Interhemispheric Asymmetries in Large-scale Traveling Ionospheric Disturbance Propagation During the 5-6 August 2011 Geomagnetic Storm

IRRI-13

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Abstract: This study focuses on the ionospheric response to the geomagnetic storm that occurred on August 5-6, 2011, with a specific focus on the cause of inter-hemispheric asymmetries (IHAs) in large-scale traveling ionospheric disturbances (LSTIDs) in the American Sector. The ground-based total electron content (TEC) measurements show that LSTIDs triggered in the Northern Hemisphere due to energy deposition during the initial phase arrive at the geomagnetic equator about an hour earlier than those triggered in the Southern Hemisphere. To investigate the cause of these IHA in LSTID propagation, we conducted a Global Ionosphere Thermosphere Model (GITM) simulation driven by field aligned currents (FACs) derived from the AMPERE dataset. The GITM accurately captures IHAs in LSTIDs when compared to measurments. Through this combination of data analysis and model simulations, we find that while the presence of Joule heating triggers the initial LSTID in the NH, there is not yet enough joule heating to trigger in the SH until ~1 hour later.

Introduction

During geomagnetic storms:

- Large-scale Traveling Atmospheric Disturbances (LSTADs) are triggered due to energy input during storms.
- Large-sale traveling ionospheric disturbances (LSTIDs) are observed by TEC measurements.

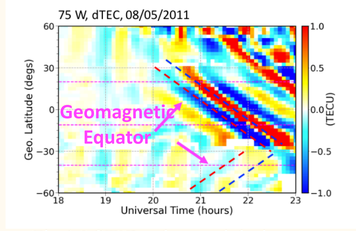

Fig 1.LSTIDs observed during Aug 5-6, 2011 storm (Valladares+, 2025).

Motivations:

- LSTIDs exhibit inter-hemispheric asymmetries (IHAs) (Fig.1)
- During Aug 5-6, 2011 storm:
  - NH TIDs are stronger than SH TIDs.
  - NH TIDs arrive at the geomagnetic equator earlier than SH TIDs.
  - What are the causes of the IHAs of LSTIDs?

Data and Model

Data:

Total Electron Content (TEC) from Madrigal: Ground based global navigation satellite system (GNSS) receivers.

Neutral Density: Gravity Field and Steady-State Ocean Circulation Explorer (GOCE).

AMPERE Field Aligned Current (FAC): 66 Iridium NEXT satellites.

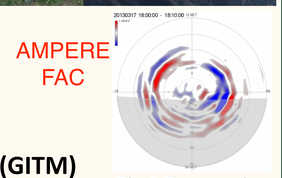

Fig 2.Data used

- **Global Ionosphere Thermosphere Model (GITM)**
  - Res: 5° LON x 2.5° LAT x 1/3 scale height
  - Non Hydrostatic;
  - Coupled with 3Dynamo solver.
  - High-latitude driving:
    - AMPERE FACs
    - Auroral electron precipitation: ASHLEY-A (Zhu+ 2021)

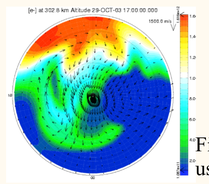

Fig 3.Data used

Result 1: Storm-time High-Latitude Electrodynamics

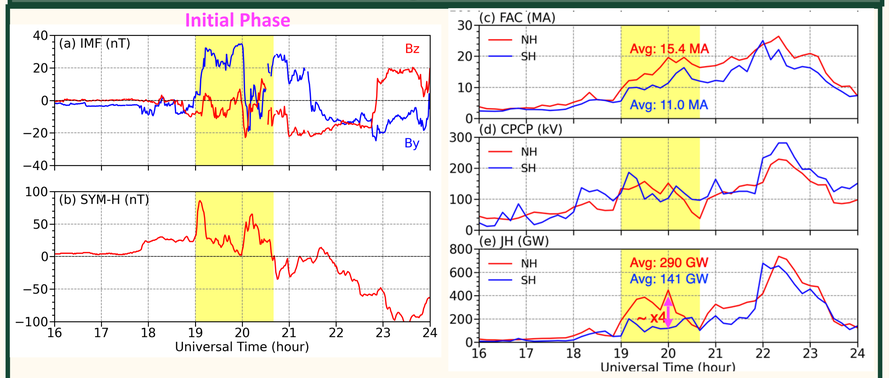

Fig 4. (a) Interplanetary magnetic field (IMF) measurements of both Bz and By components; (b) SYM-H index; (c) Total integrated hemispheric field aligned currents; (d) Cross polar cap potential output from GITM; (e) Joule heating output from GITM.

- LSTIDs shown in Figure 1 are triggered during the initial phase
- **(Figure 4c)** the FACs in the NH exceed those in the SH.
- **(Figure 4d)** the CPCP is largely symmetric between the hemispheres.
- **(Figure 4e)** Joules heating is roughly 2x as large in the NH as in the SH, reaching up to 4x greater around 20 UT.

