CORRELATED MEASUREMENTS OF THE SECONDARY COSMIC RAY FLUXES BY THE NEUTRON MONITORS AND MUON TELESCOPES

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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 the orbiting flights and electric power distribution in near polar regions. 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.

Aragats Space-Environmental Center provides monitoring of the different species of secondary cosmic rays at two altitudes and with different energy thresholds. 1-minute data is available on-line from URL <http://crdlx1.yerphi.am/DVIN>. We demonstrated the sensitivity of the different species of secondary cosmic ray flux to geophysical conditions, taking as examples extremely violent events of end of October – November 2003. Also we introduce the correlation analysis of the different components of registered time-series as a new tool for the classification of the geoeffective events.

Keywords: Space Weather; Cosmic Rays; Geomagnetic Storms

1. Introduction

The geomagnetic storms are driven by the shocks followed by the ejected magnetized solar plasma clouds, reaching the earth and interacting with the magnetosphere. During their travel in the interplanetary space the clouds 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 median energies ~ 10 GeV) and Muon Telescopes (MT, responding to GCR median energies ~ 50 GeV) well before the onset of a major geomagnetic storm.[1–3] The strength of the geomagnetic storms depends on the magnitude and space distribution of the clouds "frozen" magnetic fields. Information on the anisotropy of muons and neutrons generated in the atmosphere by the galactic cosmic rays provides the appropriate tool for "looking" inside the magnetized cloud far before it reaches the Earth and the Lagrangian L1 point (1.5×10^6 km away from Earth in Sun direction), where different measuring facilities, hosted by ACE and SOHO space stations are located.

2. The Aragats Space Environment Center (ASEC)

The ASEC[4] consists of two high altitude stations on Mt. Aragats in Armenia. Geographic coordinates: $40°30'$ N, $44°10'$ E. Cutoff rigidity: ~ 7.6 GV, altitude 3200 m and 2000 m. At these stations several monitors continuously measure the intensity of the cosmic ray fluxes and send data to the Internet in real time. The specifications of the ASEC monitors are shown in Table 1.

Table 1. Characteristics of the ASEC monitors

Detector	Altitude (m)	Surface (m^2)	Threshold(s) (MeV)	In operation since	Mean count rate (min^{-1})
NANM (18NM64)	2000	18	100	1996	2.5×10^4
ANM (18NM64)	3200	18	100	2000	6.2×10^4
SNT-4thresholds	3200	4	130, 240, 420, 700	1998	4.2×10^4
+ veto detector		4	10		1.2×10^5
NAMMM	2000	$5 + 5$	$10 + 350$	2002	2.5×10^4
AMMM	3200	48	5000	2002	1.2×10^5
MAKET-ANI	3200	70	10	1996	1.8×10^6

The two 18NM-64 neutron monitors, are in operation at Nor-Amberd (2000 m elevation) (**NANM**), and at Aragats, (3200 m elevation) (**ANM**) research stations.

The Solar Neutron Telescope (**SNT**), is in operation at 3200 m above sea level at the Aragats research station.

The Nor-Amberd Muon Multidirectional Monitor **NAMMM**, consists of two layers of plastic scintillators above and below two of the three sections of the Nor Amberd NM. The lead filter of the NM absorbs electrons and low energy muons. The data acquisition system of the NAMMM can register all coincidences of detector signals from the upper and lower layers, thus, enabling measurements of the arrival of the muons from different directions.

In the underground hall, originally constructed for the ANI Cosmic Ray experiment (Danilova *et al.*, 1992),[5] 100 plastic scintillators with area of 1 m^2 each of are located to measure the muon content of the Extensive Air Showers. Only muons with energies > 5 GeV reach the detectors. The Aragats Multidirectional Muon Monitor (**AMMM**) consists of 15 m^2 scintillation detectors, located on top of the ANI concrete calorimeter and 72 m^2 array of same type of detectors 24 m below. The geometry of the detector arrangement will allow us to detect particles arriving from the range of directions from vertical to $60°$ declination, with the accuracy of $\sim 5°$ and with very good statistics.

The **MAKET-ANI** surface array,[6] consists of 92 particle density detectors formed from plastic scintillators with thickness of 5 cm. The changing fluxes of muons and electrons are available from the MAKET- ANI data bank. All Forbush decreases and other geoeffective events are very well reproduced by these data with very good statistical provision, the number of count per minute of 1 m^2 plastic scintillator is $\sim 25,000$.

