INVESTIGATIONS OF THE SOLAR RADIOEMISSION IN THE SHAMAKHY ASTROPHYSICAL OBSERVATORY WITHIN THE PERIOD 1965-2019

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Studies of the radio emission of the Sun and its fluctuations are one of the main sources of information about dynamic phenomena that occur in the outer layers of the solar atmosphere. Together with other research institutes of Russia and employees of the Institute of the Ionosphere of the Republic of Kazakhstan, a number of studies were carried out in the Shamakhi Astrophysical Observatory of the National Academy of Sciences of Azerbaijan and the following scientific results were obtained.

I. On the relationship of solar radio emission bursts in the centimeter wave range with particle fluxes and some characteristics of the slowly-changing component of the solar radio emission.

In recent years, interest in phenomena related to the activity of solar activity has increased. The main problem is finding out the reasons leading to solar activity. In [1], the relationships between the solar radio emission bursts in the cm range and particle fluxes, and the main characteristics of the slowly varying components of the solar radio emission were studied. The bursts of radio emission from the Sun are the result of the appearance and emission of a proton flux (PP) with high energy. These bursts make it possible to "trace" from the Earth the phenomena occurring behind the limb at high altitude. Separate radio emission spectra of active regions on the Sun were obtained, and it turned out that the form of the spectrum strongly depends on the nature of the data used to obtain it. The spectra obtained as a result of statistical processing of the results of routine observations of solar radio emission have a maximum at $\lambda \geq$ 10 cm, which can be explained by the fact that they relate fully to the radiation of regions above the spots. It was shown that the radio emission of spot groups depends not only on the area of the spots, but also on the strength of the magnetic field. It was found that when the group of spots transitions to the invisible hemisphere of the Sun, a sharp change in the spectrum occurs, associated with the group of the local source of radio emission - the maximum of the spectrum from the centimeter wavelength range shifts to the long-wavelength region. This shift allows us to estimate the heights of local sources. It was shown that the nature of the frequency spectrum of the intensity of radio emission from active regions associated with sunspot groups is different for different regions of the group. The radio spectrum of the main spot remains constant up to $\lambda \sim$ 10 cm, and then decreases. It was found that a few days before the outbreak, the amplitude of the oscillations of the radiation flux greatly increases. This was confirmed in 25 cases from 30 isolated proton flares.

At the Shamakhi Astrophysical Observatory of the Azerbaijan National Academy of Sciences, which have made great efforts in developing the field of "Radio Astronomy" and participated in the training of personnel potential in this area, one may remember a lot of respect for the collaborator of the St. Petersburg State University - Doctor of Technical Sciences, Professor A.P. Molchanov and for many years leading the Department of Radio Astronomy in ShAO - Ph.D., associate professor A. R. Abbasov.

II. Microwave radiometric equipment (MWRE), methods and features of spectral measurements of thermal radio emission from astronomical and geophysical objects in the range of 1-4 GHz.

The microwave radiometric method is based on the measurement of the natural thermal radio emission of the bodies caused by electrodynamic processes in atoms and molecules of matter. At present, along with the use of radio thermal location in radio astronomy, which is widely used to study thermal radio emission from various physical, natural, and biological objects. Until now, studies of thermal radio emission from the above objects have mainly been carried out at fixed frequencies, and only the coarse-grained features of the objects have been determined. At the same time, the need arose for a more “subtle” study of the details of processes and individual structures of emitted objects. In [2], the problems of radiometric equipment in the microwave range were studied, methods and features of spectral measurements of thermal radio emission in the range of 1-4 GHz. For the first time in domestic practice, a radio spectrograph of sequential analysis in the range of 1-2 and 2-4 GHz with a high frequency resolution (20-50 MHz) was developed and created. The features of the antenna device are analyzed when measuring the spectrum of a local source on the solar disk in the range of 1-4 GHz, the optimal antenna size is determined, which is necessary for measuring the spectrum of both the integral radio emission of the Sun and for measuring the radio emission spectrum of local sources on the solar disk. For the first time, by spectral measurements, the episodic existence of the 2nd maximum of the frequency spectrum of the S-component of the solar radio emission in the range of 1.6-1.9 GHz is proved. The possibility of measuring the spectrum of thermal radio emission of various natural objects developed by microwave radiometric equipment in the range of 1-4 GHz is evaluated. It was shown that using this equipment, radio brightness contrasts of such natural objects as temperature anomalies of the water surface of 1-2 K, variations in salinity ~ 2%, soil moisture 0.75 - 1 g / dm^3 can be determined. In the short-wavelength part of the range under consideration, the radio brightness contrasts of powerful cumulus clouds significantly exceed the fluctuation threshold sensitivity of the created equipment.

