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Statistical Analysis of Forbush Decrease Events and Their Association with Coronal Mass Ejections and Solar Flares

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Abstract

This study presents a statistical investigation of Forbush decrease (FD) events and their association with solar and interplanetary drivers, particularly coronal mass ejection (CMEs) and solar flare activity. The results show that a dominant fraction of FD events (70 events; 88.57%) are associated with halo and partial-halo CMEs, confirming that Earth-directed CME structures play a key role in the generation of FD events. Among these, 54 events (77.14%) correspond to halo CMEs, while 8 events (11.42%) are linked to partial-halo CMEs.
A moderate positive correlation (r = 0.43) is observed between FD magnitude and CME speed, indicating that faster CMEs tend to produce stronger cosmic ray depressions at Earth. Importantly, all analyzed FD events (100%) are associated with solar X-ray flares of varying classes, establishing a universal flare connection. The flare distribution is dominated by M-class flares (37 events; 52.85%), followed by X-class flares (17 events; 24.28%), C-class flares (15 events; 21.42%), and a minor contribution from B-class flares (1 event; 1.42%). These findings collectively highlight that energetic, Earth-directed CMEs accompanied by significant flare activity are the primary drivers of FD events and play a crucial role in space weather modulation.

1. Introduction

Galactic cosmic rays (GCRs) continuously penetrate the heliosphere and are modulated by solar activity through a variety of transient and long-term processes. Among the most significant short-term modulations is the Forbush decrease (FD), which is characterized by a rapid reduction in cosmic ray intensity followed by a gradual recovery lasting several days. Since its first discovery by Forbush (1937, 1938), FD events have become one of the most important indicators of Sun–Earth interactions and remain fundamental for understanding the transport of energetic particles in the heliosphere. The occurrence of FD events is closely linked to solar eruptive phenomena and interplanetary disturbances, making them valuable diagnostics for investigating the physical mechanisms governing space weather.

The modulation of galactic cosmic rays is primarily controlled by large-scale heliospheric magnetic fields and transient solar wind structures. During periods of enhanced solar activity, the eruption of coronal mass ejections (CMEs), high-speed solar wind streams, and interplanetary shocks significantly alters the propagation of cosmic rays, resulting in temporary intensity depressions observed by ground-based neutron monitors and space-borne detectors (Cane, 2000; Richardson and Cane, 2011). Among these drivers, CMEs are widely recognized as the dominant cause of large-amplitude FD events because they transport enhanced magnetic fields and turbulent plasma that efficiently scatter energetic charged particles and reduce their diffusion toward Earth (Lockwood, 1971; Wibberenz et al., 1998).

A CME represents the explosive release of magnetized plasma from the solar corona into interplanetary space. When directed toward Earth, CMEs appear as halo or partial-halo events in coronagraph observations owing to projection effects. Halo CMEs, which surround the occulting disk with an apparent angular width of approximately 360°, are generally associated with Earth-directed eruptions and are considered among the most geoeffective solar transients. Partial-halo CMEs also possess a significant Earth-directed component and frequently produce interplanetary disturbances capable of influencing terrestrial space weather (Gopalswamy et al., 2007; Webb and Howard, 2012). The magnetic clouds and shock fronts associated with these CMEs compress the ambient solar wind and strengthen the interplanetary magnetic field, thereby producing efficient cosmic ray exclusion regions responsible for FD events (Burlaga et al., 1981; Cane, Richardson and Wibberenz, 1996).

Solar flares constitute another fundamental manifestation of solar magnetic activity. Produced by rapid magnetic reconnection in active regions, flares release enormous amounts of electromagnetic radiation over a broad wavelength range, from radio waves to X-rays and gamma rays. Although solar flares themselves are not regarded as the direct physical cause of FD events, they frequently occur simultaneously with CME eruptions originating from the same active region. Consequently, flare observations provide important information regarding the energy release associated with CME initiation and are widely employed as indicators of potentially geoeffective solar eruptions (Hudson, 2011; Benz, 2017). Statistical investigations have consistently demonstrated that intense flares, particularly M- and X-class events, exhibit a high probability of association with fast halo CMEs capable of producing significant geomagnetic disturbances and cosmic ray modulation (Yashiro et al., 2005; Gopalswamy et al., 2009).

