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Cosmic rays as indicators of space weather influence on the incidence of myocardial infaction, brain stroke, car and train accidents

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Abstract. It was shown in our previous papers that CR Forbush-decreases could be considered as indicators of space phenomena influencing myocardial infarction, brain stroke, and car accident incidence. These effects, obtained by the use of daily data collected by police and ambulance organizations of Moscow and St. Petersburg, were bigger than statistical errors by 4-7 times. In the present research we use monthly data of myocardial infarction, brain stroke, and car accident incidence, as well as daily and monthly data of occurrences of two types of train accidents: (i) caused by man-related factors, and (ii) caused by technological factors, on Siberian Railways (Russia) for the period 1 January, 1986–30 November, 1993. The obtained results confirm the possible connection of space weather changes (controlled by short- and long-term variations in CR intensity and solar activity) on the analyzed medical and accident data.

1 Introduction

In the last decades many investigations have been carried out on the influence of "space weather " parameters through the action of natural geomagnetic field, upon the morbidity in different diseases, so-called "biogeomagnetics" (e.g. review Roederer, 1995; Ptitsyna et al., 1998 and refs. therein). The idea of geomagnetic variations having any effects on living systems is viewed with great skepticism by physicists because magnitudes involved are very small in comparison to local intracellular electric and magnetic fields (e.g. Adair, 1991; Bennet, 1994). However emerging bodies of empirical findings support the possibility that the association has a real biophysical basis. The most significant empirical results seem to be those on cardiovascular and on nervous system diseases. Laboratory results on sensitivity of human blood system to solar and geomagnetic activity support these findings.

In the last decades some evidence has been accumulated also on the association between geomagnetic disturbances and increases in work and traffic accidents (Reiter, 1955; Srivastava and Sahena, 1980; Ptitsyna et al., 1996). 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.

One of the most important problems in biogeomagnetics is the definition of the characteristics of geomagnetic activity that are more related to health effects. Apart from usual geomagnetic indices some parameters of interplanetary medium perturbations could be used for characterizing the geomagnetic activity level and also short-term cosmic ray intensity variations, related to interplanetary disturbances, may provide alternative indications. In Villoresi et al. (1994a, b; 1998), Ptitsyna et al. (1995 1996), Dorman et al. (1999) it was shown that CR Forbush-decreases could be considered as sensitive indicators of association between geomagnetic field disturbances and such health parameters, as incidence of myocardial infarction, brain stroke, and also vehicular traffic accidents. 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.

In this paper we will widen this study by adding new data on railway malfunctions and accidents, and also by studying long-term effects.

2 Data and methods

In the present research we will use daily and monthly averaged data of malfunctions and accidents in Siberian Railways (Russia) for the period 1 January, 1986-30

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November, 1993. The data were divided on two types by Siberian Railway experts: the first related to technological factors (total number 4661), and the second related to personnel errors (man-related factors) (total number 2754). Monthly averaged data of myocardial infarction and brain stroke (Moscow, January 1979-December 1981) obtained from ambulance organizations (see Villoresi et al., 1994b) will be also used.

For studying possible long-term effects related to space weather we used data on Wolf number, neutron monitor cosmic ray intensity, tilt angle of interplanetary plasma sheet and geomagnetic index SSC (sudden commencement).

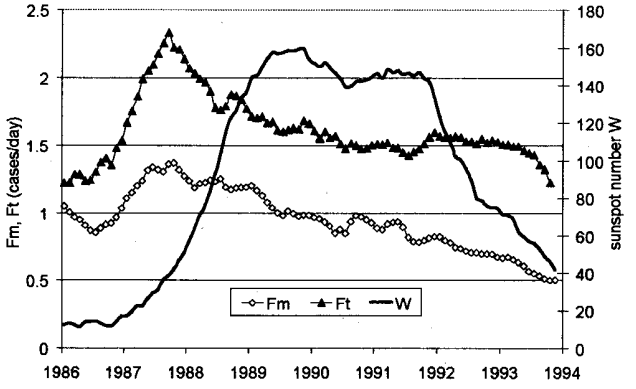

Figure 1. Daily occurrences of train malfunctions (F_m, man-related; F_t, technological) and Wolf number W.

