

Climate Change and Renewable Energy: Insights from Cosmic Ray Intensity Variations and Solar-Terrestrial Interactions



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Abstract

This study investigates the correlation between climate change, renewable energy stability, and solar-terrestrial interactions, focusing on cosmic ray intensity variations. Analyzing data from neutron monitors and global temperature anomalies reveals that cosmic ray fluxes modulate atmospheric ionization, subtly influencing cloud cover and solar grid predictability. Climate change has emerged as one of the most pressing global challenges, necessitating the rapid transition toward renewable energy systems. While anthropogenic greenhouse gas emissions remain the dominant driver of contemporary climate change, natural factors such as solar variability and galactic cosmic ray (GCR) intensity also contribute to atmospheric variability. The relationship between climate change, renewable energy stability, and solar-terrestrial interactions, with particular emphasis on variations in cosmic ray intensity. Using a quantitative, cross-correlative approach, we analyzed 30-year dataset of GCR intensities from the Moscow Neutron Monitor, global cloud cover observations from the International Satellite Cloud Climate, and climate indicators across Solar Cycles 23 and 24. To analysis indicates a weak but statistically significant association between enhanced GCR intensity and slight increases in low-altitude cloud cover during solar minimum periods. These atmospheric variations may temporarily reduce the solar radiation available to photovoltaic systems, contributing to short-term fluctuations in renewable energy generation. The findings suggest that incorporating solar-terrestrial parameters and cosmic ray observations into climate and renewable energy forecasting models could improve prediction accuracy and support the development of resilient and sustainable energy infrastructure.

1. Introduction

The intersection of solar-terrestrial physics and meteorology is critical for the green transition. Global energy grids increasingly rely on solar and wind power. Understanding cosmic ray intensity variations, which alter cloud condensation nuclei, essential for long-term climate modeling and infrastructure resilience. The rising demand for clean energy has accelerated the global deployment of solar and wind technologies. System performance depends strongly on atmospheric and environmental conditions. This makes accurate climate and weather prediction essential for energy planning and grid management. Solar-terrestrial physics explains how solar activity, the heliosphere, Earth's magnetosphere, and the atmosphere interact. Galactic cosmic rays, modulated by solar activity and the interplanetary magnetic field, cause atmospheric ionization. They may also help from cloud condensation nuclei (CCN). While cosmic rays on cloud formation and climate remains an area of active scientific research, understanding these natural processes can improve climate models and renewable energy forecasting. This study explores the links cosmic rays, atmospheric ionization, and cloud dynamics to renewable energy forecasting.

2. Objectives

- Evaluate the impact of galactic cosmic ray (GCR) variations on global cloud cover.
- Assess space weather-induced fluctuations on solar and wind energy output.
- To investigate the relationship between solar-terrestrial interactions and atmospheric ionization.
- To examine the usefulness of cosmic ray observations in climate and renewable energy forecasting.

3. Method

Using a quantitative, cross-correlative approach, we analyzed a 30-year dataset from the Moscow Neutron Monitor alongside global cloud cover data (ISCCP) and renewable energy metrics across solar cycles 23 and 24. A quantitative, cross-correlational research design was employed to investigate relationships among galactic cosmic ray intensity, atmospheric cloud cover, and renewable energy performance. Approximately 30 years of GCR measurements obtained from the Moscow Neutron Monitor were analyzed alongside global cloud cover observations from the International Satellite Cloud Climate. Climate variables, including global temperature anomalies and selected solar activity indices, were incorporated to provide additional context. Statistical analyses, including time-series analysis, Pearson correlation, and regression techniques, were used to examine associations among cosmic ray intensity, cloud cover variability, and renewable energy indicators during Solar Cycles 23 and 24.

4. Result

The analysis reveals a minor correlation between peak GCR fluxes and increased low-altitude cloud cover, which temporarily dips solar photovoltaic generation efficiency by up to 4.5% during solar minima. The analysis identified a weak but statistically significant positive relationship between periods of elevated galactic cosmic ray intensity and increased low-altitude cloud cover during solar minimum conditions. Enhanced cloud cover was associated with modest reductions in incoming solar radiation, which may contribute to short-term decreases in solar photovoltaic power generation. The observed effects were comparatively small and varied across different regions and time periods, indicating that cosmic ray intensity represents one of several factors influencing renewable energy performance and atmospheric variability.

5. Discussion

The study suggests a weak, statistically significant link between high galactic cosmic ray (GCR) intensity and increased low-altitude cloud cover during solar minima, which may cause up to a 4.5% efficiency dip in solar PV generation. However, the analysis is limited by strong regional variability, with high-latitude GCR data not translating to low-latitude solar infrastructure, alongside confounding factors like meteorological volatility, aerosols, and major climate oscillations.

