Linking Very Near-Earth Reconnection (VNERX) to Mid-Latitude Geomagnetically Induced Currents (GICs): Evidence from 7 September 2017

POSTER # 46

Bhagyashree Waghule[1], Delores J. Knipp[1], Grant K. Stephens[2], David M. Malaspina[3,4]

[1]Smead Aerospace Engineering Sciences, University of Colorado Boulder (CU Boulder)

[2]John's Hopkins University, Applied Physics Laboratory (JHU APL)

[3]Laboratory for Atmospheric and Space Physics (LASP), [4]Astrophysical and Planetary Sciences Department, CU Boulder

INTRODUCTION / MOTIVATION / BACKGROUND

- The North American Electric Reliability Corporation (**NERC**) Geomagnetically Induced Current (**GIC**) Monitor database provides essential **operational** data for GIC **research**.
- Figure 1 (left-hand side) illustrates the context of the geomagnetic storm on **7-9 September 2017**, while the right-hand side highlights a 1-hour interval during which the most significant GIC spike (**30A**) occurred near **Virginia, USA**, at 23:00 UT on 7th.
- This spike is coincident with interplanetary shock (IPS, Fig.1a,b) and Sudden Commencement (**SC**) event (Fig.1d), which also led to global GICs.
- Prior to 20:00 UT, the storm was not geoeffective (Fig1.c,d) due to a northward Interplanetary Magnetic Field (IMF) Bz component (Bz+).
- A closer look at the GIC spike near Virginia reveals that SC initiated a 20A rise, which rapidly increased to 30A after **1.7 minutes (Fig 1f')**.

Research Question: What caused the additional rapid rise in GIC spike?

Hypothesis: The additional 10A rise was driven by an injection from Very-Near-Earth Reconnection (**VNERX**) (Beyene & Angelopolous, 2024)

