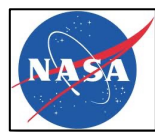


Addressing Space Weather Challenges on technology – Geomagnetically Induced Currents

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EPRI, & David Sibeck



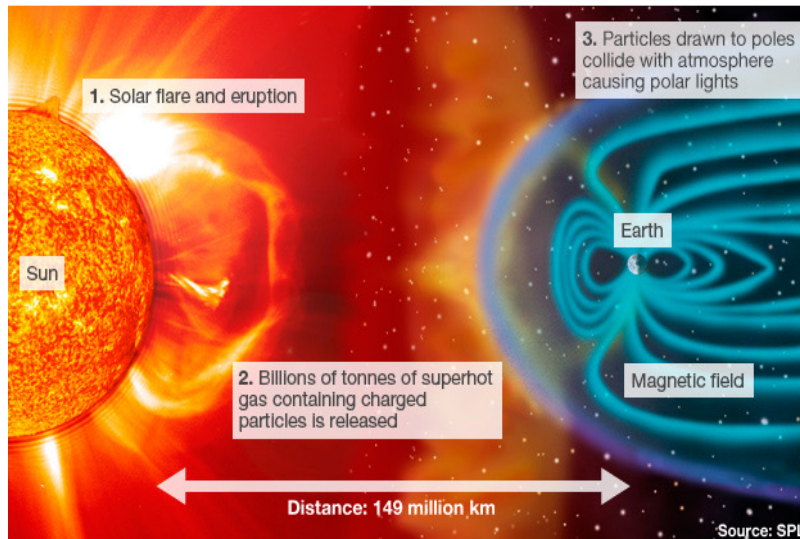
UN Workshop on International Space Weather
Initiative: The Way Forward, June 2023, Vienna, Austria

Content

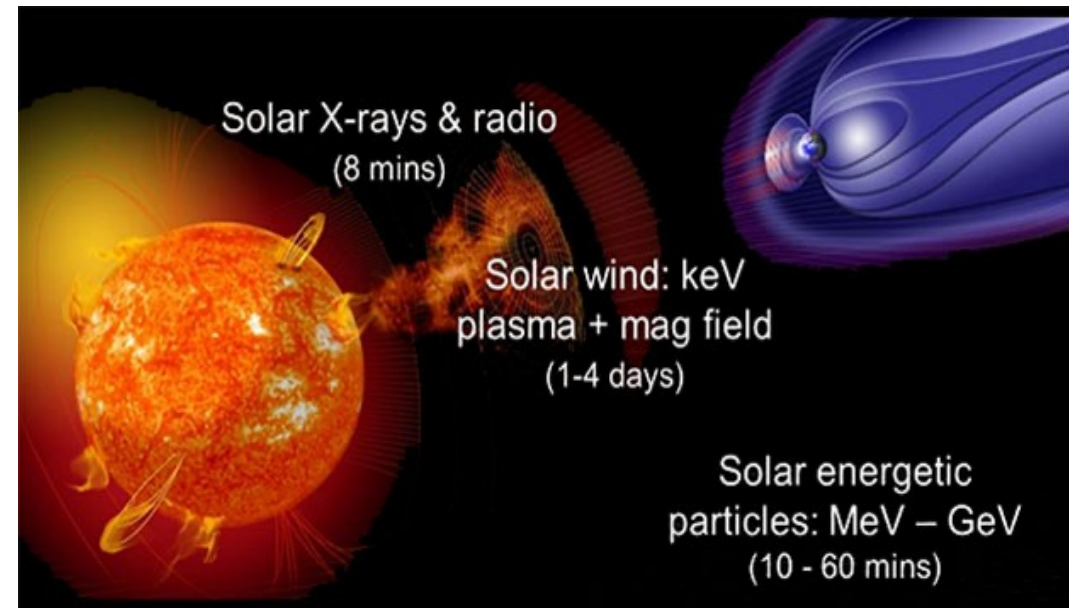
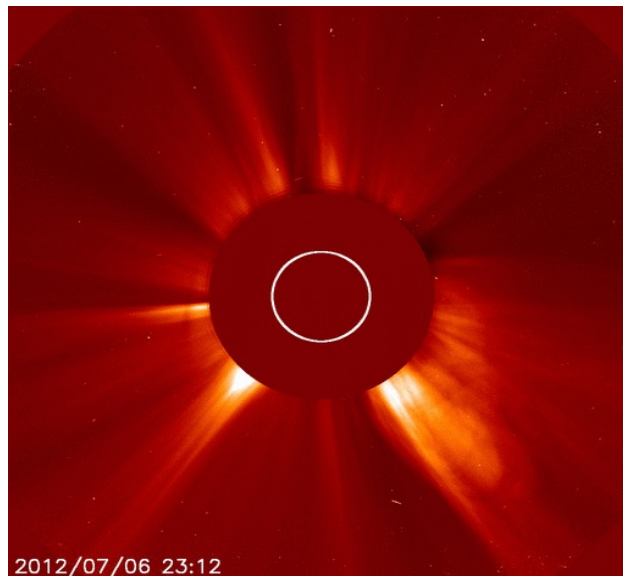
- Introduction
- Geomagnetically Induced Currents
- GIC Distribution and Drivers
 - High latitude
 - Low latitude
 - Mid latitude
- Summary



