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LARC[1] /6-NM-64: Atmospheric Pressure Effects

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ABSTRACT

An Antarctic Laboratory for Cosmic Rays (LARC) is operating on King George Island (South Shetlands) since January 19, 1991. The cosmic ray detector is a standard 6-NM-64. Results, based on the 1991-1993 dataset, are reported to facilitate the elimination of pressure-induced effects on the recorded cosmic-ray intensities. We found a barometric coefficient of about 0.74%/mb as the most appropriate value to be used.

Key words: Cosmic rays, atmospheric physics, barometric effects.

LARC[1]/6-MN-64: Los efectos de la presión atmosférica

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RESUMEN

El Laboratorio Antártico de Rayos Cósmicos (LARC), instalado en isla Rey Jorge, islas Shetland del Sur, está funcionando permanentemente desde el 19 de enero de 1991. El detector de rayos cósmicos es un monitor de tipo estándar 6 MN-64. Los resultados se basan en una serie de datos continuos obtenidos desde 1991 hasta 1993 y se informan para facilitar la eliminación de los efectos inducidos de la presión sobre los registros de intensidad de los rayos cósmicos. Encontramos un coeficiente barométrico de unos 0,74%/mb, como el valor más apropiado para ser usado.

Palabras claves: Rayos cósmicos, física atmosférica, efectos barométricos.

[1] The acronym LARC stands for "Laboratorio Antártico de Radiación Cósmica"

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INTRODUCTION

Cosmic rays are extraterrestrial charged particles (principally protons and alphas) which arrive at the top of the atmosphere from all directions in space. The incoming cosmic rays interact with the atmospheric nuclei. Hence, particles detected at ground-based stations are the secondary radiation generated in the interaction chain (characterized by: the nuclear-active or nucleonic component, the hard or mesonic component, and the soft or electromagnetic component). Moreover, cosmic ray trajectories are deflected by the geomagnetic field, producing the so-called «latitude effect» in the measured flux (i.e. a cutoff in the rigidity of the arriving charged particles). Only secondaries of energetic primary particles are able to reach the ground level and those with lower energies (i.e. those most affected by solar activity) are best detected at high geomagnetic latitudes and altitudes, particularly in polar areas.

The nuclear-active cosmic-ray component is registered by standard neutron monitors (IGY and NM-64 types). In these detectors, the neutrons produced in the lead shielding are moderated and detected by proportional counters containing B^{10} isotopes (e.g. Simpson *et al.*, 1953; Hatton, 1971 for details).

The intensity variations of the incoming cosmic rays are indicators of changes in the interplanetary medium conditions. Solar activity via trasient (related to solar flares, coronal mass ejections, and disappearing filaments) and recurrent (originating in solar coronal holes) interplanetary disturbances leave their imprints on the heliospheric space (Global Merged Interaction Regions; see Burlaga *et al.*, 1993 and references therein). The systematic study of the nucleonic component of galactic cosmic rays provides us with a powerful tool to increase our knowledge on Space Physics (Storini, 1990, 1991, 1995a) and to separate in the Earth environment solar-induced effects from the terrestrial ones (Dorman *et al.*, 1993; Cordaro and Storini, 1994; Storini, 1994, 1995b). In the following we evaluate attenuation effects induced by the overhead air mass on the cosmic ray flux registered by the LARC station.

METHOD

The counting rates of continuously operating neutron monitors show different types of variations over short and long periods of time, some of them related to pressure and temperature variations in the terrestrial atmosphere (e.g. Dorman, 1957 for an early work). Temperature effects are generally small (Hatton, 1971) and, in first approximation, neglected. The cosmic ray intensity as a function of the atmospheric pressure can be described by an exponential law. It follows that the counting rate (N), recorded at a given altitude, can be corrected (N_{corr}) for barometric variations via the equation:

$$N = N_{corr} \cdot \exp\left[a \cdot (P - P_o) \right]$$

where a is the barometric (also called attenuation) coefficient and $(P-P_0)$ refers to the deviation from the mean pressure value (P_0) for the given altitude. Thus the counting rates are reduced to a corresponding standard level to evaluate the variability of the primary cosmic-ray flux.

The barometric coefficient a depends on the cutoff rigidity of the measurement site and on the level of the cosmic ray modulation (e.g. Belov *et al.*, 1993, and references therein). It is therefore necessary to determine the attenuation coefficient a for each cosmic ray station. It is generally computed by regression analyses using the above reported equation (see Lapointe and Rose, 1962; Harman and Hatton, 1968; Bachelet *et al.*. 1972; among others). We present here results for the 6-NM-64 detector located in the LARC station.