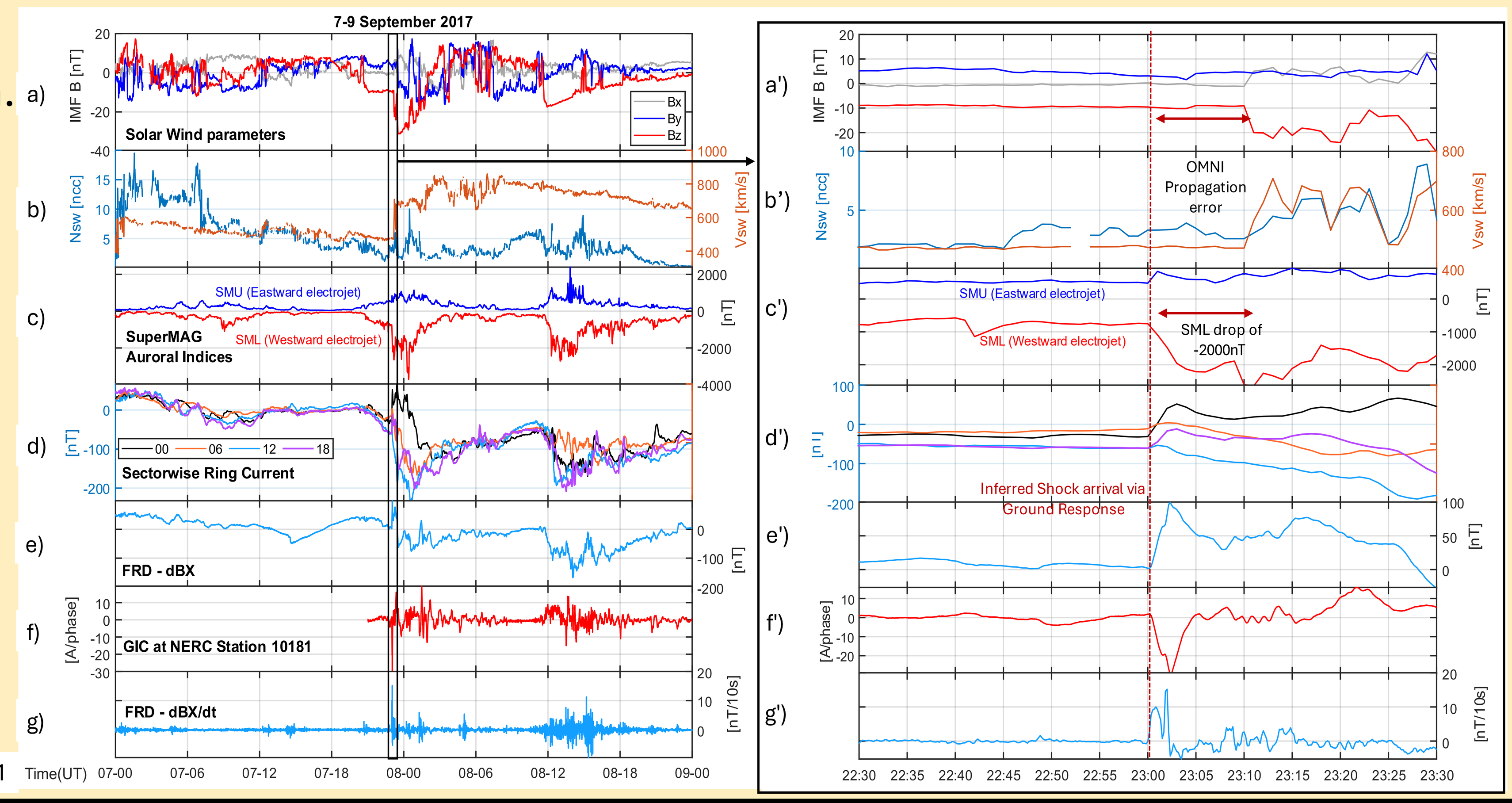


Figure 1

DATA AND METHOD

NERC GIC database

- GIC Station #10181, near the Fredericksburg magnetometer (FRD; 38°N, 77°W; ~48° MLAT) in Virginia.
- GIC are measured on the neutral of a 3-phase transformer (NERC metadata),
- For this event, GIC data is available after 21:00 UT.

Spacecrafts

THEMIS-A, GOES 13,15, Van Allen Probe (VAP) A, Magnetospheric Multiscale (MMS)

Inclined Shock Database

23:00 UT shock had an East-West shock normal component of ny= +0.170 in GSE coordinates, which indicates a duskside strike (Olivera, 2023; Samsonov et al., 2015).

Data-Mining (DM) based Magnetic field reconstruction

Input	Processing	Output
Historical archive of nearly 30 years (1995–2024) of magnetometer records.	Identify instances when magnetosphere was in a similar global configuration	Reconstructed magnetosphere with resolved Reconnection lines (X-lines)

Modifications:

1) Data from the most similar events are given a higher statistical weight in the fitting procedure
2) A finer spatial equatorial resolution is used
3) Data beyond r = 20 R_E is excluded
4) Only the historical archive of MMS was used from 2016 to November 2024, extending the database from previously published work by (Stephens et al., 2023).

Merit: The model identifies repeatable patterns from observations not only at the moment of interest, but also by searching for other times when the magnetosphere was in a similar global state.

