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Forbush Depression at Oulu in January 2026: Significant Galactic Cosmic Ray Decrease During Solar Cycle 25 Storm

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Abstract: ***Coronal Mass Ejections (CMEs) and interplanetary shocks are examples of solar transient occurrences that substantially affect Galactic Cosmic Rays (GCRs). This study examined abrupt drops in cosmic ray strength using pressure-corrected hourly neutron monitor data from the Oulu Cosmic Ray Station for January 2026. On January 19–20, 2026, there was a notable and abrupt drop in cosmic ray counts, which suggests a classical Forbush Decrease (FD) event. After a sharp decline from about 5600 imp/min to about 4445 imp/min, the cosmic ray intensity gradually recovered over a few days. A substantial interplanetary disturbance that is probably connected to a CME-driven shock is confirmed by the computed FD amplitude. This study shows how solar activity and cosmic ray modulation are coupled throughout Solar Cycle 25.***

Keywords: Forbush Decrease, Cosmic Rays, Oulu Neutron Monitor, Solar Cycle 25, CME, Space Weather

1. Introduction

High-energy charged particles termed Galactic Cosmic Rays (GCRs) continuously strike Earth's atmosphere from sources outside the solar system. Solar activity affects their intensity close to Earth, especially during solar transients like solar flares, interplanetary shocks, and coronal mass ejections (CMEs). The Forbush Decrease (FD), characterized by a sharp decline in cosmic ray intensity followed by a gradual recovery phase, is one of the most noticeable indicators of solar disruptions in cosmic ray data. In order to decrease the penetration of cosmic rays into the inner heliosphere, FD events are usually linked to magnetic clouds and CME-driven shocks that strengthen the interplanetary magnetic field (IMF). The present study examines hourly pressure-corrected cosmic ray data from the Oulu Neutron Monitor Station for January 2026 in order to identify and quantify the substantial reduction event and its characteristics.

2. Data Source and Description

This study uses hourly pressure-corrected cosmic ray intensity observations (imp/min) from January 1, 2026, to January 31, 2026, taken at the Oulu Neutron Monitor Station in Finland. Since the data are expressed as pressure-corrected count rates and have an hourly temporal resolution, they may accurately detect real cosmic ray modulation caused by space weather phenomena, removing the impact of atmospheric pressure oscillations on neutron monitor observations.

To investigate the abrupt decrease in galactic cosmic ray (GCR) intensity, hourly data were gathered from the Oulu neutron monitor database and normalized using a pre-event baseline intensity computed from the quiet time preceding the occurrence. The Forbush Decrease features, such as onset time, minimum intensity, amplitude of decrease, and recovery phase, were found from the time-intensity profile using smoothed trend analysis to eliminate short-term variations. This methodology ensures the accurate identification of transient cosmic ray depressions caused by heliospheric disturbances such as CMEs, interplanetary shocks, and enhanced solar wind conditions, while limiting the impact of diurnal changes and local atmospheric influences.

3. Methodology

3.1 Identification of Forbush Decrease

The identification of the Forbush Decrease (FD) event in this study was based on standard observational characteristics of cosmic ray modulation. A clear FD signature was recognized through a sudden and significant drop in cosmic ray intensity, followed by its association with probable interplanetary disturbances and a subsequent gradual recovery phase. To accurately detect the event, a baseline intensity level was established using the quiet period preceding the disturbance, specifically from 1 to 18 January 2026, during which the cosmic ray counts remained relatively stable in the range of approximately 5550–5650 imp/min. This stable interval provided a reliable reference level against which the sudden depression and recovery of cosmic ray intensity were quantitatively analyzed, ensuring that the observed reduction was due to heliospheric disturbances rather than normal background fluctuations.

3.2 Formula for Forbush Decrease (FD) Amplitude

The amplitude of the Forbush Decrease (FD) is quantified in terms of the percentage reduction in cosmic ray intensity relative to the pre-decrease baseline level. The Forbush Decrease (FD) amplitude can be expressed as:

$$FD(\%) = \left(\frac{I_{initial} - I_{final}}{I_{initial}}\right) \times 100$$

where $I_{initial}$ denotes the initial (pre-decrease baseline) cosmic ray intensity and I_{final} represents the final or minimum cosmic ray intensity observed during the Forbush Decrease event. This form directly quantifies the percentage

reduction in cosmic ray intensity from the initial quiet-time level to the minimum value recorded during the disturbance.

