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On the use of the South-American neutron monitors(*)

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Summary. — Cosmic ray scientific community deserves special attention to the Chacaltaya site for its over 5 km altitude. In this site, a neutron monitor of the IGY type operated from 1960 to 1969, and the one of the NM-64 type since 1966 (16.31°S, 291.85°E, height: about 5200 m a.s.l.). We discuss the relevance of such kind of detector when it is integrated with the other South-American neutron monitors: a) LARC (62.20°S, 301.04°E, height: 40 m a.s.l., King George Island, Antarctica; operating since 1991); b) LOS CERRILLOS (33.45°S, 289.40°E, height: 570 m a.s.l., Santiago, Chile; to be installed in the near future); c) HUANCAYO (12.03°S, 284.67°E, height: 3400 m a.s.l., Huancayo, Peru; hoping to recover its acquired data).

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1. – Introduction

The new discipline called *Space Weather* requires a good cosmic ray detector coverage around the world. In this paper we show some events registered in the high and middle latitudes of the South-American sector (sect. **3** and **4**), and we discuss the necessity to integrate the Chacaltaya neutron monitor, located in the Andes region, with the other detectors working at much higher latitudes (sect. **2**).

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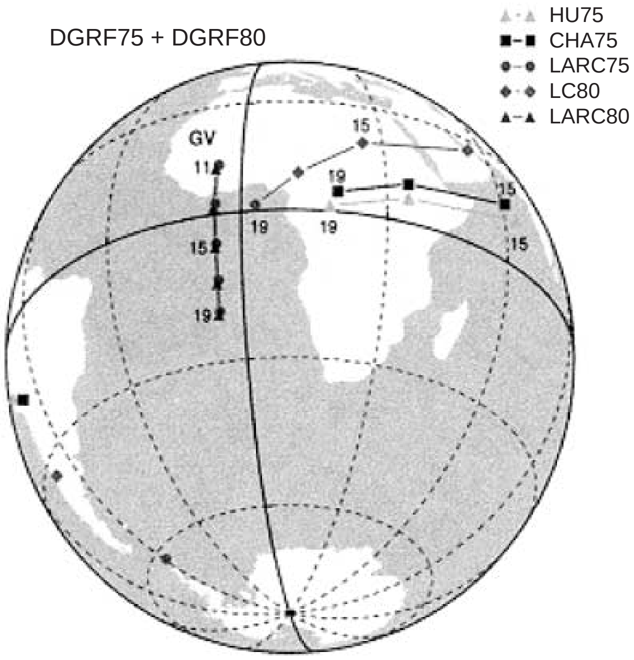

Fig. 1. – Asymptotic directions of approach of vertical incident cosmic rays particles for Huancayo 75, Chacaltaya 75, LARC 75, LC 80, LARC 80, using DGRF 75 and DGRF 80.

2. – Scientific goal for South-American cosmic ray stations

Since January 1991 the Antarctic Laboratory for Cosmic Rays (acronym LARC) has been operating with a neutron monitor (6-NM-64 type) on King George Island (South Shetlands; geographic coordinates: $62°12'09''$ [62.20°] S and $58°57'42''$ [58.96°] W; height: 40 m a.s.l.). Also Los Cerrillos Station (LC: 33.45° S, 289.40°E, height: 570 m a.s.l.) is at work near Santiago (Chile) with a muon telescope since 1980, and for two years (1988-90) only with a 6-NM-64 detector. Inside the International Chile-Italy Collaboration a new neutron monitor will be installed in Los Cerrillos in the near future (UChile/IFSI-CNR/UNIRomaTre/INACh/PNRA).

The main scientific goal for the LARC and LC (Los Cerrillos) projects is the study of the cosmic ray radiation in the high and middle latitudes of the South-American sector, the systematic analysis of the nucleonic intensity being a good tool to separate in the Earth environment solar-induced effects from the terrestrial ones (see, for instance, [1,2]). This is particularly true for the South-American neutron monitors, because they operate in locations with peculiar geophysical features (*e.g.*, the ones related to the South Atlantic magnetic anomaly). We recall that the Bolivian 12-NM-64 monitor has been operating for long near La Paz (Chacaltaya; geographic coordinates: 16.31°S, 291.85°E, height: about 5200 m a.s.l.) and its closeness to the (now lost) Huancayo detector suggests that Chacaltaya data (1975 vertical cutoff: 12.62 GV) may substitute the Huancayo ones (1975 vertical cutoff: 13.01 GV) in the future. This is clearly evident in fig. 1 (isolated symbols give station locations), where the 1975 asymptotic directions of vertically incident charged particles at Huancayo (HU75; joined grey filled triangles) and Cha-

