

Solar and Geomagnetic Activities and Related Effects on the Human physiological and Cardio-Health State: Some Results of Azerbaijani and Collaborative Studies

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Abstract. The geospace is very sensitive to solar and geomagnetic activity, to changes in these activities and its manifestations in the near-Earth space environment and on the Earth. The Sun, as the origin of visible and invisible influence, poses a health and safety threat to humans and all kinds of human activities. This paper describes recently obtained results of cross-disciplinary heliobiological studies carried out by Azerbaijani research group in collaboration with colleagues from different countries with purposes of revealing possible effects of solar, geomagnetic and cosmic ray variability on the human physiological and cardiovascular health state in middle latitudes. General conclusions, based on the results of these original researches, are outlined. Effects of severe and weak geomagnetic disturbances, latitudinal effects, and impacts of solar extreme events are briefly provided.

Keywords. solar activity, solar-terrestrial relations, space weather, heliobiology

1. Introduction

The state of near-Earth space environment is governed by the Sun and is very dynamic on all spatial and temporal scales (Bothmer & Daglis 2006). The Sun also poses a health and safety threat to humans (Palmer et al. 2006) and all kinds of human activities (Jansen et al. 2000). The geomagnetic field which protects the Earth from solar wind and cosmic rays is also essential to the evolution of life; its variations can have either direct or indirect effect on human physiology and health state even if the magnitude of the disturbance is small.

There is a limited comparison of the results of investigations carried out in high, middle and low latitudes for revealing possible effects to humans from solar (SA), geomagnetic (GMA) and cosmic ray activity (CRA) (Babayev 2003; Babayev 2007; Babayev et al. 2008a). Knowledge about the possible relationship between space weather changes and the human health would allow to get better prepared beforehand for any future space weather impacts anywhere.

This paper describes most recently obtained results of Azerbaijani and collaborative studies (jointly with scientists from Bulgaria, Russia, Israel and Greece) in the field of heliobiology - the branch of science that deals with the impact of solar activity and related effects on living organisms (it is known also as cosmobiology and/or astrobiology). Due to publication limitations, we provide only major results omitting details but directing readers to the relevant papers in case of necessity.

2. Geomagnetic Disturbances and Human Physiological and Psycho-Emotional State

Possible influence of geomagnetic disturbances of various strength on the bioelectrical activity of human brain and its functional state was studied for functionally healthy adults (twenty seven females) in different physiological states during many years of experiments within solar cycle 23 (collaboration: Prof. A.Allahverdiyev, Dr. A.Allahverdiyeva, Azerbaijan). The electroencephalographic (EEG) investigations were used as the most objective research method (Babayev & Allahverdiyeva 2007; Babayev et al. 2007). Effects of severe geomagnetic storms (namely, solar extreme events of October-November 2003) are also investigated. It is experimentally established that in middle latitudes weak and moderate geomagnetic storms do not cause significant changes in the human brain bioelectrical activity and exert only stimulating influence meanwhile severe disturbances of geomagnetic field (storms) cause negative influence, significantly disintegrate functionality of brain, activate braking processes and amplify the negative emotional background of an individual. Indisposition, weakness and presence of indistinct localized headaches were observed during the days with severe geomagnetic storms for the majority of the experiment participants meanwhile there were almost no significant complaints about functional state in periods of weakly-disturbed geomagnetic conditions.

Experimental investigations for studying possible effects of changes in GMA (geomagnetically quiet days as well as weakly, moderately and strongly-disturbed geomagnetic conditions) on the emotional - affective sphere and personality characteristics of functionally healthy persons were conducted. Luscher Color Test and other relevant psychological tests were used (Babayev & Allahverdiyeva 2007; Babayev et al. 2007). It is revealed that geomagnetic disturbances affect mainly emotional and vegetative spheres of human beings while characteristics reflecting personality properties do not undergo significant changes.

Changes in geomagnetic conditions mostly affect 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 an organism, and for adaptation to changes of a physical environment (Babayev & Allahverdiyeva 2005).

