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SPACE WEATHER EFFECTS STUDIES IN AZERBAIJAN: POTENTIAL IMPACTS ON GEOSPHERE, BIOSPHERE AND PERIODIC COMETS

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Abstract. *For getting more and better knowledge about the physical links between major space weather sources (solar, geomagnetic and cosmic ray activities) and short- and long-term effects on technical-engineering systems and biosphere, particularly, human life and health state in middle latitudes, we are conducting complex (theoretical, experimental and statistical) space weather studies in the Azerbaijan National Academy of Sciences. Part of main and recently obtained results of these collaborative investigations of potential space weather effects on functioning of power supply systems, sudden cardiac death mortality as well as an influence of changes of heliogeophysical conditions on dynamics of traffic accidents is briefly provided in this review paper. An influence of solar activity on changes of brightness curves of periodic comets 29P/Schwassmann-Wachmann and 1P/Halley is investigated on the basis of data with about 1300 and 5900 estimations of brightness and using improved by authors calculations for visual magnitude of comets.*

1. Introduction

According to the US National Space Weather Programme (1995), *space weather* refers to the "conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health". *Solar* (SA), *geomagnetic* (GMA) and *cosmic ray* (CRA) *activities*, as major constituents of *space weather*, can impact many different sectors that affect our daily life on the Earth - navigation, communications, GPS and satellites, pipelines, electric power systems as well as human health in space and in the Earth (Jansen et al, 2000; Daglis, 2001; Breus and Rapoport, 2003; Palmer et al, 2006). Technical systems are becoming more sensitive to the space environment and will continue so in the future due to developments in technology such as equipping with electronics, interconnected-nature and miniaturization.

Knowledge about the relationship between space weather induced effects and geosphere, particularly, the biosphere and the human health state would allow to get better prepared beforehand for any future space weather event and its deleterious impacts anywhere (Jansen et al, 2000), in any geomagnetic latitudes. Unfortunately, limited comparison of results of investigations on possible effects to technologies and humans from solar and geomagnetic activity exists between studies conducted in high, middle and low latitudes.

The importance of the discipline *space weather* (Bothmer and Daglis, 2007) is not only for the future of manned missions in space, but also for the present situation of life on Earth. For a clear understanding of solar, geomagnetic and cosmic ray activities' potential effects on technological, biological and ecological systems, particularly in middle latitudes, we are conducting complex investigations on these problems in the Azerbaijan National Academy of Sciences (Babayev, 2003, 2006a, 2006b). Alongside statistical investigations on the basis of astrophysical, technical and medical-biological data, there are conducted daily medical-physiological experiments in the Laboratory of Heliobiology (founders: Shamakhy Astrophysical Observatory and Medical Center "INAM" in Baku) as well as theoretical studies on the magnetic field in the solar wind, solar activity influence on comets, scintillation of microwave radio-signals, so on.

Some recently obtained and selected results of the multidisciplinary and collaborative studies of space weather impacts on above-mentioned systems are briefly described in this paper. Paper includes results of: joint investigations (Ukraine) of space weather effects on electric power distribution and supply systems located in middle latitudes; collaborative studies (Israel) for revealing an influence of the changes in solar, geomagnetic and cosmic ray activities on the sudden cardiac death (SCD) mortality; collaborative studies (Russia) of influence of changes of heliogeophysical conditions on dynamics of the traffic accidents and investigations of solar activity influence on brightness changes of the selected periodical comets.

