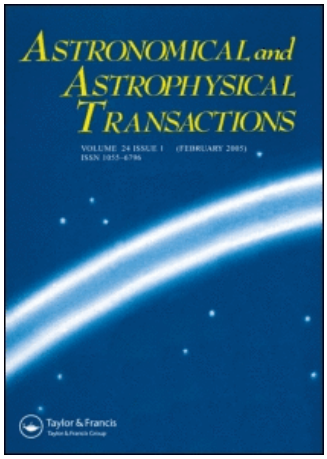

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SOME RESULTS OF INVESTIGATIONS ON THE SPACE WEATHER INFLUENCE ON FUNCTIONING OF SEVERAL ENGINEERING–TECHNICAL AND COMMUNICATION SYSTEMS AND HUMAN HEALTH

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Some results of a complex study on the influence of such space weather factors as the effects of scintillation, solar and geomagnetic storms on human health and some engineering–technical systems both space borne and of ground-based origin are briefly described. The morphology and main characteristics of ionospheric scintillation, together with its impacts on navigation and communication systems, are developed to help space system designers who are involved in activities related to the development of systems in middle latitudes for microwave radio signals for the satellite-receiver path. A study of the effects of geomagnetic storms on electrical power generation and transmission network and equipment, that is the influence of the geomagnetically induced currents of selected magnetic storms and relevant power cuts has revealed that power line disturbances mainly occur when the geomagnetic field displays sharp changes. For the purposes of studying the possible influence of the solar and geomagnetic activity on influenza (and especially influenza epidemics) in the Azerbaijan, the data covering the time period 1976–2000 is analysed. Some results of a complex investigation on the influence of heliogeophysical conditions on human health and, in particular, the effects of solar and geomagnetic storms on human brain functional activity and cardiovascular diseases are reported.

Keywords: Solar activity; Magnetic storms; Scintillation; Space weather

1 INTRODUCTION

It is well known that the Sun manages all living nature on the Earth and is of practical importance to human activity. Our increasingly technology-dependent world is sensitive to solar and geomagnetic activity, to changes in these activities and their manifestations on the Earth. We have just passed the maximum of the current 11 year solar activity cycle 23. If we are to understand the relationships between solar and geomagnetic activity and their possible effects, we need to have a clear understanding of 'weather' processes in space. 'Space Weather' not only affects the functioning of technical systems in space and on the ground but also may endanger the biosphere. The effects of space weather phenomenon are many and varied; they include electronic and power transmission failures, interruptions in telecommunications

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and navigational systems, hazards to astronauts, aircraft crews and passengers, disruption of oil–gas pipelines, railway traffic, etc.

According to the results of investigations carried within several big projects during the last twenty or so years, not only ground- and space-based technical systems but also human life and health tend to be more and more exposed influence of the solar and geomagnetic activity, and in general, space weather (Daglis, 2001). As some of the effects of geomagnetic storms can be devastating (for example, like those that registered during and after the great magnetic storm of 13–14 March 1989), it is of great importance to obtain more and better knowledge about solar and geomagnetic storms and their effects, in order to decrease and/or to forecast the disturbance factors.

Within a large research project we have studied the possible influence of such space weather factors as the effects of scintillation, solar and geomagnetic storms on human health and some engineering–technical systems both space borne and of ground-based origin. There is a well-established group of highly skilled specialists, called The Group on the investigation of Solar–Terrestrial Relations, in Baku, Azerbaijan, consisting of astrophysicists, geophysicists, medical specialists, physiologists, doctors, engineers, etc., and led by the author of this paper. Some major results of these complex investigations, omitting a detailed description of methods, formulae and figures, are briefly provided in this paper.

2 SOLAR–GEOPHYSICAL ACTIVITY AND SCINTILLATION OF MICROWAVE RADIO SIGNALS PROPAGATING THROUGH AN IONIZED MEDIUM

The morphology and main characteristics of ionospheric scintillation, together with its impacts on navigation and communication systems, are provided to help space system designers who are involved in the activities related to the development of systems in middle latitudes (Babayev, 2000). The presence of small-scale (from centimetres to metres) irregularities of electron concentration embedded in the large-scale ambient ionosphere (turbulence) can seriously affect the nature of radio waves as they propagate through the ionosphere; this effect on radio signals is called scintillation (Yeh and Liu, 1982). Establishing the constraints imposed by scintillation on the operation of satellite systems will help users to distinguish receiver problems from ionospheric scintillation. Mention should be made of the solar activity, geophysical and other processes or factors thought to be responsible for influencing the scintillation. It is established that the probability of occurrence of scintillation increases with increasing solar activity. The measurements made up to now show that scintillation activity is directly proportional to solar activity but is generally independent of the planetary geomagnetic index K_p. The severity (and its intensity) of the ionospheric scintillation varies with sunspot cycle together with other factors. Disturbance effects due to ionospheric scintillation are most significant near the solar maximum period, especially in the high- and low-latitude areas. In years of high solar flux, transionospheric propagation through polar and equatorial regions has experienced deep fading at frequencies ranging from 54 MHz to 4 GHz. The equatorial anomaly region (two belts of enhanced electron density at 15° N and 15° S of the magnetic equator) is the worst source of scintillation; during the sunspot maximum years, fades exceeding peak-to-peak 27 dB at the Global Positioning Systems' (GPS) L1 frequency (1.5 GHz) are often recorded in this region (at Ascension Island) after sunset.

