GEOMAGNETIC DISTURBANCES and PSYCHOPHYSIOLOGICAL CHARACTERISTICS OF ADULT FEMALE

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Considered problem

- Space weather changes affect not only technologies but also influence living organisms, including human beings.
- Among these various factors, geomagnetic field disturbances play a special role.
- Human brain's bioelectrical activity potentially reacts to changes in the Earth's magnetic field.
- Studies of the potential impact of geomagnetic storms on the human brain's activity always attracts attention of scientists from various fields.
- The influence of geomagnetic storms on the functional activity of the human brain, as well as on the emotional and characterological sphere of personality of different aged human beings has not been studied sufficiently and well-known studies as usual do not consider the severity of geomagnetic disturbances, as well as the ontogenetic and gender aspects of the considered problem.

NOAA Space Weather Scale for Geomagnetic Storms

G 5	**Extreme**	**Power systems:** : widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. **Other systems:** pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.)**.	Kp = 9	**Average Frequency (1 cycle = 11 years)** 4 per cycle (4 days per cycle)
G 4	**Severe**	**Power systems:** possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. **Spacecraft operations:** may experience surface charging and tracking problems, corrections may be needed for orientation problems. **Other systems:** induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.)**.	Kp = 8, including a 9-	100 per cycle (60 days per cycle)
G 3	**Strong**	**Power systems:** voltage corrections may be required, false alarms triggered on some protection devices. **Spacecraft operations:** surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. **Other systems:** intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.)**.	Kp = 7	200 per cycle (130 days per cycle)
G 2	**Moderate**	**Power systems:** high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. **Spacecraft operations:** corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. **Other systems:** HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.)**.	Kp = 6	600 per cycle (360 days per cycle)
G 1	**Minor**	**Power systems:** weak power grid fluctuations can occur. **Spacecraft operations:** minor impact on satellite operations possible. **Other systems**: **migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine)**.**	Kp = 5	1700 per cycle (900 days per cycle)

According the US NOAA “Space Weather Scale for Geomagnetic Storms”:

- **animal effects start at a G1 level**

  (with maximum of G5);

- **these effects are more pronounced as the geomagnetic field is more disturbed.**

Heliogeophysical activity & the human physiological health state

Concerning the possible links between heliogeophysical activity level and the human physiological health state the following two quantifiable measures are considered:

- **"Indirect indicators"**

They are essentially **epidemiological data** showing the temporal and spatial distribution of defined events or health disturbances involving considerable numbers of test subjects over several years.
These indirect indicators are: *temporal distribution of emergency calls and hospital admissions, dynamics of industrial (work) and traffic accidents, etc.*

- **"Direct indicators"**

They are **physiological parameters**, which can be objectively verified and which are acquired either in vivo, directly on the subject (*heart rate and its variability, blood pressure, microcirculation parameters, reaction time*), or in vitro by laboratory diagnostics or tissue investigations.

INDIRECT INDICATORS
(epidemiological data)

processed:

- sudden cardiac death (arrest) – pre-hospital – witnessed + un-witnessed
- acute myocardial infarction – mortality – pre-hospital
- acute myocardial infarction – morbidity – pre-hospital
- influenza occurrence and epidemics
- traffic accidents
- all deaths, cardio-vascular deaths, insult, traumas, infectious diseases, acute myocardial infarction mortality and morbidity (in-hospital)
- chronobiological studies

DIRECT INDICATORS
(physiological parameters from experiments)

processed:

- human brain's functional state (EEG & bioelectrical activity)
- psycho-emotional state
- heart rate & ECG
- biologically active points of human body (acupunctural points)
- heart rate variations (HRV)
- blood pressure
- brain's state at sleep

- Study of correlations between medical-biological and heliogeophysical indices bears a task of multifunctional analysis taking into account other natural and societal factors of the environment which have more intensive impact on biological objects than heliogeophysical factors.

- But, based on the theory of phase transition induced by the noise, which is applied in biology, we can consider the **human being as a biological object, acting as an open non-linear system, being in the state of non-stable dynamic balance**.

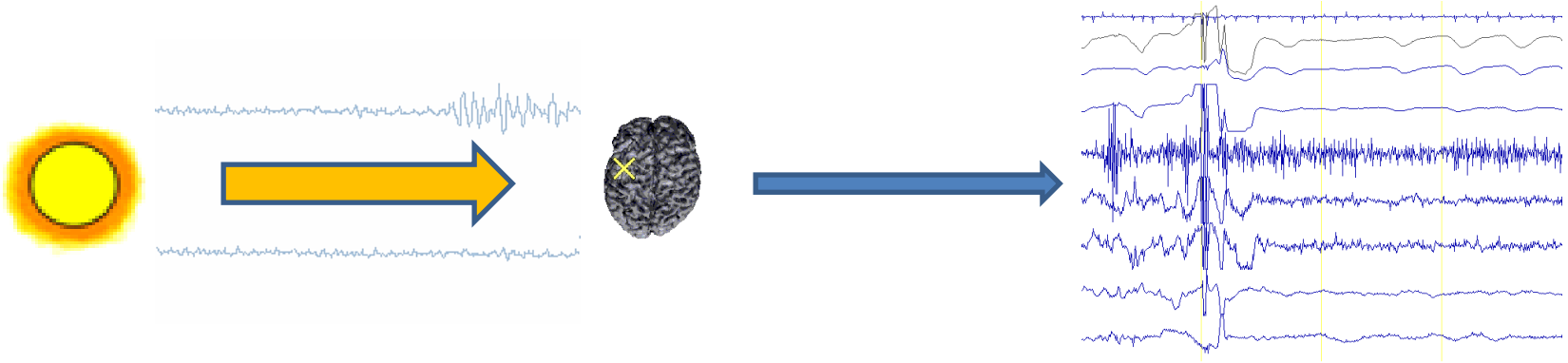
- Transition of this bio-system into critical state (illness, death, etc.) can happen even in the case of **very weak external influence** (signal) having a level of noise.

- **Periodical and/or aperiodical changes of space weather** could play a role of one of these external factors.

- **Sporadic and impulsive manifestations of space weather activity** can be considered as some “failures” of relatively regular rhythms of heliogeophysical factors.

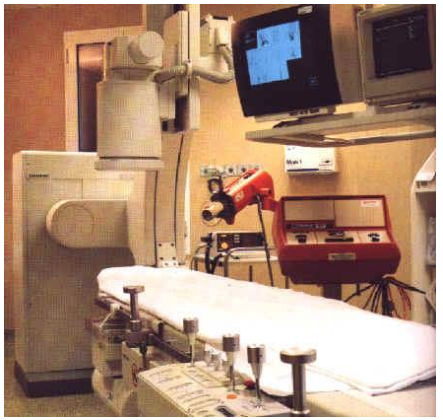
Space Weather and its Potential Influence on Functional State/ Bioelectrical Activity of the Human Brain

(experimental electroencephalographic studies of geomagnetic storm effects on the human brain's bioelectrical activity)

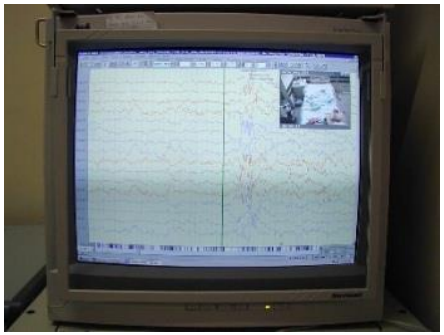


classic

portable



complex



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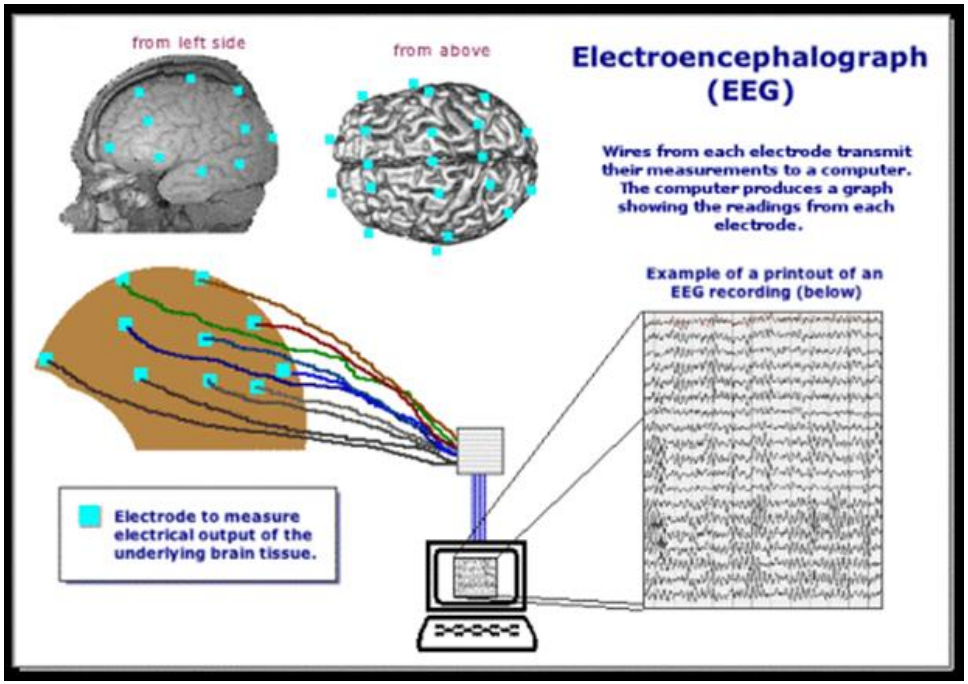
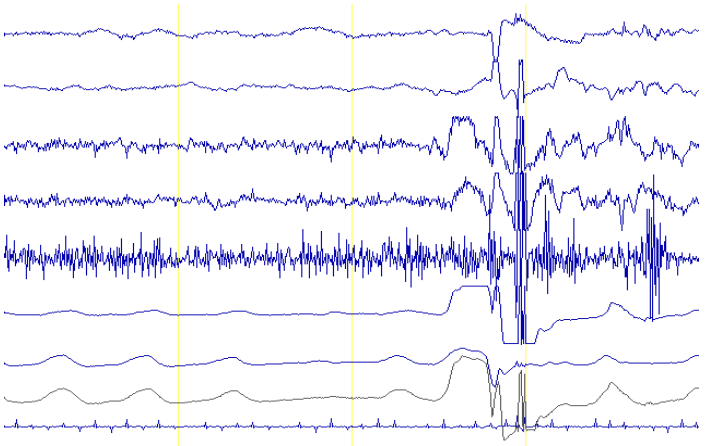




Brain waves

State	Frequency Range	State of Mind
Delta	0.5Hz - 4Hz	This occurs in a deep dreamless sleep or unconsciousness.
Theta	4Hz - 7Hz	This is associated with drowsiness. It also occurs at first stage of sleep and during deep meditation, when we are awake but open to mental imagery. It has been associated with creativity, intuition daydreaming and fantasizing. Believed to reflect activity from the limbic system and increased activity is observed in anxiety, behavioral activation and inhibition.
Alpha	8Hz - 12Hz	This is the major rhythm seen in a normal, relaxed adult. It is present during most of life. It is considered a common state during alertness but not actively processing information. Alpha has been linked to creativity (creative people show alpha when listening and coming to a solution) and mental work. Alpha activity is also associated with overall mental and body/mind coordination, calmness, alertness and learning.
Beta	12Hz - 30Hz	Beta reflects highly active processing. Occurs during normal waking consciousness and outward attention. Slow beta: 12-17 is normal information processing and mental activity; Fast beta: 17-30 is heightened alertness and fight or flight, or anxiety.
Gamma	30Hz - 100Hz	This is associated with waking states and can occur when we are simultaneously processing information in both brain hemispheres. Whales and dolphins also operate in these frequencies.