In Figure 1 we show train malfunctions in the Russian Siberian Railway (F_m is the 11-month moving average of the monthly daily frequency of man-related malfunctions and F_t is the same for technological malfunctions), and 11-month moving average of Wolf numbers. An increase in malfunctions and accidents is observed in the period 1986-1987 simultaneously with an increase in solar activity. However, at the same time the Russian "perestroika" introduced big stress factors, rapid changes and disorganization in almost all social and economical fields. For instance, traffic accidents data in St. Petersburg (1987-1989), used by Ptitsyna et al. (1995), cannot be included in the present analysis because they show an increase in this period due to the considerable increase in number of cars. To avoid this "perestroika effect" we excluded the years 1986-1987 from the analysis of long-term effects. We also tried to eliminate, at least partly, malfunctions caused by other social reasons common for both original data sets. For this purpose we correlated the original data sets; the obtained result is the following:

$$F_m = 0.6778F_t - 0.1424, \quad (1)$$

To diminish the contribution of social factors we assumed that they affect both types of malfunctions in the same way. The corrected data of man-related malfunctions will be:

$$F_m(corr) = F_m - (0.6778F_t - 0.1424). \quad (2)$$

In Figure 2 we show $F_m(corr)$ together with the neutron monitor cosmic ray intensity data at Climax.

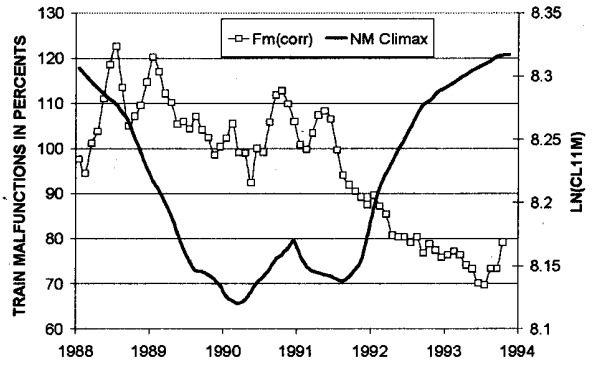

Figure 2. Time behavior of "corrected" man-related train malfunctions (in % of the average value of total period) and logarithm (LN) of Climax neutron monitor intensity.

For studying the possible association with short term perturbations in geomagnetic field (daily scale) we considered as magnetically perturbed days the first three days of the decrease phase of Forbush decreases (FD) in the cosmic ray intensity (daily amplitude >2.5% at high latitude neutron monitor station Mt. Washington). During the analyzed period such days were 141.

3 Results

3.1 Long-term effects

Table 1 presents results of correlation analysis done on three data sets of train malfunctions (technical, man-related

Table 1. Regression (b) and correlation (r) coefficients between cardiovascular pathologies, train accidents and space weather parameters.

Data		W	NM Climax	NM Rome	L	SSC
Myocard. Infarct. 1979-81	b	-0.013	-21.6	-61.7	-0.111	1.130
	r	-0.16	-0.65	-0.72	-0.69	0.54
Brain Stroke 1979-81	b	-0.031	-16.8	-46.7	-0.050	0.954
	r	-0.28	-0.64	-0.69	-0.39	0.58
F_t 1988-93	b		0.47	1.25	0.001	0.001
	r	0	0.20	0.25	0.06	0.02
F_m 1988-93	b	0.002	-0.625	-1.01	0.006	0.051
	r	0.43	-0.21	-0.16	0.39	0.28
$F_m(corr)$ 1988-93	b	0.0024	-0.922	-1.64	0.0060	0.050
	r	0.68	-0.49	-0.42	0.67	0.44

and man-related corrected for social factors), infarctions and brain strokes with different parameters of space weather: Wolf number (W), cosmic ray intensity as measured by Climax and Rome neutron monitors (NM), current sheet tilt angle (L) and storm sudden

commencement (SSC).

From Table 1 it is seen that there is good inverse correlation between number of infarctions and brain strokes and NM intensity, as it is also shown in Figure 3.

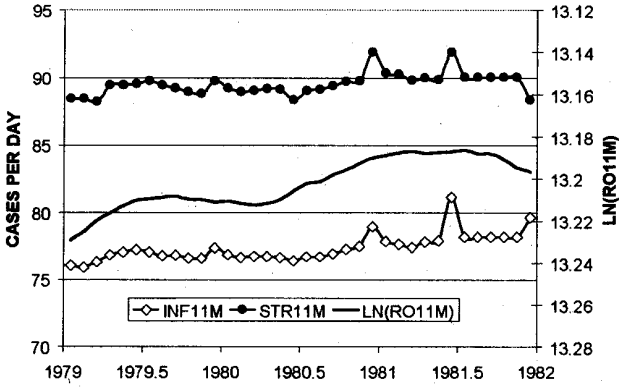

Figure 3. Time behavior of infarctions and brain stroke incidences together with cosmic ray NM intensity (note the inverse scale) at Rome for the period 1979-1981.