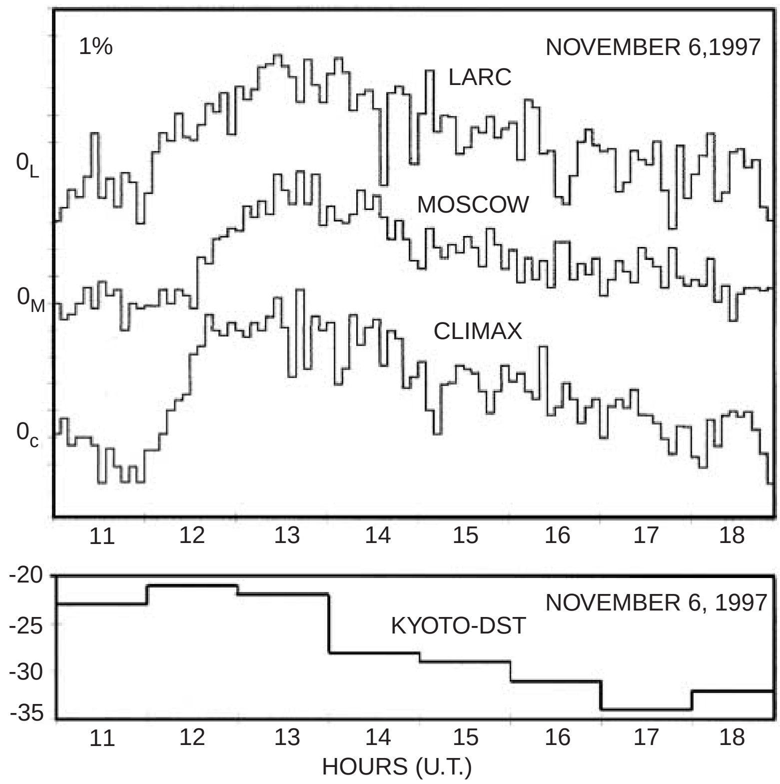

Fig. 2. – Cosmic ray intensity observed at LARC, Moscow, Climax and DST-Kyoto using the GLE event of November 6, 1997.

caltaya (CHA75; joined filled squares) sites [3] are shown for a narrow rigidity interval (15–19 GV); in the same figure the 11–19 GV interval is reported for the King George station (LARC75 [4]). While the LARC directions (joined filled circles) are nearly along a meridian, the ones of Huancayo and Chacaltaya are spread out over more than 30 degrees in longitude. Los Cerrillos (LC80, joined filled diamonds) and LARC (LARC80, joined filled triangles) particle directions are also reported for the 1980 year [4,5]. We can appreciate there the complementary cosmic ray information from LC detectors. Hence, a South-American network made up by LARC, LC and Chacaltaya will facilitate the study of longitudinal and latitudinal cosmic ray anisotropies during the different solar activity

Table I. – *Time variability of the vertical rigidity cutoff at LARC location (after* [6]*).*

Year (Cutoff in GV):	1960 (3.71)	1970 (3.60)
Year (Cutoff in GV):	1980 (3.38)	1990 (3.06)

