NEW OPPORTUNITIES OF BIOPHYSICAL MONITORING IN HIGH AND MIDDLE LATITUDES FOR THE EVALUATION OF THE IMPACT OF GEOMAGNETIC DISTURBANCE ON HUMAN HEALTH

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Abstract: This article describes the principles of multi-latitude monitoring 'Heliomed-2' conducted for obtaining new data on the impact of space weather on human health. The article presents the results of synchronous monitoring of the cardiovascular system reaction assessment and psycho-emotional state of healthy volunteers to the changes in the geomagnetic disturbance in high (Tixie settlement and the city of Yakutsk) and middle (city of Saratov) latitudes. All the examined groups exhibited the effect of synchronization of ventricular myocardial repolarization processes (according to the data on the symmetry coefficient of the T wave of the electrocardiogram) and geomagnetic disturbance (according to the Kp-index); the synchronization of reactive anxiety and geomagnetic disturbance was also revealed. It has been established that the group cardiac sensitivity and psychological sensitivity to geomagnetic disturbances coincide in the same group of volunteers, regardless of breadth of residence.

Keywords: synchronous multi-latitude monitoring, cardiovascular system, psycho-emotional state, cosmic weather, geomagnetic disturbance, T-wave T symmetry coefficient, reactive anxiety.

The clarification of the relationship between solar activity and human health is one of the fundamental problems of modern science. The state of human health largely depends on changes in environmental factors, such as for instance, meteorological components and less known factors of cosmic weather. The term 'cosmic weather' describes the state of near-Earth space, influenced mainly by the Sun. These phenomena occur in the Earth's biosphere; they are related to the solar activity, and for the first time they were brought to notice by the

founder of the Russian space biology, Professor Alexander Chizhevsky in 1915-1924 [1]. The scientist pointed out that 'our body is penetrated through electromagnetic radiation and reacts to it with the greatest sensitivity'. Geomagnetic disturbances resulting from the interaction of changing parameters of solar activity with the Earth's magnetosphere are one of the natural risk factors for human health. They affect the time sequence of information signals that the body uses to match the rhythms of biological processes with the rhythms of the environment. Geomagnetic disturbances do not cause specific diseases in humans, but due to the imbalance of the regulation systems, the existing functional impairments get aggravated [2].

Solar activity is comprehended as a set of formations arising on the Sun: spots, torches, floccules, prominences, special forms of the corona, and flares, accompanied by acceleration of radiation intensity in the far ultraviolet, X-ray and radio wave parts of the spectrum and the appearance of corpuscular radiation - protons, electrons, and other particles. The precipitation of the charged particles from the tail of the magnetosphere into the atmosphere cause auroras on the Earth, as well as geomagnetic storms, terrestrial currents, and uneven ionization of the upper layers of the atmosphere. At that, electromagnetic oscillations are being generated, which, despite their low intensity compared to man's daily living conditions, are very effective due to the proximity of their frequencies (Hertz and their shares) to the main biological rhythms [3-5]. Although the corpuscular streams themselves do not reach the Earth's surface, electromagnetic fields arise when interacting with the Earth's magnetosphere, which causes geophysical disturbances in the form of magnetic storms and substorms.

The insight of the influence of solar activity on the processes occurring in the biosphere is a key position for more than just creating a physical theory of the impact of solar activity on biosystems; it is also necessary for the development of adaptation criteria and creation of effective systems for improving health, preventing various diseases and life-threatening complications [6]. The influence of cosmic weather on human health is determined primarily by the electromagnetic radiation of the Sun and the corpuscular streams of the solar wind, which affect the magnetic field, the common envelope, and the Earth's crust. Heliogeophysical factors are part of a single physical process, closely related to solar activity, which begins on the Sun and ends on Earth.

