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Extended interpretation of the term "geoeffectiveness" of active solar processes

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Abstract

In the report, authors considered the proposed hypothesis that the term "geo-efficiency" of solar activity should take into account not only the presence of geomagnetic perturbations, but also perturbations of other geophysical fields, in particular natural atmospheric infrasound. The hypothesis is confirmed by studies of the correlation between the long-term (23 and 24 cycles of solar activity) dynamics of helio-induced changes in natural atmospheric infrasound intensity in the near Earth surface atmosphere and the dynamics of the arrival of galactic cosmic rays into the Earth's atmosphere. These studies also confirmed the existence of a stable relationship between the short-term (daytime) dynamics of atmospheric infrasound intensity and the growth of solar wind energy and solar cosmic rays.
Keywords: solar activity, geo-efficiency, galactic cosmic rays, infrasound.

1 Introduction

Within the problem of space weather, various aspects of solar-terrestrial relationships are explored, including the influence of active cosmic factors (active solar processes, galactic and solar cosmic rays) on the state of biotic and abiotic components of the geosystem. The effects of this impact are not always foreseeable, and their extent and nature are defined by the term "geo-efficiency". In the current scientific literature, they are associated, first of all, with the emergence in the near-Earth's space (NES) geomagnetic storms stimulated by active solar processes. These storms is of great interest for fundamental science and practice. In our view, this statement is somewhat narrowed, since it does not take into account the appearance of other geophysical effects that accompany the influence of active space factors on the state of biotic and abiotic components of the NES environment [1].

In view of the above, the report proposes an expanded interpretation of the term "geo-efficiency" of active space factors based on the analysis of the results of long-term experiments performed by the authors during 2010-2019, in particular:
- studies of the structure and determination of the parameters of the sporadic component of solar radio emission;
- measurement of parameters of natural atmospheric infrasound (AI) and geoelectric field in the near Earth surface atmosphere and evaluation of their dynamics;

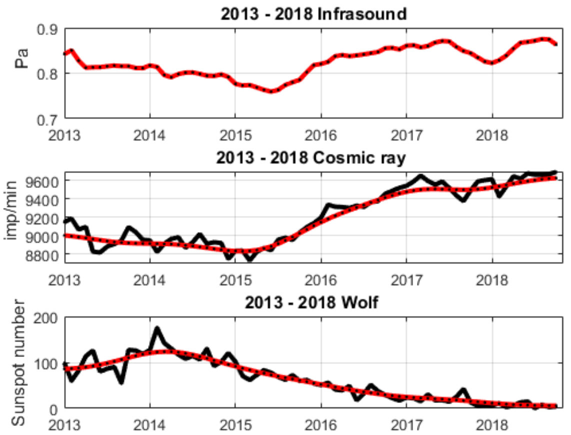
- assessment of the ecological status of biotic and abiotic components of the geosystem.

A multifunctional instrumental complex based on the decameter radio telescope URAN-3 and sensors of natural atmospheric infrasonic and geoelectric fields was used for the experiments. The complex is located in the nature reserves of the Western Polesie of Ukraine, which allowed minimizing the impact of industrial interferences and anthropogenic disturbances on the results of observations of the effects of solar and galactic cosmic rays (GCRs).

2 Basic research

The influence of solar activity on the state of the environment of the upper layers of the atmosphere has been investigated in considerable detail today [2]. However, its effect on the lower atmosphere was investigated less. This, first of all, concerns the stimulation by solar activity the generating of AI natural perturbations in the surface layer. In most cases, in the literature the scientists considers the generation of AI natural perturbations caused by the action of a perturbed solar wind on the polar region of the Earth, and AI propagation to low latitudes [3].

