Utilizing Forbush Decreases in Space Weather: Estimating the expected efficiency of CMEs as the modulator of GCRs

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Abstract: Coronal mass ejections (CMEs) and their interplanetary counterparts (ICMEs) propagate through the interplanetary medium and can modulate the intensity of galactic cosmic rays, resulting into non-recurrent Forbush decreases (FDs). In this work, we investigate the expected efficiency of CMEs as the modulator of GCRs resulting into a Forbush decrease (FD). We use specially processed data from the worldwide neutron monitor network (NMN) to pinpoint the characteristics of the recorded FDs together with CME related data from the detailed online catalog of SOHO/LASCO. Correlations of the FD magnitude to the CME initial speed, the ICME transit speed and the maximum solar wind (SW) speed are presented. Comparisons between the features of CMEs (mass, width, velocity) and the characteristics of FDs are also demonstrated. FD features for halo, partial halo and non halo CMEs is being displayed and discussed.

CMEs. ICMEs and FDs:

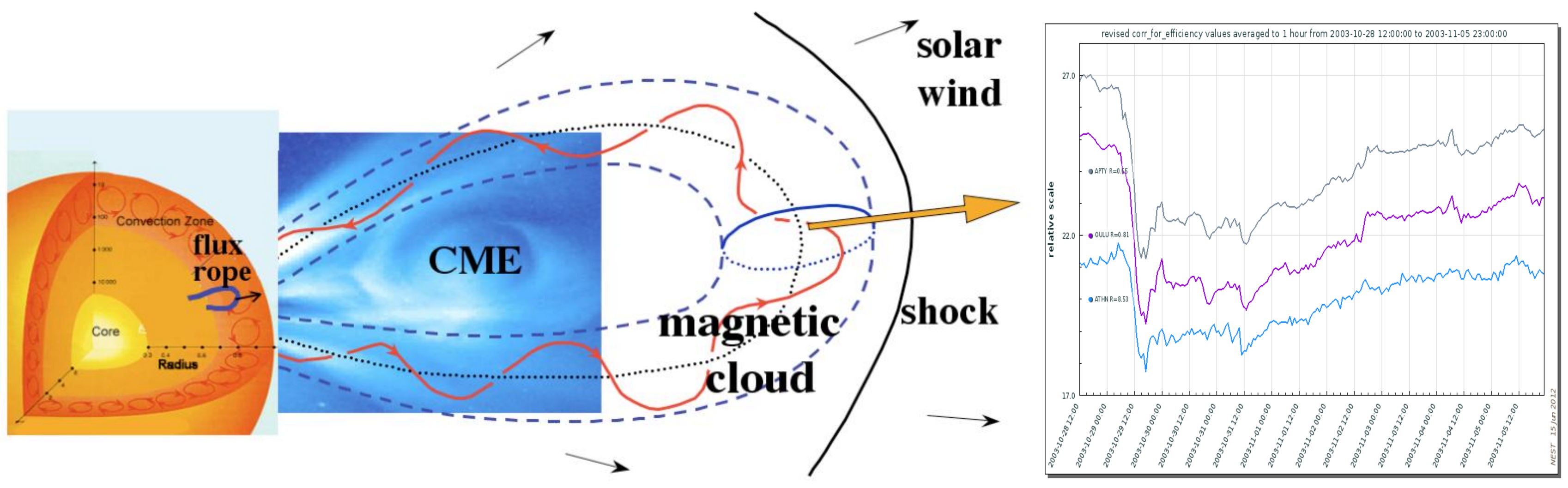

Figure 1. An artistic representation of the CME/ICME and FD chain [adapted by Démoulin, 2010]

CMEs as the driver of FDs I:

✓ We examine the statistical relation between the basic parameters of CMEs (i.e. size, mass and velocity) and FDs.