Space Weather

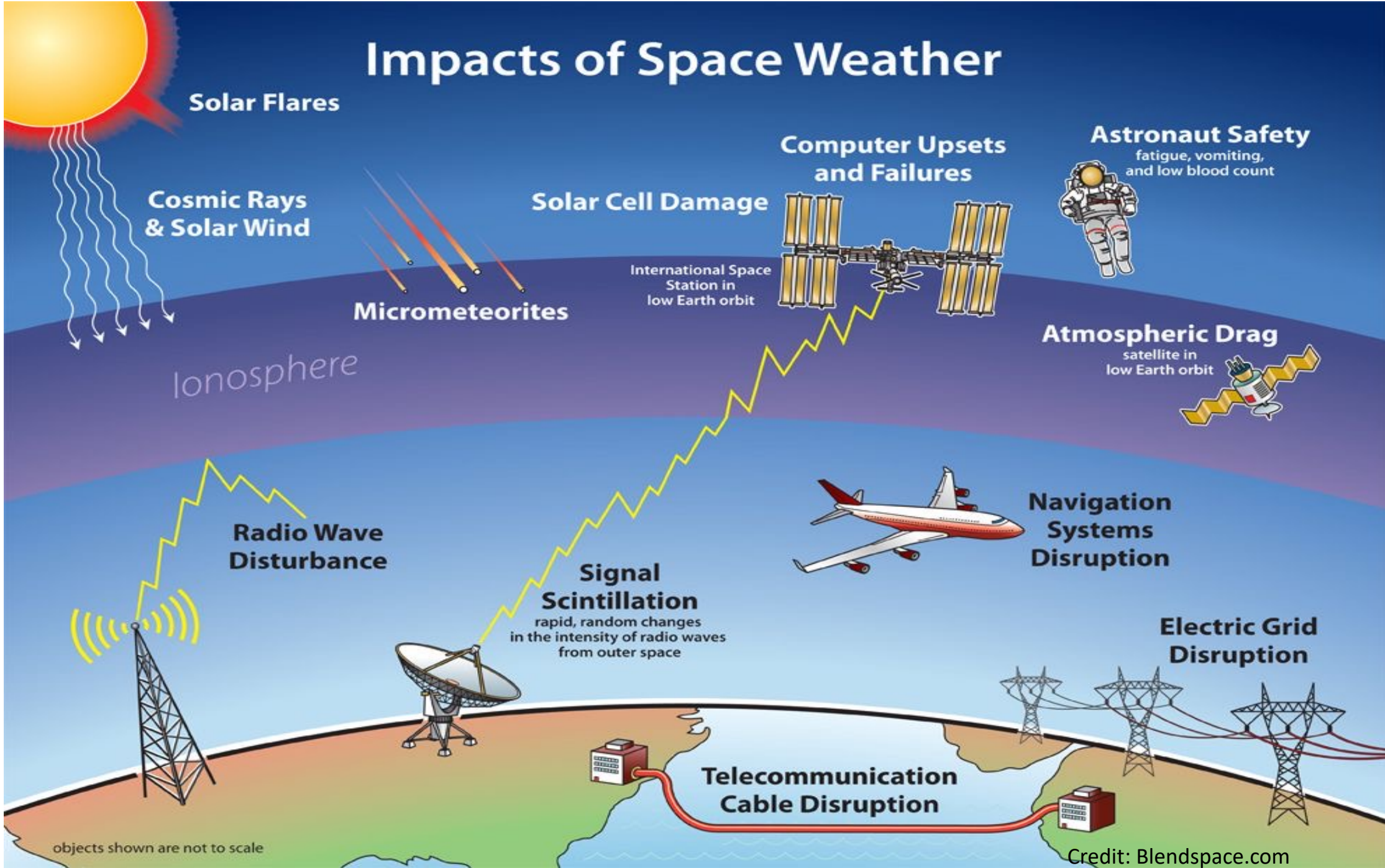


- Space weather is primarily controlled by solar activity.
- Which include, solar flares, SEPs and CMEs etc.
- Solar wind-magnetosphere coupling leads to geomagnetic storms.
- There is a growing concern of potential space weather impact on man-made technologies and national security.