2. Space weather impacts on electric power supply systems in middle latitudes

Space weather events affect also the power generation and supply network constructed for domestic and industrial use (Kappenman, 2003). Possible relationship between space weather effects (geomagnetic and

solar disturbances) and electric power supply system behavior in ascending, maximum and descending phases of solar cycle 23 is investigated on the basis of daily data for power system behavior and failures in 1994-2006 (data from "Azerenerji" Joint Stock Company) in whole Azerbaijan and daily continuous digital/graphical data in 2002-2006 (data from "Barmek-Azerbaijan" Electricity Network Ltd, currently: "BakiElektrikShebeke") in grand Baku area (including the Absheron Peninsula). Used methodic and some relevant details of study could be found in (Kuznetsov et al, 2006; Babayev et al., 2006). Spectral (Fourier), correlation and cross-correlation analyses were applied (software STATISTICA, ver.6, 2001; SPSS, ver.12, 2003). We have considered whole data (so called "non-cleaned") and those of separated as total failures, as well as data with established technical-physical reasons and the rest part (thought affected by space weather and other events). Results and figures are not described in this paper in details because of limitation of paper volume, but some major results are provided below.

Our studies have revealed that:

- number of serious power breakdowns (which can not be explained only with the reason of technical-physical character), sudden power cuts and power line disturbances are significantly increased only during days with severe geomagnetic storms when the geomagnetic field displayed sharp changes (like in October-November 2003 solar extreme events);
- there were registered increased (comparative to relatively quiet days with "usual" technical problems) system failures such as differential phase protection, earth protection failure, sudden relay operations (tripping), voltage drops, saturation of power transformers, reactive power consumption, harmonics, stray flux, overheating, black-out during stormy days;
- those transformers, which are positioned at the corners (or at turning points) of an electrical power distribution system (power lines), suffer more damage from major geomagnetic storm effects;
- the direction of power lines is found to be also significant; the lines in the East-West direction are more influenced than ones in the North-South direction: in our opinion, it could be due to the fact that the induced electric field goes mainly in the East-West direction. Also, long transmission lines carry larger geomagnetically-induced-currents and a high earth resistivity makes the geomagnetically induced geo-electric field values larger;
- the most vulnerable areas from the point of view of supply system and transformer failures are the Absheron Peninsula with capital city Baku having several millions of inhabitants, and coastally located "sea-land boundary" areas. Probably, the Caspian Sea, as oceans, can conduct electricity easily and can carry large electric currents. When these currents reach shore in the Absheron Peninsula, particularly when the crust is nonconductive, voltages can jump into wires and earthing points with potentials measuring hundreds of Volts;

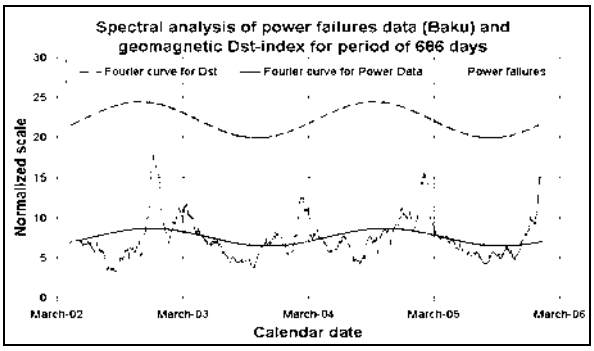

Fig.1. *Spectral analyses of power supply system failures and Dst index for period of 686 days.*

- alongside with evident rise of power failures during days with increased geomagnetic activity and their dependence on geophysical and technical parameters, there were found some periodicities. After "cleaning" (as much as possible) the available data from such subjective factors as seasonal and societal-economical influences, pure technical kind of effects, etc., the spectral (Fourier) analysis revealed in the remained data quasi-annual (343 days), quasi-biannual (686 days), quasi-weekly, 60 days, quasi-3 months and other significant periodicities. 343-days periodicity was dominant in cross-spectral analyses between failures and solar wind speed and sunspot number while 686-days periodicity was significant between failures and geomagnetic Dst and Ap-indices (Fig.1);
- data with failures, thought to be affected by changes in space weather, revealed quasi-annual periodicity as the major one. Quasi-1.3-year periodicity was found at cross-spectral analysis of failures with Dst-index. Quasi-biannual periodicity is well pronounced for data cleaned from technical reasons and thought to be affected by space weather disturbances; quasi-annual periodicity is clearly displayed in total failures data;
- improved by authors statistical analysis method was applied for studying comparative contribution of the considered agents of solar and geomagnetic activities in the so called "integrated space weather influence index"; significant contribution came from sunspot number, geomagnetic Dst index, solar radio flux at wavelength 10.7 cm, solar flare index, and geomagnetic Ap index, accordingly;
- in general, obtained results show significant interrelationship of power failures in middle latitude location with major geomagnetic and solar indices. Periodicities revealed in power failure data are well-known ones found in solar-terrestrial relations (Nayar, 2006);