The main targets for the heliogeophysical factors exposure on the human body are the cardiovascular and nervous systems. The interconnection of the occurrence of acute vascular attacks (myocardial infarction, stroke) with the fluctuations of the heliomagnetic background of the Earth has been already proved [7–9]. Changes in the magnetic field on Earth as a result of active processes on the Sun and in the Earth's magnetosphere [10] are one of the most important factors in the breakdown of adaptation and exacerbation of chronic diseases. Studies on the effects of space weather parameters conducted in recent years have shown that a healthy person on Earth can safely bear such an impact. At the same time, the impact of disturbed heliogeophysical parameters on an individual with diseases of the cardiovascular system can lead to serious complications, up to death [7, 11, 12]. Arrhythmia, heart rate changes, hypertensive crisis, blood viscosity increases, red blood cell aggregations, capillaries blood flow slowdowns and a number of other pathological changes occur when exposed to geomagnetic disturbances [6, 13-16]. The influence of the solar activity factor on the human body is strongly dispersed by the simultaneous influence of biosocial, industrial, psycho-emotional and other factors, which is why in many cases the influence of solar activity and geomagnetic disturbances is shaded, and even gets hidden in complex inter-system transitional ratios of both physical and biological nature. For instance, it is quite difficult to separate the influence of space weather and meteorological factors, which requires the use of special research methods.

One of the most important methodological principles for studying the influence of space weather parameters on the human cardiovascular system is the principle of multi-latitude monitoring of the health status of volunteers, which was implemented in the unique international telecommunication project 'Heliomed'; the project was carried out by an interdisciplinary team of physicists, biologists, information technology specialists and physicians [17]. The first stage of monitoring was conducted from 2006 to 2010 - simultaneously in the cities of Moscow (Russia), Yakutsk (Russia), Kyiv (Ukraine) and Simferopol (Ukraine), which are located in different time zones more than 6000 km away from each other. In 2011-2013 multi-latitude monitoring covered auroral (Tixie) and subauroral (Yakutsk) latitudes.

The very concept of multi-latitude monitoring included [17]:

1. Simultaneous daily study of the state of the cardiovascular system of volunteers for 2 months in the fall and/or spring seasons (during periods of maximum geo-effectiveness of space weather) at the most distant points (to eliminate the impact of meteorological and social factors).
2. Daily assessment of central hemodynamic parameters: heart rate, systolic and diastolic blood pressure.
3. Daily assessment of the state of the myocardium and autonomic regulation of the heart according to electrocardiography (ECG) using express electrocardiographic Fazagraf system, which allows performing ECG processing in phase space [18]. The determination of the symmetry coefficient of the T wave in ECG (SCT), which characterizes the functioning of the myocardium by evaluating the processes of repolarization of the ventricular myocardium, the total effect of the vegetative regulation of blood circulation, the degree of tension of regulatory systems, heart rate variability, etc. were also observed and recorded on the daily basis.
4. A single study protocol for all latitudes included 4-time daily determinations of the indicated characteristics of myocardial functioning and autonomic regulation of the heart according to the following algorithm: at rest, after an emotional load using a computer stress test, after a unified exercise, and after a 10-minute rest.
5. Individual and group reactions of the cardiovascular system of volunteers were taken into account by analyzing the response according to the event-driven principle. The methods of spectral-temporal analysis, the statistical method of superposition of epochs, Bartels' method, and other geophysical research methods were employed due to their allowance to obtain information on the frequency and phase coincidences of the series under study.

As a result of stage 1 of the multi-latitude biophysical 'Heliomed' monitoring, data included more than 50,000 measurements were collected. The data analysis revealed a coincidence of the phase and spectral characteristics of space weather parameters and meteorological parameters with the phase and spectral characteristics of medical parameters synchronized by the space weather parameter (geomagnetic disturbance index), which led to the need to determine the factor that has the main influence on cardiovascular diseases. Comparison of direct measurements of the state of the cardiovascular system of volunteers at widely distributed observation sites in Russia and Ukraine showed their coincidence [19]; the latter indicates that one of the factors affecting the state of the cardiovascular system is the space weather parameters. Thus, as a result of long-term monitoring helio-medical experiment, it was revealed that it is cosmo-physical factors that are the synchronizer of the general rhythms of the population [19].

