
EXPERIMENTAL BIOLOGY

Effects of Space Weather on Biomedical Parameters during the Solar Activity Cycles 23-24

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The results of long-term (1998-2012) biomedical monitoring of the biotropic effects of space weather are discussed. A drastic change in statistical distribution parameters in the middle of 2005 was revealed that did not conform to usual sinusoidal distribution of the biomedical data reflecting changes in the number of solar spots over a solar activity cycle. The dynamics of space weather of 2001-2012 is analyzed. The authors hypothesize that the actual change in statistical distributions corresponds to the adaptation reaction of the biosphere to nonstandard geophysical characteristics of the 24th solar activity cycle and the probable long-term decrease in solar activity up to 2067.

Key Words: *living system adaptation; Sun-Earth relations; long period variations of solar activity; biomedical monitoring*

Solar activity and its manifestations in space weather and dynamics of the biosphere constitute a complex of intricate mutually related multifactor phenomena. Traditional approach to search for relationships between changes in the biosphere and, for example, the number of sun spots is now rejected. The role of individual flashes is very important for short intervals, while longer intervals are presumably determined largely by the global fields and their evolution over a century or even many centuries. The co-evolution of the Sun and the Earth biosphere and dynamics of solar activity in 1990-2012 are previously presented in detail [7].

The duration of a standard complete cycle of solar activity (SAC) is about 22 years; it is a double 11-year cycle. Each phase of solar activity differs from another by physical characteristics. The intensity of solar UV

band increases 5-7-fold from SAC minimum to maximum. In SAC minimum and maximum, the adaptive response of human body driven by external exposure gradient is triggered by magnetic storm and its unexpected absence, respectively. There are also longer SAC – of 90, 200, 400, and 2300 years. Interactions between different periods can lead to a drastic increase of an 11-year cycle amplitude and to long-term disappearance of the amplitude cycles and in fact absence of active events in the Sun for decades [2-4,10].

Detection of the biotropic effects of space weather involves additional biomedical and ecological monitoring, comparable with 11-year SAC. Parallel monitoring carried out in different cities in 1998-2013 showed a universal (24-h) pattern of the adaptive reaction to the solar flash processes and the accompanying changes in the ultralow frequency constituent of the geomagnetic field. It is shown that all normal subjects are sensitive to variations in the cosmophysical factors and geomagnetic field, the amplitude and duration of reactions in normal subjects higher than the parameters in the

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patients. The results are published in 2000-2012 in a series of reports [5,6] and summed up [1,7].

The current 24th SAC is uncommon because of the prolonged minimum of 2005-2009 and because of the specific dynamics of space weather parameters. We discuss the manifestations of space weather cycles longer than 6 months by the results of biomedical monitoring.

MATERIALS AND METHODS

Monitoring of physiological status of a permanent group of normal subjects and of space weather parameters has been carried out since 1998 up to the present time. The parameters of electric conduction bioactive points in human skin are recorded (total database: more than 500,000 measurements).

Electric conduction of fixed skin sites is an objective physiological parameter. It is used for statistical analysis, similarly as any other objective physical parameter (temperature, wavelength, power of released energy). The measurements were daily; the data over a 2-month period were averaged for analysis of long period correlations, filtering of local ejections, and amplifying the signal/murmur proportion. On the one hand, this period allows accumulation of the volume of data sufficient for statistical analysis (at least 270 measurements), on the other hand, seasonal and annual trends of the measured parameters are taken into consideration. We deliberately do not analyze the relationships between the studied parameter and this or that human organ or system (these problem have been discussed previously [8]), as the data presented in this paper are essential for not only medical, but also biological, population, and ecological levels of the biosphere adaptation to cosmogeophysical factors.

Daily measurements of physico-chemical characteristics of metachromasia reaction to cosmogeophysical factors were carried out, *e.g.*, of polyphosphate and DNA status, DNA reparation in promotor sites of genes involved in *Sacharomyces cerevisiae* cell cycle regulation. Metachromasia is cell and tissue staining in colors other than the color of the stain. Three-color staining (MTC-1, MTC-2, MTC-3) was characteristic of the selected cell structures, the color changes depending on variations in the space weather parameters. A detailed description of the experiment technology and equipment is presented in previous reports [1,5-9] and in sites of the helio-ecological sector of Institute of Geomagnetism and Radiowave Propagation IZMIRAN (<http://heliocology.webnode.com>).