- geomagnetic storm impacts in general are not so strong in middle latitudes (particularly, in Azerbaijan) and the effects on power consumers are small during weak and mild geomagnetic storms, while they become significant at days with severe geomagnetic storms. Analysis shows that significant impacts can be triggered at even lower storm levels and not only late at night and not only during the peak of sunspot cycle.

3. Space weather influence on the sudden cardiac death mortality

Sudden cardiac death is an unexpected death due to cardiac causes, an abrupt loss of heart function, occurring in a short time period (generally within one hour of symptom onset), in a person with known or unknown cardiac disease in whom no previously diagnosed fatal condition is apparent (Priori and Zipes, 2005). Approximately half of all cardiac deaths can be classified as SCDs. Several millions of people a year die because of SCD without being admitted to a hospital or an emergency room. The time and mode of death are unexpected. There are many endogenous factors that can place a person at risk of SCD, including: coronary artery disease, ventricular fibrillation, asystolia, pulseless electrical activity, smoking, etc. (Myerburg and Castellanos, 1997). SCD is influenced by seasonal and terrestrial weather changes, by variations in temperature, atmospheric pressure, so on. But, alongside with above-mentioned medical-biological, meteorological, social and other affecting factors, disturbances and variations in space weather (external physical activity) can also play a significant role in SCD mortality as a trigger factor (Stoupel et al, 2002, 2004, 2006).

Part of main results of collaborative studies (Prof. E. Stoupel and his group, Israel) for revealing possible influence of space weather changes on SCD in middle latitudes is described in this paper. This study was based on population-based daily medical data (36 months in 2003-2005) on deaths collected from all of Emergency and First Medical Aid Stations of grand Baku area according to WHO standards (ICD-10 code I46.1). More than 1,000,000 emergency calls containing cardiovascular-related deaths were analyzed. Out-of hospital SCD number that occurred in people was 788 (84.5% male). Age limitation was chosen between 25 and 80. Spectral (Fourier), correlation and cross-correlation analyses were applied to the considered data. Data corresponds to the period of economical and societal stability in the country and to descending phase of the 11-year solar activity cycle 23 and is therefore is quite interesting.

Daily GMA (quiet, unsettled, active, minor storm levels) - SCD distribution was 0.78, 0.66, 0.64 and 0.92; women were less affected by high GMA than men. The daily CRA (neutron activity) was 8475.35 $\pm$ 339.7 for the whole 3-year period, 8538.08 $\pm$ 322.5 in 523 days (Moscow data) with SCD (probability p=0.0003). The daily number of SCD was between 1 and 5. At days with SCDs between 4 and 5 (n=16) the CRA was 8657.5 $\pm$ 189 (compared with all 1096 days, p= 0.00018, with 523 days with SCD (from 1 to 5) – p= 0.016).

Comparison of the monthly SCD data revealed a significant and inverse correlation with SA indices (Pearson coefficient r = - 0.625 ÷ - 0 .76, p< 0.0001) and with GMA indices (r = - 0.43 ÷ -0.47, p= 0.007 ÷ 0.0084). A positive correlation was found for year of study and CRA (neutron activity) (r = 0.511, p= 0.0014).