For the same data a good correlation is also observed with L and SSC, while there is no correlation with W. The lack of correlation with W indicates that in this short time period W and NM are not correlated, as it is shown in Figure 4 in which the correlation between the two data sets is r=+0.2.

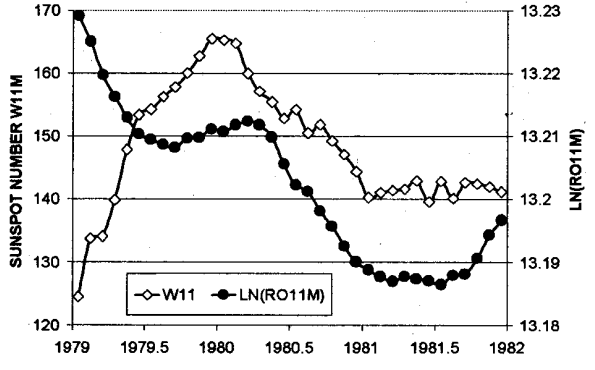

Figure 4. Time behavior of sunspot number W and cosmic ray NM intensity at Rome for the period 1979-1981.

As for train accidents, we can see that malfunctions of technological origin do not correlate with space weather parameters, as it could be expected, while malfunctions related to human factors show statistically significant correlation. Moreover, we can see that the best correlation with space weather parameters is demonstrated for the frequency of malfunctions corrected for social factors $F_m(corr)$, correlation coefficients being the highest for W and L.

Regression coefficients given in Table 1 allow estimating the expected effects. For instance, a 10% decrease in cosmic ray intensity as measured by Rome NM leads to increasing infarction incidence of about 8% (6.2 cases/day for Moscow data), brain stroke of about 5% (4.7 cases/day for Moscow data), and train accidents of about 5 cases/month in Siberian Railway.

3.2 Short-term effects

Average frequency of train malfunctions computed during magnetically quiet days (two days before the FD onset day) and disturbed days (FD onset day and two days after) are presented in Table 2.

Table 2. Train malfunctions average daily incidences from day –2 to day +2 relative to the FD onset time (day 0)

Day	-2	-1	0	+1	+2
F_m	0.98±0.17	0.96±0.17	1.11±0.18	1.26±0.18	1.15±0.16

The comparison of the average frequency of malfunctions between the first three days of FD (days 0, +1 and +2) and two days before FD (days -2 and -1) shows an increase of malfunctions of ~(20±10)% during FD days. This is in good agreement with Villoresi et al. (1994a, b; 1998), Ptitsyna et al. (1995, 1996) in which it was found that during FD days the average numbers of traffic accidents, infarctions, and brain strokes increased by (17.4±3.1)%, (10.5±1.2)% and (7.0±1.7)% respectively.

4 Conclusions

It is found that the main cardiovascular diseases, as myocardial infarction and brain strokes, as well as train malfunctions of man-related origin can be influenced by space weather parameters, both in short (during Forbush decrease events) and long-term scale (solar activity cycle).

These results on man-related train accidents give additional support to the idea that the capability of operators to react correctly to the environmental circumstances can be influenced by space weather parameters.

In short-time scale the cosmic ray intensity seems to be the best indicator of such correlation; this is true not only when the days of Forbush decrease occurrences are considered, but also when the correlation is done with the neutron monitor intensity. Also the current sheet tilt angle and the number of SSC give high levels of correlation.

Regarding long-term variations, Wolf number seems to be the best indicator of space weather influence, at least in relation to man-related train accidents, but also cosmic ray intensity, tilt angle, and SSC can be considered as reliable indicators.

In conclusion we can assert that our results (some of them obtained with high statistical power, other at the limits of statistics) indicate the possibility of some influence of space weather on the analyzed health and safety-related parameters. To draw more definite conclusions it is necessary to increase the statistics; i.e. to obtain results for several solar cycles. Anyway, the results obtained up to now suggest the necessity of forecasting the solar activity

and the related interplanetary perturbations, not only to protect technology and satellites, but also to bring benefits connected to health and safety on the Earth.

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