Collaborator of the Nizhny Novgorod Research Institute Radiophysics, who presented his valuable advice in the field of "Radiophysics", Doctor of Technical Sciences , Professor M. M. Kobrin and leading specialist in the creation of these complex objects, a hardworking and principled researcher at the observatory - candidate of technical sciences, associate professor A. M. Huseynov designed sensitive technical equipment at the Shamakhy Astrophysical Observatory - radio spectrographs operating on the principle of sequential analysis in the ranges f = 1-2 GHz and f = 2-4 GHz. We will always be thread about them.

III. On the solar and atmospheric nature of fluctuations of the centimeter radio emission of the Sun.

Currently, ground-based recording of fluctuations in the solar radio emission is one of the methods for studying wave and turbulent processes associated with various types of instabilities of the solar plasma (fluctuations are $(0.1 \div 0.5) \times 10^{-3}$ of the total solar radiation level). In a series of works [3], the solar and atmospheric nature of fluctuations of the centimeter radio emission of the Sun was studied. In order to separate the fluctuations recorded on Earth into fluctuations of solar and terrestrial origin, it is necessary to have long-term recordings of fluctuations of the solar radio emission, their processing algorithms, study the nature of the propagation of radio radiation in a perturbed atmosphere, evaluate the degree of modulation of radio waves by these disturbances, and compare its value with experimentally recorded size. As the initial data, we used the observational materials from 1982 to 1984 obtained with the RT-2, RT-12, and RT-64 radio telescopes. Based on measurements of the S-component in the range f = 2-4 GHz and fluctuations at the waves λ = 5.2 and 8.1 cm, power spectra are constructed. Modification of the methods of correlation and spectral analysis, in particular, the method of maximum entropy (MME) and spectral-temporal analysis (SWAN) for the statistical processing of fluctuations in the radio emission of a quiet Sun, has been performed. A method is proposed for determining the relative fluctuations of the radio emission of a calm Sun, based on measurements of the daily course of radio emission. It was found that the relative level of purely solar fluctuations in the observed radio emission of the Sun is $\delta T_A / T_A \approx 10^{-4}$ if a significant fraction of the mass of matter is concentrated in unresolved small-scale structures. It is shown that in the solar radiation spectrum at a wavelength of λ = 3 cm there are harmonics with periods of 5 to 20 minutes, the origin of which is associated with wave disturbances in the Earth’s atmosphere.

It is proved that fluctuations of the solar radio emission in the centimeter range, recorded at sea level during the eclipse, are largely due to the acoustic-gravitational waves of the atmosphere generated by the moving eclipse spot. A method is proposed for separating regular fluctuations of the solar radio emission into fluctuations of solar and atmospheric origin.

