



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

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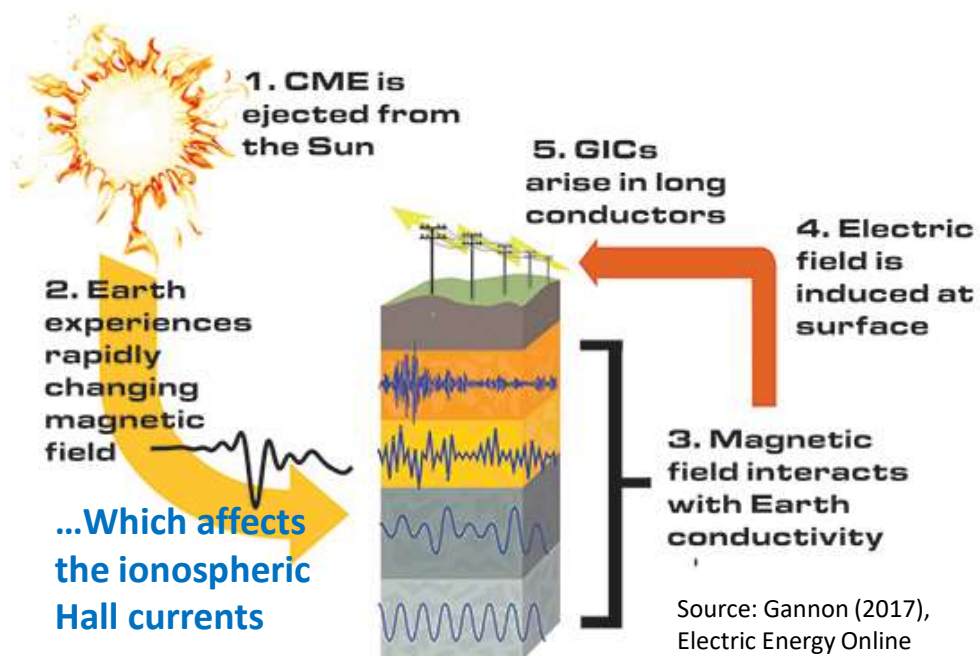
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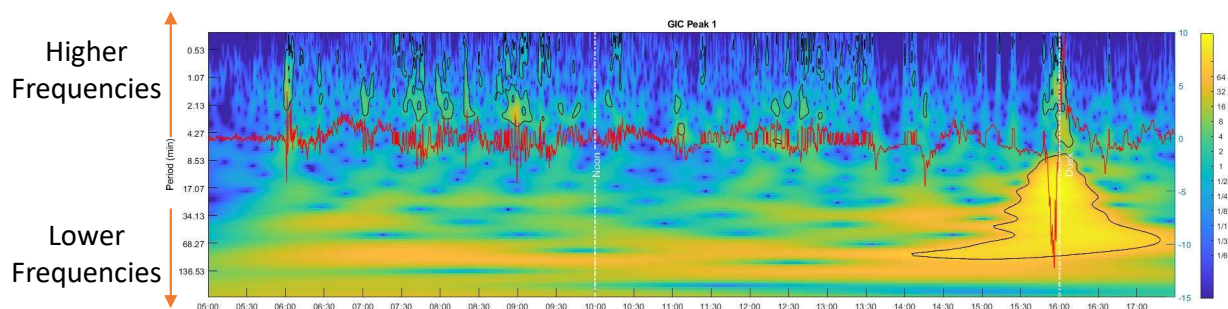


