Inter-hemispheric Asymmetry of Magnetospheric Forcings and Its Impacts on the Ionosphere-Thermosphere System During the 8-10 October 2012 Geomagnetic Storm

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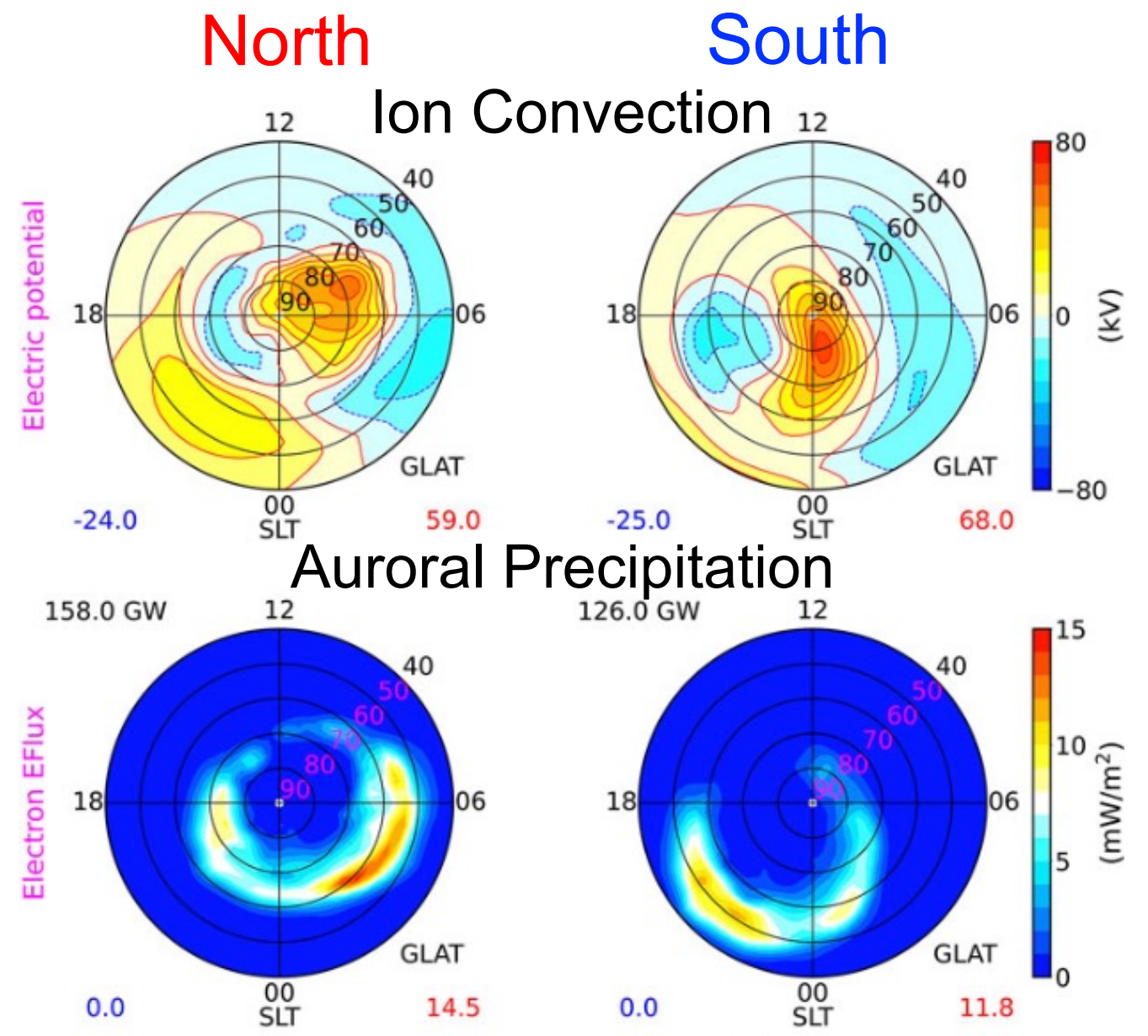
MITC - 7

Abstract The inter-hemispheric asymmetries in magnetospheric forcings, e.g., magnitude, distribution and expansion of ion convection and auroral particle precipitation during storms may not be well represented in modeling studies. In this study, the realistic magnetospheric forcings from AMIE are used to drive Global Ionosphere Thermosphere Model (GITM) to examine the global response in the IT system during the 8-10 October 2012 storm. Specifically, the average inter-hemispheric asymmetry in the cross polar cap potential drop (CPCP) and hemisphere power (HP) are 18.42% and 19.76%. The ion convection pattern and its boundary extension show a strong IMF B_y dependence during the storm. As for the consequences in the IT system, the neutral density in the northern and southern hemispheres show significantly asymmetric responses to the storm phase and IMF B_y, these asymmetries could be affected by the inter-hemispheric asymmetries from the magnetospheric forcings and their related Joule heating.

