

# A case for Wavelet Transform of Ground Magnetic Field During Solar Superstorms for Understanding Geomagnetically Induced Currents (GICs)

Bhagyashree Waghule<sup>1</sup>, Delores Knipp<sup>1</sup>, and Jennifer Gannon<sup>1</sup>

<sup>1</sup>Affiliation not available

April 16, 2024



SM44B: Understanding Geomagnetically Induced Currents and Their Impact on Technology II Oral

SM44B-06

# A case for Wavelet Transform of Ground Magnetic Field During Solar Superstorms for Understanding Geomagnetically Induced Currents (GICs)

AGU 2023

Bhagyashree Waghule, Delores J. Knipp, Jennifer Gannon

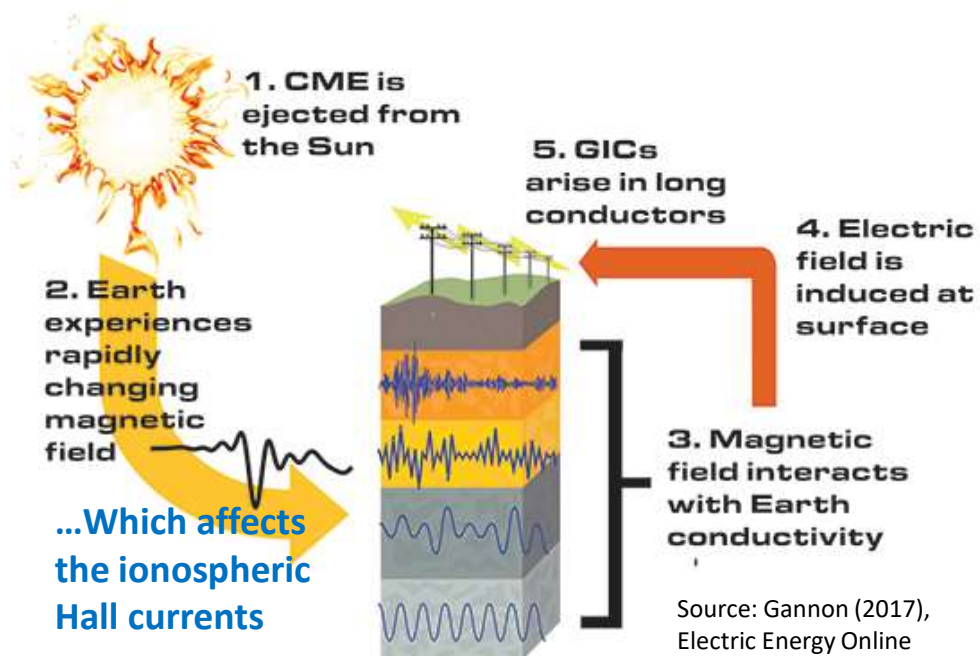
University of Colorado Boulder

Smead Aerospace Engineering Sciences

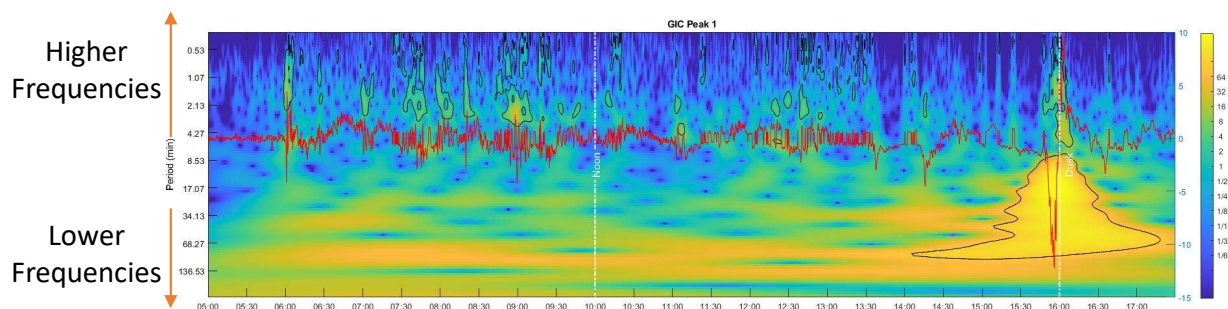


December 14, 2023

# Understanding Geomagnetically Induced Currents (GICs)



- Technology-disrupting GICs arise during Geomagnetic Storms
- They tend to be highly localized
- Wavelet analysis can show underlying frequencies in the GIC signal
- Synthesis of data analyzed using wavelet analysis and satellite data can help with finding the Magnetospheric source of GIC



