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Bio effectiveness of the geo-space agents at the Spitsbergen archipelago

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Abstract. A high degree of variability of psycho-physiological indicators of the state of the body in the subjects was revealed in the study conducted on healthy volunteers in the Spitsbergen archipelago. A dynamics of the indicators of the state of the organism in all persons (100%) correspond to fluctuations of the certain geophysical agents associated with solar activity and the magnetosphere-ionosphere interactions in the polar cusp. It was found that psycho-emotional state, as well as heart rate variability, are modulated by ground physical agents associated with events in the near the Earth' space. At the same time, many questions remain concerning the nature of the physical agents affecting on the organism, which can only be answered by conducting cooperative studies in the field of the polar cusp.

1. Introduction

The Spitsbergen archipelago is located in the Arctic Ocean, between 76 ° 26 'and 80 ° 50' north latitude and 10 ° and 32 ° east longitude. Geophysical feature of the arch. Spitsbergen is its location in the cusp region [1]- a kind of funnel on the dayside of the magnetosphere with near zero magnetic field magnitude, where, under certain conditions, the solar wind (CW) can burst through powerful plasma jets (Figure 1, [2]). This region is centered on local noon and extend approximately 2-3 hours in longitude and ~1 degree in latitude. The open field lines of the cusp is connected with those of the interplanetary magnetic field (IMF), which allows the shocked solar wind plasma of the magneto sheath to enter the magnetosphere and to penetrate to the ionosphere [3].

The unobstructed invasion of solar particles in the cusp region leads to multiple geophysical phenomena, reflected in the structural and energy characteristics of variations in the geomagnetic field (GMF). In a quiet period, electron fluxes with an energy of 100–200 eV and a particles with density of 10–2 –10–3 cm², which penetrate into the magnetosphere from the SW and propagate up to altitudes of about 1000 km, are constantly recorded in the polar day cusp. The streams of these particles generate very low frequency noise (VLF) in a wide frequency range [3]. The interaction of CW with the Earth's magnetosphere also generates geomagnetic pulsations (GP), whose oscillation frequency lies in the range of low-frequency biological rhythms [4]. GPs are characterized by a quasi-periodic structure with a frequency range from thousandths of a hertz to several hertz. The upper frequency of pulsations is determined by the gyrofrequency of protons in the magnetosphere, on the earth's surface this corresponds to a frequency range of about 3-5 Hz, to which correspond the ranges of delta and theta rhythms of the human brain. The daytime pulsations also include broadband irregular pulsations of the Pc5 range ($f \sim 1.5\text{--}5.0$ MHz) with an amplitude of the order of 15–60 nT, ipe [5, 6, 7]. The



frequency of such pulsations corresponds to ultralow brain rhythms [8]. These fluctuations are stable and continue depending on the level of geomagnetic disturbance from 2 to 10 hours. Long-period quasi-periodic magnetic perturbations with periods of 15–40 minutes and an amplitude of about 60–400 nT, called vlp (very long period) occur when high magnetic activity, high solar wind speed and negative Bz interplanetary magnetic field (MMP) on the earth's surface in the daytime sector [6,7] are detected. Super slow brain rhythms include periods of 2–3, 4–6, 7–14, 15–30, 31–59 min, that is, they correspond to long-period oscillations of the GMF. In the evening and at nighttime, the appearance of pulsed bursts of geomagnetic pulsations of the Pi2-Pi3 range is possible, and in the daytime sector, the appearance of quasi-monochromatic noise oscillations in the Pc3–4 range is registered. A part of the observed oscillations can be the result of direct penetration of hydromagnetic waves from the CW. The latitudinal peculiarity is also observed in stable geomagnetic pulsations of the Pc2-Pc5 type, whose amplitude increases with latitude [5, 6, 7].