December 14, 2023

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

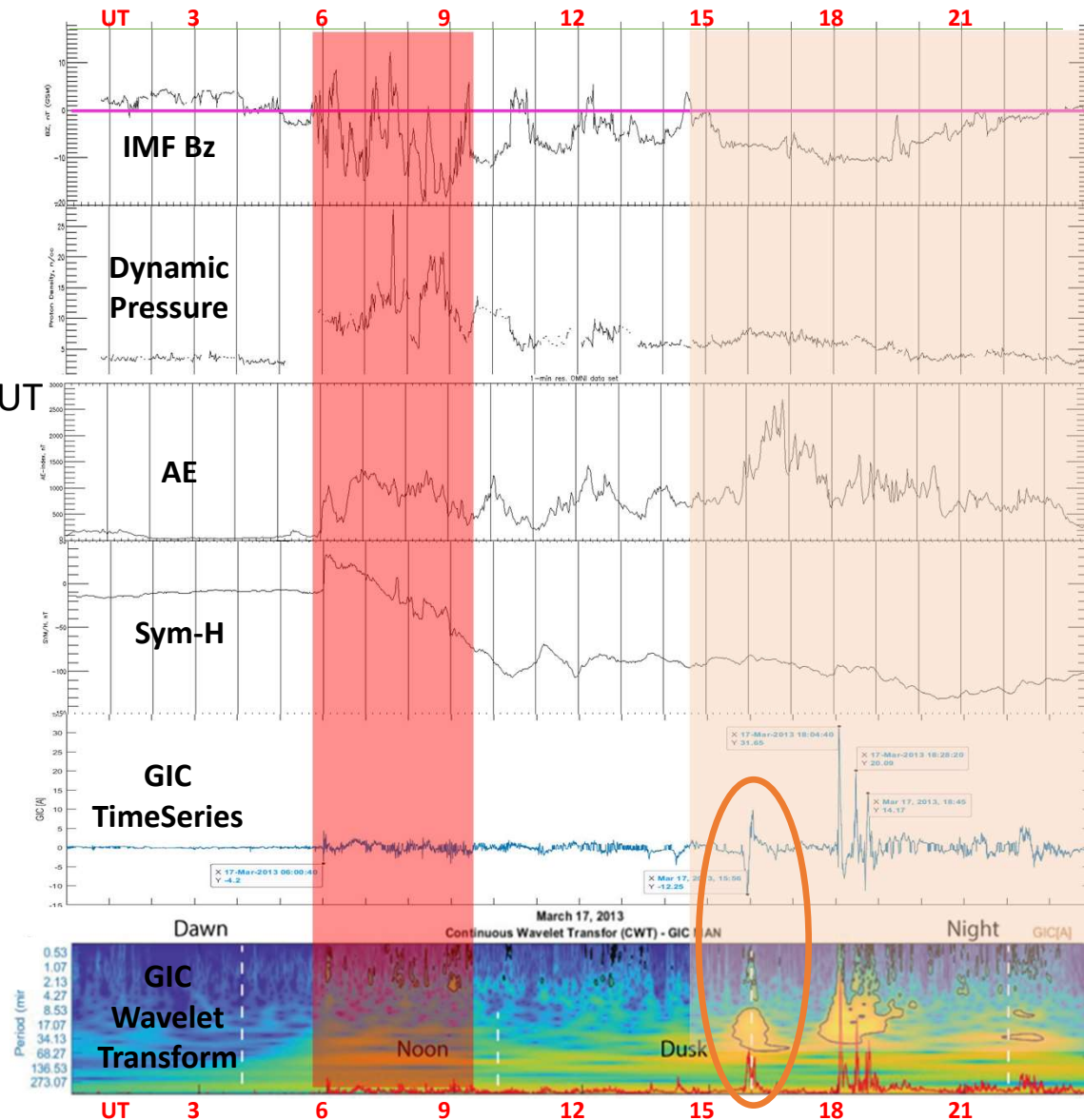
Dayside

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

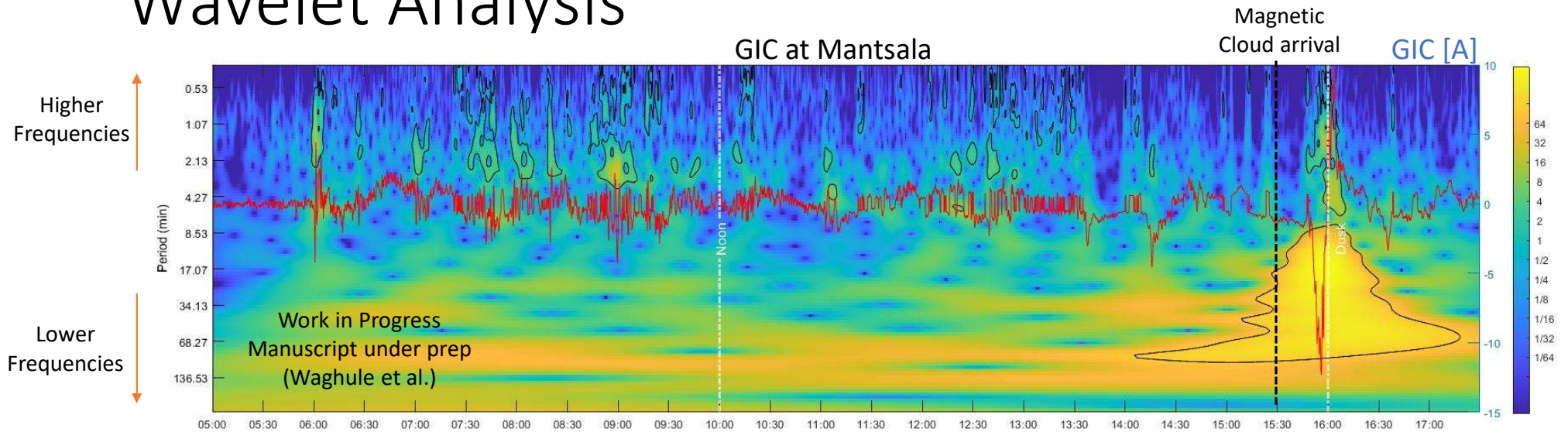
Nightside

- 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

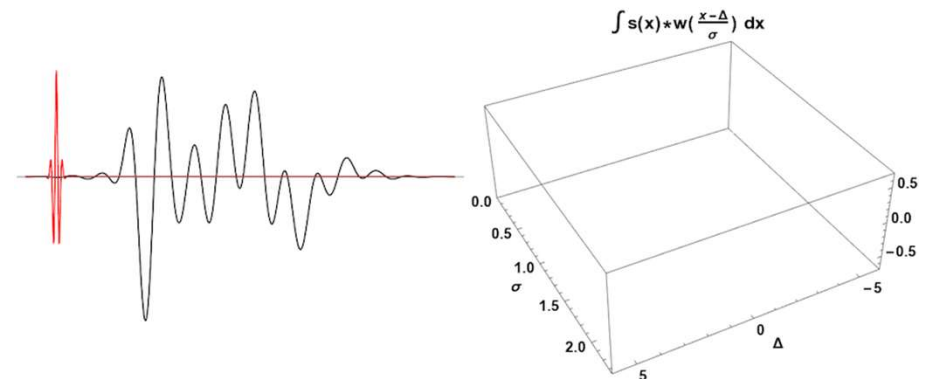


