Possible Cosmic Ray Using for Forecasting of Major Geomagnetic Storms, Accompanied by Forbush-Effects

L.I. Dorman,[1,2] A. V. Belov,[2] E. A. Eroshenko,[2] L.A. Pustil'nik,[1] A. Sternlieb,[1] V.G. Yanke,[1] I.G. Zukerman[1]
(1) Israel Cosmic Ray & Space Weather Center and Emilio Serge' Observatory, affiliated to Tel Aviv University, Technion, and Israel Space Agency; P.O.Box 2217, Qazrin 12900, ISRAEL;
(2) Cosmic Ray Department of IZMIRAN, Russian Academy of Science, Troitsk 142092, Moscow region, RUSSIA

Abstract

We present developing of methods for forecasting on the basis of NM hourly on-line data geomagnetic storms accompanied by Forbush-effects. These geomagnetic storms are dangerous for technology (influence on power systems, on spacecraft operations, on HF radio-communications and others) and people health. We show that for especially dangerous geomagnetic storms can be used global-spectrographic method if on-line will be available 35–40 NM of world-wide net. In this case for each hour can be determined CR anisotropy vector, and the specifically behavior of this vector before SC of geomagnetic storms can be used as important factor for forecast. The second factor is specifically behavior of CR density for about 30–15 hours before SC (pre-increase effect, caused mainly by galactic CR particles acceleration during interaction with shock wave moved from the Sun). The third factor is effect of cosmic ray pre-decreasing, caused by magnetic connection of the Earth with the region behind the shock wave. We demonstrate developing methods on several examples of major geomagnetic storms. This research is partly supported by the EU INTAS grant 00-0810.

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 geomagnetic 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,

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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 [1]. Some evidence has been also reported on the association between geomagnetic disturbances and increases in work and traffic accidents ([2] and refs. therein). On the basis of statistical data on several millions medical events in Moscow and in St. Petersburg were found an sufficient influence of geomagnetic storms accompanied with CR Forbush-decreases on the frequency of myocardial infarcts, brain strokes and car accident road traumas [3,4]. 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 $(17.4 \pm 3.1)\%$, $(10.5 \pm 1.2)\%$ and $(7.0 \pm 1.7)\%$ respectively.

2. Cosmic Ray on-Line One-Hour Data Using for Forecasting of Dangerous Geomagnetic Storms Accompanied with Forbush-Decreases

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 main part of data are available only after about one month, only about 10 stations gave on-line data through theirs web-sites in INTERNET). Therefore, it is necessary to found a special Real-Time CR World Data Center to transform the cosmic ray station network in a real-time working International Cosmic Ray Service (ICRS) [5]. The main features observed in CR intensity variations before the beginning of great geomagnetic storms caused by interplanetary shock wave and accompanied with FD that can be used for forecasting are the following:

1. CR pre-increase. The discovery of this effect [6] stimulated to develop the mechanism of galactic CR interactions with interplanetary shock waves [7] and further analyses [8–11] showing that this effect is related to galactic CR acceleration by interplanetary shock waves and can be used for forecasting;

2. CR pre-decrease. This effect, discovered in [12] was analyzed recently both theoretically and experimentally on the basis of the network of CR stations [9–12]. 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 IMF lines [13,14];

3. 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 [9], sometimes CR fluctuations appear as reliable phenomena for FD prediction, as expected from additional Alfven turbulence produced by

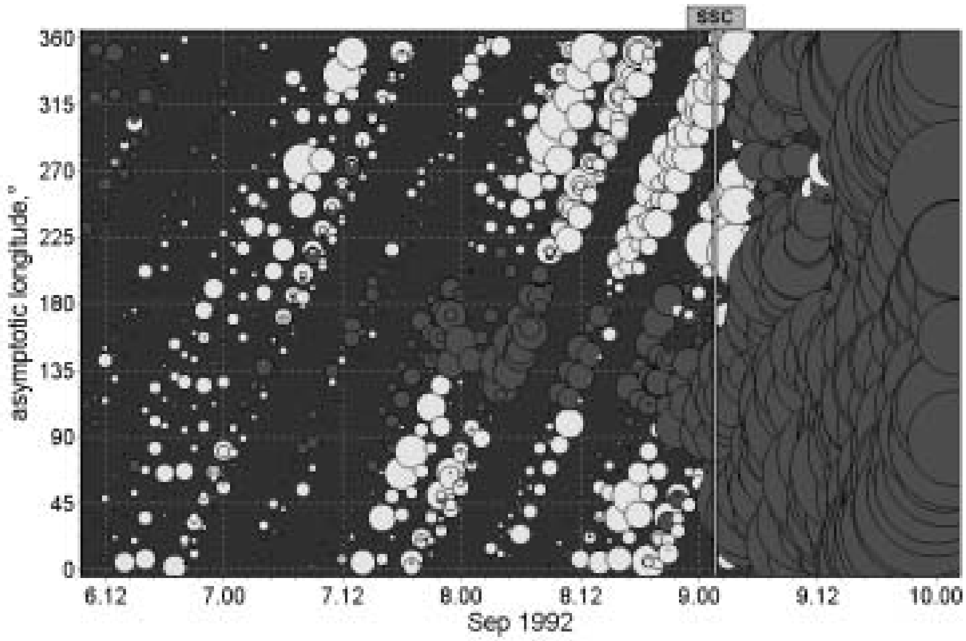

Fig. 1. Galactic CR intensity pre-increase (grey or yellow circles) and pre-decrease and Forbush — decrease (black or red circles) before and after the Sudden Storm Commencement (SSC) of great magnetic storm at 9-th September 1992. The bigger diameter of circle means bigger amplitude of CR intensity variation.

kinetic stream instability of low-energy particles accelerated by shock waves [15]; **4. Changes 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 [8–11]. 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 shortly described in [16], and in details in Chapter 3 of [17].

3. Examples of Cosmic Ray Precursory Effects and Discussion

In Fig. 1 is shown an example of CR precursory effects obtained by method of ring CR stations (see review in [17]).

From Fig. 1 can be seen that the pre-increase, as well as the pre-decrease, occurs 15–20 hours before the SSC of geomagnetic storm. In [18] we analyzed CR precursory effects for many magnetic storms accompanied with Forbush-decreases: for two geomagnetic storms in 1978 at 28 September (SSC at 21h UT) and 29 September (SSC at 3h UT) were observed clear changes of CR anisotropy, and a good pre-increase already before the first SSC, and before the second SSC a classical precursor with wide pre-increase and pre-decrease on the small pitch angles is also observed; for geomagnetic storm at 24 April 1979 (SSC at 23.58 UT) were observed the changes of anisotropy in the pitch angle — universal time distribution approximately 10 hours before the shock, and in the last several hours before SSC there was clear pre-decrease of CR intensity on the small pitch angles; for geomagnetic storm at 1 March 1982 (SSC at 11.38 UT) precursory effects (CR intensity pre-decrease and pre-increase) were observed about 5 hours before SSC, and so on. We confirm the result [19] that about 90% of major geomagnetic storms has clear precursor effects which can be used for forecasting (it is important, that the probability of exact forecasting by using CR data increases with increasing of the power of geomagnetic storm).

4. References

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