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Cosmic Ray Modulation Versus Corona Variability During the Maximum Phase of the 11-year Cycle

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Abstract

The relationship between the modulation level of galactic cosmic rays (as derived from polar-looking neutron monitors) and the one of several coronal parameters (green line brightness, solar soft X-ray background, soft X-ray flares) is investigated during the maximum phase of solar activity cycles 20 and 21. It is shown that during this phase the parameter variability tends to be reduced and the correlation between corona parameters and cosmic ray intensity is lost in a wide range of data resolution. These results emphasize the relevance of the Gnevyshev gap in the solar atmosphere (Feminella & Storini, 1997) and justify the search for effects in the heliospheric environment (Gnevyshev Gap Investigation/ISSI International Project/Bern).

1 Introduction:

The study of the cosmic ray modulation during the maximum phase of the 11-year cycle demonstrates the existence of a time interval in which cosmic ray variability is strongly reduced (e.g. Storini & Pase, 1995; Astaf’eva et al., 1997; Storini et al., 1997; Bazilevskaya et al., 1998). This time interval seems to be related to the so-called Gnevyshev gap (Storini, 1995) found in several solar activity parameters (Feminella and Storini, 1997 and references therein). Hence, the relationship between cosmic ray modulation at neutron monitor energies and corona variability is under investigation. In this paper we present a summary of the obtained results for solar activity cycles n. 20 and n. 21.

2 Data used:

In this investigation the following data sets were used:

- (i) the daily intensity of the isotropic nucleonic component of cosmic rays (CR: average energy about 10-15 GeV), from January 1968 to December 1983 (RAC-ANT database). It was derived from the average intensity of five near polar-looking detectors located in the opposite hemispheres (Alert: deg. 82.50N, 62.33W - height: 57 m a.s.l.; McMurdo: deg. 77.90S, 166.60E - 48 m; South Pole: deg. 90.00S - 2820 m; Terre Adelie: deg. 66.67S, 140.02E - 35 m; Thule: deg. 76.50N, 68.70W - 44m).

- (ii) the monthly values of the green-line (Fe XIV 530.3 nm) coronal brightness (GCB), expressed in absolute coronal units (a.c.u.), from January 1965 to December 1985. The data set was created from daily patrol coronagraphic measurements, regularly carried out by a small world-wide network of observatories, transformed to the photometric scale of Pic du Midi Observatory. Coronal brightness, both from the Eastern and Western (14 days later) limbs, was averaged to derive the central meridian intensities. Successively, monthly means were computed for each heliographic latitude included between -90° and +90°, by steps of 5 degrees (i.e., -90°, -85°, -80°,... up to +90°).

- (iii) the daily full-disk soft (0.1-0.8 nm flux) X-ray background (XBG), in units of 10^{-8} Wm^{-2}, from April 1968 to December 1982.

- (iv) the daily flare index for all soft X-ray flares (larger than B5 and disregarding their time duration: X-TFI), in units of 10^{-6} Wm^{-2}, from January 1969 to December 1982.
- (v) the daily flare index for long-duration soft X-ray flares (X-LDE flares, lasting more than 2 hours), in units of 10^{-6} Wm^{-2}, from January 1969 to December 1982.
- (vi) the daily flare index for short-duration soft X-ray flares (X-IMP flares, lasting less than 2 hours), in units of 10^{-6} Wm^{-2}, from January 1969 to December 1982.

A detailed description of soft X-ray parameters was given in Storini, Antalová & Jakimiec (1995). Here we only add that data sources are the measurement performed by several satellites (e.g. SOLRAD9, SMS1, SMS2, GOES series). Moreover, each daily value of the X-flare index has been obtained as the sum of the peak intensities of all the LDEs (IMPs) occurring on the day considered.

3 Data analysis and results:

For the isotropic nucleonic intensity the standard deviation (SD) analysis of the daily data in relation to the monthly average was performed, together with the 5-point running averages of the monthly SD. Figure 1 shows the obtained results (CR-SD) together with the sunspot number trend for solar activity cycles n.20 and n.21. During cycle 20 a prolonged time interval of SD minima is observed during its maximum phase, while during cycle 21 it is more reduced (see also Krainev et al., 1999 for SD values computed using data from other cosmic ray stations).

For each month the 37 values of the GCB (i.e. from –90° to +90°) were used to evaluate the GCB-SD in 1965-1985. Figure 2 illustrates the obtained data trends.