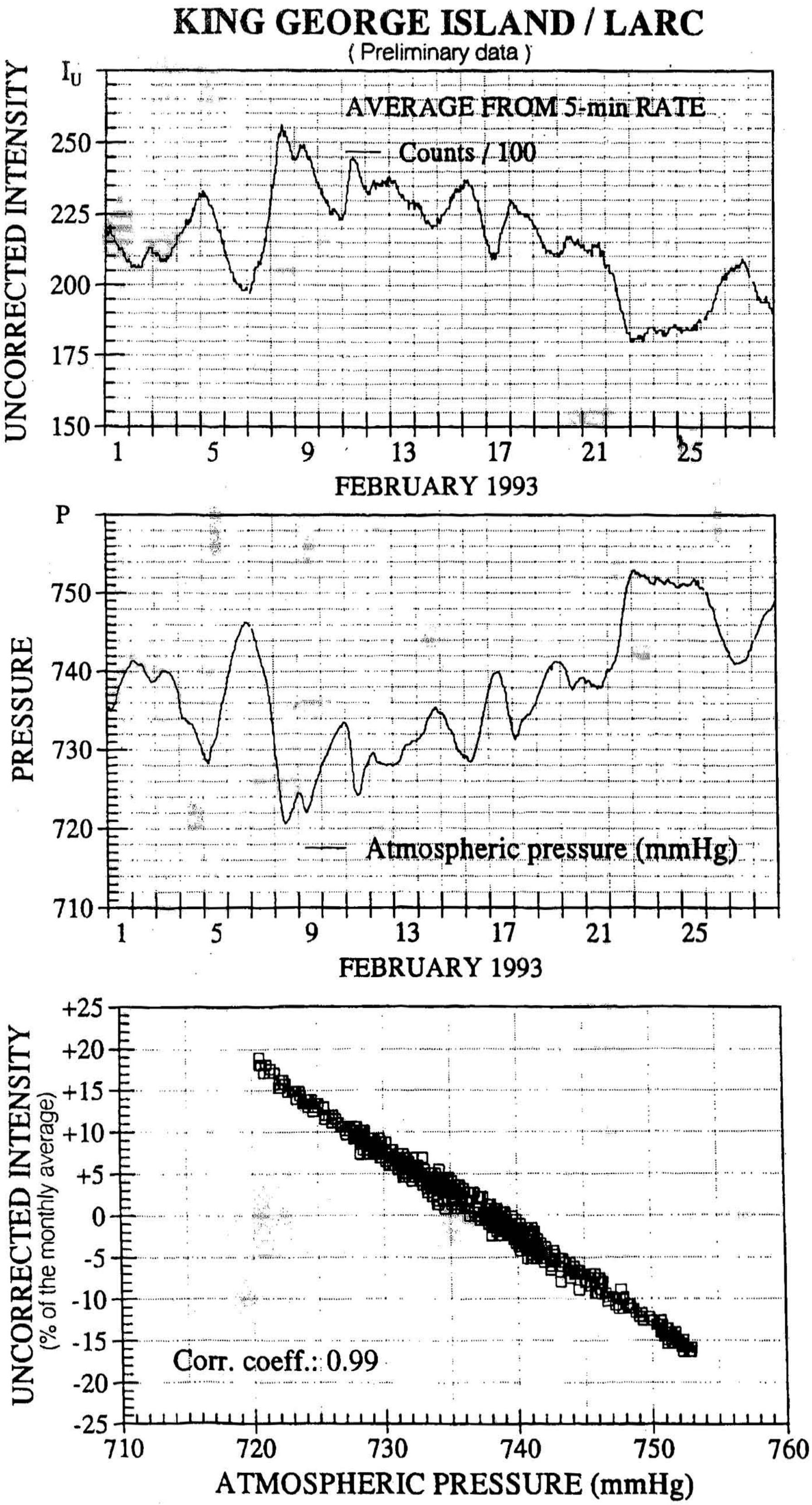

Fig. 1: The 6-NM-64 intensity (upper panel) and barometric (middle panel) hourly averages for February 1993. The lower panel reports the correlation plot between both datasets.

