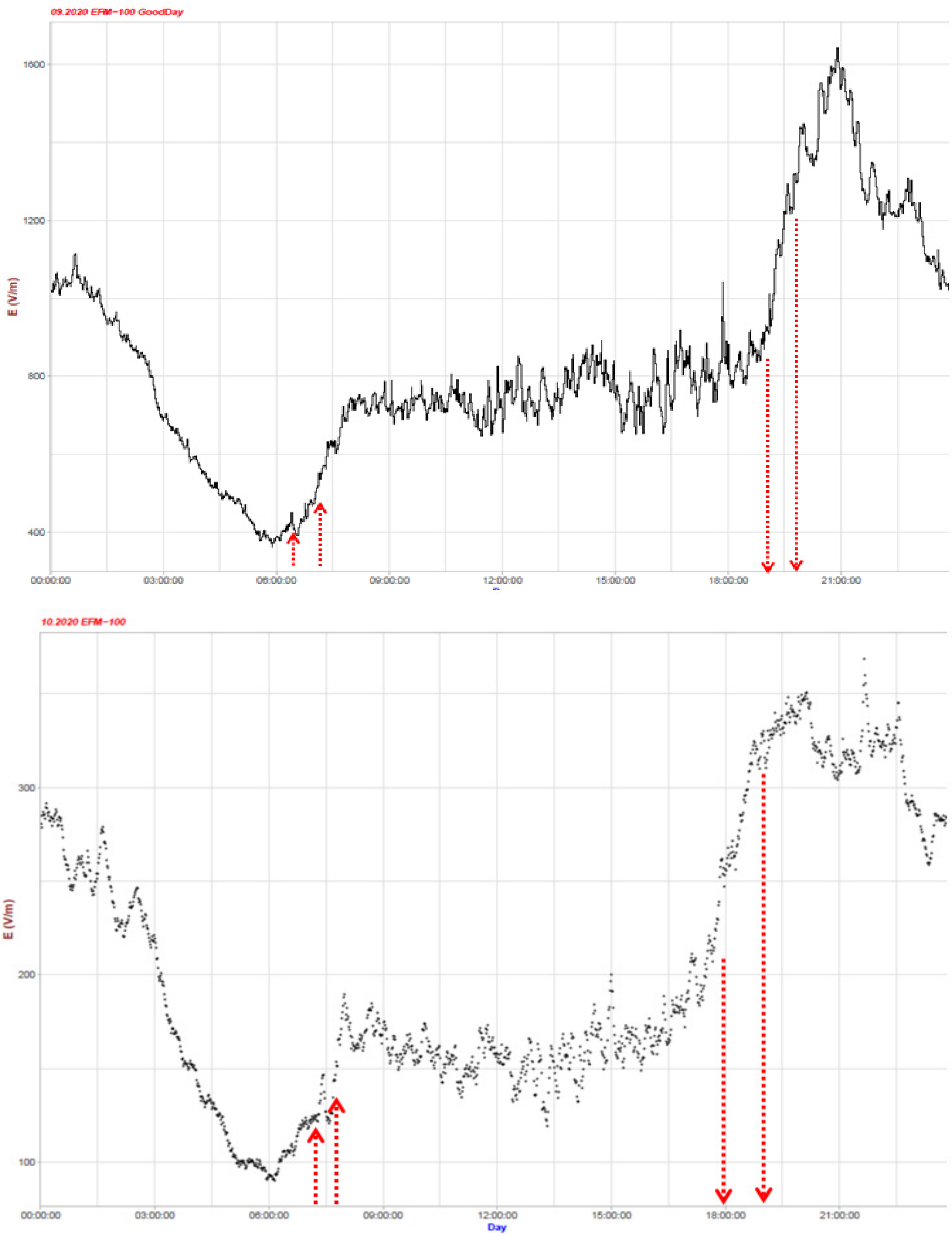


Figure 6. Monthly variations of the electric field according to the ENU complex (upper graph — September 2020, lower graph — October 2020), Arrows up — time of sunrise (at the beginning and end of the month), down — time of sunset (at the beginning and end of the month)

The dynamics of measurements of the experimental data of the ENU complex and the typical series of electric field data obtained at other measuring stations show a characteristic periodicity of the behavior of the electric field in "good weather" conditions. The periodicity of the nature of the electric field is due to the influence of the intensity of cosmic rays, as well as the change in the balance of ions during sunset and sunrise. In the formation of the atmospheric electric field an important role is played by cosmic rays, which have an ionizing effect.