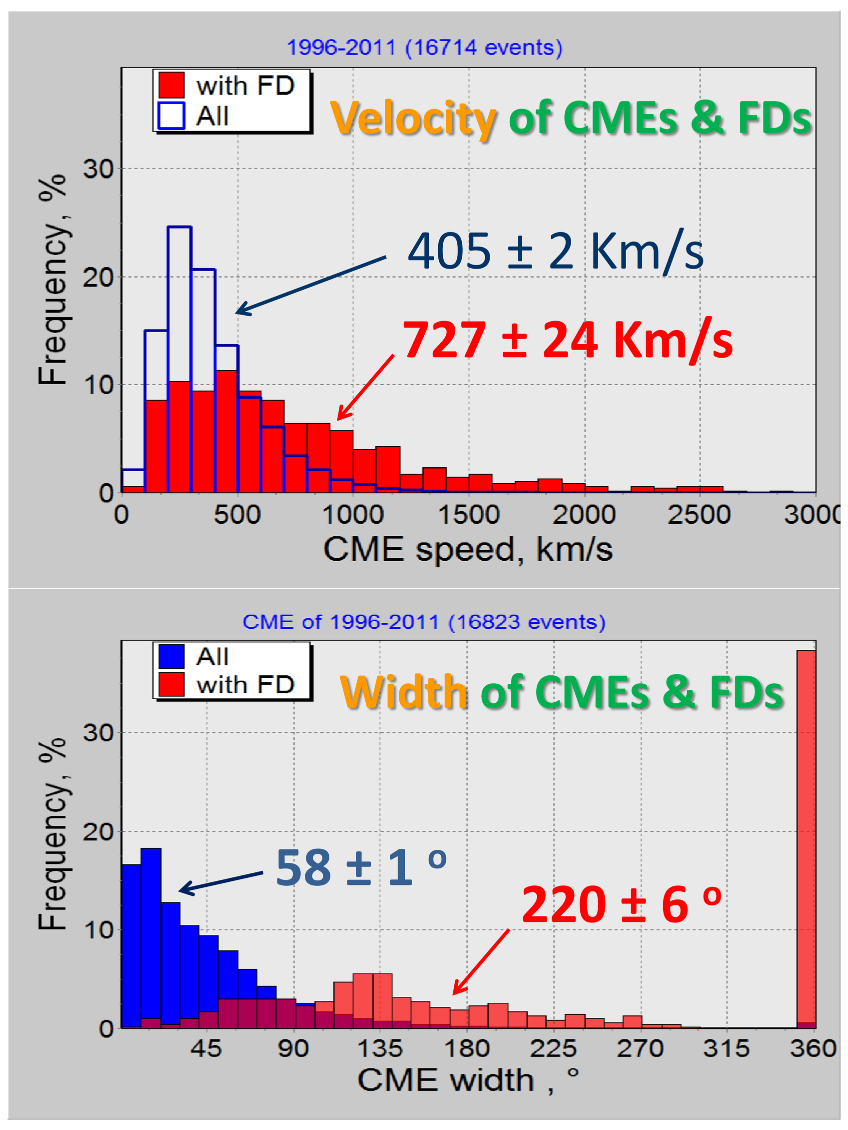

*Figure 2. **Top panel**: Velocity distribution for all CMEs (□) and for FD associated CMEs (▪) during the time period 1996-2011 (16714 events). **Bottom panel**: CMEs angular size distribution for all CMEs (▪) and for FD associated CMEs (▪) during the same time period 1996-2011 (16823 events).*

✓ **Fast CMEs** - *on average higher than the slow solar wind speed (400 Km/s) by a factor of 2* – **are correlated with FDs**, while **slow CMEs** at the limit of 400 Km/s **do not result into a pronounced decrease at the NMs count rate at Earth** (Fig.2, upper panel).

✓ The **bigger the angular width of a CME the more possible is to result into a FD** (see Fig.2, bottom panel)

✓ This is also underlined by the fact **all halo CMEs result into a decrease** in the NM count rate (see Fig.2, bottom panel for details)

✓ **Narrow** and **slow** CMEs ***do not produce*** **FDs**, while on the other hand **fast** and **wide** **CMEs *are needed*** in order for a significant ***FD*** in the cosmic ray intensity to be recorded by NMs at Earth (Fig.3, upper panel).

