# Forbush decreases in relation to CME related shocks and solar wind disturbances.

**P.L. VERMA**
Department of Physics Govt. Vivekanand P.G. College Maihar Distt. Satna (M.P.) India,
Presenter : P.L. Verma (pl_verma2003@yahoo.com) SH- 2.1

**Abstract**: -

Coronal mass ejections (CMEs) are the most energetic events in the heliosphere and are widely recognized as being responsible for production of large disturbances in solar wind, transient interplanetary shocks and Forbush decreases in cosmic ray intensity. I studied Forbush decreases, recorded with ground based monitor at Oulu for the period 1997-2006 with variation in solar wind plasma velocity, proton density, temperature and different types of interplanetary shocks related to ejecta and magnetic clouds which are interplanetary manifestations of coronal mass ejections. I found a weak positive co-relation between magnitude of jump in solar wind velocity, proton density, temperature and magnitude of Forbush decreases. Further I have concluded that the forward shocks which are related to ejecta, magnetic clouds, or ejecta and magnetic clouds both are very much effective in producing Forbush decreases of higher magnitudes in cosmic ray intensity. The results obtained in this study give very important information's about the events which are mainly responsible for Forbush decreases.

## 1. Introduction :-

Forbush decreases [FDs] are transient and rapid decreases in galactic cosmic ray intensity followed by a more gradual recovery phase typically lasting several days. These decreases are not only observed by ground based detector's but are also observed by space born detector's and so are present in interplanetary medium [1,2]. Several theories, depending on perturbations in the interplanetary conditions, have been given by previous investigators to explain Forbush decreases [FDs] [3,4,5,6,7] but non of these theories has succeeded in completely explaining the details of Forbush decrease [FD] phenomena. The perturbations could be produced by shock waves, moving magnetic clouds or high velocity solar wind streams [8,9,10,11,12,13,14,15]. Different models have been proposed by some investigators, some of the models are based on enhanced drift [16,17.] while others are concentrated on diffusive of scattering models [18,19,20,21,22] both drift and scattering mechanisms suggest that the magnitude of Forbush minimum is proportional to the magnetic field strength and irregularities in the associated interplanetary disturbances. It has now been proved by the recent studies of Forbush decreases with coronal mass ejections and the interplanetary shocks, magnetic clouds, ejecta which are interplanetary manifestations of coronal mass ejections that the Forbush decreases are strongly associated with CMEs. Burlaga et al [9] have noted that such a decrease in cosmic ray intensity, beginning with the arrival of magnetic cloud, Zhang and Burlaga [10] concluded that relatively large decreases in cosmic ray intensity is associated with magnetic clouds that are preceded by a shock, whereas only a small decreases in cosmic ray intensity is associated with magnetic clouds that are not preceded by shock. Badruddin [22,23] has reported that abrupt onset of decrease in intensity starts upon the arrival of certain shocks and decreases continue till the passage of post shock turbulent sheath. He has further determined that turbulent shocks are much more effective in producing Forbush decreases than non-turbulent shocks. He reported that halo CMEs are more effective transient modulator of cosmic ray intensity than other CMEs, and produces significant Forbush decreases. Cane et al [14] have studied Forbush decreases for 30 years period with coronal mass ejection and found that 86% FDs are associated with CMEs and interplanetary shocks that they generate. They have further concluded that depth of the Forbush decreases is dependent on the Helios longitude of the active region which ejected the associated CMEs. Cane et al [15] have inferred that the short term cosmic ray decreases are strongly associated with ejecta and shocks. They have reported that 88% short term cosmic ray decreases are associated with ejecta and 70% of these are associated with shocks. The two step Forbush decreases have been studied by wibberenz [24,25,26,27,]. They have reported that the two step FDs are caused by the combination of shocks and CMEs, they have inferred that the first step is connected to the turbulent structure behind the shocks, and the second step is connected to the enhanced magnetic field and loop-like field configuration of the CMEs. The component related to the shocks shows a gradual decreases and slow recovery whereas the ejecta component starts, with the ejecta arrival and the effects of superposition shocks and CMEs lead to the rather complex structure in the intensity profile of FDs.

