TRANSITION REGIME TO THE ACTIVE PHASE OF A SOLAR CYCLE IN COSMIC RAYS

Kozlov V.I., Krymsky G.F.

Yu. G. Shafer Institute of Cosmophysical Research and Aeronomy SD RAS,
Yakutsk, Russia, cosmoprognoz@mail.ru

ABSTRACT

By studying of the dynamics of galactic cosmic rays fluctuations (GCR) at different phases of the current 24th cycle, a transition regime to the active phase of the solar cycle was discovered: http://www.forshock.ru/predlong.html, which is determined by the presence of a precursor in cosmic rays. The moments of registration of precursors in cosmic rays coincide with the beginning of rearrangements of the magnetic field in activity complexes on the Sun. It is concluded that the precursor in cosmic rays is an indicator of the restructuring of the solar magnetic field in transition to the active phase of the solar cycle. As a result, a medium-term forecast (http://www.forshock.ru/predlong.html) of the active phases of the 11-years solar cycle was first given on cosmic rays, with advance time Δ**τ**= **3**±1 of the Sun rotations.

Keywords: cosmic rays, GCR intensity fluctuations, solar activity, inversion of the general magnetic field of the Sun.

INTRODUCTION

The behavior of the GCR fluctuations on large averaging scales is of great interest from various points of view. First of all, this is important for a studying of a transition regime to active phase of the solar cycle, the revealing and study which is the main goal of this work. Early identification of such a transitional regime could solve the practically important problem of forecasting the active phase of the solar cycle. The active phase of the solar cycle means the vicinity of the maximum phase and the beginning of the declining branch of the 11-year cycle, where maximum sporadic (flare) activity is recorded, accompanied by series outbursts of coronal mass (CME) and shock waves.

From time to time, the problem is intensively discussed in the literature: is the behavior of solar activity described by a finite and "low-dimention" attractor, which would indicate the regularity of the process? In [1] no affirmative answer to this question was received. Perhaps this is due to the low information content of Wolf numbers. So, in [2] it was noted that Wolf numbers (due to the specific rule for their calculation) can hardly be a smooth function of a true dynamic variable. A plausible estimate of the correlation (fractal) dimension we obtained by the cosmic ray flicker index [3-4]. Usually monotonic dependence d(n)~n, in our case - reached a plateau with a dimension d=2.5-3 in the vicinity of the maximum and at the beginning of the descanding branch of the 11-year cycle. Neither by Wolf numbers, nor by GCR intensity, a correct estimate of the correlation dimension was obtained.

The identification of limited and low-dimensional, i.e. partially deterministic process in variations of the GCR flicker index is, obviously, an indication of the principal possibility of predicting the period of the maximum sporadic activity of the Sun. The conclusion about the principle possibility of the prognosis of the active phase of the solar cycle, made by us base on obtained above the low and finite magnitude of the correlation dimension , was commented in sufficient detail in the relevant section of the monograph [5] devoted to the theme of fractals in the Cosmos.

METHOD

It seems that the most complete information about the process is contained in the density of the distribution function, i.e. in the empirical frequency histogram of the source data. All that remains only is to highlight the potentially possible regular signal from the noise-like signal. Naturally, a potentially possible useful signal can be contained in the second and subsequent moments of the GCR intensity distribution function. This is indicated by an estimate of the Asymmetry coefficient of the empirical frequency histogram for 10 revolutions of the Sun: from March to December 2003 (Fig. 1). As is known, the Asymmetry coefficient is calculated through the 3rd moment of the distribution function. The large value of the cross-correlation coefficient R = 0.93 between the introduced coefficient of asymmetry and the intensity of the GCR indicates a good relationship between them. Turnovers 2323-2324 (by Bartels system) are fall on the period of extreme activity of the 23rd cycle in October-November 2003. Precedes active phase the 7 turnovers of the Sun (2316-2322), but yet conditionally, are referred to the transitional regime of the solar wind.

As follows from the calculation results, positive values of the Asymmetry coefficient are registered only once: on the turnover of 2322, which precedes the turnovers of 2323-2324 with extreme activity. Positive values of the Asymmetry coefficient mean a shift of the maximum of the frequency histogram towards higher values of fluctuations in the intensity of the GCR, in contrast to the negative values of the Asymmetry coefficient recorded during the active phase (turnovers of 2323-2324). In this sense, only one solar turnover No. 2322 (September 2003) can be attributed to the real transitional regime to the active phase of the solar cycle, she occurred in October-November 2003 [6]. In addition, it would be desirable to separate the changes in the shape of the empirical (frequency) histogram from the changes in scale, which is determined by the average value of the empirical (frequency) histogram of the GCR intensity distribution.

From the probabilistic theory of continuous medium destruction and reliability theory, it is known that the generalized Weibull-Gnedenko distribution function describes the output of the system to the critical limit regime [7]. In our case, this can be considered as a transitional mode of entering the active phase of the 11-year cycle. In the language of probabilistic theory, the problem of determining the transition regime is reduced to the task of determining the function of the failures intensity of a system that has exhausted its resources. The maximum of the failure intensity function, or the maximum of the Risk function, is, in fact, the PROBABILITY of reaching the critical value of the analyzed variable, in this case, the cosmic ray intensity. The ratio of the density of the Weibull distribution function to the "reliability function" (Appendix 1) is the desired probability (the Risk function) or the PARAMETER of cosmic ray fluctuations [6].

To calculate the probability of cosmic-ray intensity reaching a critical value at the transitional stage, it will be necessary to evaluate the shape parameter of the Weibull empirical distribution, which determines the degree of deviation of the shape of the approximating function of the empirical histogram from the normal distribution. The approximating function of the empirical (integral) intensity histogram is found by the least squares method. The average values of the intensity for each bin interval of the empirical distribution function (integral histogram) will be grouped in the vicinity of the fitted line, but in a new coordinate grid (after the double logarithm procedure and variable replacement). In this case, the slope of the straight line, selected by the least squares method, and the free term give the relationships necessary for estimating the desired shape parameter and scale parameter.

The shape parameter is the KEY parameter: when it reaches a critical value, the parameter value is defined as a harbinger of reaching the critical (transitional) mode. The scale parameter is determined by the average value of the empirical (frequency) histogram of the GCR intensity distribution. Further, it remains only to isolate the precursor signal from the Gaussian noise: Gaussian noise is contained, simply put, in the "to critical" linear region of the Risk function. The desired nonlinear component of the precursor signal is formed when the degree (probability) of the correlation of the critical value process is exceeded, i.e. at $P>P_{\mathbf{cr}}$.

Below, the results of the calculation of the Risk function by real data, for the known period of extreme solar activity in October-November 2003 (solar revolutions 2323-2324). At that time, a whole series of the most extreme events of the solar cycle 23 was recorded. The calculation Risk function was carried out for 7 revolutions of the Sun: for 5 previous turnovers 2318-2322 and for turnovers 2323-2324, i.e. directly during the active phase of the solar cycle. As follows from the results of the calculation, significant (P>**0.5**) values of the maximum of the Risk function are recorded at revolutions of 2320-2321 (Fig. 2).

In this connection, the time interval falling on the revolutions of 2320-2321 during which were registered harbingers is defined by us as a transition regime to the active phase of the solar cycle that took place on the revolutions of 2323-2324. The harbinger in cosmic rays in this case was registered for the **1-2** solar turnovers before the beginning active phase of solar cycle. In contrast to the case of using the Asymmetry coefficient for this purpose, when the transitional regime was detected only for 1 rotation of the Sun before the beginning active phase of solar cycle (Fig. 1). These results indicate a greater efficiency of the proposed method for detecting the harbinger of the active phase of the solar cycle, compared with the use of the Asymmetry coefficient for this purpose. This is confirmed by the estimation of the Mutual Correlation Function (MCF) of the 27-day values of the introduced fluctuation parameter and the corresponding values of the cosmic ray intensity (Fig. 3): the value of their mutual correlation $R(\tau) \approx \mathbf{0.7}$. In this case, a shift the maximum of MCF on a value of $\boldsymbol{\tau \approx 1}$ Sun revolution indicates a systematic advance of the fluctuation parameter of the corresponding values of the GCR intensity. This is consistent with our conclusion about the prognostic capabilities of the introduced GCR fluctuation parameter.

And finally, we can bring the results of the analysis of 27-days average values of the entered parameter of fluctuations and GCR intensity by the “superimposing epochs” method regarding the “zero” turnover, i.e at the time of a sharp and deep decrease in the GCR intensity (Fig. 4). For the analysis, 10 such decreases in the GCR intensity were selected at the geoeffective phase of the beginning of the decline branch of the previous 23 cycle. Obviously, the advance time, and in this case, is, on average, the same value: **1-2** solar revolutions. At the same time, low, i.e. diagnostic values of the fluctuation parameter reflect the fact of registration, on average, of a sharp and deep decrease in the GCR intensity.