Several investigations have attempted to establish quantitative relationships between FD magnitude and various solar or interplanetary parameters, including CME speed, angular width, magnetic field strength, shock intensity, and solar wind velocity. Numerous studies have shown that faster CMEs generally generate stronger interplanetary shocks and larger magnetic disturbances, resulting in deeper Forbush decreases. Nevertheless, the relationship is often moderate rather than linear because FD intensity depends on multiple interacting physical parameters, including CME geometry, magnetic cloud structure, ambient solar wind conditions, and the level of magnetic turbulence encountered during propagation (Belov, 2008; Richardson and Cane, 2011; Dumbović et al., 2015).

Recent investigations have further emphasized the complexity of FD formation. Comparative analyses of Solar Cycles 23 and 24 demonstrated that FD characteristics depend strongly on the type of solar source, distinguishing between active-region CMEs, filament eruptions, and high-speed streams originating from coronal holes (Melkumyan et al., 2023). Statistical comparisons also revealed that FD profiles associated with active-region CMEs develop more rapidly and exhibit larger amplitudes than events produced by corotating interaction regions or filament eruptions, particularly when magnetic clouds are present within the interplanetary CME structure (Melkumyan et al., 2023). Furthermore, long-term analyses have confirmed that large FD events remain strongly correlated with geomagnetic storms driven by interplanetary CMEs and their accompanying magnetic clouds (Belov et al., 2024).

Recent advances in space weather research have highlighted the broader significance of FD events beyond cosmic ray physics. Variations in cosmic ray intensity influence atmospheric ionization, the global electric circuit, radiation exposure to spacecraft and aviation, and the near-Earth radiation environment. Consequently, FD events have become increasingly important for operational space weather forecasting and the assessment of technological hazards associated with extreme solar eruptions (Tacza et al., 2024). Advanced analyses employing nonlinear and multifractal techniques have further demonstrated that FD events exhibit complex

temporal characteristics closely linked to geomagnetic storm evolution and interplanetary plasma dynamics, providing new insights into the coupling between solar eruptions and terrestrial space weather (Savi et al., 2024).
Despite decades of research, several important questions remain unresolved. In particular, the relative contribution of halo and partial-halo CMEs to FD generation, the dependence of FD magnitude on CME speed, and the statistical association between FD events and different classes of solar X-ray flares require further investigation using homogeneous event catalogues. Moreover, although numerous case studies have examined individual extreme events, comprehensive statistical analyses simultaneously considering CME geometry, flare classification, and FD intensity remain comparatively limited.

2. Data Sources

The present study is based on a dataset of Forbush decrease (FD) events identified from ground-based neutron monitor observations. The FD magnitudes were obtained from Oulu super neutron neutron monitor data, while the associated solar and interplanetary parameters were compiled from established space-weather databases. Coronal Mass Ejection (CME) characteristics, including CME type (halo, partial-halo, and non-halo) and linear speed, were obtained from the SOHO/LASCO CME Catalog. Information on solar X-ray flares, including flare class (B, C, M, and X) and occurrence time, was collected from the GOES X-ray flare catalog. Each FD event was associated with its corresponding CME and solar flare based on temporal proximity and reported solar event associations.

3. Method of Analysis

A statistical approach was employed to investigate the relationship between Forbush decrease events and their associated solar drivers. Initially, each FD event was matched with the corresponding CME and solar X-ray flare using event timing and solar event reports. The CMEs were classified into halo, partial-halo, and non-halo categories, and their occurrence frequencies were determined. Similarly, solar flares were grouped according to their GOES X-ray classifications (B, C, M, and X classes), and their frequency distribution was analyzed.
Descriptive statistical methods were used to calculate the percentage contribution of each CME and flare category to the total number of FD events. To examine the influence of CME dynamics on FD intensity, Pearson's correlation analysis was performed between FD magnitude and CME speed. The correlation coefficient (r) was used to quantify the strength and direction of the linear relationship. Frequency distributions, percentage analysis, and correlation statistics were employed to identify the dominant solar drivers responsible for FD events and to assess their contribution to cosmic ray modulation at Earth.