Dynamics of natural AI perturbations on long time scales. At the same time, in the troposphere occur processes that also respond sensitively to active solar processes. In particular, the authors have previously recorded perturbations of natural AI caused by the action of solar high-energy particles on the Earth's atmosphere [4]. In this paper, the authors investigate the influence of GCRs on the mid-latitude troposphere based on the joint processing of own measurements of AI intensity, information on GCRs intensity (according to the Moscow Neutron Monitor), and Wolf's numbers. In particular, for the 23 and 24 cycles of solar activity, the relationship between changes in the mean monthly low frequency (LF) trend of AI perturbations, GKP intensity, and Wolf numbers was investigated. The use of GCRs data recorded by a neutron monitor in Moscow is permissible when measuring AI parameters in Lviv, given the planetary homogeneous nature of GCRs arrivals. Figure 1 presents as graphs the results of studies of LF trends in the 2 cycles of solar activity (24th and 23rd) of the following parameters: perturbations of atmospheric infrasound, average monthly GCR values, and monthly average values of Wolf numbers.



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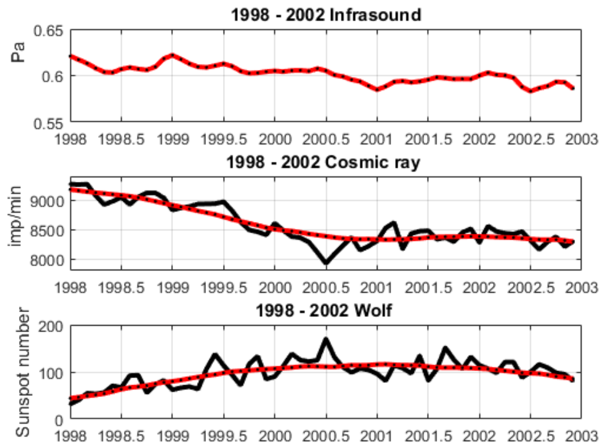

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Figure 1. 24th (a) and 23th (b) solar activity cycles: (upper panels) - trend of envelope of disturbances of atmospheric infrasound; (middle panels) - monthly mean values of GCRs intensity, and their trend (red line); (bottom panels) are the monthly average values of Wolf numbers, and the trend of their changes (red line).

The graphs below show a negative correlation between the dynamics of the average monthly values of the GCRs and the average monthly values of Wolf numbers. They also demonstrate the same pattern of change of the average monthly values of AI intensity and the average monthly values of the GCRs inflows into the Earth's atmosphere, confirming the stable relationship between GCR inflows and the occurrence of AI disruptions in the surface atmosphere. The analysis of graphs shows the dependence of the values of the envelope of AI disturbances on the intensity of arrival of GCRs (Figure 2) clarifies the appearance of this relationship. As can be seen from Figure 2, the relationship between the envelope of disturbances of atmospheric infrasound and the GCRs intensity is close to linear. The correlation coefficient for the 24th and 23th cycles of solar activity is 0.87 and 0.70, respectively. This results in a noticeable scatter in the values of the envelope of AI disturbances relative to a

