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Correlation of the 27-day variation of cosmic rays to the interplanetary parameters

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Abstract. We analyze cosmic ray data as well as interplanetary magnetic field (IMF) data, to examine the relation and correlation between their 27-day variations during the time interval 1965-1995. The amplitude of the 27-day variation of galactic cosmic rays is linearly correlated with: the IMF strength (B), the z-component (Bz) of the IMF vector and the product of the solar wind speed (V) times B (VB). It is well correlated with the heliospheric current sheet tilt angle. The cross-correlation function of the 27-day cosmic ray variation versus the solar wind speed shows a negative correlation. The solar wind speed leads the cosmic ray variation by 2 years. The 27-day variation of cosmic rays is correlated with the variation in both the x- and y-components of the IMF, it lags with 3-5 years.

1. Introduction

Galactic cosmic rays are modulated (modified) through their propagation in the heliosphere by the effect of the large scale structure of the interplanetary medium. A wavy structured neutral current sheet (NCS) separates the heliosphere into two regions of opposite magnetic polarity. During positive magnetic phase, the interplanetary magnetic field (IMF) is directed away from the Sun above the NCS and toward the Sun south of it. During negative magnetic phase the IMF direction is reversed. The angle between the Sun's equatorial plane and the NCS is referred as the tilt angle R, of the neutral sheet. It exhibits a solar activity dependence, R is small near sunspot minimum and large near solar maximum. The 27-day variations of galactic cosmic rays have been related to the changing position of the interplanetary NCS (Swinson and Yasue, 1992; Valdes-Galicia and Dorman, 1997). Here we examine the effect of the interplanetary parameters upon the 27-day variation of galactic cosmic rays during the last three solar cycles.

2. Solar Cycle Dependance

We used hourly averaged cosmic ray counts observed with neutron monitors at Deep River (DR) and Huancayo (HU) and muon surface telescope at Nagoya (NA). The amplitude of the 27-day variation has been calculated for each detector for every solar rotation during the time interval 1965 to 1995 (Sabbah, 2001). The 13-solar rotation running averages of the amplitude of the three detectors are displayed in the top panels (a & b) of Fig.1. We also used hourly averages values of IMF and plasma (OMNI data base form NSSDC) collected by variety of spacecraft near 1 AU during the same period in order to study their effect upon the 27-day cosmic ray variation. The 27-day averages of each solar rotation have been calculated for: field magnitude B, its components in the geocentric solar ecliptic coordinates (Bx, By, Bz), solar wind speed V and the product VB (Sabbah, 2000). These data cover three solar cycles (20, 21, 22). In panel (f), we plot the smoothed NCS tilt angle R. We see from the top panels (a & b) of Fig. 1 that the amplitude of the 27-day variation of cosmic ray exhibits an 11-year sunspot cycle variation, with minima occurring near sunspot minimum represented with dotted vertical lines at 1976 and 1986 and maxima occurring near sunspot maximum denoted with dashed vertical lines at 1968, 1979 and 1989. The values of the IMF magnitude B shown in (b), the product VB shown in (e) and the NCS tilt angle R, shown in (f), display separate solar cycle variation during cycles 21 and 22. Their values track the variation in the 27-day cosmic ray amplitude. The values of B and VB are enhanced right after solar activity maximum in 1979 and