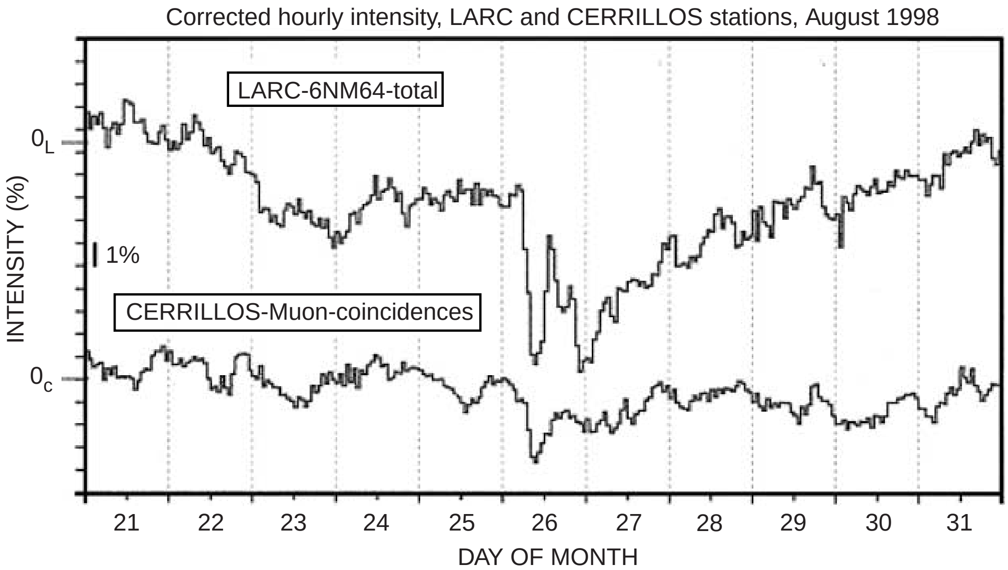

Fig. 3. – Forbush events at LRC and LARC during August 1998.

phases. However, we notice in fig. 1 the existence of particle direction changes at LARC from 1975 to 1980, due to induced effects by the secular variations in the geomagnetic field [6]. To exemplify them, table I summarizes the long-term vertical rigidity cutoff variability identified for LARC site.

We conclude that the use of the South-American detectors requires, in any detailed research, the evaluation of the corresponding cosmic ray asymptotic directions and cutoffs for the investigated periods.

3. – Some cosmic ray events during the current solar activity cycle

During November 6, 1997 the world-wide network of cosmic ray detectors identified the first ground-level enhancement (GLE) of the current solar activity cycle [7]. Figure 2 shows LARC data for this event together with the neutron monitor data reported by the Moscow (geographic latitude: 55.47 N, longitude: 37.32° E, altitude: 200 m a.s.l., cutoff: 2.43 GV) and Climax (geographic latitude: 39.37° N, longitude: 253.82 E, altitude: 3400 m a.s.l., cutoff: 2.34 GV) Web sites. The different time profile of the event at each location can be appreciated there. However, LARC and Climax GLE onsets occur in the same time interval: 12.00 UT to 12.15 UT; also the maximum phase (about 5 % above the reference level, using the 5-min time scale) is reached between 13.15 UT and 14.05 UT, suggesting that the time history of LARC and Climax data are similar, being both in the American sector. The Moscow detector shows, instead, a clear increase of the nucleonic component at 12.35 UT, with a net delay to both LARC and Climax neutron monitors. A summary of the characteristic solar parameters associated with this GLE event [8] can be made as follows:

i) *First group of data*: the related solar activity begins around 11.49 UT and goes to 11.53 UT, and it includes an active prominence disruption with an associated flare. The solar X-ray flare starts at 11.49 UT and have its maximum at 11.55 UT. The solar radio

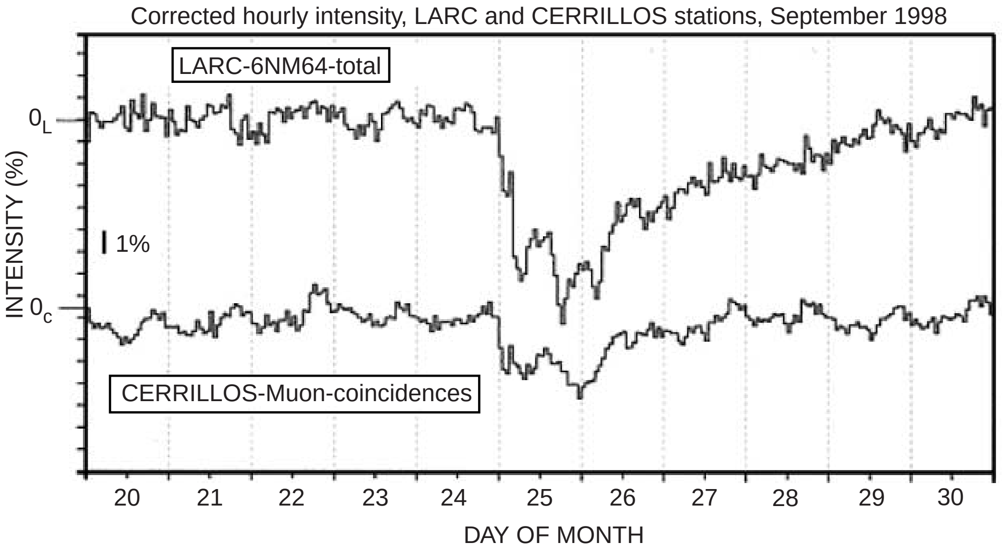

Fig. 4. – Forbush events at LRC and LARC, with significant minima, September 25-26, 1998.

emission observation has an initial evolution from 11.49 UT to 11.51 UT, with a time duration between 18.0 min and 25.0 min.

ii) *Second group of data*: there is a second active prominence disruption without an associated flare but accompanied by a solar radio emission starting at about 12.30 UT, classified as a long duration event (42.0 min to 59.0 min).