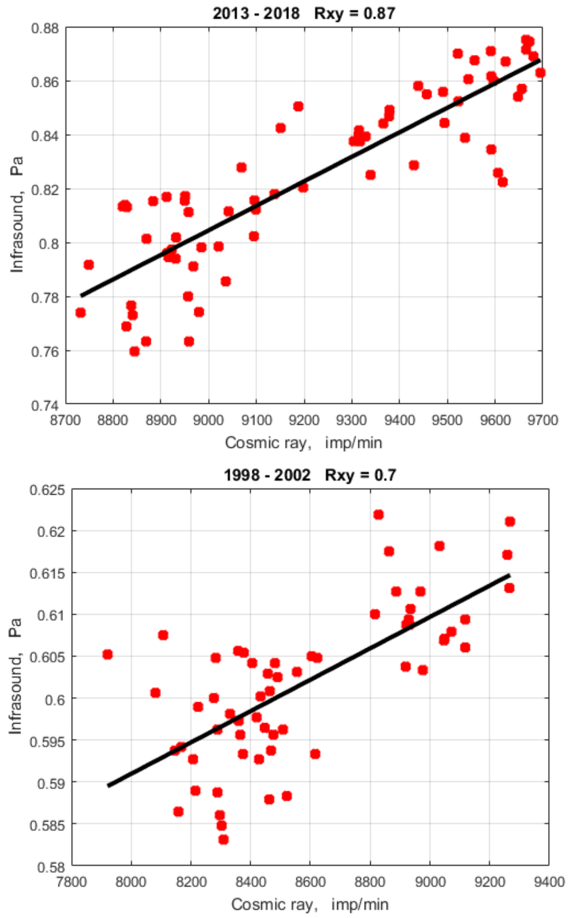


Figure 2. Relationship between values of envelope of disturbances of atmospheric infrasound and the GCRs intensity for 24th (top) and 23th (bottom) solar activity cycles.

straightforward linear regression constructed by the least squares method, which characterizes the linearity of this relation. Such a scatter is explained by the influence of other factors on the value of the envelope of disturbances of AI, among which may be the influence of solar cosmic rays, meteorological phenomena, etc.

The difference in the magnitude of the correlation coefficient for the 24th and 23th cycles of solar activity has a physical meaning. During 1998–2002, the monthly values of GCRs were significantly lower than in 2013–2018. This suggests that the direct relationship between the values of the envelope of perturbations of AI and the values of GCRs intensity is linear and that other factors have a nonlinear influence.

Dynamics of disturbances of natural AI on short time scales. Let us consider jointly the characteristic features of this process on the example of the event in the Sun (coronal mass emission, X-ray radiation) and the perturbed geophysical fields (geomagnetic field and natural infrasound) that occurred in September 2017. Active area of 2673 located in the southwestern part of the solar disk with heliographic coordinates (S10 W30) (Figure 3), became the source of six solar flares on

September 6, 2017. Among them: two Class X flashes - Class X2.2 flash that started at 08:57:00 UT and lasted 20 minutes, and Class X9.3 flash that started at 11:53:00 UT and lasted 17 minutes (data TESIS, NOAA GOES). The maximum flares occurred at 09:10:00 UT and 12:02:00 UT respectively. On September 7, 2017, the same active area became the source of eleven solar flares.

According to SOHO LASCO, a coronal mass emission (CME) with an angle of 145 ° (Figure 4) was recorded at 12:06:05 UT. After ~ 37 h from the beginning of the X2.2 solar flare, the start of the magnetic storm was recorded (Figure 5). According to WDC for Geomagnetism, Kyoto, the magnetic storm began on September 7, 2017 at 10:00 PM UT. The decrease in the Dst index reached -142 nT, and the duration of the main phase of the magnetic storm was 5 hours. At 13:00 UT 09/09/2017, the beginning of the second magnetic storm, corresponding to a delay of ~ 49 h from the start of the X9.3 solar flare, which was followed by the CME, was recorded. The decrease in the Dst index reached -124 nT, and the duration of the main phase of the magnetic storm was 6 hours. The corresponding dynamics of the change in the power spectrum of natural infrasound (before and after the solar flare) is presented in Figure 6.

3 Conclusions

1. Taking into account that active cosmic factors stimulate the appearance of perturbations of geophysical fields in the near-Earth surface atmosphere, an extended interpretation of the term "geo-efficiency" of solar activity is proposed. That interpretation, unlike the traditional one, implies not only geomagnetic perturbations, but also the appearance of perturbations of other geophysical fields, including natural atmospheric infrasound.

2. For the first time, the same pattern of dynamics of changes in the average monthly values of natural atmospheric infrasound and the average values of the arrival of galactic cosmic rays into the Earth's atmosphere over long time intervals (years) was confirmed, with the correlation between them being 0.87 and 0.70 respectively for 24 and 23 solar cycles activity.

3. It is shown that the relationship between the low-frequency trend of envelope of disturbances of atmospheric infrasound and the intensity of GCRs is close to linear one, and that the variation of the values of this trend relative to direct linear regression is caused by influence of other factors.

