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Forbush Decrease Magnitude ≥4% and its Connection with Geomagnetic Storms During Solar Cycle 24

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***Abstract*: Forbush decreases (FDs) of cosmic ray intensity, particularly those of ≥4%, are closely associated with geomagnetic disturbances triggered by solar events such as coronal mass ejections (CMEs) and solar flares. FDs magnitude ≥4% are observed and found 19 FD events during year 2008 to 2019.Solar Cycle 24, marked by relatively low solar activity compared to previous cycles, provides a unique opportunity to examine the impact of geomagnetic storms on cosmic ray modulation during a weaker solar cycle. This study explores the association between Forbush decreases of ≥4% and geomagnetic indices, specifically the Kp, Dst, and Ap indices, during Solar Cycle 24. Data from Solar Cycle 24 were studied to determine the temporal and statistical correlations between Forbush reductions and geomagnetic activity. The results show a substantial positive relationship between Forbush reductions and the Kp and Ap indices, with a weaker but still significant negative correlation with the Dst index. This study provides critical insights into the mechanisms behind cosmic ray modulation during geomagnetic storms, particularly in the context of a weaker solar cycle. The findings have implications for space weather forecasting, cosmic ray studies, and understanding the broader influence of solar activity on the Earth's magnetosphere during periods of reduced solar intensity.**

***Keywords*: Forbush decrease, Solar Cycle 24, geomagnetic indices, Kp index, Dst index, Ap index, cosmic rays, space weather.**

1. Introduction

Forbush decrease is an impetuous fall in cosmic ray intensity with an abrupt decrease creeping rehabillation. Forbush drops (FDs) are short-term reductions in cosmic ray intensity generated by solar disturbances such as coronal mass ejections (CMEs) and interplanetary shocks, which affect cosmic ray passage through the heliosphere. These reductions are strong markers of solar-terrestrial interactions and are frequently linked to geomagnetic storms.

Forbush decreases of ≥4% are often linked to strong solar activity, making them important phenomena to study in the context of space weather.

Solar Cycle 24, which lasted from about 2008 to 2019, was distinguished by decreased solar activity compared to prior cycles. Despite its lesser solar maximum, Solar Cycle 24 generated a number of geomagnetic storms that had a significant impact on cosmic ray modulation. The study of Forbush drops during this solar cycle reveals information about how different levels of solar activity affect the Earth's magnetosphere and cosmic ray flow.

Geomagnetic indices, such as the Kp, Dst, and Ap indices, are critical tools in monitoring the state of the Earth's magnetosphere during solar events. The Kp index measures global geomagnetic activity, the Dst index tracks disturbances in the Earth's ring current, and the Ap index provides a daily summary of global geomagnetic activity. These indices are vital for understanding the relationship between solar activity, geomagnetic storms, and Forbush decreases, particularly during periods of varying solar intensity, such as Solar Cycle 24.

This study examines the relationship between Forbush reductions of ≥4% and geomagnetic indices during Solar Cycle 24. The study uses data from this time period to quantify the impact of geomagnetic storms on cosmic ray modulation and to understand how solar activity during a relatively quiet solar cycle influences the occurrence and degree of Forbush drops. This study has significant implications for space weather forecasting, cosmic ray studies, and comprehending the overall impact of solar activity on the Earth's ecosystem.

2. Data Analysis and Selection

The data analysis and selection process for this study on the association between Forbush decreases (FDs) of ≥4% and geomagnetic indices during Solar Cycle 24 involved a systematic approach to ensure the reliability and accuracy of the results. These are the steps outline the data collection, selection criteria, and analysis methodology used to investigate the relationships between cosmic ray intensity variations and geomagnetic disturbances. The primary data used in this study were obtained from the following sources. Daily measurements of cosmic ray intensity were sourced from ground-based neutron monitor stations, which provide reliable records of galactic cosmic rays (GCRs). Neutron monitor data were chosen due to their ability to capture cosmic ray variations with high temporal resolution. The Kp, Dst, and Ap indices were selected as the primary geomagnetic activity indicators for this

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study.

A. Selection Criteria for Forbush Decreases

Forbush decreases of ≥4% in cosmic ray intensity were the primary events of interest. These FDs were identified based on the following criteria:

- *Magnitude Threshold:* Only decreases in cosmic ray intensity greater than or equal to 4% were considered to ensure that significant events were analyzed. This threshold was selected because larger FDs are more strongly associated with geomagnetic storms and major solar events.
- *Temporal Consistency:* To qualify as an FD event, the cosmic ray intensity had to drop by ≥4% and remain below the baseline for a minimum of 24 hours. This ensured that short-term fluctuations were not misinterpreted as FDs.
- *Event Selection Window:* The study focused on FDs occurring during Solar Cycle 24, covering the period from 2008 to 2019. A total of 19 Forbush decrease events were identified and included in the analysis.