The global ionospheric propagation model is applied to study scintillation effects on microwave radio signals in the European Civic Aviation Conference (ECAC) area, including the territory of Azerbaijan and the Canary Islands (Spain), for the worst-case scenario.

Results allowed to conclude that amplitude and phase scintilation can negatively affect the propagation of high-frequency (Giga-Hertz or GHz range) transionospheric radio communication and navigation signals under certain ionospheric and heliogeophysical conditions. Ionospheric scintillation can at times cause severe and long fades or rapid phase gradients that exceed a receiver's capability to lock on the signal. Application of scintillation models showed that in solar maximum years the ionospheric scintillation would have significant impacts on the GPS in particular applications and circumstances, especially at low latitudes (equatorial). They are not significant for midlatitude microwave radio propagation (Babayev, 2000). However, in general, an analysis of scintillation impacts is complicated and depends on a number of factors: the characteristics of the transmitter and receiver, the time in the solar cycle, the season, the location on the Earth, as well as what is occurring in the ionosphere. There is a great need not only to define but also to predict and assess scintillation impacts on the systems and to develop good solutions within space weather programmes.

3 SPACE WEATHER AND ELECTRICAL POWER SUPPLY SYSTEMS IN AZERBAIJAN

We have attempted to study the effects of geomagnetic storms on electrical power generation and transmission network and equipment, that is the influence of geomagnetically induced currents (GICs). We have applied existing theory to available data covering at least two sunspot cycles, in Azerbaijan, but there is still much work to be done and there are many unsolved questions remaining. Several great geomagnetic storms, which have occurred during the past and present solar cycles, have been considered (e.g. 13–14 March 1989, 14–15 July 2000 and 29 September–3 October 2001). Analysis of magnetic records for selected magnetic storms and relevant power cuts has revealed that power line disturbances mainly occur when the geomagnetic field displays sharp changes. A number of harmonic oscillations in the current and voltage, disrupting the signal waveforms, are recorded in GIC-saturated transformers. Preliminary results show that the transformers that are positioned at the corners of an electrical power system would suffer the worst damage from GICs. The first investigations have shown that geomagnetic storm effects were not so strong in Azerbaijan (middle latitudes) and the effects on consumers were small. We have now entered the post-maximum period of the current solar cycle, which is a powerful solar cycle. Also taking into account that 11 year variability of the geomagnetic activity reveals two peaks, one somewhat ahead of or at the solar maximum and the other 2 or 3 years after it, which is especially noticeable in the descending phase of the solar cycle, it is evident that there will be an increasing need for knowledge about geomagnetic storms, their genesis and effects on power supply equipment, high-voltage power grids and long transmission lines in order to reduce global costs of damage caused by geomagnetic storms. Even it is not so significant for middle latitudes, by receiving correct geomagnetic storm alerts and warnings or forecasts, Azerbaijani electric power companies can minimize possible damage and interruptions to power supplies and power outages and hence produce cost savings. If an electric company or national grid network supplier is warned in advance when a strong local geomagnetic storm is approaching, it can take mitigating actions and/or various controlling measures including reducing the system load, testing the capacitors or disconnecting some system components for protection. At least, knowledge of geomagnetic storm forecasts and possible effects on power systems will help domestic and industrial electric companies to differentiate between power outages produced by geomagnetic storms and those of equipment or man-made origin.

4 EFFECTS OF SOLAR AND GEOMAGNETIC ACTIVITY ON INFLUENZA AND INFLUENZA EPIDEMICS

Influenza and other strong respiratory virus infections are among a number of uncontrollable infections and until now remain the most widespread and global illnesses of humans. Despite relatively good from the epidemiological healthy viewpoint during the last 8–10 years, these viruses and infections, as always, cause 70–90% of infectious diseases and cause huge social and economic problems. Influenza is always present in the world and almost all peaks of influenza epidemics are accompanied by an increase in death rate, in particular, because of the pneumonia caused by influenza. Influenza has a special place among epidemic diseases.