Data Source and Data Type

The LARC station is operating since January 19, 1991, on a South Shetland Island. Relevant features for the station are:

Station name: LARC
Alternate name : Caleta Ardley
Location : King George Island - Fildes Bay - E. Frei Base
Geographic Latitude : 62° 11' 08" S
Geographic Longitude: 58° 55' 00" W
Altitude: 40 m.a.s.l.
Vertical cutoff rigidity: 3.07 GV (Storini *et al.*, 1995)
Instrument: 6-NM-64 (three 2-counter units: 3 x 2 BF_3)
Data resolution : 5 minutes
Scaling Factor: 100

Scientific objectives, LARC set-up, and LARC evolution in time have been described elsewhere (Cordaro *et al.*, 1992; Cordaro and Storini, 1992; Storini and Cordaro, 1992; Cordaro, 1993; Cordaro *et al.*, 1994; Cordaro, 1995; Storini and Cordaro, 1995). We only add that continuously recorded data are collected and processed in Santiago on yearly basis. Hence, they are stored in a database for further analyses. Original data strings for the 1991-1993 epoch contain: date, time (U.T.), atmospheric pressure reading (mm Hg) and the 5-min. counting rates registered by the three sections (left, middle and right channels) of the neutron monitor. Moreover, the Eduardo Frei Meteorological Center (DMCH/FACH, private communication) kindly supplied us with the meteorological parameters of Caleta Ardley (i.e., the atmospheric pressure, temperature, relative humidity, wind speed and direction for the ground level). In each year LARC pressure readings have been checked with the ones obtained by the DMCH. Figure 1 illustrates, as an example of LARC data achievement, uncorrected cosmic-ray and pressure values for February 1993. The well-known anticorrelation between both parameters is emerging. For completeness, the lower panel gives the regression plot between them.

LARC data for the 1991-93 years have been checked to prepare a reliable dataset to estimate atmospheric pressure effects on original counting rates. Uncomplete 5-min countings, due to technical failures, have been eliminated together with the cosmic-ray data strongly affected by solar activity. The percentage of data used in the present work is shown in Figure 2, while the derived averages of the cosmic ray intensity and atmospheric pressure, on monthly basis, are given in Figure 3.

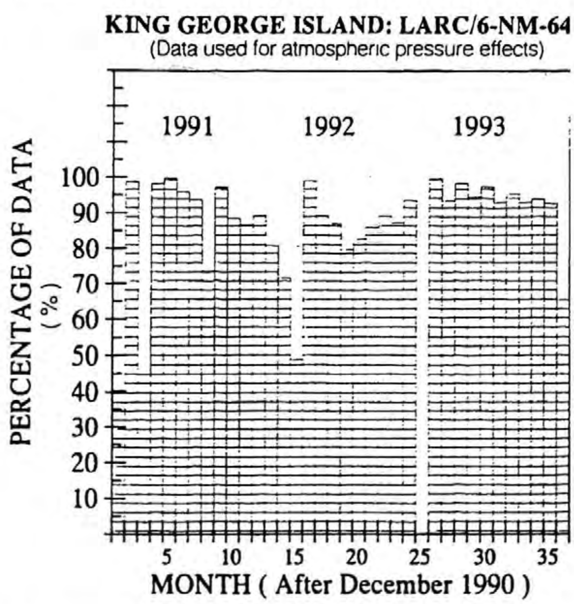

Fig. 2: Percentage of LARC data used to estimate the attenuation coefficient (a) necessary to eliminate barometric variations on LARC/6-NM-64 intensities.