Introduction & Motivations

Introduction

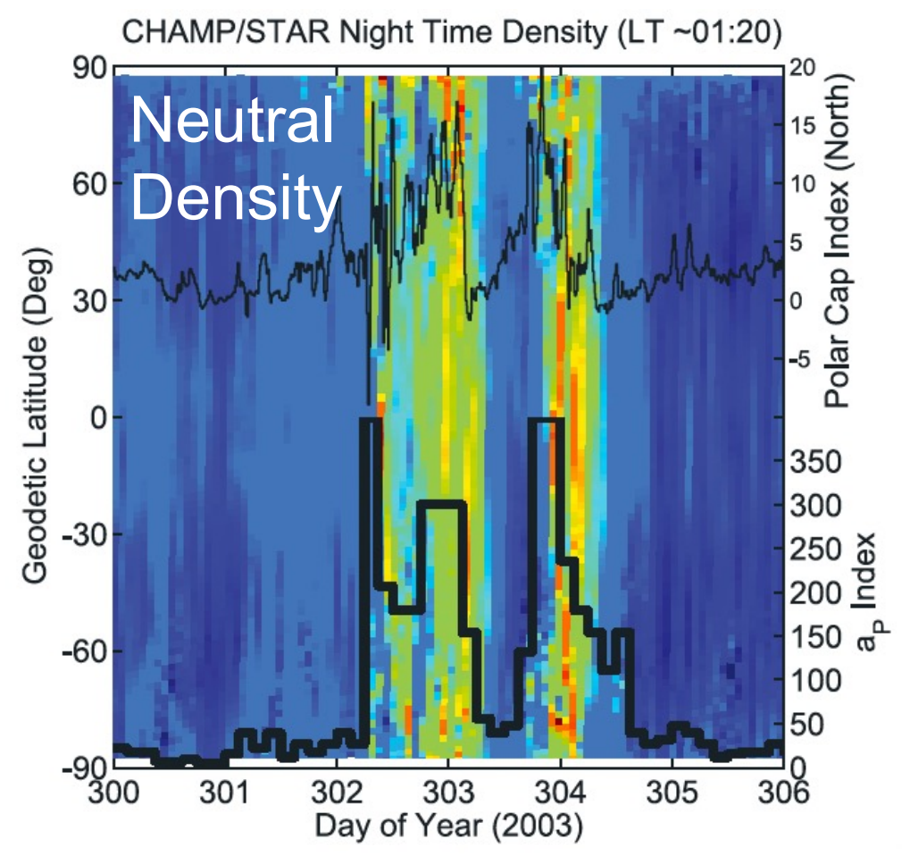
- The inter-hemispheric asymmetry (IHA) in magnetospheric forcings, ion convection and auroral particle precipitation can be pronounced during storms
- The IT system is highly affected by the IHA of these magnetospheric forcings



[Zhu et al., 2022]

Motivations

- ○ IHA of the magnetospheric forcings is not well understood during storms
- Using realistic forcings from AMIE patterns to better specify the high-latitude forcings
- ○ IHA in the IT system due to the magnetospheric forcings is not well understood during storms
- Using realistic forcings to drive GITM for examining the IHA in the IT system



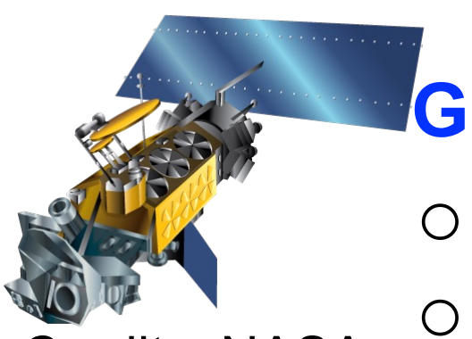
[Sutton et al., 2005]

