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Correlated measurements of secondary cosmic ray fluxes by the Aragats Space-Environmental Center monitors

A. Chilingarian*, K. Arakelyan, K. Avakyan, V. Babayan, N. Bostanjyan, S. Chilingarian, V. Danielyan, A. Daryan, A. Egikyan, V. Eganov, G. Gharagyozyan, S. Ghazaryan T. Hairapetyan, A. Hovhanissyan, T. Hovhannisyan, V. Ivanov, G. Karapetyan, G. Kostanyan, L. Kozliner, N. Gevorgyan, H. Martirosian, L. Melkumyan, M. Nazaryan, A. Reimers, G. Rostomyan, S. Tserunyan, M. Zazyan

Cosmic Ray Division, Alikhanyan Physics Institute, Alikhanyan Brother 2, Yerevan 36, Armenia

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Abstract

The Aragats Space-Environmental Center provides monitoring of different species of secondary cosmic rays at two altitudes and with different energy thresholds. One-minute data is available on-line from http://crdlx5.yerphi.am/DVIN/index2.php. We present description of the main monitors along with data acquisition electronics. Also we demonstrate the sensitivity of the different species of secondary cosmic ray flux to geophysical conditions, taking as examples the extremely violent events of October–November 2003. We introduce correlation analysis of the different components of registered time-series as a new tool for the classification of the geoeffective (events on

Abbreviations: ACE, Advanced Composition Explorer; AMMM, Aragats Multidirectional Muon Monitor; ArNM, Aragats Neutron Monitor; ASEC, Aragats Space Environmental Center; AU, Astronomical unit (distance Sun–Earth, 1.5×10^{11} m); CME, Coronal Mass Ejection; CR, Cosmic Rays; CRD, Cosmic Ray Division, Yerevan Physics Institute; EAS, Extensive Air Showers; ESA, European Space Agency; Fd, Forbush decrease; GAMMA, EAS installation on Mt. Aragats; GCR, Galactic Cosmic Rays; GLE, Ground level Enhancement (Excess, Event); GOES, Geostationary Operational Environmental Satellite; GPS, Global Positioning System; IMF, Interplanetary Magnetic Field; MAKET ANI, EAS installation on Mt. Aragats; NANM, Nor-Amberd Neutron Monitor; NAMMM, Nor-Amberd Multidirectional Muon Monitor; nT, nano Tesla; SNT, Solar Neutron Telescope; SEP, Solar Energetic Particles; SF, Solar Flare

*Corresponding author. Tel.: 374 1 344 377.
E-mail address: chili@crdlx5.yerphi.am (A. Chilingarian).

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earth affected by solar activity) events and for the forecasting of the severity of the upcoming geomagnetic storm.

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1. Introduction

Radiation and geomagnetic storms, which are elements of space weather, are part of the major obstacles for space operations. Reliable forecasting of the arrival of these dangerous elements is of vital importance for orbiting flights and some surface industries. In addition to the fleet of space-born instruments, worldwide networks of particle detectors spread along different latitudes and longitudes, provide valuable information on the intensity and anisotropy of the variable cosmic ray fluxes. The geomagnetic storms are driven by the shocks followed by magnetized plasma clouds, with southward magnetic field, reaching the earth. During their travel in the interplanetary space the shocks interact with the Galactic Cosmic Rays (GCR) filling the space uniformly and isotropically. As a result the angular distribution and density of GCR with energies up to hundreds of GeV will be modulated. Due to the relativistic speeds of these particles, the information on the upcoming severe disturbance of the Interplanetary Magnetic Field (IMF) is transmitted quickly and can be detected by the world-wide networks of Neutron Monitors (NM, responding to GCR energies $\geqslant 10$ GeV) and Muon Telescopes (MT, responding to GCR energies $\geqslant 50$ GeV) well before the onset of a major geomagnetic storm [3,11,15]. The strength of the geomagnetic storms depends on the magnitude and space distribution of the cloud's "frozen" magnetic fields. Information on the anisotropy of muons and neutrons generated in the atmosphere by the GCR provides the appropriate tool for "looking" inside the magnetized cloud far before it reaches the Earth and the L1 point, where different measuring facilities, hosted by ACE and SOHO space stations are located.

The changing intensity of the GCR also reflects the large-scale structure of the IMF and the diurnal variability of cosmic rays detected by surface monitors and has a rather complicated shape [12]. That is the reason why we need multivariate, multidetector measurements of as many components of the changing secondary cosmic rays as possible. A sudden correlated variation in the flux of neutrons, muons, and electrons, detected by the surface monitors could be an indication of an upcoming severe radiation or geomagnetic storms.

Starting from 1996 we are developing various detectors to measure fluxes of different components of secondary cosmic rays at the Aragats research stations of the Alikhanian Physics Institute (formerly known as Yerevan Physics Institute). After being down for a few years due to the economic hardships in the years following Armenia's independence, in 1996 we restarted our first detector—the Nor-Amberd Neutron Monitor 18NM64 (2000 m above sea level). A similar detector was commissioned and started to take data at the Aragats research station (3200 m above sea level) in 2000. The muon scintillation multi-directional monitor system started operation at the Nor-Amberd research station in 2002. A similiar muon detector is arranged around the Mexico City neutron monitor, 6NM64 [16]. A Solar Neutron Telescope (SNT) is in operation at the Aragats station since 1997, as part of the worldwide network coordinated by the Solar-Terrestrial laboratory of the Nagoya University [17]. In addition to the primary goal of detecting the direct neutron flux from the Sun, the SNT also has the possibility to detect muon fluxes and roughly measure the direction of the incident muons. Another monitoring system is based on the scintillation detectors of the Extensive Air Shower