Cosmic Rays and Space Weather Effects: Methods of Forecasting

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Abstract. This paper consists of 5 parts: 1. Cosmic rays (CR) and space weather influence on global climate change; 2. Global natural disaster from great magnetic storms connected with big CR Forbush-decreases and their assessment by using world-wide network of CR stations; 3. Global natural disaster from great intense radiation hazards for astronauts, crew and passengers on regular airline flights, for people on the ground due to great solar flare CR events; 4. The great hazard for the Earth's civilization from the interaction of a dust-molecular cloud with the Solar system; 5. Great radiation hazard for the Earth's civilization from CR particles generated in a nearby Supernova Explosion.

Keywords: cosmic rays; radiation hazard; solar activity; SEP events

Cosmic rays and space weather influence on global climate change

The problem of determining of the part of global climate change caused by the long-term change of cosmic ray (CR) intensity through influence on air ionization and planetary clouds formation were considered in details in [1, Chapter 12] and recently in [2]. In [2] we consider examples from the past for several hundred million years and at last hundred years of global climate change caused by CR and different space weather effects as well as method of forecasting of the part of global climate change caused by space weather factors. We show that space weather factors are about 5-6 times more important than anthropogenic factor which became sufficient at last hundred years.

Global natural disaster from great magnetic storms connected with big CR Forbush-decreases and their assessment by using world-wide network of CR stations

Great geomagnetic storms affect adversely global technology systems, high frequency radio communications are disrupted [3], electric power distribution grids are blacked out when induced currents causes safety devices to trip, and atmospheric warming causes increased drag on satellites and anomalies in their operation, increasing of frequency of infarct myocardial, brain strokes, car and train accidents; there are a lot of examples of electric power and long oil tubes catastrophes in the past in Canada and other countries.

We show that by using on-line one hour CR data from world-wide network of stations is possible to made exact assessment of this natural hazard for 15-20 hours before of the storm sudden commencement. This problem is considered in details in [4].

Global natural disaster from great intense radiation hazards for astronauts, crew and passengers on regular airline flights, for people on the ground due to great solar flare CR events

The statistical distribution of SEP events and radiation hazard in dependence of the level of solar activity, which is important for planning of new space-probes and long-time space travels to other planets and determining of necessary protecting shielding, are considered in [5].

We developed method how to use on-line one-minute CR ground observations for predicting and estimation the expected level of radiation hazard for space-probes in space, for satellites in magnetosphere, for airplanes, and for different objects on the ground. We show that the forecasting of great radiation hazard from SEP event, with high occurrence probability, can be given 20-30 minutes before the arrival of the more dangerous particle flux; this method is based on the well known fact that the main part of radiation hazard in space and in atmosphere is caused by particles with small energy (few hundreds MeV) that reach the Earth 30-60 minutes after their acceleration on the Sun.

We show that 20-30 minutes of CR observation by neutron monitors on the ground and CR on satellites of the first-coming solar high-energy particles give enough information for automatically determining total flux and energy spectrum on the Sun (source function) as well as transport parameters in the Heliosphere.

This makes it possible to predict the time-space distribution for about 48 hours of radiation hazard in interplanetary space and in the Earth's magnetosphere (for astronauts and space-probe technology) and in the Earth's atmosphere (for crew, passengers and technology in aircrafts, for people and technology on the ground) as a function of geomagnetic cut-off rigidity and altitude.

It should be noted that for forecasting we use relatively small flux of high-energy (≥ 2 GeV) particles, which can be detected by super neutron monitors and practically are not involved in the radiation hazard (these particles reach the Earth much more quickly than small energy particles mostly because of much bigger diffusion coefficient). This problem we consider in details in [6].

The great hazard for the Earth's civilization from the interaction of a dust-molecular cloud with the Solar system

From the past we know that the dust from clouds between the Sun and the Earth leads to decrease of solar irradiation flux with sufficient decreasing of global planetary temperature (on 5-7° in comparison with 0.8° from green effect for the last hundred years).

The plasma in a moving molecular dust cloud contains a frozen-in magnetic field; this field could modify the stationary galactic cosmic rays distribution function outside the Heliosphere.