Wavelet Analysis



• Continuous Wavelet Transform (CWT)

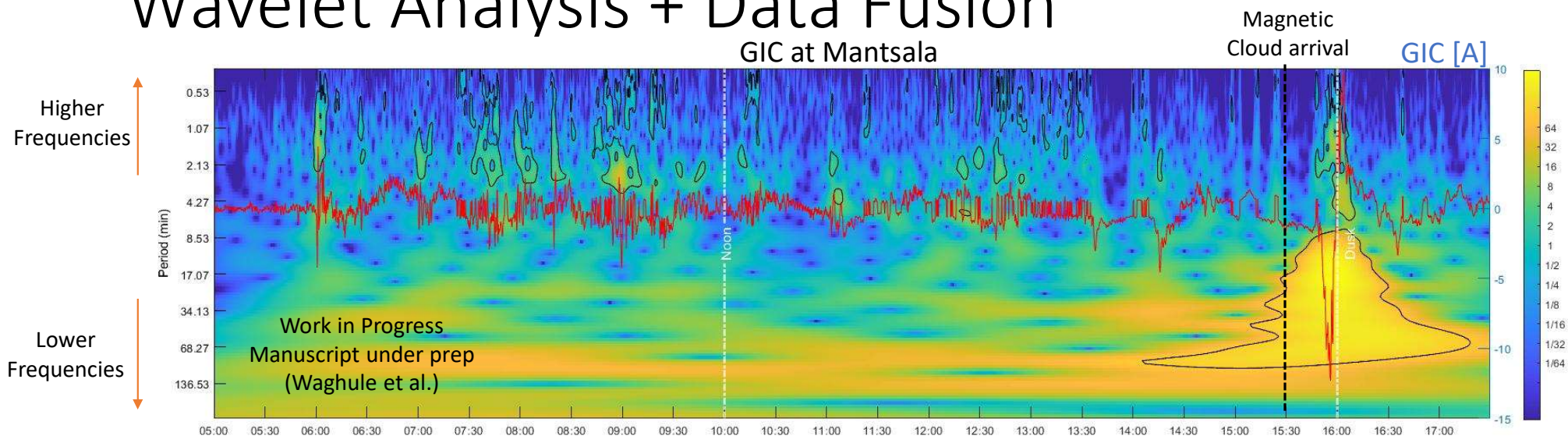
- Blue to yellow – low to high wavelet power -> Shows localized time-frequency oscillations.
- Highlighted yellow area shows time-frequency oscillations above background red noise. (Torrence and Compo, 2004)