RESULTS

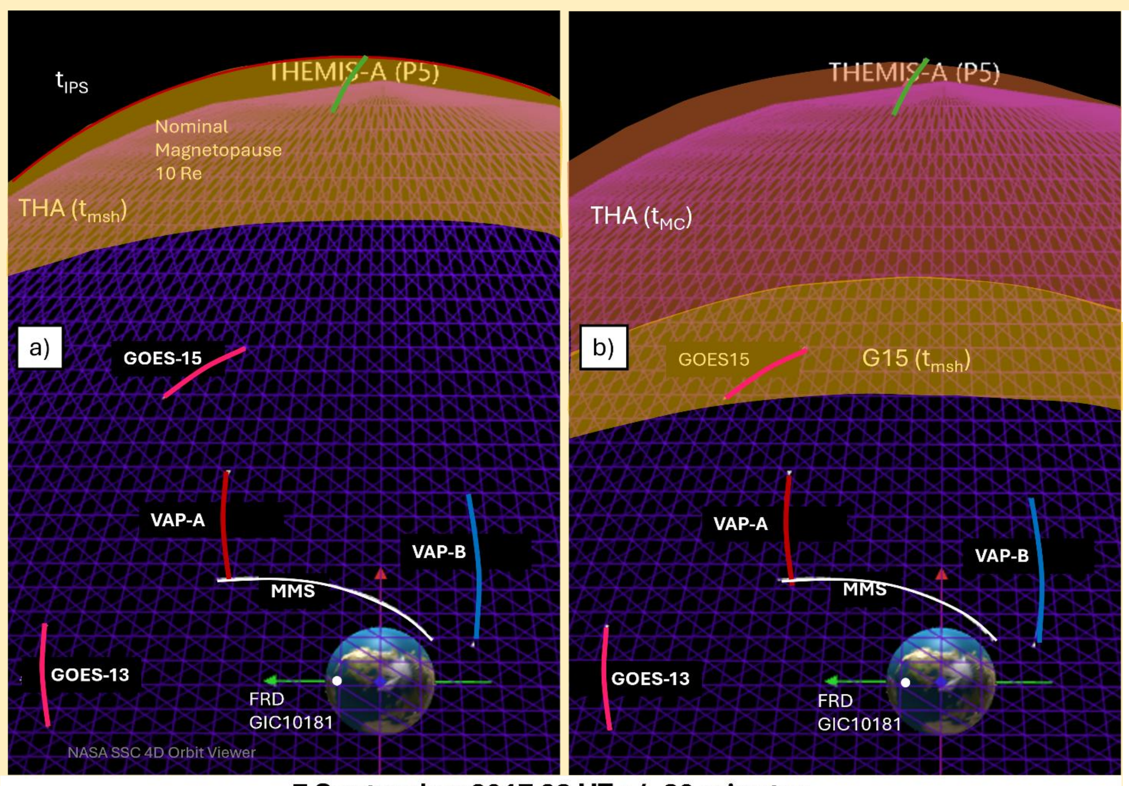