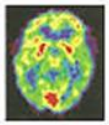
In the living brain, millions of nerve cells communicate with each other by emitting tiny electrical impulses.

This activity can be registered as oscillations (called brainwaves) by placing electrodes on the scalp, amplifying the signals and displaying them on a computer monitor.

This method of measuring is called
electro- encephalo -graphy (EEG).

PET Scan
Red - active
Blue - inactive

BETA: 15 - 50 Hz
Alert / Working

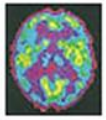


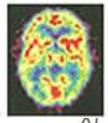
ALPHA: 9 - 14 Hz
Relaxed / Reflecting

THETA: 5 - 8 Hz
Drowsy / Idealing

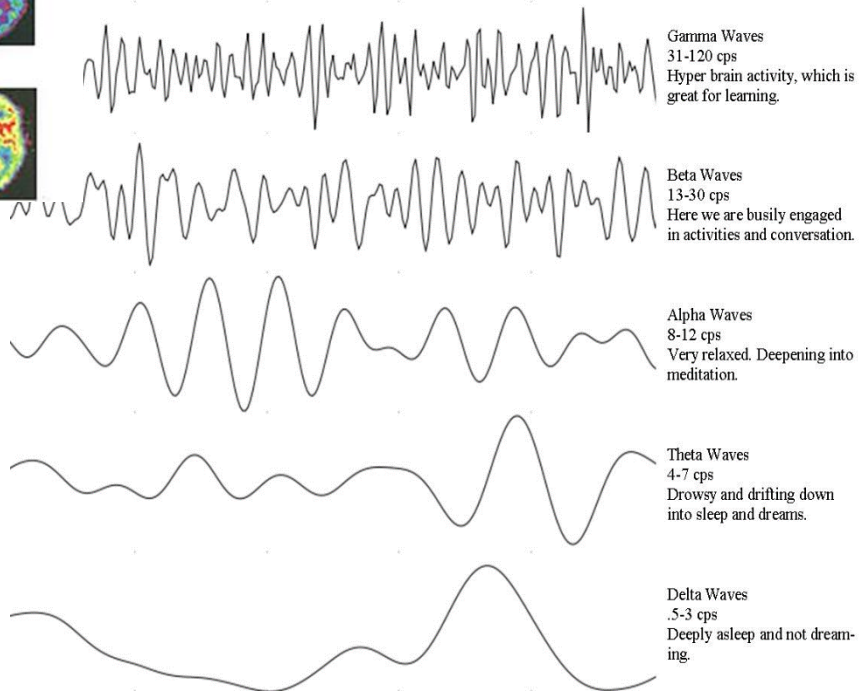
DELTA: 2 - 3 Hz
Dreamless
Deep Sleep

BETA: 15 - 30 Hz
REM Sleep /
Dreaming



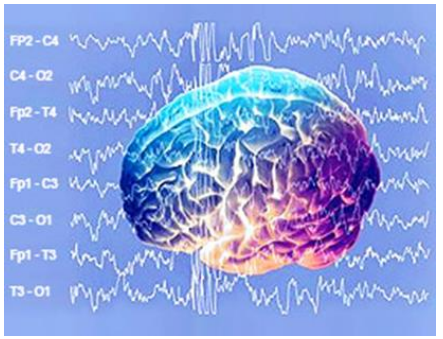


Brain Waves Graph



Brain waves

Experiments on human brain's functional state



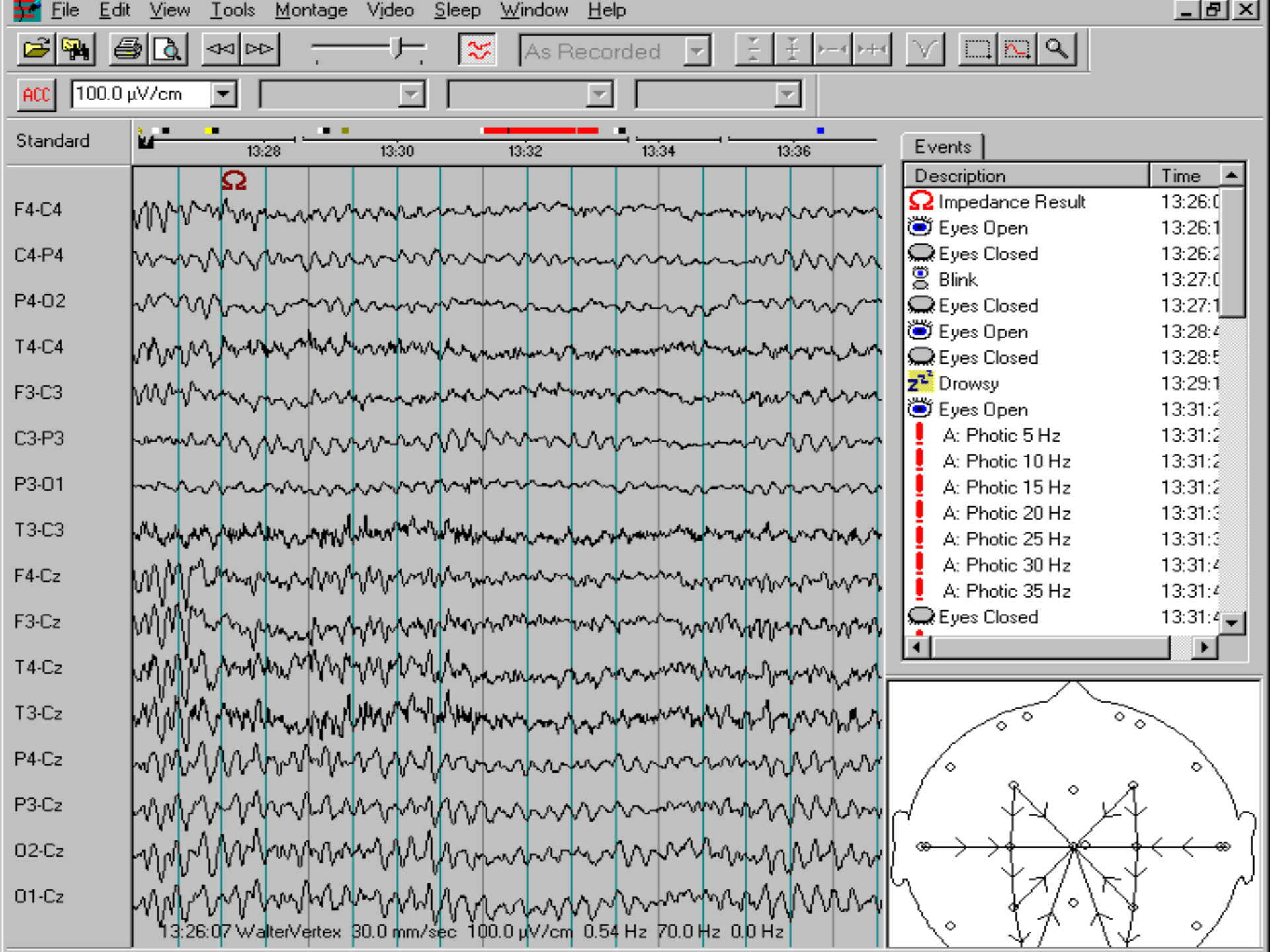
Patients:

- permanent group

- practically healthy adult female persons (50-60 y.o.)

Devices and methods:

- Electroencephalograph "Medicor", 16 channels; int. system; portable EEG
- Parallel registration of ECG, blood pressure, pulse measurements
- Using software "Neuron-Spectrum.NET" analyzing 10-second artifact-free electroencephalogram (EEG) segments of both brain hemispheres with the determination of the frequency-amplitude and index characteristics of the frontal, central, parietal, occipital and temporal regions of brain in various functional states of calm and active wakefulness
- Quiet and active awakeners; open and closed eyes; states of relax, photo-stimulation, hyperventilation
- Studies were personalized which enabled to avoid the influence of the variability of individual characteristics on the results obtained
- To assess the reactivity of the human brain, a functional test was used with the opening of the eyes - the transition from calm state to active wakefulness.
- Removal of artefact segments; software "Conan"
- Spectral and amplitude mapping/cartograms, correlation analyses
- Weather conditions, isolated room and hospital conditions; confidentiality