IDENTIFICATION OF TRANSITION REGIME TO THE ACTIVE PHASE OF A SOLAR CYCLE

The above results of testing the proposed method on the example of known events in October-November 2003 indicate predictive (and diagnostic, too) possibilities of the fluctuation parameter calculated on the basis of the function Risk of Weibull-Gnedenko distribution. In Fig. 5 are presents the results of the mid-term monitoring of cosmic rays for the period from 1999-2016. For the analysis of short-period variations of the parameter with periods from six months or more, a low-frequency trend was excluded, which is, in fact, an 11-year variation.

Transition regimes or harbingers active phases of cycle 24 were registered at the following interval times. Harbinger of the BEGINING (24 cycle) - on the back 2407: December 2009, a dotted black arrow (see also Appendix 2). The harbinger of the GROWTH phase was registered on the back 2421: January 2011, solid black arrow (ibid, Appendix 2). The harbinger of the MAXIMUM phase was registered on the turnover 2434: **January 2012**, the red arrow (Appendix 2). *The forecast of the maximum of cycle 24 was reported at the IKI RAS Conference, in **February 2012***. The precursor of the phase of the inversion of the magnetic field was registered on the back of 2449 in early 2013 (the dotted arrow is blue in Fig. 3). The harbinger of the beginning of the geo-effective phase of the DESCENDING (after completion of the polarity reversal of Sun magnetic field at the end of 2013) was registered on the back of 2469: July 2014, solid arrow of blue color in the same figure.

The dotted arrow (green) in Fig. 5 presents a precursor of a quite unexpected ACTIVIZATION of solar activity in the vicinity of the MINIMUM phase of the current solar cycle 24 in July-September 2017 (turnover 2509-2511). Obviously, the time interval corresponding to revolutions 2504-2508 (from the third decade of February to June 2017) represents a transitional regime to a rather unexpected active phase in the vicinity of the minimum of the 24th cycle ending. Really, in July and September 2017, large Forbush effects (~ 7%) and geomagnetic storms were recorded, which caused a sharp and deep decrease in 27-days values of GCR intensity on solar turnovers 2509-2511 (see Fig. 5). The relatively small variations in GCR intensity with precursors in mid-2019 are due to the passage of the Earth's orbit of high-speed flows or long-lived solar wind “jets” from coronal holes, which is common for phase of 11-year cycle minimum.

The low values of the parameter of the fluctuations of the GCR (encapsulated in the oval in Fig. 5), recorded after the harbingers against the background of low values of cosmic ray intensity, mean the diagnostics of the predicted phases of a solar cycle. In particular: the phase of the MAXIMUM sporadic activity: turnover 2437-2442 (March-July 2012). Geo-effective phase of the BEGINNING of the recession of the current cycle: turnover 2471-2479 (September 2014 - March 2015) and the quite unexpected phase ACTIVIZATION in the vicinity of the minimum of the current 24 cycle (July-September 2017). Thus, the introduced parameter of cosmic ray fluctuations allows, with an advance $\Delta \mathbf{t}$ = **3**±1 solar rotations, to give a medium-term forecast of the active phases of the 11-year solar cycle: http://www.forshock.ru/predlong.html.

It should be noted that the moments of registration of harbingers in cosmic rays coincide with the onset of the magnetic field restructuring in the complexes of activity on the Sun. This follows from the results of comparison of the moments of registration of harbingers in cosmic rays (Fig. 5) and the results of solar observations presented in [8]. Magnetic field changes were observed at the growth and declining phases of both maxima (recorded in the annual mean values of Wolf numbers in 2012 and 2014), i.e. at the phases of their maximum variability. Thus, it can be preliminary concluded that the harbinger in a cosmic rays is an indicator of the restructuring of the solar magnetic field at the transient regime to active phase of a solar cycle.

TRANSITION OSCILLATORY PROCESS OF INVERSION OF SUN MAGNETIC FIELD IN COSMIC RAYS

To verify that the location of the precursors in cosmic rays reflects the actual situation in the interplanetary medium, a joint analysis of the intensity of cosmic rays and the parameters of the solar wind is carried out below: the dispersion of the interplanetary magnetic field (IMF), the velocity of the solar wind. For the analysis, the results of direct measurements on the American ACE spacecraft [9] were used. Indeed, during the growth phase and in the vicinity of the maximum of the new 24 cycle, the annual variance of the IMF dispersion (Fig. 6) and the velocity of the solar wind plasma are clearly expressed (Fig. 7). This coincides with the annual, on average, periodicity of registration of precursors registered by us in during the analyzed period. Consequently, it can be summary concluded, that the harbinger in cosmic rays really is an indicator of the restructuring of the solar magnetic field on the transient regime to the active phase of a solar cycle.

As follows from the obtained results, the maximum values of the variation of the GCR fluctuation parameter reaches in the vicinity of the maximum and on the geoeffective phase of the beginning of the 11-year cycle of the decline (Fig. 5). To study the dynamics of variations in the GCR fluctuation parameter during the solar cycle, it is convenient to use the wavelet analysis of variations. The results of this analysis are shown in Fig. 8-10. In the *minimum of odd* cycles 21 and 23 with a *negative* sign of the general magnetic field of the Sun, the *annual* oscillation is clearly expressed, which is clearly seen in the lower diagrams of Fig. 6 and Fig. 8. The dominance of the *annual* variation at the *minimum* of the 11-year cycle with the *negative* sign of the total solar magnetic field agrees with the conclusions arising from the model of the 11-year cycle developed in [10].

At the maximum of the cycle and on the geoeffective phase of the beginning of the branch of the recession, usually the *nonstationary semiannual* variation dominates (Fig. 8-10). The nonstationary semiannual variation in the vicinity of 11-year cycle maximum is due, in our opinion, a transient oscillatory process of sign change or inversion of the global magnetic field of the Sun [6]. The transient oscillating process of the inversion of the global magnetic field of the Sun in the vicinity of the maximum of the new 24 cycle is characterized not by the traditional nonstationary semiannual variation (as was the case in cycles 21-23), but the variation with a characteristic scale of ≈**1** year. The "annual variation" in the maximum of the current cycle is quite clearly represented in the right-hand part of the diagram of the periods of variations (Fig. 10). This is consistent with modern solar observations: in [11-12], a quasi-periodic or “pulsed” structure of the growth phase of the new 24 cycle with a period of ~ **1** year is noted.

It is important to compare the fluctuation parameter of the GCR with the key modulation parameter **k=ωτ** introduced in [13] to characterize the degree of regularity of the field. Here ω is the gyro-frequency of particles in a regular magnetic field τ is the average time between the scattering events of particles. The modulation parameter is assumed to be constant for the entire heliosphere and independent of the particle energy, although it will be vary in during a solar activity cycle. It is assumed that the magnitude of the modulation parameter reflects the *relationship between the intensity of the regular and turbulent field*. The regular field in the time of the maximum is much less than the turbulent field. On the contrary, the intensity of the turbulent field is maximal during the maximum of the cycle: first the intensity of the turbulent field increases linearly with time, reaches a maximum during the polarity reversal, and then decreases linearly [13].

The relationship between the fluctuation parameter of the GCR and the degree of turbulence of the solar magnetic field follows also from the comparison of the GCR parameter with the "efficiency index of the solar multipole", which reflects the contribution of the quadrupole component of the solar magnetic field. This indicator was introduced in the works of the IZMIRAN group [14-15]. It is good (R=**0.83**) correlates with the main parameter of solar activity - Wolf numbers (Appendix 3). Below, we compared the fluctuation parameter of the GCR with the "efficiency index of the solar multipole" IZMIRAN. Their comparison shows that the envelopes of variations in the GCR fluctuation parameter and variations of the “solar multipole efficiency index”, on average, are consistent with each other (Fig. 11). This is confirmed by a rather high (**R= -0.77**) value of the coefficient of their regression connection, in general (Fig. 12). Thus, the fluctuation parameter clearly reflects the contribution of the *quadrupole* component of the solar magnetic field, which is largely due to the *restructuring* of the solar magnetic field in the vicinity of the maximum of the 11-year cycle.

Indeed, as follows from the results of analysis of [16], the contribution of the quadrupole component of the solar magnetic field is dominant in the vicinity of the maximum of the solar cycle. In this sense, the unsteady oscillatory process in cosmic rays in the vicinity of the maximum of the solar cycle (Fig. 11) is an indicator of the transition regime of inversion of the solar magnetic field. This is confirmed by the analysis of the fluctuating component of the solar magnetic dipole for the same 3 cycles of solar activity 21-23 [17]. These authors conclude that during the field inversion, the component of the magnetic dipole does not vanish. It has a fluctuating nature and therefore is not described (http://www.aanda.org/articles/aa/pdf/2014/07/aa23319-13.pdf) in the framework of the traditional theory of dynamo of the mean field. In addition, the presence of a transient oscillatory process of changing the sign of the total magnetic field of the Sun allows us to explain from a single point of view the so-called “failure (s) of Gnevyshev” [18-19], observed in the vicinity of the maximum of the 11-year cycle, including “Quasi-two-year”, as well as “semi-annual” variations of the interplanetary magnetic field [20].