IV. Some features of the characteristics of chaotic oscillations, and short-term quantitative forecast of solar flare.

The problem of turbulence in hydrodynamics is common to plasma physics, the theory of planets and stars, radiophysics, and many other sciences. The theory of determinate chaos has not yet been used to analyze nonlinear processes in the solar atmosphere. The dynamic mode can be characterized using Fourier analysis, but Fourier analysis does not allow to distinguish between deterministic chaos and white noise. All living and nonliving things on Earth are dependent on the processes taking place on the Sun. Therefore, the task of studying the Sun in order to predict powerful solar flares is of great scientific and applied value. In the last 20-30 years, for forecasting solar flares, their multi-parameter modeling is mainly used. Simultaneously with the method of multi-parameter modeling, a technique was also developed based on the search for several optimal parameters (1 ÷ 3), which would reflect the development of powerful solar flares. Among the most important unresolved unambiguously problems, one should include the question of the relative role of the contribution of instrumental errors and absorption in the earth's atmosphere to the recorded fluctuations of radio emission. This problem is of fundamental importance both from the point of view of the physics of the Sun, and in the applied problems of studying the Earth's atmosphere by the method of transmission. The work [4] is devoted to applied methods of the theory of determinate chaos and the processing of fluctuations of the centimeter radio emission of the Sun associated with the application of these methods. The results can be used to solve the problem of forecasting solar flares. It is known that when studying preflare states in activity centers, studying the structure of the frequency spectrum of the S-component radio emission and its changes provide information on the physical conditions for the appearance of a powerful flash in the solar atmosphere. When processing time series, spectral and fractal analysis was used. The application of fractal analysis to the processing of chaotic signals makes it possible to some extent improve the accuracy of predicting powerful solar flares. In particular, the following results were obtained. Using the Takens algorithm for the simultaneous implementation of a dynamic system, its multidimensional phase portrait is constructed. The power spectrum, constructed from long-term observational data on fluctuations of the centimeter radio emission of the Sun, mainly has a wide frequency band, and the autocorrelation function decays with time. It was found that with approaching the outbreak (in 2-3 days) the turbulent process gradually transfers to a deterministic chaotic process with an average period of about 20 or 30 minutes. It was found that, 2-3 days before the outbreak, the fractal dimension reaches a value of $D \geq 1.65 \pm 0.16$, and the entropy of the dynamic system decreases and the spectrum becomes high-frequency. In the initial phase of the flare, the entropy of the dynamic system gradually increases, and at the end of this phase, the spectrum becomes low-frequency. Thus, we can conclude that the exact calculation of the fractal dimension D and the estimation of the entropy of the dynamical system is an effective criterion for quantitative forecasting of solar flares with a power of ≥2 points 2-3 days before the outbreak. For a quantitative analysis of the system, a more convenient integral equation is obtained that relates the radio emission characteristics of a calm Sun with the parameters of its atmosphere. A model of the Poisson random process is considered as a universal mechanism for the formation of the observed fluctuation power spectra. The level of solar fluctuations can be an order of magnitude lower than the observed $\delta T_A/T_A \approx 10^{-3}$ on large paraboloids without any contradiction with the experiment, up to $\delta T_A/T_A \approx 10^{-4}$ due to the spectral indistinguishability of true solar fluctuations and interference. As a result of the analysis of the dynamics of the radio emission spectra of active regions with their flare activity, a block diagram of the probabilistic method algorithms is developed, which allows predicting the power of flashes (≥2 points) in 1-3 days.

It is known that the main drawback of modern forecasting of solar flares and the low level of reliability of forecasts is the insufficient use of physical knowledge about the mechanism of flares. Note that at present an adequate probabilistic method for predicting solar flares has not been developed.

V. On the possibility of predicting plasma turbulence in the solar atmosphere.

The sun, like a volcano, explodes from time to time with sudden force - discrete phenomena occur, called solar flares. A solar flare occurs in the corona above a group of active sunspots; its geometry and dynamics are determined by magnetic fields. The observational data from 1981-82 and 1989 were used as initial data. The material was obtained on the RT-12 radio telescope of the Ionosphere Institute of the Academy of Sciences of the Republic of Kazakhstan. Radio spectrographs operating in the 1-2 GHz and 2-4 GHz bands were developed by A.M. Huseynov, respectively, 1975 and 1978, the Analysis shows that the radio emission of the active regions at frequencies of 1÷4 GHz, begins to be observed approximately 1÷2 days before the release of the corresponding group of spots on the solar disk and ceases to be received ~2 days after the arrival of the group of spots over the edge of the disk. The increase in the radio visibility of bursts is due to the fact that the most powerful bursts are generated in the deeper layers of the solar atmosphere.

