CME Types, their Interplanetary Manifestations (ICMEs) and Effects on Cosmic Ray Intensity

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Abstract

We have considered CMEs, halo CMEs and partial halo CMEs and their interplanetary signatures (magnetic clouds, ejecta and shocks). Influences of these structures on cosmic ray intensity have been studied. Method of superposed epoch (Chree) analysis has been employed; key days correspond to the arrival of these structures. It is observed that halo CMEs are most effective transient modulators as compared to others. Consideration of interplanetary manifestations of these CMEs shows that the effects of magnetic clouds and ejecta itself, on cosmic ray modulation are small and not significantly different in two cases. However, both the shock-ejecta and shock-cloud combinations are much more effective in transient modulation and any difference in their effectiveness apparently does not depend on the structure (ejecta or magnetic cloud) following the shock.

1. Introduction

The existence of unusual magnetized clouds of plasma emitted by the active sun was proposed by Morrison [7] as a cause of the worldwide decreases in cosmic ray intensity lasting for days. Specific magnetic field structures with geometry consistent with magnetic loop, called magnetic clouds, were identified in the solar wind by Burlaga and his co-workers [11]. After the identification of magnetic clouds in the interplanetary plasma and field data, detailed studies of relations between magnetic clouds and cosmic rays have been made [2, 3, 5, 6, 10, 11]. Magnetic clouds are thought to be a subset of interplanetary manifestations of CMEs. Observation of CMEs led to suggestion [8] that the interplanetary manifestations of CMEs may play an important role in galactic cosmic ray modulation and it would be interesting to investigate the most spectacular CMEs as the source of rare Forbush decreases of cosmic rays.

2. Method

CME, ICME events observed by instruments onboard SOHO and Wind spacecraft during 1995-2000 [4] have been considered. Chree analysis method has been applied on the pressure corrected daily average cosmic ray intensity data

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with respect to CMEs and ICMEs. Analysis has also been performed with respect to CMEs, halo CMEs and partial halo CMEs as well as ICMEs (magnetic clouds/ejecta associated with shocks, magnetic clouds, ejecta). Statistical significance of the results so obtained is evaluated by using a method suitable for Chree analysis [1].

3. Results

Halo CMEs are more effective transient modulators of cosmic ray intensity as compared to others, but the result is not significant statistically in either case (Figs. 1 and 2). As regards ICMEs, both the ejecta and magnetic clouds associated with shocks are much more efficient in transient modulation and any difference in their effectiveness does not depend on structures concerned i.e. ejecta or magnetic cloud associated with shocks. Statistical test shows that this result is statistically significant (Fig. 3). However, the effect of magnetic clouds and ejecta, on cosmic ray intensity, is small and not different in two cases (Figs. 4 and 5). Moreover, this result is found to be insignificant when subjected to statistical test.

4. Discussion

As shown in Figs. 1 and 2, the effecs on cosmic ray intensity due to halo CMEs is more than the partial halo and other CMEs. But these effects are found to be statistically insignificant. This is understandable as halo CMEs may be directed either towards or away from the earth. Moreover, not all the halo CMEs give rise to interplanetary shocks and sheaths behind the shocks, that may be effective in modulation. When the analysis is done by considering ICMEs (magnetic clouds/ejecta with shocks), as shown in Fig. 3, a significant (Forbush type) decrease is observed. These results are in concurrence with those obtained earlier (e.g. [2, 6, 11]). When magnetic clouds and ejecta, not associated with shocks, were separated from ICMEs, and cosmic ray data subjected to superposed analysis with respect to these two group of ICMEs, the decrease observed due to them (Figs. 4 and 5) is neither different nor statistically significant. Thus the role of isolated magnetic clouds and ejecta is relatively unimportant in producing Forbush decreases.