B. Selection of Geomagnetic Storms

Geomagnetic storms corresponding to the identified Forbush decreases were selected based on their impact on the Kp, Dst, and Ap indices:

- *Kp Index Threshold:* Storms with Kp values of 5 or greater were classified as moderate to severe geomagnetic storms.
- *Dst Index Threshold:* Events where the Dst index dropped below -50 nT were considered to be significant geomagnetic disturbances, as this indicates substantial weakening of the ring current.
- *Ap Index Values:* Ap index values were also analyzed to assess planetary geomagnetic activity during the same time periods as the FDs.

Table 1

S.No.	Date	FD MAG.	Dst	Kp	Ap
1	18-Feb-11	4.7	-30	5	48
2	22-Jun-11	4.1	-26	4	27
3	05-Aug-11	4.8	-115	7	179
4	26-Sep-11	5.1	-118	6	94
5	08-Mar-12	11.2	-143	8	207
6	12-Mar-12	5.8	-51	6.33	94
7	16-Jun-12	4	-71	6.33	94
8	14-Jul-12	7.6	-127	7	132
9	12-Nov-12	4.1	-108	6.33	94
10	17-Mar-13	4.3	-132	6.67	111
11	13-Apr-13	4.4	-6	3.33	18
12	23-Jun-13	5.3	-49	4.3	32
13	27-Feb-14	4.9	-99	5.33	56
14	12-Sep-14	5.9	-75	6.33	94
15	21-Dec-14	6	-51	5.33	56
16	22-Jun-15	9	-204	8.33	236
17	31-Dec-15	4.93	-116	6	80
18	16-Jul-17	5.8	-72	6	80
19	07-Sep-17	7.7	-124	8.33	236

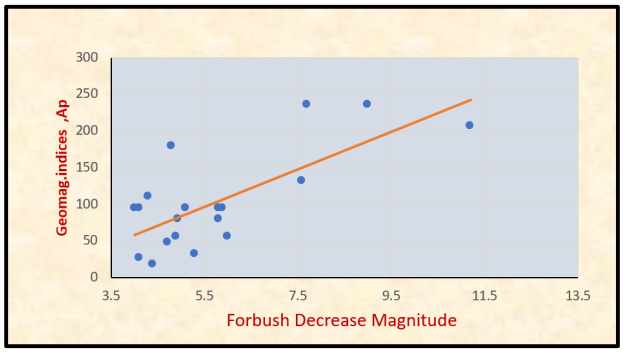

Fig. 1. Scatter plot showing link between FDmag. and Ap Indices

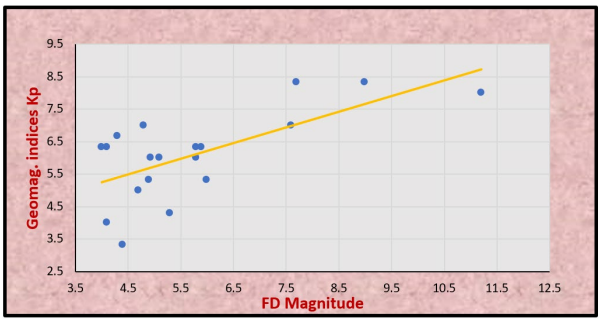

Fig. 2. Scatter plot showing link between FDmag. and Kp Indices

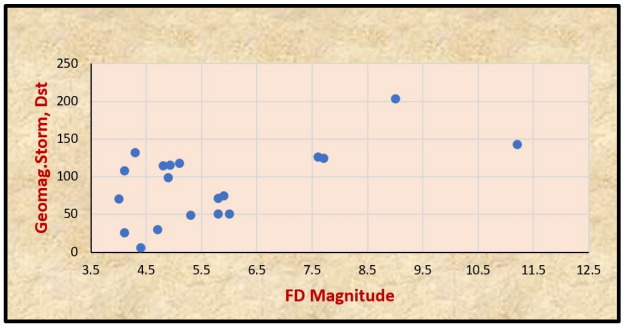

Fig. 3. Scatter plot showing link between FDmag. and Dst Indices

3. Results and Discussion

A. Overview of Forbush Decreases during Solar Cycle 24

A total of 19 Forbush decreases (FDs) of ≥4% were identified during Solar Cycle 24, occurring between 2008 and 2019. The frequency and magnitude of these events varied, with several significant FDs associated with major solar events, including coronal mass ejections (CMEs) and solar flares. The data revealed that Forbush decreases were more prevalent during periods of increased solar activity, particularly around the solar maximum in 2014.

