Formation of SED and EPB during April 2023 Storm Using GITM-SAMI3

Yulu Peng[1], Shasha Zou[1], Zihan Wang[2], Xiantong Wang[1], Joe Huba[3], Aaron Ridley[1]

1. University of Michigan, Ann Arbor 2. University of Texas at Arlington
3. Syntek Technologies, Fairfax, VA, USA

Contact: yulupeng@umich.edu

1. Introduction

- During geomagnetic storms, ionospheric storms consist of large-scale variations of ionospheric electron density.
- Ionospheric responses are complex because it has EM-coupling with the SW-magnetosphere and collisional-coupling with the thermophere.
- SEDs are electron density enhancements (positive phase) that often occur in the mid-latitude region from postnoon to dusk sector during storm times. Occasionally, SEDs extend northwestward to higher latitudes and form a SED plume.
- EPBs (Equatorial Plasma Bubbles) are large-scale plasma depletions, rising into the topside ionosphere during post-sunset sector, which are associated with PRE (pre-revsersal enhance-ment) and initiated by generalized Rayleigh-Taylor instability.
- Density variations of these ionospheric phenomenon are crutial for radio communication.

2. Methodology

Two runs using the one-way coupled GITM-SAMI3 from 2023/04/22 to 2023/04/25:

1. Use the **Weimer** model as high latitude electric potential.
2. Use IE output from **BASTRUS MHD** model with a new ionospheric **conductance COMPASS** model.

***NOT include initial density perturbations!!!

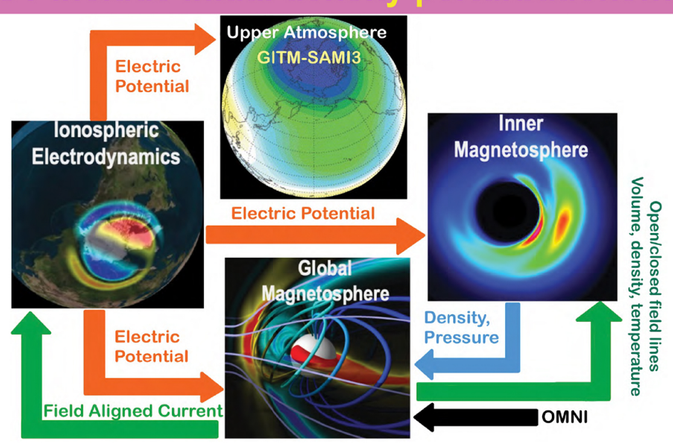
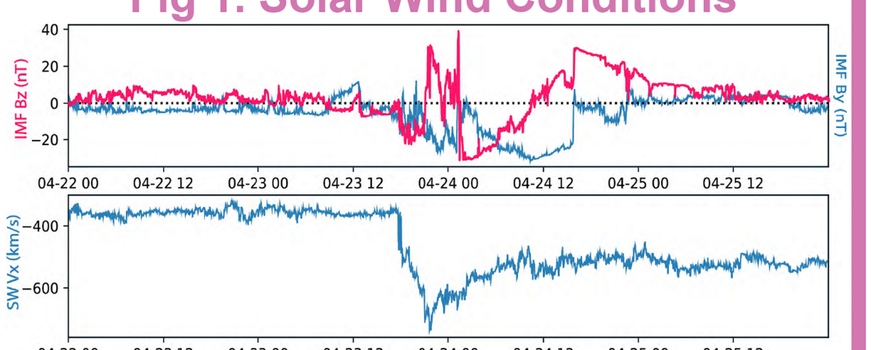