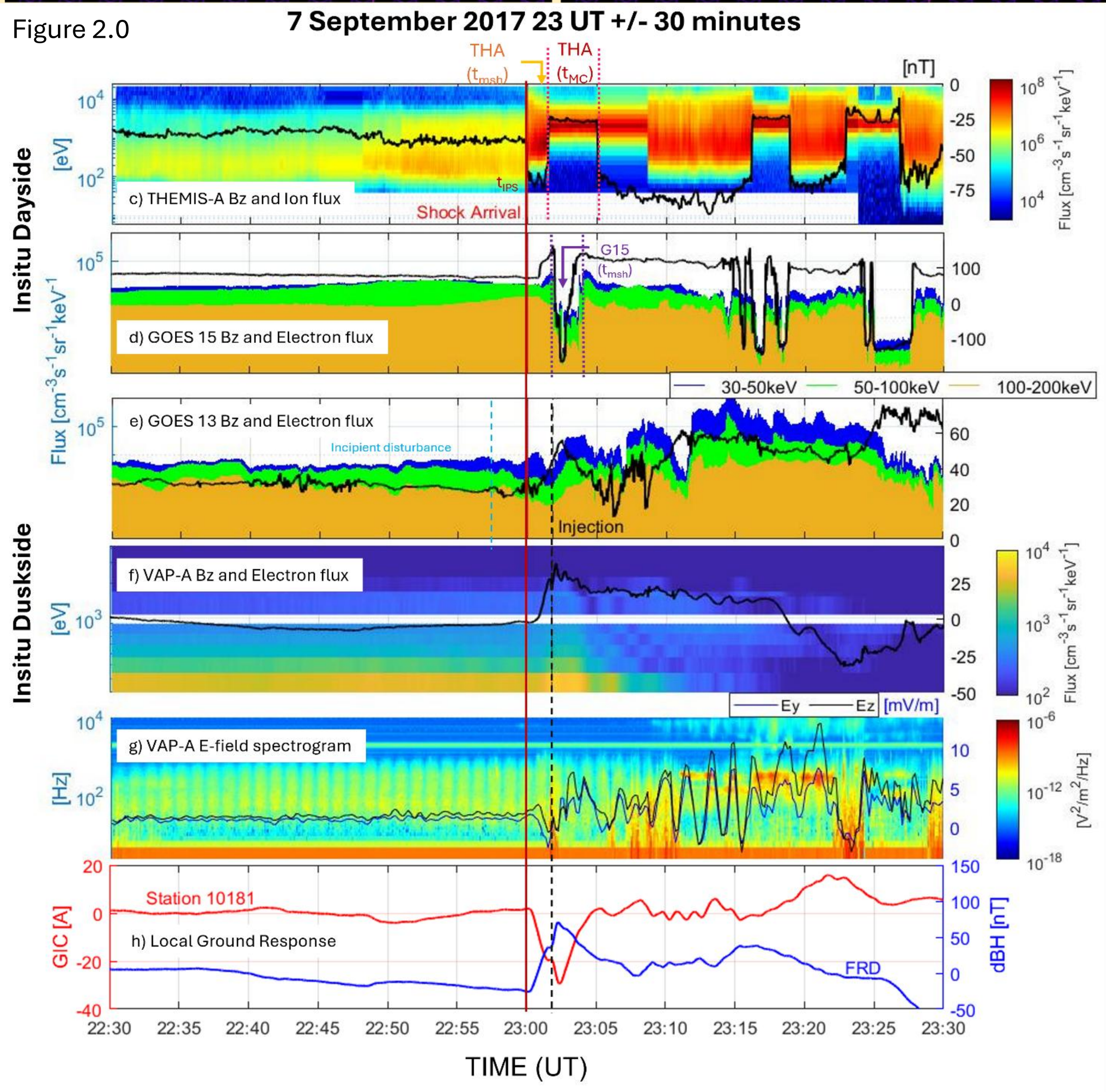