The bio efficiency of physical phenomena in the field of the polar cusp has not been practically studied, although their role in the global modulation of mental processes is indirectly confirmed [8]. In our works, a link was found between the structural and energetic characteristics of the variations of the GMF and the functional activity of the brain [9]; between the characteristics of solar activity (SA), the disturbance of the interplanetary environment and the psycho-emotional state of patients with bronchial asthma and the healthy volunteers [10,11,12]; between the variations of the geo space agents and the morbidity of residents of Russian villages on the arch. Svalbard [13]. In addition, it was shown that amplitude-frequency and spatial-temporal reorganizations of the bioelectric activity of the human brain in the healthy persons occur when the geomagnetic activity increases [14,15,16]. The effect of variations in the GMF on the functional state of human brain can be result of combined resonances and desynchronizes, manifested in a wide range of psychotic phenomena: in psychopathic and hysteric reactions, in depression and arousal, in a state of altered consciousness, etc. [10].

The purpose of this research was to study the effect of high-latitude geo space agents on the human body in the polar cusp at the arch. Svalbard to identify their bioefficiency and to predict the status of biosystems.

2. Material and methods

The study involved 43 volunteers, in which daily were recorded of the indicators of the psycho-physiological state of the body (from July 30 to August 18, 2018), as well as 12 people in 2017 (from July 26 to August 11, 2017). The indicators included the statistical and spectral characteristics of heart rate variability (HRV) [17], obtained using the OMEGA-M instrument-instrumental complex; finger luminescence characteristics coupled with psychophysiological state by using the method of gas discharge visualization, GDV, [18] with filter mode and without filter, obtained using the GDV-Compact hardware-software complex (Biotechprogress LLC); indicators of galvanic skin response, peripheral temperature of the fingers, systolic wave amplitudes based on photoplethysmogram evaluation [19] by using the REAKOR complex; characteristics of psycho-emotional state based on the questionnaires of SUN and Spielberger-Khanin, Luscher color test [20]; characteristics of clotting time (coagulation) of the blood. The site (<http://nssdc.gsfc.nasa.gov/omniweb/>) has been used for selected of the geo-space data for the studied period, the neutron monitor data was kindly provided by the staff of the Polar Geophysical Institute of the Russian Academy of Sciences (the station of the neutron monitor of the PGI RAS).

3. Results of research

3.1. Results of research

Despite on the relatively quiet period of the geomagnetic activity (GMA), the relationship between the average daily values of the dynamics of the cardiovascular system (SSS) in the subjects and variations of the geo-space agents was revealed, $p < 0.05$. Figure 1 shows the correspondence between the individual daily dynamics of heart rate variability (HRV) and the parameters of MMP.

The condition of the cardiovascular system was characterized by the following indicators: arterial systolic and diastolic pressure (ADS and ADD, respectively), heart rate (HR), arterial oxygen saturation (O₂), minute blood volume (IOC), duration of the cardiac interval (RR), mode (Mo, ms) amplitude of mode (Amo), spectral components of heart rate variability (HRV): total spectrum power - Total (ms²), high-frequency (HF ms²), low-frequency (LF, ms²), very low-frequency (VLF ms²), ultra low-frequency (ULF, ms²) component s, statistical indicators BCP: SDSD - standard deviation of the differences between adjacent NN-intervals (ms), SDNN-average value of standard deviations NN-intervals calculated by 5-minute intervals during the whole recording (ms). Significant connections between ADD, cosmic rays (CL) and atmospheric pressure (Datm) ($r = 0.49$, $r = -0.49$, respectively, $p < 0.05$); between blood saturation with oxygen and the geomagnetic index (Ak) ($r = -0.51$, $p < 0.05$), between the IOC, R-R, Amo, SDSD, SDNN, HF and the DST index. In addition, the relationship between RR and f10.7 index ($r = -0.57$, $p < 0.05$), Amo and PR > 60 MeV ($r = -0.47$, $p < 0.05$), between SDSD and protons with energies > 30 and > 60 MeV (PR > 30 MeV, PR > 60 MeV), CL, Datm ($r = 0.46$, $r = 0.68$, $r = -0.49$, $r = 0.49$, respectively, $p < 0.05$); between HF and PR > 30 MeV, radio emission from the Sun at a wavelength of 10.7 cm (f10.7 index) ($r = 0.50$, $r = 0.45$, respectively, $p < 0.05$), between HF (%) and PR > 30 MeV, CL, Datum ($r = 0.57$, $r = -0.54$, $r = -0.54$, respectively, $p < 0.05$); between VLF (%) and PR > 30 MeV ($r = -0.48$, $p < 0.05$), between LF / HF and PR > 10 MeV, PR > 30 MeV, PR > 60 MeV ($r = -0.60$, $r = -0.51$, $r = -0.50$, respectively, $p < 0.05$); between VLF / HF and PR > 30 MeV, PR > 60 MeV ($r = -0.45$, $r = -0.45$, respectively, $p < 0.05$) were shown.

