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Testing cosmic ray continuos records for Space Weather

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The response of the nucleonic intensity to the passage of interplanetary perturbations is here discussed for two solar activity epochs: January 7-15, 1997 (near the minimum phase) and August 8-16, 2000 (near the maximum phase). Several algorithms were used to test cosmic ray data for nowcast and forecast issues of Space Weather. It is found that interplanetary coronal mass ejections can be easily identified from indices derived from neutron monitor records.

1. Introduction

Cosmic ray (CR) continuos records are indispensable tools for Space Weather studies. Their use ranges from precursor indices for interplanetary disturbances to dose evaluation on board airplane, satellite and space station [1]. In this context the improving of our learning for nowcast and forecast works is demanded.

Several CR indices to describe the near-Earth space were tested by us. They are mainly based on a simplified measure of the CR anisotropy and/or the temporal variability of the counting rate of neutron monitors [2]. Events such as those occurring during 23-28 March 1991, 4-7 June 1991, 7-13 November 1991, 15-21 February 1998, 1-6 May 1998, 25 October-5 November 2003, 15-21 November 2003 were discussed considering CR and geomagnetic data. On the other hand, it is interesting to check the use of CR indices after the identification of the interplanetary perturbation type (i.e. by knowing the perturbation origin in flare/CME, coronal hole or solar filament outputs). Therefore, we selected to investigate the variability of CR indices during two different solar activity epochs: 7-15 January 1997 and 8-16 August 2000. The first epoch pertains to the minimum activity phase and the related space perturbation is an interplanetary coronal mass ejection (ICME, originated from a CME accompanied by a Hα filament disappearance occurred on January 6) followed by a co-rotating/regular high-speed solar wind stream (RHSS). The second analyzed period belongs to the maximum activity phase. The interplanetary perturbation is of composite type made by a short/low-speed stream, followed by a complex high-speed stream (CHSS), with ejecta inside. For the latter a CME eruption on August 9 was identified but for the former the association with a CME occurring on August 6 seems to be doubtful [3]. Nevertheless it presents the classical features of solar ejecta.

2. Data and Indices

For both periods of investigation interplanetary hourly parameters at 1 AU were obtained from the NASA/OMNIWeb Data Service and the Dst from the World Data Center for Geomagnetism/Kyoto. Hourly intensity records (N) from SVIRCO ("Studio Variazioni Intensità Raggi Cosmici", Rome: RM; rigidity cut-off ~ 6.3 GV), LS (Lomnický Štít, High Tatras mountains; rigidity cutoff ~ 3.9 GV) and LARC ("Laboratorio Antartico per i Raggi Cosmici", King George Island; rigidity cut-off ~ 3.0 GV) neutron monitors were used to derive:

1. The hourly nucleonic intensity normalized to the past 24 hours, i.e. $I(t) = N(t)/N[t-25,t-1]$. In this way medium and long-term trends were excluded from the data series.

2. The CR variability over 24 h without the diurnal wave: D[t]. The used procedure includes (i) the data fitting with the least square method to obtain the diurnal amplitude and phase, (ii) the computation of the deviation between diurnal variation and registered values at time t and (iii) the sum of square deviations normalized to the mean.
3. The CR variability over different time scales: D[k], i.e. D[3] for [t-4,t-1],... D[24] for [t-25, t-1].

Figure 1 shows examples of the obtained results.