Data and Model

Data

DMSP F16 & F17

- ○ Alt: 850 km, Dawn-Dusk
- ○ Cross-track ion drift: V_Y



Credits: NASA

GOCE Satellite

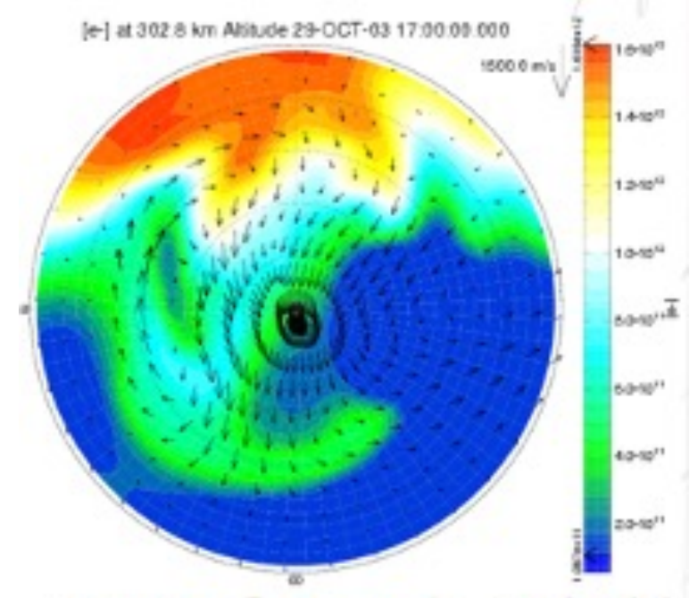
- ○ Alt: 250-280 km, Dawn-Dusk
- ○ Neutral density (normalized at 270 km)

Credits: ESA

Model

GITM (Global Ionosphere Thermosphere Model)

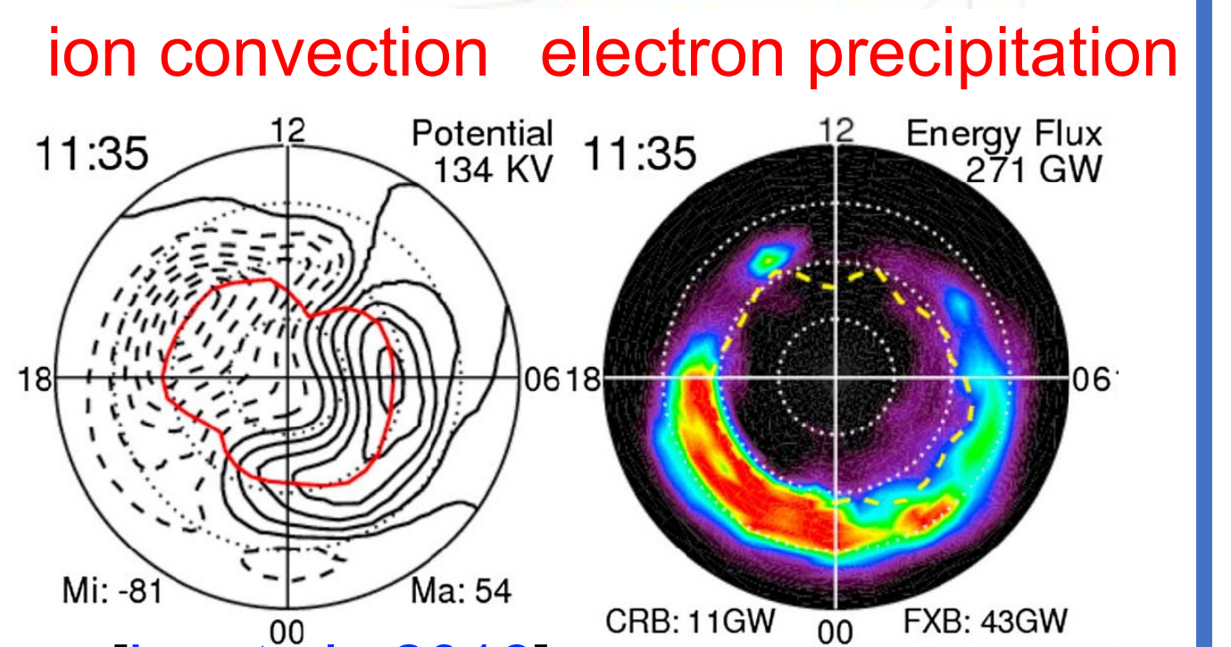
- ○ 6 Neutral & 5 Ion Species
- ○ Ion and neutral density, velocity and temperature
- ○ Flexible grid resolution, non-hydrostatic solutions



[Ridley, A et al., 2006]

AMIE (high-latitude driver)

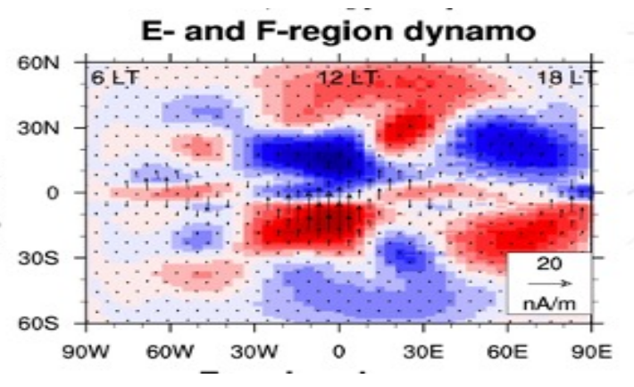
- ○ Based on a variety of ground-based and spaced-based measurements, e.g., magnetometers, DMSP, super Dual
- ○ Data assimilative patterns