3. Correlation analysis of ASEC monitors recordings.

The biggest Forbush decrease (**Fd**) from 29 October 2003 was detected by all ASEC monitors. From Fig. 1 we can see that neutron flux is attenuated by 20% (a,b), low energy

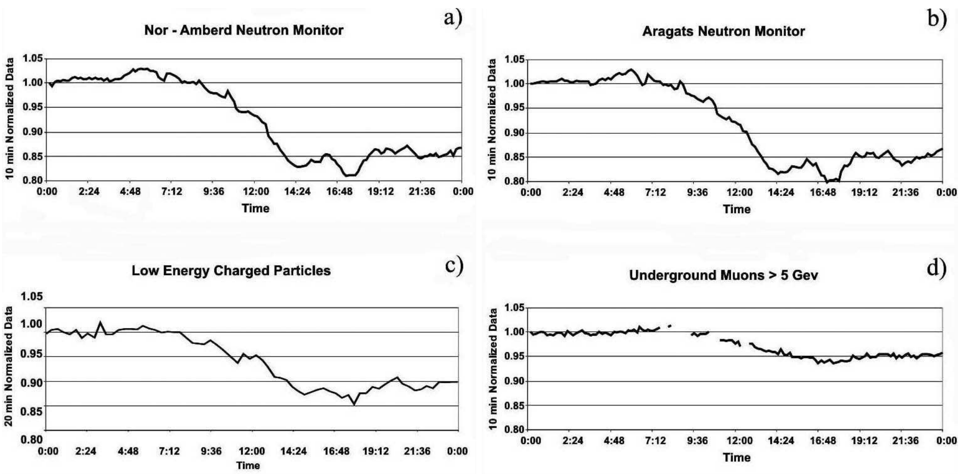

Fig. 1. Forbush decrease at 29 October 2003 detected by ASEC monitors.

charged flux by 15% (c) and high energy muons by $7 - 8\%$ (d). The relative values of flux attenuation in different components of the secondary cosmic ray flux can be used as a characteristic of the Fd magnitude.

For the investigation of parameters of secondary fluxes, which are the most sensitive to the characteristics of the geoeffective event, we select 4 distinct test cases. One - corresponding to the silent phase of geomagnetic disturbance, and others – to the Fd of different magnitude from modest, to strongest one. They are: 25 January 2004, 20 November 2003, 27 July 2004, 29 October 2003. Correlations between different particle fluxes calculated for the day 25 January 2003, when the geomagnetic activity was very small. For October 29 Fd it is seen very strong correlations between all monitors, so that all monitors count rates are decreasing in the similar way. For smaller event of 27 July 2004 the correlations between monitor's count rates are large for the low energy particles and they are decreasing with the energy. From Fig. 2 it is apparent a strong association between correlation coefficients and minimal values of Dst index, characterize the geoeffectivity of the event. Dst index is constructed by averaging the horizontal component of the geomagnetic field from mid-latitude and equatorial magnetometers from all over the world. Thus, the correlation matrixes contain valuable information on the geoeffectiveness of the event: the higher correlation coefficient between ArNM and AMMM, or between ArNM and 0-th threshold of SNT, the stronger is geomagnetic disturbance. We performed also correlation analysis of 2003 huge geomagnetic storm of 20 November. The correlations between ArNM and NANM is strong (~ 0.90), because these two monitors are instruments of the same type

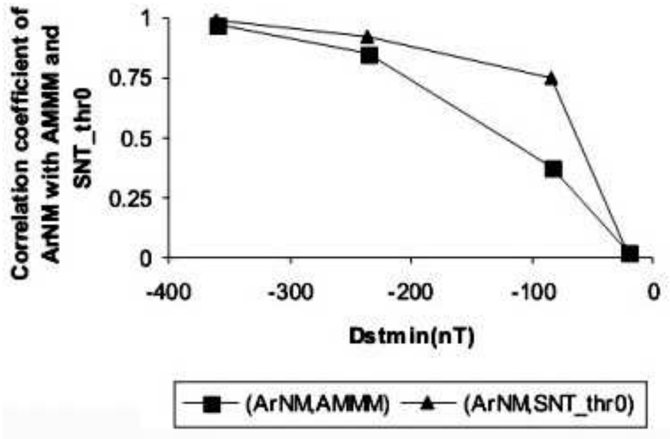

Fig. 2. Correlation coefficients between (ArNM, AMMM) and (ArNM, 0-th threshold of SNT) versus minimal value of Dst.

and register the same neutron flux, originated by the primaries of low energies. Correlation between neutron and high-energy muon fluxes is weak, because primaries originating these particles have different energies (lower for neutrons and higher for muons) and the decrease of the geomagnetic cut-off doesn't influence 5 GeV muons flux.

4. Conclusion

We have demonstrated the sensitivity of correlation analysis to the different types of events caused by strong geomagnetic disturbances. We conclude that the correlations between different ASEC monitors count rates could be used for the identification of geoeffectiveness of events according to their type and severity. The possibility of the early diagnostic of the expected hazard of geomagnetic or/and radiation storms using the correlation information on the changing fluxes of the ASEC monitors is under investigation now.

5. Acknowledgement

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