Cosmic Ray variability around the geomagnetic disturbances

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Abstract

Various measures of CR variability and simplified estimates of CR anisotropy at 4 middle and high cutoff rigidity are checked in relation to Dst in 1982–2002. Different distribution of variability indices ∼24 h before the sharp Dst decrease in comparison with the quiet periods is found. Multiple regression of Dst with prehistory of CR variability is described. However, no connection to the polarity of IMF Bz is deduced from the introduced CR characteristics.

1. Introduction. Data base

CR relations to geomagnetic activity are studied since [3]. Recently the space weather attracted this item again: CR anisotropy/variability connected to geomagnetic activity is checked ([1, 2, 4–7, 9–11] and others). Some of the earlier studies used either a ring of high latitude neutron monitors (NM) or multidirectional muon telescopes. We summarize the statistical properties of CR variability at 4 medium and high cutoff NMs before geomagnetic disturbances. The hourly values of pressure corrected data from 4 NM in 1982–2002 are used: Lomnicky Stit (LS, Rc ∼ 4 GV), Rome (RM, IFSI/UNIRoma3 coll., Rc∼6.3 GV), Beijing (BJ, Rc∼10.2 GV), Huancayo/Haleakala (HH, data from http://ulysses.sr.unh.edu/NeutronMonitor, Rc∼12.8 GV). The disadvantage of medium/low latitude NMs is wide asymptotic longitude range. The advantage is low number of GLEs. Simplified estimates of CR anisotropy and temporal variability are computed at each hour T. D1 = |LSI-1| + |RMI-1| + |BJI-1| + |HHI-1|, where LSI, RMI, BJI, HHI are the intensity at NMs normalized to the mean over past 24 h (T-25, T-1), is a simplified measure of the CR anisotropy. The diurnal variation is fitted. The sum of squares of deviations between fit and observations at each NM (DLS, DRM, DBJ, DHH) are measures of CR variability over 24 h without the diurnal wave. VN (CR variability at $N = 3, 6, 9, 12, 24$ h) are ratios of the standard deviation to the mean in (T-N-1, T-1). Solar wind speed (v), density (n), IMF Bz and Dst are used from http://nssdc.gsfc.nasa.gov/omniweb and http://swdcdb.kugi.kyoto-u.ac.jp/dstdir.

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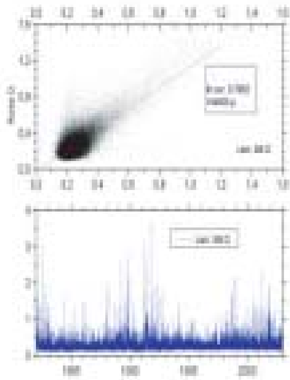

Fig. 1. DLS (lower panel) and a scatter plot of DRM vs. DLS.

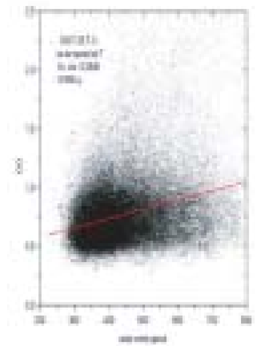

Fig. 2. DD(T) obtained from (T-25, T-1) plotted versus the solar wind speed v (km/h) at T for 1982–2002.

2. Results and discussion

Values D can be used as indices of CR activity for middle and high cut-off NMs (Fig. 1). The highest correlation (0.788) for pairs of D values is for LS-RM, the lowest one for the two high cut-off stations BJ-HH (0.490). DD (mean of D from all NMs) is correlated with the solar wind velocity (Fig. 2, r = 0.265). Correlations of $\mathrm{DD(T+12)}$ and $\mathrm{DD(T-12)}$ vs. v are both < 0.230, significantly lower (http://faculty.vassar.edu/lowry). Including high cut-off NMs increases the correlation of DD vs v (the highest one from single NMs is that of HH, r = 0.234). The correlation with n is < 0.05 and with Bz is < 0.03 with no indication of a clear connection with these parameters.

The complexity of CR variations before and during a large geomagnetic storm on March 30–31, 2001 shows Fig. 3. While signatures of anisotropy and/or rigidity spectra change is seen at the beginning of day 86 and during a slight disturbance (18–24UT on 86), a small anisotropy appears on days 88, 89. Just 1–2 hours before the strong decrease of Dst (04 UT on 90) the CR anisotropy increases significantly. The correlations of Dst with different measures of the CR variability introduced here are summarized in Fig. 4. Around the previous solar maximum (1991–1992) a clear correlation of Dst vs. the prehistory of CR variability at a single NM was found [6]. For the long period here considered, the asymmetry although persistent, is less pronounced and dependences on the time lag are flatter.

We selected sharp Dst decreases: 83 cases $\mathrm{Dst(T)} - \mathrm{Dst(T-1)} < -50$ nT are found. The differences in distribution of DD, VN, $\mathrm{D1}(T-M)$ for that subset compared with the quiet intervals are found (N = 3, 6, 9, 12; M = $1, \ldots, 15$).