RESULTS

Analysis of the results of daily measurements of acupuncture point conduction in 25 volunteers over a pe-

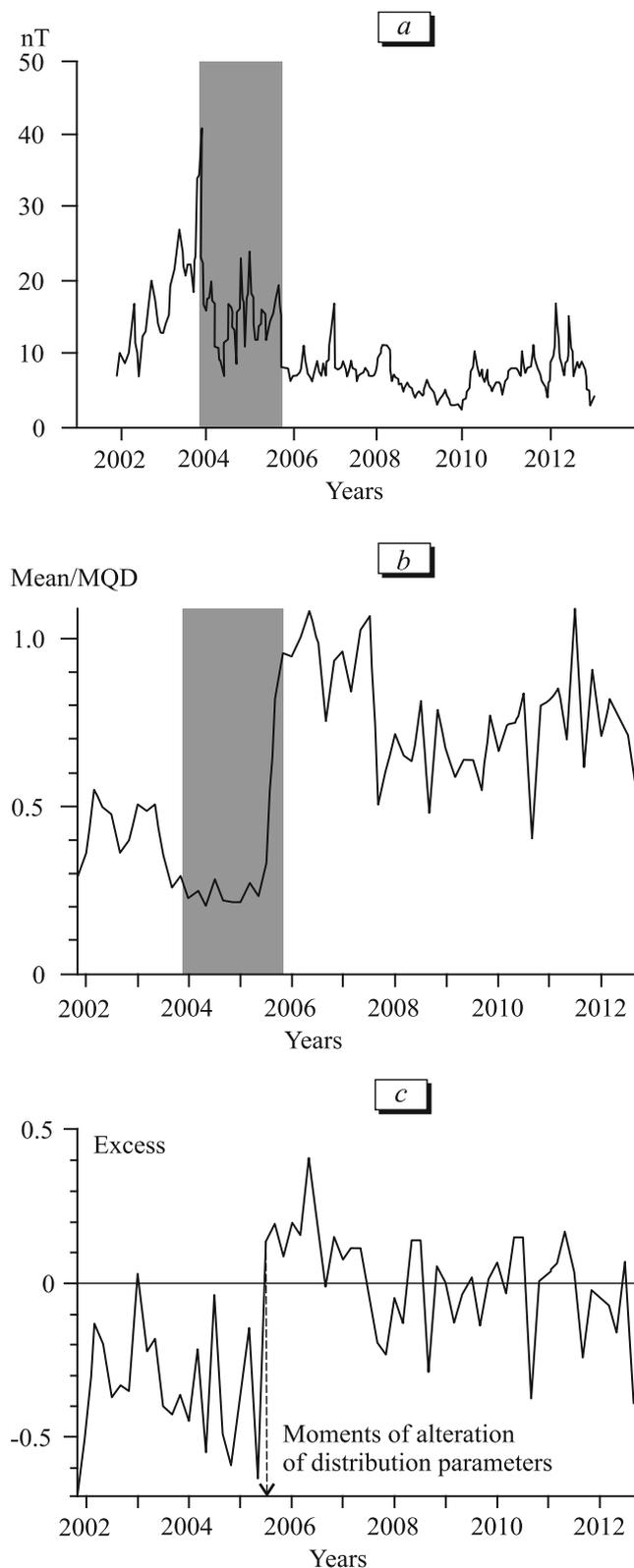


Fig. 1. Geomagnetic activity Ar-index (a), proportion of the mean-for-group value of selected skin site conductivity to the mean quadratic deviation (MQD) of this parameter (b), and dynamics of the mean-for-group value of selected skin site conductivity (c) over 2002-2012. Gray color shows the period of restructuring of the Sun-Earth relations.