Based on the above considerations and the obtained quantitative estimates, we propose that in the case when spots develop (the areas of individual spots and the number of spots increase), a power spectrum is observed in which many periods of oscillations disappear in the range from 5 to 15 minutes and longer periods of ≥25 minutes. We propose that the reason for the disappearance of a certain part of the short orders of pulsations is the new oscillations that arise in the activated areas of the spots and contribute to the damping of the previous fluctuations. Due to this attenuation, peaks corresponding to oscillations corresponding to 25 min are observed in the power spectra. Long-term intensive research (over 40 years) in the optical and radio bands has confirmed that the atmosphere of the Sun is substantially heterogeneous. This heterogeneity has both stationary and non-stationary components. Among the processes of flash activity - are among the most turbulent and powerful events occurring in the atmosphere of the Sun. A flash is a rather fast ($10^2 - 10^3$ sec) release of a large amount of energy ($10^{32} - 10^{34}$ erg) in a relatively small volume ($10^{26} - 10^{27}\text{cm}^3$). Researchers in this area focused on the analysis of the regular component, in particular, as a result of long-term studies, a great deal of material has been accumulated on the existence of quasiperiodic pulsations (CPP) in the “active” and “calm” regions of the Sun. Although there have been a number of mechanisms to explain this phenomenon to date, the nature of the transmission has not yet been established. In these works on the analysis of time series, they were obtained at a fixed frequency, the so-called radiometric method. The main difficulty is that the amplitude of the fluctuations is ($10^{-3}\div10^{-4}$) from the level of the total radio emission of the Sun. In other words, for spectral analysis, the level of compiled time series (signal-to-noise ratio) is very low. Therefore, the results obtained in these studies contradict each other. Chromospheric flare on the Sun is an extensive complex of phenomena with extremely complex development in space and time. It follows from the foregoing that for a more adequate solution of the problem posed, the determination of the characteristic parameters of turbulence, i.e. its forecasting.

In [5], the spectral-temporal method (STM), maximum entropy method (MEM) and fractal analysis were used to process turbulence in time series. Using the modified method based on the theory of deterministic chaos, the entropy of the analyzed time series is estimated.

As a result of the studies and quantitative estimates obtained, the following main conclusions were made:

1. Based on long-term statistical observational materials, it was confirmed that the frequency spectrum of the S - component of the solar radiation in the f = 1-2 GHz and f = 2-4 GHz bands has a “fine structure” with sizes of 70-120 MHz and 100-200 MHz, respectively.
2. An increase in solar activity has the most distinct connection with the short-wave part of the radio spectra (λ = 8.5 ÷ 12 cm).

3. Of the 15 powerful solar flares in 13 (~ 87%) cases, the flux ratio of the S - component $F_{7.5}/F_{15}$ за 1÷3 days before solar flares with a force of ≥ 2 points, i.e. more than average monthly.
4. It was established that for flares with a power of ≥ 2 points, the degree of tilt of the radio spectra □ increases from α≅ 1.7±0.3 to α≅ 2.7±0.4 in 1÷3 days before the appearance of flashes.
5. Based on the radio spectrographic measurements in the ranges f = 1-2 GHz and f = 2-4 GHz, the time series were constructed using the flow ratios S – component $F_{7.5}/F_{15}$. Basically, the series contain pulsations with a characteristic time greater than t_x ≥ 25 min. 1÷3 days before a flash with a level of ≥ 2 points.
6. It was found that 1-3 days before the outbreak, the turbulent process gradually switches to deterministic chaotic processes with an average period T [T ≥ (25 ± 2) min].

Thus, we can conclude that the observed pulsations in the radio spectra of the centimeter radio emission of the Sun t_x ≥ 25 minute changes and an increase in the degree of α from α≅ 1.7 ± 0.3 to α≅ 2.7 ± 0.4 is an effective criterion for quantitative forecasting of solar flares with a power of ≥ 2 points 1-3 days before the outbreak.

