VARIATIONS OF INTERPLANETARY PARAMETERS AND COSMIC-RAY INTENSITIES

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ABSTRACT

Observations of cosmic ray intensity depressions by earth bound neutron monitors and measurements of interplanetary parameter's variations aboard geocentric satellites in the period January 1972-July 1974 are analysed and grouped according to their correlation among them. From this analysis of about 30 cases it came out that the majority of the depressions correlates with the average propagation speed of interplanetary shocks as well as with the amplitude of the interplanetary magnetic field after the eruption of a solar flare. About one fourth of the events correlates with corotating fast solar wind streams. As the recovery time of the shock-related depressions depends strongly on the heliographic longitude of the causitive solar flare, it seems that the cosmic ray modulation region has a corotative-like feature.

I. INTRODUCTION

Many authors, in order to find the mechanism of cosmic ray decreases, investigated any possible relations between cosmic ray intensities and interplanetary and solar parameters (Conforto, 1973; Barnden, 1973; Hedgecock, 1975; Bland, 1976; Barouch and Burlaga, 1975; Kane, 1977; Iucci et al., 1973, 1975; Lockwood and Webber, 1977). In many of these studies only the pronounced CR decreases, the so-called Forbush Decreases (Forbush, 1966; Lockwood, 1971) were used and their characteristics as the amplitude and the recovery time, were related to solar flares, IMFs, solar wind velocities, and hydromagnetic shock waves (Dryer, 1975). Barouch and Burlaga found inverse correlations between almost all kinds of CR intensity fluctuations and IMF amplitude, observations which are also supported by Lockwood and Webber (1977).

In the past most times the well-known models of Gold (1960), and Parker (1963) have been used to explain the CR decreases. However, unique conclusions could not always be drawn because of the lack of

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knowledge on the state of the interplanetary plasma and the processes going on there. Therefore, in this work we continue correlative studies of earthbound CR observations and in situ plasma observations. Using low rigidity neutron monitor stations cosmic ray data we identify CR decreases and compare them to simultaneously occurring enhanced solar activity, IMF amplitude and solar wind velocity, in order to improve our understanding of the macroscopic conditions and mechanisms responsible for these decreases.

II. DATA PRESENTATION

Neutron monitor data from Alert and Deep River stations of the period January 1972 to July 1974 showing CR decreases are analysed together with interplanetary parameters measured by HEOS 2, or taken from multiple spacecraft measurements (Grunwaldt, 1975; King, 1975). For each CR decrease greater than 2% the hourly averages of neutron monitor data corrected for atmospheric pressure and normalized to the counting rate just before the depression were plotted. Long-term variation corrections were not applied because of the relatively short time period under consideration. The diurnal variation effect was taken into account for the estimation of the maximum depression. Three-hour averages of the solar wind speed and the IMF amplitude in the vicinity of the earth were plotted for the same periods of time. An example of a moderate CRD falling into a high speed solar wind stream and not related with any solar flare or a Storm Sudden Commencement (ssc) is shown in Figure 1.

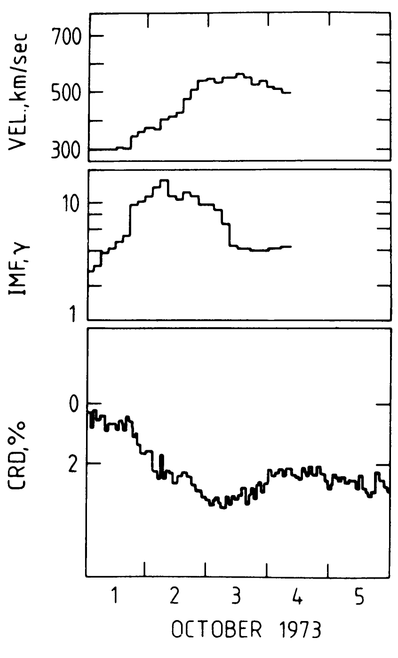

Figure 1. A high speed solar wind stream falling into a CR decrease.

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The travelling time of the solar wind from the point of observation to the magnetosphere could be neglected. We used the time delay between the flare onset and the observed ssc in order to calculate the mean transient velocities of the interplanetary disturbances which were suspicious of having caused a CRD, and we tried to identify the solar flares which possibly could have generated these disturbances. The selection criteria of the flares were that their optical importance was greater than 1 N and the time delay was no longer than six days.