To study the possible influence of space weather on influenza, a correlation between influenza epidemics and solar–geomagnetic activity was investigated (Babayev *et al.*, 2002). The empirical data used contain material on the circulation of influenza in the Absheron Peninsula (Azerbaijan) for the time period from 1976 to 2000 and include almost two 11 year cycles of solar activity. The dependence of the total number of patients having by influenza on the sunspot number for each year has revealed that the minimum number of influenza cases in the considered solar cycles almost precisely coincides with the minimum of sunspot numbers. However, the maximum of the influenza epidemic in the first considered cycle (year 1978) appears 1–2 years prior to the proper maximum of solar activity, while in the second considered cycle it happens approximately 3 years (year 1993) after achievement by the Sun of its next maximum activity. The period, duration, intensity and seasonal behaviour of the influenza epidemic, and the tendency of where it begins within a solar cycle, are studied. An analysis of the obtained results allowed us to conclude that the solar activity influences an influenza epidemic not directly but by means of geomagnetic activity. That is, the maximum distribution of the influenza epidemic corresponds to the maximum averaged number of magnetic storms within the 11 year cycle of solar activity. The seasonal dependence of the number of influenza patients reveals that the maximum in Baku and surrounding near regions reached in February and the minimum in August. The seasonal factor can move nearer or further from the peak of the epidemic. The results obtained are interpreted and compared with similar data. For a more detailed study of the influence of solar and geomagnetic activity on epidemic and pandemic influenza, a multifactorial investigation covering many solar 11 years cycles should be carried out.

5 SPACE WEATHER AND ITS POSSIBLE INFLUENCE ON THE FUNCTIONAL ACTIVITY OF THE HUMAN BRAIN AND DISEASES OF THE CARDIOVASCULAR SYSTEM

The influence of Space Weather on human health and life, that is on different biological and physiological systems, is important (Mizun and Mizun, 1984). It has been established that at least 75% of magnetic storms are followed by an average increase of 1.5 times in the number of hospitalized persons with cardiovascular and nervous diseases (myocardial infarction, brain vascular injury, suicide attempts, etc.). An investigation into the blood of the tested patients gave interesting results. The viscosity of blood during magnetic storms increased sharply (in some cases almost two fold), the erythrocytes became adhesive and the bloodstream was slowed down. Therefore magnetic storms increase the risk of development of cardiovascular diseases. Not only the central but also the vegetative nervous system of humans are very sensitive (responsive) to geomagnetic disturbances. It has been established that, during weak and moderate magnetic storms, the tone of the sympathetic part (section) of

the vegetative nervous system increases. Only in some cases and, most often, for men is an increase in (amplification of) the tone of the parasympathetic section of the vegetative nervous system observed.

On the basis of electro-encephalographic research it has been established that the nervous systems of patients respond to geomagnetic disturbances by a diphasic reaction. On days with a magnetic storm there is a generalized reduction in the indices of spatial synchronization of the electro-encephalogram (EEG) while on the next day, on the contrary, a generalized increase in contrast with the long-lived quiet period is recorded. It should be noted that only a few papers are dedicated to the analysis of the influence of space weather (especially geomagnetic disturbances) on the bioelectric activity of the human brain with the help of EEGs. Nevertheless, there is evidence that the nervous system is a target and/or messenger for fluctuations of a geomagnetic field that affect physiological states of humans and, in particular, functional states of the human brain. Therefore, the results of investigations on EEGs were conducted by us as one of the most objective methods for reflecting functional states of the human brain (Allahverdiyev, 1989; Allahverdiyev *et al.*, 2002). The Holter method was used in our experiments to record (with the help of a small portable magnetograph, which is a multichannel digital recorder intended for polygraph recording of physiological characteristics) the bioelectrical activity of the brain with subsequent processing of data with the help of special software. The Holter method allows us to conduct investigations of the free behaviour of the tested person on implementation of routine activity continuously for different functional and mental conditions during the total wakefulness–sleep diurnal cycle. Investigations were carried out for quiet and active awake healthy young persons in conditions with open and closed eyes, in the state of mental stress (strain) and process of hyperventilation, and taking into account solar and geomagnetic activity. The most effective parameters of geomagnetic activity for biomedical problems are the A_p and D_{st} indices, and we have used these in our research. The reaction of the vegetative nervous system to geomagnetic disturbances was also investigated by means of the measurement of the pulse (sphygmus) and the arterial pressure and tests on vegetative reactivity. Also electrocardiograms (ECGs) were recorded on relatively geomagnetically quiet and unfavourable (i.e. with magnetic storms) days. In general, contrary to records conducted on favourable days, the increase in excitation of cortical activity in the state of rest was marked during geomagnetically disturbed days. An increase in the manifestation of the high-frequency component clearly appeared on the spectrograms and frequency cartograms. At the same time, a decrease in the α-rhythm index, a delay in its frequency and, in some cases, a sharpening of the shape were pronounced. Meanwhile, the data of amplitude mapping showed an increase in the amplitude of the fast and slow waves.