File Edit View Tools Montage Video Sleep Window Help
As Recorded
ACC
100.0 µV/cm
Standard
13:28
13:30
13:32
13:34
13:36
F4-C4
C4-P4
P4-O2
T4-C4
F3-C3
C3-P3
P3-O1
T3-C3
F4-Cz
F3-Cz
T4-Cz
T3-Cz
P4-Cz
P3-Cz
O2-Cz
O1-Cz
13:26:07 WalterVertex 30.0 mm/sec 100.0 µV/cm 0.54 Hz 70.0 Hz 0.0 Hz
Events
Description
Time
Impedance Result 13:26:0
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Eyes Closed 13:26:2
Blink 13:27:0
Eyes Closed 13:27:1
Eyes Open 13:28:4
Eyes Closed 13:28:5
Drowsy 13:29:1
Eyes Open 13:31:2
A: Photic 5 Hz 13:31:2
A: Photic 10 Hz 13:31:2
A: Photic 15 Hz 13:31:2
A: Photic 20 Hz 13:31:3
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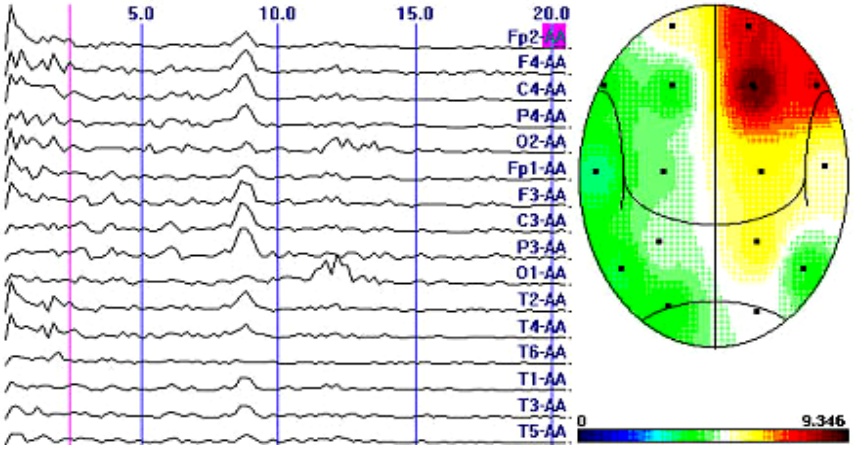
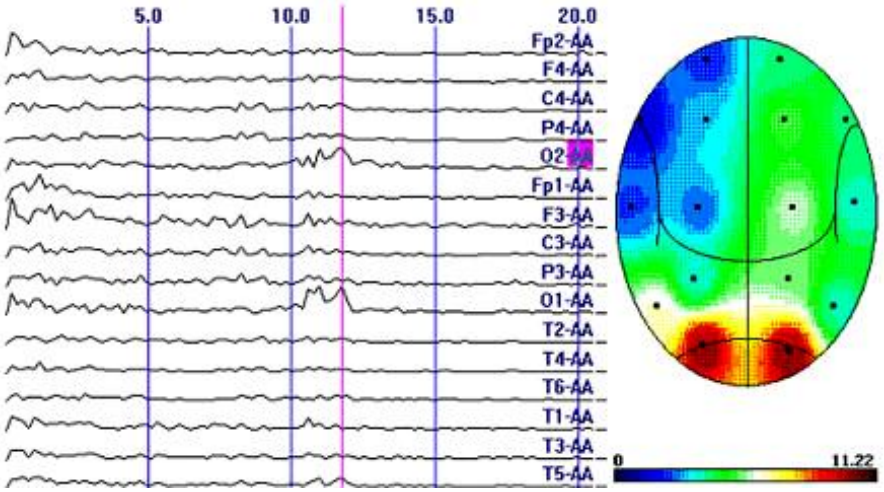
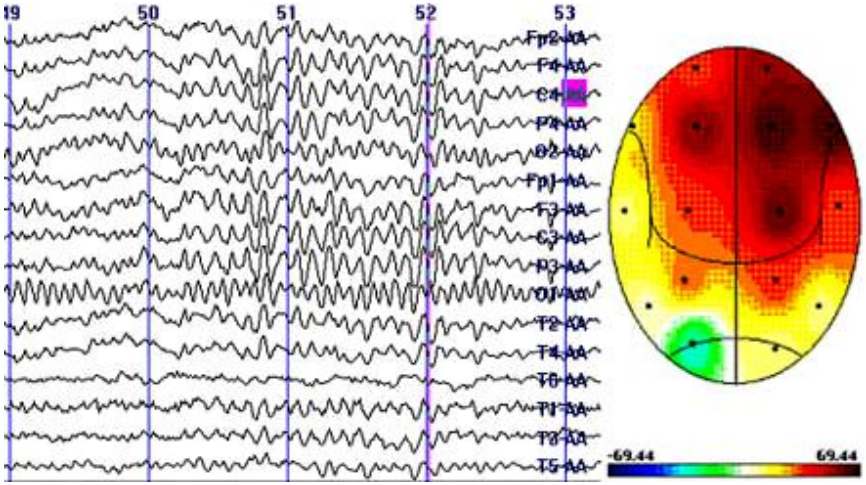


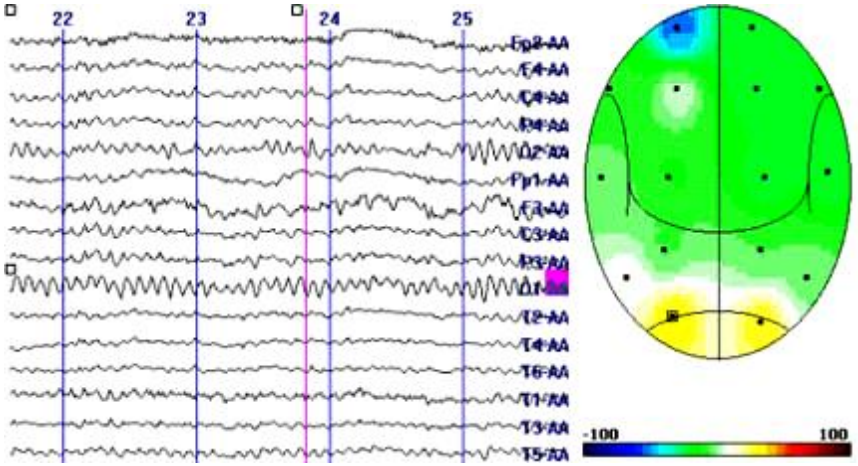
Frequency histogram and frequency cartogram during the major geomagnetic storms



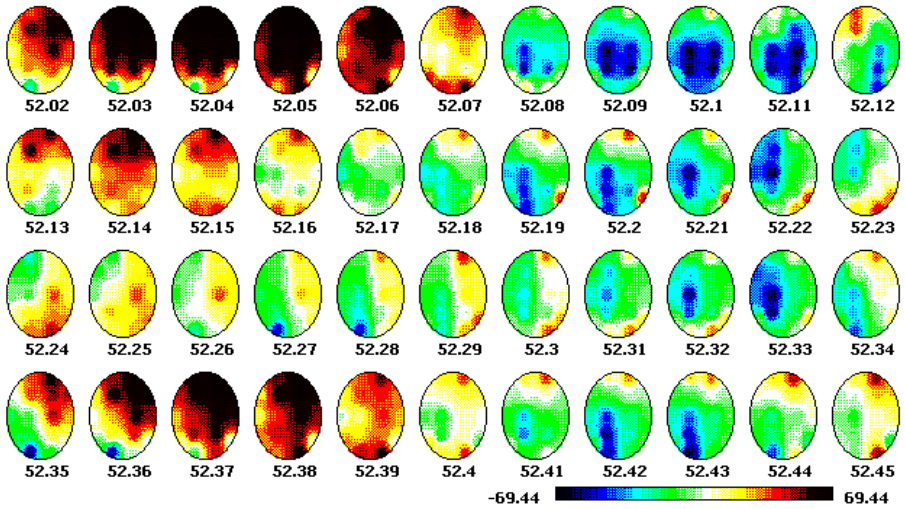
Frequency histogram and frequency cartogram at the comparatively geomagnetically quiet conditions



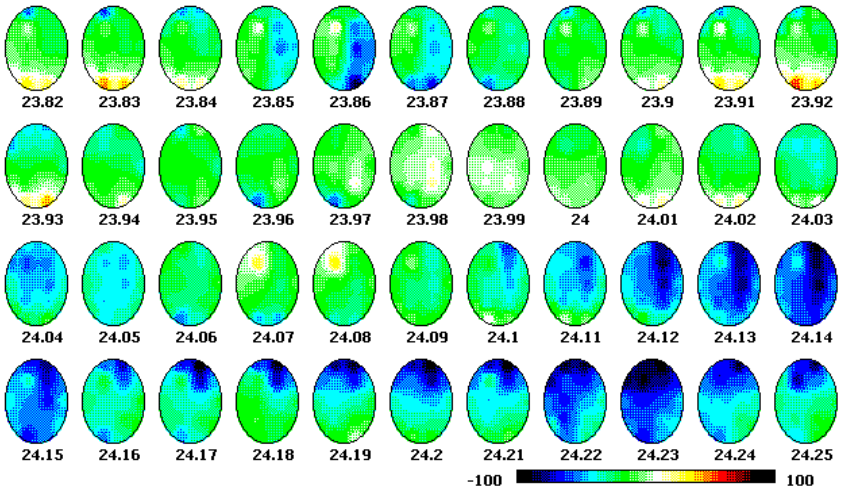
EEG and total (summary) amplitude cartogram during the severe geomagnetic storms



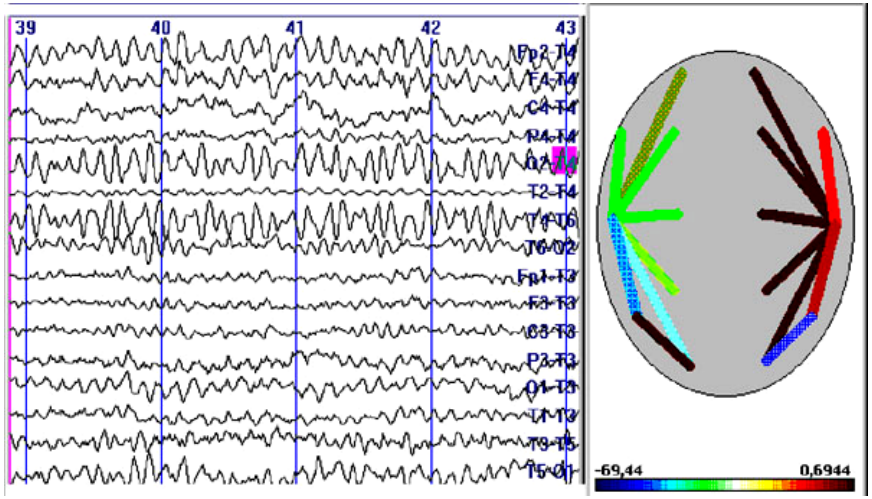
EEG and total (summary) amplitude cartogram at the comparatively geomagnetically quiet conditions