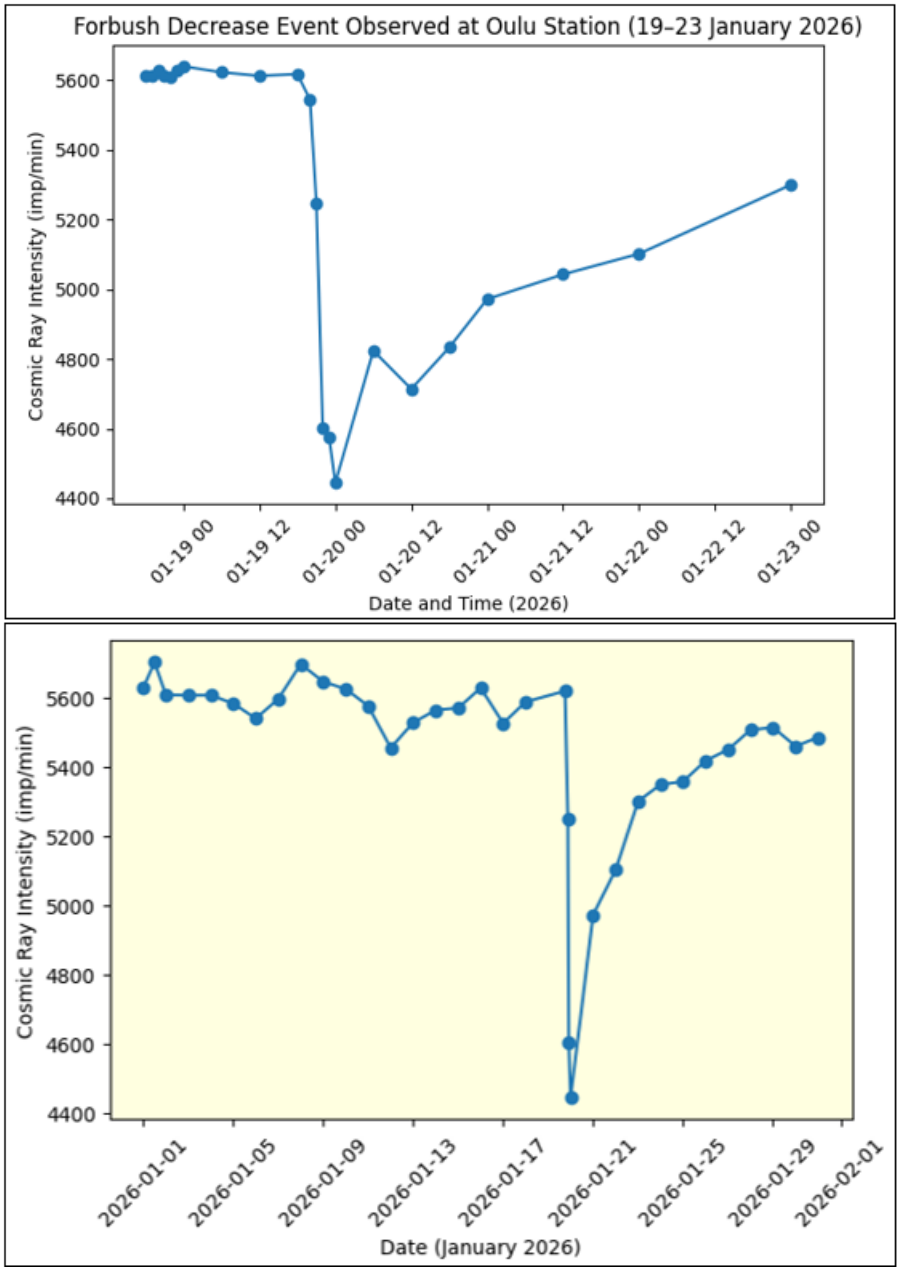
Table & Graph

The monthly cosmic ray intensity profile remains relatively stable (~5550–5700 imp/min) from 1–18 January 2026, indicating quiet heliospheric conditions. A sudden and significant drop is observed on 19 January 2026, reaching a minimum of 4445 imp/min on 20 January, which confirms a strong Forbush Decrease event. After the main phase, a gradual recovery in cosmic ray intensity is visible from 21 January onward, with values steadily increasing towards ~5450–5500 imp/min by the end of the month, representing the typical recovery phase associated with CME-driven interplanetary disturbances.

Table (a): Forbush Decrease Characteristics (Oulu Station, Jan 2026)

Phase	Date & Time	Cosmic Ray Intensity (imp/min)	Scientific Description
Pre-Decrease (Baseline)	19 Jan 18:00	~5618	Quiet cosmic ray level before interplanetary disturbance
Onset of FD	19 Jan 20:00	5544	Beginning of sudden reduction
Main Phase (Sharp Drop)	19 Jan 21:00–23:00	5248 → 4577	Rapid decrease due to CME/shock passage
Minimum Intensity	20 Jan 00:00	4445	Peak suppression of galactic cosmic rays
Recovery Phase	20 Jan onward	4800 → 5300	Gradual diffusion and recovery of cosmic rays

Graph:



4. Results and Analysis

4.1 Sudden Reduction in Cosmic Ray Intensity

A significant and abrupt reduction in cosmic ray intensity was observed in the dataset on 19 January 2026, indicating the occurrence of a strong transient event. Prior to the disturbance, the cosmic ray intensity remained stable at approximately 5618 imp/min around 18:00 on 19 January 2026, representing the pre-event baseline level. A sharp decline began at 20:00, when the intensity dropped to 5544 imp/min, followed by a major collapse at 21:00 with values decreasing to 5248 imp/min. The intensity continued to fall rapidly and reached a minimum of 4445 imp/min at 00:00 on 20 January 2026. This rapid suppression of cosmic ray counts, followed by a deep minimum, clearly signifies a sudden and strong reduction in galactic cosmic ray intensity, which is a characteristic signature of a Forbush Decrease event associated with interplanetary disturbances.