To investigate the influence of solar and geomagnetic activity on diseases of cardiovascular system, the data collected from hospitals and clinics as well from emergency services were used. The Wolf sunspot number, the solar radio flux at the wavelength 10.7 cm, the geomagnetic A_p, D_{st} and K indices describing heliogeophysical conditions, and the direction of the interplanetary magnetic field were involved in the analyses. Correlation analysis and monitoring of the state of patients with cardiovascular pathology (hypertonia, atherosclerosis, ischaemia etc.) have revealed the aggravation of general symptoms of patients. Coronary circulation aggravation is discovered in ECG records (dispersion of the S–T segment, displaying or intensification of negative T, etc.). The number of diseases, especially such sensitive diseases as myocardial infarctions, stenocardia and hypertonia, increases not only during solar and geomagnetic storms but also 1–2 days prior to geomagnetic storms and *i.e.* days after these storms. The most marked symptoms were headache, flaccidity, irritability, stethalgia sleep disturbance, increase in systolic arterial pressure, etc. It is concluded that strong magnetic storms with a sudden beginning have less effect than streams 'background' storms with

a gradual beginning and storms caused by high-speed solar wind streams from coronal holes together with a southern direction of the interplanetary magnetic field. Prophylactic methods can be developed which include medical and psychological treatments: medication, 'active' relaxation, etc. Improved early warning of impending hazards from space, especially the prediction of magnetic storms is also needed. They are carried out, in particular, in domestic media, newspapers, television and radio broadcasts, as daily space weather forecasts, which are addressed mainly to public, medical and technical specialists.

6 SUMMARY

(i) Amplitude and phase scintillation effects can be a potential problem for certain trans-ionospheric communication and navigation systems, and satellite personal telephone communications as proposed by Motorola (the 'Iridium' system) and other commercial companies. Ionospheric scintillation can at times cause severe and long fades or rapid phase gradients that exceed a receiver's capability to lock on the signal. Application of scintillation models showed that in solar maximum years the ionospheric scintillation would have significant impacts on the GPS in particular applications and circumstances, especially at low latitudes. They are not significant for midlatitude microwave radio propagation. However, in general, an analysis of scintillation impacts is complicated and depends on a number of factors: the characteristics of the transmitter and receiver, the time in the solar cycle, the season, the location on the Earth, as well as what is occurring in the ionosphere. There is a great need not only to define but also to predict and assess scintillation impacts on the systems and to develop good solutions within space weather programmes.

(ii) Analysis of selected magnetic storms and relevant power cuts has revealed that power line disturbances mainly occur when the geomagnetic field displays sharp changes, which resulted in harmonic oscillations in the current and voltage, disrupting the signal waveforms recorded in GIC-saturated transformers. Transformers that are positioned at the corners of an electrical power system would suffer the worst damage from GICs. It is established that geomagnetic storm effects are not so strong for middle latitudes.

(iii) Investigations reveal that influenza epidemics usually begin 2–3 years before and/or 2–3 years after the sunspot cycle maximum. We suppose that solar activity affects influenza epidemics mainly through geomagnetic activity (magnetic storms).

(iv) The obtained results allowed us to conclude that disturbances of the geomagnetic field undoubtedly affects humans and in particular have an effect on the functional activity of the brain, changing its background state and disturbing the adequacy of reacting (response) during the transition from the test phase to 'normal' activity, especially upsetting the balance of synchronic and non-synchronic systems, and ergotrophic and trophotrophic episegmentary vegetative centers. These changes are most probably connected to the dysfunction of the central integrative brain apparatus accompanied by the strengthening of activating systems and by an insufficiency (deficit) of inhibiting mechanisms. Dysfunction affects, in turn, episegmentary vegetative centres, which are followed by the non-adequacy of vegetative securing of routine activity. Prophylactic methods can be developed which include medical and psychological treatments (warnings, medicine, 'active' relaxation, etc.).

(v) Correlation analysis and monitoring of state of patients with cardiovascular pathology have revealed aggravation of the general symptoms of patients and coronary circulation. Myocardial infarctions, stenocardia and hypertonia increase not only during solar and

geomagnetic storms but also 1–2 days prior to geomagnetic storms and 1–2 days after these storms. Detailed analyses allowed to conclude that relatively weak "background" storms with a gradual beginning have more influence than strong magnetic storms with a sudden beginning.

(vi) A study of solar geomagnetic activity effects has a practical importance for human health. The study of the 11 year variability of the geomagnetic activity shows peaks shortly before and about 2–3 years after sunspot maximum. Therefore the next few years 2003–2004 will provide another good chance to study this influence deeply. Improved early warning of impending hazards from space is also needed.

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