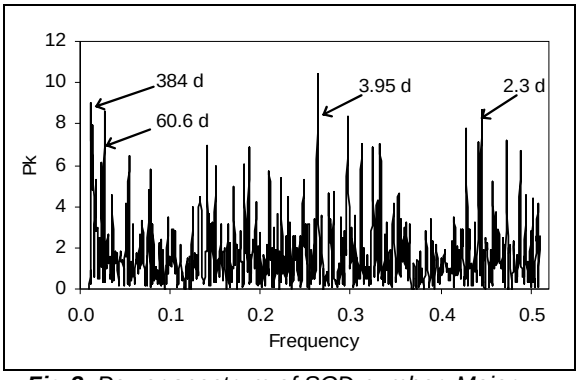

Fig 2*. Power spectrum of SCD number. Major periodicities are shown on curves.*

The conducted study on revealing possible influence of space weather changes on SCD resulted in the following conclusions:

- spectral analysis of the “cleaned” data has revealed certain periodicities (Fig.2) in SCD mortality data (with dominant period of 384 days or 1.05 year) which are approximately equal and/or close to periodicities well displayed in changes of heliogeophysical parameters; for example, 1.03 year periodicity was found in the lower frequency part of the power spectrum of variations of the mean magnetic field of the Sun for 1968-2000 (Kotov et al, 2002);
- monthly changes of ratio of SCD numbers “male/female” show minimums every 3 months with deeper minimum in October and around;
- study of SCD for different ages of victims distributed on months of year did not show significant changes. There are slight differences in June and April, shifted a little from the maximum around the age 50 towards younger ages;
- the timing of SCD shows significant relationship to space weather (physical) activity parameters;
- the number of SCD is rising on the highest and lowest daily levels of GMA. The relatively rare GMA storms concentrate most of SCD at days of lowest GMA;
- days with SCD are accompanied by higher CRA (neutron activity on the Earth’s surface) and it is additionally increased at days with multiple SCD. These results are in agreement with observations in some other parts of the world (Stoupel et al, 2004);
- monthly number of SCD was related to CRA and inversely related to SA and GMA;

- gender differences in SCD links with GMA were found: men were more sensitive and apparently affected more;
- cosmic ray activity could be considered as one of the regulating factors in human homeostasis (Stoupel et al, 2004, 2006).

4. Changes of heliogeophysical conditions and dynamics of traffic accidents

There are numerous indications that solar activity and solar activity variability-driven time variations of the geomagnetic field can be hazardous in relation to human health state and safety. Some evidence has been reported on the association between geomagnetic disturbances and increases in work and traffic accidents (Ptitsyna et al., 1998 and references therein). These studies were based on the hypothesis that a significant part of traffic accidents could be caused by the incorrect or retarded reaction of drivers to the traffic circumstances, the capability to react correctly being influenced by the environmental magnetic and electric fields.

Reiter (1955) found that work and traffic accidents in Germany were associated with disturbances in atmospheric electricity and in the geomagnetic field (defined by sudden perturbations in radio-wave propagation). On the basis of 25 reaction tests, it was found also that the human reaction time, during these disturbed periods, was considerably retarded. Retarded reaction in connection with naturally occurred magnetic field disturbances was observed also by Konig and Ankermuller (1982).

On the basis of huge statistical data on several millions medical events in Moscow and in St.Petersburg there were found an sufficient influence of geomagnetic storms accompanied with Cosmic Ray (CR) Forbush-decreases on the frequency of myocardial infarctions, brain strokes and car accident road traumas (Villoresi et al., 1994). The most remarkable and statistically significant effects have been observed during days of geomagnetic perturbations defined by the days of the declining phase of Forbush decreases in CR intensity. During these days the average numbers of traffic accidents increase by (17.4±3.1)% (Dorman, 2005). Some studies show correlations between high SA and GMA and increased number of traffic accidents (Stoupel et al., 2004).