# March 17, 2013 Storm - Overview

## GICs at Mantsala

- Disturbance from ~6 UT
- 4 Spikes – one at 16 UT; three between 18-19 UT

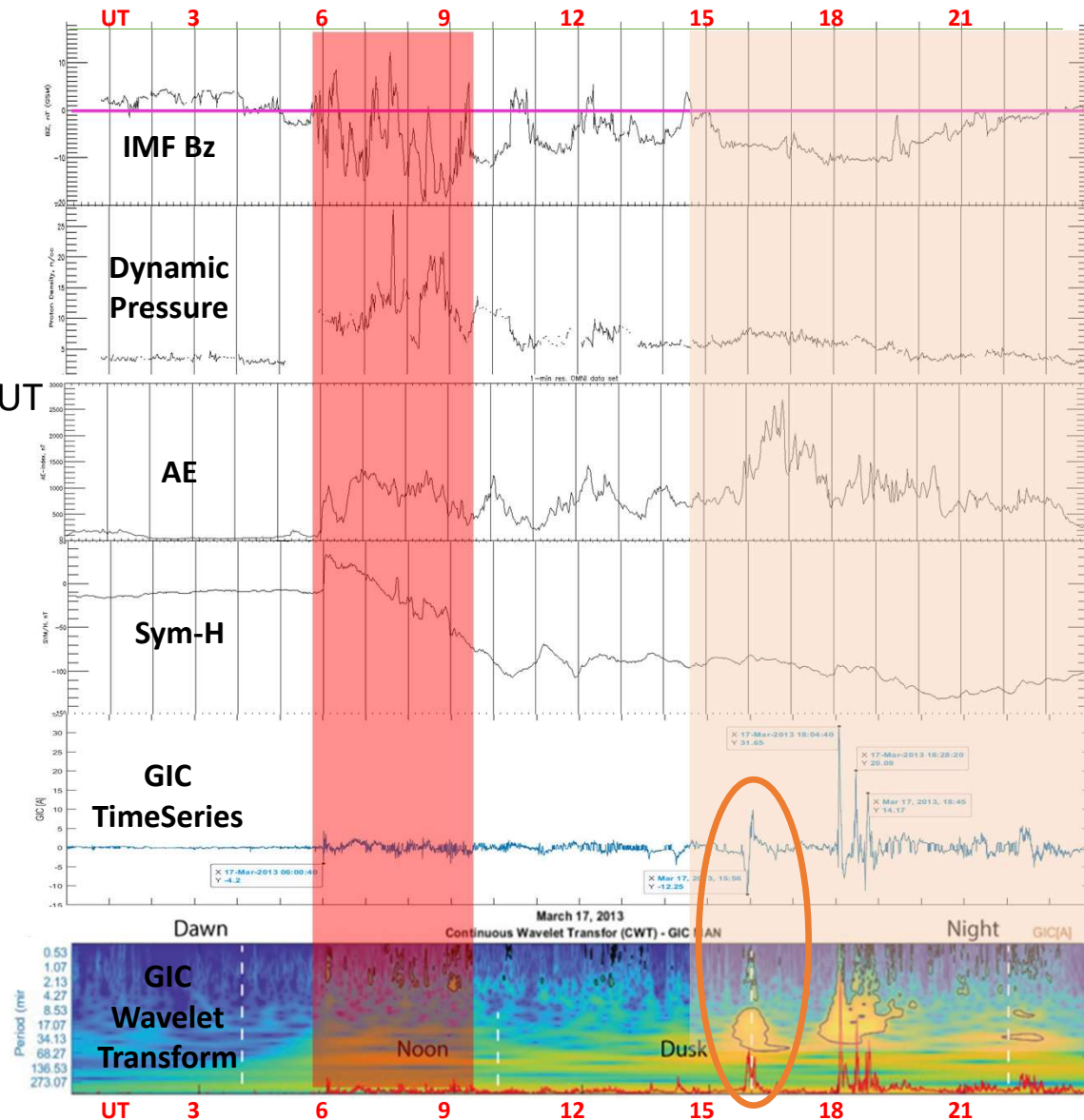
## Dayside

- Shock Arrival 6 UT
- Magnetic Cloud 15:30 onwards

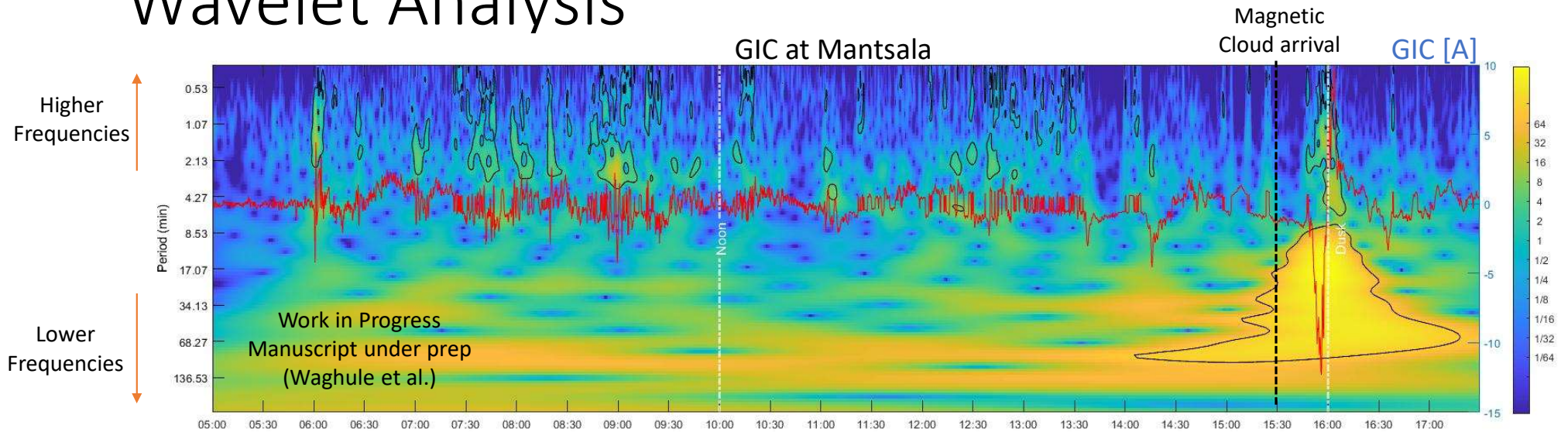