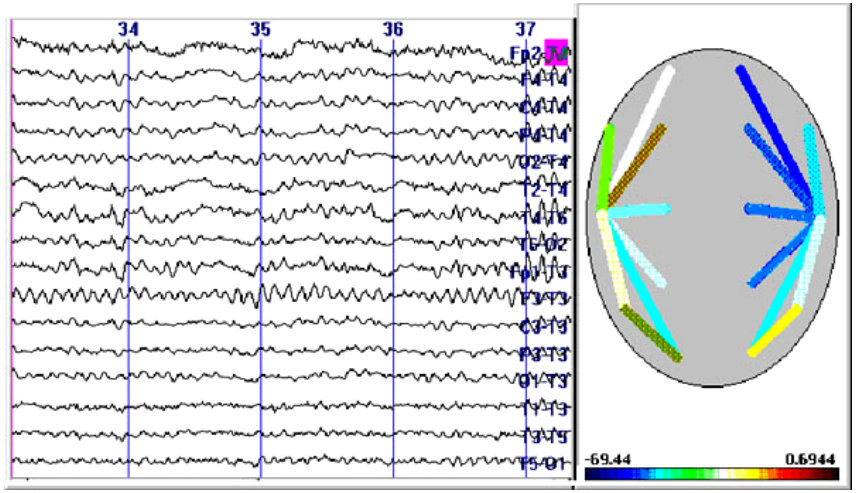
Total (summary) amplitude cartograms during the major geomagnetic storms along the whole length of hyperventilation



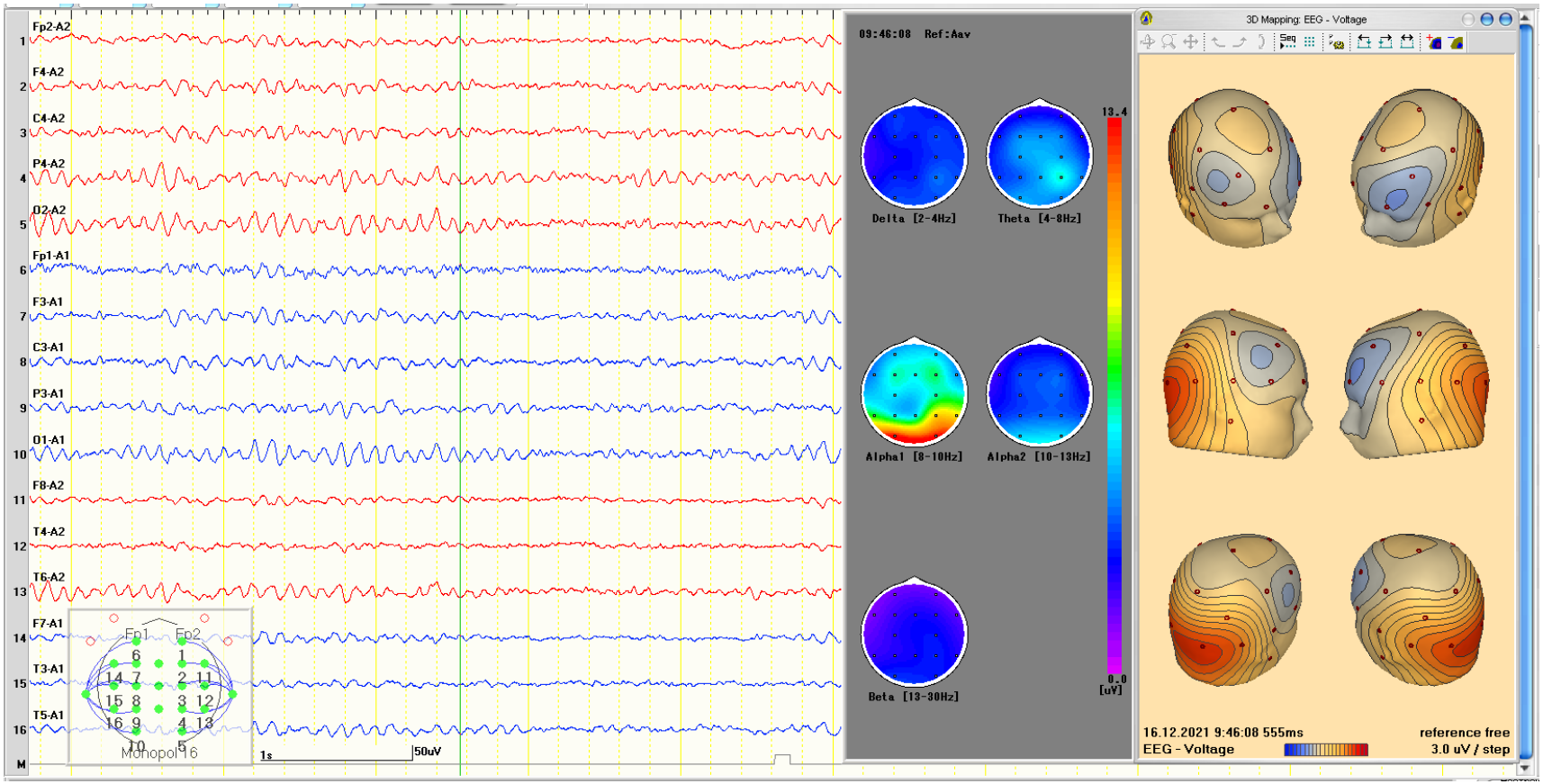
Total (summary) amplitude cartograms at the geomagnetically quiet conditions along the whole length of hyperventilation