CONCLUSIONS

1. By studying the dynamics of intensity fluctuations of galactic cosmic rays at different phases of the current 24th cycle, a transition regime to the active phase of the solar cycle was found: http://www.forshock.ru/predlong.html, which is determined by the presence of a harbinger in cosmic rays. The moments of registration of precursors in cosmic rays coincide with the beginning of rearrangements of the magnetic field in activity complexes on the Sun. It is concluded that the harbinger in cosmic rays is an indicator of the restructuring of the solar magnetic field in transition to the active phase of the solar cycle.

2. First time is given medium-term forecast of the active phases of the 11-year cycle with the advance time $\Delta\tau = 3 \pm 1$ revolution of the Sun: http://www.forshock.ru/predlong.html. This is due to the fact that the harbinger in cosmic rays is an indicator of the restructuring of the magnetic field in transition to the active phase of the solar cycle.

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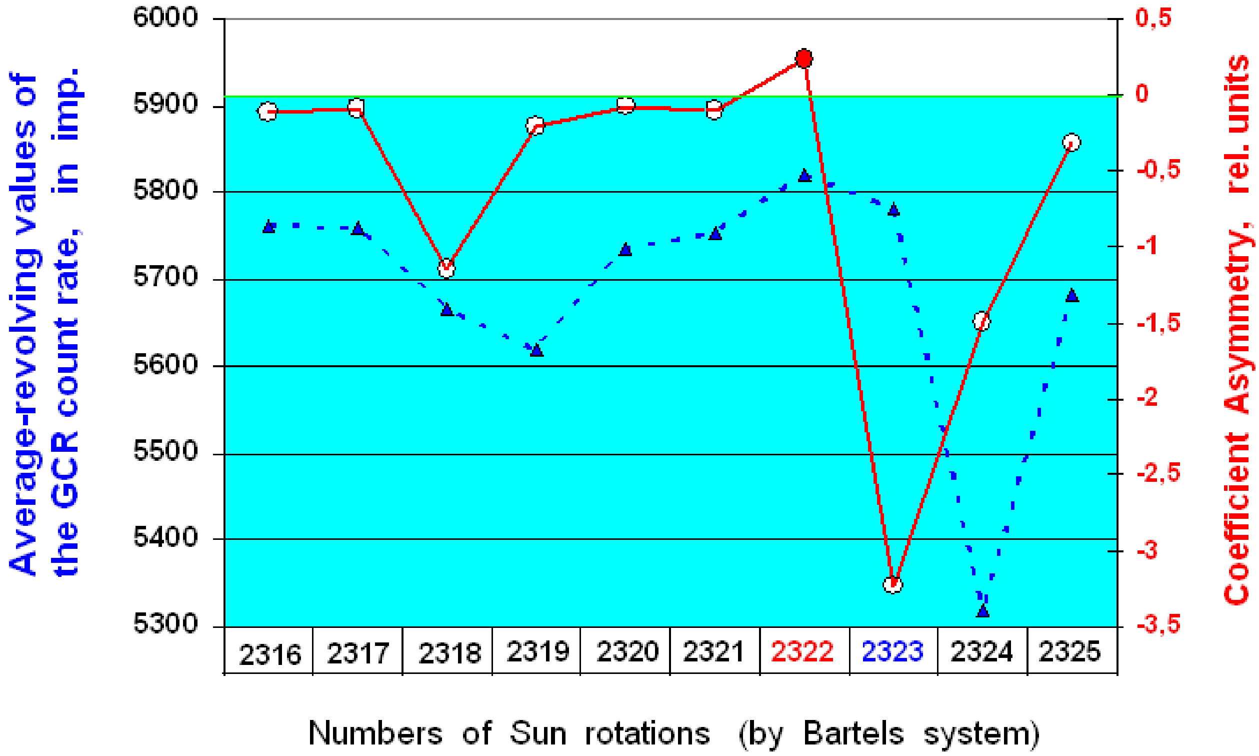


Fig. 1. **Asymmetry coefficient** calculated from 7776 points of a five-minute values count rate of cosmic rays (in pulses) during each revolution of the Sun, starting from No. 2316-2325 (03/28/2003 - 12/22/2003). By the ordinate axis: the scale on the left, the dashed curve is the cosmic ray counting speed in pulses over 5 minutes, averaged over 7776 points of five-minute values during each revolution of the Sun (27 days) by data of neutron monitor Oulu station (Finland). The scale on the right, the solid curve is the value of the Asymmetry coefficient in relative units. By the abscissa axis - time: the serial numbers of the revolutions of the sun (according to the Bartels system).

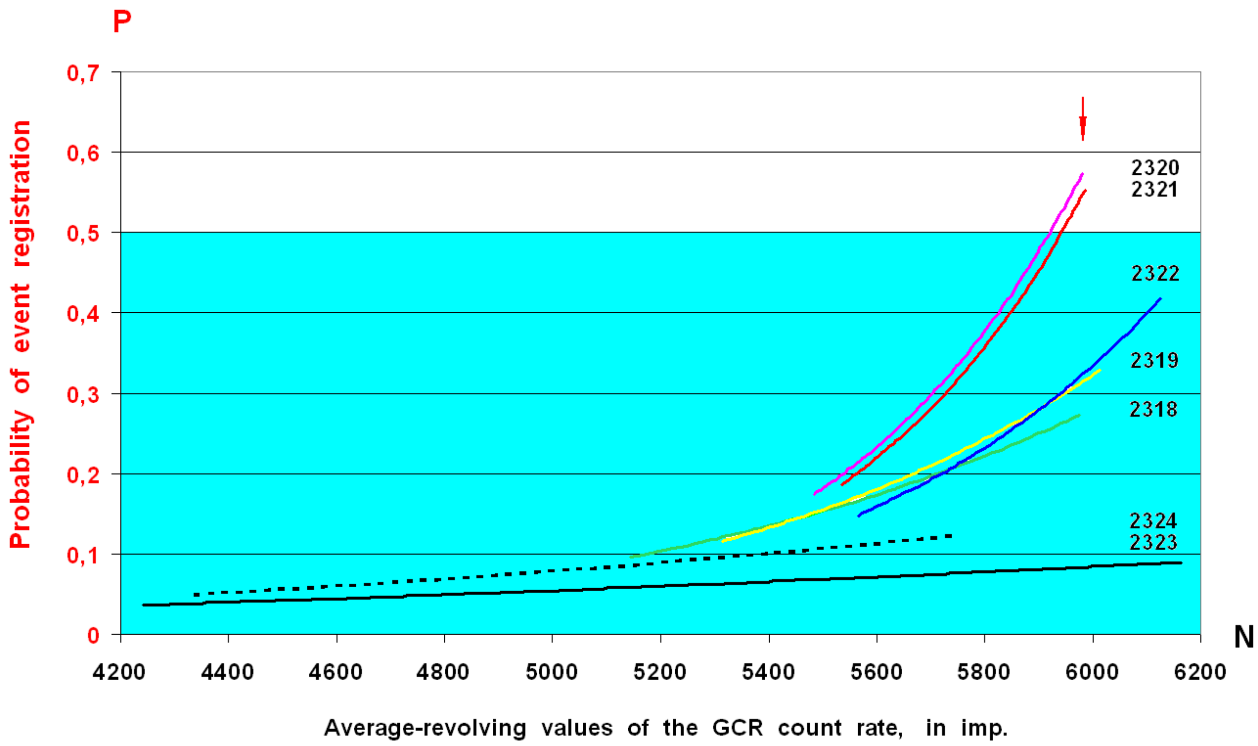
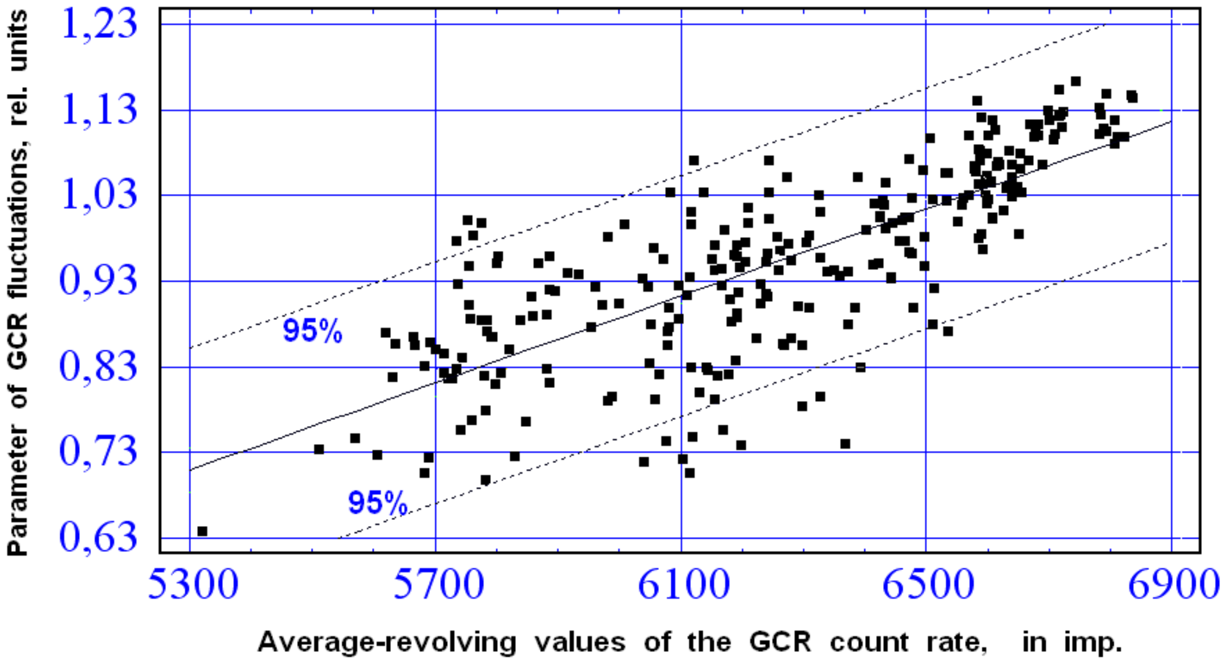


