A Statistical Analysis of the Morphology of Storm-Enhanced Density Plumes

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Summary

This study provides a statistical analysis of SED plume morphology over the continental United States (CONUS) to show common characteristics over a set intense storms. The results of this project help to build a general knowledge of SEDs and provide a new way to observe and compare SED plume characteristics within and between events.

Key Points

1. A comprehensive list of 49 SED events over the continental US was identified for periods of intense geomagnetic storms during 2000–2023.
2. A first-time statistical analysis of SEDs demonstrates their geomagnetic dependence, seasonal distribution, and solar cycle variation.
3. SEDs demonstrate a sub-corotate feature with respect to the Earth, with westward drifting speeds of 50–400 m/s and a duration of 3–10 hours.

Background

Storm-Enhanced Densities (SED) are disturbances in the plasma of the midlatitude ionosphere that occur during geomagnetic storms. They result in heightened levels of Total Electron Content (TEC) plume structure that stretches sunward and poleward from local afternoon. SEDs are predictable phenomena that are dynamic in aspects like their location and intensity based on many conditions that aren’t fully known. SED can impact telecommunication, so it is important to better understand their morphology.

Methodology

Storm Identification

We looked at a list of intense geomagnetic storms (Minimum Sym-H index < -100 nT) and identified 49 storms which exhibited clear SED plumes over CONUS from 2000-2023. For each plume, we recorded the start time, end time, upper latitude bound, and lower latitude bound.

Gaussian Fitting

We fitted a Gaussian at each time bin in the interval, over all the SED plume latitudes, then averaged to derive SED plume key features: central longitude ($\phi$), plume half-width ($a$), and plume intensity ($b$). The variables $a$, $b$, and $c$ describe the background TEC value.

Results

The following graphs use the statistical characteristics derived from the gaussian fittings to compare SED features over separate days (Figures 3 and 4) and to geomagnetic activity, time of year, and solar activity (Figures 5 and 6). In Figures 3 and 4, the blue dots represent the mean value during that time over all SED latitudes and the bars represent the standard deviation. In Figures 5 and 6, the dots represent daily mean value of a given characteristic.

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