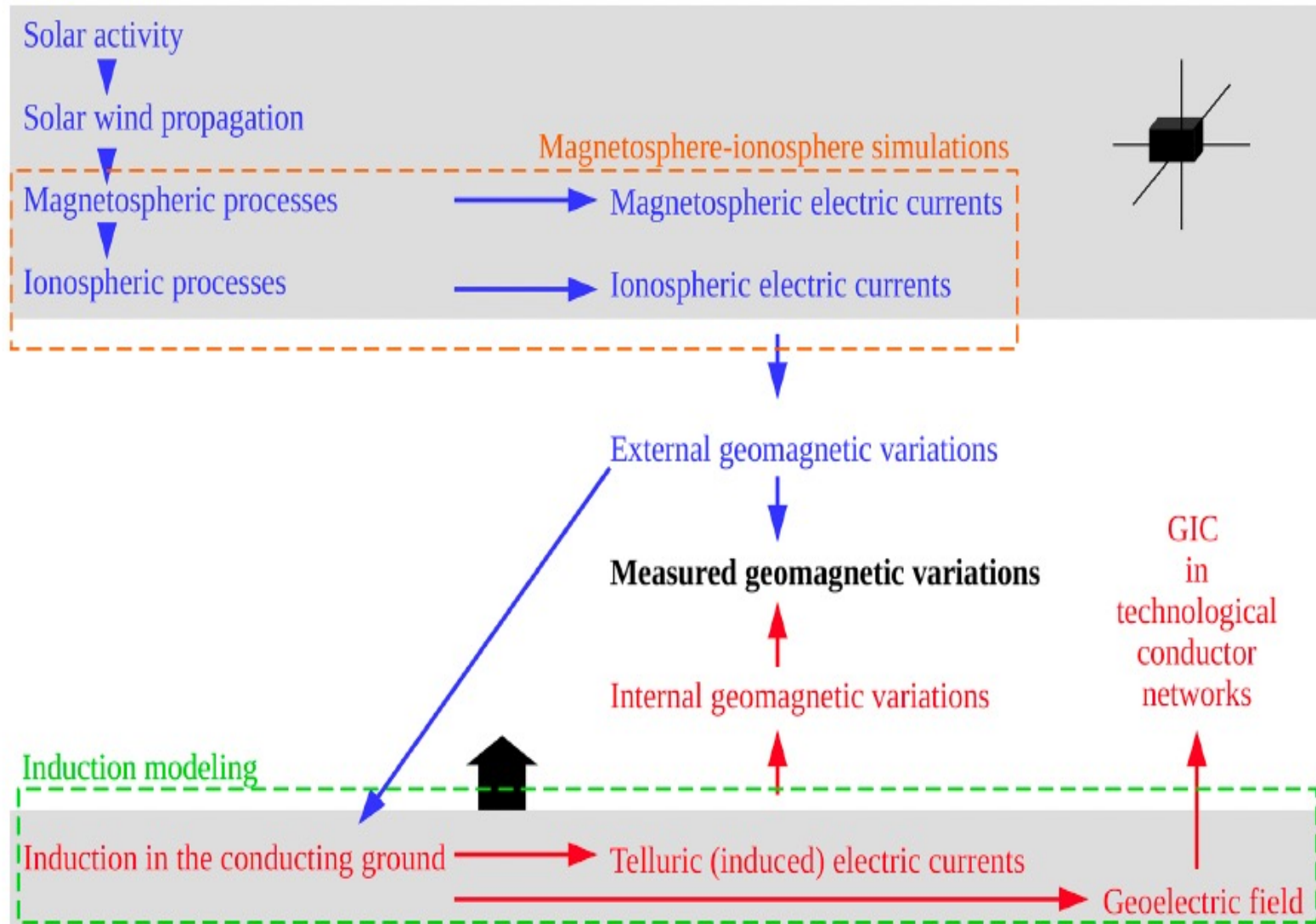


Multi-scales solar phenomenon

Impacts of Space Weather



The GIC Chain: Sun to Mud – [Juusola et al., 2023]



Geomagnetically Induced Currents (GICs)

- Faraday's law:

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

- We use a two-step approach to compute GIC flowing through specific power network node:

- Geophysical step: Modeling geoelectric field based on magnetosphere-ionosphere currents and ground conductivity structure.

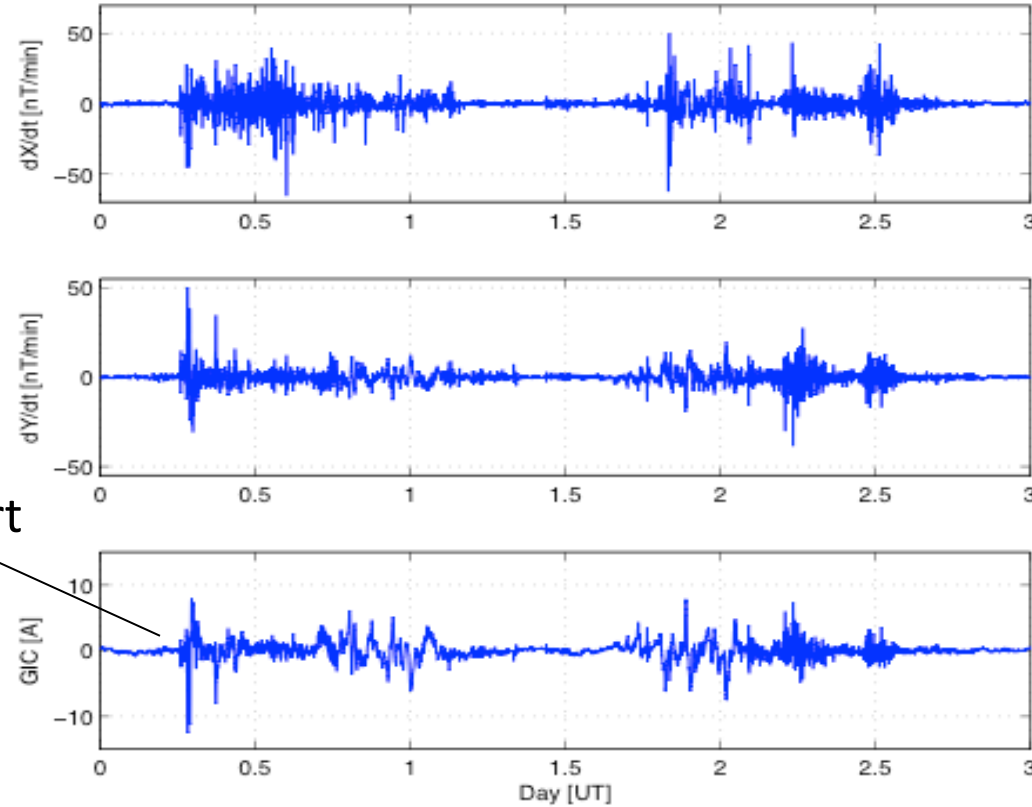
$$E_{y,x} = m \sqrt{\frac{\omega}{\mu\sigma}} e^{\frac{i\pi}{4}} B_{x,y}$$

- Engineering step: Modeling GIC flowing in the power system in response to the determined geoelectric field.

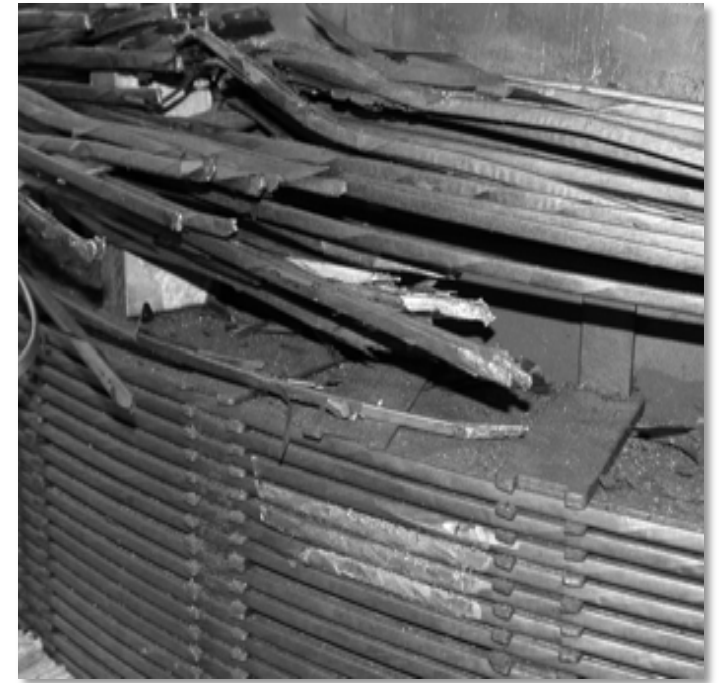
$$GIC = aE_x + bE_y$$

Electric field is the major quantity that determines the level of GIC flowing in power systems.

