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Proceedings IAU Symposium No. 226, 2004
NAME OF EDITORS

DOI: 00.0000/X000000000000000X

Relationships between magnetic clouds, CMEs and geomagnetic storms

Chin-Chun Wu[1,2] **R. P. Lepping**[2] **and N. Gopalswamy**[2]
[1]CSPAR/The University of Alabama, Huntsville, AL 35899, USA
[2]Laboratory for Extraterrestrial Physics, NASA/GSFC, Greenbelt, MD 20771, USA

Abstract. During solar cycle 23, 82 interplanetary magnetic clouds (MCs) were identified by the MFI team using Wind solar wind plasma and magnetic field data for the interval 1995-2003. The average occurrence rate is 9.5 MCs per year for the overall period. It is found that some of the anomalies in the frequency of occurrence were during the early part of the solar cycle 23: (i) only 4 MCs were observed in 1999, (ii) an unusually large number of MCs (17 events) were observed in 1997, when the Sun was starting to leave solar minimum. We also discuss the relationship between MCs, coronal mass ejections (CMEs) and geomagnetic storms. During the period, 1996-2003, almost eight thousand CMEs were observed by SOHO LASCO. The occurrence frequency of MCs appears to be related neither to the occurrence of CMEs as observed by SOHO LASCO nor to the sunspot number. If we include the magnetic cloud-like structures (MCLs) (Lepping, Wu & Berdichevsky (2004)), then we found that the occurrence of the joint set (MC+MCL) is correlated to both sunspot number and the occurrence rate of CMEs.

Keywords. Magnetic Cloud, CME, Solar activity

1. Introduction

A magnetic cloud (MC) is defined as a region of high magnetic field strength, low proton temperature, low proton beta, and smoothly changing (rotating) magnetic field (Burlaga, Sittler & Mariani (1981)). Plasma beta is very low in MCs and, hence, they are magnetic field dominated. By using 1995-1998 Wind data (Wu & Lepping (2002)) found that ~90% (30 in 34) of MCs generated geomagnetic storms. Wu, Lepping & Gopalswamy (2003) first reported that (1) the occurrence frequency of magnetic cloud was related neither to the occurrence of solar coronal mass ejections (CMEs) *as observed by SOHO* nor to solar activity cycle, (2) the intensity of geomagnetic storms related to magnetic clouds is affected by both solar activity and the occurrence frequency of CMEs, and (3) ~91% of magnetic clouds induced geomagnetic storms. There is a growing number of solar and solar wind physicists who believe that many magnetic clouds are directly associated with (or are part of) ICMEs (interplanetary CMEs) (Gopalswamy, *et al.* (1998)). Therefore, it motivates us to re-investigate the relationship between MCs, CMEs and solar activity.

2. Data Analysis and Conclusion

The magnetic clouds cataloged at the Wind-MFI website from January 1995 to August 2003 (http://lepmfi.gsfc.nasa.gov/mfi/mag_cloud_pub1.html) satisfy the classical definition of a magnetic cloud (Burlaga, Sittler & Mariani (1981)). There might be some other MCs in the interval of interest that have not yet been identified. However, we believe that it is unlikely that many are missing, if we require that each MC must have a duration of 5 or more hours. There were 8, 4, 17, 11, 4, 14, 10, 10 MCs observed in the year of 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, respectively. In addition, there were

4 MCs for the period of January - August 2003. The average occurrence rate is ∼9.5 magnetic clouds per year for the overall period (i.e., 82 events/8.6 years). It is easy to understand why only four clouds were observed in 1996, since this year occurs at solar minimum which has lower solar activity. However, it is difficult to understand why only 4 clouds were observed in 1999 which is in the rising phase of solar maximum. Lepping, Wu & Berdichevsky (2004) recently developed a scheme which is able to automatically identify MCs and MC-like (MCLs) events, and they found 185 combined MCs+MCLs (joint set). This automatic MC identification scheme successfully found ∼90% of the MFI MCs previously identified and two new ones. Both MCs are now included in the list of MFI MCs data set. Hence, the newly developed MC identification scheme can identify real MCs which are not found by visual inspection. Sixty seven of the 185 in the joint set are a part of MFI MCs. The automatic detection proceedure identified a lot more events in 1998 (29 vs. 11) and 1999 (23 vs. 4) than the manual procedure.

The left panel of Figure 1 shows that the yearly number of MFI MCs (visually detected MCs by a dashed line with diamonds) have a poor c.c. with sunspot number (by triangles); the c.c. is 0.12. However, the c.c. is good between the yearly joint events (in solid line with x's) and yearly averaged sunspot number (the c.c. is 0.8). In addition, the c.c. is 0.11 between CMEs and MCs, and 0.73 between CMEs and the joint set. The right panel of Figure 1 shows the monthly sunspot number (by triangles) and yearly occurrence rate of CMEs (by stars). The correlation coefficient (c.c.) is 0.97 between yearly average sunspot number and yearly occurrence rate of CMEs. The results of this study show that (1) the averaged occurrence rate is ∼9.5 magnetic clouds per year during 1995-August 2003 (8.6 years), (2) the occurrence rate of MCs is not related to either solar activity or to occurrence frequency of CMEs, but (3) the joint set (MCs + MCLs) is related to both solar activity and CME occurrence rate.

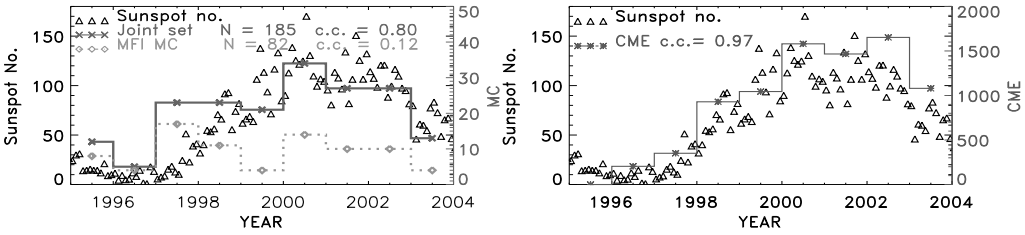

Figure 1. Histogram of MCs, MCLs, CMEs and sunspot number during 1995-2003. Joint set refers to the combined (MC+MCL) set.

Acknowledgements

We are grateful to Wind SWE and MFI, LASCO/SOHO (CME data), Kyoto University (*Dst* data) and NOAA (sunspot no.) teams for use of their data. The work of CCW was supported by NASA Grant NAG-12527, NAG-512467 and NSF Grant ATM-028414.

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