It is well known that coronal mass ejection events produces measure disturbances in solar wind and interplanetary magnetic field. Belov et al [28] have studied Forbush decreases with interplanetary disturbances. They

have concluded that magnitude of FDs are directly proportional to Hm, Vm where Hm in maximum disturbance value for the interplanetary magnetic field strength and Vm is maximum solar wind velocity, In this investigation an attempt has been made to co-relate magnitude of FDs and variation in solar wind velocity, density, temperature during the arrival of shocks and to determine the role of CME related shocks in producing for FDs of higher magnitude and to known the physical process mainly responsible for production of FDs.

## 2. Data and Analysis :-

In this investigation hourly count rate of cosmic ray, recorded by oulu neutron monitor over the period 1997 through 2006 has been used to determine Forbush decreases (FDs). The oulu neutron monitor (NM) is situated in Northern Finland (65.05ºN, 25.47ºE). The local vertical geomagnetic cut off rigidity is about .8GV and the neutron monitor in oulu is one of the most stable and reliable stations of the world neutron monitor Network. In this work we

have selected only those FDs, which have decrease greater than 5% for the determination of variation (sudden jump) in solar wind velocity proton
group from the SOHO observations, shock arrival derived by the IPS group from A.C.E. observations, shock arrival derived by WIND group from WIND observations, list of the shocks (on firmed by Ulysses magnetometer, and ACE list of disturbances and transient SOHO, LASCO CME catalogue consists all CMEs manually identified since 1996 from the Large Angle and spectrometric coronagraph on board the solar and Heliospheric observatory mission (SOHO).

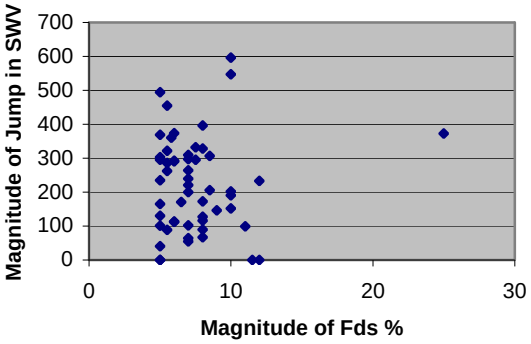


***Figure** – 1 (a) Magnitude of Forbush decrease versus magnitude of jump in associated solar wind velocity (SWV), showing a weak positive co-relation with co-relation co-efficient (0.10)*

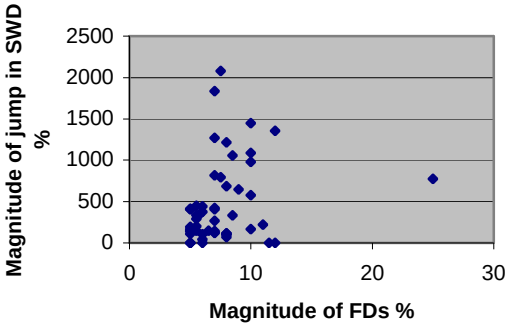


***Figure** – 1 (b) Magnitude of Forbush decrease versus magnitude of jump in associated solar wind density (SWD), showing a weak positive co-relation with co-relation co-efficient (0.26)*

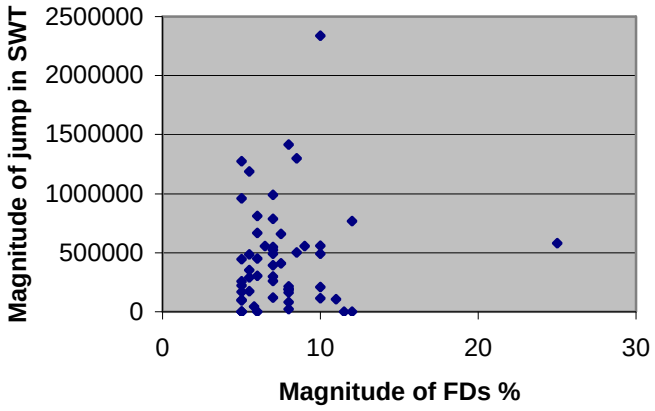


***Figure** – 1 (c) Magnitude of Forbush decrease versus magnitude of jump in associated solar wind temperature (SWT), showing a weak positive co-relation with co-relation co-efficient (0.26)*

