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Cosmic Ray Forbush-Decreases as Indicators of Space Dangerous Phenomena and Possible Use of Cosmic Ray Data for their Prediction

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Abstract

We consider the influence of space phenomena, as strong interplanetary shock waves causing great cosmic ray Forbush-decreases, on satellite electronics, as well as on people health and technology at ground level. The hazardous potential of great magnetic storms accompanied by cosmic ray Forbush-effects was studied by a number of authors (see review in Ptitsyna et al. 1998). The prediction of this dangerous phenomenon can be done by using cosmic ray data on pre-increase and pre-decrease effects and on the change of 3-D cosmic ray anisotropy. We show that this prediction may be done accurately in the frame of an International Cosmic Ray Service (ICRS) (Dorman et al. 1993). For forecasting dangerous Forbush-decreases it will be necessary to analyze cosmic ray one-hourly data in real time.

1 Introduction:

There are numerous indications that natural, solar variability-driven time variations of the Earth's magnetic field can be hazardous in relation to health and safety. There are two lines of their possible influence: effects on physical systems and on human beings as biological systems. High frequency radio communications are disrupted, electric power distribution grids are blacked out when geomagnetically induced currents cause safety devices to trip, and atmospheric warming causes increased drag on satellites. An example of a major disruption on high technology operations by magnetic variations of large extent occurred in March 1989, when an intense geomagnetic storm upset communication systems, orbiting satellites, and electric power systems around the world. Several large power transformers also failed in Canada and United States, and there were hundreds of misoperations of relays and protective systems (Kappenman 1990; Hruska & Shea 1993). Some evidence has been also reported on the association between geomagnetic disturbances and increases in work and traffic accidents (Ptitsyna et al. 1998 and refs. 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. The analysis of accidents caused by human factors in the biggest atomic station of former USSR, "Kurskaya", during 1985-1989, showed that ~70% of these accidents happened in the days of geomagnetic storms. In Reiter (1954, 1955) it was found that work and traffic accidents in Germany were associated with disturbances in atmospheric electricity and in 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 Koenig & Ankermueller (1982). Moreover, a number of investigations showed significant correlation between the incidence of clinically important pathologies and strong geomagnetic field variations. The most significant results have been those on cardiovascular and nervous

system diseases, showing some association with geomagnetic activity; a number of laboratory results on correlation between human blood system and solar and geomagnetic activity supported these findings (Ptitsyna et al. 1998 and refs. therein). Recently, the monitoring of cardiovascular function among cosmonauts of "MIR" space station revealed a reduction of heart rate variability during geomagnetic storms (Baevsky et al. 1996); the reduction in heart rate variability has been associated with 550% increase in the risk of coronary artery diseases (Baevsky et al. 1997 and refs. therein). In present paper we discuss the possibility of forecasting by cosmic ray (CR) data hazardous geomagnetic field disturbances.

2 Forbush Decreases as Indicators of Magnetic Storms Hazardous for Health and Safety:

Earlier we found that among all characteristics of geomagnetic activity, Forbush decreases are better related to hazardous effects of solar variability-driven disturbances of the geomagnetic field (Ptitsyna et al. 1998). Figure 1 shows the correlation between cardiovascular diseases, car accidents and different characteristics of geomagnetic activity (planetary index Aa, major geomagnetic storms MGS, sudden commencement of geomagnetic storm SSC, occurrence of downward vertical component of the interplanetary magnetic field B_z and also decreasing phase of Forbush decreases (FD)). 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, infarctions, and brain strokes increase by (17.4±3.1)%, (10.5±1.2)% and (7.0±1.7)% respectively.

In Figure 2 we show the effect on pathology rates during the time development of FD. All FD have been divided into two groups, according to the time duration T of the FD decreasing phase. Then, the average incidence of infarctions and traffic accidents was computed beginning from one day before the FD-onset till 5 days after. For the first group (T≤1 day) the average daily incidence of infarctions and traffic incidence increases only in the first day of FD; no effect is observed during the recovery phase (that usually lasts for several days). Also for the second group (1 day<T≤2 days) the increase in incidence rates is observed only during the 2-day period of the decreasing phase of FD. Thus, FD events can be used as reliable indicators of health- and safety-related harmful geomagnetic storms.