EEG and correlogram during the major geomagnetic storms

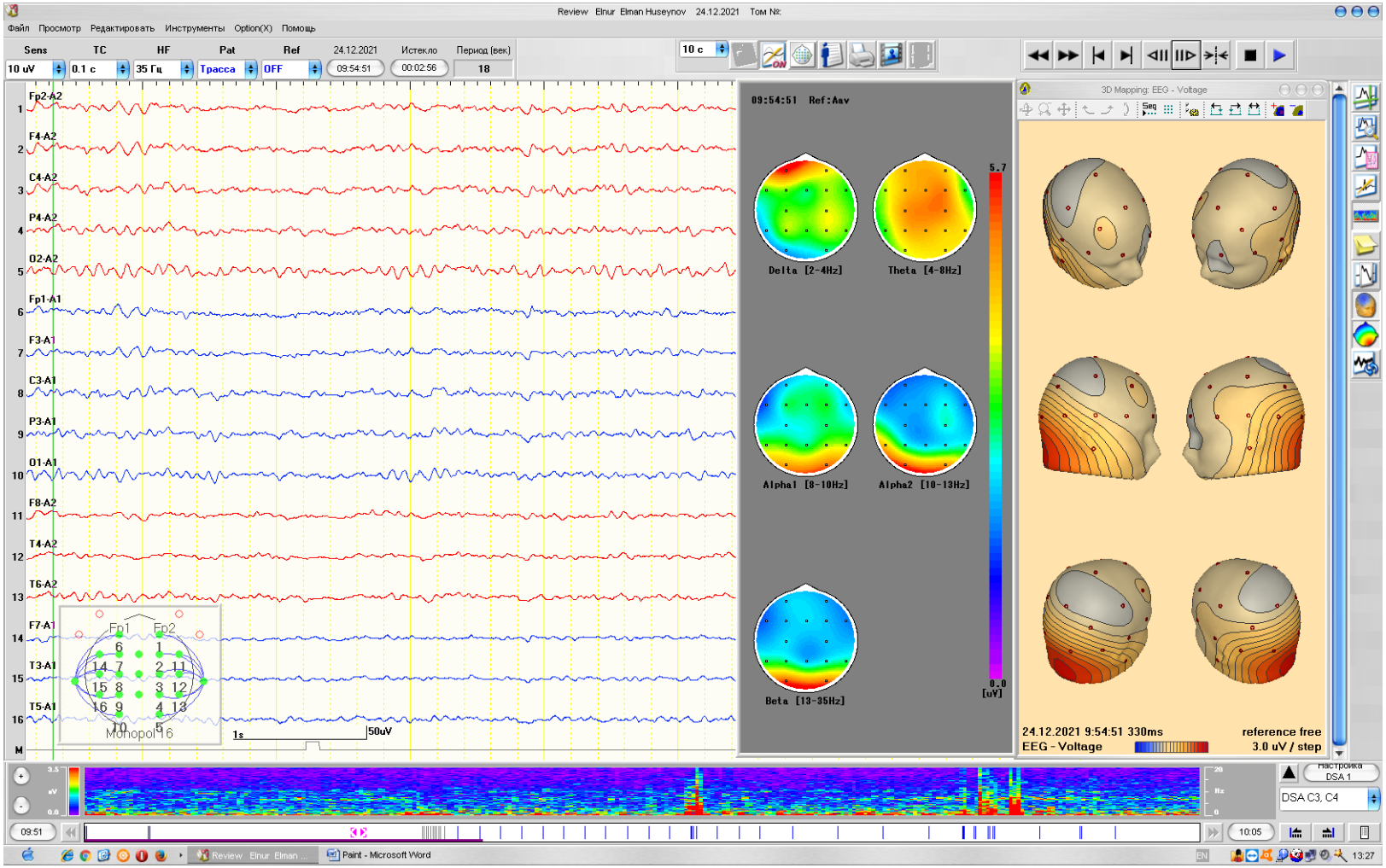


EEG and correlogram at the comparatively geomagnetically quiet conditions



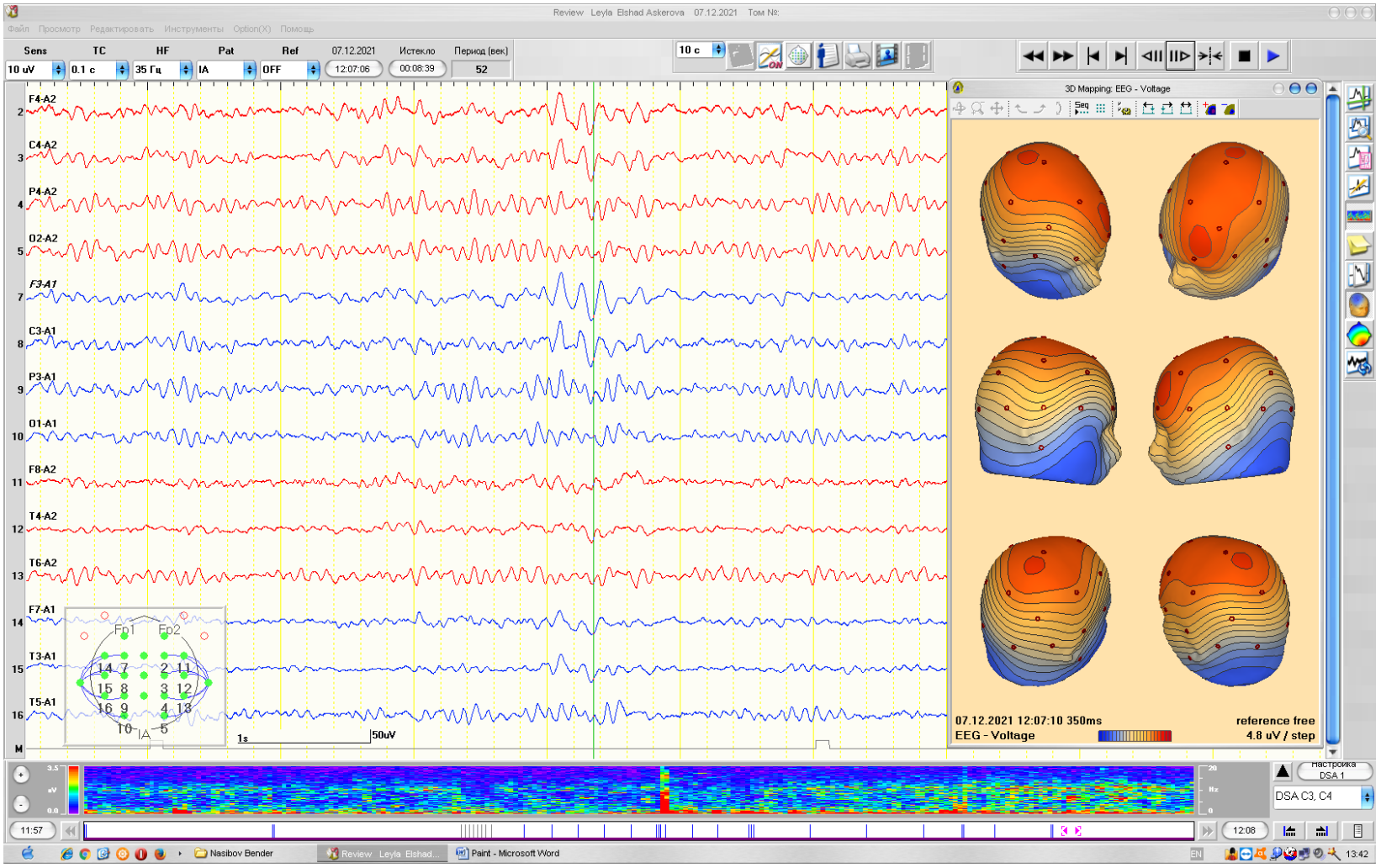
EEG of woman in a state of calm wakefulness on geomagnetically calm days; the areas of the right hemisphere are shown in red, the left hemisphere is in blue, and the areas of the cerebral cortex under study are from top to bottom left.

2D - representation of frequency characteristics is shown by regions, 3D - severity of amplitude indicators of rhythms by regions.



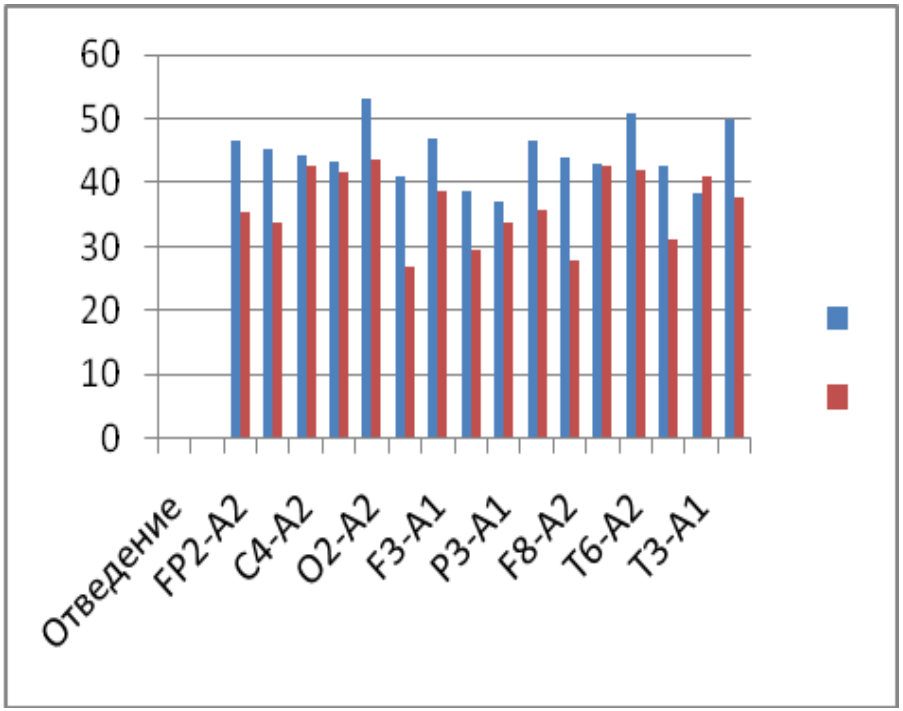
EEG of woman in a state of calm wakefulness on geomagnetically disturbed days; the areas of the right hemisphere are shown in red, the left hemisphere is in blue, and from top to bottom left are the areas of the cerebral cortex under study.

2D - representation of frequency characteristics are shown by regions, 3D - severity of amplitude indicators of rhythms by regions.



EEG of woman in a state of calm wakefulness on geomagnetically disturbed days; the areas of the right hemisphere are shown in red, the left hemisphere is in blue, and the areas of the cerebral cortex under study are from top to bottom left.

2D - representation of frequency characteristics are shown by regions, 3D - severity of amplitude indicators of rhythms by regions.



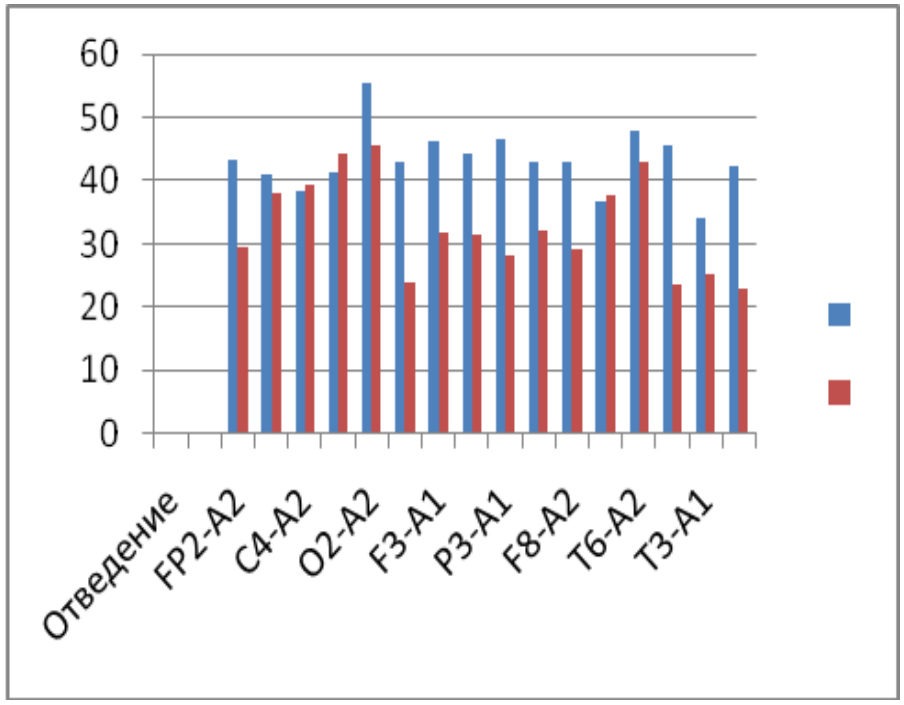
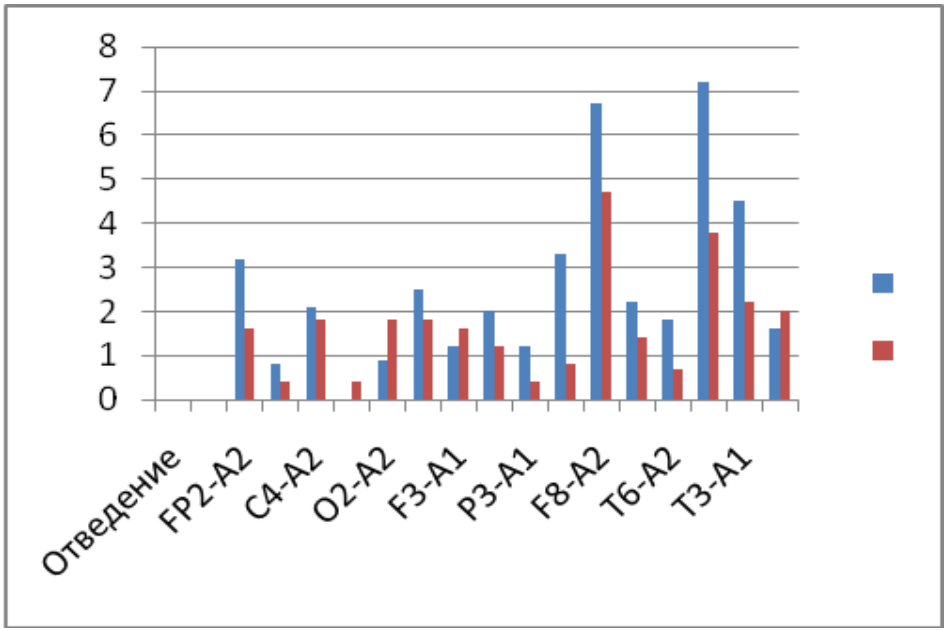


Diagram of index indicators of alpha - rhythm at rest (blue color) and when opening eyes (red color) on calm (LEFT) and geomagnetically active days (RIGHT) in adult woman. On the abscissa axis - cortical areas, on the ordinate axis – percentage expression