Fig 1. Solar Wind Conditions

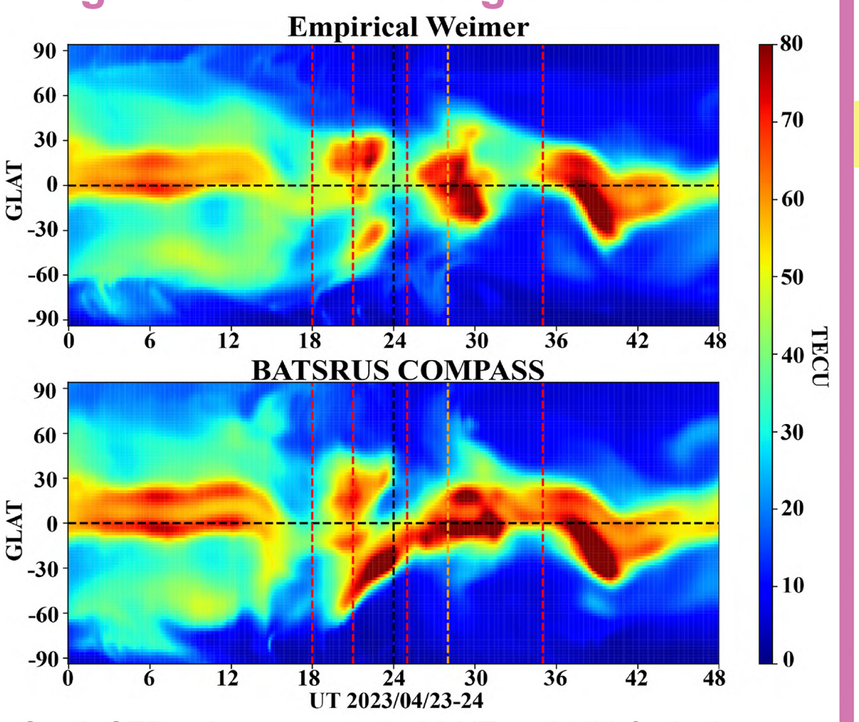


- 1st southward Bz turning: 04/23/18-21 UT due to a full-halo CME hit Earth at 04/23/17:37 UT
- 2nd southward Bz turning: 04/24 01-11 UT due to the continued effect of CME with magnetic cloud.
- Minimum Sym-H reached -233 nT at 04/24 04:03 UT.