✓ **CMEs** with **greater mass** and **width** are ***associated to*** the **FD** initiation (Fig.3, bottom panel)

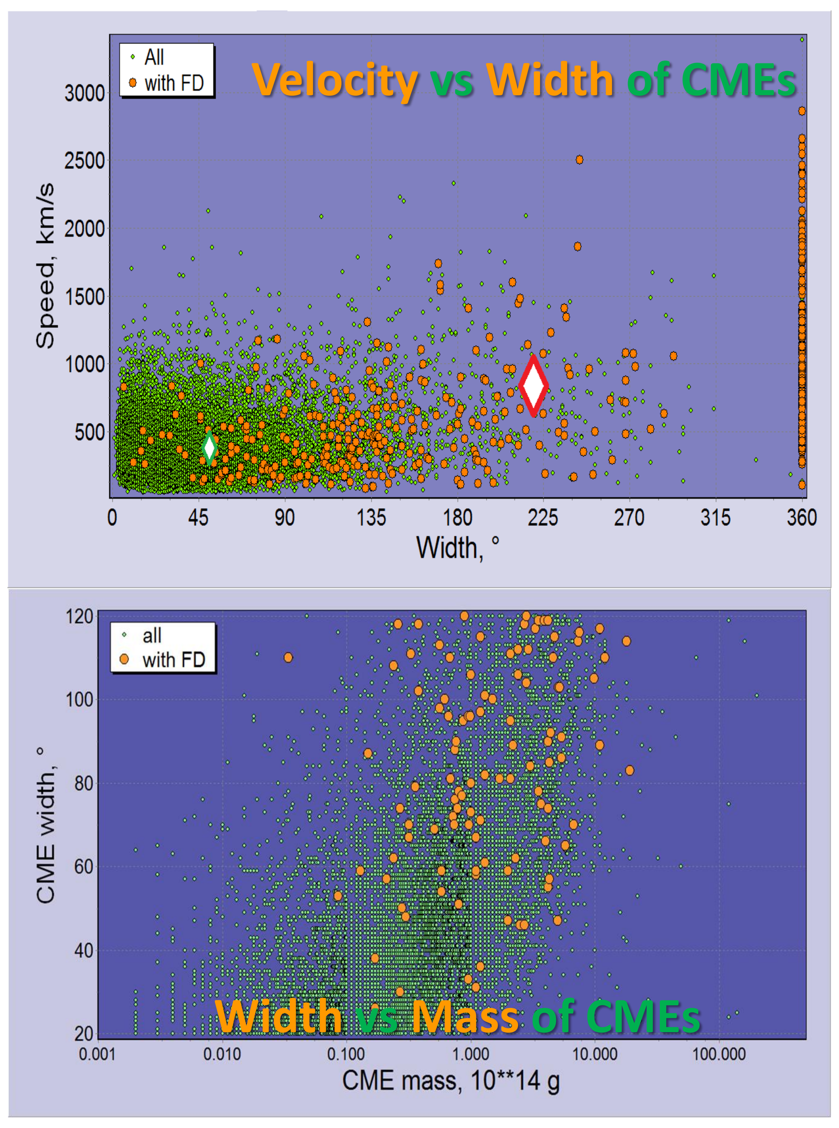

*Figure 3. **Top panel**: Relation between angle size and the CME velocity in all CME events (●) and in the FD subset (●). **Bottom panel**: Connection of the mass (in g) and angular size (in °) of CME for all CME events (●) and for the FD subset (●).*

CMEs as the driver of FDs II:

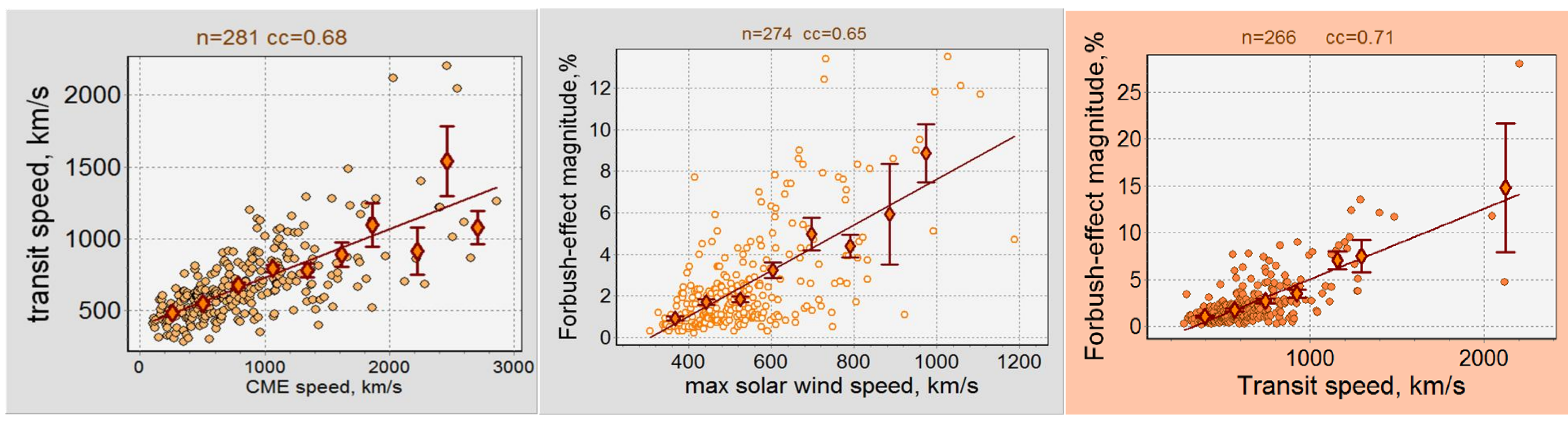

*Figure 4. **Left figure**: Relation of the transit speed of ejection to the speed of CME in the picture plane near the Sun for the events in the FD group. Dependence of the FD magnitude on the maximum speed of solar wind in the near Earth, disturbance (**Middle figure:**) and on the transit speed of CME (**Right figure**)*

✓ **CMEs *do create* FDs** but the **FDs are not created** near the Sun or close to Earth but rather during the travel time of the ICME through the IP medium

ICMEs acceleration and/or deceleration and FDs:

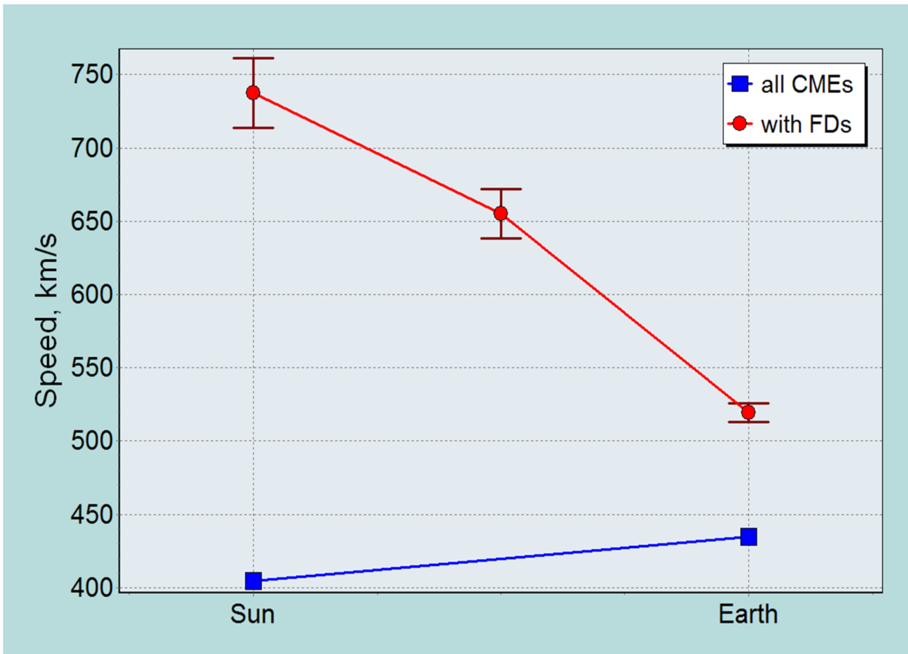

*Figure 5. **Averaged velocities of CME/ICME near the Sun and Earth in all CME events (▪) and in FD subset (●).***

✓ **ICMEs *that produce* FDs** suffer **deceleration** whereas the **CMEs** that ***do not produce*** **FDs** are **accelerated**

✓The **deceleration itself is significant** and it shows that the dominant physical process that plays major role in the motion of the interplanetary ejecta which results into a significant decrease of the cosmic ray intensity is the **aerodynamic drag** .