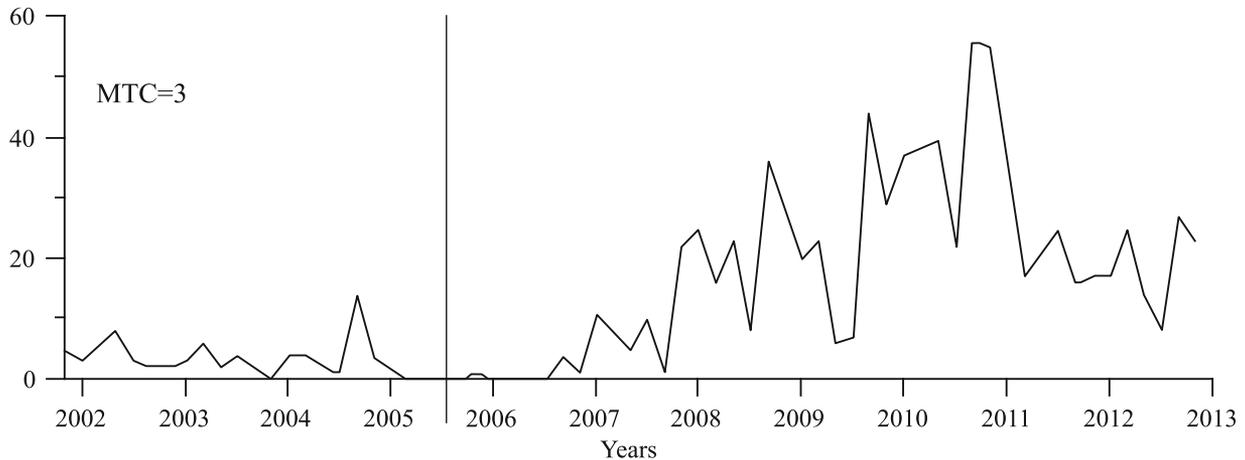


Fig. 2. Dynamics of MTC-3 states for reference *S. cerevisiae* cell structures in 2002-2012.

riod of 1998-2012 indicates that the statistical distribution of some biomedical parameters in the same volunteers differed significantly over the 14-year monitoring and varied in different years, depending on the solar activity phase.

An unexpected result of analysis of the individual regularities was manifest alteration of the type of physiological parameters distribution in September-October, 2005. Before analysis, we expected to find long-term changes in the parameters during the minimum of 2007-2008 or the beginning of the new cycle 24 in 2009, associated with more fine effects of short-term pulsed exposure to solar activity. However, analysis of experimental data has shown alteration of the statistical distribution type in September-October, 2005. The probable impact of volunteer's age and gender was discussed previously [8] and was rejected in the course of multifactorial statistic analysis. We have fixed a linear trend in the amplitude parameters of the volunteers over 11 years, which (in accordance with the mathematical statistical rules) is inessential for the discussed distribution of statistical moments.

The dynamics of geomagnetic activity Ar-index and the main parameters of acupuncture point conduction in 2002-2012 are presented in Figure 1. The period of data accumulation for evaluating the distribution parameters was 2 months. The number of measurements during each period varied from 17,000 to 45,000. All curves show a sharp break of the distribution parameters in 2005, which is not an artifact. The absence of zero point shifts or device's scale distortion during measurements is confirmed by the break in the excess curve (Fig. 1, c). The excess is known to be invariant with respect to zero point shifts or scale modification. All curves demonstrate three periods in the dynamics of statistical parameters of biomedical data: 2001-2003, 2004-2006 with break of all parameters in the middle of 2005, and 2007-2012 with a slight abnormality in 2010 (Fig. 1). At present the proportion of

the daily average for the acupuncture point conduction to the mean quadratic deviation surpasses 3-fold the values of 2001-2003, while the statistical distribution of the parameters differs significantly from Gaussian. Similar results on alteration of the reaction adaptation programs in 2005 and 2010 were obtained in studies on *S. cerevisiae* cell structures [8]. The dynamics of the number of states with MTC-3 for reference *S. cerevisiae* cell structures in 2002-2012 is presented in Figure 2. From the end of 2004 till the middle of 2006 the mean number of events per 2 months was 0.1 instead of 5 during the previous period and 21 during the next period. The similarity of results indicates adaptation of the biological objects of different levels of organization to the same external factor, most likely the uncommon 23rd-24th SAC.