## Nightside

- AE peak (>2500nT) between 16-17 UT
- Ring current maintained at ~75 nT

**We focus on one of the many current systems responsible for the GIC spike at 16 UT**

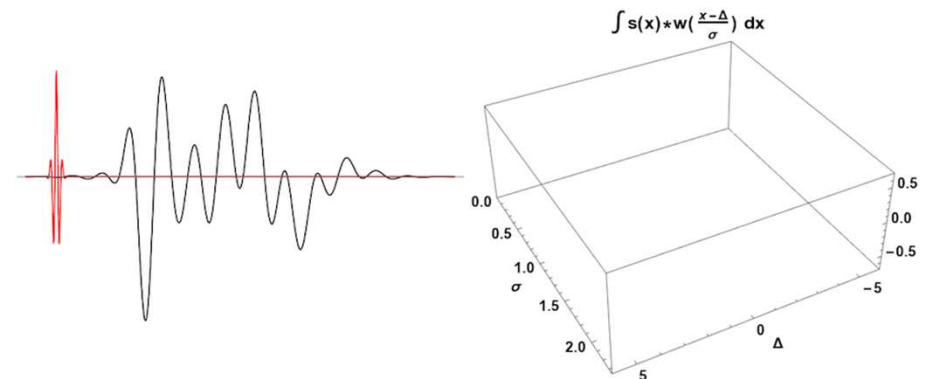


# Wavelet Analysis



- Continuous Wavelet Transform (CWT)

