

Introduction

Auroras are luminous phenomena resulting from the precipitation of energetic particles into Earth's ionosphere-thermosphere system that typically manifest as a persistent oval encircling the geomagnetic poles and are generally considered 2-dimensional manifestations of 3-dimensional solar wind-magnetosphere-ionosphere-thermosphere (SW-M-I-T) coupling processes.

Although the Earth's dipole magnetic field predicts hemispheric conjugacy in auroral systems, multiple physical drivers induce strong spatial and temporal asymmetries such as the hemispheric field strength variations, the offset between magnetic and geographic poles/the dipole tilt angle (Laundal et al., 2017; Oznovich et al., 1993), solar wind/interplanetary magnetic field (IMF) orientation effects (Fillingim et al., 2005; Shue et al., 2001; Østgaard et al., 2011), and diurnal/seasonal solar zenith angle variations (Coxon et al., 2016). Accordingly, auroral asymmetries can arise from uneven solar illumination, interhemispheric disparities in ionosphere-thermosphere coupling, or contributions from higher-order multipole magnetic fields (Pakhotin et al., 2021).

Therefore, we performed a comprehensive statistical analysis of Defense Meteorological Satellite Program (DMSP) observations to characterize SAA-related auroral asymmetries and their spatial distribution, temporal evolution, and contribution to global asymmetry patterns.

Data and Methods

- Data: DMSP F17 / SSUSI (2016–2023), LBHL band (165–180 nm)
- SAA Region Definition: Geographic longitude -90° to 90°
- MLT: Dusk (18–24 MLT), Dawn (00–06 MLT)
- Geomagnetic Activity: Quiet (SME < 400 nT), Active (SME \geq 400 nT)

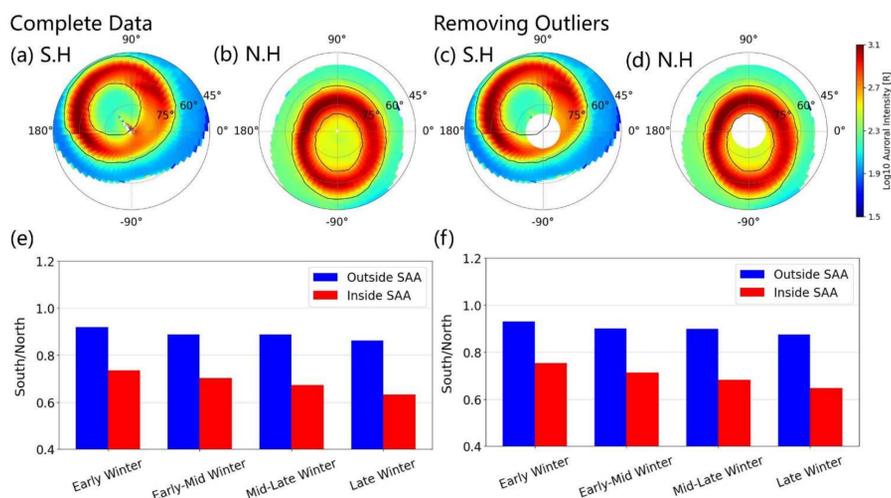


Figure 1. (a, b) Full data sets encompassing both polar regions, including contaminated measurements during polar day conditions. (c, d) Data sets filtered for solar-illumination-induced artifacts. (e) South/north intensity ratios with complete data sets restricted to polar night conditions (local winter). (f) Corresponding ratios obtained from cleaned data sets under identical seasonal constraints.

The sun-synchronous orbit of DMSP satellites results in excessive exposure over polar regions, particularly under continuous summer daylight. To mitigate potential artifacts, we systematically identified and removed contaminated data points. To ensure a robust comparison, we analyzed the south/north intensity ratios derived from both the complete and cleaned data sets, focusing exclusively on local winter periods to eliminate hemispheric solar illumination biases. The two data sets exhibited nearly identical temporal variations, confirming that the removal of a few outliers did not significantly affect the results, and validating our data-cleaning approach.

Wang, W., Huang, K., Zong, Q., Liu, Y., Li, L., & Ye, Y. (2025). Auroral asymmetry associated with the South Atlantic anomaly. *Geophysical Research Letters*, 52, e2025GL118899. <https://doi.org/10.1029/2025GL118899>

Results and Analysis

Hemispheric Asymmetry

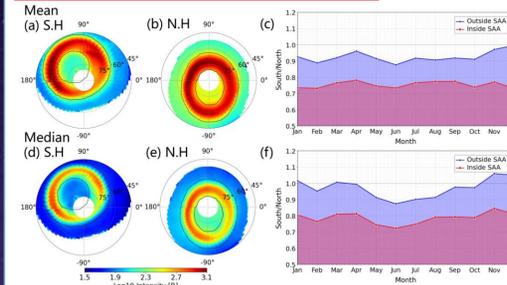


Figure 2. (a, b, d, e) Geographic distribution of mean and median nighttime auroral intensities observed by DMSP F17/SSUSI LBHL during 2016–2023. Black solid lines denote auroral oval boundaries (60° – 75° magnetic latitude). Geographic reference lines are shown as dashed gray lines, including latitude meridians at 45° , 60° , and 75° and longitude meridians at -90° , 0° , 90° , and 180° . (c, f) Monthly distribution of south/north intensity ratios inside and outside the South Atlantic anomaly region.

