Longitudinal and Local Time Variations of EIA peak Brightness: GOLD Observations

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Introduction & Motivations

Introduction

- The Equatorial Ionization Anomaly (EIA) is a region of enhanced ionospheric plasma density in the equatorial and low-latitude F–region, formed primarily due to dayside eastward electric field and Pre-Reversal Enhancement(PRE).
- The EIA can interfere with radio waves, leading to degraded performance of satellite communications, GPS accuracy, radio signals, and weather monitoring systems.

Motivations

- The climatology and morphology of the EIA varies significantly with seasons, longitude, local time, solar activity and geomagnetic condition.
- The NASA GOLD satellite [Eastes et al., 2019] provides 2D images that reveal spatio-temporal evolution of nightside ionosphere.
- **GOLD observations from 2020 show that the average nighttime EIA crest latitudes vary with longitude during equinoxes and December solstice [Eastes et al., 2023].**

Science Question

SQ: *How do the nightside EIA crests' peak amplitude vary with geomagnetic longitude (MLON) and geomagnetic local time (MLT) during quiet geomagnetic conditions?*

GOLD Satellite and Data

- **GOLD Field of View (FOV):** from 120°W to 20°E and from 70°S to 70°N. *In Apex*, it is from 55°S to 75°N.
- **Observation Period:** Nighttime observations every 15–30 minutes from 20:10 UT to 00:25 UT. In LT, ~ 19 to 22 hours.
- **Data Source**: OI 136.5-nm nightglow emission contained in "Level 2 – NMAX (v5)" products of the variable "RADIANCE_OI_1356".
- Only scans with data quality index (DQI) = 0 during March, September and December from 2020 to 2024 were used.

Methodology

- **Coordinate Transformation**: Geographic to apex geomagnetic.
- **Data Rebinning**: 2D grids based on MLAT, MLON, and MLAT, MLT.
- **Bin Resolution**: 1° MLAT, 5° MLON; 1° MLAT, 0.2 h MLT.
- **Geomagnetic condition**: Kp < 3.
- **Latitudinal Focus**: within ±40° geomagnetic latitude (MLAT).
- **SZA Cutoff**: $\Theta_{max} \approx 107°$.

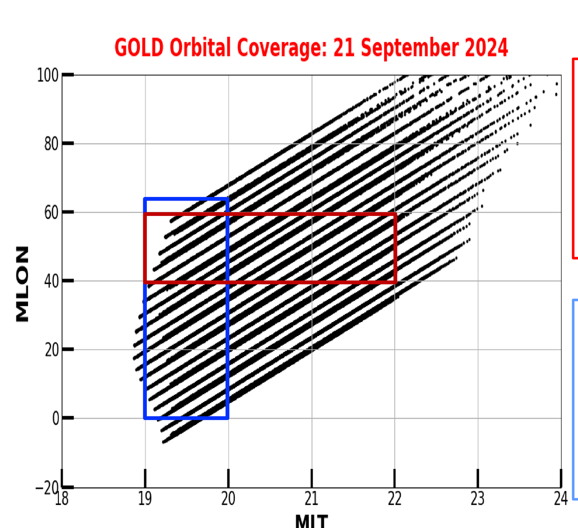
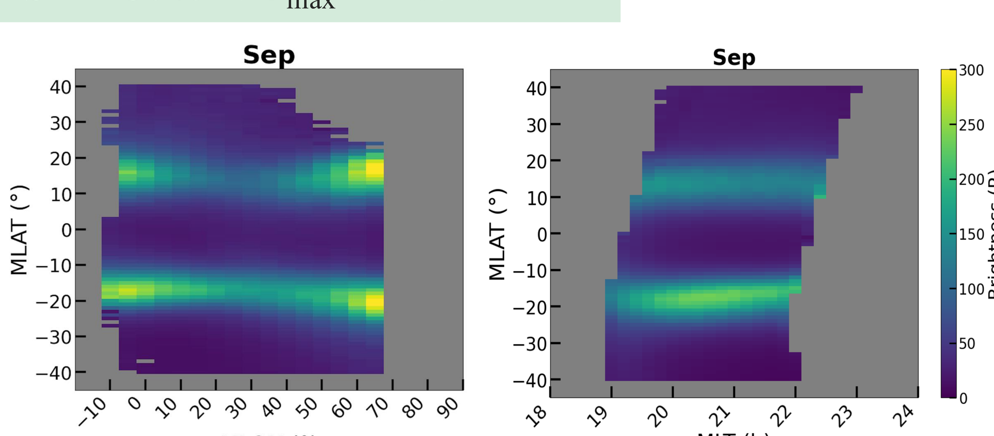