VI. Some aspects of predicting weak and powerful solar flares from radio-optical data.

The problem of manifestations of flare activity of spot groups in the optical and microwave ranges of radiation has long attracted the attention of researchers. The evolution of these events covers a large volume of the atmosphere of the Sun, starting from the lower chromosphere and ending with the corona. From the foregoing, it follows that for the exact solution of the problem posed, of definite interest is the determination of the characteristic parameters of non-stationarity, i.e. its prediction. The aim of this work is to identify the prognostic parameter of solar activity. In [6], they continued by the example of more than 50 isolated solar flares with a power of ≥ 2 points observed in 1979–82 and 1989-90 on the RT-12 radio telescope of the Institute of the Ionosphere of the Republic of Kazakhstan and RT-22 of the Radio Astronomy Station of the Physical Institute of the Russian Academy of Sciences. The modulations of the S-component of the solar microwave radiation at frequencies f = 1-2 GHz and f = 2-4 GHz were studied. It is shown that under certain conditions, as the flare approaches, the turbulent process gradually transfers to deterministic chaotic processes with an average period of T ≥ 25 ± 2 min. If relative fluctuations of the calm atmosphere of the Sun are known, then, by performing radio-spectrographic measurements in active regions in a wide range, it becomes possible to study low-frequency pulsations with a characteristic time t_x ≡ 5-70 min. When studying pre-flare states in activity centers with developing sunspot groups, also on selected days according to the Solar Data Bulletin, solar optical maps were visually analyzed and the number of sunspots in each group was calculated 1-3 days before the outbreak with a force of ≥ 2 points. It was found that the observed pulsations in the radio spectra of the centimeter radio emission of the Sun t_x ≥ 25 minute changes, increase and decrease in the number of spots in groups, is an effective criterion for predicting powerful solar flares 1÷3 days before the outbreak.

It is proved that the behavior of the Earth's atmosphere, animal and plant life on Earth is associated with the activity of the Sun. Therefore, the study of their laws is of great theoretical and applied value. In this work, we used the spectral-temporal (STAM), maximum entropy (MME) method and fractal analysis to handle the non-stationarity in time series. Using the modified method based on the theory of determinate chaos, the entropy and fractal dimension of the analyzed time series are estimated. This series was obtained due to fluctuations of microwave radiation by us, fluctuations of the radio emission of the S-component, and the ratio of the S-component fluxes $F_{7.5}/F_{15}$, which are indicators of the solar flare activity. In all of the 50 flare events considered, we could not make accurate estimates for the six events. The article presents histograms reflecting the dependence of the frequency of the appearance of the pulsation on its characteristic time tx for two subranges: 5-15 min and 20-65 min. Also, the averaged relative spectra of the S-component of the solar radio emission in the range of 2-4 GHz are shown, which reflect the development of active regions and give a flash with a power of ≥ 2 points 1-3 days before the outbreak. The graphs show that the largest changes in the spectrum occur in the range 3.1÷3.6 GHz. In other words, during the active period, the slope of the α - spectra varies from 5 to 10 percent compared to signals obtained at a calm level (on an undeveloped group of spots) in the solar atmosphere.

Based on the studies (in the radio and optical ranges) and the quantitative estimates obtained, the following conclusions were made:

1. Based on extensive observational materials, it is confirmed that the frequency spectrum of the S-component of the solar radio emission in the ranges f = 1-2 GHz and f = 2-4 GHz has a "Fine structure" with dimensions, respectively, 70-120 MHz and 100-200 MHz.
2. The constructed time series for the flow ratios of the S-components $F_{7.5}/F_{15}$- mainly contain pulsations with a characteristic time of more than $t_x \geq 25$ min. 1-3 days before the flash with a level of ≥ 2 points.
3. Of the 50 powerful solar flares in 44 (~ 90%) cases on the surface of the Sun, the number of spots in the groups decreases (~ 20 ÷ 50%) 1-3 days before the flare with a power of ≥ 2n points.
4. On flashes with a power of ≥ 2 f and 2 b for 1-2 days in groups, the number of spots is approximately stable or increases (30 - 50%).
5. It was found that after powerful solar flares with a power of ≥ 2 points, the number of spots in the groups increases ~ 1.5 - 2 times.

Summarizing the above, we can conclude that the observed pulsations in the radio spectra of the centimeter radio emission of the Sun $t_x \geq 25$ minute changes, increase and decrease in the number of spots in groups, is an effective criterion for predicting solar flares with a power of ≥ 2 points in 1-3 days before the outbreak .

VII. The study of the characteristics of the parameters of solar radio bursts as an effective criterion for predicting space weather.