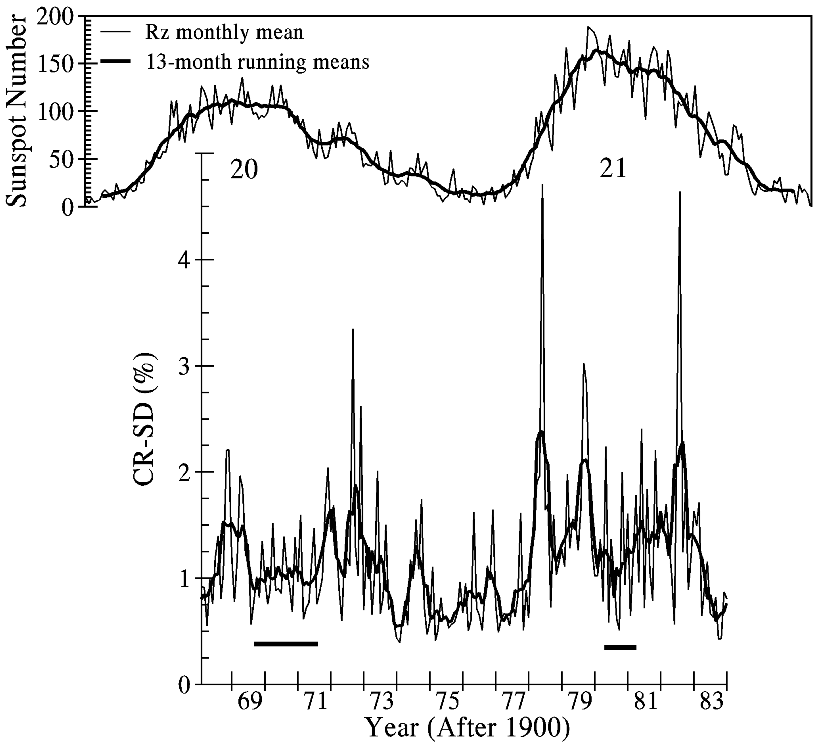

Figure 1: Monthly means of the sunspot number (Rz) and 13-month running means of Rz (upper panel), together with the standard deviation of the isotropic nucleonic intensity (CR-SD; thin line of the lower panel) and its 5-month running averages (thick line, lower panel). Segments show CR-SD minima during the maximum phase of cycles 20 and 21

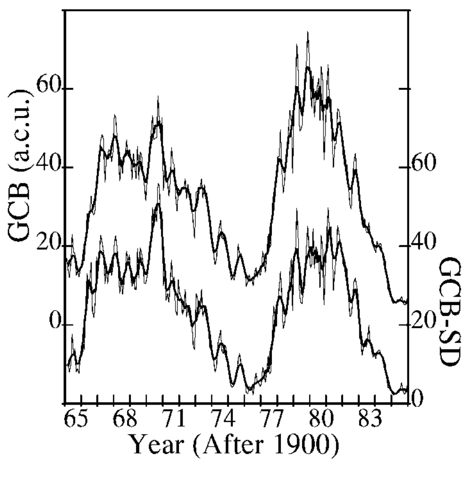

Figure 2: Monthly GCB (upper curves, left scale) and GCB-SD (lower curves, right scale), estimated from the 37 latitudinal values at the central meridian of the Sun (thin lines) and their 5-month running averages (thick lines).

Due to the high oscillating behaviour of the GCB-SD the Gnevyshev gap in Figure 2 is not clearly seen, but the 5-month running averages show a long valley in cycle 20 and dips in cycle 21 (with a relative minimum in 1980). When the GCB is investigated in the solar hemispheric activity the Gnevyshev gap is better identified (e.g. Gnevyshev, 1977 and references therein). On the other hand, the total green corona brightness is the result of solar activity at the different heliolatitudinal belts, which implies contemporary regions with high and low intensity levels. Feminella & Storini (1997) showed that the Gnevyshev gap is more distinct when solar parameters related to intense and/or long-lasting activity events are considered. The SD-analysis applied to the soft X-ray parameters demonstrates that their monthly means presents clear relative minima or dips during 1969 and 1980, as their SD values (Figure 3).