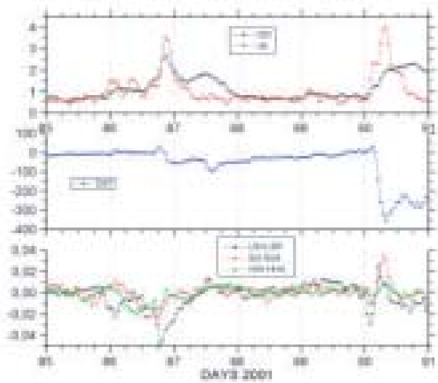

Fig. 3. From bottom to top: LSI, BJI and HHI; Dst; DD and V6 respectively.

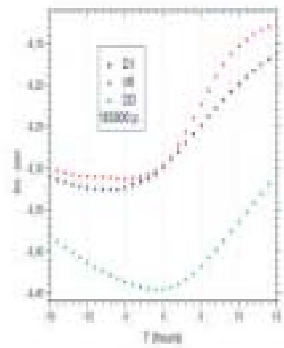

Fig. 4. Coefficient r of different measures of CR variability: DD(T-25, T-1), V6(T-7, T-1), D1(T-1) with Dst(0) for the dataset 1982–2002. The confidence intervals at 0.95 level are $\sim \pm 0.003$ and $\sim \pm 0.004$ for r = 0.45 and r = 0.25 respectively.

While DD > 1 for $\sim 2/3$ of all disturbed cases, in quiet conditions it is valid only in 7% cases. We checked the possibility to use the CR variability/anisotropy characteristics for a simple forecast of Dst(T): using DD(T − L), V6(T − L) and D1(T − L), $L = 1, \ldots, 18$ by multiple regression on the data set. The quality of the fit is characterized by the correlation coefficient of the model vs. data. The results are in Table 1. Correlation coefficients r of the fit $\mathrm{Dst(T)} = \mathrm{A_0} + \mathrm{A_1.Q(T - L_1)} + \ldots + \mathrm{A_N.Q(T - L_N)}$ is listed.

$L_1,\ldots,L_N$|Variables Q	DD	V6	D1
3,6,9	0.456	0.375	0.369
6,9,12	0.443	0.374	0.370
9,12,15	0.426	0.368	0.359
3,6,9,12	0.458	0.393	0.389
6,9,12,15	0.444	0.389	0.380
3,6,9,12,15,18	0.461	0.414	0.400

Including only low L parameters r does not improve significantly. The best fit from the checked ones was that of DD in the last row of the table (r=0.461).

3. Summary

Extensive data set of CR variability and simple estimates of anisotropy over 21 years from 4 NMs combined with IMF, solar wind and geomagnetic indices (derived here) is suitable for the statistical check of the relevance of middle and high cut-off CR measurements for geomagnetic activity forecast and for case studies. DD index is correlated with the SW speed. A combination of many interplanetary events (various duration and geometry), either causing the geomagnetic disturbance or not (e.g. when a CME is not passing the Earth's orbit), affects the angular distribution and rigidity spectra of CR at Earth and probably leads to a flat cross-correlation between the Dst and the prehistory of CR variability/anisotropy in summary statistics. None of the parameters analyzed here is clearly correlated with IMF Bz. However, the asymmetry of the cross-correlation mentioned, the difference in parameter distribution before the sharp Dst decreases in comparison with the quiet time periods, and the relatively high correlations of the multiple linear regression of the fits of Dst using prehistory of CR, indicate that the CR variability/anisotropy parameters are probably useful as additional parameters (to IMF and solar wind) for the geomagnetic activity forecasts. For that the addition of data from more NMs (e.g. those collected in WDC-C2[12]) into the data set and using methods such as ANN [8] will be useful. Some of the tasks are in progress.

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4. References

1. Belov A.V. et al. 2001, Proc. 27^{th} ICRC 9, 3507
2. Bieber J.W. and Evenson P. 1998, Geophys. Res. Lett. 25, No 15, 2955
3. Forbush S.E. 1937, Phys. Rev. 51, 1108
4. Hofer M. and Flückiger E.O. 2000, J. Geophys. Res. 105, A10, 23,085
5. Kozlov V.I. et al. 2001, Proc. 27^{th} ICRC 9, 3562
6. Kudela K., Venkatesan D., and Langer R. 1995, J. Geomag. Geoel. 48, 1017
7. Kudela K. et al. 2000, Space Sci. Rev. 93, 153
8. Lundstedt H. and Wintoft P. 1994, Ann. Geophys. 12, 19
9. Munakata K. et al. 2001, Proc. 27^{th} ICRC 9, 3494
10. Munakata K. et al. 2000, J. Geophys. Res. 105, 27,457
11. Storini M. et al. 1999, ESA WPP-155, 339
12. Watanabe T. 2001, personnal communication