Figure 1. Spatiotemporal distribution of NASA GOLD nighttime filtered radiance measurements on 21 September 2024, plotted as MLON vs MLT.

Red rectangle: 40° ⩽ MLON ⩽ 60° - data used for MLT analysis.

Blue rectangle: 19 ⩽ MLT ⩽ 20 hours - data used for MLON analysis.

The Blue and red rectangle condition is employed for all days during rebinning process of GOLD data.



- Clear **hemispheric asymmetry** in peak brightness even during September equinox.
- Comparatively enhanced peak brightness around west African longitudes (MLON~60 °).

Figure 2. Distribution of average OI 136.5 nm radiance in each bin in 2024 September for (a) magnetic longitude (MLON) dependence and (b) magnetic local time (MLT) dependence.

Peak Identification

- Average the binned radiance data based on MLON or MLT.
- The maximum radiance point within 0° to 30° MLAT in both hemispheres is labelled as peak.

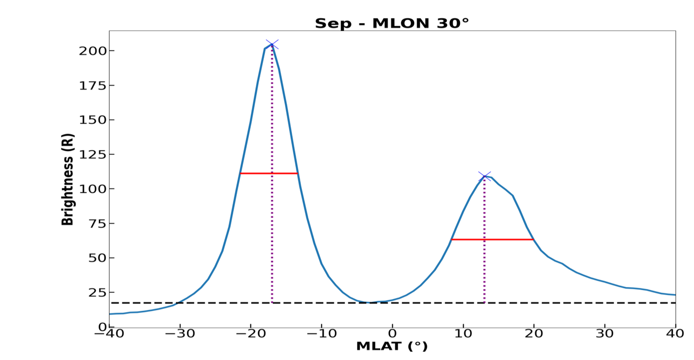


Figure 3. A double peak latitudinal EIA profile in September 2024 at 30° MLON.