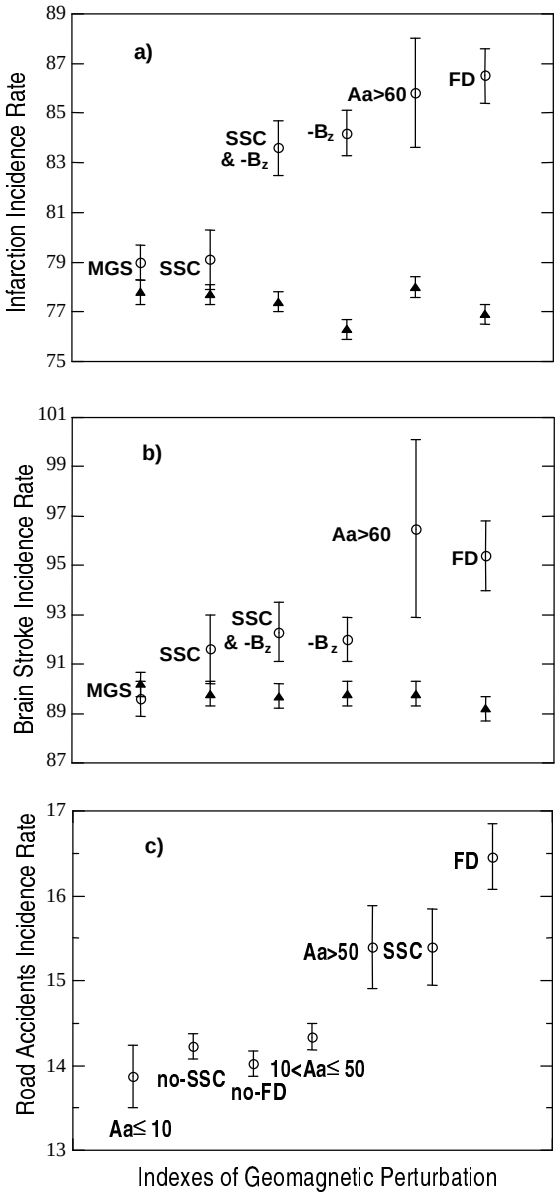

Figure 1: Myocardial infarction (a), brain stroke (b) and road accident (c) incidence during geomagnetically quiet and perturbed days according to different indexes of activity.

3 International Cosmic Ray Service (ICRS) as a Tool for Forecasting Health- and Safety-Related Hazardous Geomagnetic Storms:

For a practical realization of forecasting hazardous geomagnetic storms by means of FD indicators, it will be necessary to get data from most CR stations in real-time (now the data are available only after some months). Therefore, it is necessary to found a special Real-Time Cosmic Ray World Data Center to transform the cosmic ray station network in a real-time International Cosmic Ray Service (ICRS) (Dorman et al. 1993). We present here basic ideas of the organization of such real-time data collection and processing, for providing a reliable forecast-service of FD and related dangerous disturbances of geomagnetic field.

The main features observed in CR intensity before the beginning of FD that can be used for FD forecasting are the following:

(i) **CR pre-increase (**Dorman 1963). The discovery of this effect stimulated to develop theories (Dorman 1959) and further analyses (Dorman 1995, Belov et al. 1995) showing that this effect is related to particle interaction and acceleration by interplanetary shock waves;

(ii) **CR pre-decrease** (McCracken and Parsons 1958, Fenton et al 1959). This effect was analyzed recently both theoretically (Dorman 1995) and experimentally on the basis of the network of CR stations (Belov et al. 1995). The pre-decrease effect can be due to a magnetic connection of the Earth with regions (moving from the Sun) with reduced CR density; this lower density can be observed at the Earth along the actual direction of MF lines (Nagashima et al. 1990, Bavassano et al. 1994);

(iii) **CR fluctuations.** Many authors found some peculiarities in behavior of CR fluctuations before FD: changes in frequency spectrum; appearance of peaks in spectrum at some frequencies; variations in some special parameter introduced for characterizing the variability of fluctuations. Though the obtained results are often contradictory (Dorman et al. 1995), sometimes CR fluctuations appear as reliable phenomena for FD prediction, as expected from additional Alfven turbulence produced by kinetic

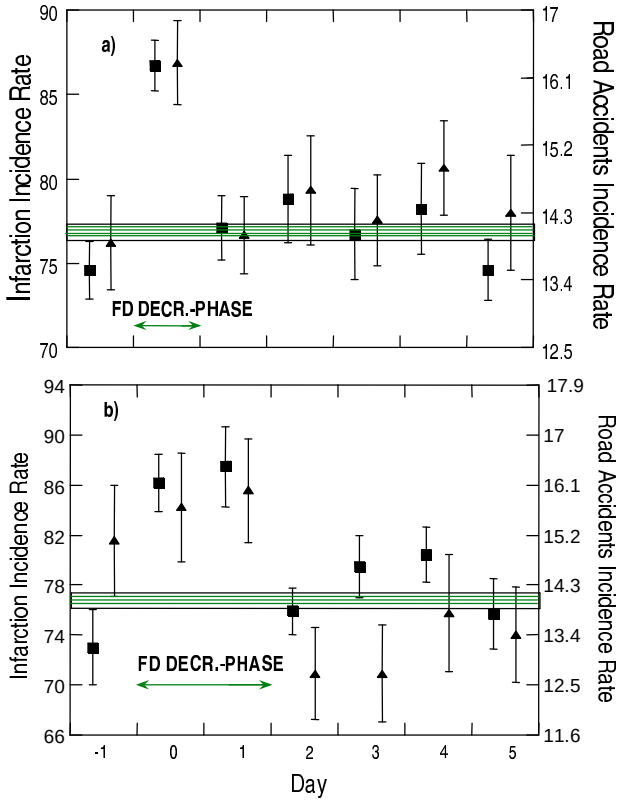

Figure 2: Infarction (■) and road accidents (▲) incidence during the time development of FD. (a): decrease phase T≤1 day; (b): 1 day<T≤2 day