## 3. Results :-

The association between Forbush decreases ≥ 5% and ejecta – CME, magnetic cloud related shocks for the period Jan. 1997 to Dec. 2006 are given in table no. 1. The vast majority of ≥ 5% FDs are found to be related with ejecta – CME related shocks and related shocks are forward shocks. I have identified 54 FDs in which 52 (96.3%) are related with ejacta CME related shocks. I have incomplete data for quality of shocks; out of 53 shocks the available data for quality of shocks is forty two in which forty one are forward shocks and one is reverse. I found 23 (45%) out of 52 Fds, related with ejecta – CME shocks are also related with magnetic cloud in 29 cases the magnetic cloud are not seen. Forbush decrease of 24 Sep 1998 is only FD which is related to magnetic cloud only.

**TABLE NO.1 FORBUSH DECREASES ≥ 5% WITH EJECTA – CME & MAGNETIC CLOUDS RELATED SHOCKS & SOLAR WIND DISTURBANCES. (Jan. 1997 – Dec. 2006)**

| Forbush Decreases | | | Shocks | | | Magnetic Clouds | Solar wind Disturbances | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Onset time DD (HH) | Mag. In % | Arrival Time DD(HH) | Quality F/R | Sources CME/ Ejecta/M cloud | Start Time DD (HH) | Jump in SWV | Jump in SWD % | Jump in SWT °k |
| 10-04-97 | 10(20) | 5 | 10(13) | F | EJ,M | 11(06) | 235 | 168 | 169574 |
| 01-05-98 | 01(14) | 5 | 01(21) | F | CME,M | 02(12) | 295 | 196 | 99559 |
| 04-05-98 | 04(08) | 5 | 04(03) | F | EJ. CME | NA | 369 | 410 | 959580 |
| 05-06-98 | 05(16) | 5 | NA | NA | NA | NA | 41 | 408 | 95453 |
| 26-08-98 | 26(08) | 8 | 26(06) | F | EJ.H-CME | NA | 67 | 68 | 23055 |
| 24-09-98 | 24(04) | 10 | 24(23) | F | M | 25(10) | 152 | 165 | 209323 |
| 08-11-98 | 08(12) | 8 | 08(04) | F | M,H-CME] | 08(23) | 173 | 687 | 215560 |
| 22-01-99 | 22(12) | 7 | 22(20) | F | EJ. | NA | 221 | 267 | 522927 |
| 18-02-99 | 18(00) | 6 | 18(12) | F | EJ,M | 18(16) | 292 | 376 | 450164 |
| 12-12-99 | 12(12) | 7.5 | 12(16) | F | EJ. | NA | 332 | 2080 | 660214 |
| 11-02-00 | 11(03) | 5.5 | 11(03) | F | EJ,H-CME,M | 12(17) | 89 | 203 | 173078 |
| 08-06-00 | 08(12) | 8 | 08(09) | F | EJ.H-CME,M | 08(06) | 127 | 110 | 189449 |
| 15-07-00 | 15(08) | 10 | 15(15) | F | EJ,M | 15(07) | 191 | 1448 | 558474 |
| 17-09-00 | 17(08) | 8 | 17(17) | F | EJ,CME,M | 18(02) | 90 | 98 | 80141 |
| 28-10-00 | 28(20) | 5 | 28(10) | F | H-CME,M | 28(23) | 101 | ND | ND |
| 06-11-00 | 06(20) | 6 | 06(10) | F | H-CME,M | 06(23) | 113 | 44 | 303563 |
| 26-11-00 | 26(04) | 7 | 26(11) | F | EJ,H-CME | NA | 200 | 127 | 259983 |
| 27-03-01 | 27(08) | 5.5 | 27(02) | F | EJ.CME | NA | 322 | 337 | 290035 |
| 04-04-01 | 04(16) | 8 | 04(15) | F | EJ,M | 04(21) | 328 | 116 | 190447 |
