Post-Sunset Equatorial Ionization Anomaly (EIA) merging during a weak geomagnetic activity on 23-24 February 2023

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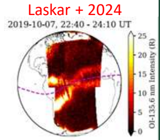
Abstract: This study explores the evolution of the post-sunset Equatorial Ionization Anomaly (EIA) following a weak geomagnetic activity on 23–24 February 2023 over the American sector (65°W), using observations and Global Ionosphere Thermosphere Model (GITM) simulations. Merging of EIA crests is observed on 24 February, with a faster equatorward motion of the northern crest. GITM simulation well captures the observed EIA merging and its interhemispheric asymmetries (IHAs). GITM simulation indicates that reduced upward ion drift partly contributes to the merging and an equatorward propagating traveling atmospheric disturbance (TAD) accelerates the equatorward movement of the NH EIA peak. The IHAs in the TAD propagation result from IHAs in the Joule heating deposition. Stronger Joule heating is deposited in the NH that drives the NH TAD, while no evident Joule heating is deposited in the SH at the same time.

Introduction and Motivations

EIA Merging

- Observed during both quiet and active times.
- Potential Causes:
  - Downward ExB drift (Laskar+2024 , Wu+2024)
  - Equatorward winds (Balan+2013)

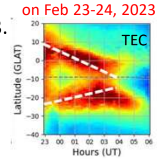
EIA merging
Laskar + 2024



Motivations

- EIA merging can exhibit Interhemispheric Asymmetries (IHAs):
  - Post-sunset EIA merges after a weak geomagnetic activity occurred on Feb 23, 2023.
  - **Equatorward movement of Northern peak is faster than Southern peak.**

EIA merging at 65W on Feb 23-24, 2023



GOAL: Investigating underlying physical mechanisms driving IHAs during this EIA merging event.

Data and Model

Data from Madrigal Database

(i) Total Electron Content (TEC):

- Ground-based GNSS receivers near 65W.

(ii) Neutral Wind at 250 km

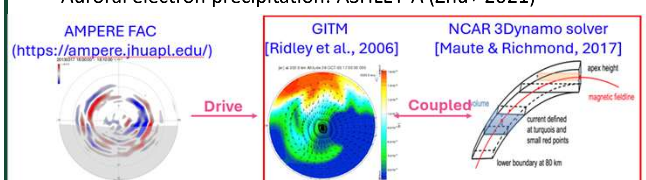
- Fabry Perot Interferometer (FPI) at Culebra (18.33N, 65.3W)

GPS receiver

FPI

Global Ionosphere Thermosphere Model (GITM, Ridley+ 2006)

- 3D General Circulation Model for the ionosphere and thermosphere;
- Non-hydrostatic; Altitude grid;
- Coupled with the NCAR 3Dynamo solver;
- High-latitude driving:
  - AMPERE Field-Aligned Currents (FACs)
  - Auroral electron precipitation: ASHLEY-A (Zhu+ 2021)



Result 1: EIA Merging: Data-Model Comparison

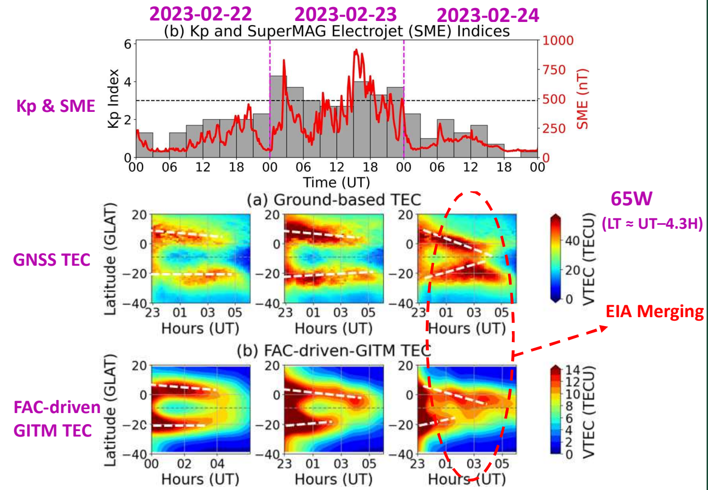


Fig. 1: (Top) Kp & SME, (Middle) GNSS TEC, and (Bottom) FAC-driven GITM TEC around 65W GLON during Feb 22-24, 2023

- Weak geomagnetic activities seen on 23rd with Kp ≈ 4 and SME index reaching over 800 nT (SMR was consistently above -30 nT).
- GNSS TEC (top-right) shows EIA merging on 24th Feb. **NH peak is moving equatorward more quickly than SH peak. FAC-driven GITM replicates the phenomenon very well.**