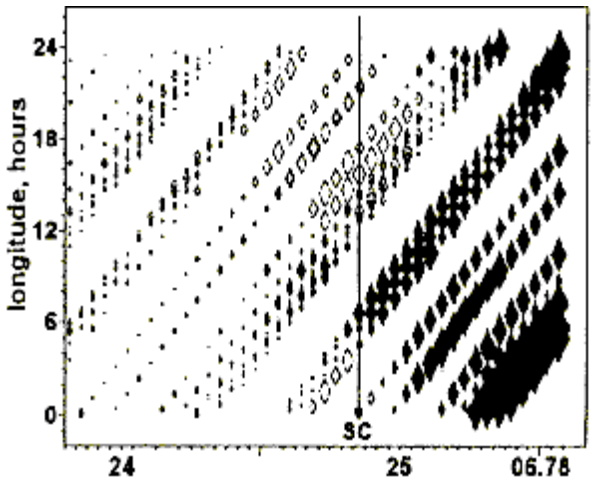

Figure 3: Galactic cosmic ray pre-decreases (dark rhombs) and pre-increases (light rhombs) for the June, 1978 event.

stream instability of low-energy particles accelerated by shock waves (Berezhko et al. 1997);

(iv) **Change in 3-D anisotropy.** The CR longitudinal dependence changes abruptly in directions close to usual directions of interplanetary magnetic field and depends on the character and source of the disturbance. These effects, appearing much before Forbush decreases (up to 1 day) may be considered as predictors of FD. Estimation of CR anisotropy vector may be done by the global survey method described in Belov et al. (1997). In Figure 3 we show an example of such estimation done for the 25.05.78 event represented as a longitude-time distribution. The dark rhombs mark the CR intensity decrease, light ones - the increase. The size of rhombs indicates the magnitude of the effect. The vertical line marks the time of SSC. One can see that the increase, as well as the decrease, occurs some hours before the SSC.

The ICRS will be based on real-time collection and exchange by Internet of the data from all cosmic-ray stations of the network. Then, computerized data analysis and interpretation will be done on the basis of modern theories listed in (i-iv). It will be necessary to use also related spacecraft data in real time: cosmic ray variations in small and very small energy regions, interplanetary magnetic field and solar wind data. Neutron monitor stations of the network should have a counting rate of 250-300 Hz and a data collection time of 1 hour.

The organization of ICRS will provide necessary information to space agencies, health authorities, road police and other organizations to apply the appropriate preventive procedures.

References

Baevsky, R.M. et al. 1996, Proc MEFA Int Fair of Medical Technology & Pharmacy (Brno, Chec Republic)

Baevsky, R.M., Petrov, V.M., Cornelissen, G., Halberg, F., Orth-Gomer, K., Akerstedt, T., Otsuka, K., Breus, T., Siegelova, J., Dusek, J., & Fiser, B. 1997, Scripta Medica 70, 199

Bavassano, B. et al. 1994, J. Geophys Res. 99, 4227

Belov, A.V. et al. Proc. 24th ICRC (Rome, 1995) 4, 888

Belov, A.V., Eroshenko, E.A., & Yanke, V.G., Proc. 25th ICRC (Durban, 1997) 1, 437

Berezhko, E. B. et al. Proc. 20th ICRC (Moscow, 1987) 4, 99

Dorman, L. I., & Friedman G. I. Proc. MHD and Plasma Phys. (Riga, 1959) p. 77

Dorman, L. I. 1963 Geophys. and Astrophysical Aspects of Cosmic Rays, Amsterdam, North-Holland Publ.

Dorman, L.I., Iucci, N, & Villoresi, G. 1993, Astroph. and Space Sci. 208, 55

Dorman, L. I., Iucci, N, & Villoresi, G. Proc 24th ICRC (Rome, 1995) 4, 892

Dorman, L.I. et al. 1995, Nucl Phys B, Proc Suppl 39A, 136

Fenton, A. G. et al. 1959, Can. J. Phys. 37, 970

Hruska, J., & Shea, M.A. 1993, Adv. Space Res. 13, 451

Kappenman, J.G., & Albertson, V.D. 1990, IEEE Spectrum, March

Koenig, H., & Ankermueller, F. 1982, Naturwissenscahften 17, 47

McCracken, K., & Parsons, N. 1958, Phys. Rev. 112, 1798

Nagashima, K et al. 1990, Nuovo Cimento C 13, 551

Ptitsyna, N.G., Villoresi, G., Dorman, L., Iucci, N., & Tyasto, M. 1998, Physics Uspechi Nauk 41, 687

Reiter, R. 1954, Arch. Phys. Therap. 6, 210

Reiter, R. 1955, Phys. Blaetter 11, 453