Fig. 2. Calculation of the **Risk function** or probability (ordinate axis, scale on the left) of the occurrence of an “event” based on the Weibull-Gnedenko distribution. By the abscissa axis is the counting speed of cosmic rays in pulses in 5 minutes, averaged over 7776 points of five-minute values during each revolution of the sun. On the revolutions of **2320-2321**, i.e. for **1-2** turns before the start of the growth phase of solar activity in October-November 2003 (revolutions 2323-2324) significant (**P>0.5**) probability values are recorded, i.e. harbingers of begin of the active phase of the solar cycle.



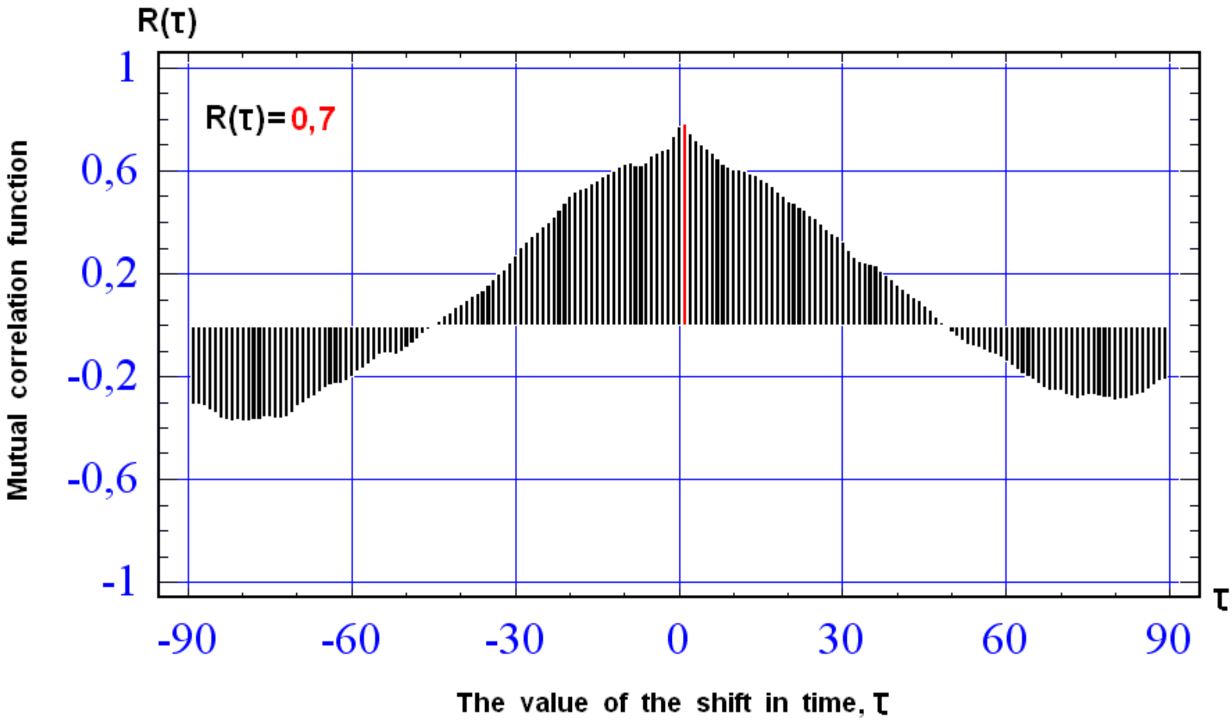


Fig. 3. Estimation of the connection of 27-day values of the cosmic-ray fluctuation parameter and cosmic-ray counting rate in pulses over 5 minutes, averaged over 7776 points of five-minute values during each revolution of the Sun: statistical relationship was established at 95%, the value of their cross-correlation coefficient is $R(\tau)\approx 0.7$. The **average value of the advance time of the precursor** (in parameter of GCR fluctuations) relative to the intensity of cosmic rays is determined by the value of the time shift by axis τ: $\boldsymbol{\tau\approx 1}$ Sun`s revolution.

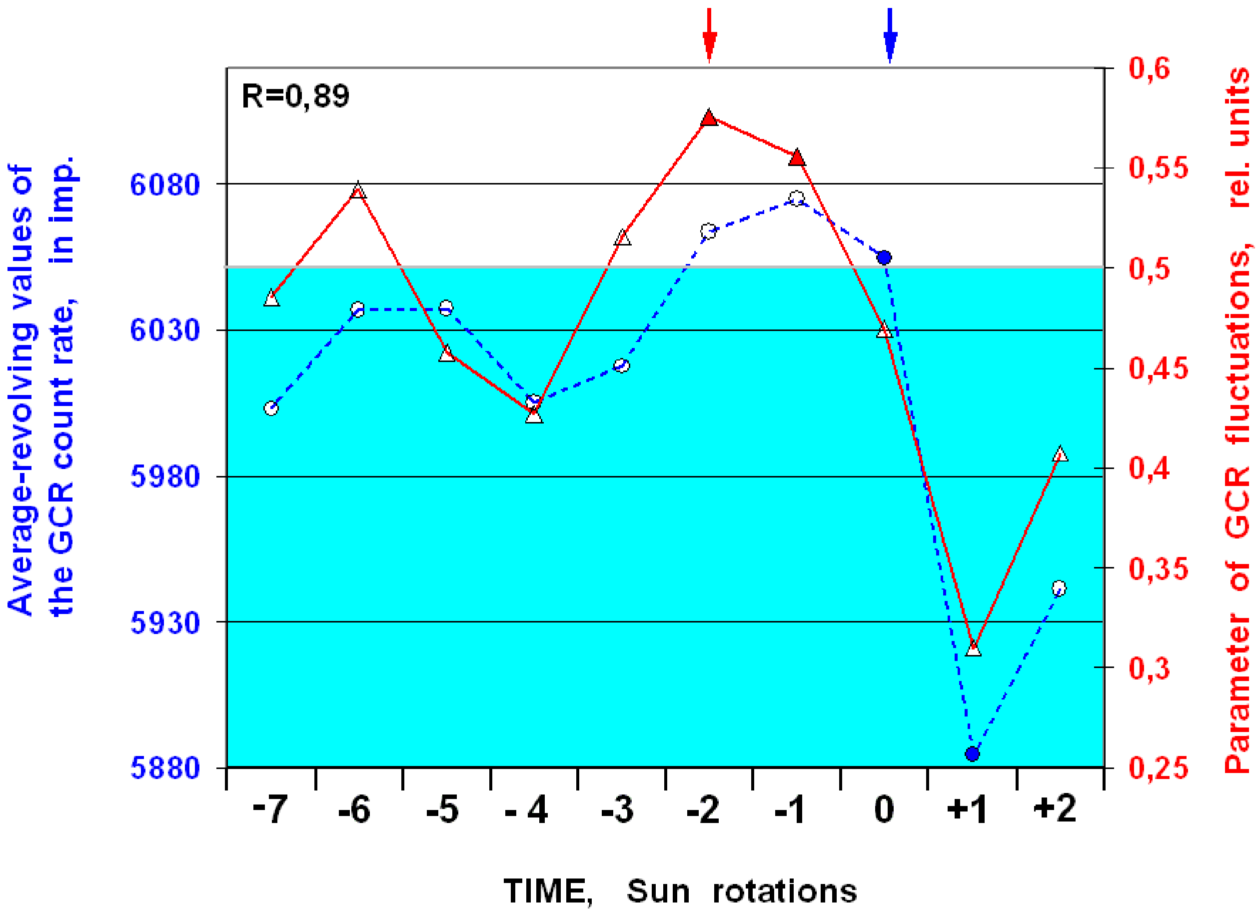


Fig. 4. The results analysis by the "**superposition of epochs**" method for 10 cases of sharp and deep minima in the GCR intensity recorded in the previous 23 cycle of solar activity. The scale on the left, the dashed curve is the cosmic ray count rate in pulses in 5 minutes, averaged over 7776 points of five-minute values during each revolution of the Sun. The scale on the right, the solid curve - is the parameter of the GCR fluctuations in relative units. By the abscissa axis - is the time (in conventional) revolutions of the sun. The turnover from which a sharp and deep decrease in the GCR intensity begins begins is indicated as a "**zero**" revolution.