Sample Time Series: October 29-31, 2003



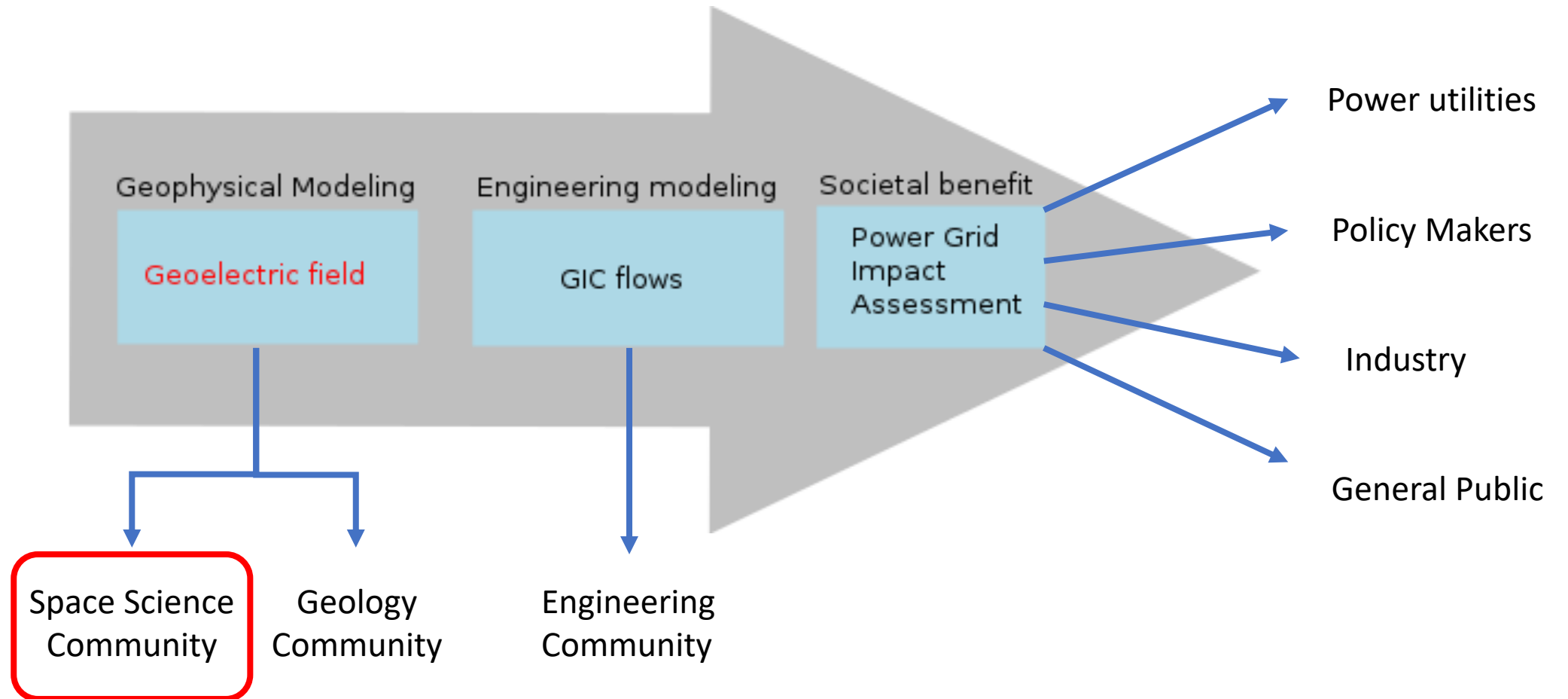
Sudden start



Transformer damage in South Africa

[Ngwira et al., SW, 2009]