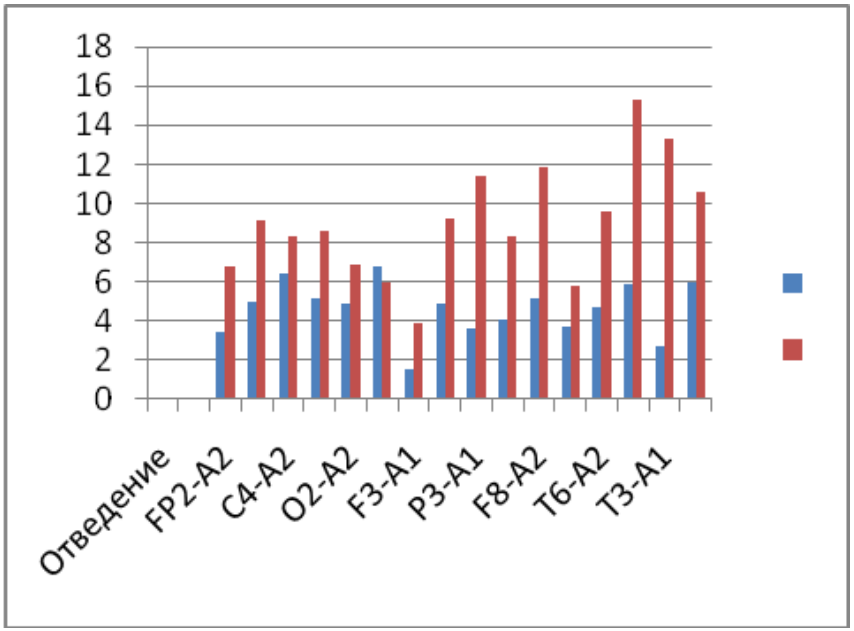


Diagram of index indicators of the delta rhythm at rest (blue color) and opening eyes (red color) on calm (LEFT) and geomagnetically active days (RIGHT) in adult woman. The abscissa shows cortical areas, the ordinate shows the percentage of indices

Results

- Disturbances of the geomagnetic conditions have an effect on functional activity of a brain, changing its background state.

- During severe geomagnetic storms, for the overwhelming majority of patients under test, as a rule, there were characteristic states: an indisposition, weakness, and presence of indistinct localized headaches.

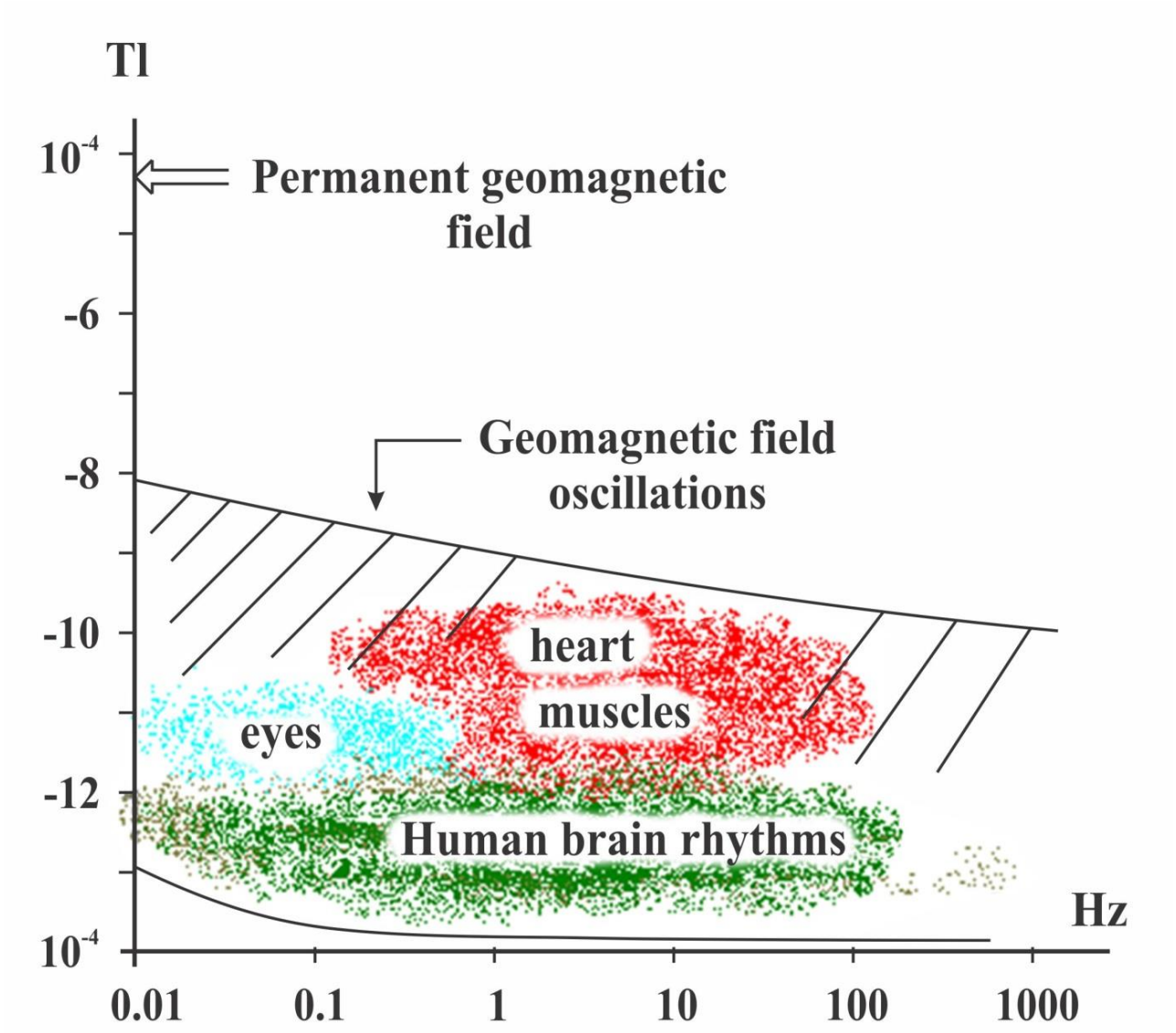
- At **weakly disturbed days** – a few cases of weakness were observed. No pathological activity, a small increase of dominating alpha-rhythm.

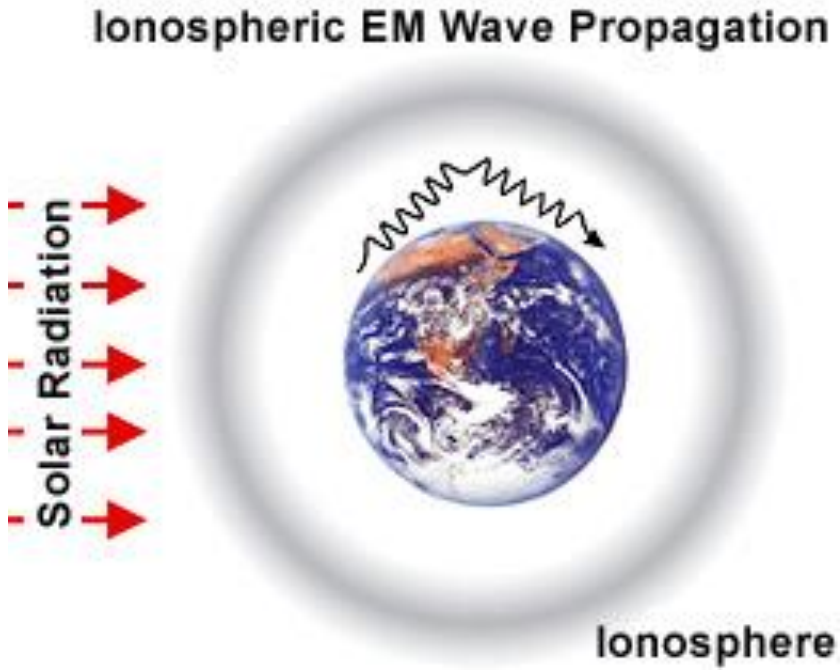
- In most cases, bioelectric activity of the human brain was characterized by reduce of frequencies of a dominating rhythm (7.5-13 Hz), amplification (strengthening) of expressiveness of slow-wave component (mainly, a theta-rhythm – 3.5-7.5 Hz) and increase in amplitude of total bioelectrical activity.

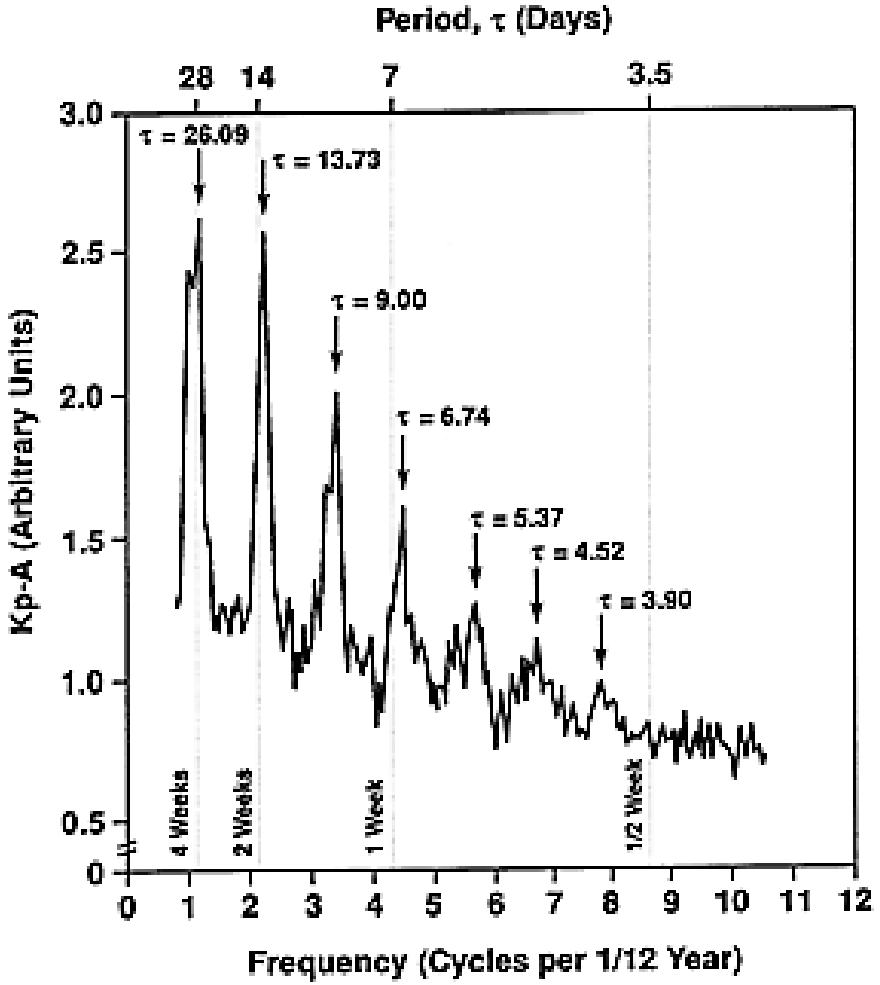
- The form of waves has got the pointed outlines, and strengthening of process of synchronization of activity was observed.