[Lu et al., 2016]

NCAR-3Dynamo (global driver)

- ○ Solves for global ionospheric current (3D), E-field and magnetic perturbations
- ○ Electrodynamics solved in APEX coordinate



[Maute & Richmond, 2017]

Result - 1: IHA in the high-latitude: magnetospheric forcings

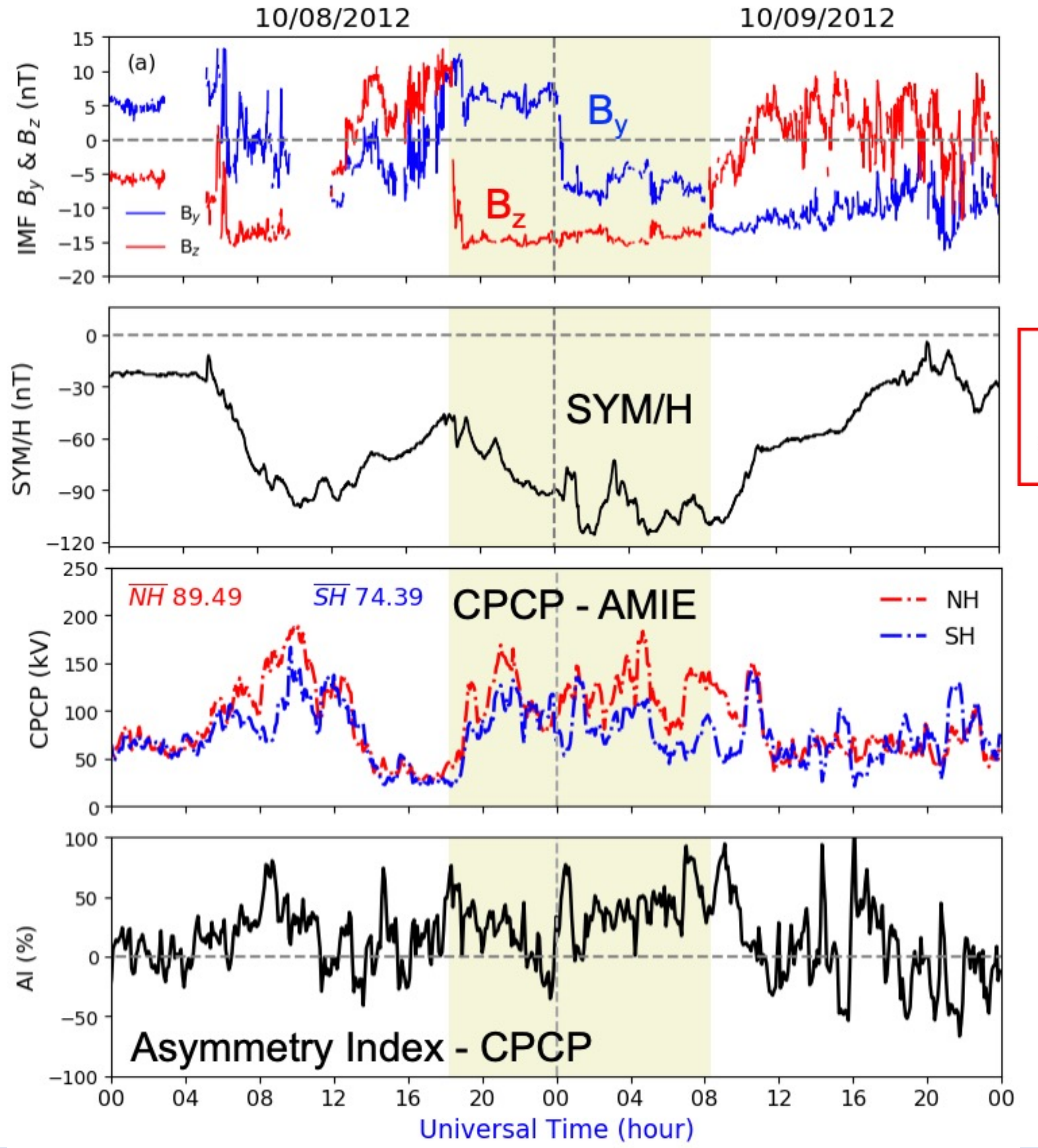


Fig 1. (a) IMF B_y and B_z, (b) SYM/H , (c) CPCP, (d) Asymmetry Index for CPCP during the 2012 October 08-09 storm

- IMF B_z lasted around 16 hours
- IMF B_Y flipped from positive to negative during main phase

Asymmetry Index

$$I = \frac{2(\mathrm{NH}-\mathrm{SH})}{(\mathrm{NH}+\mathrm{SH})} \times 100\%$$