Who are the Players



Near-Earth Space Current Systems

- GIC study Domains

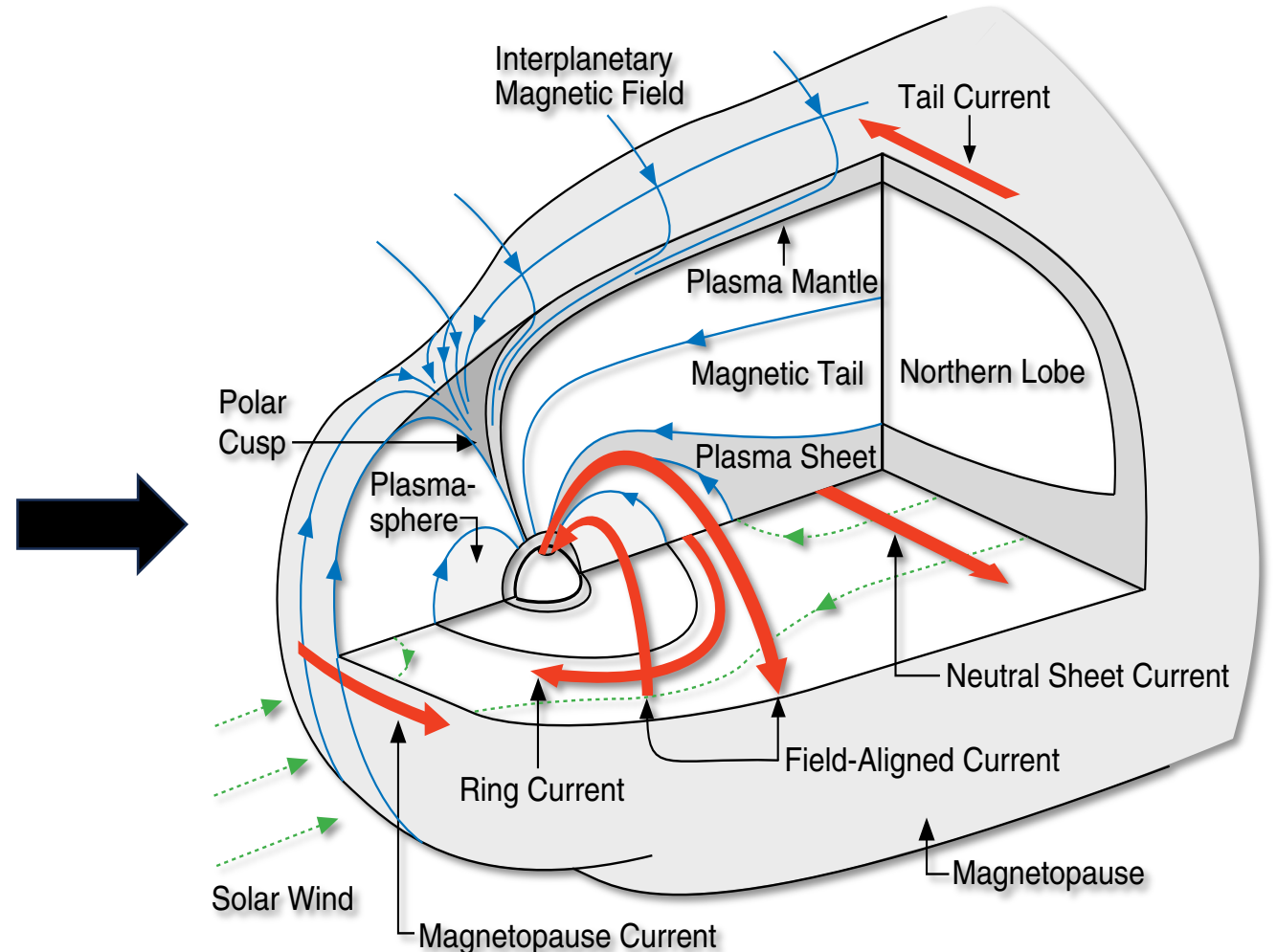
- Data analysis

- Numerical modeling (MHD prominent)

- Machine learning

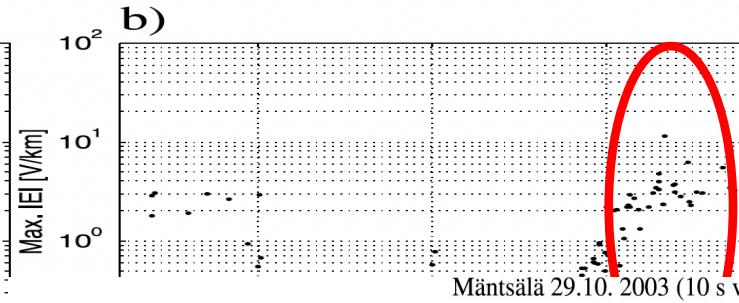
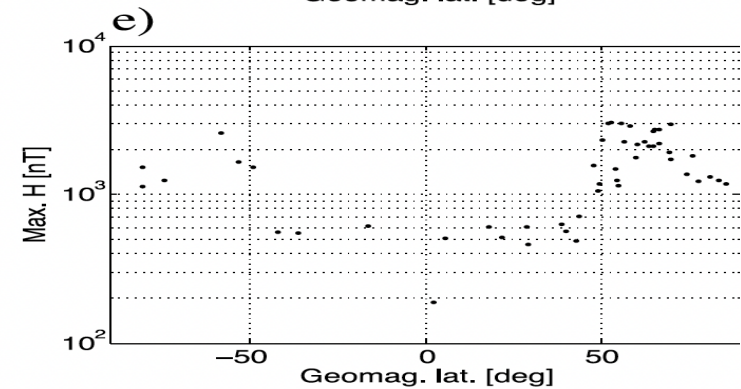
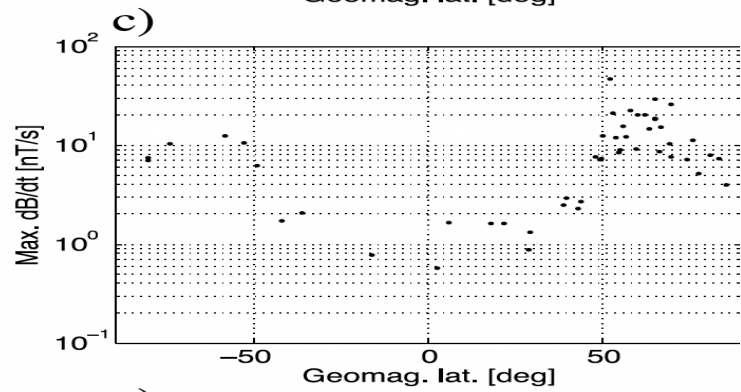
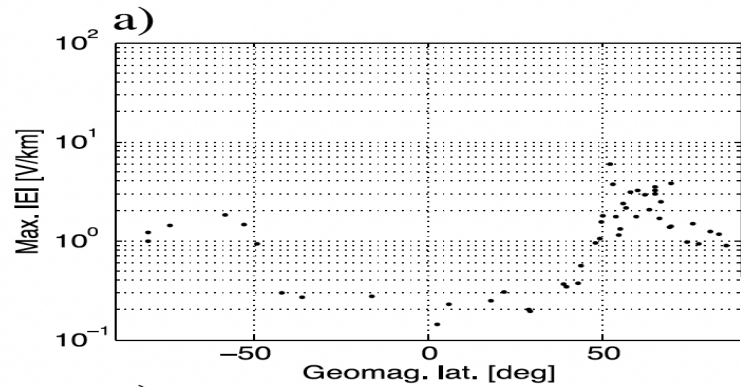
- Compelling breath of physics to cover

- To accurately model ground magnetic perturbations, you need to capture the physics of near-space electric currents systems.