- Blue to yellow – low to high wavelet power -> Shows localized time-frequency oscillations.
- Highlighted yellow area shows time-frequency oscillations above background red noise. (Torrence and Compo, 2004)

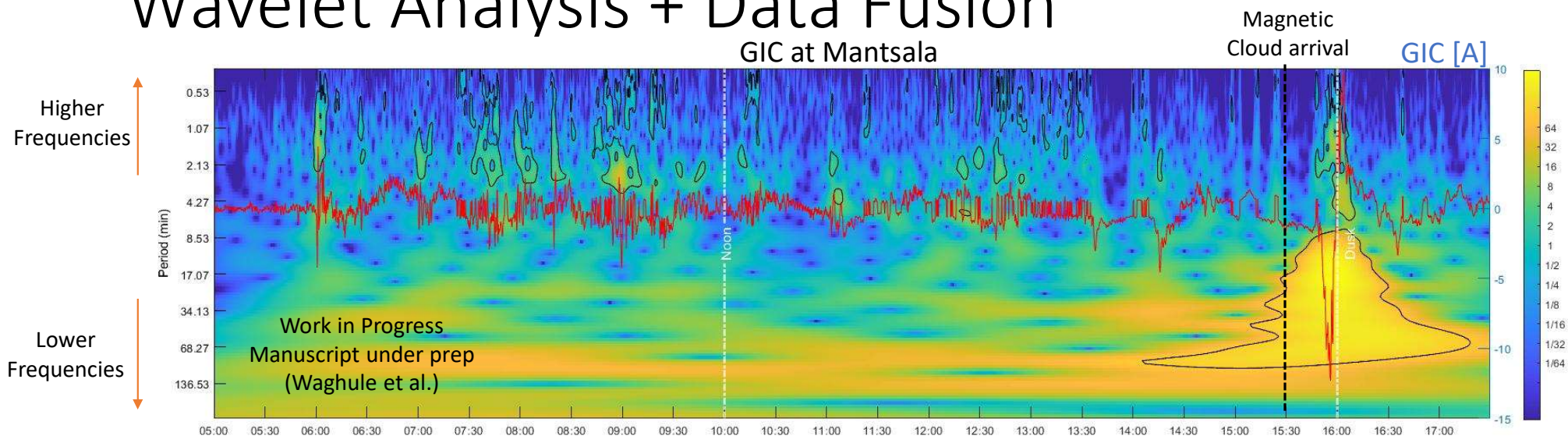


Waghule et al. (AGU 2023)

[https://en.wikipedia.org/wiki/Continuous\\_wavelet\\_transform](https://en.wikipedia.org/wiki/Continuous_wavelet_transform)



# Wavelet Analysis + Data Fusion



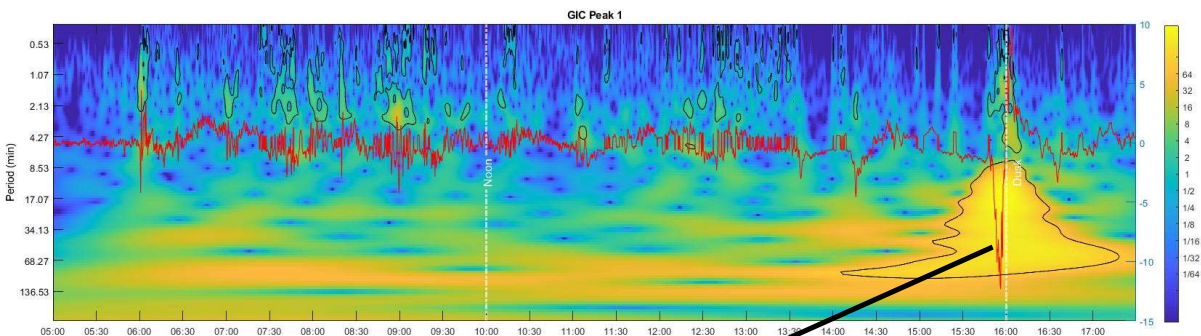
- Continuous Wavelet Transform (CWT)