[Hong et al., 2021]

- Clear asymmetry in CPCP, with larger Index when B_y is negative than positive

The CPCP has pronounced IHA during storm period, the biggest |AI| can up to ~ 113%

Result - 2: IHA of ion convection extension to lower latitudes

2.1 DMSP: ion convection extension

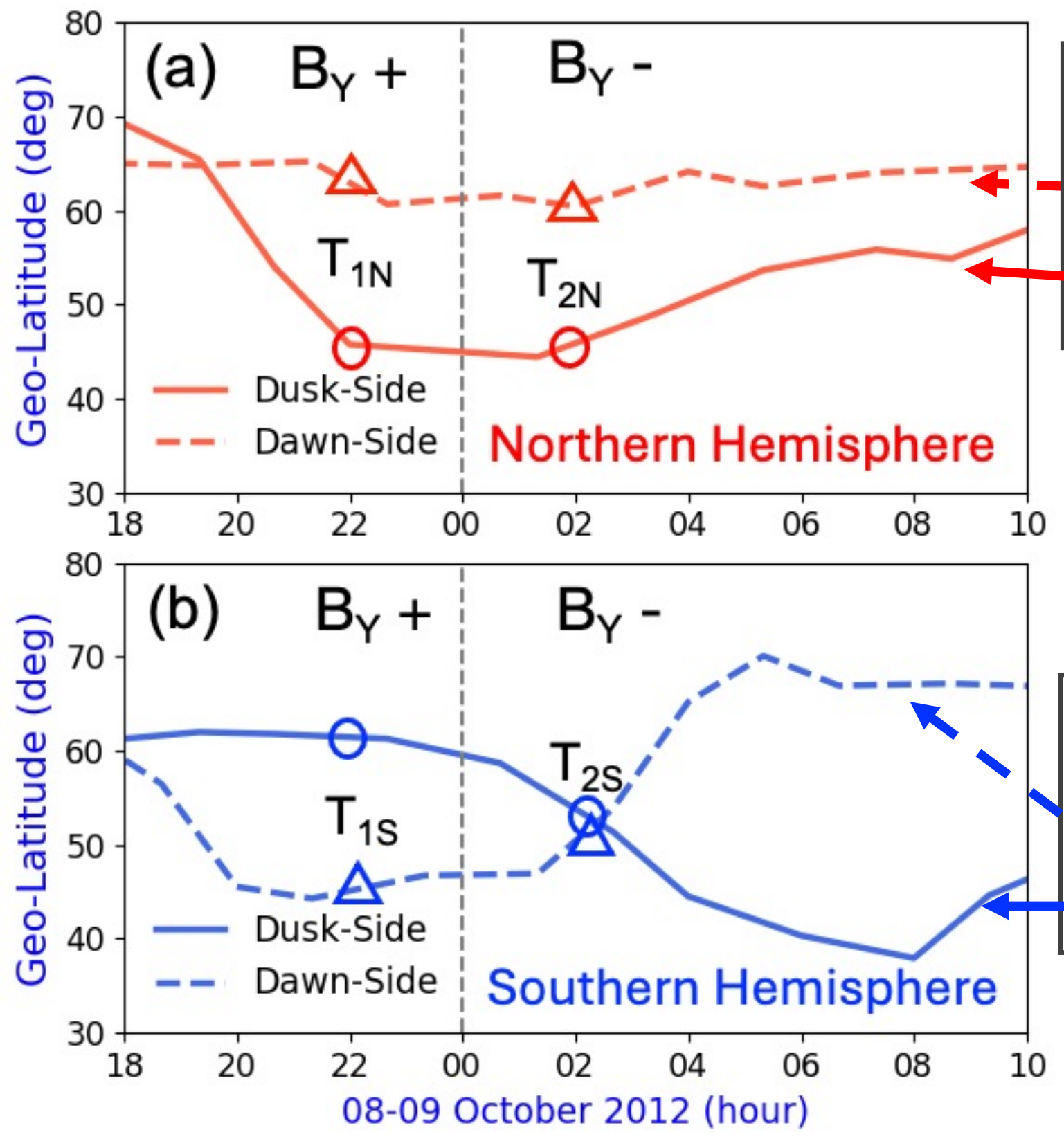


Fig 2. Ion convection boundary observed by DMSP in northern (a) and southern (b) hemispheres of both dusk-side and dawn-side.

