
Principles of Cosmic Ray using for Space Weather Monitoring and Forecasting

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Abstract

We describe here shortly the principles of cosmic ray (CR) using for space weather (SW) monitoring and forecasting (mostly for great radiation and magnetic storms). This research is partly supported by the EU INTAS Grant 00810.

1. Introduction

Cosmic rays (CR) are one of important objects of space weather (SW) because namely CR of galactic and solar origin determined radiation storms and radiation hazard for people and technology, computer and memory upsets and failures, solar cell damage, radio wave propagation disturbances, failures in communication and navigation systems. Beside this CR can be used as effective instrument for SW monitoring and forecasting dangerous phenomena. We will consider here two types of space dangerous phenomena: great FEP and big geomagnetic storms.

2. Great FEP Events in the Past and NOAA Radiation Storms Scale

NOAA SW Scale establishes 5 gradations of FEP events, what are called Solar Radiation Storms: from S1 (the lowest level, the flux about $10 \text{ protpns. cm}^{-2} \cdot \text{sec}^{-1}$ for protons with energy $> 10 \text{ MeV}$). up to S5 (the highest level of radiation, corresponded to the flux of solar protons with energy $> 10 \text{ MeV}$ about $10^5 \text{ protpns. cm}^{-2} \cdot \text{sec}^{-1}$). I have three comments to this Scale: 1) for satellite damage and influence on people health and technology is important the total fluency of FEP during the event (corresponding fluencies for S1–S5 Radiation Storms will be $\sim 10^6, 10^7, 10^8, 10^9, 10^{10} \text{ protpns/cm}^2$); 2) the level S5 is not maximal; the radiation hazard level can be much higher, but with much smaller probability than S5 (as it was shown recently in [1], the dependence of event probability from fluency F can be prolonged at least up to $F \approx 10^{12} \text{ protpns. cm}^{-2}$) — so we

Table 1. Extended part of NOAA SW Scale for Solar Radiation Storms

FEP events radiation hazard			Fluency $\geq 10\text{MeV}$ protons	Frequency
S7	Ultra extreme	<p>Biological: Lethal doze for astronauts, for passengers and crew on commercial jets; influence on people health and gene mutations on the ground</p> <p>Satellite operations: very big damages of satellites electronics and computers memory, damage to solar panels, loosing of many satellites</p> <p>Other systems: complete black-out of HF (high frequency) communications through polar and middle-latitude regions, big position errors make navigation operations extremely difficult.</p>	10^{12}	One in few thousand years
S6	Very extreme	<p>Biological: About lethal doze for astronauts, serious influence on passengers and crew health on commercial jets; possible influence on people health and genes mutations on the ground</p> <p>Satellite operations: a big damages of satellites electronics and computers memory, damage to solar panels, loosing of several satellites</p> <p>Other systems: complete blackout of HF communications through polar regions, some position errors make navigation operations very difficult.</p>	10^{11}	One in few hundred years

suppose to add to the NOAA Scale two new levels of radiation hazard S6 and S7 (see Table 1); 3) the expected frequencies of FEP events shown in the last column of NOAA Scale are averaged over solar cycle, but really these frequencies depend also from the level of solar activity — as it was shown in [2–4], they are much higher in periods of high solar activity than in periods of low solar activity.

3. Principles of FEP Radiation Hazard Forecasting

Now more than 10 neutron monitors in the World gave data in real-time in Internet, but only few — one minute data (namely these data are necessary to have on-line for FEP radiation hazard forecasting). In the Emilio Segre' Observatory (of Israel CR Center) on Mt Hermon works continuously on-line on the basis of real-time one minute NM data (of total neutron intensity and many different multiplicities) the programs “FEP Search-K min” (where $K = 1, 2, 3,$ and 5). The programs “FEP Search-K min” determine automatically the start of FEP event and send in Internet corresponding Alerts on FEP start (in [5] was shown that the probability of false Alert and probability of missing Alert are negligible). The first, what is necessary to do that many CR Observatories will give in Internet one minute data in real time scale and use the automatically worked programs “FEP Search-K min”. If any of CR Observatories will send Alert on the start of FEP, immediately begin to work on-line program “FEP-Collecting” for continuously collecting all available data on the FEP event from CR Observatories and satellites. The programs “FEP Research” then analyze the collecting data.

The real-time research method consists from:

- 1) determination of the **energy spectrum above the atmosphere** from the start of the FEP-event by using coupling functions method (programs “FEP Research-Spectrum”);
- 2) determination of the **anisotropy and its energy dependence** (program “FEP Research-Anisotropy”);
- 3) determination of the **propagation parameters, time of FEP ejection** into the solar wind and **total source flux of FEP** as a function of energy (programs “FEP Research-Propagation,” “FEP Research-Time Ejection,” “FEP Research-Source”).

The next, **final step**: on the basis of obtained results to made on-line automatically **forecasting** of expected time variations of fluxes, FEP spectrum, expected fluency and radiation hazard **in space**, in the **magnetosphere** and in the **atmosphere** (programs “FEP-Forecast in Space,” “FEP-Forecast in Magnetosphere,” “FEP-Forecast in Atmosphere”). If the forecast fluxes and fluency are expected to be dangerous, corresponding Alerts will be sending.

4. CR Using for Forecasting of Dangerous Geomagnetic Storms Accompanied with Forbush-Decreases

The following main features observed in CR variations before the beginning of great geomagnetic storms accompanied with Forbush-decreases can be used for forecasting ([6–8]): 1. **CR pre-increase**, 2. **CR pre-decrease**, 3. **CR fluctuations**, and 4. **Change in 3-D anisotropy**. As it was shown in [6], 89% of “major” geomagnetic storms have clear CR precursor effects which can be used

for forecasting.

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6. References

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