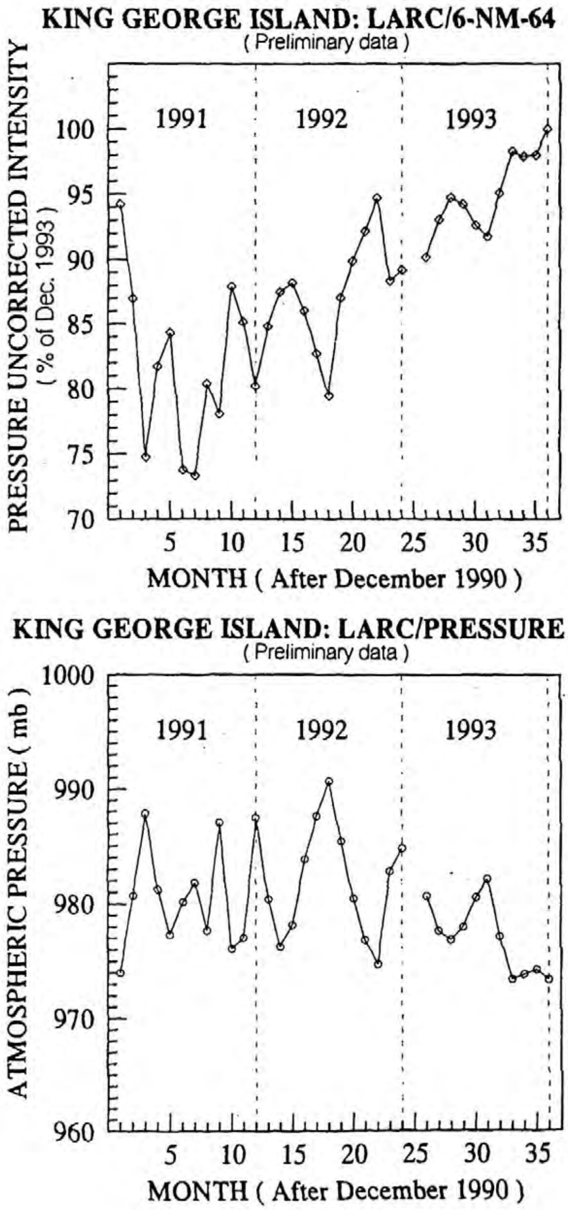

Fig. 3

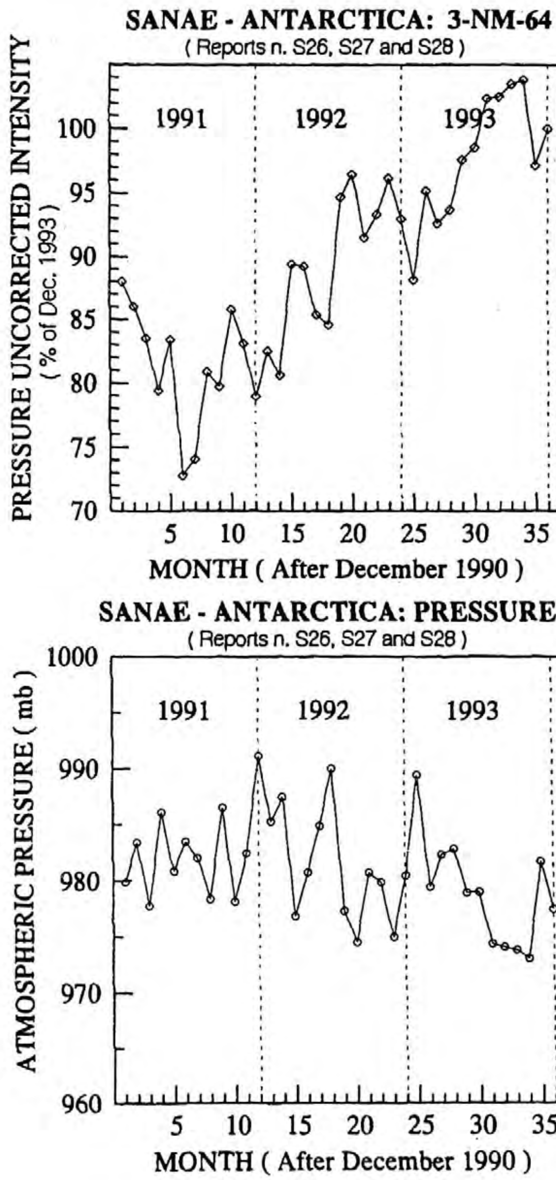

Fig. 4

Fig. 3: Monthly pressure uncorrected intensity and atmospheric pressure averages derived from the 5-min rates of LARC/6-NM-64 detector.

Fig. 4: Monthly pressure uncorrected intensity and atmospheric pressure averages of SANAE/3-NM-64 detector.

The obtained parametric trends may be compared with those reported in Figure 4 for Sanae cosmic-ray station (Antarctica: 70^0 19'S, 02^0 21'W, altitude: 52 m; Sanae, 1992, 1993, 1994).

A fairly good agreement is found for the long-term trend of uncorrected cosmic-ray intensities, particularly when the different cutoff rigidities and the barometric variations are considered. This comparison allows us to use LARC data with a good confidence level.

RESULTS AND DISCUSSION

From the linear correlative analyses between neutron monitor data and atmospheric pressure values from LARC we have obtained the correlation coefficients reported in Table 1, and the barometric coefficient series illustrated in Figure 5.

Table 1

Correlation coefficients estimated on monthly basis between cosmic ray data and pressure values from 1991 to 1993.