- Northern Hemisphere (NH)
  - Dawnside has almost no extensions
  - Duskside extends to lower latitude

Clear IHA in ion convection equatorial extension of both dusk and dawn sides

- Southern Hemisphere (SH)
  - Dawnside extends to lower under B_Y+
  - Duskside extends to lower under B_Y -

2.2 GITM: ion convection extension

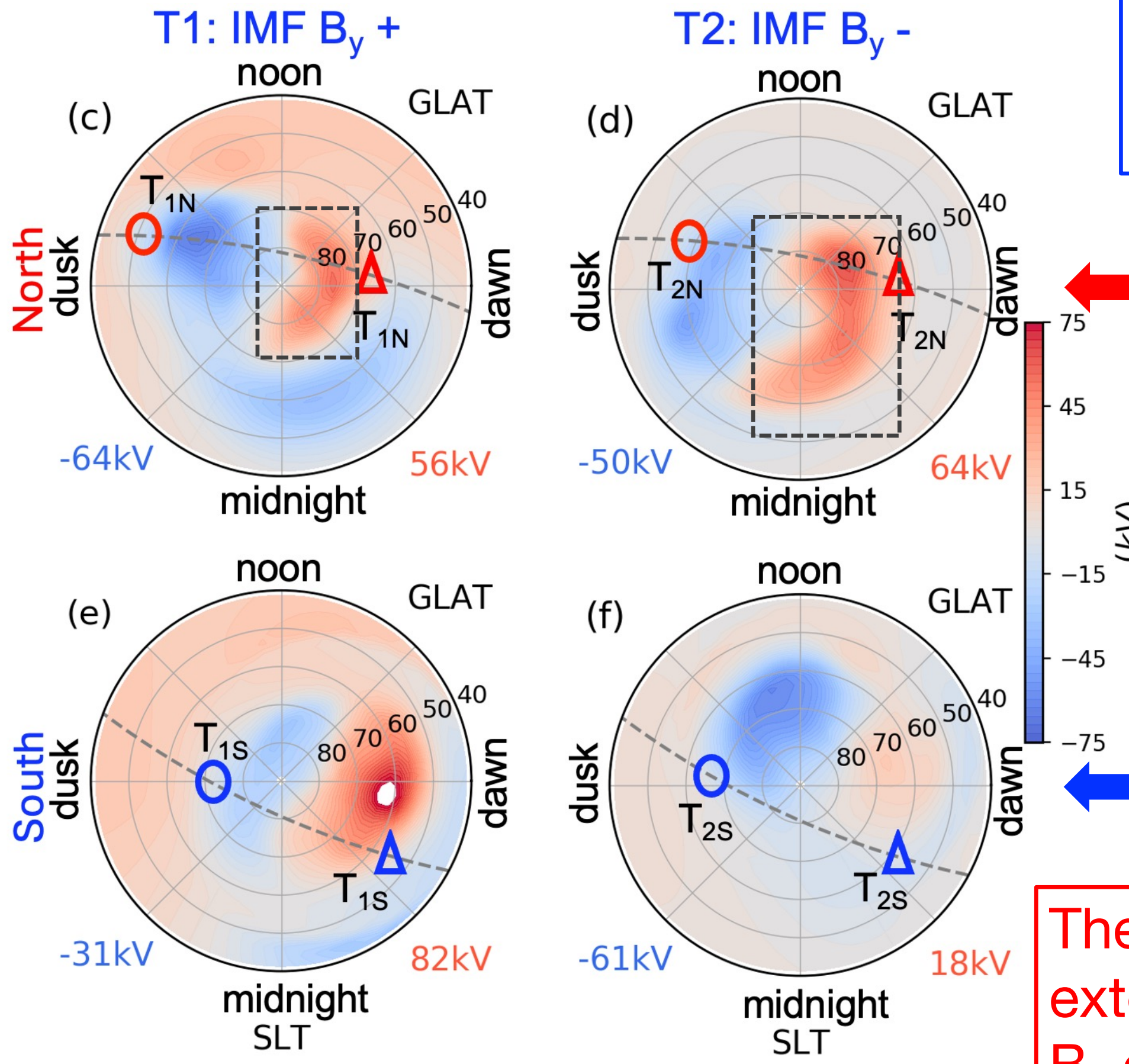


Fig 3. Snapshots of GITM-AMIE convection patterns in northern (top) and southern (bottom) hemispheres.

- **DMSP & GITM comparisons**

Symbol: circle – duskside; triangle – dawnside

GITM ion convection patterns show similar changes and IHA with DMSP observations

NH has less changes in the two-cells and CPCP than the SH but is stretched (dawnside) in the noon-to-midnight direction

SH has more obvious changes in two-cells and B_y dependence

The ion convection boundary extension has obvious IHA, with the B_y dependence in both hemispheres