The change in the CR distribution function can be significant, and it should be possible to identify these changes when the distance between the cloud and the Sun becomes comparable with the dimension of the cloud.

The continuous observations of a time variation of the CR distribution function for many years should provide the possibility of determining the direction and the speed of the cloud relative to the Sun, as well as its geometry.

Therefore by CR measurements we may predict its evolution in space and determine whether the dust-molecular cloud will catch the Sun or not. In the case of high probability of capture, we could predict the time of the capture and how long the solar system will be inside the cloud.

Great radiation hazard for the Earth's civilization from CR particles generated in a nearby Supernova Explosion

It is well known that the Sun is a star of the second generation, in that it was born together with solar system from Supernova explosion about 5 milliard years ago. From the energetic balance of CR in the Galaxy it follows that the full power for CR production is about $3\cdot 10^{33}$ W. Now it is commonly accepted that the Supernova explosions are the main sources of galactic CR. At each explosion the average energy transferred to CR is about 10^{43} – 10^{44} J. From this quantity we can determine the expected frequency of Supernova explosions in our Galaxy and in vicinity of the Sun, and estimate: the probability of Supernova explosions at different distances from the Sun; the expected UV radiation flux (destroyer of our ozone layer and hence a significant player in our Earth's climate), and the expected CR flux. It has been estimated in [7, 8] that if such an event does take place, the levels of CR radiation reaching our Earth could reach levels extremely dangerous to our civilization and biosphere.

We show that by high energy CR measurements by ground and underground muon telescopes and low-latitude neutron monitors on the Earth there will be obtained information on the source function and diffusion coefficient in the interstellar space for many years before when real radiation hazard will be formatted on the Earth.

We show how on the basis of this information we can made exact forecasting on developing in time of the radiation hazard in space and in the atmosphere on different altitudes and cutoff rigidities (different geomagnetic latitudes) by using method of coupling functions.

On the basis of this information experts must to decide how to prevent the Earth's civilization (in some cases it will be necessary for people to live underground or in special protected buildings for several hundred years, and go out only for very short time).

It is important that on the basis of obtained forecast the Earth's civilization will have time at least several tens years to prepare the life underground and in special protected buildings.

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The Role of Space Weather and Cosmic Ray Effects in Climate Change. Lev I. Dorman, in Climate Change, 2009. 2.3 Cosmic Rays as an Important Link between Solar Activity and Climate Change.Â A widespread method of study of the turbulence of the interplanetary medium is to study fluctuations. Short-period changes of the interplanetary magnetic field and fluctuations of cosmic rays are connected since they appear on account of cosmic ray charged particle scattering on random nonuniformities of the interplanetary magnetic field (Libin, 1983a; Libin and Dorman, 1985; Libin et al., 1996c). Two possible mechanisms linking cosmic rays to weather and climate. by Jake Hebert. Long-age interpretations of earth history have led uniformitarian climate scientists to conclude that dramatic climate fluctuations that occurred in the past could also occur in the present, with possibly disastrous consequences.Â In particular, there has been considerable recent interest in the possibility that cosmic rays could somehow be affecting weather and climate. The radiation environment in space has severe adverse effects on electronic systems. To evaluate radiation sensitivity, electronics are tested on earth with different types of irradiation sources. Cosmic rays (CR) are the most difficult to simulate on earth, because CR can have energies up to 1020 eV, with a flux maximum of around 1 GeV/n. However, only particles with energies up to several GeV/nucleon are relevant for radiation effect testing of space electronics due to the negligible fluxes beyond. Traditionally single-event effects of these particles were simulated with heavy ions having en Effects Of Space Weather On Technology Infrastructure (Ed. I A Daglis) (Dordrecht: Kluwer Acad. Publ., 2004) p. 147.Â Dorman L I "Using cosmic rays for monitoring and forecasting dangerous solar flare events" Neutrinos And Explosive Events In The Universe (Eds M M Shapiro, T Stanev, J P Wefel) (Dordrecht: Springer, 2005) p. 131. Dorman L I Proc. of the 17th ESA Symp. on European Rocket and Balloon Programmes and Related Research, Sanefjord, Norway, 2005 (Ed.