4. It has been experimentally established that at short intervals (up to several days) the growth of energy of solar wind and solar cosmic rays results in a short-term increase in the intensity of atmospheric infrasound. It have been demonstrated, on the example of the Sun's activity in the period 01.09–07.09 2017, that in the absence of active solar events, the intensity of natural infrasound is low. And their presence within 4 hours after the outbreak of the Sun stimulates the appearance of sufficiently intense perturbations of the natural infrasound field. This corresponds to a period during which high-energy particles of the solar wind reach the Earth's atmosphere.

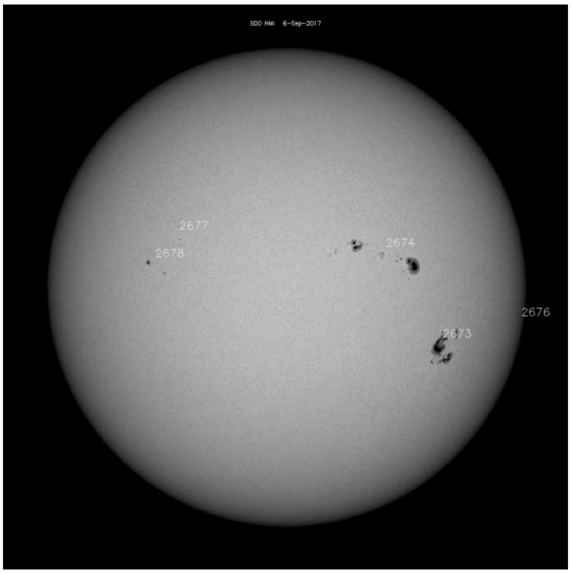


Figure 3. Active areas on the Sun surface that took place on September 06, 2017.

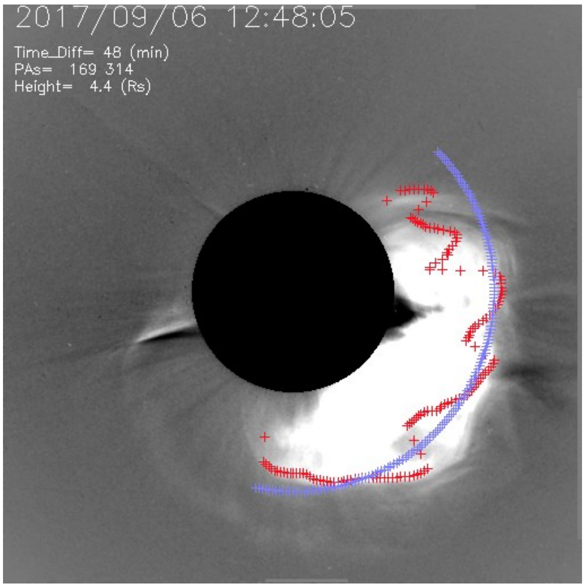


Figure 4. Coronal mass ejection on 6 September 2017.

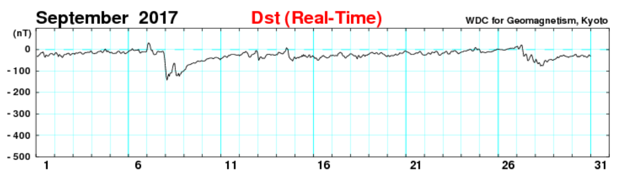
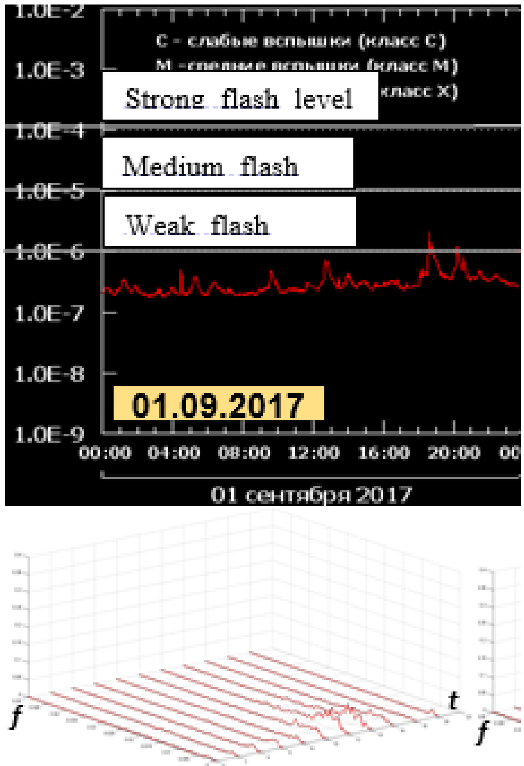