Outside the SAA, the mean ratios remained below 1.0, whereas the median ratios followed a similar pattern, but with more pronounced annual fluctuations, occasionally exceeding 1.0 throughout the NH winter months.

The south/north ratios within the SAA exhibit systematically lower values than those outside the SAA region (~ 0.7 – 0.8 inside vs. >0.9 outside).

Seasonal Asymmetry

Enhanced emissions (represented by darker colors) were observed during spring and autumn, verified by the double-peak structure in Figure 3b. The semiannual variation persisted both inside and outside the SAA, with the fitted curves peaking around March and September (equinoxes) and minima observed around June and December (solstices).

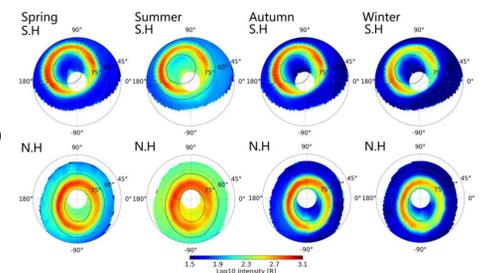


Figure 3. (a) Seasonal distributions of auroral emission intensities in polar diagrams. (b) Monthly averaged auroral intensities presented as solid lines with superimposed fitted curves (dashed lines), comparing regions inside (left panel) and outside (right panel) the South Atlantic Anomaly.

Dawn–Dusk Asymmetry

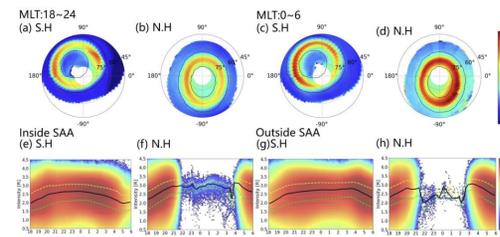


Figure 4. (a–d) Geographic distributions of median auroral intensities in the dusk (18–24 MLT) and dawn (00–06 MLT) sectors. (e–h) Comparative analysis of particle number density (color-coded) inside versus outside the South Atlantic anomaly region, with overlaid MLT profiles of auroral intensity (black lines) showing the 25th, 50th (median), and 75th percentiles.

In both hemispheres, the observed dawnside dominance of intensities is consistent with statistical patterns of auroral energy flux, where diffuse precipitation typically dominates the total energy deposition (Liou et al., 2011; Newell et al., 2009).

The SAA persistently weakens SH auroral intensities, whereas the NH exhibits dusk-sector attenuation but an unexpected dawn-sector enhancement.

Geomagnetic Activity

The auroral system changes with substorm levels, with intensified emissions and equatorward expansion of the auroral oval during active periods, while the SAA-induced attenuation persisted under all geomagnetic conditions.

The inside/outside ratios exhibit distinct equinoctial peaks during geomagnetic activity, suggesting significantly stronger attenuation of the SAA during solstices compared to equinoxes.

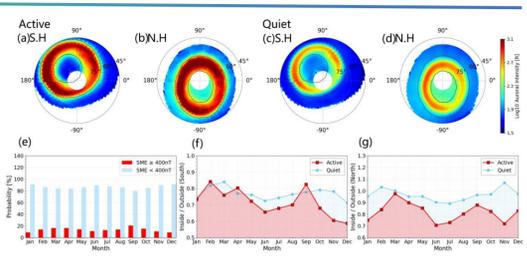


Figure 5. (a–d) Geographic maps of median auroral intensities during active (SuperMAG Electrojet (SME) \geq 400 nT) and quiet (SME < 400 nT) periods. (e) Occurrence probability of substorms in terms of the SME index. (f, g) Hemispherically asymmetric response of auroral emissions to the South Atlantic anomaly (SAA), presented as monthly variations in the intensity ratio between SAA and non-SAA regions (inside/outside) for the (f) northern hemisphere and (g) southern hemispheres under active and quiet conditions.

Conclusions

1. We observed systematic hemispheric asymmetry in auroral intensities, with consistently enhanced emissions in the NH relative to the SH. **The SAA introduces a localized suppression of intensity in both hemispheres, though the attenuation effect was stronger in the SH.**
2. Our results reveal a persistent semiannual variation in auroral precipitation both inside and outside the SAA, peaking near equinoxes and minimizing near solstices. The asymmetry aligns with the Russell-McPherron or the equinoctial effects.
3. The observed dawn-dusk asymmetry in auroral intensities aligns with established precipitation mechanisms. While both hemispheres exhibit dawnside-enhanced energy flux consistent with diffuse precipitation's dominance, the SAA introduces hemispheric disparities.
4. The SAA's suppression effect exhibits strong seasonal dependence during active periods, with stronger attenuation during solstices compared to equinoxes, consistent with substorm injection frequency variations. More frequent substorm injections during equinoxes may partially compensate for the SAA-induced suppression of particle precipitation, thereby revealing the intrinsic semiannual periodicity.