Waghule et al. (AGU 2023)

https://en.wikipedia.org/wiki/Continuous_wavelet_transform

Wavelet Analysis + Data Fusion



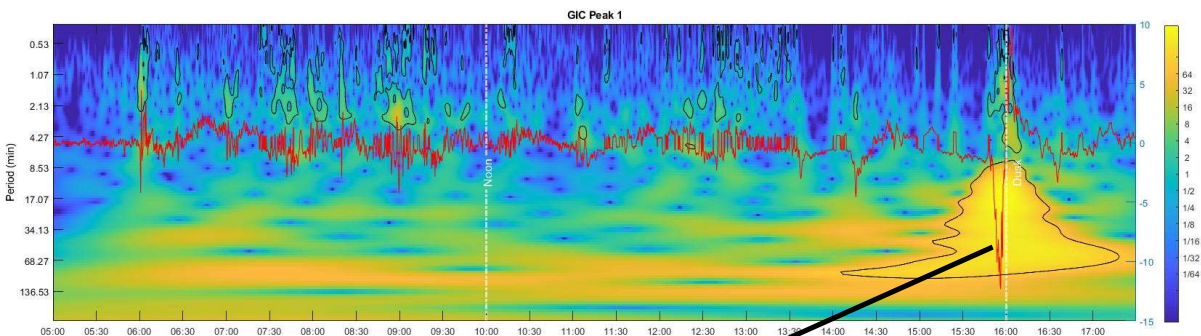
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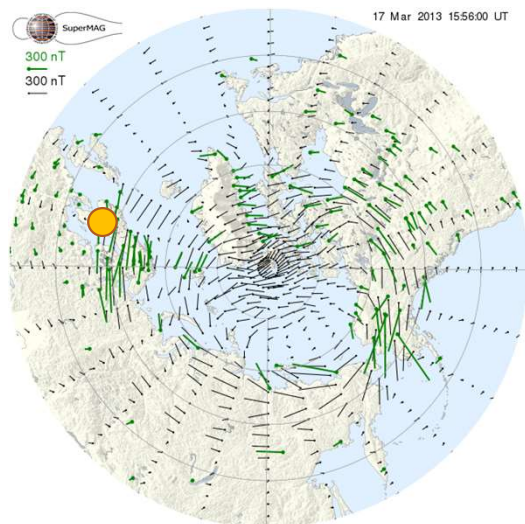
- Multi-minute periodicities centered at 16 UT