About 25 years ago in solar-terrestrial physics a new term “space weather“ was appeared. The concept of “space weather” includes a number of phenomena that are observed on Earth and in near-Earth space, characterizing a change in the Sun. It is known that solar flares, ejections of the coronal masses of the sun and coronal “holes” have the greatest influence on changes in space weather, when a large flux of solar energy from the sun is released in the form of electromagnetic radiation and clouds behind magnetized plasma. Today, the fact of the influence of solar activity on the sphere of human life is considered established. However, in many cases, these relationships are statistical in nature and the physicochemical mechanism of such an effect has not been resolved. Currently, much attention is paid to the study of solar-terrestrial relations and space weather forecasting. Despite this, a comparison of solar phenomena with geomagnetic disturbances shows that the prediction efficiency does not exceed 40 ÷ 50%.

In this regard, the analysis of solar data and the identification of new characteristics suitable for forecasting that should increase the reliability of the forecast are of particular interest.

The bursts of radio emission from the Sun in various wavelength ranges can serve as predictors of disturbances in the vicinity of the Earth, due to the difference in the speeds of electromagnetic and particle emission of the Sun. The data on radio bursts are very important both for studying the physics of the Sun, and in the applied aspect for predicting space weather. The forecast of geoeffective solar phenomena is understood as the totality of all types of forecasts (on the Sun, the solar wind and in near-Earth space) at a given time or for a certain time interval.

In [7], a study was made of the fluctuations of the solar radio emission at frequencies f=1 GHz and f=3 GHz. The data (polarized) of radio emissions at frequencies f = 1, 4, 9, 17 GHz, obtained using the Nobeiama solar radio polarimeter (Japan) were analyzed.

The data on radio bursts are very important both for studying the physics of the Sun and in the applied aspect for diagnosing and predicting space weather. Background flows of suprathermal and energetic charged particles on the Sun and in the heliosphere always exist. Especially strong acceleration of protons and other ions can take place during flares on the Sun, as well as on the front of a propagating shock wave in the corona of the Sun and in the interplanetary medium. Proton events are one of the most important and dangerous cosmic weather phenomena that needs to be carefully studied.

Based on the studies and quantitative estimates obtained, the following conclusions were made:

1. It was found that the observed pulsations with characteristic times $t_x \geq 35$ min in the centimeter range of solar radiation, it can be a parameter for predicting powerful solar flares ($6.5 \leq M \leq 8.7$) 1-4 days before the events.
2. It was revealed that 1÷4 days before the outbreak, the dimension of the attractor is D=3÷4 attached toward the outbreak increases. A low D-score means that deterministic chaos exists in the time series under study.
3. For five large proton events 1 ÷ 4 days before the outbreak, the criterion $F_{3,5}/F_{7,5}>1$, $F_{3,5}/F_{10}>1$ $F_{3,5}/F_{15}>1$ similar to the Tanaka-Enome criterion $F_3/F_8 \geq 1$ will also be fulfilled.

Thus, it was found that out of 25 isolated solar bursts, 17 outbreaks have a score of $6.5 \leq M \leq 8.7$ points. To increase the reliability of the short-term forecast (1-4 days) of solar flares, it is necessary to use information on the state of solar and heliospheric activity, including data from a network of neutron monitors. This in turn enables us to double the time interval for predicting the state of space weather.

VIII. Modern problems of statistical and dynamic modeling of centimeter - decimeter time sequences of solar radio emission.

Towards the end of the 20th century, Russian radiophysicist O.I. Yudin, who studied solar radio emission, confirmed the existence of fluctuations associated with the physical processes occurring on the Sun during these radio emissions. Researcher at the Radiophysical Research Institute, located in Nizhny Novgorod in the 70s of the same century, prof. M.M. Kobrin (together with his collaborators) began to publish scientific results confirming that the dynamics of these fluctuations is associated with solar flares. Despite the fact that these observations are carried out on radio astronomy telescopes with a diameter of 2÷100 meters and operating at frequencies f = 1÷17 GHz in the territories of different countries, the results obtained currently contradict one another.