The results were described in detail in the collective monograph [17]; same results also allowed determining the following range of problems that need to be solved: which

parameter or combination of several space weather parameters influence the state of the human cardiovascular system? How deeply related are the responses of the cardiovascular system to changes in space weather with the psycho-emotional state reaction? And are there any genetically determined predictors of human sensitivity to space weather factors? To solve these issues, a second stage of the multi-latitude synchronous biophysical experiment was initiated in 2014; the 'Heliomed-2' was carried out in compliance with the above principles. At the same time, 'Heliomed-2' is not just a continuation of stage 1, but the next independent step in the study of the impact of space weather on human health, since it includes new advanced methodological approaches to solve quite a new problem. 'Heliomed-2' is featured by:

1. Changes in the geography of the study: a comparison of the Arctic (Tixie), subarctic (Yakutsk) regions and middle latitudes zone (Saratov). The survey points are distant from each other on more than 5000 km and 5 time zones. The settlement of Tixie is located on the coast of the Arctic Ocean (71-degree north latitude); as of January 1, 2018, Tixie accounted for a total of 4,537 inhabitants, and therefore the group of volunteers at this monitoring point was the smallest one.

2. For the first time, an integrated approach was employed to simultaneous monitoring of the state of the cardiovascular system and the psycho-emotional state of volunteers according to the principles developed by the scientific group [20].

3. For the first time, a study was conducted on the genetic characteristics of the participating volunteers, originated from different latitudes [21].

More than 30,000 complex measurements have been accumulated since 2014 (each of which included a characteristic of the state of the cardiovascular system and the psycho-emotional state). This allows for correct statistical processing (also for the first time) in assessing the influence of space weather factors not on some particular system of the human body, but simultaneously on the two main life-determining systems of functioning - cardiovascular and nervous - in the same group of volunteers, residing at different latitudes. According to the available literature, such experimental multi-latitude studies have not yet been recorded.

The **purpose of the study** was to assess the opportunities of long-term simultaneous multi-latitude monitoring in identifying features of individual and group reactions of health indicators synchronization (processes of cardiac ventricular repolarization and psycho-emotional state) of volunteers from high (auroral and subauroral) and middle latitude zones with geomagnetic disturbance. **Objects and methods of research:** Synchronous monitoring of the cardiovascular system and psycho-emotional state of volunteers was carried out simultaneously in high and middle latitude zones. A group of volunteers in high latitudes (44 participants) included 11 residents of Tixie (auroral latitudes) and 33 residents of Yakutsk (subauroral); 31 monitoring participants from the middle latitude zone were represented by the residents of Saratov.

The monitoring duration was 60 days; daily measurements were taken in groups of volunteers in the spring period (March-April) of 2014. The spring season is transitional; it is at this time that the most pronounced changes in the geomagnetic disturbance of the Earth occur in terms of number and amplitude, which allows tracing the psycho-emotional state as well as the response of the cardiovascular system.

ECG was evaluated daily at rest in phase space with the determination of the symmetry coefficient of the T wave (SCT, standard unit), which reflects the processes of ventricular myocardial repolarization, using the Fazagraf express cardiograph [18]. This method of studying the state of the myocardium has proven itself not only in screening for coronary artery disease but also in assessing the influence of space weather parameters, in particular,

solar activity, on the morphological parameters of the heart muscle [22-25]. Normally, the value of SCT is 0.45-0.70; with increasing CST, myocardial repolarization disorders increase and there is a risk of ischemic changes. The psycho-emotional state was assessed in accordance with the methodological principles set out in [20]: by indicators of reactive (daily monitoring) and personal anxiety (Spielberger's Test Anxiety Inventory modified by Y. Khanin), features of building stress-overcoming behavior (E. Heim's questionnaire), and by typological determining of a participant's personality (projective Psycho-Geometrics test by S. Dellinger, adapted by A. Alekseev and M. Gromova).

Geomagnetic activity was estimated daily during the entire observation period by the global geomagnetic disturbance indicator — the Kp index. The Kp-index (standard unit) reflects global geomagnetic disturbance (GGD) and differs from other space weather indices by the logarithmic measurement scale, therefore it is the best to describe weak disturbances. As it was shown in an earlier conducted study [26], a response is observed in the state of the human cardiovascular system even with a weak GGD. Individual and group synchronization effects 'SCT-Kp', as well as 'reactive anxiety-Kp' (RA-Kp) also were evaluated. Synchronization shows how the state of the myocardium and reactive anxiety of a person react to changes in the geomagnetic field of the Earth. This process characterizes the adaptive capacity of the myocardium and nervous system during external stress impacts.