5. Conclusions

Halo CMEs are more effective transient modulators of cosmic ray intensity than other CMEs. However, the result is not statistically significant in both the cases. ICMEs (Magnetic clouds/shocks, Ejecta/shocks) produce significant Forbush-type decrease. Effects of other ICMEs such as magnetic clouds or ejecta

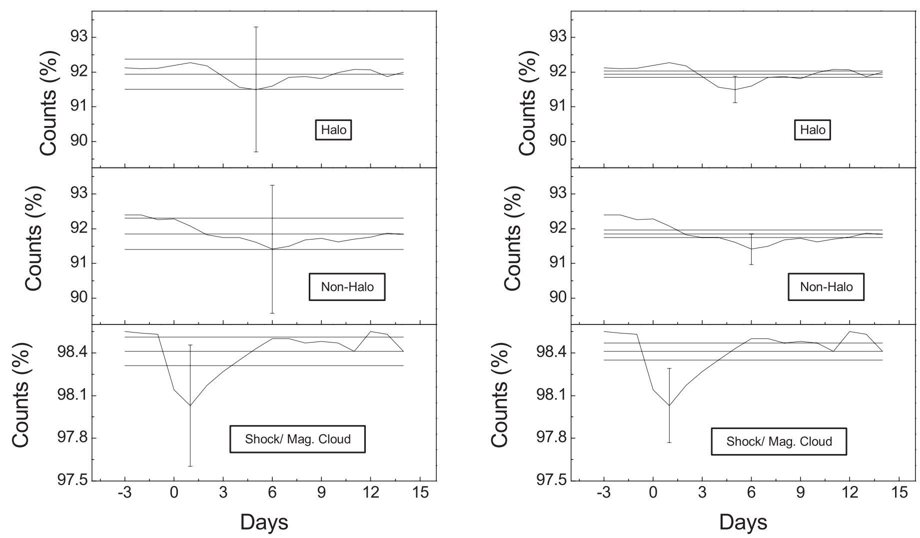

Fig. 1. Superposed epoch results of cosmic ray intensity due to Halo CMEs before (upper left) and after (upper right) correction. **Fig. 2.** Same as Fig. 1 for non-Halo CMEs (middle). **Fig. 3.** same as Fig. 1 for shock associated magnetic clouds.

are small (and not much different in two cases) and statistically insignificant. These results are consistent with the conclusion that Forbush decreases occur due to a shock and sheath region formed ahead of magnetic clouds/ejecta and role of isolated magnetic cloud or ejecta itself in producing Forbush decreases is relatively unimportant. However, study of the simultaneous changes in solar wind plasma field parameters during the passage of CMEs, ICMEs e.g. their transit speed, magnetic field enhancement and field variance etc., is needed for a better model and is in progress.

6. References

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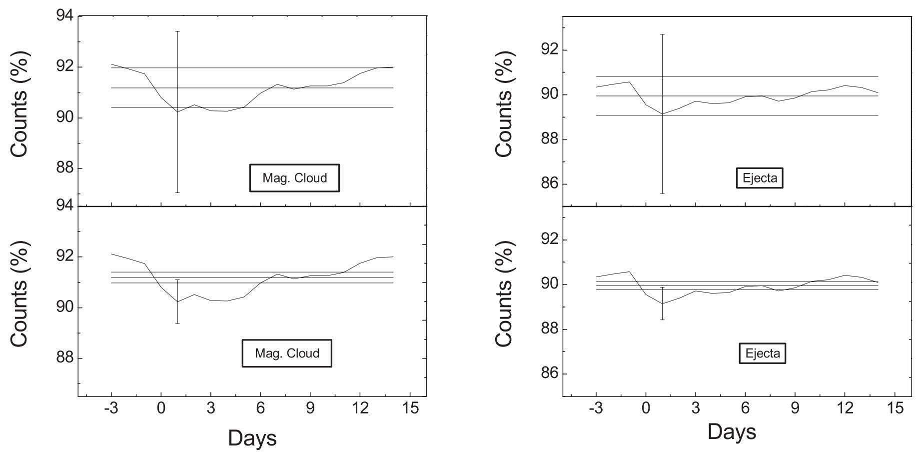

Fig. 4. Superposed epoch results of cosmic ray intensity due to magnetic clouds before (upper left) and after (lower left) correction. **Fig. 5.** Same as Fig. 4 for ejecta.

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