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

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

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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

Source: Gannon (2017), Electric Energy Online

Waghule et al. (AGU 2023)
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)

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

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

Electrojet (E-Region)

Work in Progress

Waghule et al. (AGU 2023)
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

Electrojet (E-Region)

M-I Coupling (700-800 km)

Work in Progress
Interpretation of Data Fusion

Interpretation of Data Fusion

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

Waghule et al. (AGU 2023)
Thank you!

Open to discussing after the session if interested...

Questions?
Please reach out to
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