The individual synchronization effect for the subject (SCT-Kp and RA-Kp) reflects the coincidence between the maxima of the medical indicator (T - symmetry coefficient of the ECG or the 'reactive anxiety' indicator) and the Kp-index of geomagnetic disturbance in the analysis of the time series for these indicators for each volunteer during 60-days observation. Since 2 types of synchronization - SCT-Kp and RA-Kp - were evaluated, it became necessary to organize the terms, since we faced the fact that SCT-Kp and RA-Kp synchronizations did not always coincide for each volunteer.

In this regard, the authors introduced the term 'cardiac sensitivity' to the GGD oscillations. Individual cardiac sensitivity reflects the SCT-Kp synchronization for each subject and is expressed in% of the total number of Kp maxima during the observation period. With an individual cardiac sensitivity of more than 66.7%, the volunteer's cardiovascular system was considered to be sensitive to changes in the GGD and therefore such participant was enrolled in the 'cardiac sensitive' group of his region. Further, the group effect of cardiac sensitivity was determined, which showed the number of cardiac-sensitive volunteers in% of the total number of the group.

The authors also employed an indicator of 'psychological sensitivity' to GGD [27]. Individual psychological sensitivity reflects the synchronization of the RA-Kp of each subject and is expressed in% of the total number of Kp maxima during the observation period. With an individual psychological sensitivity of more than 66.7%, the volunteer's nervous system was thought to be sensitive to changes in GGD and therefore such participant was enrolled in the 'psychologically sensitive' group of his region. Further, the group effect of psychological sensitivity was determined, which showed the number of volunteers psychologically sensitive to GGD in% of the total number of the group.

Thus, the indices of individual cardio and psychological sensitivity for each volunteer have been determined, as well as the group effects of cardio and psychological sensitivity (on the basis of the data obtained) in 2 examined groups – for high and medium latitudes. Statistical processing was performed using the MEDSTAT program; $\chi 2$ methods and Fisher's exact test were used to compare the cardio and psychological sensitivity to GGD.

RESULTS AND DISCUSSION

The average age of volunteers constituted 38.6 ± 5.7 for participants from high latitude zones, and 40.6 ± 2.2 for middle latitude residents ($p>0.05$). Synchronization of SCT-

Kp, and also Ra-Kp was observed in both groups examined, both in high and in middle latitudes. According to the above algorithm, cardiac-sensitive volunteers were selected (in high and middle latitude zones) and SCT-Kp synchronization charts were constructed (Fig.).