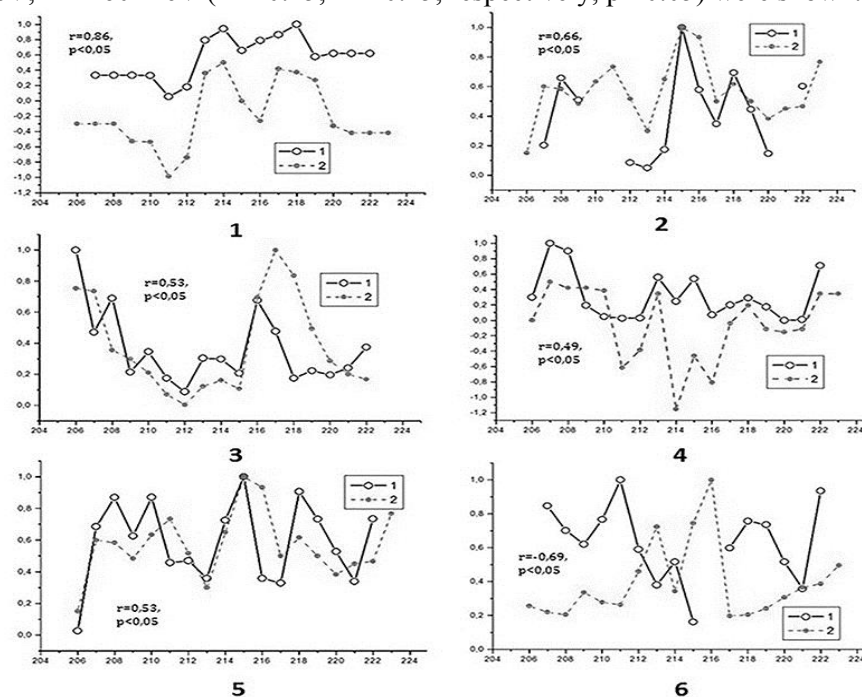


Figure 1. Correspondence between individual dynamics of heart rate variability (HRV) indices and MMP parameters. Fig.1.1: the index of the very low-frequency spectral component of HRV (VLF, ms²) and the angular characteristics of the solar wind (Bulk flow longitude, degrees), Fig.1.2: VLF, ms² (1) and the vector characteristics of the interplanetary magnetic field (Magnitude of Average, nT, Field vector, ||) (2); Fig.1.3: VLF, ms² (1) and the angular velocity of the solar wind (Bulk flow longitude, km / s) (2); Fig. 1.4: total power of the spectral components of HRV (TR, ms²) (1) and the angular characteristics of the solar wind (Bulk flow latitude, degrees), (2); Fig. 1.5: the high-frequency component of HRV (HF, ms²), (1) and the vector characteristics of the interplanetary magnetic field (Mag. of Av., NT, Field vector, ||), (2); Fig.1.6: - high-frequency component of HRV (HF, ms²), (1) and proton flux density (Proton density), (2). The abscissa is the days of the year (July 25-August 11, 2017); ordinate - normalized values of indicators.