Result - 3: IHA in the global ionosphere-thermosphere system

3.1 GOCE observed duskside neutral density $d\rho$

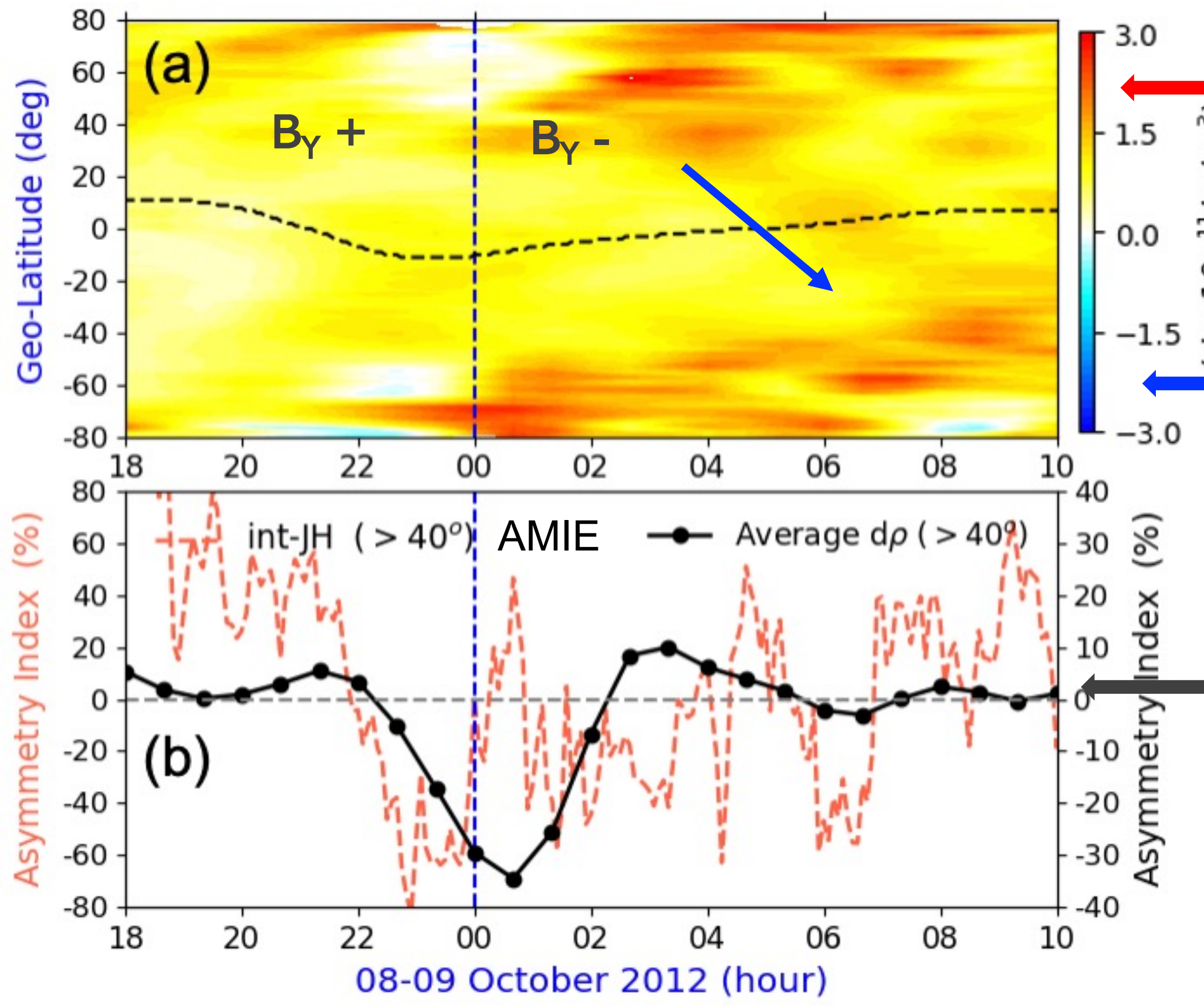


Fig 4. GOCE measured $d\rho$ at 270km (a), asymmetry index of AMIE total Joule heating and averaged $d\rho$ (> |40°| GLAT).

NH is enhanced earlier under B_y + and delayed under B_y -

SH is delayed under B_y + and boosted when B_y reversed

- IHA and B_y dependence

Both total Joule heating and $d\rho$ have B_y flip responses, they have similar changes with ~2-3 hours differences