- Flashes of pointed and sharp alpha- and theta-waves were registered, having right cerebral hemisphere's accent (stress).

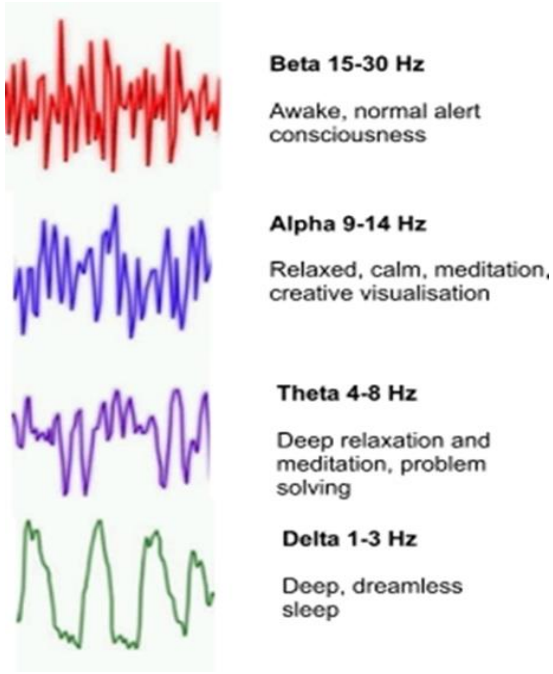
- Smoothing of interzonal distinctions was observed as well.
- At a part of examinees diffuse synchronization was traced on frequency ranges of alpha 1-2 rhythms.
- Reactivity of dominating activity was weakened, and reactions of adopting of a rhythm were observed on lower frequencies of the alpha-range.
- During the hyperventilation process, observable flashes of both pointed and sharp alpha- and theta-rhythms were amplified, and their amplitude was increased as well -> dysfunction! Infringe of activity of hypothalamus, imbalance in ergo- and tropho-tropic interrelations-> reduction of convulsive readiness.
- Figure of correlation interrelations, inherent to various functional conditions, was broken. Interhemispheric asymmetry was revealed.
- The leading role in interrelations has got temporal area of the right cerebral hemisphere.
- Activation of rostral-temporal and caudal-temporal connections (links) of the right hemisphere was marked (negative emotional reactions).
- It is established that weak and moderate geomagnetic storms exert stimulating influence while the strong disturbances of the geomagnetic conditions activate braking (inhibiting) processes.
- **We got results for traffic accidents, bees – same !**


Tl
10-4
-6
-8
-10
-12
10-4
Permanent geomagnetic field
Geomagnetic field oscillations
heart
muscles
eyes
Human brain rhythms
Hz
0.01
0.1
1
10
100
1000

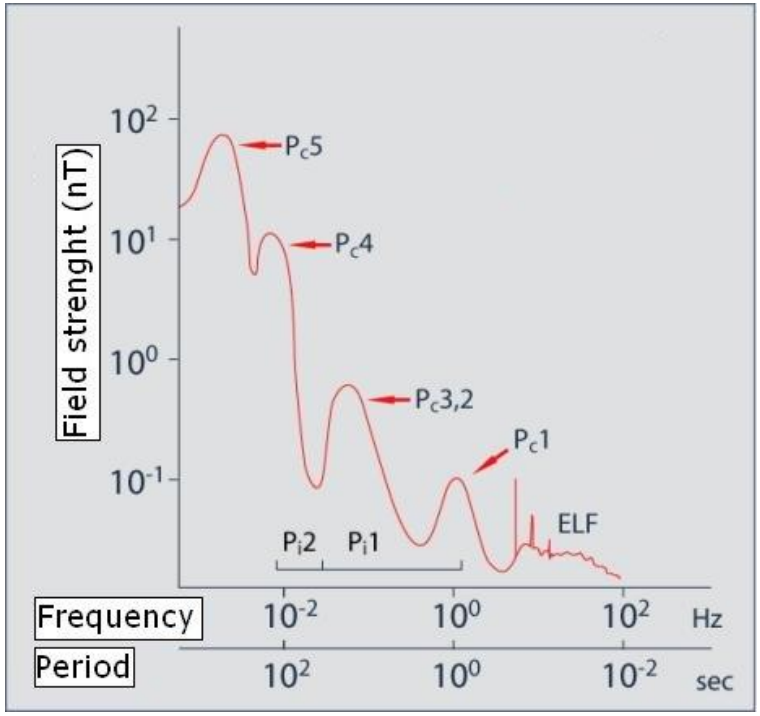




The lowest-frequency mode of the Schumann resonances is approximately 7.83 Hz, with a daily variation of about ± 0.5 Hz. The other frequencies are 14, 20, 26, 33, 39 and 45 Hz.

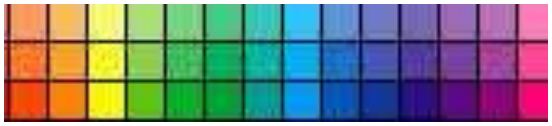


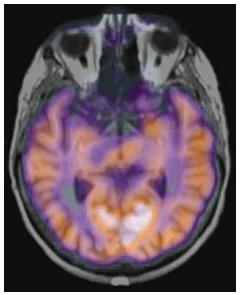
IAGA classification of geomagnetic pulsations

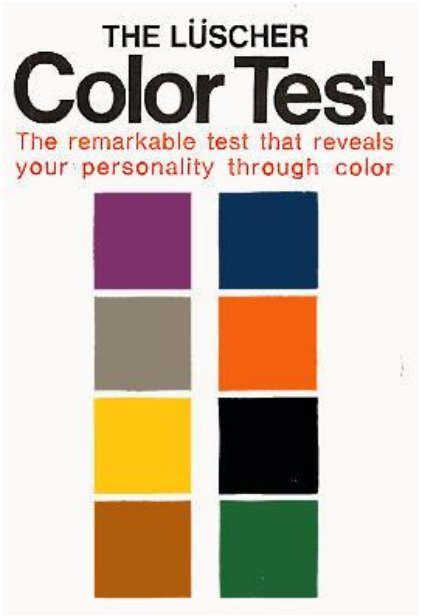


Continuous pulsations			Irregular pulsations		
Notation	Period(s)	Frequency (mHz)	Notation	Period(s)	Frequency (mHz)
Pc1	0.2 - 5	200 - 5000	Pi1	1 - 40	25 - 1000
Pc2	5 - 10	100 - 200	Pi2	40 - 150	7 - 25
Pc3	10 - 45	22 - 100			
Pc4	45 - 150	7 - 22			
Pc5	150 - 600	2 - 7			

Psycho-emotional sphere of human beings in the days with different levels of geomagnetic activity



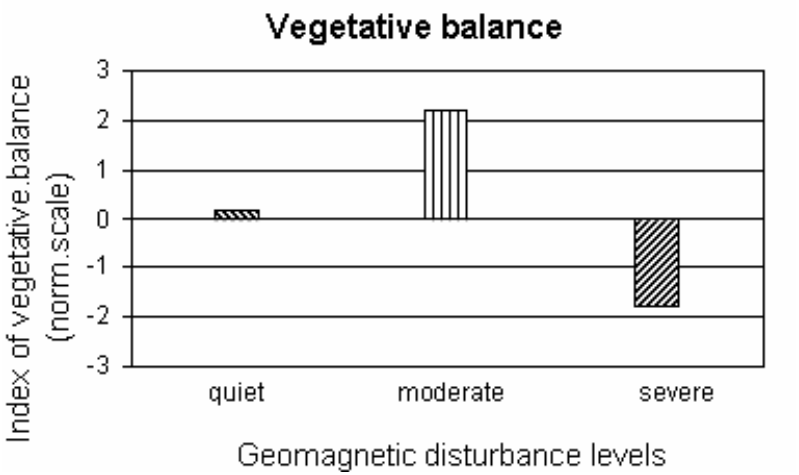


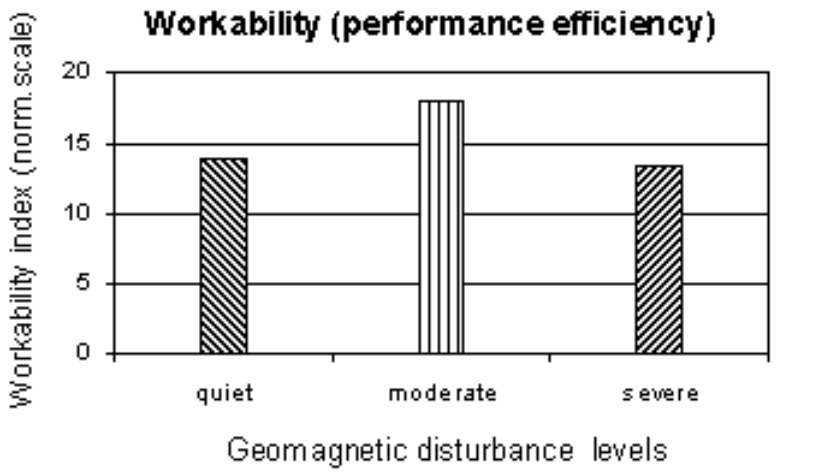


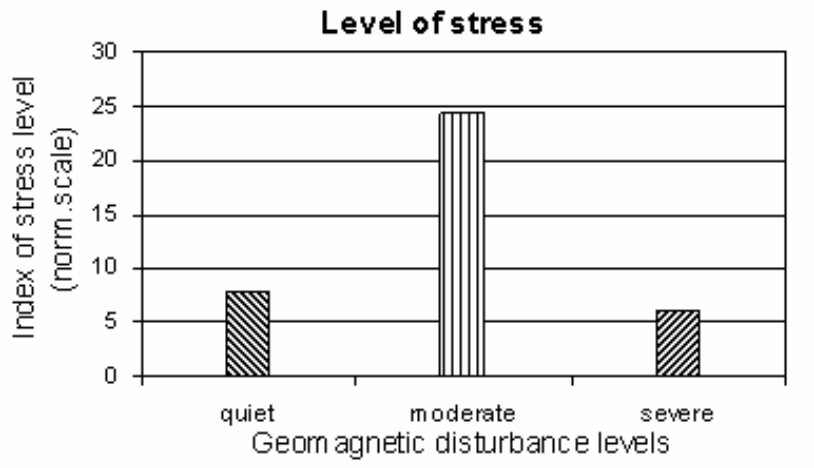
Emotional sphere of human beings in the days with different levels of geomagnetic activity