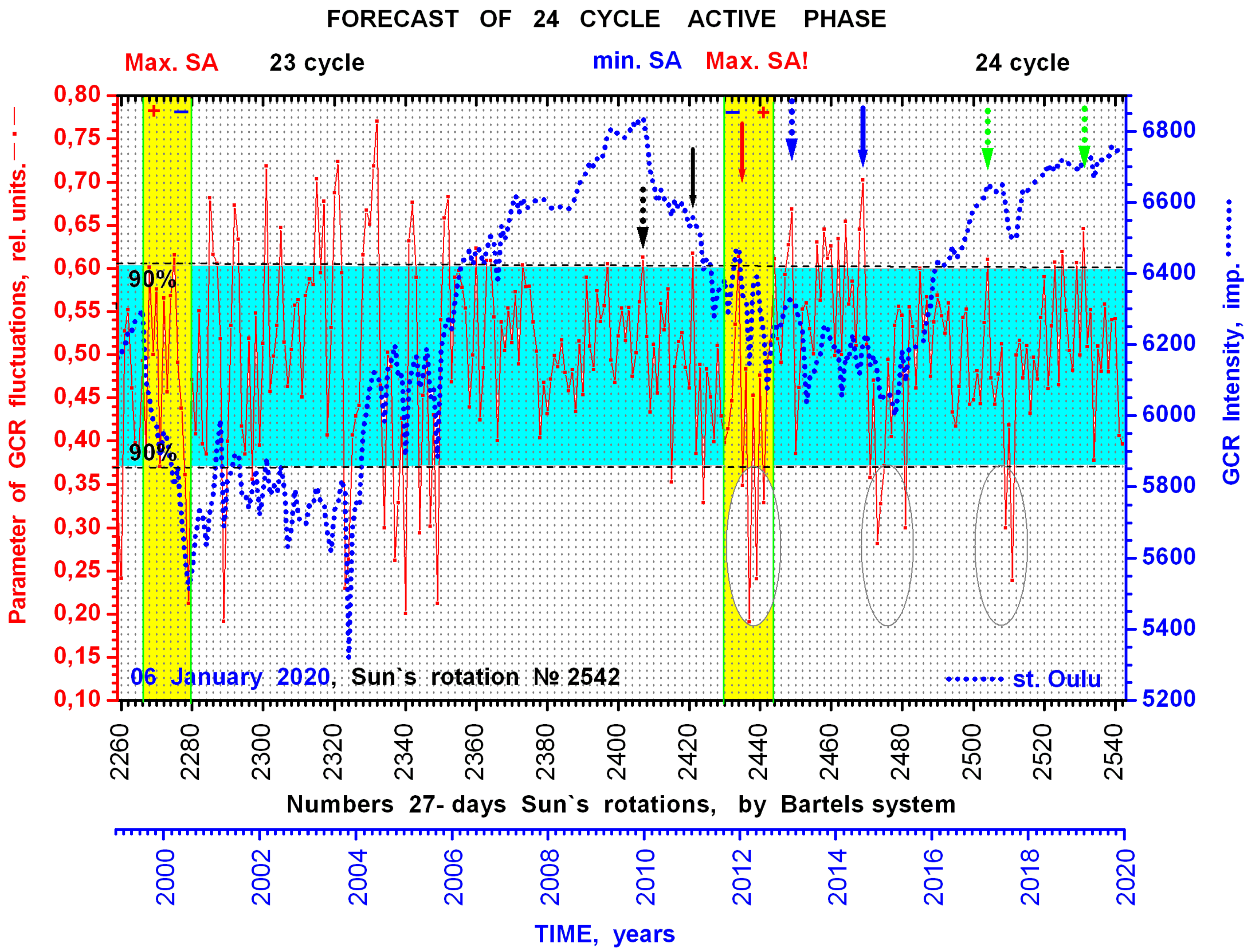


Fig. 5. The solid curve is the 27-day GCR fluctuation parameter values in relative units, the scale on the left. A 90% significance level is shown. The dashed curve is the cosmic ray count rate in pulses over 5 minutes, averaged over 7776 points of five-minute values during each revolution of the Sun. Harbingers: THE BEGINNING of the 24th cycle is indicated by a dotted arrow, the GROWTH phases of the current cycle are shown by a solid arrow in black, the MAXIMUM phase of cycle 24 are shown by a solid arrow by red, the ending of the polarity-reversal phase by a dashed arrow by blue, and the geoeffective phase of the beginning of the decline branch by a solid arrow by blue. LOW fluctuation parameter values in 2011-2012, 2014-2015, and 2017. (enclosed in an oval) - means the DIAGNOSTICS of the active phases of the solar cycle.

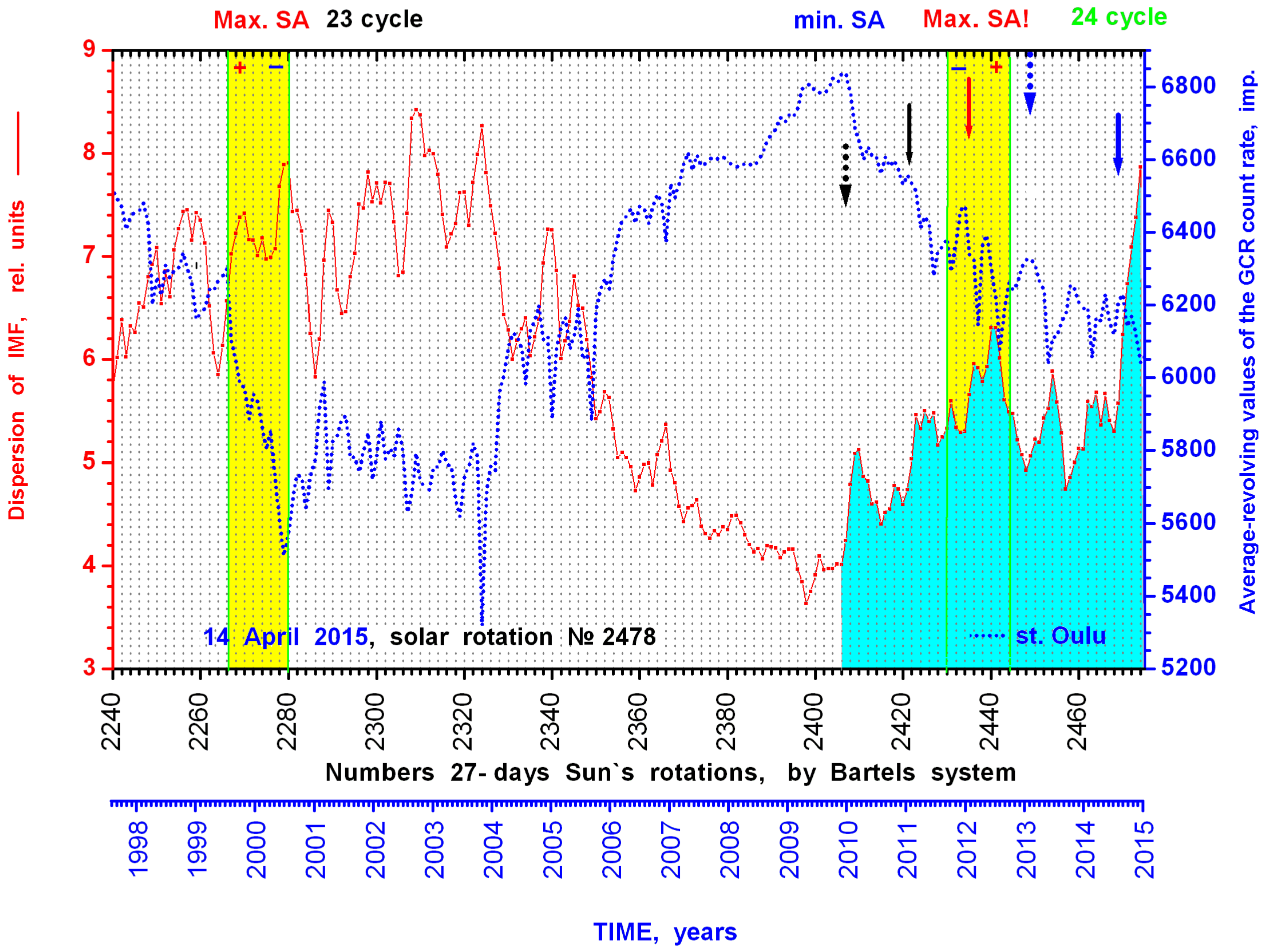


Fig. 6. Comparison of 27-day values of the count rate of cosmic rays in pulses (dashed curve) and dispersion of the interplanetary **magnetic field** intensity (a continuous curve) by data a space vehicle the ACE [9], at 23-24 cycles of solar activity: 1997-2014. Precursors in cosmic rays are shown by vertical arrows. All precursors are preceded to global maxima in intensity of a magnetic field. Both in fluctuations parameter and in magnetic field intensity the **annual** variation is registered.