Result-1: Longitudinal Variation of EIA Brightness

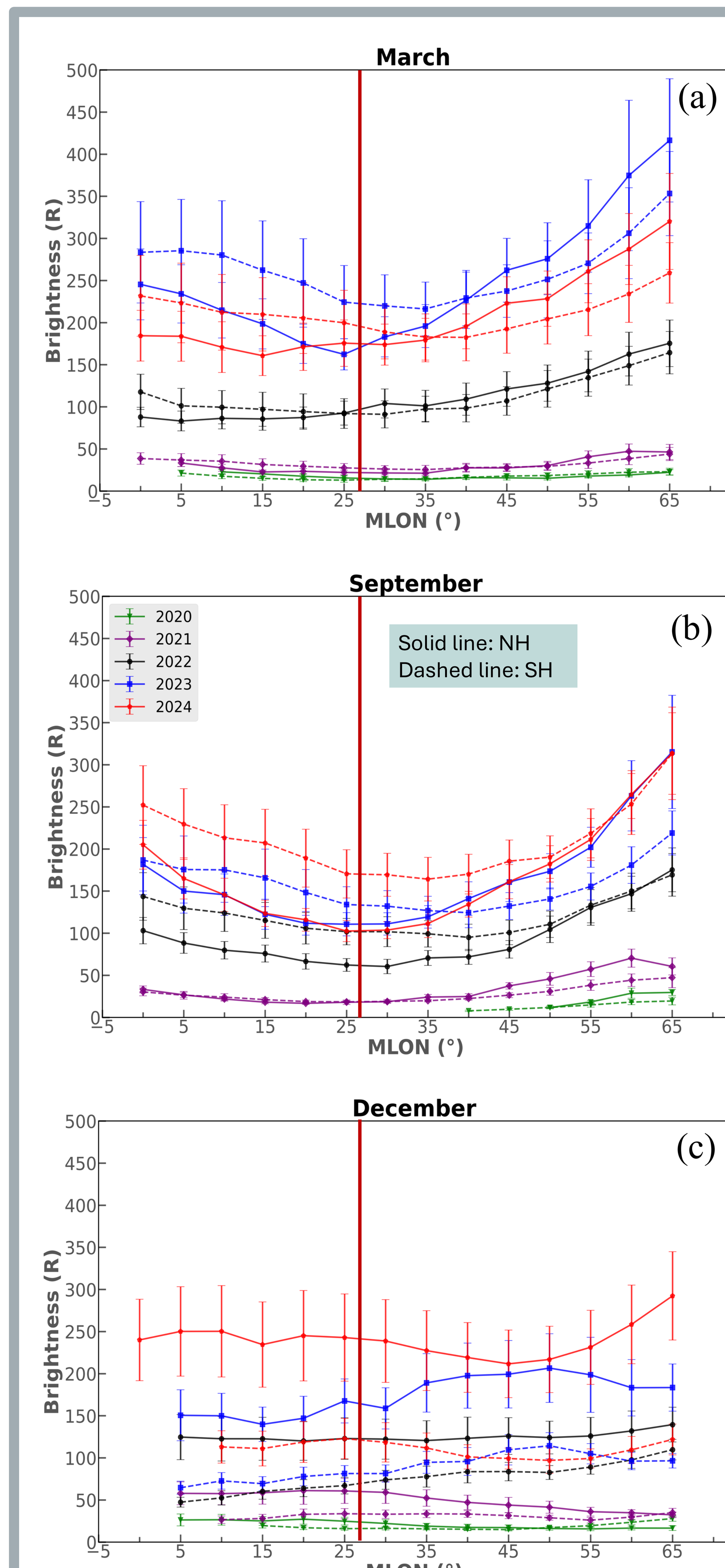


Figure 4. Monthly mean EIA brightness (Rayleigh) as a function of magnetic longitude (MLON) for (a) Top: March equinox (b) Middle: September equinox (c) Bottom: December solstice. Solid lines represent northern hemisphere (NH) while dashed lines for southern hemisphere (SH) with green: 2020; purple: 2021; black: 2022; blue: 2023; red: 2024. The solid vertical red line indicates the longitude (~27°MLON) where geomagnetic and geographic equators cross.

- During equinoxes (Figures **4a and 4b**), peak amplitude of the **EIA crest has a minimum** near 27° MLON where difference between geographic and geomagnetic equators is smallest..
- The observed longitudinal trend in GOLD is similar to that seen in longitudinal wavenumber 4 (**WN-4**: four peaks at four different longitudes) structure of TEC (**Figure 5**).