Possible influence of changes of heliogeophysical conditions on dynamics of traffic accidents in middle latitudes (collaboration: Prof. V.N.Obridko, Russia) was investigated (Babayev et al. 2008a; Babayev et al. 2008b). Synthetic curve taking into account influence of heliogeophysical activity and so called Integrated Space Weather Influence Index was calculated. There is high correlation between cosmic ray activity (CRA) (neutron data on the surface of Earth) and number of traffic accidents. One can conclude that impulsive geomagnetic events (storms) affect the number of traffic accidents more significantly than background GMA. It could be due to the retarded or inaccurate/inadequate reactions of the human brain.

There are results of different medical and biological experiments over the world, which demonstrate that the extreme weather events and fast climate changes of the last years are over the limits of human adaptation and may be a threat for population health. But this statement must be confirmed by synchronous experiments in different cities to reveal continuous influence of environment on people. Such experiment was carried out (collaboration: Dr. O.V.Khabarova, Dr. M.V.Ragulskaya and others, Russia) for the better knowledge about influence of permanent existing external factors like atmospheric and space weather changes on human life and health. We conduct (Khabarova et al. 2008a; Khabarova et al. 2008b) the parallel investigations as a part of collaborative study in different geographic latitudes and longitudes, namely, in Baku (Azerbaijan), Troitsk

(Moscow region, Russia) and Yakutsk (Russia). The experiment was based on a method of electrical conductivity measurements of biologically active (acupunctural) points of human skin. The method (electroacupunctural method by Dr. R.Voll) is very sensitive to current state of an organism and characterizes the functional condition of different organs and systems and enables expressing so-called Health Status of Group in the units, suitable for comparison with meteorological and physical parameters. Measurements were carried out daily with permanent group of functionally healthy persons (Moscow - 19, Yakutsk - 22, Baku - 12 volunteers). Daily monitoring of nervous, endocrine, lymphatic systems; blood, lungs, thick and thin intestine, heart and parenchymatic organs, allergy and hypophysis was conducted simultaneously with analyses of space weather (parameters of SA and GMA), as well as local meteorological parameters (temperature, atmospheric pressure, humidity, wind speed, etc.). It was found that: (i) human reaction to sharp changes of external parameters evolves like typical stress-reaction with hyperfunction and depression phases; (ii) the lower the latitude, the more the human body becomes susceptible to changes of meteorological parameters (especially humidity and temperature), the less sensitive it is to changes of GMA.

3. Space Weather Changes and Human Cardio-Vascular Health State at the Surface of the Earth

There are collaborative studies (collaboration: Prof. E.Stoupel and others, Israel) in Azerbaijan, carried out to reveal a possible influence of space weather changes on two groups of acute cardiac events - acute myocardial infarction (AMI) morbidity and mortality, and sudden cardiac death (SCD) in middle latitudes (Stoupel et al. 2006; Stoupel et al. 2007a; Stoupel et al. 2007b). The daily medical data (1096 days in 2003-2005) were taken from the Emergency and First Medical Aid Stations in Grand Baku Area. 788 SCD, 4919 AMI patients, 440 fatal AMI before admission to hospital were studied. Results show links between environmental physical activity and these cardiovascular risk events. Studies have revealed a rise in both SCD and AMI numbers on days of extreme (high/low) levels of GMA. As a result of rare GMA storms in middle latitudes the most events concentrated at lowest levels of GMA, accompanied by the high CRA (neutron activity). Links with neutron activity were more significantly expressed by monthly SCD, fatal AMI, and for all AMI. Despite the daily raise of AMI mortality at highest GMA levels, the days of lowest GMA and higher CRA are much more predominant for AMI occurrence and acute (pre-hospital) mortality. In the monthly comparison, there was also an inverse link of both acute cardiac events with SA and GMA. The conclusion is that both SCD mortality and AMI occurrence increase in high CRA (neutron) levels, and GMA and CRA could be considered as two of the most significant regulating factors in human homeostasis. Not only high levels, but also low levels of GMA influence the number of considered acute cardiac events (Stoupel et al. 2008).

