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Galactic cosmic ray decreases associated with non-interacting magnetic clouds in the 23^{rd} solar cycle

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Abstract. Sudden Galactic Cosmic Ray (GCR) intensity decreases are related to the passage of Interplanetary Coronal Mass Ejections (ICMEs). These phenomena are also known as Forbush Decreases (FDs). The deepest FDs are associated with the passage of Magnetic Clouds (MCs). In this preliminary study we select "non-interacting" MCs associated with FDs observed from ground Neutron Monitors in the period 1996-2009, with the aim of reducing the complexity and the number of parameters involved in the GCR-MC interactions. We introduce a method to determine properties of the "*ejecta* component" of the FD. We analyze properties of the *ejecta* component in combination with properties of MCs. From the resulting selection of events, we find that those FDs containing *ejecta* components show stronger correlations with MC parameters than our total sample of events.

Keywords. Sun: magnetic fields, Sun: coronal mass ejections (CMEs), cosmic rays

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Introduction: Forbush decreases (FDs) are depletions of fluxes of Galactic Cosmic Rays (GCRs), typically observed at Earth using ground Neutron Monitors (NMs). Magnetic Clouds (MCs) are a particular subset of Interplanetary Coronal Mass Ejections (ICMEs), and the deepest FDs are associated with the passage of a MC through the terrestrial environment [Richardson & Cane (2011)].

In many cases, FDs present two different phases: (a) a gradual one during the passage of the post-shock turbulent region, and (b) a steeper one during the passage of the MC or *ejecta*. They are said to have a two-step FD profile. The decomposition of the effects of shock and *ejecta* components is very important, in particular for comparisons of FD observations with model predictions.

In the present study we select "clean" ICMEs associated with FDs in the period 1996-2009. We then introduce a method to determine the *ejecta* components for those FDs showing a two-step profile. Finally, we present the correlations between the *ejecta* components and MC properties.

Selection and decomposition: From the ICME list in Richardson & Cane (2011), we select those classified as MCs, because their structure are better understood and/or modeled [e.g., Lepping *et al.* (2003)]. If the leading edge of the analyzed MC shows larger velocity than the MC trailing edge, and the velocity profile is linear in the MC temporal window, we consider it an unperturbed expansion and select it, otherwise we discard it.

Richardson & Cane (2011) report a total of 322 ICMEs, from which 99 are MCs. Four of them are reported as multiple MCs. From the 95 remaining, we determined that 35 have an unperturbed expansion, and 13 of these have an associated Forbush Decrease in the NM of Rome ($Rc = 6.3GV$, http://cr0.izmiran.rssi.ru/rome). So these events correspond to significant shielding affecting GCRs with $R \gtrsim 6\ GV$. In order to analyze effects of MCs on GCRs with lower values of R, in this work we analyze the FDs observed from the McMurdo NM ($Rc = 0.01\ GV$, http://neutronm.bartol.udel.edu/realtime/mcmurdo.html) and *in situ* observations from the OMNI data compilation (http://omniweb.gsfc.nasa.gov/html/HROdocum.html) for MC properties. The MC parameters were determined according to the start and end times reported in Richardson & Cane (2010).

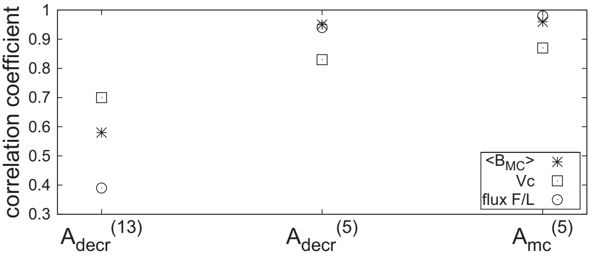

Figure 1. Summary of correlations coefficients between MC and FD parameters. The upper indexes in FD parameters (horizontal axis) indicate the number of events taken into account. The highest correlation (very close to 1) is obtained between $A_{mc}^{(5)}$ and each MC parameter, with better correlation for F/L.

From our selection of 13 events, only 6 show a two-step FD profile and only 5 show no other interplanetary transients in $\sim 2 days$ before the event. We select these 5 events to make component decompositions in the cosmic ray data.

To determine the shock component, we make a polynomial fit of degree $n = 6$, $P(t) = \sum_{i=0}^{n} a_i t^i$ to the observed time structure of the FD, excluding the time range of the cloud passage. We chose a polynomial degree $n = 6$ because it is the minimum value that simultaneously captures the trends before and after the cloud in the 5 analyzed events. The *ejecta* component is determined by substracting the shock profile from the original data.

Results, Discussion, and Conclusions: After we make the shock-cloud decompositions, we determine the peak amplitudes of the observed total FD (A_{decr}) and of the *ejecta* component (A_{mc}) profiles. Following Dasso *et al.* (2006), we use the definition of the cumulative magnetic flux per unit length $F/L = \int_{X_{in}}^{x} B_{y,cloud}(x')dx'$, as expressed in their eq. (19), but using the module of the magnetic field instead of a component. For the present study, x' is the coordinate parallel to the spacecraft path through the MC, and the limits of integration are the MC borders. We determine this quantity as a proxy of the flux traversed by CRs when they pass through the MC. The properties determined from spacecraft obsevations we analyze here are: the mean magnetic field strength inside the MC, $< B_{MC} >$, the bulk plasma velocity at the MC center, V_c, and the magnetic flux per unit length F/L. The correlation coefficients between the FD parameters (A_{decr} and A_{mc}) and MC properties ($< B_{MC} >$, V_c, and F/L) are summarized in Figure 1.

We find that the correlation coefficients are higher for FDs with two-step profiles. From the comparison of the correlation coefficients of MCs parameters with A_{decr} and A_{mc}, we find a larger correlation with A_{mc}, the decomposed cloud peak amplitude.

These preliminary results suggest that the parameters we define here better represent the MC effects on GCR transport.

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