As can be seen from the figures, the magnitude of the atmospheric electric field increases during sunrise with the manifestation of the solar terminator effect; the solar terminator is a line of day dividing the Earth's atmosphere into daytime and nighttime regions. Simultaneously, the evening solar terminator is especially noted. It has been proven that the solar terminator effect affects the processes in the ionosphere and atmosphere [5, 6]. One of the unique properties of the electric field is that the E_Z value everywhere at 19:00 UT increases by about 20 % [7]. According to the analysis for the study of the terminator effect, this stable phenomenon of an increase in the value of E_Z is associated with the generation of internal gravitational waves on the Earth's surface during a lowering of temperature at sunset.

As mentioned above, in order to study the physical properties of the atmospheric electric field it is important to investigate its relationship with the heliophysical effects of the Sun and variations of cosmic rays. At the same time it seems interesting to compare and establish the correlation between E_Z and the intensity of the cosmic ray flux.

The relationship of the cosmic ray flux with other quantities is especially well manifested during decreases in its intensity, in particular during the periods of registration of Forbush decreases. For example, the response of the atmospheric electric field does not always depend on solar-terrestrial phenomena. However, it has been established that a decrease in the value of E_Z proceeds simultaneously with a sharp decrease in the intensity of the cosmic ray flux — the Forbush effect [8], .

Figure 7 shows the correlation between the intensity of cosmic rays and E_Z according to the observations of the neutron monitor at the Paratunka observatory in Magadan, Russia, from which it can be seen that a decrease in the intensity of cosmic rays by 3-10 % leads to a decrease in the value of E_Z to 20-80 % [7, 9].

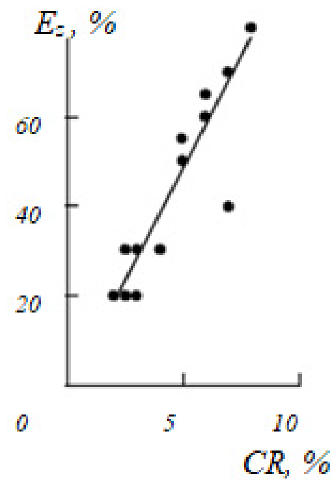


Figure 7. Dependence of E_Z on the intensity of cosmic rays during the Forbush-decreases

In future works of the group of authors it is planned to study this phenomenon based on the results of observations of the L.N. Gumilyov ENU scientific cosmophysical complex after the detection of noticeable Forbush-decreases in cosmic rays.

Conclusions

In this work a stable effect of a sharp and regular increase in the concentration of charged ions during the hours of sunset was found. The increase in E_Z in the morning has a well-pronounced oscillatory character. Similar oscillations excited in the atmosphere during the solar terminator period are known and studied. Therefore it is particularly interesting to study the phenomenon and observe the value of E_Z during the Forbush-decrease effect for different time periods. This is necessary to explain the relationship between the direct dependence of the GCR intensity on the E_Z value, which shows that the conductivity of the atmosphere is affected by the CR intensity, as well as to construct a model of the electric field of the atmosphere. In turn, this dependence proves that the electric field of the atmosphere is an indicator of geophysical processes in the atmosphere.

At the same time it should be noted that for future work on the study of the relationship of CR variations with the electric field we will use the experimental data of the CARPET detector of the ENU cosmophysical complex, which has proven itself well during its operation. The analysis of the obtained preliminary experimental observation data shows that the facilities of the ENU cosmophysical complex allow us to study the nature of CR variations, as well as their interaction with atmospheric processes for different time intervals. The collection and automatic storage of data from the EFM-100 device will make it possible to measure the electric field of Nur-Sultan in an automatic mode, which is a necessary factor in the study of geophysical processes and is relevant for solving practical problems.

The data of the ground-based complex also allows for long-term research and can qualitatively supplement the global data bank along with the data of the existing network of ground-based detectors.