4. Data Analysis

4.1 Analysis of Forbush Decreases with Coronal Mass Ejections Cycle 23 and 24

The results indicate a strong and clear relationship between Forbush decrease (FD) events and Earth-directed coronal mass ejection (CMEs), emphasizing the dominant role of CME geometry in modulating cosmic ray intensity at Earth.
The first result shows that a large majority of FD events (70 events; 88.57%) are associated with halo and partial-halo CMEs. This high percentage suggests that FD events are predominantly produced when CMEs are directed toward Earth or have a significant Earth-impacting component. Such CMEs drive strong interplanetary disturbances, including shock waves and enhanced magnetic fields, which are known to reduce the intensity of galactic cosmic rays reaching Earth. Therefore, this result clearly supports the idea that Earth-directed CME structures are the primary triggers of FD events.
The second result provides a more detailed breakdown of these associations, showing that 54 events (77.14%) are linked to halo CMEs, while 8 events (11.42%) are associated with partial-halo CMEs. This distribution further strengthens the interpretation that halo CMEs are the dominant contributors to FD events. Halo CMEs, which appear as complete rings in coronagraph images, represent eruptions directed either toward or away from Earth, but those associated with FD events are typically Earth-directed and highly geoeffective. Their higher frequency indicates that direct or near-direct CME impacts are most efficient in producing significant cosmic ray depressions.
In contrast, partial-halo CMEs represent events with a smaller angular width or slightly off-center propagation relative to Earth. Their lower contribution suggests that while they can still influence cosmic ray intensity, their effectiveness in generating FD events is comparatively weaker due to reduced interaction strength with Earth’s magnetosphere and interplanetary environment.
Overall, these results demonstrate that the geometry and Earth-directed nature of CMEs play a crucial role in FD generation, with halo CMEs being the most significant drivers, followed by a smaller contribution from partial-halo CMEs.

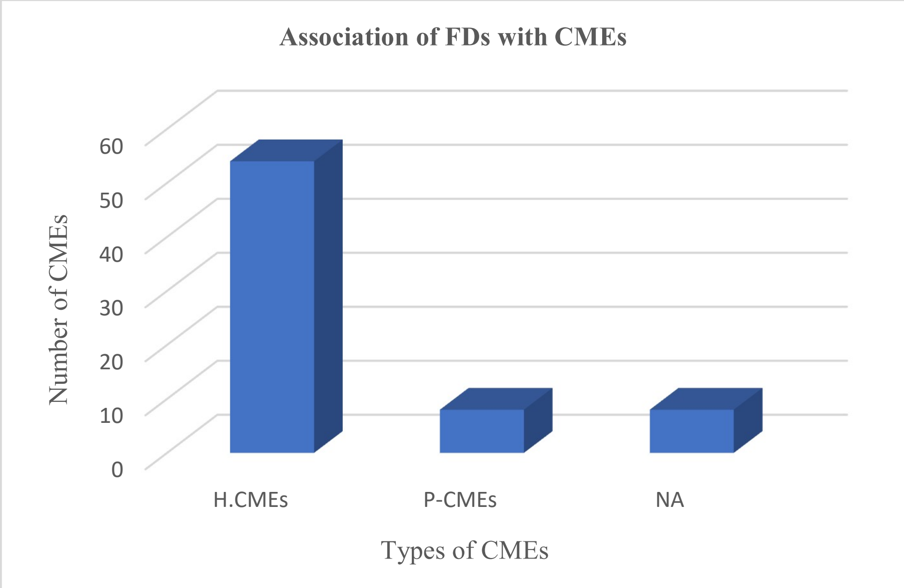

Fig.1 Shows bar diagram of coronal mass ejections and frequency of associated Forbush decreases (Fds) for the period of solar cycle 23 and 24.

The result indicates a moderate positive correlation (r = 0.43) between the magnitude of Forbush decrease (FD) events and the speed of the associated coronal mass ejection (CMEs). This means that, in general, faster CMEs tend to produce stronger decreases in cosmic ray intensity at Earth, although the relationship is not perfectly linear. A correlation coefficient of 0.43 suggests a noticeable but not dominant dependence, implying that CME speed is an important contributing factor but not the only parameter controlling FD magnitude. Physically, faster CMEs generate stronger interplanetary shocks and more turbulent plasma environments as they propagate through the heliosphere. These disturbed regions act as barriers that reduce the entry of galactic cosmic rays into the inner solar system, leading to deeper FD events.