3. Results

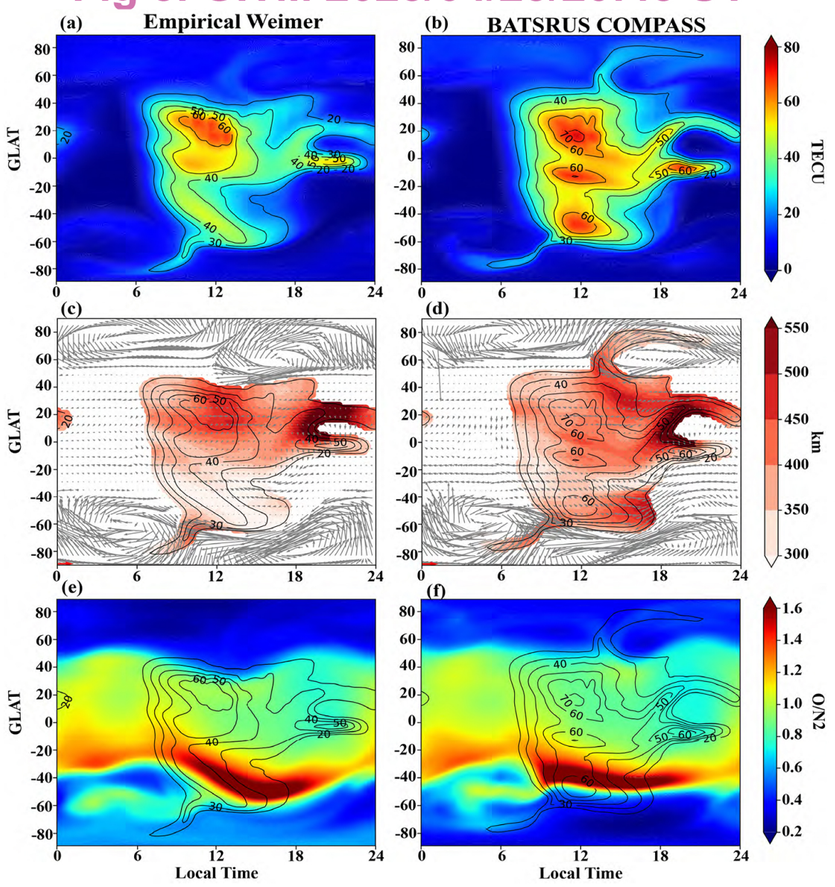
3.1 SED

Fig 2. GITM TEC Keograms at Noon



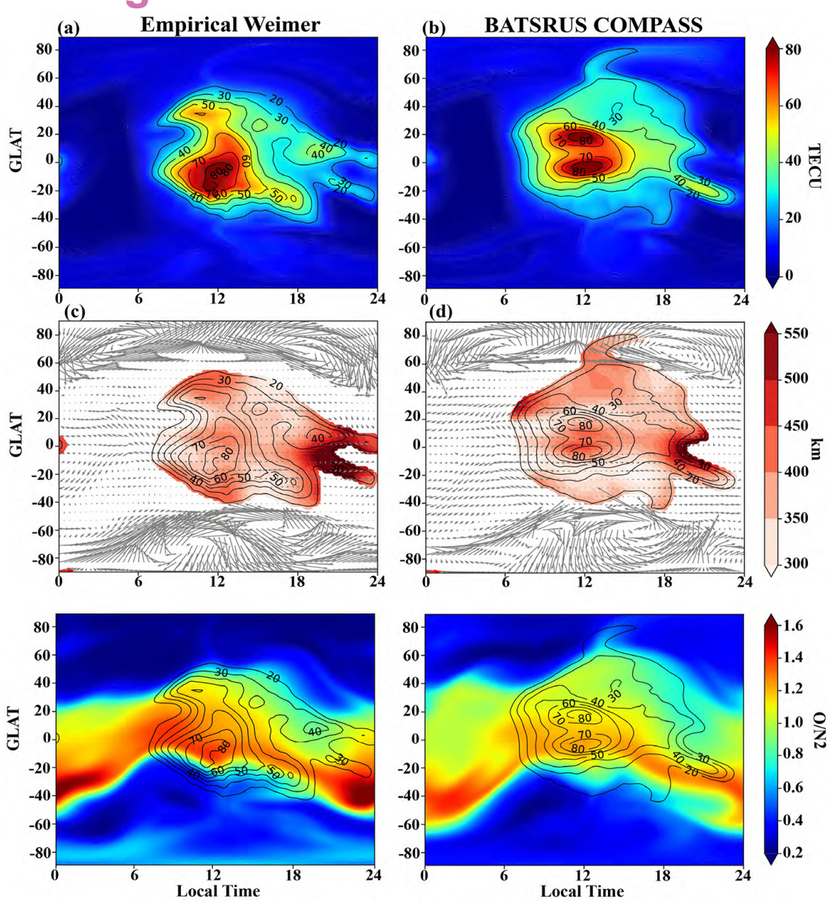
- South SED enhancement at ~08 UT on 04/23 for both runs.
- During 19-24 UT 04/23, both runs have significantly greater SED base and EIA at south mid-latitude region.
- Negative phase at the high latitude after the storm initiation.

Fig 3. GITM 2023/04/23/20:45 UT



- Both runs formed clear north and south SED plumes.
- COMPASS run formed a south (-50 GLAT) SED base at ~480 km separated from EIA height with strong poleward ion flows
- O/N2 hemispheric asymmetry might be due to seasonal effect reinforced by storm effects.

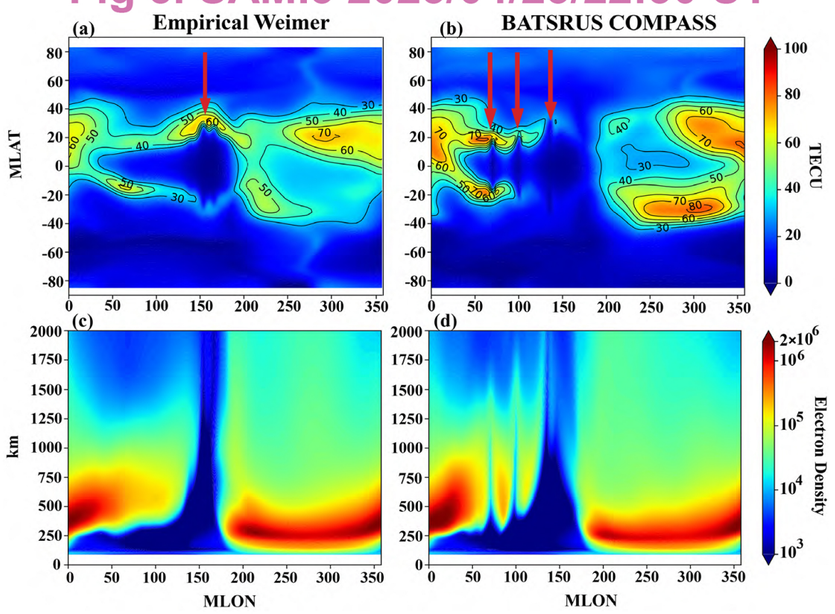
Fig 4. GITM 2023/04/24/05:30 UT



- COMPASS run forms a north SED plume with a separated SED base at 40-60 GLAT with ~420 km.
- Weimer run has smaller TECU and shows a weaker and more asymmetric EIA structure or SED.