Figure 2.0



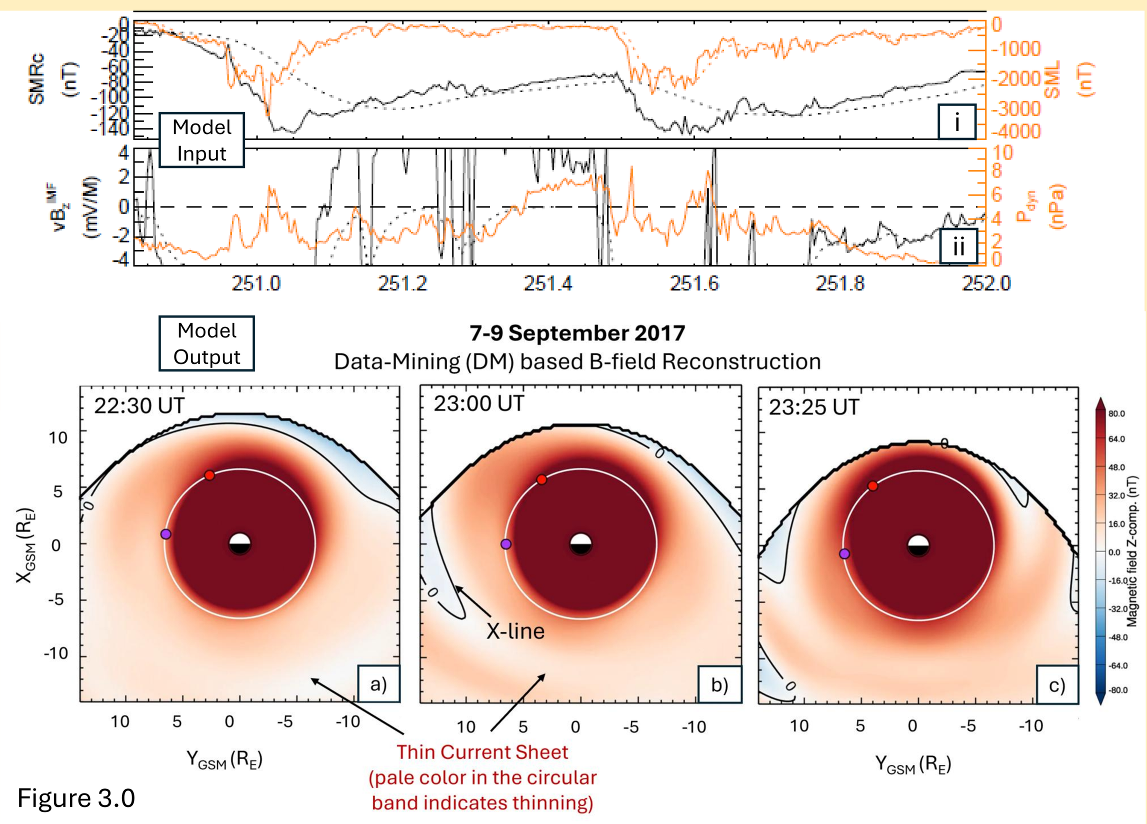
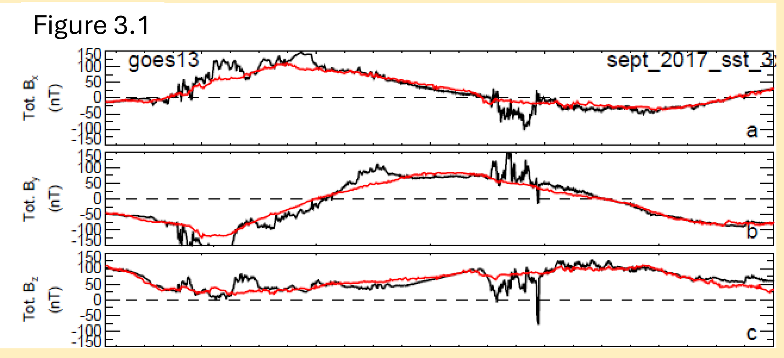


Figure 3.0

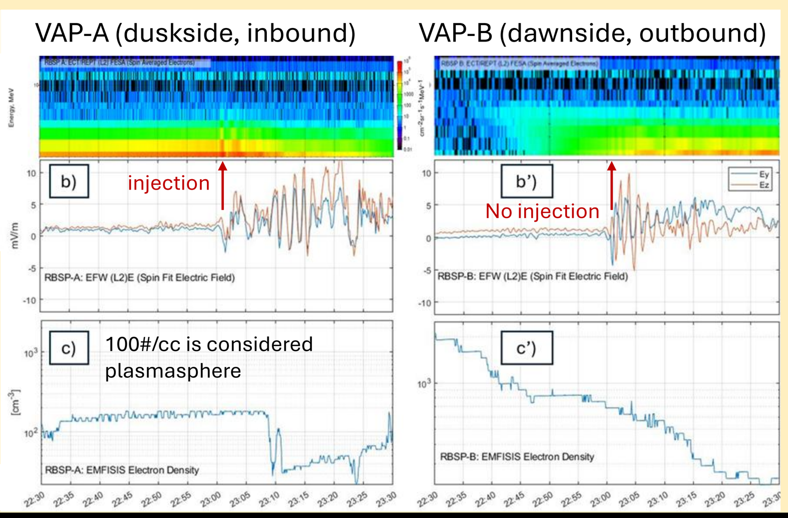
The DM-based B-field reconstruction shows a weakening in the equatorial Bz at ~12 R_E, 30 minutes before IPS arrival (Fig.3a), consistent with a stretched field or thinning of plasma sheet. The model resolves the strongest X-line in the dusk sector at ~12R_E at 23:00 UT (Fig.3b), i.e. with shock arrival, followed by relaxation of the field (Fig.3c).