However, the moderate value of the correlation also indicates that other factors significantly influence FD magnitude. These may include CME magnetic field strength, CME width, interaction with preceding solar wind structures, and the orientation and complexity of the interplanetary magnetic field. Additionally, the efficiency of cosmic ray modulation depends not only on speed but also on how effectively the CME-driven disturbance evolves during propagation from the Sun to Earth.

Overall, this result highlights that CME speed is a key physical parameter controlling FD intensity, but FD events are the result of a combination of multiple interplanetary conditions rather than a single driving factor.

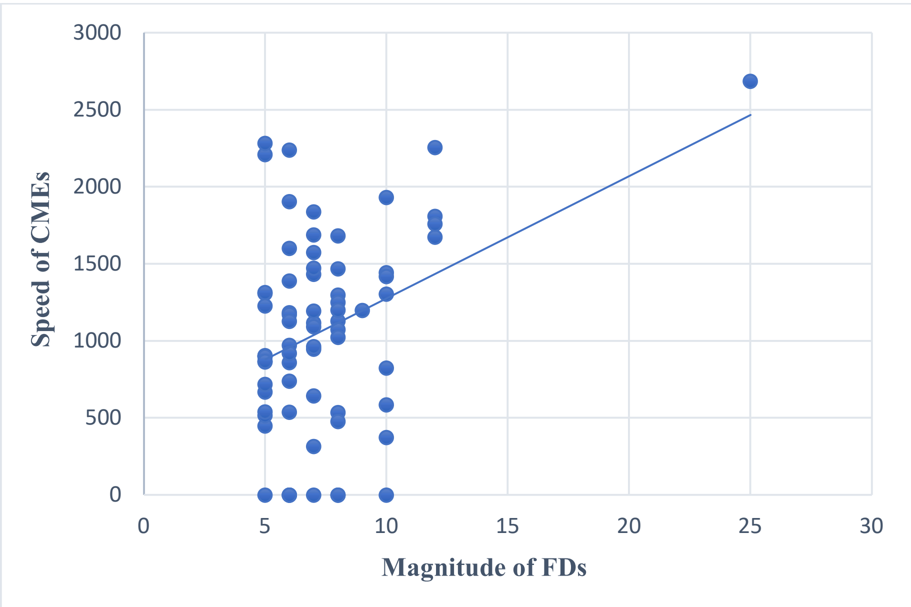

Fig.2 Shows Scatter plot between magnitude of Forbush decreases (Fds) and speed of associated CMEs for the period of solar cycle 23 and 24.

4.2 Analysis of Forbush Decreases with Solar Flares Cycle 23 and 24

The result stating that all analyzed Forbush decrease (FD) events (100%) are associated with solar X-ray flares of varying classes indicates a very strong and universal relationship between FD events and solar flare activity. This implies that every FD event in the dataset has a corresponding solar flare occurrence, confirming that flare activity is an integral part of the solar eruptive processes that ultimately influence cosmic ray modulation at Earth.

From a physical standpoint, this 100% association does not necessarily mean that flares alone cause FD events, but rather that they are co-temporal or physically linked components of the same eruptive solar events. In most cases, solar flares and coronal mass ejections (CMEs) originate from the same active regions on the Sun, driven by magnetic reconnection processes. Therefore, the presence of a flare strongly indicates that significant magnetic energy release has occurred, often accompanied by a CME that propagates through the heliosphere and interacts with Earth's magnetosphere.

This universal association highlights that FD events are not isolated interplanetary phenomena but are part of a complete solar eruption chain, beginning with magnetic energy buildup, followed by flare emission in X-rays, and often accompanied by CME ejection. The flare acts as an observational signature of this energy release process, while the CME and its interplanetary shock are primarily responsible for the actual reduction in cosmic ray intensity.

The result also reinforces the idea that flare classification (B, C, M, X classes) provides useful information about the energy scale of the associated eruption, with higher-class flares generally indicating more energetic and potentially more geoeffective events. However, even lower-class flares are still present in FD-associated events, suggesting that the occurrence of a flare—regardless of its intensity—signals an underlying eruptive process capable of producing interplanetary disturbances.

Overall, this finding confirms a universal flare–FD association, emphasizing that every FD event in the dataset is linked to solar eruptive activity, and reinforcing the strong physical connection between solar magnetic energy release, flare emission, CME propagation, and cosmic ray modulation in interplanetary space.