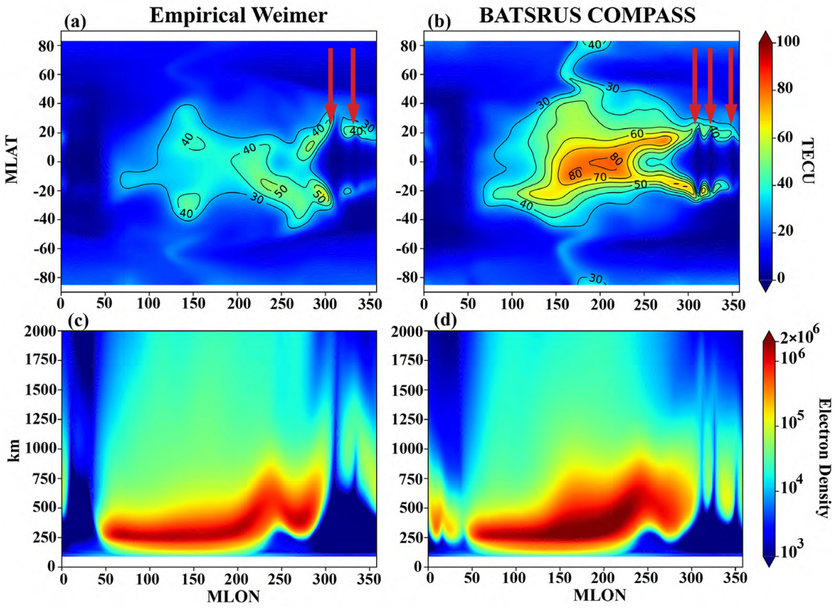
3.2 EPBs

Fig 5. SAMI3 2023/04/23/22:30 UT



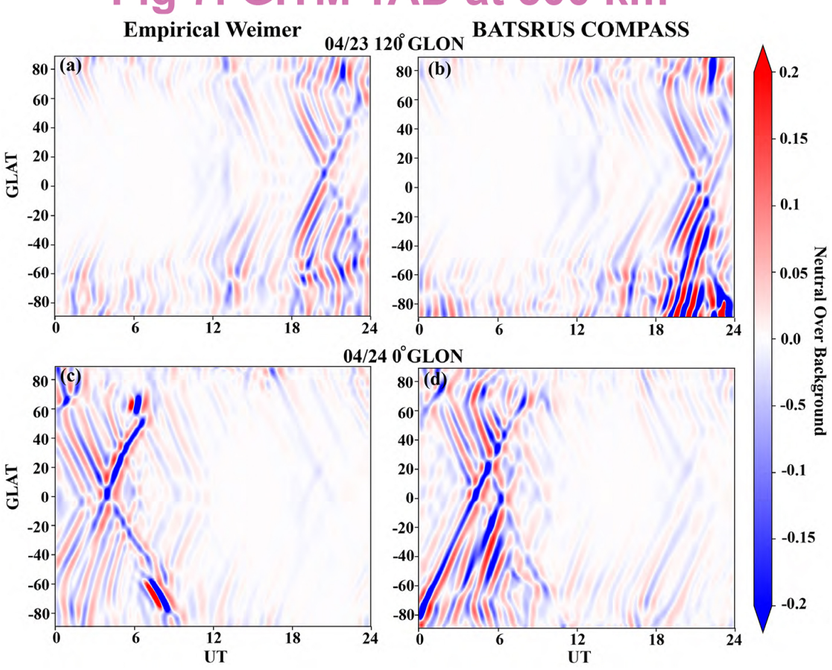
- Both Weimer and COMPASS runs form EPB depletions.
  - Weimer run: 2 strips at 160 MLon (pre-dawn).
  - COMPASS run: 3 strips at ~70, 100, 130 MLon (~22-03 LT).
- Electron density altitude profiles at the magnetic equator (fig 5e and 5f) show apparent irregularities on the bottomside of the ionosphere, which develop into EPBs.

Fig 6. SAMI3 2023/04/24/07:30 UT



- SAMI3-COMPASS run developes aprrent SED plumes at both hemispheres.
- Both Weimer and COMPASS runs form EPB depletions.
  - Weimer run: 2 strips at 310, 330 MLon (~20 MLT).
  - COMPASS run: 3 strips at 310, 320, 350 MLon.
- Electron density altitude profiles at the magnetic equator (fig 6e and 6f) show PRE and bottomside ionospheric irregularities.

Fig 7. GITM TAD at 500 km



- Fig 7a-b and 7c-d show strong GITM TADs correspond to two EPB periods at pre-dawn 04/23 and ~22-03 LT 04/24.
- On 04/23, TADs start at 18 UT after 1st Bz southward turning, and take ~3 hr to reach the equator.
- In both cases, TADs reach the equator in ~2-3 hours.

4. Conclusions

1. GITM-SAMI3 model successfully captures large-scale iono-spheric phenomenon such as SED and SED plumes, and their hemispheric asymmetries.
2. Two episodes of SEDs formed during two southward IMF periods
3. GITM-SAMI3 using BATSRUS COMPASS produces stronger SEDs than empirical Weimer. Data and model comparison shows better agreement (not shown).
4. Two periods of EPBs formed during this storm in both Weimer and COMPASS runs (04/23/21:00--04/24/01:30 and 04/24/05:00--04/24/10:30).
5. EPBs formed without the initial density seeding. We suggest that large TADs formed in GITM may create initial density variations in SAMI3 to seed EPBs.

5. Acknowledge

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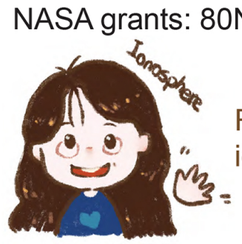

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