The model tracks (red) the global changes in the G13 B-field (black) but misses higher-order abrupt changes, suggesting that the model does not capture the full intensity of the disturbance at shock arrival.

Figure 3.1



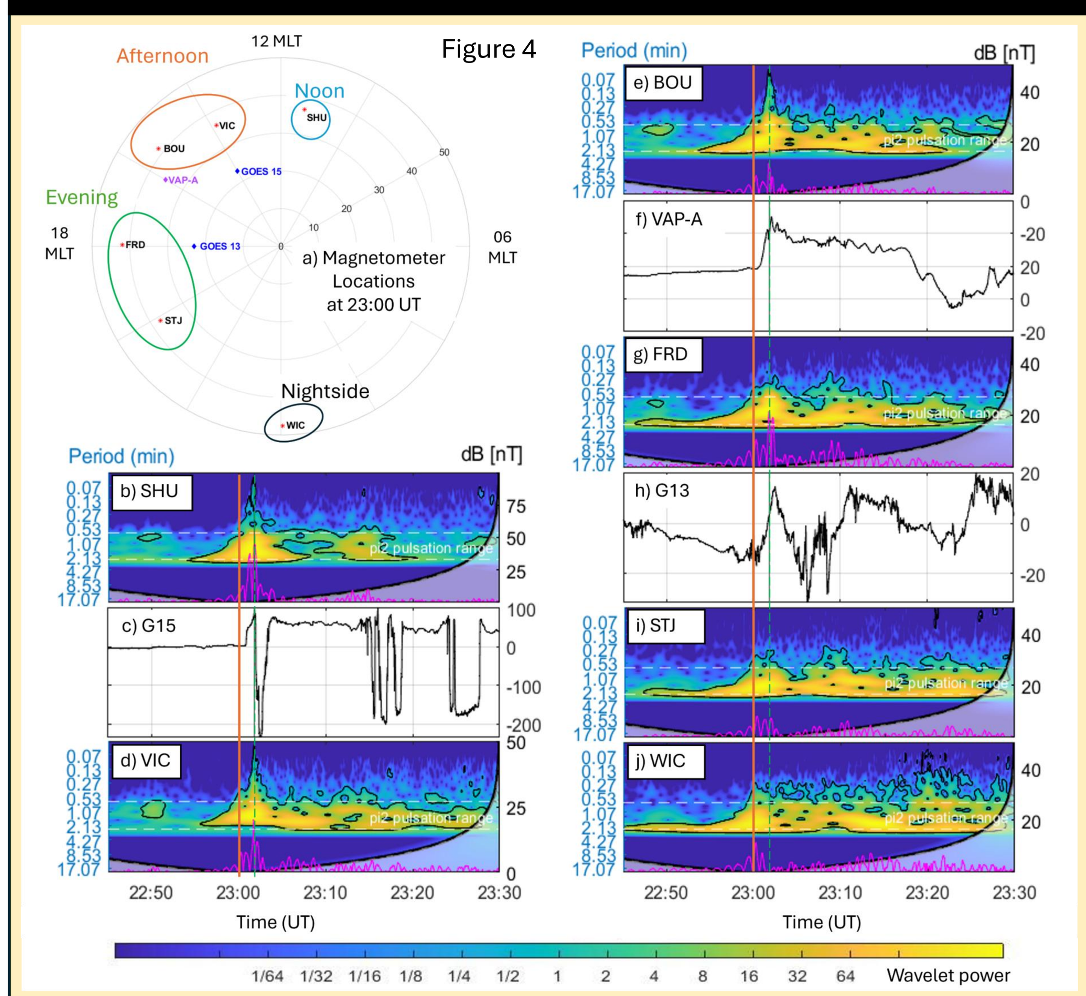
VAP-A and B show different electron flux distribution at dawn and dusk sides, suggesting injection signal was not symmetric.