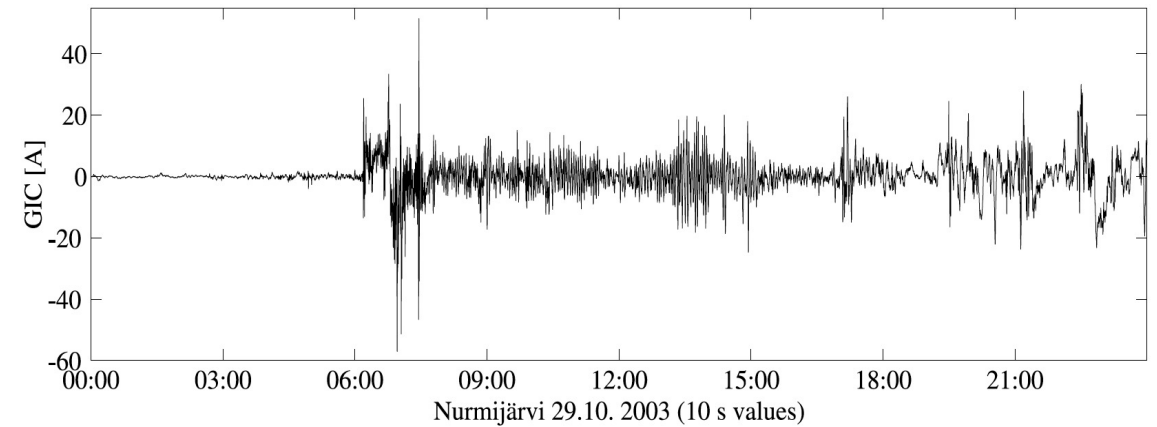
Global Distribution of GICs

[Pulkkinen et al., 2012]

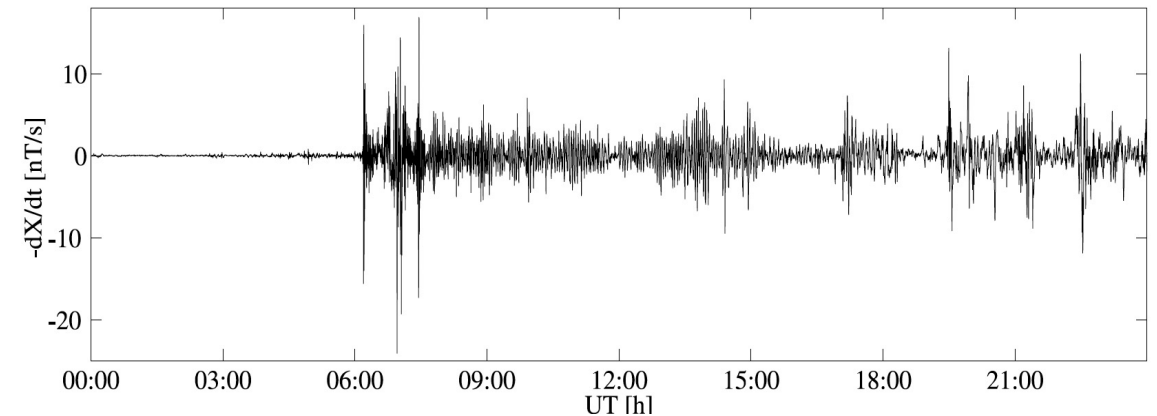


Mäntsälä 29.10. 2003 (10 s values)