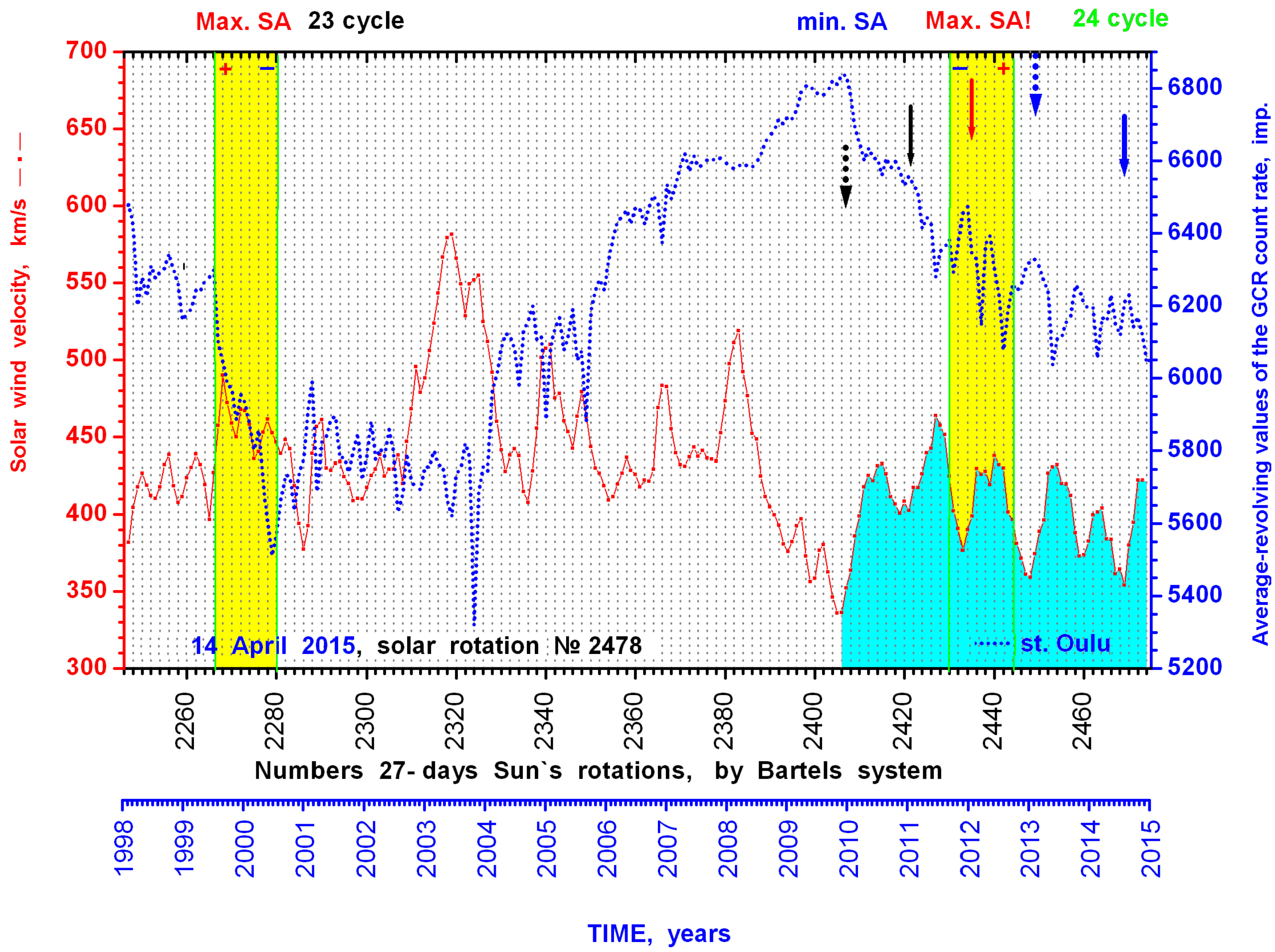


Fig. 7. Comparison of 27-day values of the count rate of cosmic rays in pulses (dashed curve) and solar wind velocity (a continuous curve) by data a space vehicle the ACE [9], at 23-24 cycles of solar activity: 1997-2014. Precursors in cosmic rays are shown by vertical arrows. All precursors are preceded to global maxima in solar wind **velocity**. Both in fluctuations parameter and in solar wind velocity the **annual** variation is registered.

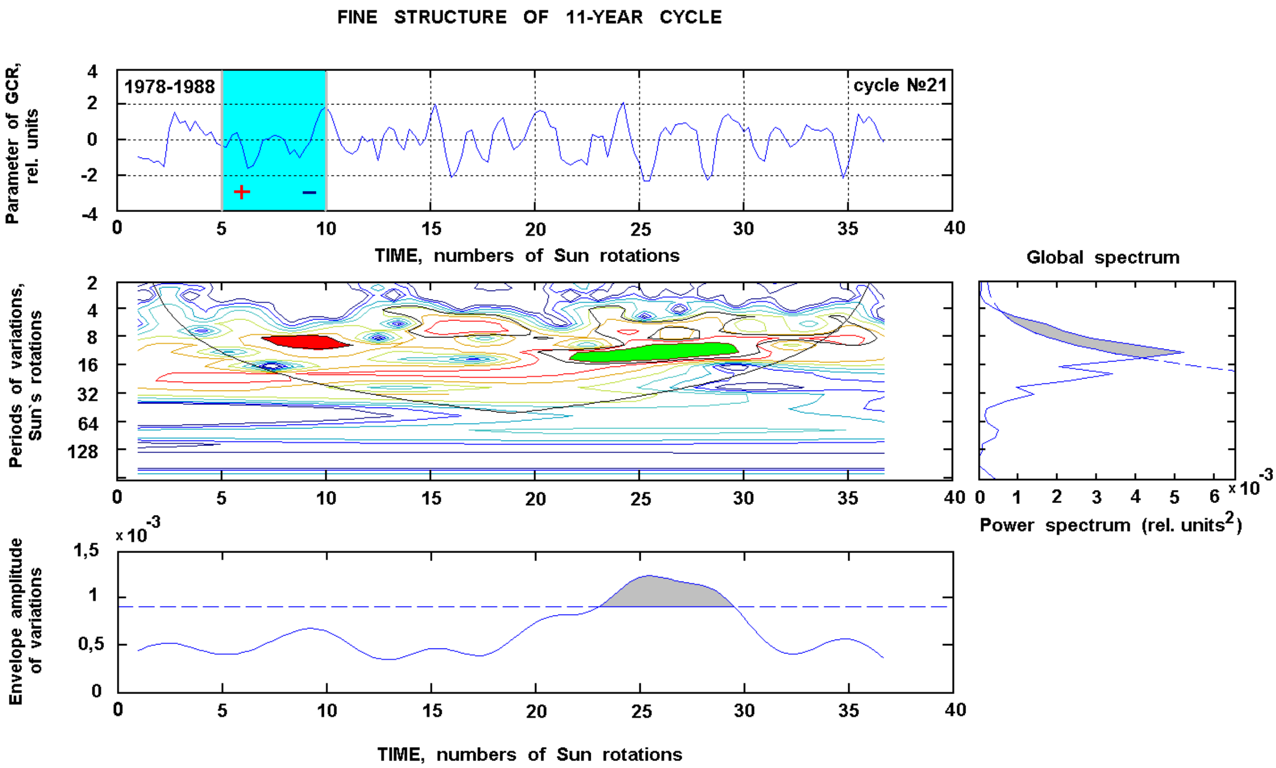


Fig. 8. The results of wavelet analysis of the fine structure of the parameter of cosmic ray fluctuations in cycle **21**. In the vicinity of the *inversion* of Sun magnetic field, the traditional non-stationary HALF-YEAR variation dominates. At the *minimum* of an *odd* cycle 21 with a *negative* sign of the general magnetic field of the Sun, the traditional **annual** oscillation dominates. On the right is the global spectrum as a whole. At the bottom of the figure: the amplitude of the envelope of variations. The abscissa is the time or number of solar revolutions.