Figure 5. The time dependence of the geomagnetic activity index Dst according to WDC for Geomagnetism, Kyoto (09/01/2017 - 09/31/2017).



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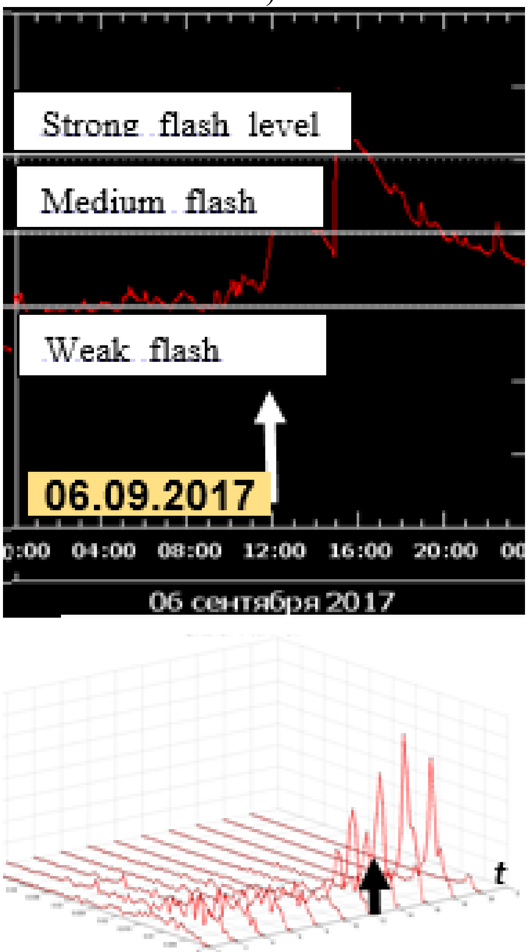

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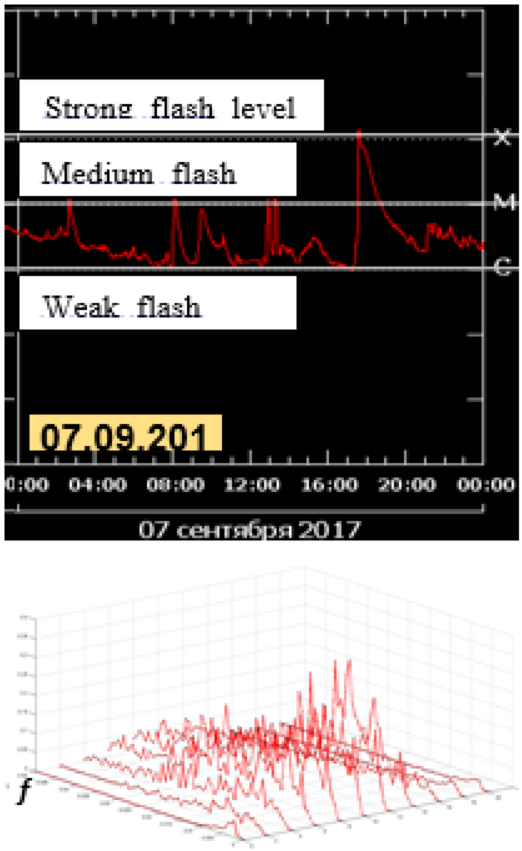

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Figure 6. X-ray intensity of the Sun according to TECIS data and the power spectrum of natural infrasound (before solar flare - 01.09.2017 (a); 06.09.2017 (b) and 07.09.2017 (c) - after solar flare).

4 References

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