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Long-term cutoff changes and L parameter at LARC neutron monitor location

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Abstract. Storini et al. (1999) found a significant change of the effective, lower and upper cutoff rigidities at LARC station (62° 12' 09" S , 58° 57' 42" W) over the past 40 years. Being the vertical cutoff rigidities well approached by the L parameter (Shea et al., 1987), we computed the L values using two different codes. Results show relatively strong variation for L, from 2.05 in 1955 to 2.21 in 1995. Moreover, the comparison between the predicted cutoffs, as derived from Shea et al. (1987) results, and the long term L evolution at LARC position is made. The rigidity cutoffs, especially the effective and the upper ones are well organized according to L and are suggesting a dependence even steeper than L^{-2} at the LARC position.

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1 Introduction

The magnetospheric transparency for cosmic rays is usually examined by the trajectory tracing of charged particles in a model of the geomagnetic field. A recent review (Smart et al., 2000) summarized progress on this topic. To organize particle rigidity cutoffs, the simplified estimates use the L parameter of the magnetic field (McIlwain, 1961). Shea et al. (1987) reported relatively large values for the secular changes of cutoff rigidities in Latin America and in both the North and South Atlantic ocean, after comparing the obtained values between 1955 and 1980. Flückiger et al. (1985), summarizing the sign of the change of cutoff at many cosmic ray stations, presented two tables from which it is apparent that at none of the stations of the Southern hemisphere there exists a positive change in time. The knowledge of the long term variations of particle cutoffs is relevant to estimate the cosmic ray modulation induced by

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solar activity from neutron monitors. Here we examine changes in cutoff rigidities for the period 1955-1995 at one particular cosmic ray station of South America: LARC (geographic coordinates 62.20°S, 58.96°W, height: 0.04 km), fitting them with a function of the local L McIlwain´s parameter and comparing results with the much smaller changes of cutoff and L at another middle latitude station in the Northern hemisphere: Lomnický Štít (LS: 49.20°N, 20.22° E; 2.634 m above sea level).

2 Long-term B and L variations at LARC position

The strength of the geomagnetic field $|\mathbf{B}|$ (DGRF models) for LARC and Lomnický Štít positions, as well as the L value computed at the altitude of 20 km, were evaluated using the procedure available at http://www.ngdc.noaa.gov/ and http://www.spenvis.oma.be, respectively. Results are plotted in Fig. 1 and Fig. 2; the B-strength is shown for a long time interval (1900-2000), while the L value only for 1945-2000.

Using the Z component of $\mathbf{B}$, the pitch angles of vertically accessing particles at both detector positions were also determined. The vertical direction (for which the calculations of particle trajectories are done to estimate the cutoff rigidities) corresponds with small variations to $\beta=25°$ at LARC and to 30° at LS position.

The two considered geographic locations (LARC and LS) had similar $|\mathbf{B}|$ values at the beginning of the last century (even if Lomnický Štít had a lower $|\mathbf{B}|$ at that time). While the LS local field is slightly increasing up to 2000, the LARC position is characterized by a very strong $|\mathbf{B}|$ decrease (up to ~ 36000 nT), i.e. by a factor of ~ 0.76. In early 50s the L values, as well as the corresponding cutoff rigidities, were at both locations very similar, if the local

pitch angles at the zenith direction are taken into account. Nevertheless from 1955 on there is a strong departure from such a behaviour: a fast increase of L for LARC and a corresponding decrease of the LARC cutoffs.
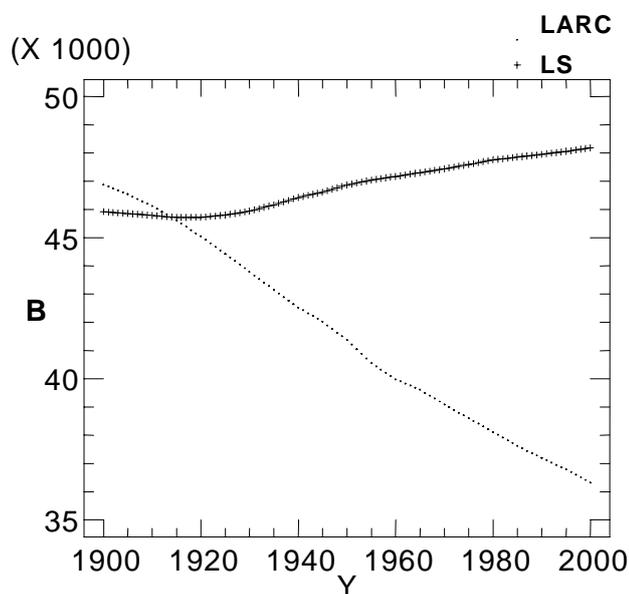

