Recent Cosmic Ray Studies with Lead Free Neutron Monitor at Basic Environmental Observatory Moussala

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Abstract. The recently developed lead free neutron monitor at Basic Environmental Observatory Moussala (BEO Moussala) is presented. The device is devoted for cosmic ray variations studies and space weather at BEO Moussala. The detector design and corresponding Monte Carlo simulations and methodological measurements are presented. The barometric effect is demonstrated. The scientific potential of the existing complex is discussed.

Keywords: cosmic ray; detector modeling; space weather; heliospheric processes

Introduction

The cosmic rays (both galactic and solar) play important role in the interplanetary and extraterrestrial space. At the same time they can affect the human activity [1, 2]. A modern and interesting topic is related to space weather studies. The space weather refers to the dynamic, variable conditions on the Sun, solar wind and Earth's magnetosphere and ionosphere that can diminish the performance and reliability of spacecraft and ground-based systems [3]. Therefore study of cosmic rays, especially the variation of cosmic ray flux is very important [4].

The advantages of high-mountain observatories are related to the possibility to register with better statistics the secondary cosmic ray particles compared to lower observation levels. This is the reason that in the last several decades the high-mountain observatories have been exploited for astrophysical studies and observations of the Sun-Earth system.

The Basic Environmental Observatory (BEO) Moussala is located on the top of the highest mountain at Balkan Peninsula, namely at 2925 *m* above sea level. At present different changes and processes in the Earth's atmosphere, atmospheric physics and chemistry, aerosol physics, radiation processes are investigated at the top level. In addition, different components of secondary cosmic rays, namely the atmospheric Cherenkov light, muon component are measured in attempt to study different problems of the cosmic rays, space weather and Sun-Earth connections. Obviously the detailed analyses of the collected data permits to study the possible relation between different kind of parameters and factors connected with environment, atmospheric processes and the system Sun - Earth.

The changes in the large-scale atmospheric circulation may be associated with solar activity phenomena [5] and long-term cosmic ray intensity variations [6]. The possibility that galactic cosmic rays (GCR) are related to Earth's cloud cover [7, 8] and have an important impact on the Earth's climate forcing, has become a leading candidate to explain the observed Sun-climate connection [9, 10].

A powerful tool for investigations from Earth the variation of cosmic ray flux is based on registration of secondary cosmic ray neutrons. In this connection recently there was designed and constructed lead free neutron monitor at BEO Moussala. The main purpose of the device is the registration of the secondary cosmic ray neutrons and study of cosmic ray variations.

Materials and methods

The neutron monitor represents an instrument that measures the number of high-energy particles impacting Earth from space and provides continuous recording of the hadronic component in atmospheric secondary cosmic rays. The purpose of the neutron monitor is to detect, deep within the atmosphere, variations of intensity in the interplanetary cosmic ray spectrum. The secondary cosmic ray neutrons are not slowed by ionization loss, they fall in the energy range of a few hundred *MeV* up to about 1 *GeV*. Thus, the neutron monitors are most sensitive to the low energy (1-20 *GeV*) part of the spectrum. The introduction of the neutron monitor as a continuous recorder of the primary cosmic ray intensity resulted from the design by Simpson [11] of a neutron monitor pile.

The lead free neutron monitor at BEO Moussala is mid latitude (42.11 deg N), mid rigidity (6.5 GV) and high altitude (2925 *m* above sea level) neutron monitor. The principal aim of the device is to investigate the cosmic ray variations and to study the possible connection between cosmic ray and atmospheric processes [4], simultaneously with other equipment at BEO Moussala [12]. It represents complex of six BF_3 tubes type SNM-15 with 2 *m* length and 15 *cm* diameter. The detector complex represents two identical modules each one of 3 detectors. A sketch of the lead free neutron monitor at BEO Moussala is shown in Fig.1.

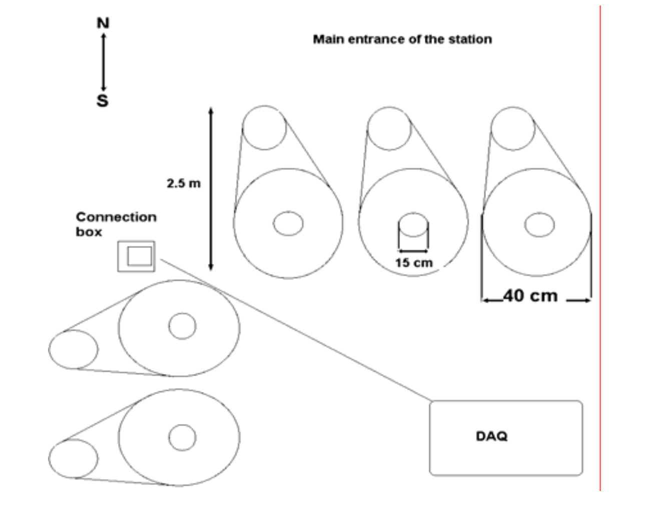

Fig. 1. Sketch of the lead free neutron monitor at BEO Moussala.