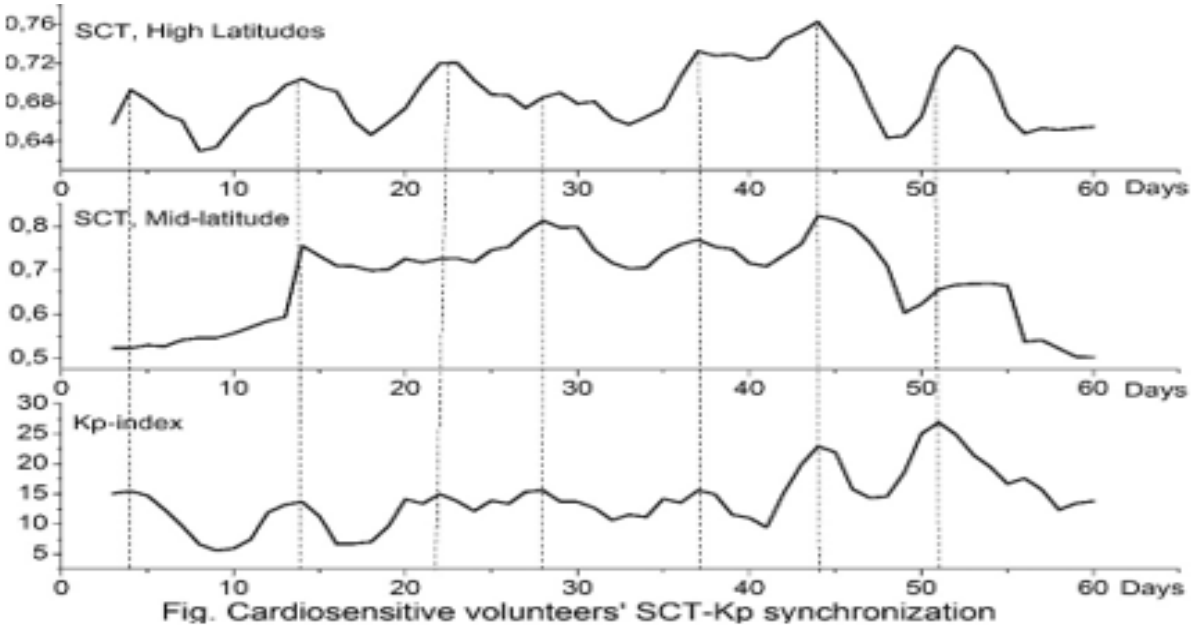

Fig. Cardiosensitive volunteers' SCT-Kp synchronization

The upper graph of the Figure shows the dynamics of the SCT for 60 days of monitoring in the group of volunteers at high latitudes, the middle graph - the dynamics of the SCT in the group of volunteers at middle latitudes, and the lower graph - the dynamics of the Kp-index for the same period. The dashed lines show the Kp-index maxima and the corresponding SCT values in groups of volunteers from high and middle latitude zones. Of the 7 Kp-index maxima over the observation period, high latitude zone volunteers reacted with an increase in SCT on the same day in 5 cases (on the 1st, 2nd, 3rd, 5th and 6th Kp-index maximums), and on the remaining 2 (4th and 7th) - with a delay of 1-2 days. In mid-latitudes, the SCT maximums occurred in response to the 2nd, 4th, 5th, 6th, and 7th maximums of the Kp-index (also in 5 cases out of 7). Thus, the cardiac-sensitive volunteers at different latitudes, separated by more than 5000 km, demonstrated almost the same type of SCT-Kp synchronization reactions: synchronization was observed in 5 cases out of 7 in both observation groups (71%).

The data obtained suggest that the phenomenon of cardiac sensitivity to GGD, which is manifested in the same way at different latitudes, appears inherent to the human body. However, it should be taken into account that, probably, there are also latitude-dependent features of the effects of sensitivity to geomagnetic disturbances. Thus, at high latitudes, the group effect of cardiac sensitivity to GGD was 38.6%: out of 44 volunteers, SCT-Kp synchronization in more than 66.7% was manifested by 17 people. At that, the group effect of psychological sensitivity to GGD at high latitudes was 33.5% and 15 volunteers exhibited synchronization of RA-Kp more than 66.7%. Thus, the group effects of cardio and psychological sensitivity to GGD in high latitudes have coincided (38.6% and 33.5%, $p>0.05$).

As it was revealed earlier, the response of the SCT-Kp synchronization in the auroral latitudes (Tixie settlement) was noted only with powerful geomagnetic disturbances, and in subauroral (Yakutsk) - with both powerful and weak GGDs [23]. The explanation of this phenomenon may lie in the geophysical features of auroral latitudes, where powerful electrical currents (auroral electrojets) flow up to a value of millions of amperes at an altitude of 100

km [5]. Probably, in these conditions, the myocardium adapts and stops responding to weak geomagnetic disturbances, maintaining sensitivity only to the most powerful ones. Since the group effects of cardio and psycho-emotional sensitivity in the examined high latitudes coincide, it should be assumed that the nervous system of volunteers in the auroral zone also adapts to the increased geomagnetic background and responds by synchronizing RA-Kp with significant GGD. Currently, to clarify this assumption, the authors are conducting studies to assess the psychological sensitivity separately in auroral and subauroral latitudes.

The group effect of cardiac sensitivity to GGD in mid-latitudes was 61.3%; the group effect of psychological sensitivity was detected in 52.4 % of the same group [27]. Thus, in the middle latitudes, the group effects of cardio and psychological sensitivity to GGD also coincided (61.3% and 52.4%, $p > 0.05$), which was manifested in synchronization reactions with GGDs of different amplitudes; volunteers had reacted to both weak and strong GGDs. It is known that at mid-latitudes, the group effect of synchronization of SCT-Kp may vary from 61.3% (when evaluating SCT of ECG at rest) to 74.2% (based on the results of 4-time SCT measurements: at rest, after emotional load, after physical activity, and after rest) [22, 23]. Since the evaluation of reactive anxiety was carried out in volunteers at rest (without additional emotional and physical stress), it is methodologically correct to employ the ECG data taken at rest to estimate the correlation of psychological sensitivity and cardiac sensitivity to GGD. The obtained data indicate that the group effects of the cardio and psychological sensitivity of volunteers to GGD coincide with each other in both high and middle latitudes. Thus, the adaptive reactions of the cardiovascular and nervous systems are synchronized with each other and the degree of this synchronization does not depend on the region of residence.