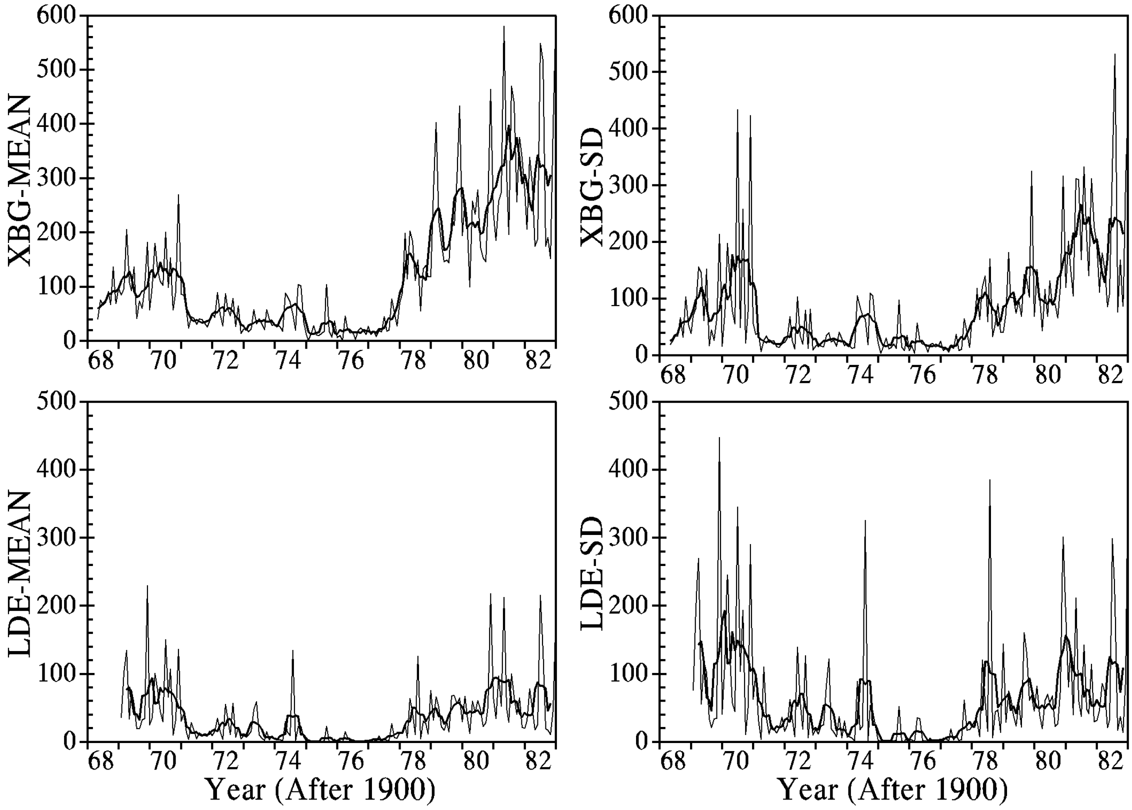

Figure 3: Monthly averages of XBG (solar soft X-ray Background) and LDE (long duration X-ray flares) indices together with their 5-month running averages (left panels, thin and thick curves, respectively) and SD and 5-SD values (right panels).

More details will be given at the poster session of this conference. We only notice, that these findings, added with the ones obtained by Feminella & Storini (1997), support the reliability of the Gnevyshev gap in the solar atmosphere.

Cross-correlation analysis of daily cosmic ray data and soft X-ray parameters have been also performed. During the maximum phase of each solar activity cycle (see also Jakimiec, Storini & Antalová, 1995 and 1997) there is a clear lost of correlation between CR and X-ray parameters; the same result is obtained using averaged data for different time intervals (e.g. 3, 7, 15, 27,… days): only a week relationship with the very short-term corona variability is identified, but not traces are found using monthly averages of each year. For a more longer time-scale (annual averages) the relationship is rebuilt, i.e. the quasi-stationary component of the cosmic ray modulation is well related with the quasi-stationary corona variability, as shown by Storini et al. (1997). Moreover, it was found that the degree of linkage between cosmic ray intensity and solar soft X-ray parameters is highly dependent on the solar activity phases.

4 Conclusion and remarks:

We are investigating the corona variability on different time scales by means of the green corona data and several soft X-ray parameters. Structured activity maxima are seen in the corona layer in each 11-year activity cycle (Figures 2 and 3), with a period in-between (called ‘Gnevyshev gap’) in which the dynamical component (SD) of the coronal parameters has its relative minima. We believe that the phenomenon is connected with the time variability of the magnetic energy released from the sun (Feminella & Storini, 1997; Bieber & Rust, 1995). Figure 1 reported by Krainev et al. (1999) shows the effects of the Gnevyshev gap on the interplanetary magnetic field intensity and in the power of its fluctuating component, as in the cosmic ray data. Our Figure 1 shows the SD variability of the isotropic nucleonic intensity derived from near polar-looking neutron monitors. We understood that the Gnevyshev gap has a role in the heliospherical physical conditions. We expect that the International Project on the Gnevyshev gap of the ISSI/Bern will clarify several aspects of the matter.

5 Acknowledgements:

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