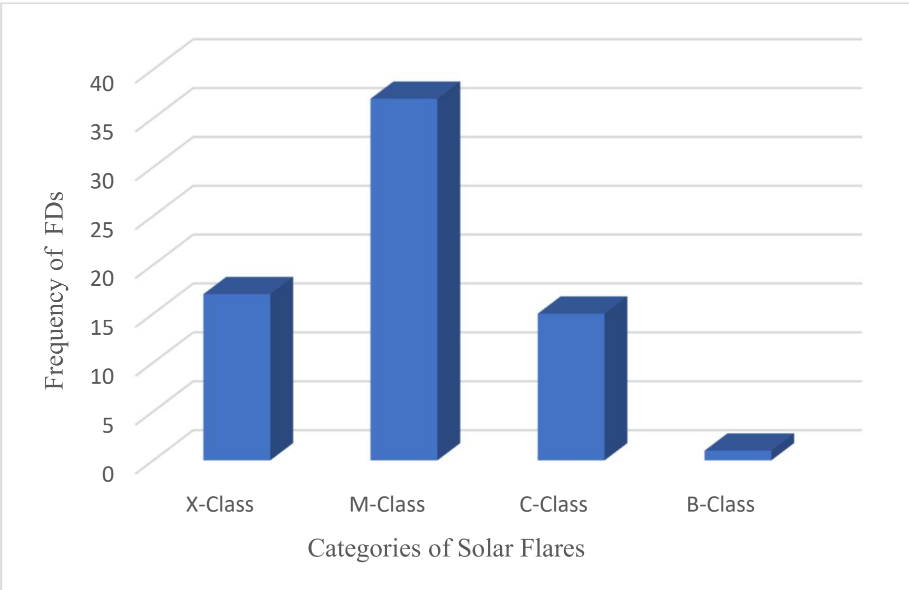

Fig.3 Shows bar diagram between different types of X-Ray solar flares and frequency of associated Forbush decreases (Fds) for the period of solar cycle 23 and 24.

The flare distribution result shows how different classes of solar flare are associated with Forbush decrease (FD) events, and it provides important information about the typical energy scale of solar eruptions that contribute to cosmic ray modulation at Earth.

The dominance of M-class flares (37 events; 52.85%) indicates that most FD-related solar eruptions originate from moderately strong solar energy release events. M-class flares are significant in terms of radiative output and are usually associated with active regions capable of producing coronal mass ejections (CMEs). Their high frequency suggests that FD events do not require only extreme solar activity (such as X-class flares), but can also be triggered effectively by moderately energetic eruptions when accompanied by CME-driven interplanetary disturbances.

The second most frequent category is X-class flares (17 events; 24.28%), which represent the most powerful solar flare events. Their substantial contribution indicates that a significant fraction of FD events is associated with high-energy solar eruptions, which typically produce strong CMEs, intense shocks, and highly disturbed

interplanetary conditions. These events are expected to generate deeper and more pronounced Forbush decreases due to their stronger heliospheric impact.
C-class flares (15 events; 21.42%) also contribute meaningfully to FD events, suggesting that even relatively weaker flares can be associated with cosmic ray modulation when they occur in active regions capable of producing Earth-directed CMEs. This highlights that flare intensity alone does not fully determine FD occurrence; rather, the combined flare-CME system is the key driver.
The extremely low occurrence of B-class flares (1 event; 1.42%) shows that very weak solar flares are rarely associated with FD events. This is physically reasonable because B-class flares typically reflect minor magnetic energy release that is less likely to be accompanied by significant CMEs or strong interplanetary disturbances capable of affecting cosmic ray flux at Earth.
Overall, this distribution demonstrates that FD events are most commonly linked to moderate-to-strong solar eruptive activity, with M-class flares being the dominant contributor, followed by X-class and C-class flares. This pattern reinforces the idea that FD events are primarily driven by energetic solar eruptions associated with CME activity, where flare class serves as an indicator of the underlying magnetic energy

