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Research Article

Evidence of Strong Electric Fields at the Equatorial Ionosphere Driven by a Substorm in the Absence of Geomagnetic Storm

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Abstract

We show strong electrodynamic responses over the equatorial ionosphere driven by a substorm in the absence of a geomagnetic storm on 21–22 August 2017 (henceforth referred to as an isolated substorm). Observations from the Jicamarca Incoherent Scatter Radar (ISR) and equatorial electrojet (EEJ) measurements across different longitude sectors reveal a significant eastward electric field penetration over the equatorial ionosphere associated with the isolated substorm event. The ISR measurements show that vertical $E \times B$ plasma drifts turned upward despite local nighttime conditions, reaching ~ 121 m/s; this suggests an intense penetration electric field of ~ 3 mV/m over the equator. The zonal plasma drifts also reached high values of ~ 400 m/s associated with strong meridional electric fields. These electrodynamic changes are accompanied by a sharp uplift of the F-region virtual height ($h'F$) from ~ 250 to 390 km. The enhanced $E \times B$ drifts led to the upward spread of ionospheric irregularities to higher altitudes, which lasted for several hours. In addition, the EEJ observations across different longitudinal sectors showed simultaneous enhancements during the isolated substorm, even though the southward component of the interplanetary magnetic field (IMF B_z) remained nearly stable. Therefore, the isolated substorm drove intense, global-scale electrodynamic changes in the equatorial ionosphere. These results underscore the importance of substorm events in driving significant equatorial electrodynamic perturbations, even in the absence of geomagnetic storm activity.

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The authors declare no conflicts of interest relevant to this study.

Availability Statement

The ISR-measured plasma drift and F-region irregularity data were obtained from the Madrigal database (<https://www.igp.gob.pe/observatorios/radio-observatorio-jicamarca/madrigal/list>). Solar wind and geomagnetic parameters were taken from the OMNIWeb database (https://omniweb.gsfc.nasa.gov/form/omni_min.html). Ionosonde and equatorial electrojet (EEJ) data over Jicamarca were obtained from the Low-Latitude Ionospheric Sensor Network (LISN) (<https://lisn.igp.gob.pe/database/dataset/>). Magnetometer data for calculating EEJ over the Philippines sector were taken from the AMBER magnetometer network (Yizengaw & Moldwin, 2009) <https://dauntless.bc.edu/magnetometers/public/dat/amber/>. Magnetometer data for calculating EEJ over the East Asian sector and at different latitudes were sourced from the INTERMAGNET data portal (https://intermagnet.org/data_download).

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