The possible effects of geomagnetic disturbances of various strength and type on the lethality from AMI were studied (Dimitrova et al. 2008a) on the basis of AMI mortality data from two middle-latitude locations, but in different longitudes, taken namely from University Hospital for Active Treatment St. Anna, Sofia, Bulgaria (109 consecutive months from 01.12.1995 to 31.12.2004, covering 175 cases in hospital) and from all of Emergency and First Medical Aid Stations of Grand Baku Area, Azerbaijan (36 months daily pre-hospital data from 01.01.2003 to 31.12.2005, covering 440 cases). The statistical method of Analysis of Variance (ANOVA) was applied to check the significance of the influence of different GMA indices (Ap, Am, Kp and Dst) on the dynamics of lethal cases. The same analysis was performed as well to study the effect of the type

of geomagnetic storms (those caused by solar origin magnetic clouds (MC) or by high-speed solar wind streams (HSSWS)) on AMI mortality. Results have revealed that AMI mortality in both regions increased with GMA increase and on the days before, during and after geomagnetic storms with different intensity. Lethal AMI incidences increased also on the days with low GMA for the period 2003-2004. Geomagnetic storms caused by MC showed relation to an increase of AMI mortality both in Sofia and in Baku for all studied periods in comparison with the storms caused by HSSWS.

A collaborative study (Dimitrova et al. 2008b) was based on the analysis and comparison of results of coordinated experimental investigations also conducted in Bulgaria and Azerbaijan to reveal a possible influence of SA changes and related GMA variations on the human cardio-vascular state. Arterial blood pressure (ABP) and heart rate (HR) of 86 healthy volunteers were measured on working days during a period of comparatively high SA and GMA (2799 measurements in autumn 2001 and spring 2002) in Sofia. Daily experimental investigations of parameters of cardio-vascular health state were performed in Azerbaijan with a permanent group of examined persons. HR and electrocardiograms were digitally registered (in total 1532 records) for seven functionally healthy persons on working days and Saturdays, in the Laboratory of Heliobiology at the Medical Center INAM in Baku, from 15.07.2006 to 13.11.2007. Obtained digital recordings were subjected to medical, statistical and spectral analyses. Special attention was paid to effects of solar extreme events, particularly those of November 2001 and December 2006. ANOVA and Post Hoc analysis were applied to check the significance of the influence of GMA on the cardio-vascular parameters under consideration. Results revealed statistically significant increments for the mean systolic and diastolic blood pressure values of the group with geomagnetic activity increase. ABP values started increasing two days prior to geomagnetic storms and kept their high values up to two days after the storms. HR reaction was ambiguous and not significant for healthy persons examined (for both groups) under conditions with GMA changes. We conclude that HR for healthy persons at middle latitudes can be considered as a relatively stable physiological parameter not so sensitive to environmental changes, while the dynamics of ABP reveals a compensatory reaction of the human organism designed for adaptation.

The study (collaboration: Dr. S. Dimitrova, Bulgaria, Dr. H. Mavromichalaki and others, Greece) of possible effect of geomagnetic disturbances and cosmic ray intensity (CRI) variations on human cardio-health state refers to the time period from 15 July 2005 until 31 March 2008. Daily HR data, which were digitally registered for seven functionally healthy persons on working days (including Saturdays) in the aforementioned Laboratory of Heliobiology are related to daily variations of CRI, as measured by the Neutron Monitor of the University of Athens and daily variations of Dst and Ap geomagnetic indices. The time interval from 4 - 22 December 2006 is most interesting as it is characterized by extreme SA and GMA. Intense cosmic ray events were recorded during this period, such as a series of Forbush decreases started on 6 December 2006 and lasted until the end of the month and a solar proton event causing a Ground Level Enhancement (GLE) of the CRI on 13 December 2006. A sudden decrease of the CRI on 15 December resulted in a geomagnetic storm, which was recorded also by the Athens station (cut-off rigidity 8.53 GV) with amplitude of 5 per cent. Our study (Mavromichalaki et al. 2008) reveals that HR variations can be connected to geomagnetic disturbances and CRI variations. During geomagnetically quiet days the HR and the CRI variations were positively correlated. When intense cosmic ray variations, like Forbush decreases, occur, CRI and HR get minimum values and their variations also coincide. The effects of HR increase were more pronounced for high levels of GMA (when geomagnetic storms occur) and large

CRI decreases. HR increased on the days before, during and after geomagnetic storms with high intensities and on the days preceding and following CRI decreases.