5. Results

A total of 79 Forbush decrease (FD) events were statistically analyzed to investigate their association with coronal mass ejections (CMEs) and solar X-ray flares. The analysis reveals a strong relationship between FD events and Earth-directed solar eruptions.
Among the analyzed events, 70 FD events (88.57%) were associated with halo and partial-halo CMEs, indicating that Earth-directed CMEs are the dominant drivers of cosmic ray intensity reductions. Halo CMEs accounted for the majority of the associated events, with 54 occurrences (77.14%), whereas partial-halo CMEs contributed 8 events (11.42%). Only a small fraction of FD events were associated with non-halo CMEs or showed no clear halo characteristics, suggesting that the spatial extent and Earth-directed propagation of CMEs significantly influence the occurrence of Forbush decreases.
The relationship between FD magnitude and CME speed was further examined using Pearson's correlation analysis. A moderate positive correlation ($r = 0.43$) was obtained, indicating that faster CMEs generally produce larger decreases in galactic cosmic ray intensity. Although the correlation is not sufficiently strong to imply that CME speed alone determines FD magnitude, the result demonstrates that CME velocity is an important contributing parameter. The observed variability suggests that additional factors, such as CME magnetic field strength, size, interplanetary evolution, and shock characteristics, also influence the magnitude of Forbush decreases.
The association between FD events and solar X-ray flares was found to be universal, with all analyzed FD events (100%) corresponding to flare activity. The flare distribution shows that M-class flares were the most common, accounting for 37 events (52.85%). X-class flares represented the second-largest group with 17 events (24.28%), followed by C-class flares with 15 events (21.42%), while only one event (1.42%) was associated with a B-class flare. The predominance of M- and X-class flares indicates that moderate-to-high energy solar eruptions are most effective in producing the CME structures responsible for Forbush decreases.
Overall, the statistical results demonstrate that halo CMEs accompanied by energetic solar flares constitute the primary solar drivers of FD events. The findings further indicate that CME speed contributes positively to FD intensity, although the relationship is moderated by other interplanetary parameters governing CME propagation and interaction with Earth's magnetosphere.

6. Conclusion

This study presents a statistical analysis of 79 Forbush decrease events to examine their relationship with coronal mass ejections and solar X-ray flares. The results clearly demonstrate that Earth-directed CMEs are the principal drivers of FD events, with 88.57% of the analyzed events associated with halo or partial-halo CMEs. The predominance of halo CMEs emphasizes the importance of CME geometry and propagation direction in determining the effectiveness of cosmic ray modulation near Earth.
A moderate positive correlation ($r = 0.43$) between CME speed and FD magnitude indicates that faster CMEs generally produce stronger reductions in galactic cosmic ray intensity. However, the moderate strength of the correlation suggests that additional physical parameters, including CME magnetic field strength, shock properties, and interplanetary evolution, also contribute significantly to the observed FD magnitude.
The study further establishes a complete association between FD events and solar X-ray flares, with every analyzed FD event linked to flare activity. The dominance of M-class (52.85%) and X-class (24.28%) flares indicates that energetic solar eruptions are the most effective precursors of the CME disturbances responsible for Forbush decreases.
Overall, the findings confirm that energetic, Earth-directed CMEs accompanied by significant flare activity play a dominant role in the generation of Forbush decreases and the modulation of galactic cosmic rays. These results improve the understanding of Sun–Earth interactions and contribute to the development of more reliable space weather forecasting models based on solar eruption characteristics. Future studies incorporating additional interplanetary parameters, such as CME magnetic field strength, solar wind conditions, and shock properties,

may further improve the prediction of Forbush decrease intensity and their impact on the near-Earth space environment.

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Conflict of Interest

Here by I declare that there is no conflict of Interest in the preparation of this research paper.

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Authors Contribution

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References

[1] Belov, A. (2008). Forbush effects and their connection with solar, interplanetary and geomagnetic phenomena. In H. O. Vázquez, R. A. Mewaldt, K. P. Wenzel, & V. B. Baranov (Eds.), *Proceedings of the International Astronomical Union*, 4(S257), 439–450.

[2] Belov, A., Eroshenko, E., Yanke, V., Melkumyan, A., Abunin, A., Abunina, M., Papaioannou, A. (2024). Large Forbush decreases and geomagnetic storms associated with interplanetary coronal mass ejections during Solar Cycles 23–25. *Solar Physics*, 299, Article 33.