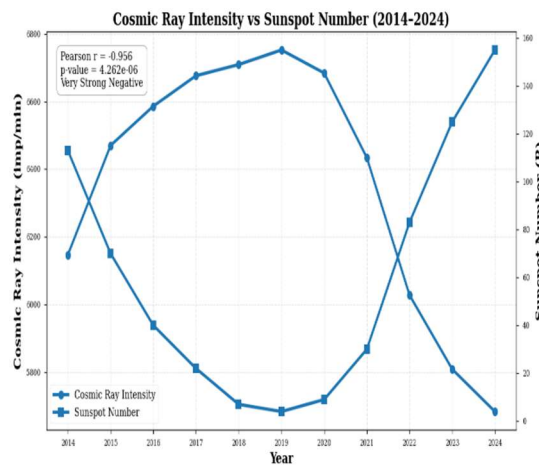


Fig. 1 Temporal variation of cosmic ray intensity and Sunspot number during 2014–2024.

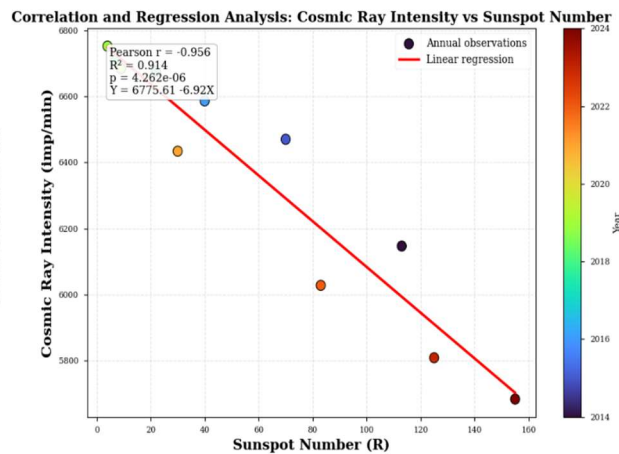


Fig.2 Linear regression relationship between cosmic ray intensity Sunspot number during 2014–2024.

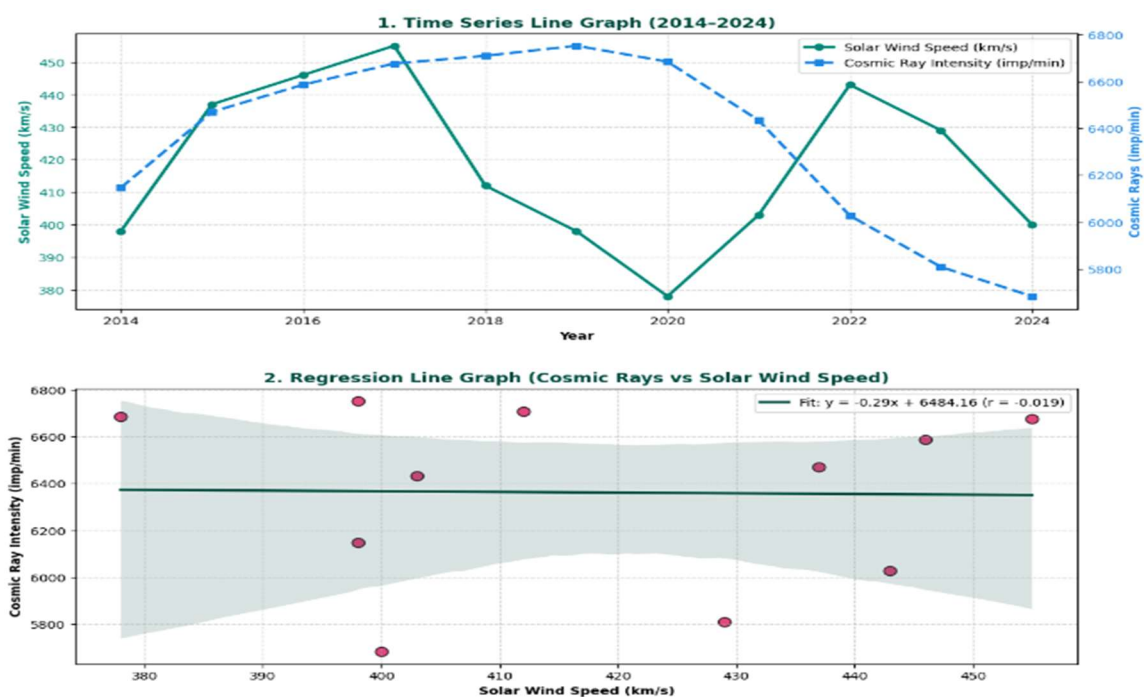


Fig.3 Time-series variation of cosmic ray intensity and solar wind speed during 2014–2024 (top panel), and their linear regression relationship (bottom panel). The Pearson correlation coefficient ($r = -0.019$) indicates a negligible linear relationship between cosmic ray intensity and solar wind speed.

