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A Comparative Analysis of dH/dt for Evaluating GIC Risk in the Equatorial Region

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Introduction

During periods of intense geomagnetic field disturbance, sharp variations in the H-component indicate a heightened risk for the induction of Geomagnetically Induced Currents (GICs). While GIC-related studies are well established in high- and mid-latitude regions, there remains a significant lack of research in low and, particularly, equatorial latitudes — a gap that becomes more pronounced when considering the role of the Equatorial Electrojet (EEJ) as a potential driver of these currents. This study investigates the variation in the time derivative of the H-component (d**H**/dt), a widely recognized proxy in the literature for identifying GIC occurrence, using data from two geomagnetic stations: Kourou (KOU), located at low latitude, and Macapá (MAA), positioned nearly directly beneath the magnetic equator. In these regions, the EEJ plays a significant role in modulating local magnetic field variations, especially in the H-component observed at stations situated just below the magnetic (dip) equator. Recent studies have underscored the importance of the EEJ in the intensification of GICs, reinforcing the need for targeted investigations at these latitudes. Given the limited number of studies addressing this topic, the present work provides a detailed analysis of d***H***/dt in the equatorial region during the geomagnetic storm of May 10–11, 2024, considered the most intense event since the Halloween storm of 2003.

Method and/or Theory

In this study, the variation of the H-component of the geomagnetic field was derived from data recorded at the magnetic stations in Kourou (5.21°N, 52.73°W; KOU) and Macapá (0.038°S, 51.095°W; MAA). This was accomplished by subtracting the reference geomagnetic field values provided by the International Geomagnetic Reference Field (IGRF) model to isolate only the external variations of the magnetic field. The H-component data were recorded at a sampling rate of 1 second. Subsequently, the ordinary time derivative of the H-component was computed, representing a key step for analyzing rapid variations associated with potential GIC events.

Results and Conclusions

At the KOU station, significant d**H**/dt peaks were identified: 1.52 nT/s during the initial phase of the storm, and –2.24 and –3.19 nT/s during the recovery phase. In contrast, the values recorded at MAA were even more pronounced, highlighting the amplifying effect of the EEJ: with peaks of 3.16 nT/s in the initial phase and –4.83 nT/s during recovery. These amplitudes reinforce the potential for GIC generation in these regions and raise a relevant warning regarding the safe operation of power transmission lines located near the magnetic equator. In light of the current peak of Solar Cycle 25, the vulnerability of such infrastructures becomes increasingly critical, underscoring the need for enhanced monitoring and continued research.

The largest peaks observed during the initial phase of the storm are associated with the arrival of the interplanetary shock from the coronal mass ejection and its interaction with the magnetospheric cavity. These peaks occur in phase at both stations analyzed, suggesting a coherent response of the regional magnetosphere to the solar disturbance. Additionally, the d**H**/dt values recorded at MAA show significant amplification compared to KOU, reinforcing the influence of proximity to the magnetic equator. The values obtained in this study clearly demonstrate the influence of the EEJ in amplifying the d**H**/dt peaks recorded at MAA. In contrast, the values observed at KOU (located at a latitude farther from the magnetic equator) show lower sensitivity to the EEJ's influence. Given the current solar maximum, ground-based technological systems, such as power transmission lines, may be particularly vulnerable to space weather effects, including GICs, which calls for increased attention from power system operators.