[3] Benz, A. O. (2017). Flare observations. *Living Reviews in Solar Physics*, 14, Article 2. https://doi.org/10.1007/s41116-016-0004-3

[4] Burlaga, L. F., Sittler, E., Mariani, F., Schwenn, R. (1981). Magnetic loop behind an interplanetary shock: Voyager, Helios, and IMP-8 observations. *Journal of Geophysical Research*, 86, 6673–6684. https://doi.org/10.1029/JA086iA08p06673

[5] Cane, H. V. (2000). Coronal mass ejections and Forbush decreases. *Space Science Reviews*, 93, 55–77. https://doi.org/10.1023/A:1026532125747

[6] Cane, H. V., Richardson, I. G., Wibberenz, G. (1996). Cosmic ray decreases and shock disturbances: A statistical study of their association. *Journal of Geophysical Research*, 101(A10), 21561–21572. https://doi.org/10.1029/96JA01964

[7] Dumbović, M., Vršnak, B., Čalogović, J., & Karlica, M. (2015). Cosmic ray Forbush decreases associated with coronal mass ejections. *Astronomy & Astrophysics*, 576, A83. https://doi.org/10.1051/0004-6361/201425290

[8] Forbush, S. E. (1937). On the effects in cosmic-ray intensity observed during the recent magnetic storm. *Physical Review*, 51, 1108–1109. https://doi.org/10.1103/PhysRev.51.1108.3

[9] Forbush, S. E. (1938). On worldwide changes in cosmic-ray intensity. *Physical Review*, 54, 975–988. https://doi.org/10.1103/PhysRev.54.975

[10] 1Gopalswamy, N., Yashiro, S., Akiyama, S., Michalek, G., Howard, R. A. (2007). Solar source of the largest geomagnetic storm of cycle 23. *Journal of Geophysical Research*, 112, A06112. https://doi.org/10.1029/2006JA012149

[11] Gopalswamy, N., Dal Lago, A., Yashiro, S., & Akiyama, S. (2009). The expansion and radial speeds of coronal mass ejections. *Central European Astrophysical Bulletin*, 33, 115–124.

[12] Hudson, H. S. (2011). Global properties of solar flares. *Space Science Reviews*, 158, 5–41. https://doi.org/10.1007/s11214-010-9721-4

[13] Lockwood, J. A. (1971). Forbush decreases in the cosmic radiation. *Space Science Reviews*, 12, 658–715. https://doi.org/10.1007/BF00173346

[14] Melkumyan, A. A., Belov, A. V., Eroshenko, E. A., Abunin, A. A., Abunina, M. A. (2023). Comparative analysis of Forbush decreases generated by different solar sources during Solar Cycles 23 and 24. *Solar Physics*, 298, Article 63. https://doi.org/10.1007/s11207-023-02164-9

[15] Richardson, I. G., Cane, H. V. (2011). Galactic cosmic ray intensity response to interplanetary coronal mass ejections/magnetic clouds in 1995–2009. *Solar Physics*, 270, 609–627. https://doi.org/10.1007/s11207-011-9774-x

[16] Savi, M. A., de Souza, E., Mendes, O., Papa, A. R. R. (2024). Multifractal characteristics of Forbush decreases and geomagnetic storm dynamics. *Chaos, Solitons & Fractals*, 179, 114444. https://doi.org/10.1016/j.chaos.2023.114444

[17] Tacza, J., Siluszyk, M., Wawrzynczak, A., et al. (2024). Forbush decreases and their relevance to modern space weather applications. *Space Weather*, 22, e2024SW003xxx.

[18] Webb, D. F., Howard, T. A. (2012). Coronal mass ejections: Observations. *Living Reviews in Solar Physics*, 9, Article 3. https://doi.org/10.12942/lrsp-2012-3

[19] Wibberenz, G., Le Roux, J. A., Potgieter, M. S., & Bieber, J. W. (1998). Transient effects and disturbed conditions. In J. A. Simpson & K. R. Pyle (Eds.), *Cosmic Rays and Earth* (Space Science Series). Kluwer Academic Publishers.

[20] Yashiro, S., Gopalswamy, N., Akiyama, S., Michalek, G., Howard, R. A., Kajiwara, Y., Shibasaki, K. (2005). Visibility of coronal mass ejections as a function of flare location and intensity. *Journal of Geophysical Research*, 110, A12S05. https://doi.org/10.1029/2005JA011151