- Experimental investigations on possible influence of geomagnetic storms of various strengths on the emotional - affective sphere and personal characteristics of functionally healthy female persons
- Lüscher's Color Test and other relevant psychological non-verbal tests
- The characteristics reflecting anxiety, emotional and vegetative basis, as well as the level of working capacity were analyzed.
- Permanent group of practically (functionally) healthy adult women and from same geographical region
- investigations in geomagnetically quiet (favorable) days as well as in days with weakly-, moderately- and strongly-disturbed geomagnetic conditions
- All female persons were examined taking into account their real social and personal problems.
- Daily monitoring of meteorological (temperature, atmospheric pressure, humidity, wind speed, etc.) conditions
- Persons under test were not familiarized in advance with space weather conditions in order to avoid possible subjective psychological influence upon them.

- non-verbal psychological test method of diagnosis uses the principles of color psychology, measures a person's psychophysical state, his or her ability to withstand stress, to perform, and to communicate.
- It uncovers the cause of psychological stress, which can lead to physical symptoms.
- Objectivity of this test is that there are no subjective factors either when administering the test or during its diagnostic evaluation.
- Levels of anxiety (uneasiness) were determined using
  - Personality Scale of Manifest Anxiety developed by J.Teylor and adapted by T.A. Nemchin.
  - Levels of reactive and personality anxiety were determined by the help of Scale of Self-Rating developed by Ch.Spilberger and adapted by Yu.Khanin.
  - Depression level was determined by the Depression Rating Scale developed in the Scientific Research Institute of Psychoneurology named after V.M.Bekhterev.
- The obtained data on psychological testing had a digital form, which was subjected to mathematical analysis and the criterions of reliability for groups were calculated using relevant mathematical methods.


Vegetative balance
Index of vegetative balance (norm.scale)
3
2
1
0
-1
-2
-3
quiet
moderate
severe
Geomagnetic disturbance levels


Workability (performance efficiency)
Workability index (norm.scale)
20
15
10
5
0
quiet
moderate
severe
Geomagnetic disturbance levels


Level of stress
Index of stress level (norm.scale)
30
25
20
15
10
5
0
quiet
moderate
severe
Geomagnetic disturbance levels

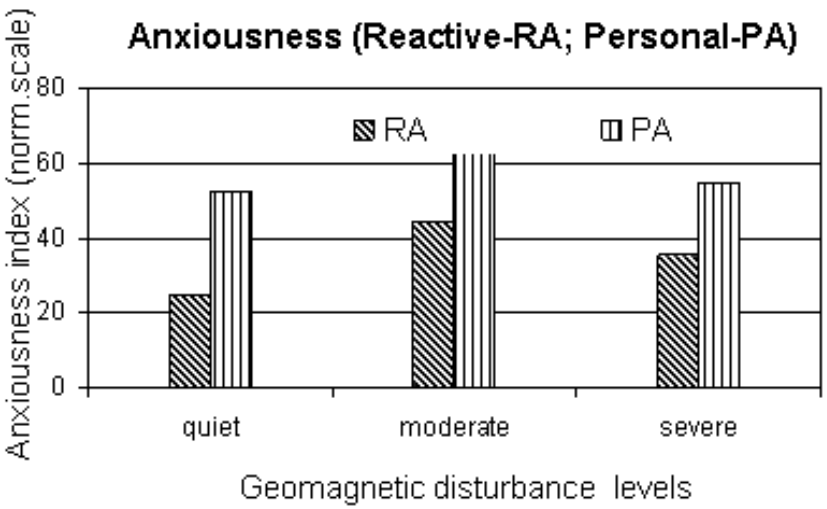
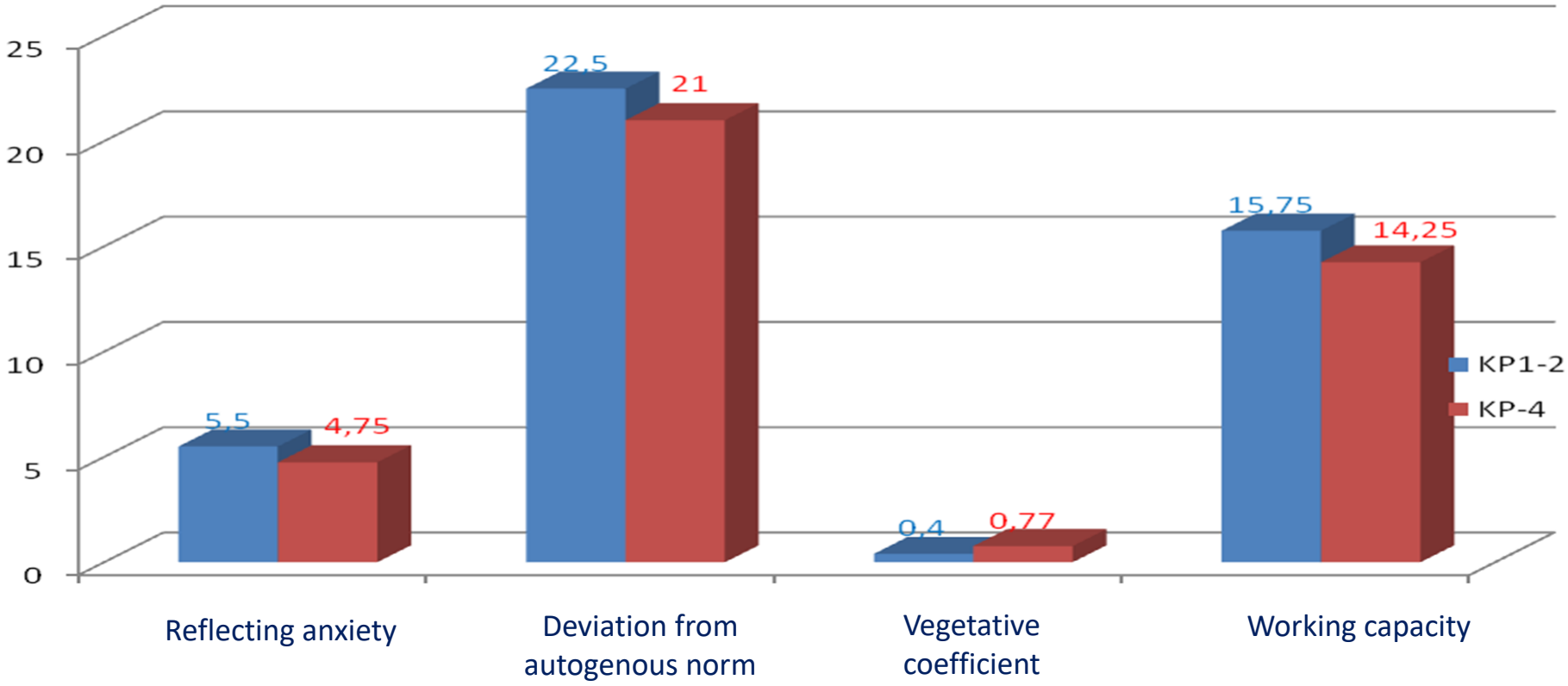

Anxiousness (Reactive-RA; Personal-PA)
Anxiousness index (norm.scale)
80
60
40
20
0
RA
PA
quiet
moderate
severe
Geomagnetic disturbance levels

Diagram of the results of the study on the Luscher test, in the general group of women 50-60 years old, on days with different levels of geomagnetic activity.
On the horizontal axis - personal characteristics. On the columns there are the average group values of the characteristics. The blue color shows the characteristics for days with Kp=1-2, the bordo color shows the characteristics for days with Kp=4.



- Obtained results clearly demonstrate that the increased geomagnetic activity is mainly accompanied by disturbance in the brain's response to eye opening, which reflects adaptive reactivity.
- Violations are traced in the slow-wave spectrum and in the low-frequency range of fast activity. There is an opposite correlation of theta- and predominantly delta-waves with a low-frequency beta-rhythm.
- A functional test with eye opening is accompanied by a disturbance of the balance observed at rest between the activating and deactivating mechanisms of nonspecific brain systems, with a predominance of deactivating processes.
- The results of a psychological study indicate that in adult females, a decrease in the autonomic tone and level of performance is significantly pronounced and was observed both on calm days and on days of geomagnetic disturbances.
- A high level of anxiety and an emotional-characteristic basis was also revealed which is not related to the level of geomagnetic activity and apparently reflects the surrounding situational environment.
- **The changes of geomagnetic conditions affect**, first of all, the activity of regulating systems, which are related to high cortical mechanisms of regulation and sub-cortical integrative apparatuses responsible for organization of **routine activity of organism**, and for adaptation to changes of physical environment.

General conclusions

- Living beings on the Earth is potentially predisposed to adverse health due to geomagnetic variations;
- Geomagnetic activity could be considered as one of the main regulating factors in the human homeostasis;
- Not only “regular” disturbances of geomagnetic field, but extremely high as well as extremely low values of Geomagnetic Activity (GMA) seem to have adverse health effects.
- Weak and moderate geomagnetic storms exert stimulating influence while the strong disturbances of the geomagnetic conditions activate braking (inhibiting) processes.
- Geomagnetic disturbances affect mainly the emotional and vegetative sphere of human beings.
- It is possible that some of the electromagnetic field changes, which accompany geomagnetic storms, have favorable and stimulating effects.
- Different types of geomagnetic storms, through their different parameters, can affect in different ways living organisms, including the human health state, particularly, human brain.