| 08-04-01 | 08(08) | 7 | 08(11) | F | EJ,M- HCME | 08(04) | 309 | 425 | 989580 |
| 11-04-01 | 11(12) | 12 | 11(14) | F | EJ,H-CME,M | 12(08) | 233 | 1353 | 767211 |
| 28-04-01 | 28(04) | 7 | 28(05) | F | EJ,H-CME,M | 29(02) | 297 | 406 | 787156 |
| 17-08-01 | 17(08) | 7 | 17(12) | F | EJ, H-CME | NA | 264 | 1838 | 299070 |
| 28-08-01 | 28(12) | 5 | 27(20) | F | EJ,H-CME, M | 28(09) | 165 | 139 | 257957 |
| 25-09-01 | 25(20) | 8.5 | 25(20) | F | EJ,H-CME | NA | 307 | 1054 | 1298057 |
| 11-10-01 | 11(12) | 7 | 11(17) | F | EJ,H-CME | NA | 240 | 1269 | 547893 |
| 21-10-01 | 21(16) | 5.8 | 21(17) | F | EJ,H-CME | NA | 360 | 351 | 42395 |
| 06-11-01 | 06(00) | 11 | 06(02) | F | EJ,H-CME | NA | 99 | 220 | 105551 |
| 24-11-01 | 24(04) | 10 | 24(06) | F | EJ,-H-CME-M | 24(16) | 596 | 1086 | 2336589 |
| 30-12-01 | 30(16) | 6 | 30(20) | F | EJ,H-CME | NA | 291 | 104 | 667132 |
| 10-01-02 | 10(16) | 5 | 10(17) | F | EJ | NA | 303 | 107 | 446245 |
| 17-04-02 | 17(08) | 5.5 | 17(11) | F | EJ,M | 18(04) | 286 | 291 | 353020 |
| 23-05-02 | 23(08) | 5.5 | 23(22) | F | EJ,M, H-CME | 23(23) | 455 | 147 | 1185586 |
| 17-07-02 | 17(12) | 5 | 17(15) | F | EJ | NA | 130 | 148 | 221232 |
| 19-07-02 | 19(08) | 5 | 19(15) | F | EJ, H-CME | NA | 494 | 412 | 1272550 |
| 10-11-02 | 10(12) | 7 | 09(18) | F | NA | NA | 55 | 820 | 393495 |
| 17-11-02 | 17(04) | 7 | 16(23) | ND | EJ | NA | 64 | 121 | 118453 |
| 29-05-03 | 29(08) | 9 | 29(12) | F | H-CME. | NA | 146 | 650 | 555972 |
| 28-10-03 | 28(16) | 25 | 29(06) | ND | H-CME | NA | 373 | 775 | 579536 |
| 15-11-03 | 15(04) | 7 | 15(05) | F | CME | NA | 102 | 144 | 492331 |
| 20-11-03 | 20(08) | 5.5 | 20(07) | F | H-CME-M | 20(10) | 262 | 450 | 487107 |
| 06-01-04 | 06(20) | 6.5 | 06(19) | ND | CME | NA | 171 | 148 | 555367 |
| 22-01-04 | 22(00) | 8.5 | 22(01) | R | H-CME | NA | 206 | 334 | 501487 |
| 22-07-04 | 22(04) | 5 | 22(10) | F | H-CME,M | 22(15) | NJ | NJ | NJ |
| 27-07-04 | 27(00) | 10 | 26(22) | F | H-CME | NA | 202 | 980 | 491514 |
| 13-09-04 | 13(12) | 6 | 13(20) | ND | H-CME | NA | 112 | ND | ND |
| 07-11-04 | 07(04) | 12 | 07(18) | F | H-CME,M | 08(03) | NJ | NJ | NJ |
| 05-12-04 | 05(08) | 5 | 05(07) | ND | H-CME | NA | NJ | ND | ND |
| 08-05-05 | 08(12) | 6 | 8(06) | ND | H-CME | NA | 374 | 441 | 811250 |
| 15-05-05 | 15(00) | 10 | 15(02) | ND | H-CME,M | 15(06) | 547 | 577 | 114406 |
| 16-07-05 | 16(12) | 8 | 17(01) | ND | H-CME,M | 17(15) | 116 | 114 | 162826 |
| 24-08-05 | 24(08) | 7.5 | 24(06) | ND | H-CME | NA | 295 | 797 | 408610 |
| 10-09-05 | 10(20) | 11.5 | 9(13) | ND | H-CME | NA | ND | ND | ND |
| 14-12-06 | 14(10) | 8 | 14(14) | ND | H-CME | NA | 396 | 1217 | 1414664 |