The results of the study allow suggesting common reception for changes in geomagnetic disturbances on the side of the cardiovascular and the nervous systems. One of these mechanisms can be cyclic changes in the nitric oxide system [6, 16], which regulates the basic mechanisms of the reaction of the cardiovascular system to changes in geomagnetic disturbance: fluctuations in blood pressure, development of thrombosis and arrhythmias, disturbance of the rheological blood properties [13-15, 19]. At present, there is direct experimental evidence of the relationship between fluctuations in the content of nitric oxide in the human body with the state of geomagnetic disturbance [28]. It is known that the nitric oxide cycle is involved in the regulation of the nervous system due to the effect on neuron-neuron and neuron-glial interactions as well [29-31]. Meanwhile, it is also known that the rhythms of the brain synchronize all physiological processes of the body [32]; therefore, adaptive changes in the state of the nervous system can also cause similar adaptive reactions from other systems and, in particular, from the cardiovascular system. The presented study expands the known understanding of the influence of space weather factors on human health [33-36].
This work was partially supported by the Russian Foundation for Basic Research grant №18-415-140002.

CONCLUSION

1. For the first time, the concept of individual cardiac sensitivity to geomagnetic disturbance was introduced on the basis of synchronization of the SCT ECG maxima and the Kp-index in the dynamic series of these indicators during daily measurements for 60 days.
2. It has been established that the cardiovascular system of cardiac-sensitive volunteers generally responds in the same way at different latitudes to changes in a geomagnetic disturbance.
3. For the first time, a comprehensive definition of cardio and psychological sensitivity to geomagnetic disturbances was carried out in the same groups of

volunteers using the developed algorithm implemented in the synchronous multi-latitude 'Heliomed-2'monitoring project.

4. It was revealed, according to the results of the 2014 monitoring, that the group effects of the cardio- and psychological sensitivity of volunteers to geomagnetic disturbances coincide with each other when residing in both high and middle latitudes; thus, the reactions of the cardiovascular and nervous systems of healthy volunteers to changes in geomagnetic disturbances are synchronized with each other, regardless of the region of residence.

REFERENCES

[1] Chizhevsky, A. L. The Terrestrial Echo of Solar Storms / Moscow: Myisl, 1976:367.
[2] Oransky I.E., Tsarfis, P.G. Biorhythmology and chronotherapy / M: "Vysshaya Shkola", 1989:159.
[3] Gnevyshev, M.N. The results of the study of solar activity and solar–terrestrial relationship / Pulkovo Observatory, 1982:43.
[4] Kleimenova, N.G. Seasonal variations in myocardial infarction and possible biotropic effect of short-period pulsations of the geomagnetic field on the cardiovascular system / N.G. Kleimenova [et al.] // Biofizika. - 2007. - № 6. P. 1112–1119.
[5] Samsonov S.N., Kleimenova N.G., Kozyreva O.V., Petrova P.G. Influence of space weather on diseases of cardiovascular system of a human being in subauroral latitudes // Izvestiya Atmospheric and oceanic physics. 2014. - V. 50. № 7. C.719-727.
[6] Parshina S.S., Samsonov S.N., Reutov V.P., Sorokina E.G. XXI century: space weather and nitrate-nitrite baseline levels in human existence // New information technologies in medicine, biology, pharmacology and ecology: proceedings of the IT + M&Ec`2017 International Conference, P. 164-181 https://elibrary.ru/item.asp?id=29917988
[7] Cornelissen G, Halberg F, Breus T, Syutkina EV, Baevsky R, Weydahl A, et al. Nonphotic solar associations of heart rate variability and myocardial infarction // J. Atmos. Solar-Terr. Phys. 2002. V.64. P. 707–720.
[8] Samsonov S.N., Petrova P.G., Strekalovskaya A.A., Manykina V.I., Tomsky M.I., Alekseev R.Z.. The connection of solar and geophysical disturbances with cardiovascular diseases // Science and Education, 2008; №2 (50):50-55.
[9] Samsonov S.N., Manykina V.I., Scryabin N.G., Krymsky G.F., Petrova P.G., Vishnevsky V.V., Grigoryev P.E., Podladchikova T.N., Ragulskaya M.V. The influence of geomagnetic disturbances on the state of the human cardiovascular system // Journal of New Medical Technologies, 2009; №1:246-248.
[10] Obridko V.N., Ragulskaya M.V., Khabarova O.V., Miroshnichenko L.I., Khramova E.G. Cosmophysical factors of evolution of biosphere: new lines of research // "Psychosomatic and Integrative Research" Journal, 2014. T.1. №1. http://pssr.pro/articles/237
[11] Samsonov S.N., Petrova P.G., Strekalovskaya A.A., Manykina V.I., Tomsky M.I., Alekseev R.Z. The connection of solar and geophysical disturbances with cardiovascular diseases // Science and Education, 2008; №2 (50):50-55.
[12] Breus T.K., Ozheredov V.A., Syuitkina E.V., Rogoza A.N. Some aspects of the biological effects of space weather // J. Atmosph. Solar-Terr. Physics. 2008. V.70. P. 436-441.
[13] Gurfinkel', Yu. I. Coronary Heart Disease and Solar Activity / Moscow: El'F-3, VINITI, 2004: 170.
[14] Gurfinkel Yu.I., Ozheredov V.A., Breus T.K., Sasonko M.L. The Effects of Space and Terrestrial Weather Factors on Arterial Stiffness and Endothelial Function in Humans / Biophysics, 2018, Vol. 63, Issue 2:402-411.