Result 2: IHAs in TIDs and TADs

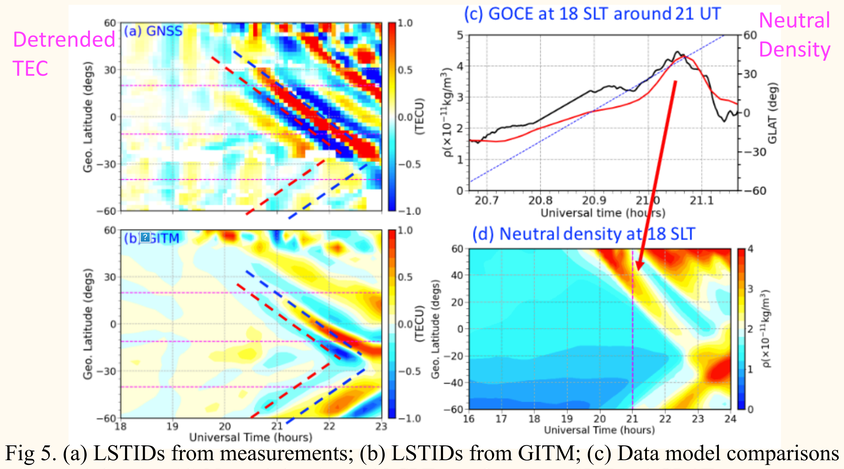

Fig 5. (a) LSTIDs from measurements; (b) LSTIDs from GITM; (c) Data model comparisons of neutral density; (d) Neutral density at 18 SLT as a function of UT and GLAT.

- (Figures 5a & 5b) GITM simulation accurately captures the IHAs in TIDs.
- (Figure 5c & 5d) The TIDs shown in 5b are driven by TADs

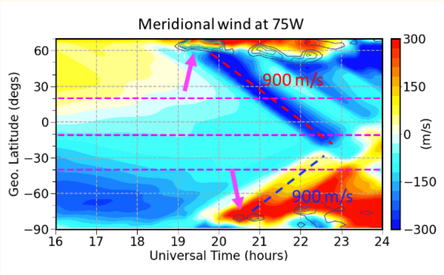

Fig 6. Meridional winds from GITM at 75W.

- The NH and SH TADs triggered exhibit similar phase speeds (~ 900 m/s).
- The NH TAD is triggered around 1 hour earlier than the SH TAD.
- The NH TAD is stronger and dissipates more slowly than the SH TAD.

Result 3: IHAs in TADs vs IHAs in Joule heating

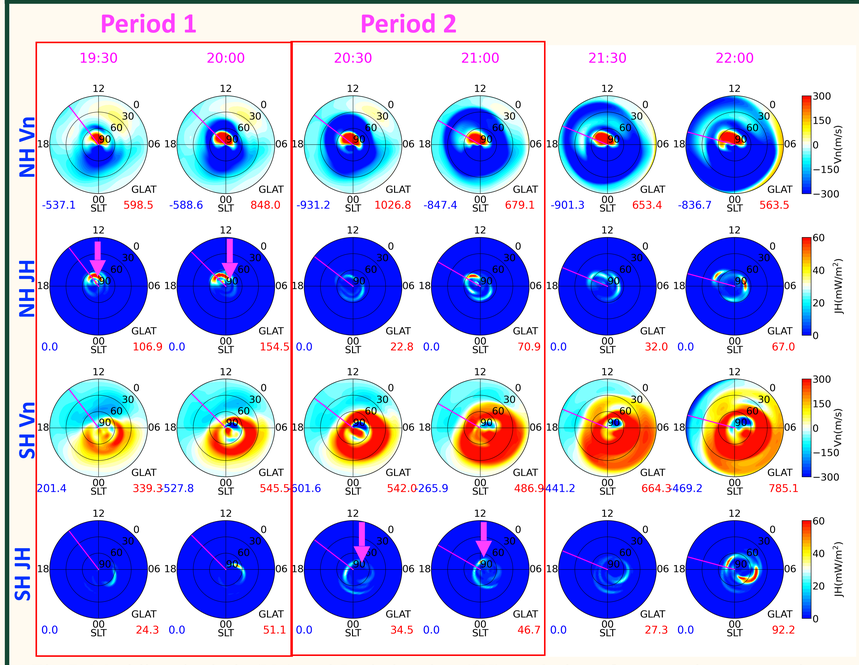

Fig 7. Meridional winds (Vn) and Joule heating (JH) evolutions from a polar perspective at 75W. The top two rows show data for the NH and the bottom two rows for the SH.

Period 1:

1) At 75 W, the NH has strong Joule heating deposition which triggers a TAD as shown in the meridional wind.
2) SH does not have strong heating to trigger TADs.

Period 2:

1) Heating at 75 W is enough to trigger a TAD in the SH moving northward.
2) Time delays in Joule heating deposition corresponds to time delays in TAD.

Summary

Large-scale traveling ionospheric disturbances (LSTIDs) triggered during the initial phase of the August 5-6 2011 geomagnetic storm show significant Interhemispherics asymmetries (IHAs) in the American Sector:

- **TEC measurements:** LSTIDs triggered in the NH arrive at the geomagnetic equator earlier than the SH by 1 hour.
- **GITM simulation:** IHAs in TIDs are caused by IHAs in Joule heating. Joule heating corresponding to the NH TID occurs about 1 hour earlier than the SH TID.

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References:

- Ceasar+ (2025): doi: 10.3389/fpas.2025.1517762
- Zhu+ (2021): doi: 10.1029/2020SW002671

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