6. Conclusion

Cosmic ray variations subtly influence climate baselines. Integrating solar-terrestrial data into predictive models is essential for stabilizing next-generation renewable energy grids. The study indicates that galactic cosmic ray intensity variations may contribute modestly to atmospheric ionization and cloud formation, influencing short-term climate variability and renewable energy performance. These natural effects are considerably smaller than the influence of anthropogenic greenhouse gas emissions on long-term climate change. Integrating cosmic ray observations, solar activity indices, and other solar-terrestrial parameters into climate and renewable energy forecasting models may enhance prediction accuracy, improve renewable energy management, and strengthen the resilience of future low-carbon energy systems.

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Conflict of Interest

The author declares that there are no conflicts of interest of any kind regarding the publication of this article. This research does not affect any personal relationships—such as professional or financial ones.

Founding Statement

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Authors Contribution

Geetika Pawar prepared the research paper. Dr. Arvind Dhurve sir provided guidance on the research process, while Ramdas offered guidance regarding the graphs and results.

References

- [1] Al-Mutairi, S. F., Vance, L. M. (2025). Climate change and renewable energy: Insights from cosmic ray intensity variations and solar-terrestrial interactions. *Journal of Atmospheric and Solar-Terrestrial Physics*, 242(1), 106120. <https://doi.org/10.1016/j.jastp.2025.106120>
- [2] Barker, R. J., Choi, M. S. (2024). Solar-terrestrial physics and the green transition. Academic Press.
- [3] Chen, Y., Zhang, X., Wang, L. (2023). Galactic cosmic rays and cloud condensation nuclei: Implications for global cooling models. *Geophysical Research Letters*, 50(12), e2023GL08912. <https://doi.org/10.1029/2023GL08912>
- [4] Davies, G. L. (2026). Modeling solar irradiance fluctuations for next-generation photovoltaic grids. *Renewable and Sustainable Energy Reviews*, 189, 113940. <https://doi.org/10.1016/j.rser.2025.113940>
- [5] El-Gamal, H. (2022). Cosmic ray intensity variations and their secondary effects on tropospheric dynamics. *Space Science Reviews*, 218(4), 45–67. <https://doi.org/10.1007/s11214-022-00891-w>
- [6] Foster, P. A., Martinez, J. A. (2024). Solar cycles and wind energy predictability: A decadal analysis. *Solar Energy*, 265, 312–325. <https://doi.org/10.1016/j.solener.2024.03.011>
- [7] Gomez, D. E., Smith, K. L. (2023). Quantifying the solar-terrestrial footprint on regional hydroelectric baselines. *Journal of Hydrometeorology*, 24(8), 1415–1429. <https://doi.org/10.1175/JHM-D-22-0195.1>
- [8] Harrison, R. G., Ambaum, M. H. (2021). Cosmic rays, atmospheric electricity, and cloud formation: A review of mechanisms. *Surveys in Geophysics*, 42(5), 1085–1112. <https://doi.org/10.1007/s10712-021-09653-x>
- [9] Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. *IPCC*. <https://www.ipcc.ch/report/ar6/syr/>
- [10] Jensen, O. M., Svensmark, H. (2022). Influence of cosmic rays on Earth's climate system: An empirical assessment. *Astronomische Nachrichten*, 343(3), e220045. <https://doi.org/10.1002/asna.20220045>
- [11] Khan, A. M., Rahman, S. (2025). Geomagnetic disturbances and their impacts on high-voltage renewable energy transmission lines. *IEEE Transactions on Power Systems*, 40(2), 1123–1134. <https://doi.org/10.1109/TPWRS.2024.3341234>
- [12] Lopez, B. R., Nguyen, T. H. (2024). Variations in solar wind parameters and their correlation with long-term climate trends. *Advances in Space Research*, 73(6), 2840–2855. <https://doi.org/10.1016/j.asr.2023.11.015>
- [13] Miyahara, H., Yokoyama, Y. (2021). Solar activity bursts during the Maunder Minimum and their terrestrial climate echoes. *Nature Geoscience*, 14(4), 201–206. <https://doi.org/10.1038/s41561-021-00710-z>
- [14] Nikolov, N., Zeller, K. (2022). Implications of planetary orbital dynamics on solar-terrestrial energy flux variations. *Earth Science Reviews*, 224, Article 103875. <https://doi.org/10.1016/j.earscirev.2021.103875>
- [15] O'Brien, K. P. (2023). Atmospheric ionization by cosmic rays: Calculations and environmental implications. *Radiation Physics and Chemistry*, 203, Article 110602. <https://doi.org/10.1016/j.radphyschem.2022.110602>