FDs time profiles as a function of the CME type:

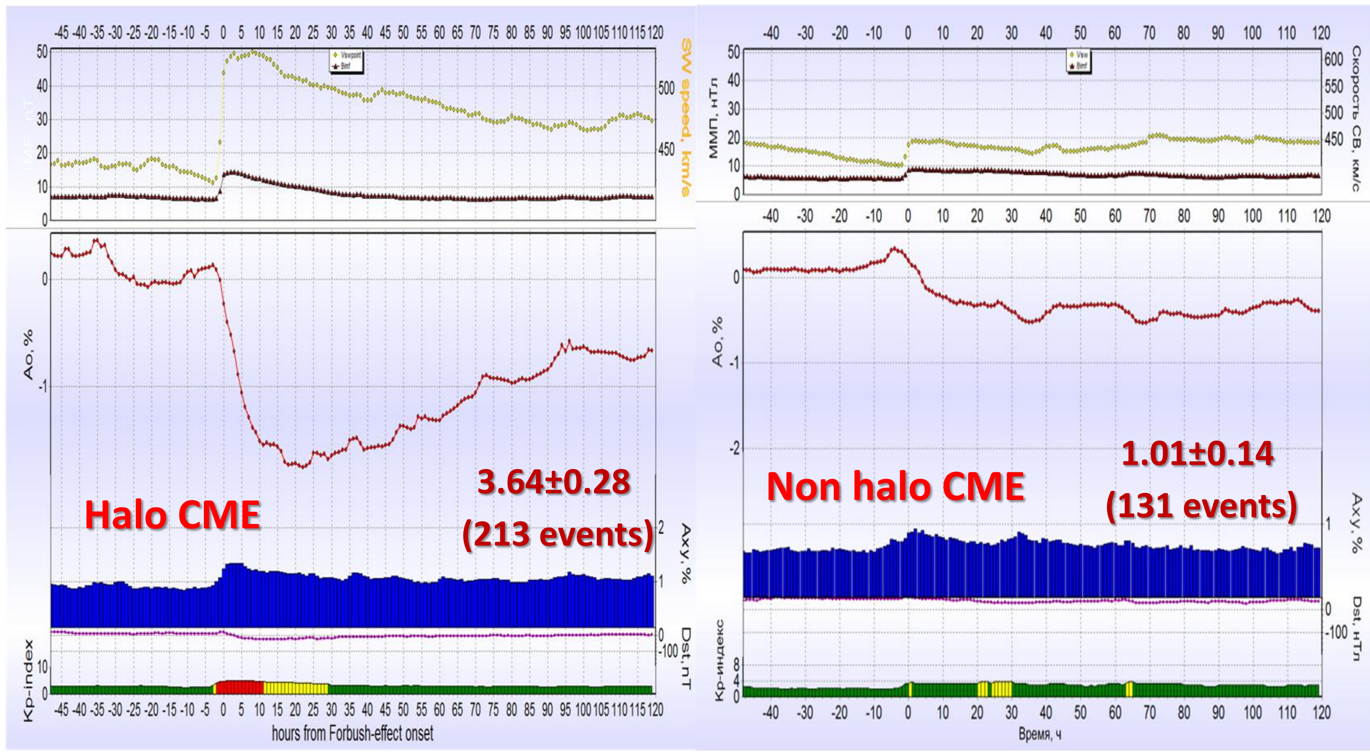

*Figure 6. **Averaged by the epoch method, a behavior of the solar wind velocity, IMF intensity (upper panel); density and equatorial component of the CR anisotropy for 10 GV particles (middle panel); Dst and Kp-indices of geomagnetic activity (bottom panel) for the events caused by halo CMEs (figure on the left) and for non-halo CMEs events (figure on the right).***

Conclusions:

✓**CMEs *associated*** with **FDs** are characterized by **significantly higher velocity**, **wider angular sizes** and **larger mass**.

✓The correlations of the **CME characteristics to the FD magnitude**, allow us, to ***estimate the expected efficiency of CMEs as the modulator of GCRs*** that result into FDs at 1 AU

✓**FDs** appear to be **a very useful asset** for **CME analysis** and **Space Weather**: their **magnitude** allow comparisons to the expected efficiency of CMEs in the IP space, the modulation of GCRs and the geomagnetic field's.

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