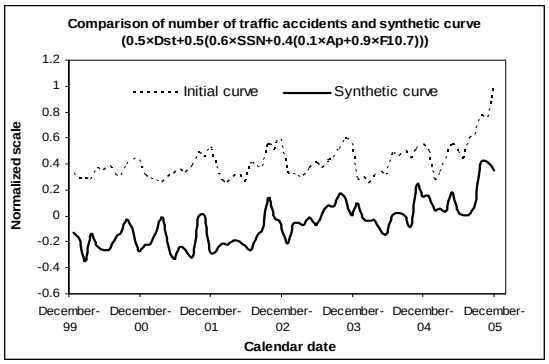

Fig. 3.*Traffic accidents and synthetic curve.*

We have considered possible influence of changes of heliogeophysical conditions on dynamics of traffic accidents in middle latitudes. Data (2000-2005), taken from Baku city traffic police department, contain detailed information about accidents, deaths and injuries. Spectral, correlation and cross-correlation analysis was applied. Results of study are briefly provided below:

- improved statistical analyses method was applied for studying comparative contribution of solar and geomagnetic activities agents in the so called "integrated space weather influence index" and for calculating synthetic spectrum taking into account this influence (Fig.3). Significant contribution came from geomagnetic Dst index and partly from sunspot number;
- correlation analyses of accidents showed high correlation (Pearson correlation coefficient: r=0.38 with probability p=0.001) with Cosmic Ray Activity (neutron data; imp/min), inverse correlation with SSN and non-significant correlation with geomagnetic indices describing gradual changes of geomagnetic field;
- there were revealed some major and well-known (in solar-terrestrial relations) (Nayar, 2006) periodicities in the dynamics of traffic accidents: 13.6, 11.33, 6.18, 5.67, 2.43, 4.53, 4.0 months and others;
- it is concluded that impulsive geomagnetic events significantly affects the number of traffic accidents more than background geomagnetic activity.

5. Solar activity influence on the brightness changes of periodic comets

Fundamental goals of cometary investigations are to understand the origin and nature of cometary nuclei and tail, their physical and chemical composition. Of particular interest are investigations of solar activity influence on comets, their formation, brightness, outburst, etc. Many papers are devoted to study of this problem. Andrienko and Vashchenko (1981) in their monograph summarized results of studies on relationship between solar corpuscular radiation and brightness outburst of comets and different mechanisms. On the basis of an analysis of a catalog of flares of cometary brightness of 29P/Schwassmann-Wachmann it is shown that cometary flare activity depends on the phase of the 11-year solar activity cycle. Studies showed that the comet outburst activity dependence on the heliocentric distance is in good accordance with the behavior of the solar wind velocity waves. Studies of the light curves showed that integral brightness of comet Halley (1986 III) correlates with the changes in solar activity and solar wind velocity (Ptitsyna et al., 1987; Churyumov and Filonenko, 1991).

In this paper we provide results of study of "solar activity - comet's brightness variations" relationships for two well-known periodic comets – 29P/Schwassmann-Wachmann (nearly circular orbit just outside that of

Jupiter, orbital eccentricity: e=0.044, perihelion distance: 5.722 AU, orbital period: 14.9 years) and 1P/Halley (retrograde orbit, inclined about 18^0 to the ecliptic, orbital eccentricity: e=0.967, perihelion distance: 0.587 AU, orbital period: 76.0 years). 5863 visual magnitudes of comet 1P (time period 02.12.1981 - 03.01.1989) and 1275 visual magnitudes of comet 29P (25.11.1976 - 08.11.2005) within solar cycles 21, 22 and 23 were investigated.

Spectral (Fourier), correlation and cross-correlation analyses were performed with the help of software STATISTICA, ver.6 (2001) and SPSS, ver.12 (2003).

Visual magnitude of comet was calculated on base of modified and improved (Guliyev, 2007) Orlov's formula (Orlov, 1958) taking into account an influence of apertures of telescopes:

$$m_{\Delta} = H_1 + y_1 \lg r + k_1\psi + hD + \Theta t ,$$

where H_1 and y_1 are photometric parameters in different scales, r is the heliocentric distance of comet, ψ is the elongation angle, k_1 and h are the relevant coefficients, t is the time past from the initial moment (in years; in our case, since 1976), θ denotes losses of comet brightness during a year, D is the telescope's aperture. This formula, containing aperture, reduces additionally residual dispersion to minimum as much as possible (i.e., 15% for comet 1P), which is one of important tasks of cometary investigations. It was possible as used in this paper formula contained a maximum quantity of parameters reflecting influence of different factors, such as helio- and geo-centric distances, phase angle and elongation of comet at the moment of observation, the aperture of the used telescope, etc.