Simultaneous changes in the curves presenting all the studied parameters of biomedical distribution indicate changes in the biological object reaction programs in response to significant changes in the global parameters of the environment. The mean quadratic deviation curve suggests alteration of the biotrophic agent of space weather, which started about 2 years before the events discussed, in September-October, 2003. Let us see which, specifically, changes could take place.

Restructuring of the Sun-Earth relations of 2004-2005 involved a complex of factors: dynamics of the solar magnetic fields, space weather and solar wind parameters, and the pattern of geomagnetic activity. For example, the proportion of the numbers of geomagnetic storms with sudden and gradual onset changed in 2004-2005. The cycle development was sufficiently traditional before 2003, and by 2005, the minimum number of solar spots was expected. However, in 2005, the phenomenon usually called "protracted minimum" started. The number of spots was slowly reducing, while other sources of geomagnetic perturbations (coronary holes and coronary

ejections) disappeared sharply. All these events led to a sharp drop of the geomagnetic field intensity in 2004-2006. The current 24th SAC remains not high, but the number of nonstationary phenomena is unproportionally low even for this not high cycle. Analytical prognoses in the heliogeophysics suggest the onset of a long many-year period of low solar activity in the nearest future, similar to Moulder's minimum 400 years ago.

The dynamics of solar activity does not directly influence the living organisms because of the magnetosphere and atmosphere. However, changes in the space weather result primarily in variations of the geomagnetic field. Qualitative changes in the geomagnetic perturbations and statistical distributions of biological parameters were virtually synchronous in September-October of 2005. The dynamics of the geomagnetic activity Ar-index changed significantly in 2003-2004, and its amplitude decreased after the middle of 2005, reaching the values previously observed for the last time in 1965-1966 (Fig. 1, *a*). The mean Ar-index values before and after this period were 13.1 and 7 nT, respectively. The changes of the geomagnetic activity were caused mainly by the storms with a gradual onset, which, in turn, depended on the number of solar equatorial coronary holes. Search for the dominant biotropic factor of space weather should be carried out with due consideration for the uncommon behavior of the galactic space rays, their abnormal changes observed in 2004-2005, while the previous analogous situation was recorded only in 1983. The spectrum of rigid solar radiation changed in parallel with this. If we consider the biological systems as a collective detector of external cosmogeophysical exposures, we may suggest that this collective detector has fixed in 2004-2006 a drastic alteration of the parameters of the Sun-Earth relations, persisting up to the present time.

Alteration of the pattern of statistical distribution of biological parameters in 2004-2006 proved to be extremely unexpected for specialists in solar physics and the Sun-Earth relations. For this reason it is essential to analyze the data of long-term monitoring, carried out by other teams. A drastic change of the statistical distributions of biological parameters, recorded in 2005 in our many-year monitoring, cannot be interpreted within the framework of the traditional relationship between the biomedical data and the classical sinusoid presenting the dynamics of the number of solar spots over a SAC. After this paper was submitted for publication, a conference on plasma

astrophysics was held in February, 2014, at Institute of Space Research, the Russian Academy of Sciences. The main topic discussed at the conference was the expected transition to a long (up to 2067) period of low solar activity. Hence, the biological systems, from man to cells, fixed the just starting global changes in the heliospherical relations in 2004-2006, while the specialists in the heliogeophysics only by 2014 have summed up the totality of facts, each not very important alone, and predicted a global restructuring of all Sun-Earth relations for the nearest 30-40 years. Starting from the middle of 2004, we live under cosmoheliospheric conditions differing in principle from the 20th century situations, amply studied in physics and medicine. The latest solar cycle similar to the current one took place more than 180 years ago. A lasting low level of geomagnetic activity and a high level of galactic space rays cannot but tell on the dynamic processes in the biosphere.

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