High latitudes
Largest GICs

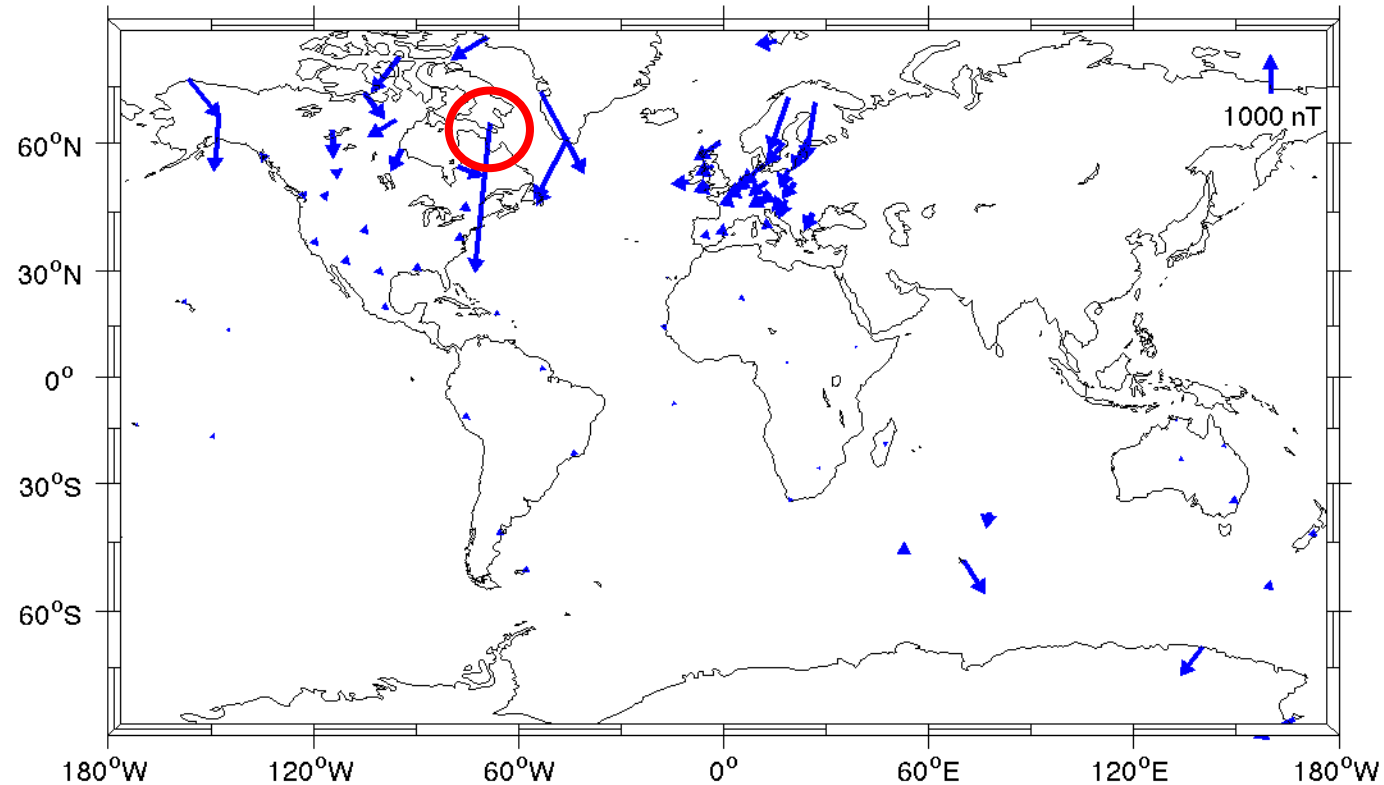


Nurmijärvi 29.10. 2003 (10 s values)



[Pirjola et al., 2005]

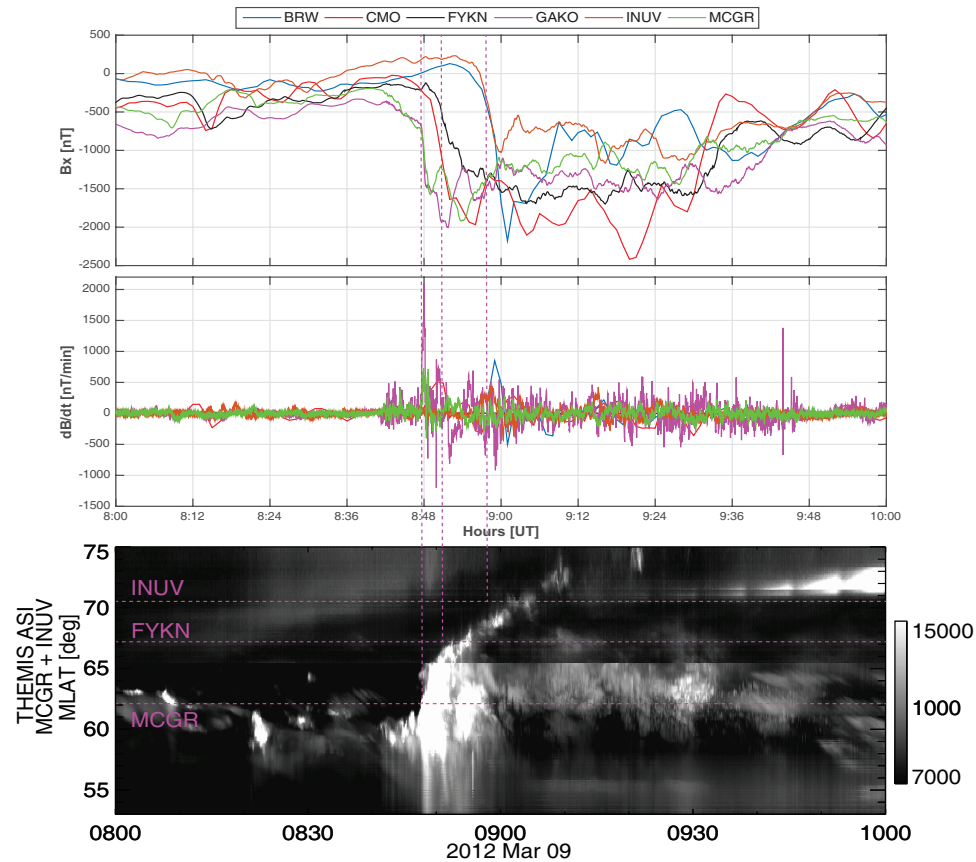
What processes create the small-scale features associated with large peak dB/dt during geomagnetic storms?



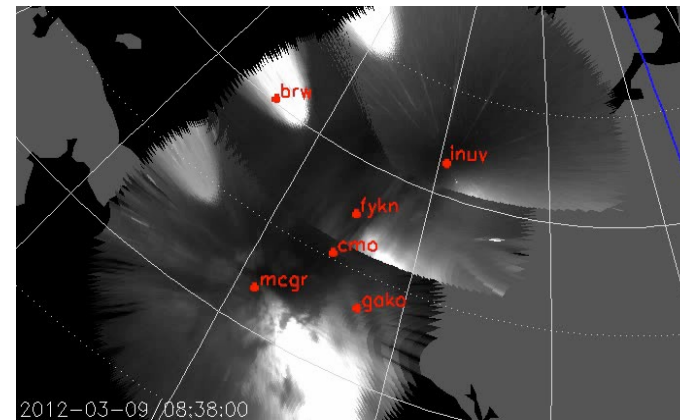
Snapshot of extreme delta-B variations from Halloween 2003 storm