- Blue to yellow – low to high wavelet power -> Shows localized time-frequency oscillations.
- Highlighted yellow area shows time-frequency oscillations above background red noise. (Torrence and Compo, 2004)

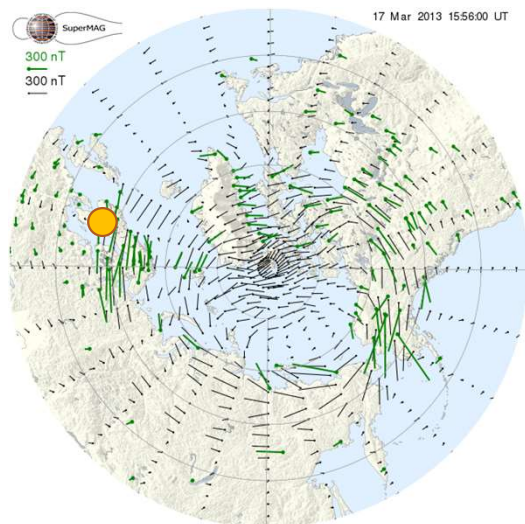
- Multi-minute periodicities centered at 16 UT

- Rapid fluctuations superposed on a longer lasting disturbance
- Ground-up approach - Other observations in ascending order of altitude

# Wavelet Analysis + Data Fusion



Ground



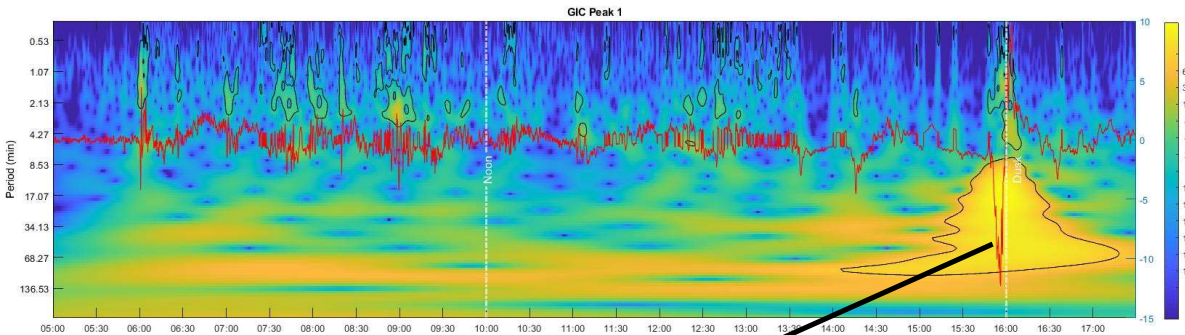
Work in Progress

Electrojet (E-Region)

## SuperMAG

- Electrojets affect ground magnetic field and GICs
- Strong extended Westward Electrojet (wEJ)
- Strong localized Eastward Electrojet (eEJ)
- Mantsala sitting equatorward of the eEJ under a vortex