3.2. Coherency of the psycho-emotional state with variations of geo space agents

The psychoemotional state was assessed on the basis of indicators: well-being (CAM), activity (AST), mood (NST), situational and personal anxiety (CT and LT, respectively), as well as an indicator of the total deviation from the autologous norm (S) calculated on the basis of the test Lusher Significant ($p < 0.05$) correlations between mean daily values (for a sample of subjects) of psycho-emotional state indicators and indices characterizing variations of geocosmic agents are shown (Table 1.). Table 1 shows that state of health (CAM), activity (ACT), mood (NST) increase with decreasing GMA (positive correlation coefficients with the DST index and negative with Ak index), while situational anxiety (ST) and total deviation from autogenous norms. The same effects are observed with increasing solar radiation flux (f10.7_Index). Increasing the flux density of protons with energies more than 30 MeV (PROT > 30 MeV) leads to a decrease in the total deviation from the autogenous norm (CO) and, consequently, to an improvement in the psycho-emotional state.

Table 1.

Indices	Lat. Angle of avg. Deg. Field vector	Bx,GSE	Bulk speed	Kp*10	R	DST Index	f10.7- index	Ak
Self	-0,42	0,49	-0,58	-0,45	-0,56	0,47	0,51	-0,50
Act	-0,41	0,44	-0,52	-0,36	-0,49	0,48	0,52	-0,40
Mood	-0,47	0,47	-0,55	-0,48	-0,63	0,55	0,44	-0,61
San	0,50	-0,54	0,58	0,21	0,64	-0,57	-0,53	0,40
Pan	0,58	0,00	0,32	0,19	0,22	-0,38	-0,40	0,34
Sdev	-0,08	-0,21	0,37	0,22	0,36	-0,56	-0,55	0,35

An increase in the neutron flux at the surface of the earth (CL), on the contrary, worsens the indices of the psychoemotional state, as well as the decrease in atmospheric pressure (Datm). It is shown that indicators of psycho-emotional state, such as galvanic skin response (GSR) and finger temperature (T), are also associated with variations of geocosmic agents, Figure 2 A, B.

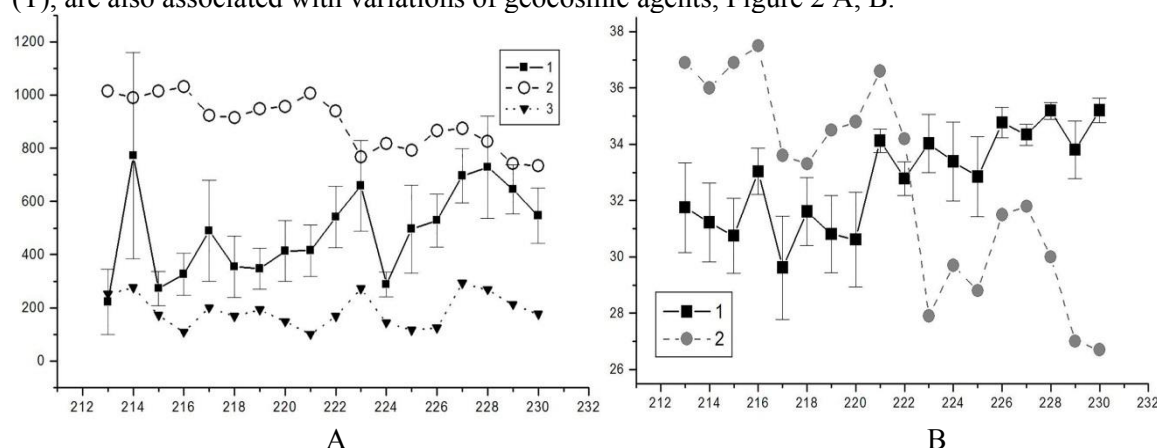


Figure 2. Coherency of average daily dynamics of the skin-galvanic (GSR) reaction (A, 1) and temperature of the fingers, T (B, 1) with the average daily values of the solar radio emission flux (F-10.7) (A, 2; B, 2) and interplanetary magnetic field (MMFav). Correlation coefficients between GSR, F-10.7 and MMFav $r = -0.48$; $r = 0.56$, respectively; between T and F-10.7 $r = -0.52$, $p < 0.05$. The abscissa is the days of the year (from July 1 to August 18, 2018); ordinate - the values of the indicators in conventional units.