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

Wavelet Analysis + Data Fusion



Ground



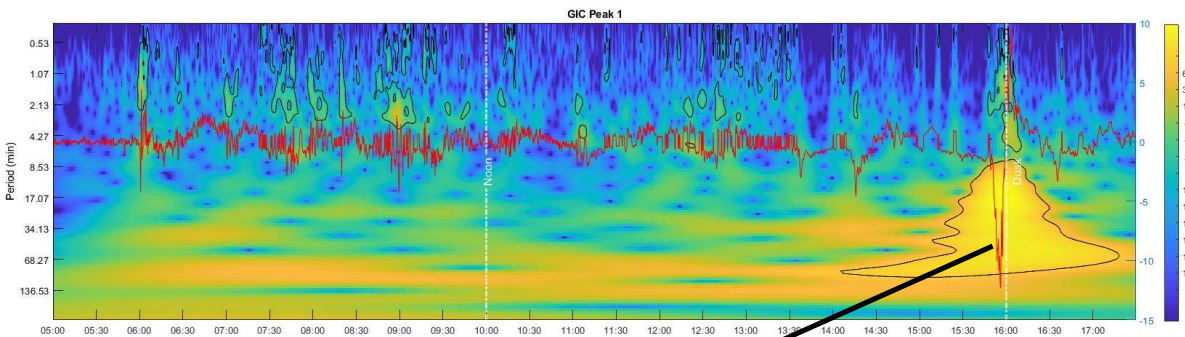
Electrojet (E-Region)

Work in Progress

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

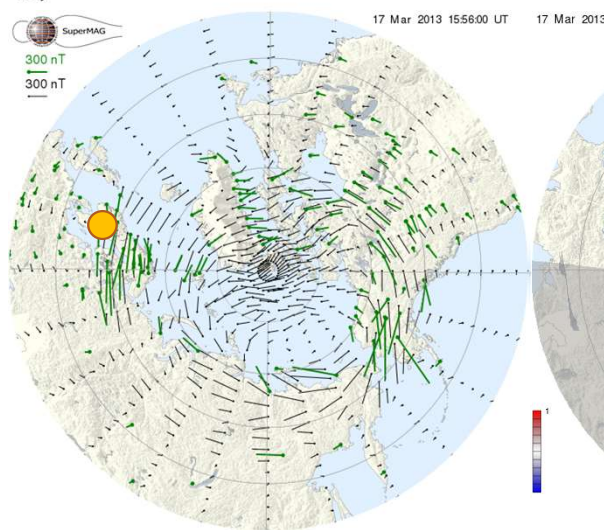


AMPERE and DMSP SSUSI

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

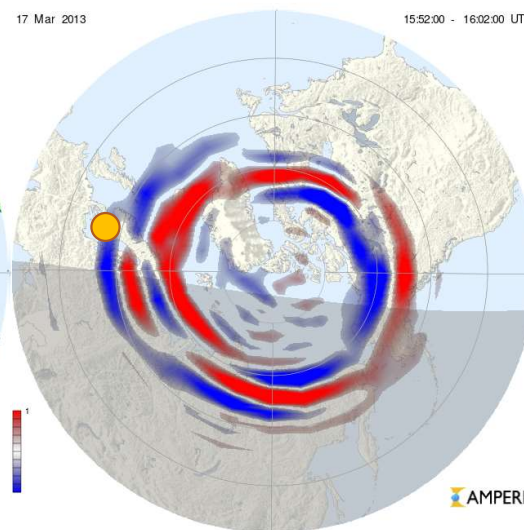
Ground

b)

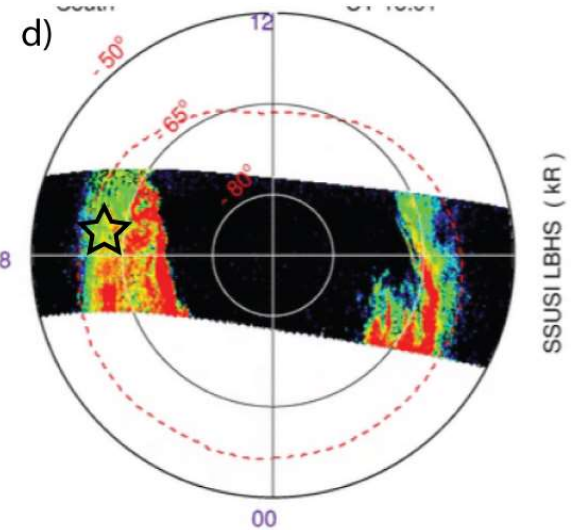


Work in Progress

Electrojet (E-Region)