A simultaneous rise in electron flux and Bz at GOES 13 (Fig.2e,f) is observed. This can be explained by injection reaching GOES 13 and its deceleration energizing low energy electrons at VAP-A in the plasmasphere (Fig.2.1c) at the same time (Turner et al, 2015; Zhang et al. 2021)

Figure 2.1

DISCUSSION AND CONCLUSION



To assess the extent of VNERX-associated disturbance, we analyze 1-second horizontal (BH) data from mid-latitude (45–55° MLAT) range from INTERMAGNET database.

BH is filtered to capture only high frequency fluctuations (<150 seconds).

- Significant Pi1/Psc1-3 pulsations (Saito, 1969) of period < 10 seconds appear at dayside (Fig.4b).
- After 1.7 minutes, when IPS-driven compression reached G15 (Fig.4c), afternoon stations, VIC and BOU (Fig.4d-e) also showed Pi1/Psc1-3 activity.
- The dusk-evening stations, FRD and STJ, exhibit predominantly Pi2-range activity near 23:01:50 UT (Fig.4g,i), consistent with the G13 Bz injection (Fig.4h).

Summary of events

22:59:45 UT: THA entered magnetosheath with IPS arrival.
23:00:17 UT: +dBx measured in the mid-latitude stations.
23:01:42 UT: Bz and electron flux increased at multiple energy channels at GOES 13.
23:01:45 UT: Similar Bz and electron behavior at VAP-A.
23:01:50 UT: Bx (GIC) near Virginia showed 40nT (10A) rise.

These observations suggest that a duskside injection was triggered very close to Earth due to the thinning of the plasma sheet, also captured by the empirical model.

Why Duskside?

1. Preconditioning : prolonged IMF Bz+ accompanied with large density filled magnetosphere with cold dense plasma
2. IMF Bz- :energized the dense plasma and thinned the sheet
3. IMF By+ : harangue discontinuity twisted towards dusk
4. Inclined IPS : destabilized the current sheet near dusk

The relatively new archived **Operational** data from US NERC GIC monitor system enabled this comprehensive **Research**. This study emphasizes the need for future GIC hazard assessments to move beyond simplified SC frameworks and account for the mesoscale structure of the magnetospheric state—particularly at mid-latitudes.

REFERENCES / ACKNOWLEDGEMENTS

BW and DJK are partially supported by NSF Award 1933040, NASA Awards 80NSSC20K1784 and HIWIND 80NAAC21K0014P00001. GKS is supported by NASA grant 80NSSC24K0556 and NSF grant AGS-2411808. We thank NERC for providing and maintaining GIC data, and INTERMAGNET and SuperMAG for providing high quality ground magnetometer data. We thank the VAP team, THEMIS mission team, GOES mission team, and instrument PIs to enable this research.

Waghule, B., et al. (2024). What Drove the GICs >10 A During the 17 March 2013 Event at Mäntsälä? A Novel Framework for Distinguishing the Magnetospheric Sources. *Space Weather*, *22*(7), e2024SW003980. https://doi.org/10.1029/2024SW003980

Turner, D. L., et al. (2015). Energetic electron injections deep into the inner magnetosphere associated with substorm activity. *Geophysical Research Letters*, *42*(7), 2079–2087. https://doi.org/10.1002/2015GL063225

Oliveira, D. M. (2023). Interplanetary shock data base. Frontiers in Astronomy and Space Sciences, 10. https://doi.org/10.3389/fspas.2023.1240323

Beyene, F., & Angelopoulos, V. (2024). Storm-Time Very-Near-Earth Magnetotail Reconnection: A Statistical Perspective. Journal of Geophysical Research: Space Physics, 129(5), e2024JA032434. https://doi.org/10.1029/2024JA032434

Stephens, G. K., et al. (2019). Global Empirical Picture of Magnetospheric Substorms Inferred From Multimission Magnetometer Data. Journal of Geophysical Research: Space Physics, 124(2), 1085–1110. https://doi.org/10.1029/2018JA025843

Stephens, G. K., et al. (2023). Global Structure of Magnetotail Reconnection Revealed by Mining Space Magnetometer Data. Journal of Geophysical Research: Space Physics, 128(2), e2022JA031066. https://doi.org/10.1029/2022JA031066