3. DISCUSSION-CONCLUSION

Assuming radial expansion of shock waves, the correlation between their mean propagation speed and the amplitude of the related CRD came out to be positive, Figure 2.

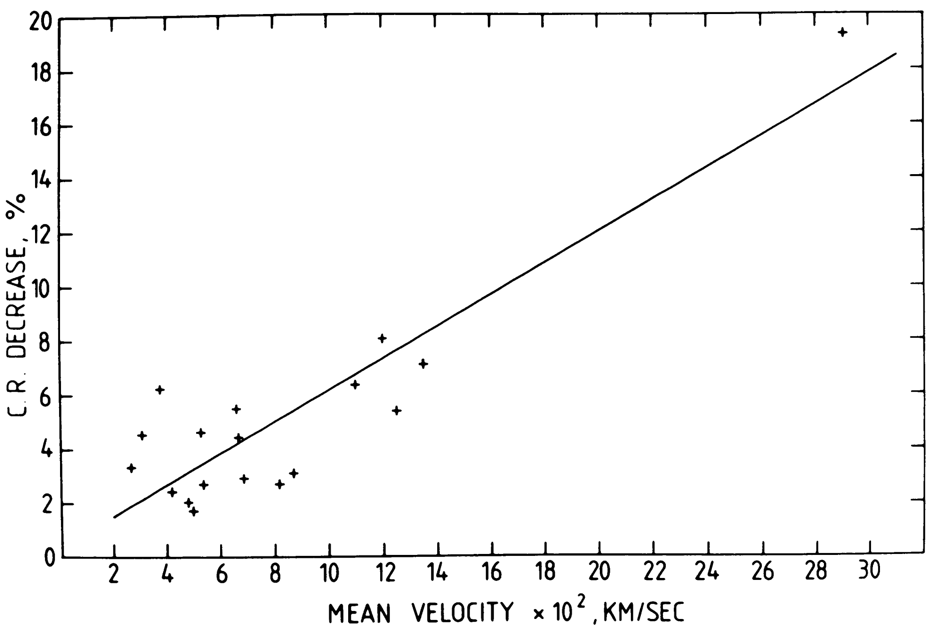

Figure 2. Correlation between cosmic ray depressions and the mean propagation speeds of the related shocks.

The same correlation of solar wind stream-related CRDs showed to be only qualitative, where now the maximum speed of the stream during the CRD is used. For the same cases we correlated the maximum amplitude of the IMF observed at 1 AU with the amplitude of the CR depressions, and we got a similar relation (Figure 3).

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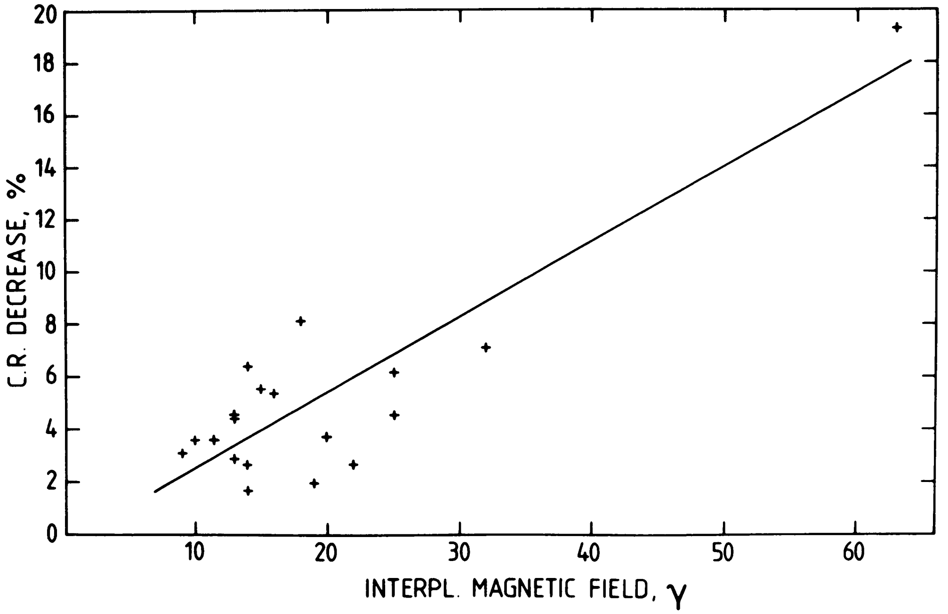

Figure 3. Correlation between cosmic ray depressions and IMF amplitude for shock related events.