The FDs listed in table no. 1 are strongly associated with disturbances produced in solar wind during the arrival of shocks. I have listed 54 FDs out of which 50 FDs are related to jump in SWV and 48 are related to jump in SWD and SWT also. We have no data of SWV for one cases and SWD and SWT for four cases. The scatter plot between magnitude of jump in Solar wind velocity (SWV), jump in Solar wind density (SWD), jump in solar wind temperature (SWT) and magnitude of FDs are shown in figure 1(a),(b),(c) showing a weak positive co-relation. Statistically calculated co-relation coefficient are (.10) between magnitude of jump in SWV and magnitude of FDs (0.26) between magnitude of jump in SWV and magnitude of FDs, (.20) between magnitude of jump in solar wind temperature and magnitude of Fds.

## 4. Conclusions :-

From our study 53 out of 54 FDs ≥ 5% have been identified as being associated with ejecta - CME related (52) or magnetic cloud (24) related shocks and the related shocks are forward shocks giving an association rate of 98.2%. Since ejecta, magnetic clouds on the interplanetary manifestation of the coronal mass ejections (CMEs) so it may be concluded the vast majority of FDs ≥ 5% on associated with CME related shocks. This result is higher than result obtained by cane et al [14]; They have studied FDs ≥ 4% with CME related shocks and found 86% are associated with coronal mass ejections or the shocks that they generate. These results suggests that the Forbush decreases of lower magnitudes may be produced by other interplanetary physical process but the FDs of higher magnitudes are produced by coronal mass ejections and shocks that they generate.

The FDs which are in our list are related to ejecta/CME, related, shocks, magnetic cloud related shocks or the shocks related to combination of ejecta/CME and Magnetic clouds. Since we have listed only those FDs which magnitude ≥ 5% so the above result suggesting that the shocks which are related to ejecta/CME, magnetic cloud or combination of these are very much effective in producing Forbush decreases of higher magnitude. This result is same as the Budruddin [21] have found in his study.

The weak positive co-relation between magnitude of Fds and magnitude of jump in solar wind velocity, (SWV) solar wind density (SWD), Solar wind temperature (SWT), suggests that jump in SWV, SWD and SWT do not contribut in producing FDs of higher magnitudes individually.

Below et al [28] have concluded that the magnitude of Fds are directly proportional to product of Hm .Vm where Hm is maximum disturbance value for interplanetary magnetic field and Vm is maximum solar wind velocity. These results suggest that the magnitude of jump in solar wind velocity, density and temperature individually do not play crucial role in producing Forbush decreases of higher magnitude but combination of these may yield significant result related to FDs. There is lot of scope to get new results about FDs by studying Fds with SWV, SWD, SWT with the combination of other interplanetary parameters.