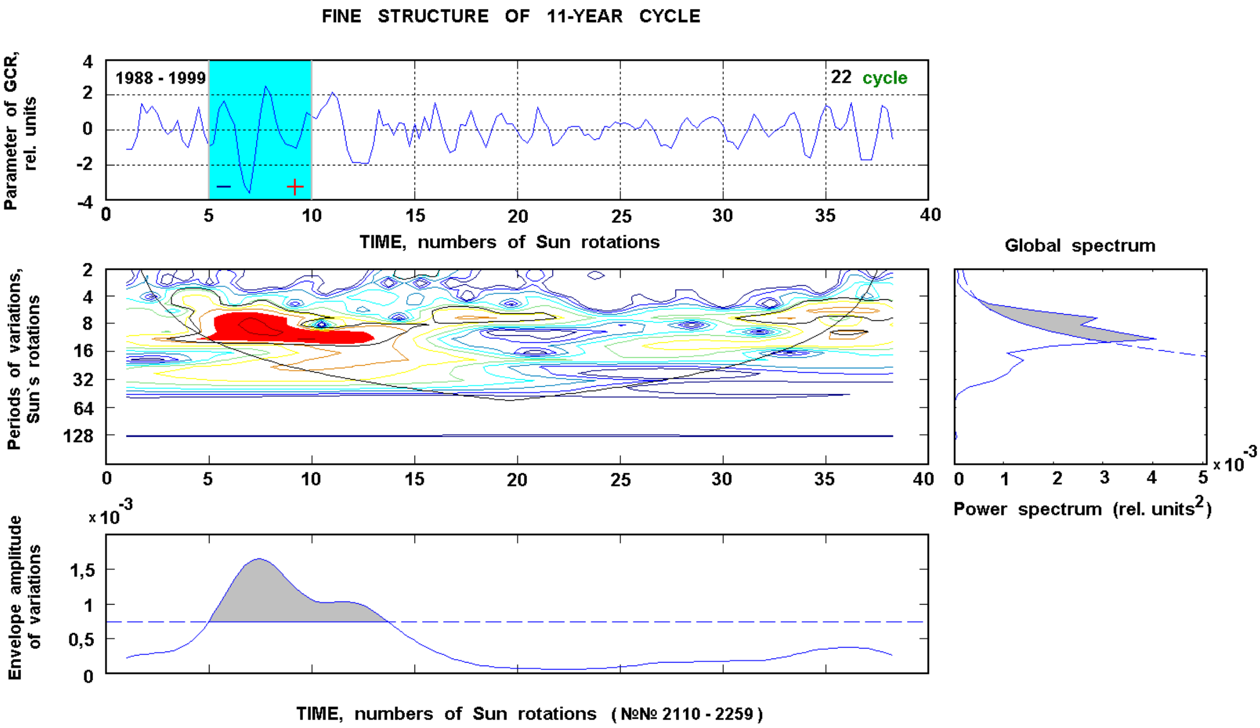


Fig. 9. The results of wavelet analysis of the fine structure of the parameter of cosmic ray fluctuations in cycle **22**. In the vicinity of the *inversion* of Sun magnetic field, the traditional non-stationary HALF-YEAR variation dominates. On the right is the global spectrum as a whole. At the bottom of the figure: the amplitude of the envelope of variations. The abscissa is the time or number of solar revolutions.

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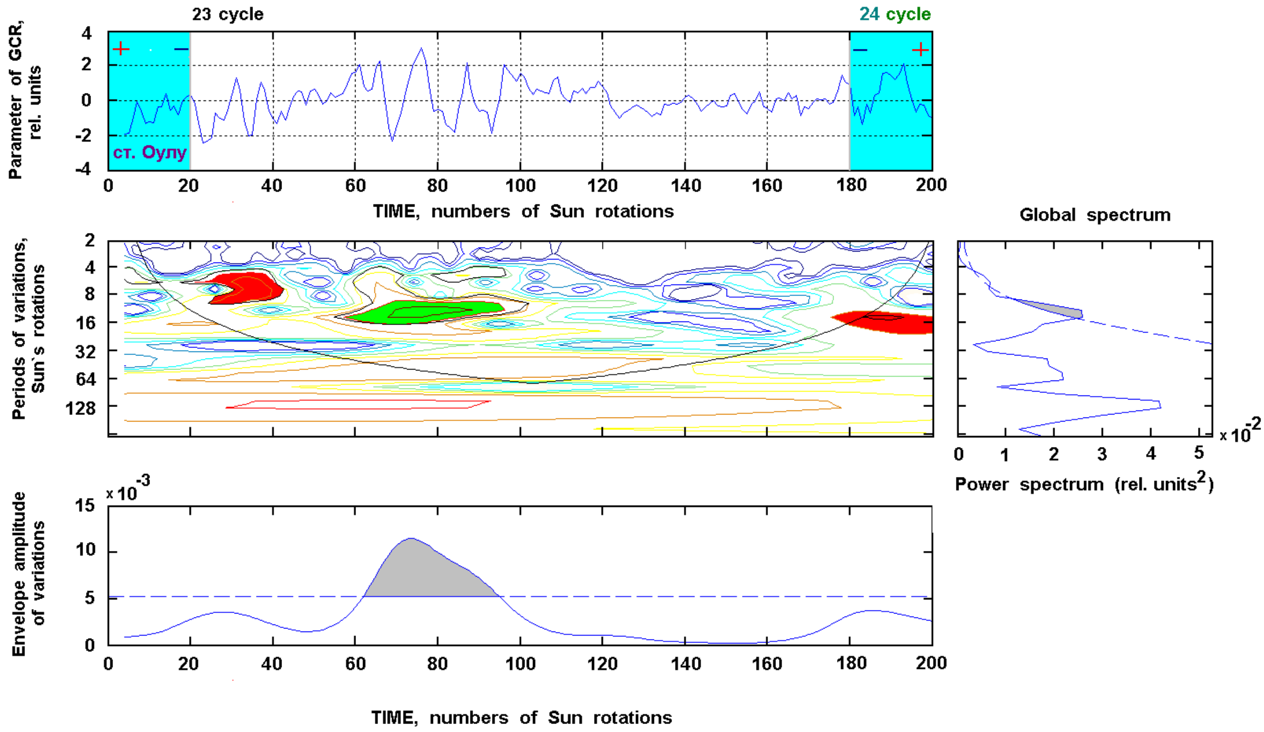


Fig. 10. Results of the wavelet - analysis a thin structure of fluctuations parameter: in cycle 23 and in the beginning 24 cycle. In vicinity POLARITY REVERSAL is dominate a traditional non-stationary SEMI-ANNUAL variation. In *minimum odd* cycle **23** (with a *negative* sign on the Sun general magnetic field) is dominates the traditional polarity reversal **annual** wave. In **24** cycle polarity reversal phase is dominate the **unusual** ANNUAL variation. On the right: the global spectrum, as a whole. In the bottom part of figure: amplitude bending around variations. On an abscissa axis – time: number of solar rotations.

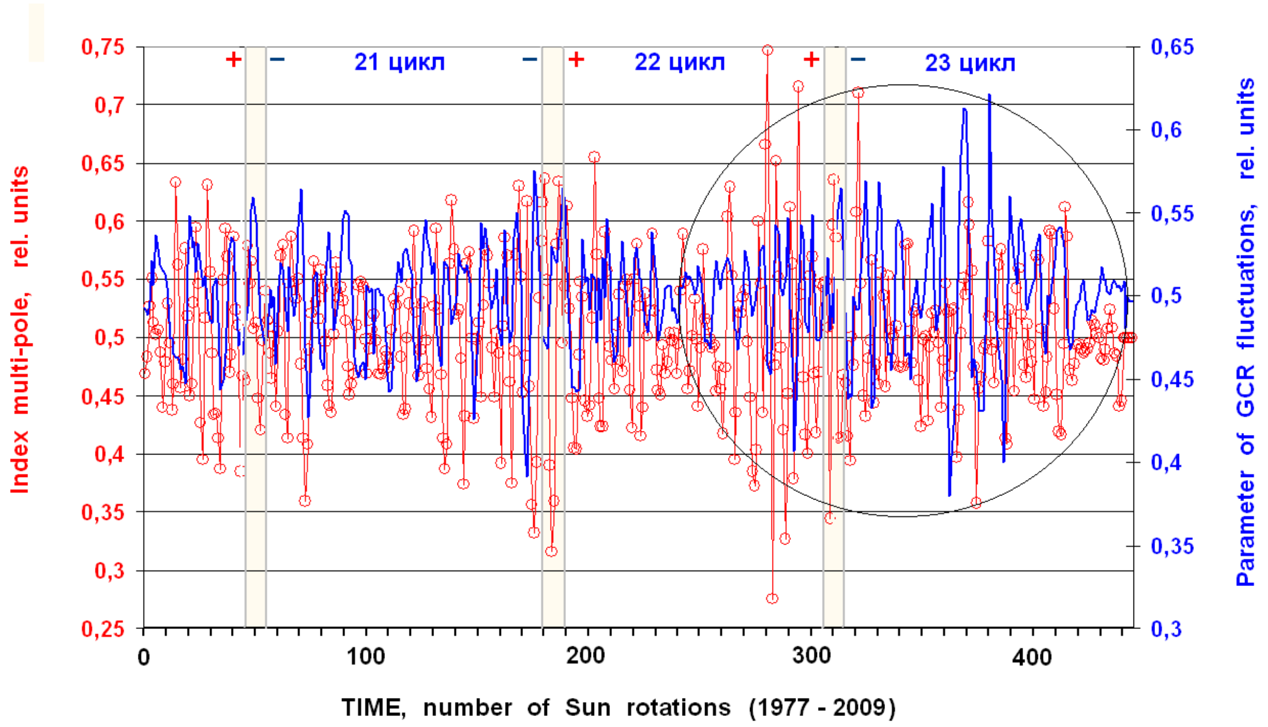


Fig. 11. Multi-field index (Sun magnetic field): open mugs - a scale at the left. Cosmic rays fluctuations parameter - a scale on the right (a dark blue curve). On an axis abscissa: time, numbers of solar rotations (with 1977 - 2008). Numbers of cycles, conditionally are shown, the periods of Sun general magnetic field sign change are noted. **Bending** around fluctuations parameter variations and a “multifield index” are reached a maximum, practically, **simultaneously**.