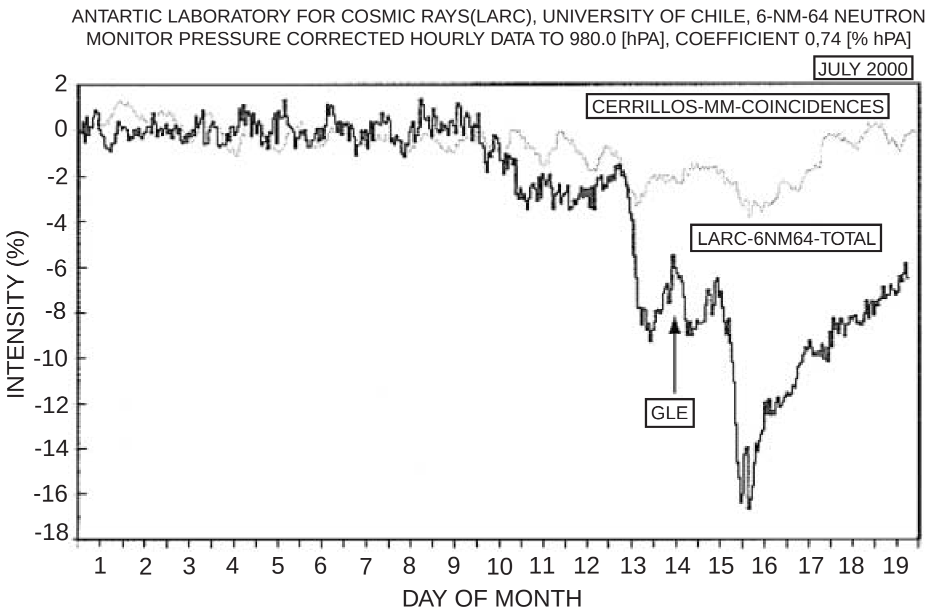

Fig. 5. – Forbush events at LRC and LARC, with a GLE event at LARC (July 14, 2000).

Certainly, this GLE is an interesting event to be studied with the global data set of the international cosmic ray network, available at the Air Force Research Laboratory of Hanscom AFB-MA, USA (gentile@plh.af.mil). Nevertheless, the preliminary evaluation of the LARC response to the November 6, 1997 event was reported [9, 10].

Figures 3 and 4 show two Forbush decreases registered by LC and LARC during the last eleven days of August and September, 1998. Because the LARC and LC stations are reached by particles having energies larger than 3 GV and 10 GV, respectively (see previous section), the maximun intensity depression of each Forbush event is registered by the detector located in Antarctica, where the geomagnetic shielding effect is lower.

Figure 5 illustrates for the same cosmic ray stations the recent Forbush decrease occurred during July, 2000. Inside this Forbush decrease another GLE occurred on July 14. The event is clearly identified in LARC records [11] but not in the ones of LC station. The continuous use of LARC, LC and Chacaltaya data will allow the evaluation of the energy dependence of such kind of events in the South-American sector.

4. – Conclusions

Ground level enhancements have a relevant role in the modern concept of space weather. GLE identification helps a prompt forecast of interplanetary disturbances in the near-Earth plasma enviroment and the short-term modulation of the galactic cosmic ray flux. A world-wide network of ground-based cosmic ray detectors distributed avoiding gaps in the South-American area is needed, and LARC and LC fill this gap. Nevertheless, we showed that by including Chacaltaya records of solar and galactic events a better view of the cosmic ray flux from the equatorial to the Antarctic zone can be obtained (see sect. **2**). Moreover, a recent study for the LARC station [6] confirmed a steady decrease in the LARC rigidity cutoffs, as it was found in the past for Huancayo station [12]. Hence, a similar behaviour is expected for LC and Chacaltaya sites. The knowledge of the influence of the changing geomagnetic field on cosmic ray measurements is a prerequisite of any good cosmic ray research on long-term–induced effects in the Earth environment.

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