## 5. Acknowledgement: -

The author is grateful to N.P.L. New Delhi for providing necessary facilities for this work. He also express his thanks to prof. S.K. Nigam (Retd. Professor in Physics) Ex. Vice Chancellor, A.P.S. University Rewa (M.P.) India and Professor B.P. Chandra (Retd. Professor in Physics) Ex. Vice Chancellor R.S. University Raipur (C.G.) India. For providing valuable suggestion .

## References :-

[1] Webber, W.R., J.A. lockwood and S.R. Jokipii (1986). J. Geophys. Res. 91, 4103-4110.
[2] Webber, W.R., FB Mc Donald, J.A. Lockwood and B, Heikkilo (2002); Geophys. Res. Lett. 29 (10), 1377, doi : 10, 1029/2007 GLO14729.
[3] Gold, T, Astro-Phys. J. suppli. Ser. 4,406,1960.
[4] Parker, E, N, Interplanetary Dynamical processes, monographs and texts in physics and Astronomy, inter science, Newyork 1963
[5] Barnden. L.R., proc. 13th Int. cosmic ray 1973.
[6] Nishida, A, J. Geophys. Res. 88, 785-791-1983.
[7] Kadakura, A, and A, Nishida, two dimensional. Modeling of the cosmic ray, king, J.H. interplanetary data book – Appendix A-R-and 577-049 september 1977.
[8] Lockwood, J.A. space. Science Rev. 12, 688-715 1971.
[9] Burlaga, L.F., E, sittler, F, Mariani, and R. Schwenn J. Geophys. Res, 86 6673 1981.
[10] L.F. Burlaga, G.Ghang, J. Geophys Res. 93, 2511-7518 1988
[11] Fluckiger, E.O. Solar and terrestrial modulation, proc 22nd intern. Cosmic ray conf. 5, 273-291 1991.
[12] Cane H.V.I.G.Richardson, T, T, Von Rosenving and G, wibberenz. J Geophys, Res. 49, 21479, 1994.
[13] Cane, H.V. and I.G. Richardson, J, Geophys. Res 100, 1755, 1995
[14] Cane H.V.I.G. Richardson and T.T. Von Rosenving (1996). J. Geophys. Res. 10(A10) 21-561, 21572
[15] Cane H.V.I.G. Richardson, and G.wibberenze 1997, J. Geophys.Res. 102(A4) 7075-7086.
[16] Cheng, A.F.E.T.Sarris, and Dodopoulos (1990), Astrophys. J. 350, 413-418.
[17] Rana, D.S.N.K. Sharma, and R.S. yadov (1996), solar phys 167, 371-380.
[18] Lockwood J.A. W.R. webbere and J.R. Jokipii 1986, J. Geophys. Res. 91,2751-7857.
[19] Wibberenz,G and H.V., Cane (2000), J. Geophys. Res. 105(A8) 18,315,18326.
[20] Chih P.P and M.A. Lee (1986), J.Geophys.Res. 91, 2963-2913-22
[21] Badruddin, B.(2002), solar physics 209(1), 195-206.
[22] Badruddin (2001) Proc. ICRC 2001.
[23] Badruddin (2003) proc. 28th ICRC 2003, CME types, their interplanetary manifestations and effects on cosmic rays.
[24] Wibberenz, G, cane H.V. and Richardson, I.G. proc 25 ICRCI, 397 1997
[25] Wibberenz, G. Le roux, J.A. potgieter, M.S. and Bieber, J.W. , space sci, Rev 83/1-2, 309 1998.
[26] Cane, H.V. Richardson I.G. and Von Rosenvings. T.T. and wibberenz, G, J.Geophys. Res – 99 A11, 27, 429-21, 441 1994.
[27] Cane H.V. coronal mass ejection and Forbush decreases space sci rev 93, 49, 2000.
[28] Belov, A.V. Eroshenko, E.A. olenever, V, A, et al 2001 c proc. 27th ICRC 2001.