The correlation between CR depressions and fast solar wind streams, where a shock wave was absent, was almost zero. Again, for the shock related cases we calculated the momentary speed (W) of the shock assuming a radially symmetric motion and mass conservation

$$W = (V_2N_2 - N_1V_1)/(N_2 - N_1)$$

where V and N are the measured speeds and densities of the solar wind, and subscripts 1 and 2 refer to values before and after the shock front passage, respectively. Correlation between W and CRD amplitude failed. This was due perhaps to the fact that W characterizes the shock only at the time of the observation, where the mean propagation speed characterizes the motion of the shock from the sun up to 1 AU. In order to estimate whether or not the modulation region in which CR are depressed corotates with the sun, we plotted the recovery time for each CRD (i.e., the time which is needed for the CR to reach its predecrease value) with the heliographic longitude of the related flare, Figure 4. It is evident that long-recovering CRDs correspond on the average to solar flares generated in the eastern part of the solar disc, while short recovering decreases correspond to flares in the western part. This "asymmetry" could reveal a westward corotative motion of the modulated region and therefore, for eastern situated flares, the earth-bound neutron monitors remain longer inside the modulation region, while for western flares this time is considerably shorter. The positive correlation between CRD and mean propagation speed of the shock, shown in Figure 2, could emphasize the "frozen-in" characteristics of the IMF in the solar wind.

Finally, due to the positive correlation between the CRD amplitude and the IMF amplitude, as well as mean speed of the related shock, and due to the negative correlation between the recovery time of the heliographic longitude of the causitive flare we suggest that the cosmic ray modulation region has to corotate with the sun as it expands radially with the characteristics of a shock front.

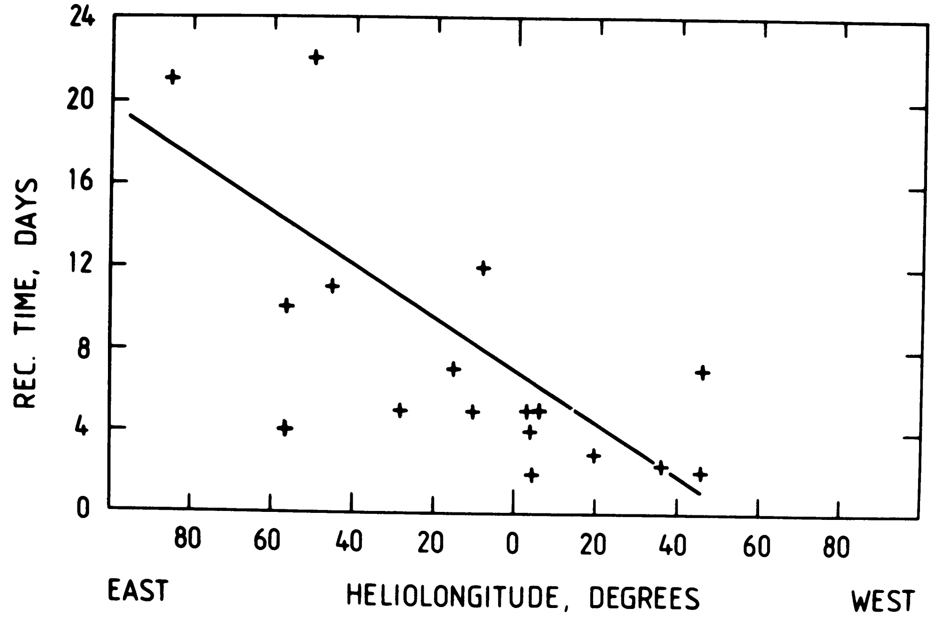

Figure 4. Correlation between the recovery time of CRD and the heliographic longitude of the related flare.

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