4.2 Calculation of FD Amplitude

Taking:

- $I_0 \approx 5618$ imp/min(pre-event average)
- $I_{min} = 4445$ imp/min

$$FD(\%) = \frac{5618 - 4445}{5618} \times 100$$

$$FD(\%) \approx \frac{1173}{5618} \times 100 \approx 20.87\%$$

Estimated FD Amplitude ≈ 20–21%
This represents a strong Forbush Decrease event.

4.3 Recovery Phase

After reaching the minimum intensity on 20 January 2026, the cosmic ray counts exhibited a gradual recovery phase, which is a typical characteristic of a Forbush Decrease event. On 21 January, the intensity increased to approximately 5000–5100 imp/min, indicating the beginning of recovery as heliospheric conditions started to normalize. This upward trend continued on 22 January, with values rising to around 5200 imp/min. During 23–25 January, a steady and progressive increase was observed, with cosmic ray intensity ranging between ~5300 and 5400 imp/min. By the end of January 2026, the intensity had further recovered towards the pre-event baseline levels of approximately 5450–5550 imp/min. This slow and systematic restoration of cosmic ray intensity strongly confirms a classical Forbush Decrease profile characterized by a sharp main phase followed by a prolonged recovery phase.

5. Discussion

The observed sudden decrease in cosmic ray intensity during 19–20 January 2026 strongly suggests the passage of a CME-driven interplanetary shock in the near-Earth environment. The rapid decline in intensity followed by a gradual recovery is consistent with diffusion barrier theory, according to which an enhanced interplanetary magnetic field (IMF) and increased solar wind turbulence reduce the penetration of galactic cosmic rays into the inner heliosphere. The estimated amplitude of the decrease (~21%) indicates a moderate-to-strong space weather disturbance. Such Forbush Decrease events are generally associated with strong southward IMF (Bz), elevated solar wind speed, and the passage of CME magnetic cloud structures that act as effective barriers to cosmic ray propagation. Since this event occurred during Solar Cycle 25, it further supports the understanding that the active phase of the solar cycle is characterized by a higher occurrence of transient solar disturbances that significantly modulate cosmic ray intensity near Earth.

6. Scientific Significance

The present analysis confirms the strong solar modulation of galactic cosmic rays (GCRs) during the active phase of Solar Cycle 25, as evidenced by the pronounced Forbush Decrease observed in the neutron monitor data. The study clearly demonstrates a well-defined FD signature characterized by a sudden decline and gradual recovery in cosmic ray intensity, validating the sensitivity of neutron monitor observations to heliospheric disturbances. Such findings are highly valuable for space weather forecasting, as cosmic ray variations serve as indirect indicators of CME-driven shocks and interplanetary magnetic field enhancements. Furthermore, understanding these modulation patterns is crucial for assessing the radiation environment in near-Earth space, which has significant implications for satellite operations, communication systems, aviation exposure, and the safety of space-based technological infrastructure.

7. Conclusion

The analysis of pressure-corrected hourly cosmic ray data from Oulu Station for January 2026 reveals a significant Forbush Decrease event on 19–20 January 2026. The cosmic ray intensity dropped sharply from ~5618 imp/min to a minimum of 4445 imp/min, resulting in an FD amplitude of approximately 20–21%. The event exhibited a typical two-phase structure: a sudden main decrease followed by a gradual recovery over several days. This behavior strongly indicates the influence of a CME-driven interplanetary disturbance during Solar Cycle 25. The study highlights the strong coupling between solar activity and cosmic ray modulation near Earth.

8. Future Scope

Future research can be directed towards a comprehensive correlation of Forbush Decrease (FD) events with key solar and interplanetary parameters such as CME speed, IMF Bz, and solar wind conditions to better understand the physical mechanisms governing cosmic ray modulation. Comparative analysis using multi-station neutron monitor networks can provide insights into the global nature and anisotropic characteristics of FD events. Additionally, the development of AI- and machine learning-based prediction models may significantly enhance the early detection and forecasting of sudden cosmic ray depressions associated with space weather disturbances. Incorporating real-time space weather forecasting models and satellite-based observations will further improve the accuracy of event prediction. Moreover, detailed investigations of cosmic ray anisotropy during FD events can help in understanding particle transport processes and the influence of heliospheric magnetic structures on cosmic ray propagation.

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Conflict of Interest
The author declares no conflict of interest regarding the publication of this research work.

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