The detectors are situated under the roof of the main building of BEO Moussala, which permits to avoid snow moderating effects. The neutron monitor is without lead, i.e. it is a lead free neutron monitor. The moderator is glycerin, filled in cylindrical tanks. The capacity of glycerin to thermalize fast neutrons is practically the same as polyethylene. The moderator tank represents a cylinder with 40 *cm* diameter and 2.5 *m* length. The detector complex area is 5.28 m^2. Taking into account that the glycerin is liquid, it is easy to provide cylindrical symmetry of the detector complex, which simplifies considerably the construction.

The detector design and detector response are obtained on the basis of Monte Carlo simulation using MCNP code [13]. This permitted to estimate the layer of moderator and to obtain the expected counting rates. In this study we used the measured at Testa Grigia neutron spectrum [14] as input for the simulations.

Results

The total neutron current, function of the moderator layer is obtained for different moderator thickness (4 *cm*, 7 *cm*, 10 *cm*, 15 *cm*, 20 *cm*, 25 *cm*, 30 *cm*, 35 *cm* and 40 *cm*) presented in Fig.2. The proposed 12.5 *cm* moderator of glycerin permits, to render the monitor essentially opaque to low energy background neutrons due to interaction of high energy cosmic rays with the ground and detector surroundings. At the same time this layer assures high counting rate, which results on a good statistics of the measurements.

The integration in the sensitive range of BF_3 detector (Fig.2) permits to estimate the expected counting rate of the lead free neutron monitor at BEO Moussala to 500 *counts/min*. The preliminary measurements confirmed the expectations. The response function of the detector complex is according [15].

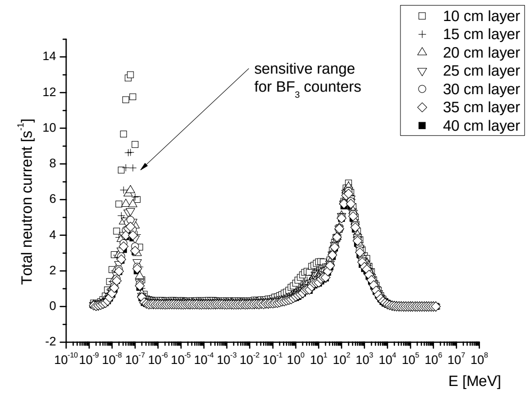

Fig. 2. Neutron current as a function of the moderator layer.

The detector complex is operational since April 2007. The estimation of measurements accuracy is obtained on the basis of statistical analysis of one week data, when the barometric pressure is relatively constant (the variation of the pressure is lees than 2 *hPa*). The estimated accuracy of the measurements of the neutron flux is 0.014. This corresponds to about 1% statistical accuracy for 10 *min* measurements. The measured data are fitted with Gaussian with mean value of 5260 and σ=250. The latter analysis shows good statistical quality of the measured data.

The first test for the recently operational lead free neutron monitor at BEO Moussala is the observed anti-correlation with barometric pressure (Fig. 3). The obtained attenuation coefficient is 0.21% per *hPa*. The first measurements carried out with lead free neutron monitor at BEO Moussala confirmed the proper work of the device and theoretical expectations.

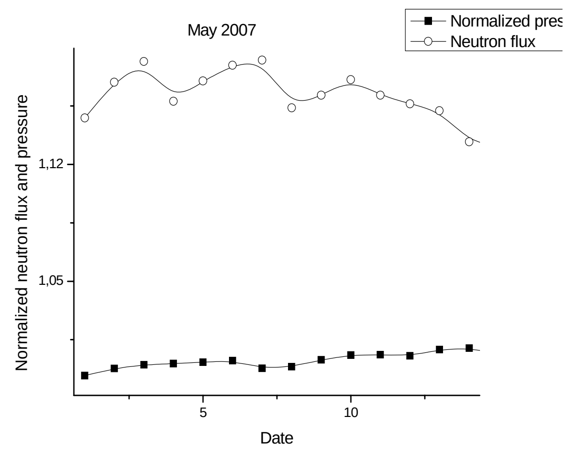

Fig.3. Normalized neutron flux and pressure in anti-correlation for May 2007.

Discussion

The precise long-term measurements with lead free neutron monitor give excellent possibility to understand the role of cosmic ray variation of the Earth climate and to check different mechanisms of such type of influence. Moreover this gives the possibility to check at experimental point of view different proposed models.

Recently one of the most existing topics in the area of Sun-Earth system is connected to the relations between solar variability, respectively cosmic ray variability and the possible influence of cosmic ray on processes in Earth's atmosphere and human activity [1, 2, 16, 17].

This enables to study the influence of galactic cosmic rays on the solar radiation input to the lower atmosphere, especially increases of the total radiation fluxes associated with Forbush-decreases in the galactic cosmic rays [4, 18], the possible influence of different helio- and geophysical factors such as solar flares, galactic cosmic ray variations, auroral phenomena on the solar radiation input to the lower atmosphere [19], as well as the as the latitudinal dependence of such effects [20].

It is clear that the scientific potential of detector complex is promising especially for space weather applications. The relativistic cosmic rays (both galactic and solar) play a useful key in space weather storms forecasting and in the specification of magnetic properties of coronal mass ejections, shocks and ground level enhancements.

In this connection we presented one of main BEO Moussala activities which is connected to secondary cosmic ray registration, i.e. the neutron component. Obviously the high quality data can be useful as a basis to check several models on the influence of high energy particles on the middle atmosphere [21, 22, 23, 24].

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