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Е. Төлеков, А.К. Морзабаев, В.С. Махмутов, В.И. Ерхов

2020 жылғы Еуразия ұлттық университетінің Космофизикалық кешеніндегі бақылаудың алдын-ала алынған деректері бойынша электр өрісінің вариациясын зерттеу

E_z атмосфералық электр өрісі — бұл атмосфералық физиканы, ондағы процестерді зерттеудің ең өзекті мәселесі. Зерттеулер электр өрісінің атмосфералық процестермен байланысын көрсетеді. Оның өзгерістерін бақылау тәжірибелік мәселелерді шешу үшін қажет. Мақалада Л.Н. Гумилев атындағы Еуразия ұлттық университетіндегі (ЕҰУ) EFM-100 ғылыми Космофизикалық эксперименттік кешеніне электростатикалық флюксметрін орнатудың қысқаша сипаттамалары және оның 2020 жылы алынған эксперименттік деректері келтірілген. Сонымен қатар жер бетіне жақын атмосфералық-электрлік сипаттамаларды бақылау және Нұр-Сұлтан қаласы атмосферасының электр өрісінің мониторингі нәтижелері ұсынылған, атап айтқанда EFM-100 флюксметрімен алынған мәліметтер негізінде Күннің шығуы мен батуы кезінде атмосфераның жер үсті қабатының электр өрісінің өзгеруін бағалау көрсетілген. Метеомәліметтерді атмосфераның электр өрісінің кернеулігі деректерімен салыстыру берілген. 2020 жылдың қыркүйек және қазан айларында «жақсы ауа-райы» жағдайлары көрсетілген күндерге, айларға талдау жасалған. Басқа өлшеу станцияларында алынған электр өрісінің осы қатарлары электр өрісінің тәртібіне тән жиілігін көрсетеді. Күн терминаторының әсері пайда болған және күн шыққан кезде атмосфералық электр өрісінің мөлшері арта түсетіні анықталды. Атмосфераның электр өрісінің мөлшері мен ғарыштық сәулелер ағынының қарқындылығы, әсіресе Форбуш эффектісі арасындағы байланысты зерттеу қызықты болып көрінеді. ЕҰУ жер бетіндегі эксперименттік кешенінің деректері атмосфера физикасын зерттеу, оның ішінде атомдық электр энергиясы, сондай-ақ олардың ғарыштық сәулелермен және метоеожағдайлармен өзара әрекеттесуі бойынша зерттеулер жүргізуге мүмкіндік береді.

Кілт сөздер: космофизикалық кешен, электр өрісінің өзгеруі, ғарыштық сәулелер ағыны, электростатикалық флюксметр, электр өрісі, күн терминаторы, Форбуш эффектісі, мониторинг.

Е. Тулеков, А.К. Морзабаев, В.С. Махмутов, В.И. Ерхов

Исследование вариации электрического поля по предварительным данным наблюдений Космофизического комплекса Евразийского национального университета в 2020 году

Атмосферное электрическое поле E_z является наиболее актуальной проблемой изучения физики атмосферы и происходящих в ней процессов. Проведенные исследования показывают взаимосвязь электрического поля с атмосферными процессами. Мониторинг его изменений необходим для решения практических задач. В статье представлены краткие характеристики установки электростатического флюксметра EFM-100 научного Космофизического экспериментального комплекса в Евразийском национальном университете им. Л.Н. Гумилева (ЕНУ) и экспериментальные данные, полученные в 2020 г. Кроме того, даны результаты наблюдения атмосферно-электрических характеристик вблизи поверхности Земли и мониторинга электрического поля атмосферы города Нур-Султана, в частности, показаны оценки вариации электрического поля приземного слоя атмосферы, во время восхода и заката Солнца на основании сведений, полученных флюксметром EFM–100. Проведено сравнение метеоданных с показателями напряженности электрического поля атмосферы, а также проанализированы дни в сентябре и октябре 2020 г., когда проявлялись условия «хорошей погоды». Ряды данных электрического поля, полученные на других измерительных станциях, показывают характерную периодичность поведения электрического поля. Установлено, что величина атмосферного электрического поля возрастает во время восхода Солнца при проявлении эффекта солнечного терминатора. Представляется интересным изучение связи между величиной электрического поля атмосферы и интенсивностью потока космических лучей, особенно при Форбуш-эффектах. Данные Наземного экспериментального комплекса ЕНУ позволяют проводить исследования по изучению физики атмосферы, в том числе атомферного электричества, а также их взаимодействия с космическими лучами и метеоусловиями.

Ключевые слова: космофизический комплекс, вариация электрического поля, поток космических лучей, электростатистический флюксметр, электрическое поле, солнечный терминатор, Форбуш-эффект, мониторинг.

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