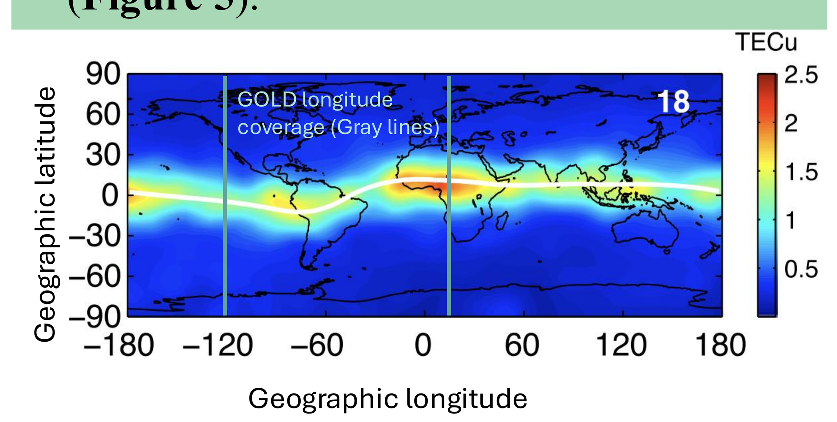


Figure 5. Longitudinal structure of the TEC between 400-450 km altitude derived from COSMIC-GPS measurements averaged over Sep-Oct 2006 for 18-20 LT **[Lin et al., 2007]**.

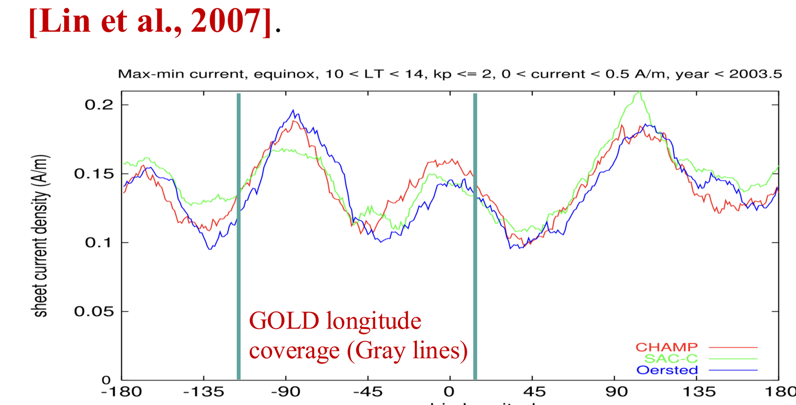


Figure 6. Peak of noontime electrojet sheet current density as a function for longitude for Kp ⩽ 2 around the March Equinox **[England et al., 2006]** .

The observed minimum of Nmax can be explained by **DE3 tide.**
DE3 tide => EEJ => TEC and Nmax.
The WN-4 longitudinal structure in EIA is modulated by DE3 tide through modulation of E-region dynamo and **our result of longitudinal variation primarily be influenced by DE3 tide during equinoxes** .

During the December solstice (**Panel 4c**), the observed longitudinal variation cannot be explained by the DE3 tide. Winter anomaly in peak amplitude could primarily be due to O/N2 variation between the hemisphere.