4. Discussion

This paper is an outcome of collaboration of four different research groups, and it focuses on the possible relation between solar and geomagnetic activity and cosmic ray intensity changes, and human physiological and cardio-health state through experimentally measured parameters and created statistical database (middle latitudes). Results of these studies are irrefutable; the human organism is sensitive to changes in environmental physical activity and reacts to them through a series of variations of its physiological parameters such as systolic blood pressure, diastolic blood pressure, heart rate, bioelectrical activity of human brain, etc.

Heliobiological and experimental studies conducted in middle latitudes and their analysis enabled to conclude that human cardio-vascular and physiological health state could be affected by SA variations, GMA disturbances and CRA changes. Studies show that, in general, in low latitudes a human being is more susceptible to changes of meteorological parameters (especially humidity and temperature) in comparison to effects caused by changes in GMA. However, different levels of GMA have different effects in middle latitudes.

Human brain displays different reactions to GMA: during severe disturbances of geomagnetic field, the negative emotional background of a person is amplified. We conclude that changes in GMA mostly affect the activity of regulating systems related to high cortical mechanisms of regulation and sub-cortical integrative apparatuses. The indexes of reactive anxiousness of humans increase in the days with severe geomagnetic disturbances while characteristics of personal anxiousness do not change significantly. Geomagnetic storms increase the number of traffic accidents (acting as a trigger factor); this is presumably a result of retarded or inaccurate/inadequate reactions in the human brain.

It is well established that both high and very low levels of GMA influence the number of some acute cardiac events (sudden cardiac death, acute myocardial infarction morbidity and mortality). We conclude that both SCD mortality and AMI occurrence increase in high CRA (neutron) levels, and GMA and accompanied CRA could be considered as some of the most significant regulating factors in human homeostasis. It is shown experimentally that for healthy persons under geomagnetic field variations, the heart rate is a more stable cardio-physiological parameter than other physiological parameters (i.e., blood pressure, which increases with GMA increment).

5. Conclusions

Weak and severe geomagnetic storms affect the functional state (bioelectrical activity) of the human brain in a different way.

Geomagnetic storms amplify the negative emotional background of an individual and can affect, for example, the brain of a driving person, thus increasing the risk of an accident.

Parameters reflecting a state of vegetative sphere of a human being significantly differ and are dependent on the strength of geomagnetic disturbances.

Heart rate dynamics (variations) of a human can be affected by space weather changes like variations in geomagnetic activity and cosmic ray intensity.

Different types of geomagnetic storms (i.e., magnetic-cloud origin or caused by high-speed solar wind streams) affect cardio-vascular system in different ways.

Not only extremely high levels, but also very low levels of geomagnetic activity influence the human health state, particularly, significantly affecting the number of some acute cardiac events (sudden cardiac death, acute myocardial infarction morbidity and mortality).

Geomagnetic disturbances of various intensities, accompanied by changes in cosmic ray activity, could be considered as one of the regulating factors in the human homeostasis.

It is of great importance to conduct complex, long-period, detailed and synchronic investigation of geomagnetic storms effects on human beings in different latitudinal and longitudinal areas in order to get more and better knowledge about solar and geomagnetic storms and their possible effects on human health state in order to decrease adverse effects of these disturbance factors and to clarify the possible biophysical and medical-biological mechanisms through which different geomagnetic activity indices and different geomagnetic activity levels affect human cardio-vascular system. Very low level geomagnetic activity effects on cardio-vascular and other pathologies should be carefully investigated.

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