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SOLAR FLARE EFFECTS ON GEOMAGNETIC FIELDS IN THE MID AND LOW ALTITUDES

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Abstract

This review investigates the effects of solar flares on geomagnetic fields, particularly focusing on mid- and low-altitude regions of the Earth's atmosphere. The interaction between solar activity and geomagnetic fields is a key aspect of space weather, influencing both natural processes and technological systems dependent on radio propagation. The study explores the structure of the atmosphere in relation to altitude, distinguishing between thermal and magneto-electronic layers, and highlights the regions most affected by solar flare events, primarily the ionosphere, plasmasphere, and magnetosphere below approximately 500 km altitude. Solar flares, characterized by intense bursts of electromagnetic radiation such as X-rays and extreme ultraviolet (EUV) emissions, significantly alter the total electron content (TEC) of the ionosphere and can induce geomagnetic storms. These variations have direct implications for communication and navigation systems.

Through a review of historical case studies and recent scientific advances, the paper emphasizes the complexity of magnetosphere–ionosphere coupling at mid- and low altitudes, where solar flare-induced changes can be highly variable depending on local time, solar zenith angle, and geographic position relative to the magnetic equator. The authors discuss significant events, such as the major solar flares recorded during solar cycles 20–24, and analyze their impact on geomagnetic indices and TEC enhancements. Recent developments in machine learning are identified as valuable tools for correlating solar flare activity with ionospheric responses, offering improved prediction and analysis of space weather phenomena. The review concludes that while progress has been made in understanding the physics of solar flare effects at various altitudes, gaps remain, particularly in the global assessment of ionospheric responses due to limited observational data. The authors advocate for the broader adoption of advanced data-driven techniques to enhance the analysis and forecasting of solar flare impacts. Overall, the study provides insights for researchers and practitioners in space weather and environmental engineering, underscoring the importance of continued investigation into the dynamic interactions between solar activity and the Earth's geomagnetic environment.

Key words: geomagnetic fields, ionosphere, mid- and low altitudes, solar flare

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