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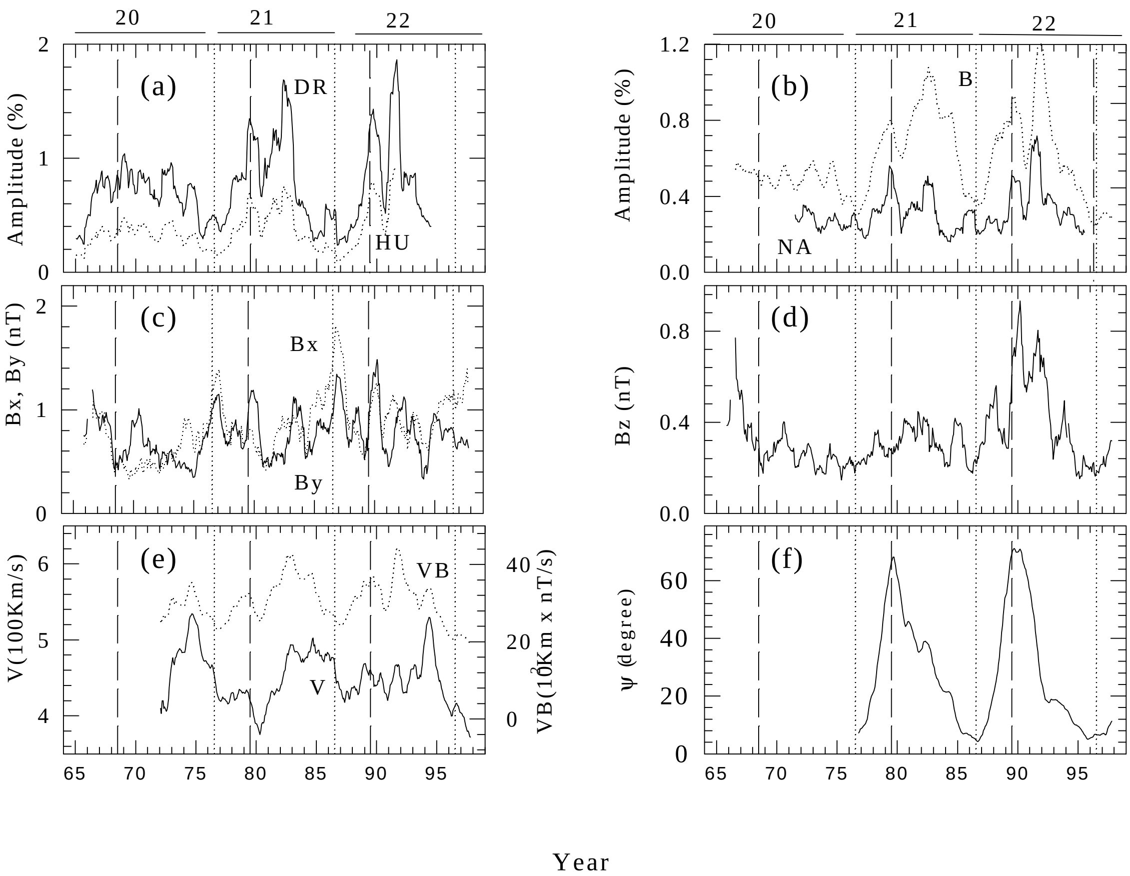

Fig. 1 Plots of the smoothed (13 point averages) of the 27-day averages of: (a & b) The cosmic ray amplitudes, (b) the IMF magnitude, (c & d) the IMF components, (e) the solar wind speed and the product VB and (f) the NCS tilt angle.

1989. The cosmic ray amplitudes are enhanced during the same time as well (See panels, a & b). The Bz component of the IMF is also related to the variation in cosmic ray amplitude, it reaches the highest value right after solar activity maximum in 1989. The other two field components (B_x and B_y) reach their highest values during solar activity minimum.

4. Cross-Correlation Function

Here we study again the correlation between the cosmic ray 27-day variation and the IMF and plasma parameters, but with time lag. We shift the cosmic ray amplitude one solar rotation (27-day) at the time forward (or backward) with respect to each parameter and calculate the correlation coefficient each time. In Fig. 2, we plot the cross-correlation function (CCF) of HU neutron monitor which has the best correlation with the sunspot number among the three detectors. The CCF has been displayed for various time lags (0, ±27, ±54,........, ± 4320 day). We see from Fig. 2 that the cosmic ray amplitude is linearly correlated (lag= 0) with: the IMF strength with correlation coefficient (r=0.74), the product VB (r=0.67), the NCS tilt angle R shown on (d) with r=0.95 and the Bz filed component with r=0.5. The CCFs of theses parameters are symmetric around the zero time. The two minima around the zero make ~11-year cycle while the two maxima makes ~20-year cycle. We also see a negative correlation between cosmic ray variation and the solar wind speed shownin Fig. 1a, with r=0.76 at time lag of -2 years (the solar wind speed V leads cosmic ray amplitude). This is also clear form Fig. 1: the cosmic ray amplitude reaches maximum ~2 years after solar wind speed minimum in 1980. It also reaches minimum ~2 years after solar wind maximum in 1974. The other two filed components (Bx & By, shown in Fig. 1c) lag the 27-day amplitude with 5 and 3 years respectively.