[15] Kameneva, E.G. The impact of heliogeomagnetic activity on the functional state of the cardiovascular system in healthy people and patients with coronary artery disease: PhD (Biology) thesis / St. Petersbugd, 2009; 146:5.
[16] Parshina S.S., Samsonov S.N., Reutov V.P., Sorokina E.G. Space weather impacts and nitric oxide system / Proceedings of XII International Crimean Conference Cosmos and Biosphere, Crimea, 2017: 140-143.
[17] Biotropic Impact of Space Weather Based on the Data of the. Russian±Ukrainian Heliomed Monitoring 2003±2010 / Ed. by M.V. Ragulskaya. M., Kyiv – St. Petersburg: VVM Publishers, 2010: 312.
[18] Fainzilberg, L.S. Information technology for signal processing of complex shape. Theory and practice. Kiev: Naukova Dumka, 2008. 333 p.
[19] Samsonov, S.N. Space weather parameters and the state of human cardiovascular system: group and population effects / In Biotropic Impact of Space Weather Based on the Data of the Russian±Ukrainian Heliomed Monitoring 2003±2010 / Ed. by M.V. Ragulskaya. M., Kyiv – St. Petersburg: VVM Publishers, 2010; 69-90.
[20] Kodochigova, A.I.; Parshina, S.S.; Samsonov, S.N.; Afanasyeva, T.N.; Olenko, E.S. Justification for methodological approaches to assessing the impact of space weather on psychoemotional state of volunteers. Psychosomatic and Integrative Research, 2016; 2: 0105.
[21] Kirill V. Komzin, Palmira G. Petrova, Alena A. Strekalovskaya, Sergey N. Samsonov, Svetlana S. Parshina, Yuliana V. Terentyeva. SINGLE NUCLEOTIDE POLYMORPHISMS OF THE CYP11B2, GNB3 AND NOS3 GENES IN VARIOUS ETHNIC GROUPS OF ARCTIC ZONE OF YAKUTIA SUFFERING FROM ARTERIAL HYPERTENSION// Wiadomosci Lekarskie 2018, 71, 9, 1742-1748.
[22] Parshina S.S., Samsonov S.N., Manykina V.I. et al. PECULIARITIES OF A GROUP RESPONSE OF CARDIOVASCULAR SYSTEM TO CHANGES OF SPACE WEATHER PARAMETERS // New information technologies in medicine, biology, pharmacology and ecology: proceedings of the IT + M&Ec`2015 International Conference, P. 316-322. http://glorioz.com/doki/me/2015/2015_5.pdf.
[23] S.S. Parshina, T.N. Afanasyeva, S.N. Samsonov, V.I. Manykina, V.D. Petrova, P.G. Petrova, A.A. Strekalovskaya, V.V. Vishnevsky. T.I. Kaplanova, M.V. Potapova. Impact of space weather on the processes of myocard repolarization among volunteers in high and middle latitudes // Vestnik of NEFU, Series “Medical sciences”, 2016. 4 (05).16-21.
[24] L. S. Fainzilberg, Information processing algorithm about the functional status of the operator of the visual profile // Control Systems and Machines, 1998. №4: 40-45.
[25] V. V. Vishnevsky, L.S. Fainzilberg, M.V. Ragulskaya. The impact of solar activity on morphological parameters of ECG of health person // Biomedical technology and electronics, 2003. №3:3-11.
[26] Samsonov S.N. Space weather and a state of cardiovascular system of human being with a weakened adaptation system // Odessa Astronomical Publications. 2013. V. 26/2. P. 297-299
[27] Kodochigova A.I., Parshina S.S., Samsonov S.N., Olenko E.S., Afanasyeva T.N., Dzheyranova M.O., Soltaeva M.A., Kantaeva, H.R., Belousova K.O., Petrova V.D. Psychological susceptibility to heliogeomagnetic factors among volunteers living in middle latitudes: relation to coping behavior and personality pattern. Psychosomatic and Integrative Research, 2018; 4; 0104.
[28] Yamshanov V. A., Koshelevsky V.K. The influence of geomagnetic variations on the formation of nitric oxide in human exhaled air, Biofizika, 2007, vol. 52, no. 4, P. 718-721.
[29] N. P. Larionova, V. P. Reutov, N. V. Samosudova, L. M. Chaylakhyan. Comparative Analysis of Plasticity of Neuro-neuronal and Neuroglial Encapsulating Interactions of Molecular Layer of Isolated Frog Cerebellum Exposed to Excess L-Glutamate and NO-Generating Compound // RAS reports, 2003. Vol. 393. № 5: 698–702.