Result 2: EIA merging and its IHAs: Mechanisms

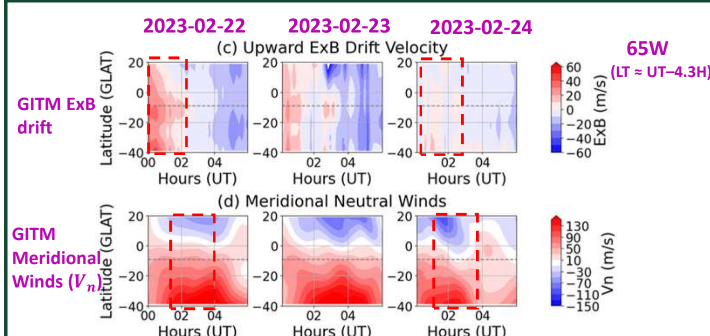


Fig. 2: (Top) ExB drift and (Bottom) Meridional neutral winds from GITM.

Comparing parameters on Feb 24 to those on Feb 22 (Quiet time):

- Weaker upward ExB drift → Favoring overall merging of NH & SH EIA peaks
- Equatorward wind in NH is stronger →Most likely associated with a traveling atmospheric disturbance (TAD) → Favoring the equatorward movement of the NH EIA peak.
- Equatorward wind in SH is weaker → Not Favoring the equatorward movement of the SH EIA peak.

→ IHA in the EIA merging results from the IHA in the TAD propagation.

Result 2: EIA merging and its IHAs: Mechanisms

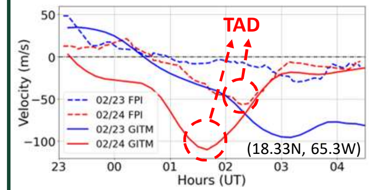


Fig. 3: Meridional winds from the FPI measurement (dashed) and GITM simulation (solid) at Culebra.

- Although there are discrepancies in the magnitude and timing, the **NH TAD shown in Fig 2 is captured by GITM.**

Result 3: IHAs in Joule Heating and TADs

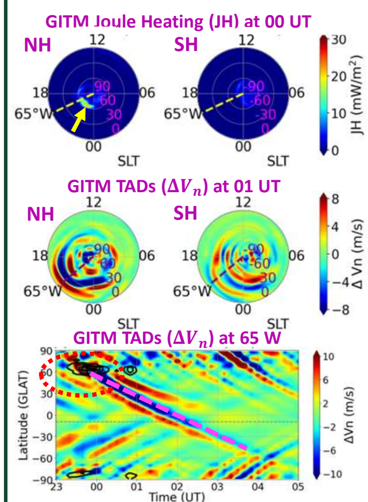


Fig. 4: (Top) Height-integrated Joule Heating and (Middle) Detrended meridional wind at 400 km in NH and SH as a function of SLT and GLAT. (Bottom) Detrended meridional wind at 400 km and at 65W as a function of UT and GLAT. The Joule heating contours are overplotted on the color contour.

- Top: Stronger JH is observed in NH than in SH.
- Middle & Bottom :
  - Detrended meridional wind: $\Delta V_n = V_n - < V_n >_{30min}$
  - **TADs triggered in the NH is much stronger, which result from stronger Joule heating in the NH.** → TADs are more observable in the NH meridional wind as shown in Fig 2.

Summary

- Post-sunset EIA merging is observed by GNSS TEC following a weak geomagnetic activity occurred on 23-24 Feb 2023 near 65W. Particularly, NH EIA peak moves equatorward much faster than the SH peak.
- FAC-driven GITM simulation well captures the observed EIA merging and the interhemispheric asymmetries (IHAs) in the merging.
- GITM simulation indicates that reduced upward ion drift partly contributes to the merging and an equatorward propagating TAD accelerates the equatorward movement of the NH EIA peak. No evident equatorward propagating TAD is observed in GITM in the SH.
- Stronger Joule heating is deposited in the NH that drives the NH TAD, while no evident Joule heating is deposited in the SH at the same time.

Vishwakarma, P., Zhu, Q., Valladares, C., Anderson, P., Wu, Q., Kerr, R., & Vines, S. Post-Sunset Equatorial Ionization Anomaly (EIA) merging during a weak geomagnetic activity on 23-24 February 2023, *JGR: Space Physics*, to be submitted.

References:

- Laskar+(2024), 10.1029/2023JA032224;
- Wu+(2024), 10.1029/2024JA032896
- Balan+(2013), 10.1002/jgra.50275;
- Ridley+(2006), 10.1016/j.jastp.2006.01.008
- Maute & Richmond (2017): 10.1007/s11214-016-0262-3
- Zhu+(2021): 10.1029/2020SW002671

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