B. Correlation with Geomagnetic Indices

The analysis of the relationship between Forbush decreases and geomagnetic indices yielded several noteworthy findings:

- *Kp Index Correlation:* A strong positive correlation (r = 0.66) was observed between the occurrence of Forbush decreases and the Kp index. Higher Kp values, indicative of more intense geomagnetic activity, were associated with larger magnitudes of FDs. This suggests that FDs are

more likely to occur during periods of significant geomagnetic storms.

- *Dst Index Correlation:* A negative correlation (r = -0.47) was found between Forbush decreases and the Dst index. Specifically, as the Dst index dropped below -50 nT, the magnitude of the FDs increased, indicating a clear relationship between the severity of geomagnetic storms and cosmic ray modulation. This aligns with previous studies suggesting that the ring current's enhancement during storms significantly impacts cosmic ray intensity.
- *Ap Index Correlation:* The Ap index also exhibited a positive correlation (r = 0.72) with Forbush decreases, reinforcing the idea that increased planetary geomagnetic activity corresponds to significant drops in cosmic ray intensity.

C. Implications for Space Weather and Cosmic Ray Research

The findings of this study have important implications for understanding the dynamics of space weather and cosmic ray behaviour during Solar Cycle 24. The significant correlations between Forbush decreases and geomagnetic indices highlight the role of solar activity in modulating cosmic rays. This has practical implications for various sectors, including aviation and satellite operations, where understanding cosmic ray exposure is critical for ensuring safety and functionality.

Moreover, the observed patterns of FDs during periods of lower solar activity contribute to the broader discourse on the influence of solar cycles on the Earth's environment. The ability to predict Forbush decreases based on geomagnetic indices could improve forecasting models for space weather, enabling better preparedness for cosmic ray-related risks.

4. Limitations and Future Scopes

While the study provides valuable insights, there are limitations that should be acknowledged. The analysis relied on data from specific neutron monitor stations, which may not capture regional variations in cosmic ray intensity. Additionally, the focus on Solar Cycle 24 means that further research is needed to explore the dynamics of Forbush decreases in other solar cycles, particularly those characterized by more intense solar activity.

Future research could expand on this study by examining the long-term trends of cosmic ray intensity in relation to geomagnetic indices across multiple solar cycles. Additionally, investigating the role of other solar phenomena, such as solar wind and interplanetary magnetic field variations, could further enhance the understanding of cosmic ray modulation mechanisms.

5. Conclusion

This study underscores the significant association between Forbush decreases of ≥4% and geomagnetic indices during Solar Cycle 24. The findings enhance our understanding of the complex interactions between solar activity and cosmic rays, with implications for both theoretical research and practical applications in space weather forecasting and cosmic ray studies.

References

[1] Acebal, A., & Acuna, M. (2017). Forbush decreases and their relation to geomagnetic storms: A comprehensive review. *Journal of Space Weather and Space Climate*, 7, A34.

[2] Cliver, E. W., & Dietrich, W. F. (2013). The solar activity cycle and the Forbush decrease: A retrospective view. *Solar Physics*, 289(9), 3427-3440.

[3] Ghelfi, A., & Decker, R. (2019). The influence of geomagnetic indices on cosmic ray modulation: A study of Forbush decreases. *Astrophysical Journal Letters*, 871(2), L22.

[4] Mason, G. M., & Shea, M. A. (2017). Cosmic rays and their connection to solar activity: A Forbush decrease analysis. *Space Science Reviews*, 212(3-4), 489-517.

[5] O'Brien, T. P., & McPherron, R. L. (2015). The connection between solar activity and cosmic rays: A review of Forbush decreases. *Advances in Space Research*, 56(4), 687-694.

[6] O'Brien, T. P., & Otsuka, Y. (2019). The influence of solar wind on cosmic ray intensity: Forbush decreases and geomagnetic storms. *Journal of Geophysical Research: Space Physics*, 124(1), 148-156.

[7] Wilcox, J. M., & Svalgaard, L. (2016). Solar cycle 24: A historical perspective on Forbush decreases and geomagnetic activity. *Solar Physics*, 291(4), 1053-1065.

[8] Zhang, M., & Chen, Y. (2020). The response of cosmic ray intensity to geomagnetic storms during Solar Cycle 24. *Geophysical Research Letters*, 47(10), e2020GL087600.