Result-2: Local Time Variation of EIA Brightness

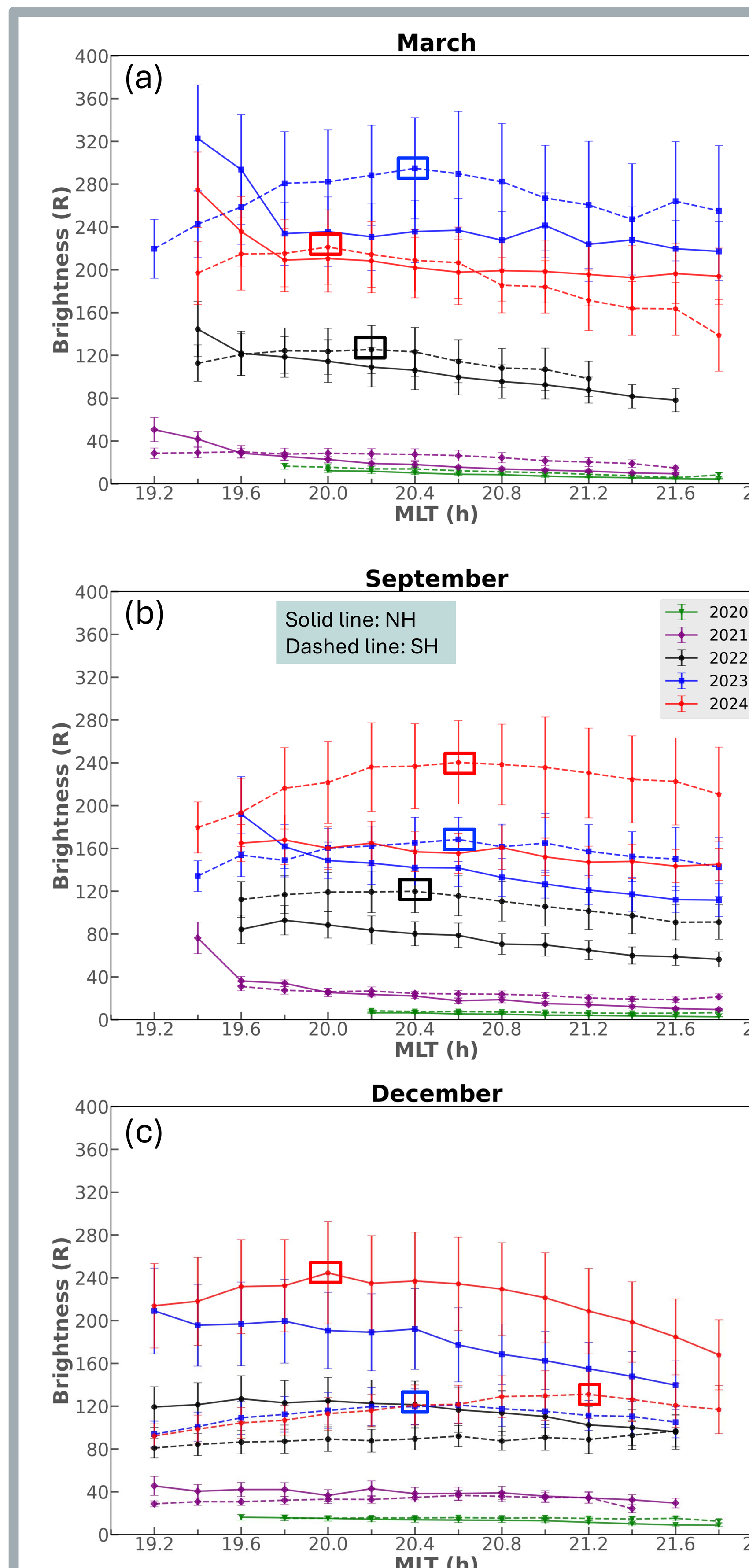


Figure 7. Same as figure 4 but as a function of magnetic local time (MLT).

Figure 7 shows that there is clear **hemispherical asymmetry in peak brightness during equinoxes and December solstice** for all years.

- In panel 7a (March equinox) and 7b (September equinox),peak brightness of the EIA crest decreases with MLT **during low solar active years.**
- **During high solar active years**, SH peak brightness has a **local maximum** (shown in small boxes) while NH peak brightness keeps decreasing with MLT.

- In panel 7c (December solstice), brightness amplitude decrease with MLT during low solar active years.
- During high solar active periods, peak brightness has local maximum in SH as well NH of December 2024.

Main Takeaways and Next Steps

1. Significant hemispheric asymmetry in peak brightness during equinoxes.
2. **MLON**: During the equinoxes, peak amplitude has a local minimum. The observed longitudinal trend in GOLD may be primarily due to nonmigrating DE3 tidal influence.
2. **MLT:** Peak Brightness in SH has a local maximum during high solar active years. During low solar period, peak brightness in both NH and SH decreases with MLT.

Next Steps:

1. MLT variation in EIA crests' peak location and latitudinal extension (width).
2. Investigation of DE3 tide influence on longitudinal variation in peak brightness and location of the EIA crest using coupled GITM-SAMI3 model.

Acknowledgement and References

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