Fig. 1 – Time evolution of the magnetic field strength B in nT at the two considered cosmic ray stations during the last century (points: LARC, crosses: LS). Y stands for year.
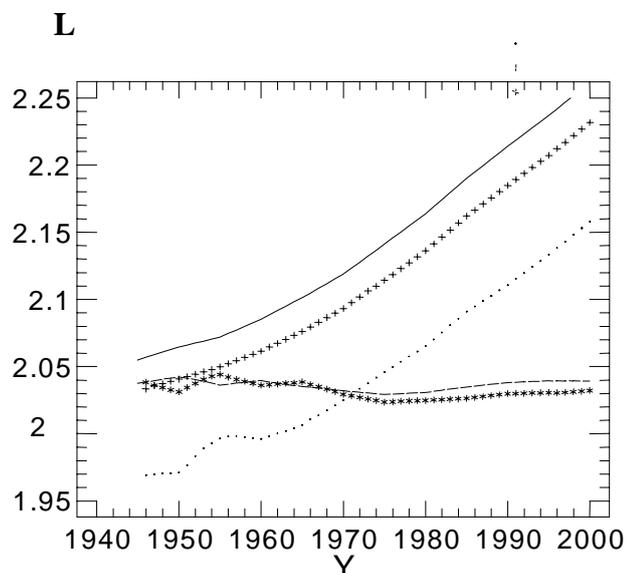

Fig. 2 – L value for LARC and LS in the period 1945-2000. The "flat" curves correspond to LS and pitch angle: 30° (stars) and 90° (dashed line). The enhanced L increase during the investigated epoch correspond to: $\beta = 25°$ (crosses), 10° (dots) and 90° (line).

3 Relationship between changing LARC cutoffs and L

Since variations of cutoff rigidities at LARC position, as well as the ones for L values, are large for the period 1955-

1995 (i.e. the lower RL, the effective RC and upper RU cutoff rigidities - as defined by Cooke et al., 1991 - and computed by Storini et al., 1999), it is of some interest to compare the LARC cutoff values with the local L parameter. Fig. 3 shows the effective and the upper rigidity cutoff values versus the estimated L from different approaches (see the caption). The best fits for K and α, as well as the corresponding correlation coefficients are presented in Table 1; L10, L30, L90 and LC are the same parameters of Figure 2.
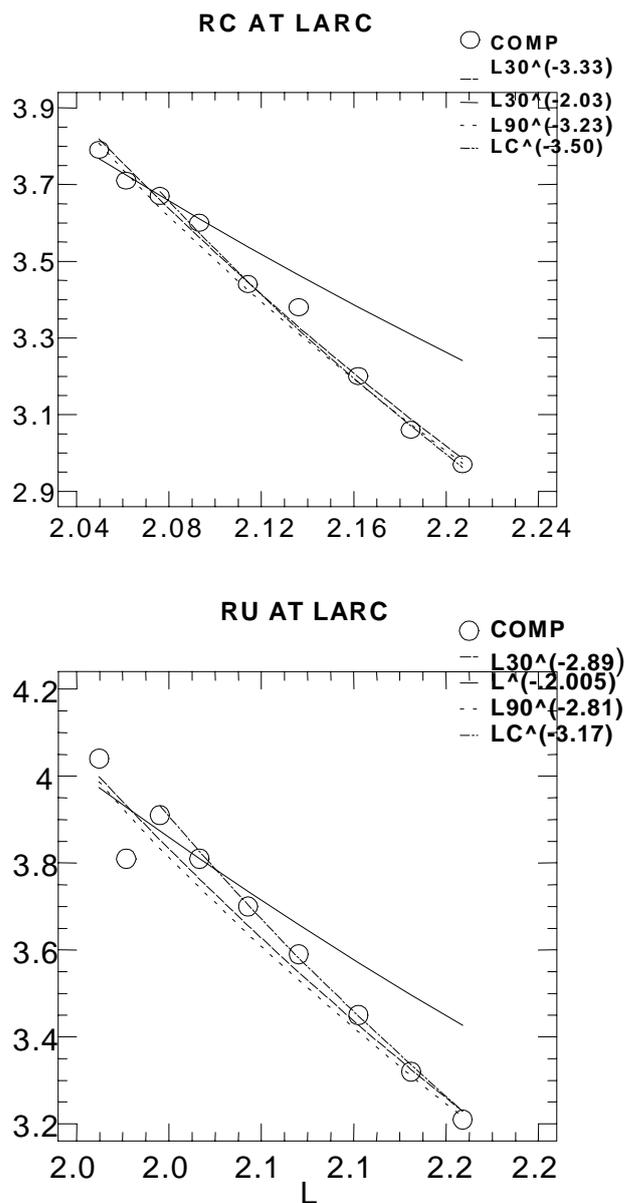