3.3. Gas-discharge visualization (GDV) method as an indicator of the effect of geocosmic agents on the human body at the arch. Svalbard

Comprehensive assessment of the adequacy of the GDV method for the detection of biomedical effects of geo space agents on the human body under the conditions of arch. Spitsbergen showed that GDV indices show a high degree of sensitivity to variations of geo space agents even in unperturbed conditions with background variations of the geomagnetic field. In addition, a connection was found between the indicators of GDV, blood clotting time (FSC), finger temperature, GSR, mood, activity, situational anxiety, and many parameters of the heart rhythm. Figure 3 shows the dependence of physiological parameters on variations of geocosmic agents.

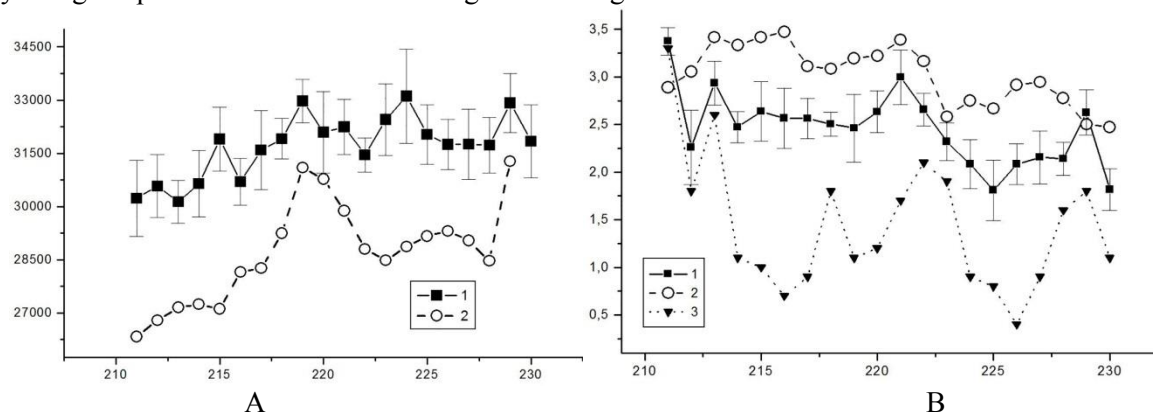


Figure 3. Coherancy of the dynamics of average daily values of the glow area (S) of the fingers (A, 1), neutron intensity variations near the Earth's surface (CL) in the village of Barentsburg (A, 2); average daily values of blood clotting time from a sample of subjects (SRS) (B, 1), average daily values of the solar radio flux (F10.7) (B, 2), angular velocity of the solar wind (sigma theta-V) (B, 3). The correlation coefficient between S and CL is $r = 0.62$, $p < 0.05$; between WRC, F10.7 and sigma theta-V $r = 0.54$, $r = 0.68$, respectively, $p < 0.05$. The abscissa is the days of the year (July 30 - August 18, 2018); on the ordinate axis - the value of the glow area and the neutron counting rate in arbitrary units.

Fig. 3A shows the dynamics of average daily values from a sample of the tested areas of the glow of the fingers (1), in the registration mode with a filter, and average daily variations in the neutron intensity near the surface (2); in Fig. 3B shows the conjugacy of average daily values of blood clotting time for a sample of subjects (1), average daily values of the solar radio flux (2), and the angular velocity of the solar wind (sigma theta-V) (3).2.3.

4. Conclusion

The conducted research allowed us to obtain new knowledge about the effects of geo space agents in the field of polar cusp on the functional state of the human body under the conditions of arch. Svalbard. A joint analysis of the dynamics of the functional state of the body and variations of geo space agents associated with space weather in the polar cusp region showed that all subjects (100%) are sensitive to certain geo space agents whose properties are due to the magnetosphere-ionosphere interactions in the polar cusp region. At the same time, many questions remain regarding the nature of the physical agents affecting the body, which indicate the need for interdisciplinary research in the field of the polar cusp on the Spitzbergen archipelago.

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