5. Conclusions

In this analysis, we have examined the effect of the interplanetary parameters upon the 27-day cosmic ray variation during the time interval 1965 to 1995. We show that the 27-day variation of the cosmic ray amplitude is linearly correlated with the NCS tilt angle R, the IMF magnitude B,

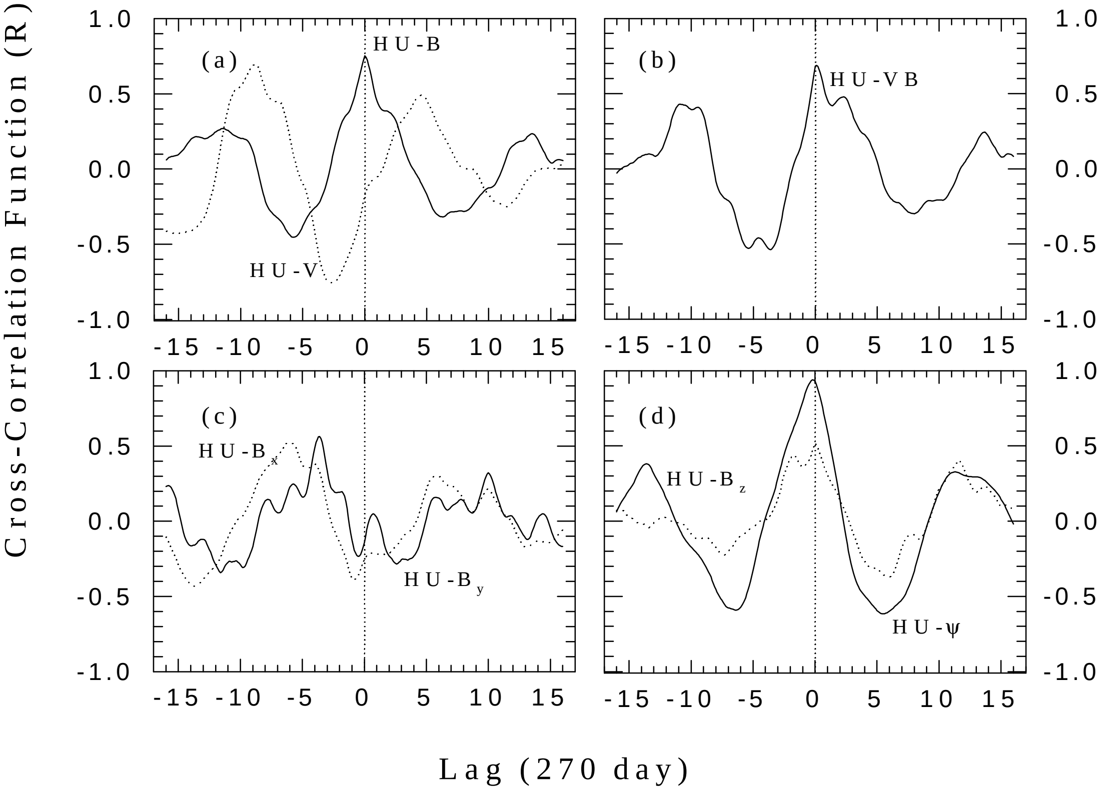

Fig. 2 Cross-correlation function of the 27-day cosmic ray amplitude versus the interplanetary parameters.

its product with the solar wind speed (VB) and the Bz component of the IMF vector. This correlations show solar as well as magnetic cycle variations. The cosmic ray 27-day amplitude is also related to the solar wind speed V and the other two components of the IMF, with time lag. The most effective parameter that contributes to the 27-day modulation is the neutral current sheet tilt angle.

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