# Wavelet Analysis + Data Fusion

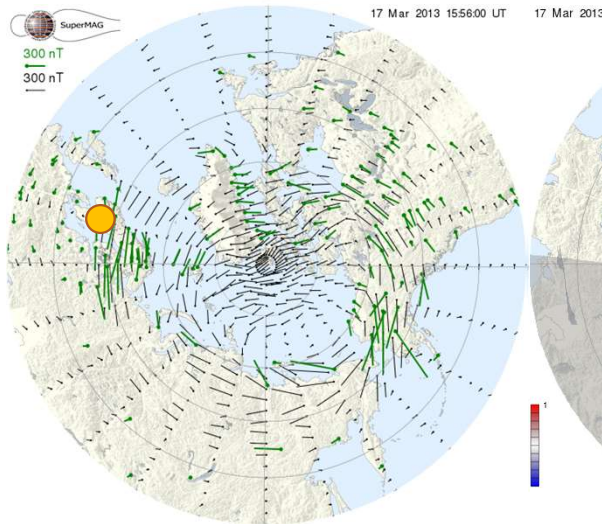


## AMPERE and DMSP SSUSI

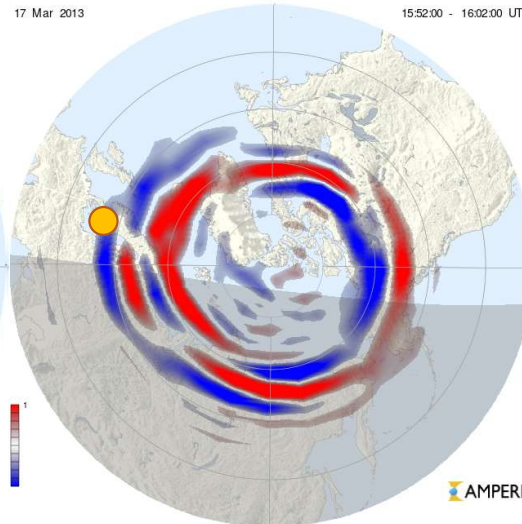
- Field Aligned Currents (FAC) alter electrojets
- Red upward FAC, Blue downward FAC
- FAC Couplet (alternating red and blue) at dusk
- Collocated enhanced particle precipitation

Ground

b)

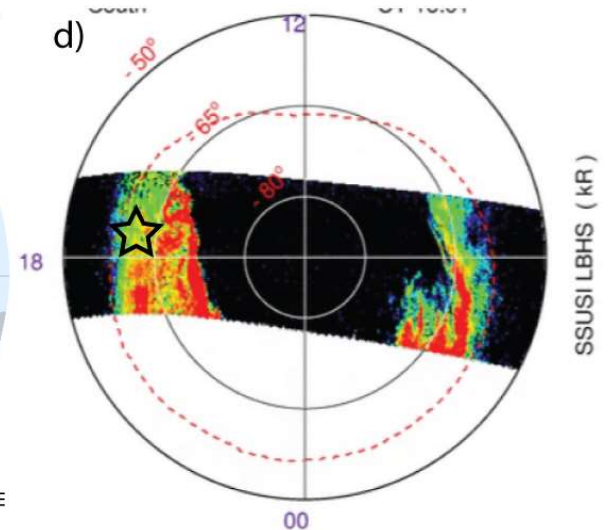


Electrojet (E-Region)



M-I Coupling (700-800 km)

d)