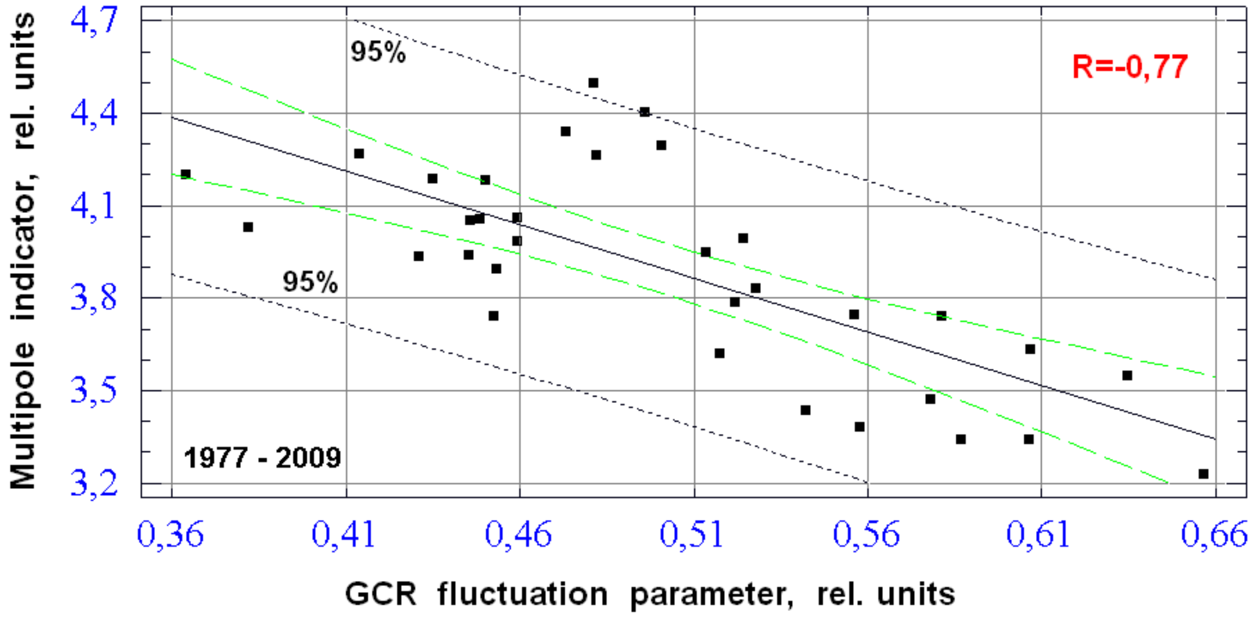


Fig. 12. Estimation of the regression relationship (R = **-0.77**), in **general**, between the average annual values of the "solar multipole" indicator (IZMIRAN) and the cosmic ray fluctuation parameter according to the linear regression model. A 95% significance level is shown.

Weibull distribution function:

$$F(x) = 1 - \exp\{-[(x-\theta)/b]^{c}\}$$

where

$\theta < x,\ b > 0,\ c > 0$

b - scale parameter

c - shape parameter

θ - pozition parameter

Distribution function density:

$$f(x) = c/b * [(x-\theta)/b]^{c-1} * \exp\hat{}\{-[(x-\theta)/b]^{c}\}$$

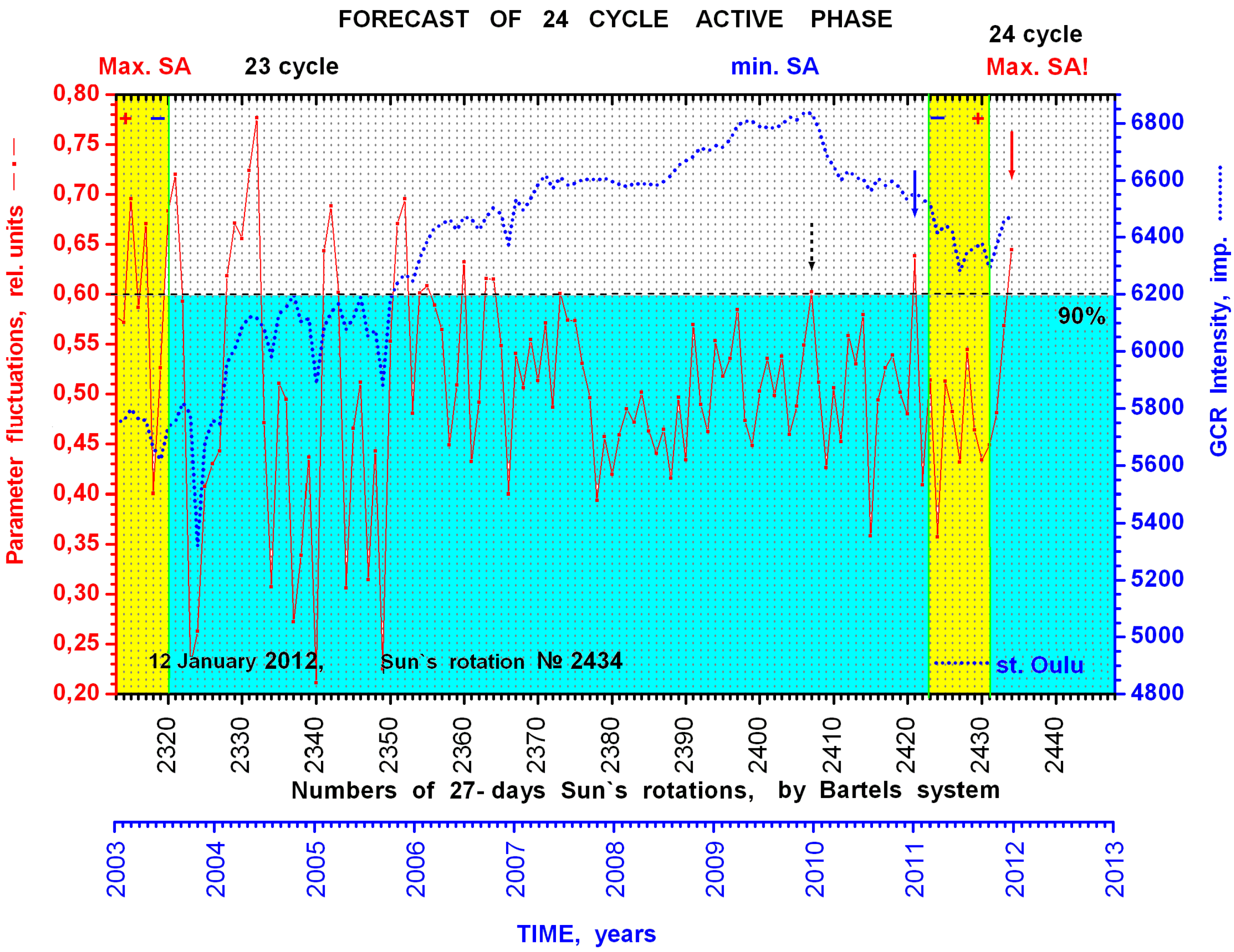
Reliability function:

$$R(x) = 1 - F(x)$$

Hazard function:

$$h(x)=f(x)/R(x)= [c * (x-\theta)^{(c-1)}] / b^{c}$$

Appendix 1. Mathematical expressions determining the Risk function used in calculating the PARAMETER of cosmic ray fluctuations from the values of the shape parameters (**c**), scale (**b**) and shift (**θ**).



Appendix 2. A dotted curve - are shown (27-days) values of cosmic rays intensity with 1999-**2012**, scale on the right. Continuous curve - corresponding values of fluctuations parameter - a scale at the left. The level of significance (90%) is shown. Precursors: the BEGINNING of cycle 24 is shown by dotted arrow, phase GROWTH of a current cycle - a continuous arrow of black color, a phase of a MAXIMUM 24 cycles - an arrow of **red** color. *The forecast of the maximum of cycle 24 was reported at the IKI RAS Conference, in* ***February 2012***.

	Parameter GCR	Int. GCR	N-Dst	W	Index mp	N-Ey
Parameter GCR	1	0,80	- 0, 85	-0,74	-0,77	-0,76
Int. GCR	0,80	1	- 0,89	- 0,87	-0,68	- 0,67
N-Dst	- 0, 85	- 0,89	1	0,86	0,74	0,83
W	-0,74	- 0,87	0,86	1	0,83	0,59
Index mp	-0,77	-0,68	0,74	0,83	1	0,61
N-Ey	-0,76	- 0,67	0,83	0,59	0,61	1

Appendix 3. The matrix of correlations of the parameter of fluctuations of GCR with the intensity of cosmic rays, solar wind parameters and solar activity indices: with a GCR intensity R = **0.80**; With Wolf numbers R = **-0.74**; with the index of the "electric field of the solar wind" R = **-0.76**. The most value is the anticorrelation of the fluctuation parameter of the GCR with the Dst-variation R = **-0.85**.