Year Month	1991	1992	1993
Jan	0.91	0.93	- -
Feb.	0.97	0.96	0.99
Mar.	0.93	0.98	0.96
Apr.	0.96	0.98	0.98
May	0.95	0.96	0.98
June	.0.86	0.98	0.99
July	.0.95	0.98	0.99
Aug.	0.98	0.95	0.99
Sept.	0.98	0.97	0.99
Oct.	0.95	0.99	0.99
Nov.	0.87	0.97	0.98
Dec.	0.91	0.98	0.96

From figure 5 we notice that the monthly attenuation coefficients are expresed in %/mb, being current pressure unit 1 hPa = 1 mb. We observe that the a series shows several oscillations along each year. This effect arises in part from statistical uncertainties and in part from residual effects of non-atmospheric intensity variations. In fact, minor a oscillations are present during the 1993 year when solar activity attains a low intensity level. We conclude that a coefficient of about 0.74 %/mb (roughly the a average for the investigated epoch) is the most appropriate value to eliminate barometric induced variations on LARC data, while, the standard pressure level (P_0) is about 980 mb. We notice that for Sanae station the a and P_0 values used to generate pressure-corrected intensities (see Figure 6) are: a = 0.73 %/mb and P_0 = 987.2 mb. Therefore, we infer that the results obtained are confident and they mean a successful goal of the enterprise.

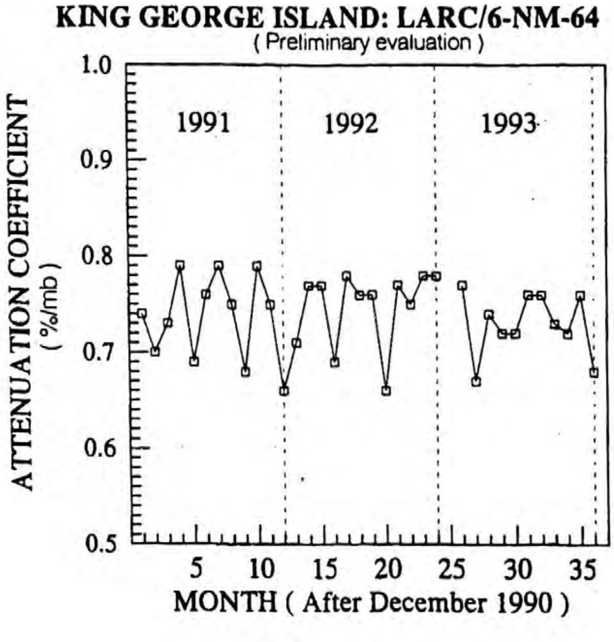

Figure 5

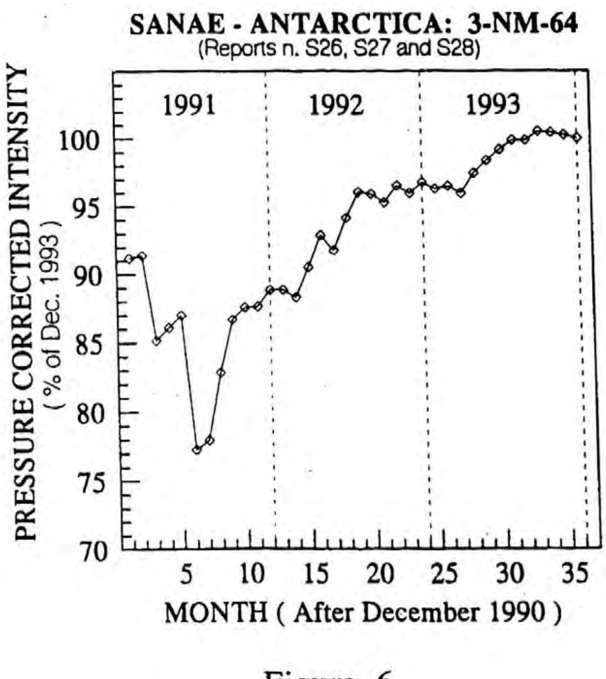

Figure 6

Fig. 5: Monthly attenuation coefficient for the nucleonic component registered by the LARC/6-NM-64 detector in the 1991-93 years.

Fig. 6: Three years (1991-93) of the monthly recovery phase of the nucleonic intensity during solar cycle n.22, as seen at Sanae-Antarctica

CONCLUSIONS

Present analysis, based on the first three years of data recorded by the LARC station, shows that the nucleonic component of galactic cosmic rays registered by the Antarctic 6-NM-64 detector can be used with a good confidence level to solve open problems in Solar-Terrestrial Physics. However, atmospheric effects must be eliminated before any study of galactic flux variability in the interplanetary space. We obtained here a reliable barometric coefficient (0.74 %/mb) to apply to the 1991-1993 dataset. A detailed analysis for the 1991-1994 epoch will be published separately, because a data quality improvement is expected from the 1994 LARC implementation (Chile-Italia Collaboration).

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