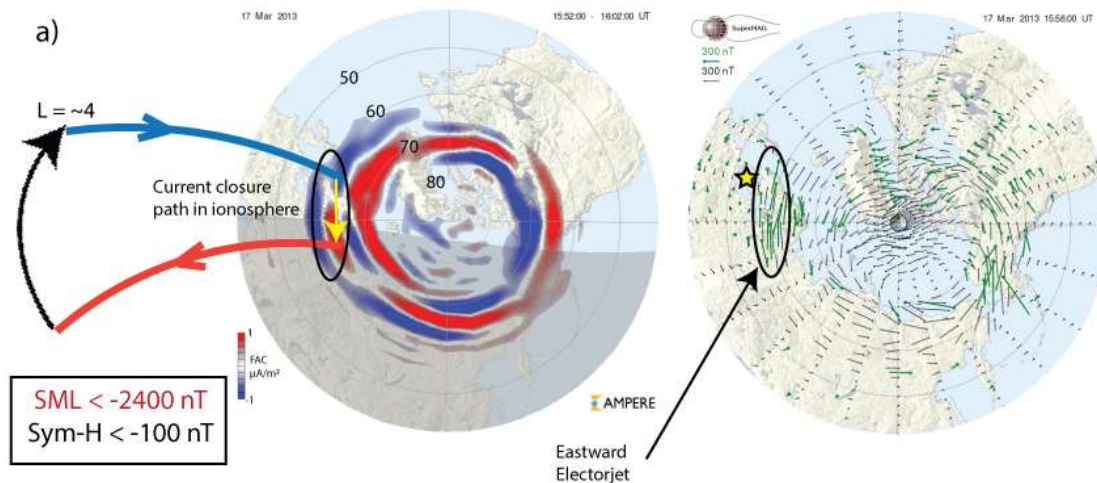


Work in Progress



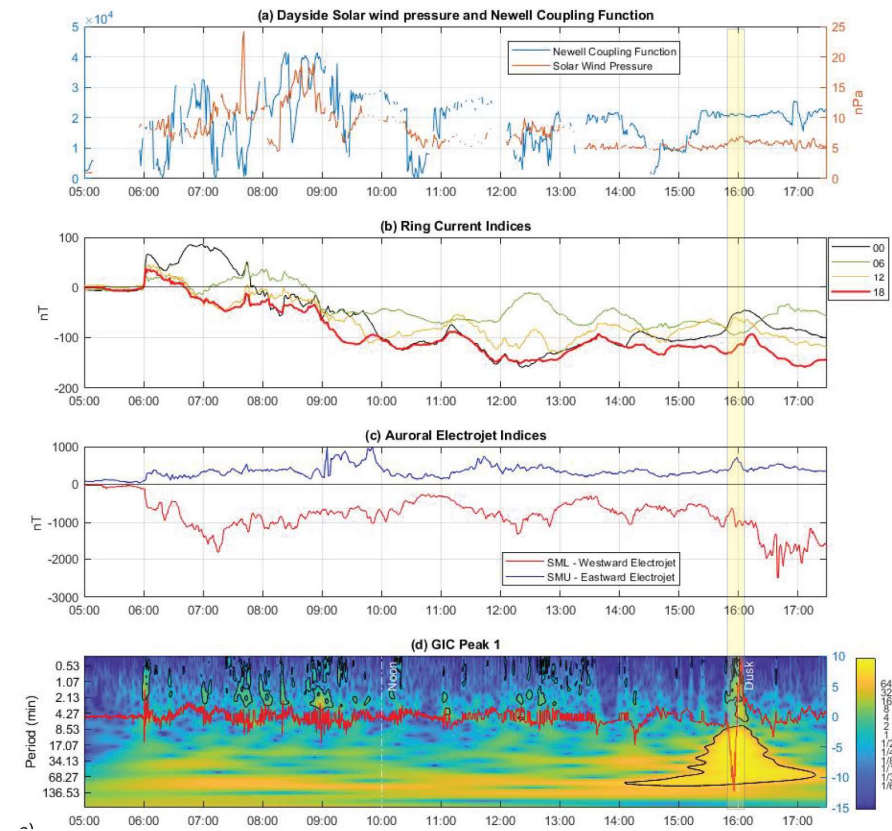
# Interpretation of Data Fusion

## GIC Peak 1 - 15:56 UT Primary Driver - SuperSubstorm



High amplitude GIC occurs over 20 mins during which...

- Was also noted at VKH Transformer Station in Kola Peninsula
- High magnetic flux input to the magnetosphere
- Ring Current at dusk side decreases in magnitude
- Eastward Auroral electrojet shows a 300 nT enhancement before supersubstorm



Waghule et al. (AGU 2023)

# Summary

- The line of investigation which began with wavelet analysis of GIC, led us to find multi-minute periodicities during the spike at 16 UT.
- We found that this GIC spike occurred during a Supersubstorm onset.
- With increasing number of observations this approach can be useful for GIC impact prediction.
- Work in progress – Manuscript under preparation.
- Future work:
  - Cause of the other 3 GICs between 18-19 UT
  - Hemispheric asymmetry
  - Similar investigation of other storms

# Thank you!

Open to discussing after the session if interested...

Questions?

Please reach out to

[bhagyashree.Waghule@colorado.edu](mailto:bhagyashree.Waghule@colorado.edu)