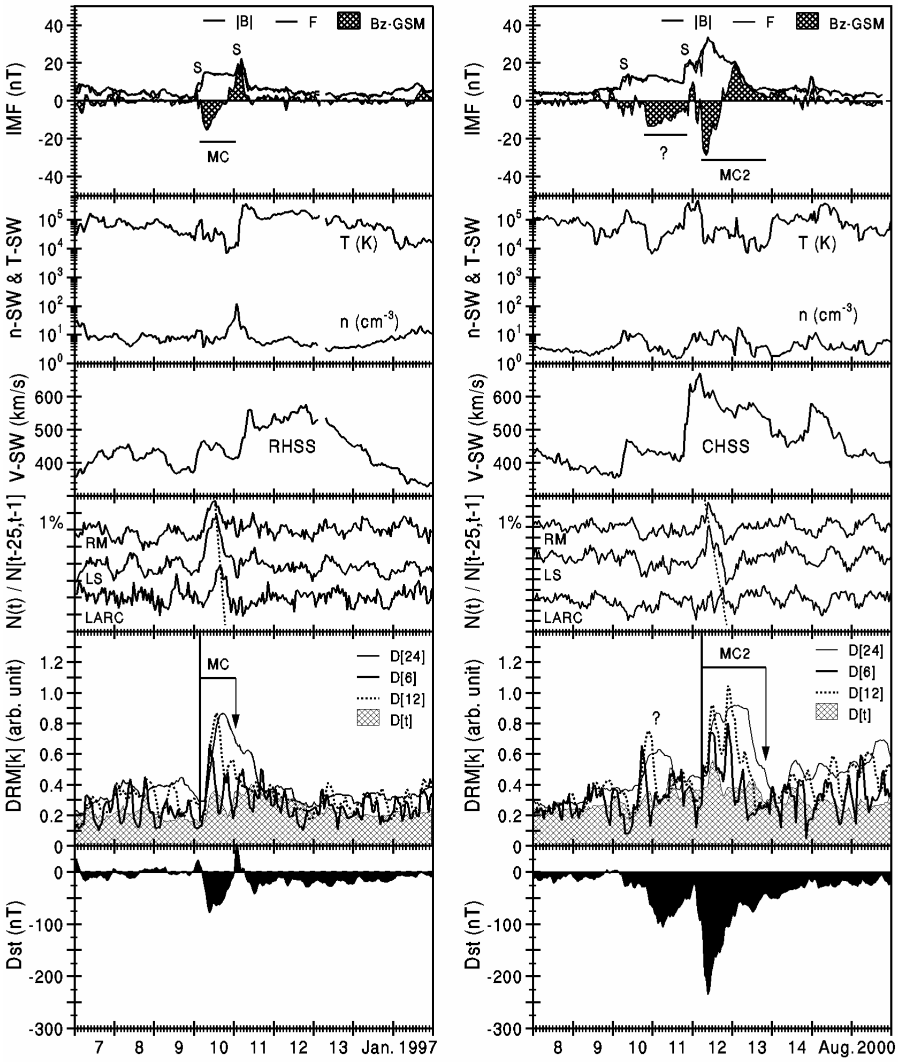

Figure 1. Solar wind (SW) parameters (|B|: field magnitude average, F: magnitude of average field vector, Bz-GSM: z-component of the field in the geocentric solar-magnetospheric [GSM] coordinate system; T: proton temperature, n: proton density and V: flow speed), CR indices (see the text for details) and Dst values for 7-15 January 1997 (left) and 8-16 August 2000 (right). S stands for Shock and/or SSC occurrence, and MC for "magnetic cloud" identification by using the variance matrix technique as in past works [4].

3. Discussion

The January 1997 event (Figure 1, left) was extensively discussed in literature (see, for instance [5]). The first boundary of the perturbation is a small shock and the ICME is a magnetic cloud (MC) of South-North type ($\Delta T \sim 22$ h; see Bz-GSM). Follows a stream interface with a shock under development plus a RHSS of about 4 days. The I(t) index (third panel from the bottom of Figure 1) shows that during the MC passage an enhanced CR anisotropy (different from the classical diurnal variation) is detected, as reported in the past [4]. The dotted diagonal helps the reader to follow the peak maximum. The position of the maximum is related with the detector (RM, LS and LARC) view according its own asymptotic longitude. The second panel from the bottom of Figure 1, instead, illustrates some D[k] variabilities for RM; the MC identification is also shown (horizontal bar). The start of the cloud practically coincides with a nearly contemporary increase of D[24], D[12] and D[6] and for several hours their values are well above the preceding variations (roughly by a factor 2). The end of the cloud, instead, occurs before the return of D[24] and D[12] to the previous levels. To notice the oscillating nature of D[12] and D[6] with a clear damping process from the cloud to inside the RHSS structure.

The August 2000 event (Figure 1, right) starts also with a small shock and the ICME presents a magnetic structure mainly characterized by a South-field ($\Delta T_1 \sim 25$ h; see Bz-GSM). Follows a CHSS with a shock ahead and again a South-North MC ($\Delta T_2 \sim 41$ h; see Bz-GSM). The I(t) index does not demonstrate an outstanding CR anisotropy during the ΔT_1 period. However, RM and LS clearly show such anisotropy during a part of the ΔT_2 interval. Looking at DRM[k] parameters we notice the enhanced values of D[24], D[12] and D[6] (roughly by a factor 2) during ΔT_1, the return to low values and the fast increase (more than a factor 2) with the MC2 start. During the ΔT_2 interval the oscillating feature of D[12] and D[6] (seen also during the January 1997 event) suggests amplification before their damping in the rear part of the cloud. This interpretation is also suggested by the D[24] trend, which is showing a clear double-peaked structure.

Are the above described CR signatures relevant for the ICME identification in the near-Earth space? An answer can be obtained from Figure 2.

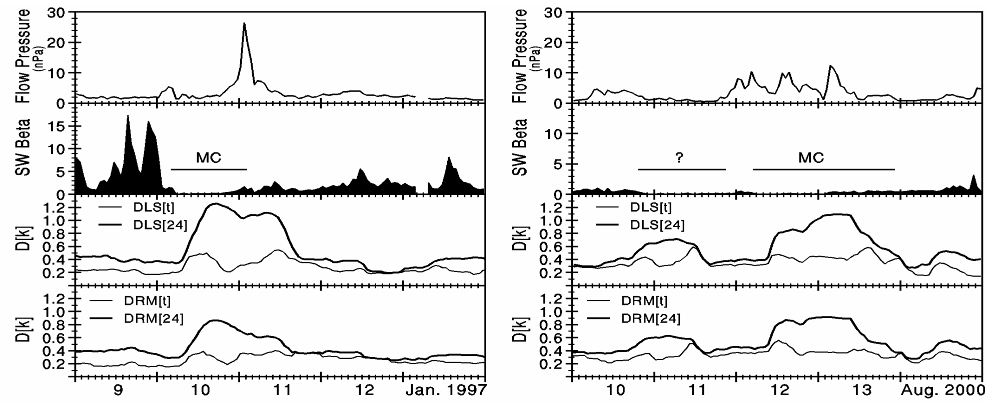

Figure 2. Time history of some SW hourly parameters (flow pressure and plasma beta), D[t] and D[24] for LS and RM detectors during 9-13 January, 1997 (left) and 10-14 August 2000 (right). See the text for details.

Figure 2 shows the D[t] and D[24] for RM (bottom) and LS (center - lower panel) detectors, together with other two SW parameters: the plasma beta (center - upper panel) and the flow pressure (top). Even if the solar wind regime results to be very different when the first event is compared with the second one, D[t] and D[24] have similar behaviors for the three ICMEs.

4. Conclusions

The obtained results suggest that indices for CR variabilities are indeed useful tools for a fast nowcast of the near-Earth space status. If our clues will be confirmed for more events we should conclude that also data from a single middle- or low-latitude neutron monitor could be used for the learning work inside Space Weather and Climate [6]. Finally, we notice that in the absence of in-situ measurements, the ensemble of the above CR findings is a good indicator of the ICME structure passage at the Earth.

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