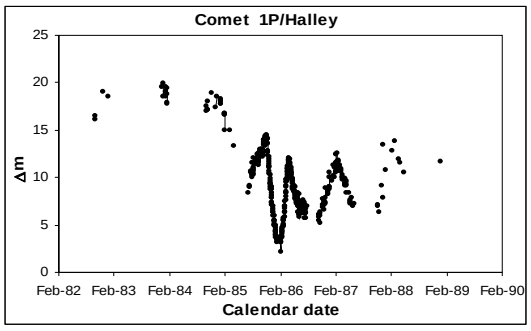

Fig.4. *Changes of brightness of comet 1P/Halley.*

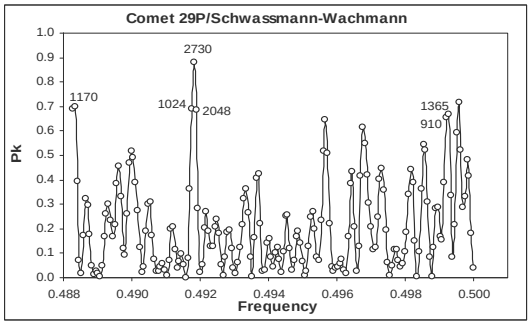

Fig.5. *Power spectrum with periodicities (shown on curves, in days) found in changes of brightness of comet 29P/Schwassmann-*

Brightness curve of comet 29P is displayed in Fig.4. In this paper diversions of visual magnitude (brightness) of 1P/H and 29P/S-W with the help of improved formulas were studied and compared with solar activity agents. Applied spectral analysis and improved method of analysis have revealed certain major periodicities in the brightness changes (we will call them major "modes"; synthetic curve constructed as a sum of these modes closely fits the initial brightness curve): 7.09, 3.54, 1.77, 1.18, 1.01 years for 1P/H and 7.48, 5.61, 4.99, 4.49, 2.04 years for 29P/S-W. Revealed periodicities (in days) are displayed in the power spectrum of 29P/S-W (Fig.5).

There are some close periodicities found in brightness changes of 1P/H and 29P/S-W. As considered time periods for comets have different lengths one can not expect exact coinciding of these revealed periodicities.

Comet 29P/S-W showed a steady 7.48 year while 1P/H displayed 7.09 year periodicity in brightness changes and in all of considered solar activity parameters. On other hand, quasi-biannual periodicity was dominant one for 1P/H and sunspot number (SSN), solar radio flux F10.7 and solar wind (corpuscular mechanism). Spectrum of interplanetary magnetic field's (IMF) By component shows 7-year periodicity as one of main ones alongside with 27 days recurrent, 16 year, 1 and 1.3 year activities (Nayar, 2006). 2.1, 3, 4, 5.5, 7.2 year periodicities are considered to be one of the important rhythms in solar activity. Periodicity of about 1.7 year has been identified in solar wind speed, North-South component of IMF and geomagnetic activity (Nayar, 2006).

Obtained results show that interrelations between solar activity and changes of brightness of studied comets are significant. The following conclusions are made on the base of conducted studies:

- corrections taking into account an influence of the aperture of telescope on comet brightness makes possible to reduce residual dispersion which in turn improves the results significantly;
- spectral analyses which were carried out for both variations in solar activity (different mechanisms) and for changes of brightness of the considered comets showed a presence of similar changes in both cases for the same considered time period;
- solar activity influence analysis showed very close values of periods in brightness changes for both considered comets (for example, quasi-7-year periodicity);
- some well-known periodicities in solar activity variations were revealed in periodical changes of brightness of considered comets;
- solar wind (corpuscular mechanism) influence could be considered as one of major mechanisms in the explaining of brightness changes of comets.

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