The application of the Fourier transformation and its various modifications based on fluctuations of solar radio emission is the most important of these reasons, although these classical methods allow obtaining more realistic results in the study of stationary processes. Over the past few decades, researchers have discovered that there are a number of important events and processes in the world that cannot be interpreted only by the theory of oscillations and waves. Here, “chaos” is implied as an indicator of the transition to nonlinear systems in real evolutionary processes. Thus, in order to understand the essence of complex events and processes, it is necessary to accept the nonlinearity and dissipativity of dynamic systems. The theory of dissipative structure is understood as a complex of concepts of open physical systems and nonlinear dynamics. These are the main indicators for describing non-linear events that occur in the world. The causes of changes in action and evolution, according to this theory, are created by matter itself. Thus, regularity should be sought in their particular development. Various dynamic and statistical methods are used to study time series reflecting stationary and non-stationary random processes. The “chaos” defined in the time series is intended for dynamic methods, and the “noise” is used in statistical methods. Each of these methods has its advantages and disadvantages. Over the past 30 years, specialists and experts in various fields of science have developed valuable scientific proposals and methods for studying the causes and evolution of processes occurring in living and non-living objects in the world. Some of them are widely covered in monographs and textbooks. The study of time series based on our observations in any open systems consists in determining its structure and studying the future based on past data. Based on the above scientific works, in the proposed work [8], by applying fractal analysis methods to time series obtained from radio astronomical observations of the Sun, an attempt was made to establish a forecast and diagnose a flare process and its effect on the Earth’s atmosphere. In other words, by controlling the “chaos” of the process that we are exploring in dynamic methods (Fractal analysis, Wavelet and the Empirical model), the existence of deterministic randomness and its dynamics is investigated.

As observational data, 12 isolated solar radio bursts with a power of 2≤K≤3 were used. The observations were carried out on a 12-meter radio telescope at frequencies f = 1 GHz and f = 3 GHz at the Institute of the Ionosphere of the Republic of Kazakhstan in 2010-15. Observations of the Sun continued regularly, from 08:00 to 18:00 (local time) at wavelengths of 10.7 and 27.8 cm. Given that the discrete amount of data received is Δt = 5 seconds, the amount of daily data is 7-8 hours is N = 5400-5700. It also allows you to observe the dynamics of long characteristic fluctuations, ranging from 5 to 70 minutes. The estimated radio flares and their observational data around them were processed using the dynamic Fourier transform (DFT) method and the fractal analysis method (MPA). On the 24th cycle of solar activity, thanks to joint research, in addition to the proton events that took place on May 17 and January 6, 2014, three proton events were confirmed - January 27, March 7 and March 13, 2012. During these proton events, there was an increase in solar radiation on Earth. Proton event - is one of the most important and dangerous manifestations of space weather and requires careful and comprehensive study. In addition, we also used the data of radio polarimeters operating at frequencies of 1.2.3 and 4 GHz, obtained in 2010-15 at the Nobeyama Radio Observatory (Japan). Information for mathematical processing was taken from the site "httpsolar.nro.ac. jp ". Time series are based on discrete values Δt = 1 min. We studied time series associated with flare processes, which, in turn, were associated with the evolution of spots (field changes, increase in intensity) and variations in the range 5.5 ≤ M ≤ 8.7. At present, the intensity of perturbations during proton events is estimated on a five-point scale from R1 (for a M-point flash) to R5 (M-12.5) for the brightest flash.

The research presented in this work gives us the opportunity to draw the following scientific conclusions:

1. It was established that 1-3 days before an outbreak with a power of 2 ≤ K ≤ 3 points, pulsations with a characteristic change time $t_x \geq 35$ min prevail.
2. It was found that the time series of fluctuations of solar radio emission, in accordance with a certain fractal value $1<D_t<1.5$ are continuous (inertial) time series. In other words, with the approach of flare processes, randomness is replaced by a more smoothly defined randomness.
3. The study of 5 proton events showed that the value of the calculated degree of fractal dimension is inversely proportional to the power of the proton event. More precisely, 1-3 days before the proton event события the conditions $\boldsymbol{D_{t(strong)}}<\boldsymbol{D_{t(weak)}}$ are preserved.
4. It is established that when using the dynamic method of fractal analysis in radio astronomy time series, the control of the restrained randomness of the physical state caused by the processes occurring on the Sun and its interaction with the Earth's atmosphere is taken into account. This allows us to qualitatively and quantitatively evaluate the energy balance of the object we are studying.

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