[30] N. V. Samosudova, V. P. Reutov, N. P. Larionova, L. M. Chaylakhyan. Possible role of nitric oxide in the interneuron interactions // RAS reports, 2001. Vol. 378. № 3: 417–420.
[31] A. V. Gurin. The functional role of nitric oxide in the central nervous system // Advances in Physiological Sciences Journal, 1997. Vol. 28. №1: 53-60.
[32] Obridko V.N., Ragulskaya M.V., Khabarova O.V., Rudenchik E.A. Monitoring of IZMIRAN Experiments of 1998–2010 on Studying Biosphere Processes Synchronization by Cosmogeophysical Factors // In Biotropic Impact of Space Weather Based on the Data of the Russian±Ukrainian Heliomed Monitoring 2003±2010 / Ed. by M.V. Ragulskaya. M., Kyiv – St. Petersburg: VVM Publishers, 2010; 205-246.
[33] Ozheredov V. A., T. K. Breus, Yu. I. Gurfinkel, B. A. Revich, T. A. Mitrofanova. Role of Space Weather Factors in Health Status of People with Cardiovascular Pathology // Global Telemedicine and eHealth Updates: Knowledge Resources, – 2009– Vol. 2, Editors: Malina Jordanova, Frank Lievens, p. 388-393.
[34] Breus T.K., Ozheredov V.A., Syuitkina E.V., and Rogoza A.N., Some aspects of the biological effects of space weather // J. Atmosph.Solar-Terr.Physics, – 2008. – V.7. – P.436-441.
[35] Germaine Cornélissen, Franz Halberg, R.B. Singh. Unseen Space Weather Also Relates to Cardiac Events // World Heart Journal. Volume 1, Number 1, 2008. P.15-21.
[36] Franz Halberg, Germaine Cornй‌lissen, Kuniaki Otsuka, Yoshihiko Watanabe, George S. Katinas, Naoto Burioka, Anatoly Delyukov, Yuri Gorgo, Ziyan Zhao, Andi Weydahl, Robert B. Sothern, Jarmila Siegelova, Bohumil Fiser, Jiri Dusek, Elena V. Syutkina, Federico Perfetto, Roberto Tarquini, R.B. Singh, Brad Rhees, Dennis Lofstrom, Paula Lofstrom, Paul William, Cort Johnson, Othild Schwartzkopff & the International BIOCOS Study Group. Cross-spectrally coherent ~10.5- and 21-year biological and physical cycles, magnetic storms and myocardial infarctions. Neuroendocrinology Letters 2000, 21: 233–258.