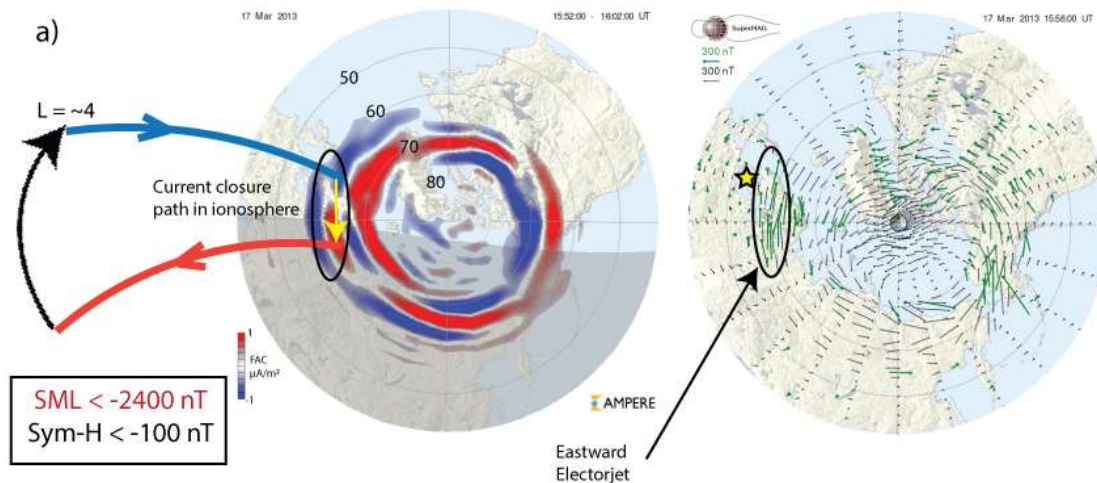


M-I Coupling (700-800 km)



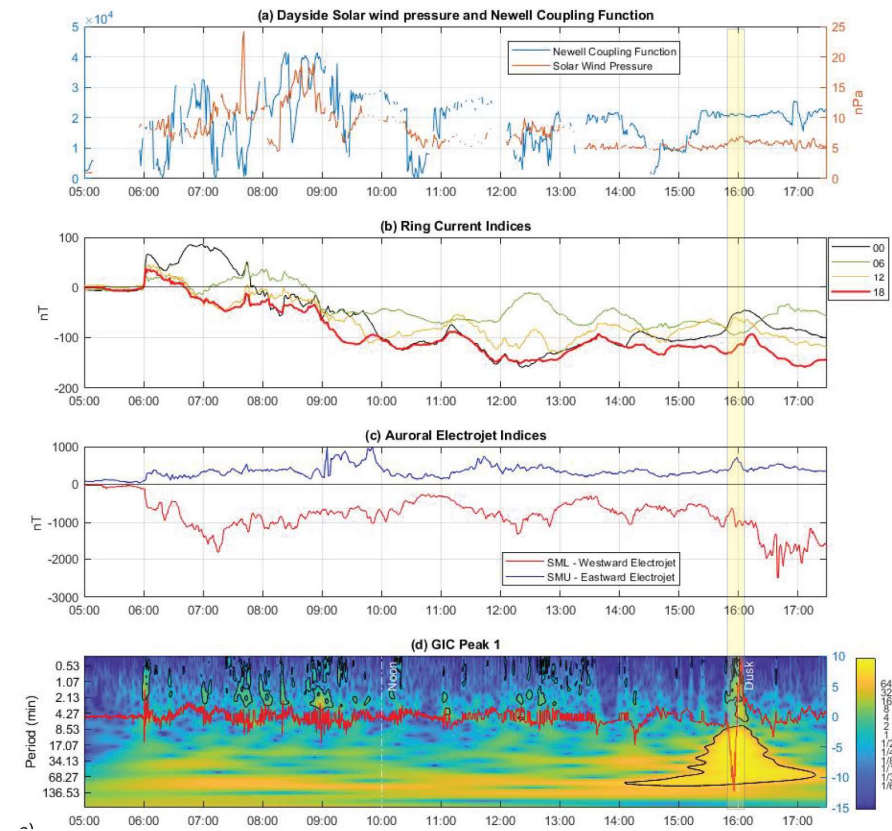
Interpretation of Data Fusion

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



Work in Progress

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

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