Fig. 3. The effective (RC: top panel) and the upper (RU: bottom panel) rigidities obtained by computations (Storini et al., 1999) plotted versus L at LARC for pitch angle 30° (circles, the highest value is for 1955, the lowest one for 1995). The dotted and dashed lines correspond to best fits (see Table 1) for $R=K \cdot L^{\alpha}$. L30, L90 and LC correspond to two different pitch angles β, namely 30° and 90° and to the values L obtained by CADR5 code (Galperin and Zinin, 2000, data for 1965-1995 only). The fits with a power law indices, taken from Shea et al. (1987) are plotted as full lines.

Table 1 – Results from the best fits of rigidity cutoff vs. L at LARC position (see the text for details).

Cutoff	L	ln (K)	α	Corr. Coeff.	Fit No
RL	L10	2.97±0.44	-2.64±0.61	-.85284	1
RU	L10	3.49±0.18	-3.05±0.25	-.97755	2
RC	L10	3.76±0.10	-3.53±0.13	-.99507	3
RL	L90	2.96±0.40	-2.47±0.53	-.87010	4
RU	L90	3.43±0.16	-2.81±0.21	-.98089	5
RC	L90	3.69±0.10	-3.23±0.13	-.99420	6
RL	L30	2.98±0.41	-2.54±0.55	-.86821	7
RU	L30	3.46±0.16	-2.89±0.21	-.98154	8
RC	L30	3.73±0.10	-3.33±0.13	-.99490	9
RL	LC	2.85±0.59	-2.32±0.76	-.80429	10
RU	LC	3.73±0.05	-3.17±0.06	-.99896	11
RC	LC	3.91±0.11	-3.50±0.15	-.99542	12

4 Discussion and conclusion

For earlier periods (epochs 1955, 1965 and 1980), Shea et al. (1987) - using large data sets and covering extended areas - obtained stable fits for the relationship between cutoff values (RU, RC, and RL) and L, being it of a power law character. The power index resulted to be close to –2. However, the L value as well as the rigidity cutoffs for Lomnický Štít cosmic-ray station are only slightly changing during the whole epoch here examined (see also Bobik et al., 2001). Moreover, the R vs. L dependence is not giving a clear trend. Instead, at LARC position the particle access characteristics are strongly changing over the past 40 years; the variability persists also after 1980 (Shea et al., 2000; Smart et al., 2000b; Storini et al., 2000b,c). The relatively large range of cutoffs computed and of estimated L values provided the possibility to check the mutual relationship between the parameters at this particular position (62.20°S - 301.04°E). From Fig. 3 and Table 1 it is clear that the L dependence on LARC cutoffs is steeper than expected. Similar values of α, as listed in Table 1, were obtained by checking L also at different altitudes (not shown here). In agreement with Shea et al. (1987) the best fit is for RC and the worst one for RL, if the complete interval of 40 years is analyzed. If only the 1955 – 1980 period is included in the analysis, lower values of α are obtained, closer to those reported earlier.

The long term check of cutoff variability in the South American region, which is important for the neutron monitor data correction, remains a relevant task for the future (Storini et al., 2000a), particularly if cosmic ray intensity variability will be studied on a long term scale.

Also the relatively large L variability here obtained can be used for further studies on the secular cutoff dependence.

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