LT differences in high-latitude

3.2 GITM simulated duskside $d\rho$

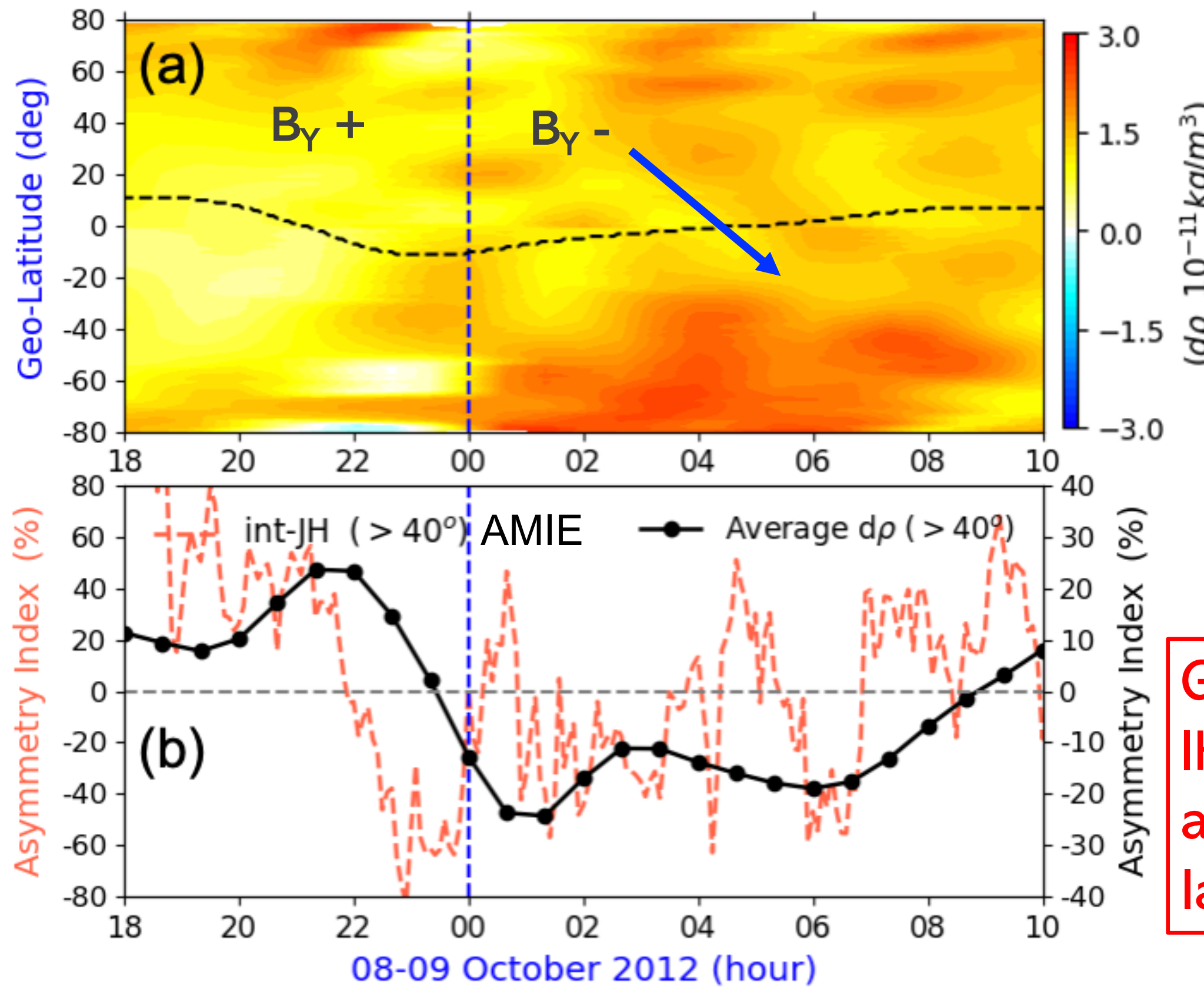


Fig 5. Similar to Fig 4 but for GITM simulated results.

Data-Model comparisons show some similar storm-time responses and TAD structures in $d\rho$

GITM $d\rho$ has more clear and closer responses to Joule heating and larger $d\rho$ when B_y -

GOCE and GITM $d\rho$ have clear IHA with B_y (flip) dependence and are affected by the high latitude forcings/Joule heating

Summary & Conclusions

➡ IHA in the high-latitude region: magnetospheric forcings

AMIE outputs magnetospheric forcings have obvious IHA during storm period

Quantity	North	South	Asymmetry Index
CPCP	89.5 kV	74.4 kV	AI = 18.42%
HP	32.3 GW	26.5 GW	AI = 19.76%
int-JH	174 GW	184 GW	AI = -5.91%

➡ IHA in the mid- and low-latitudes: ion convection extension

The convection extension shows strong storm phase and B_y dependences, as showed by both DMSP measurements and GITM simulations

➡ IHA in the global IT system: neutral mass density $d\rho$

GITM (AMIE) and GOCE $d\rho$ show similar IHA to the storm, which could be affected by the IHA in magnetospheric forcings and related Joule heating

COMING SOON

Hong et al., (2022) Inter-hemispheric asymmetry of Ion convection and its impacts on the ionosphere-thermosphere system during the 08-10 October 2012 geomagnetic storm, *Frontiers*, to be submitted

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