***This is a potential area that will be addressed by upcoming missions like GDC, EZIE, SNIPE, and TRACERS**

Drivers of the Extreme dB/dt Localization

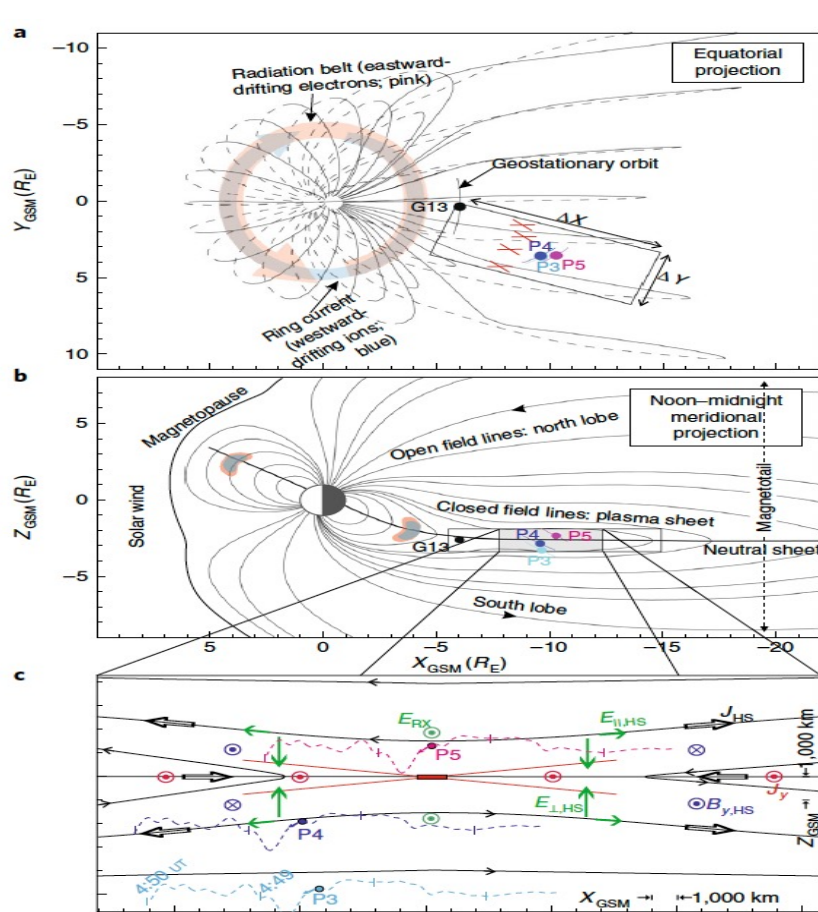


- Comparison between the dB/dt and THEMIS All-Sky Imager (ASI) auroral keograms.
- Intense dB/dt confined to the poleward edge of the poleward-expanding aurora.
- This corresponds to the region of most powerful aurora during a substorm [Weygand et al., 2000].

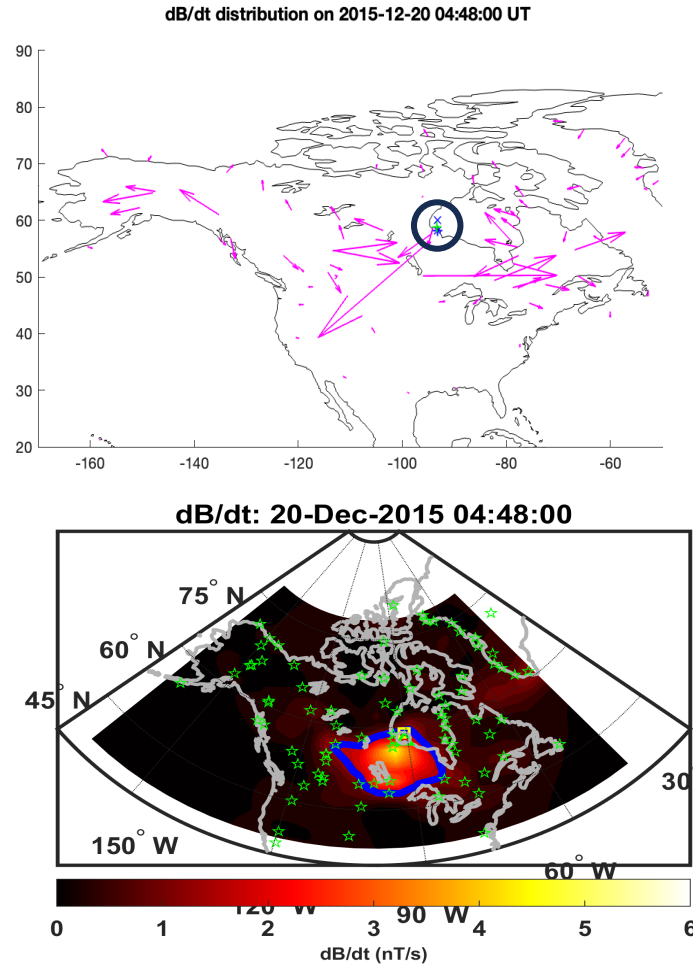


[Ngwira et al., 2018]

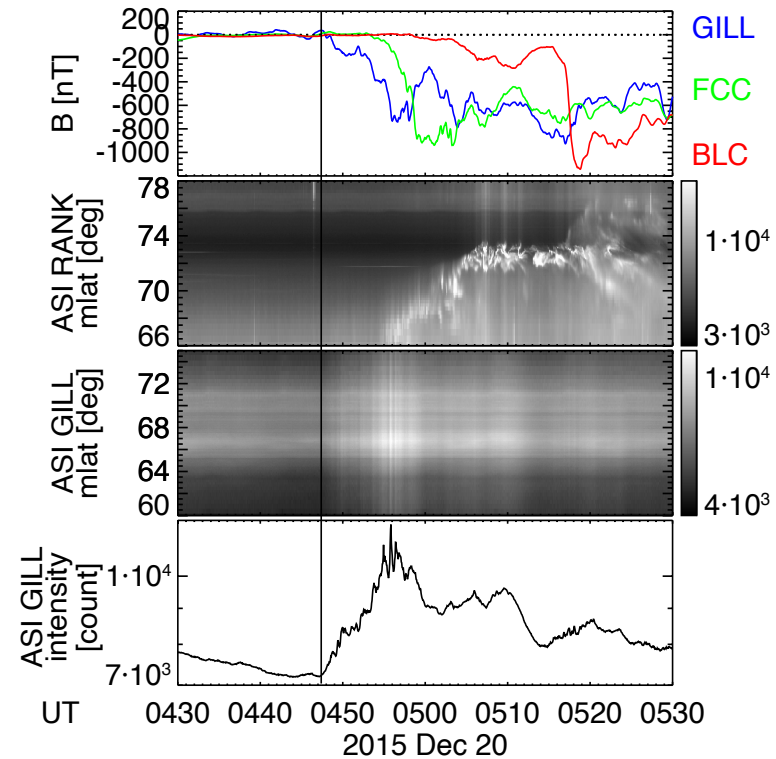
Magnetotail Reconnection Powering Large dB/dt



[Angelopoulos et al., 2020]

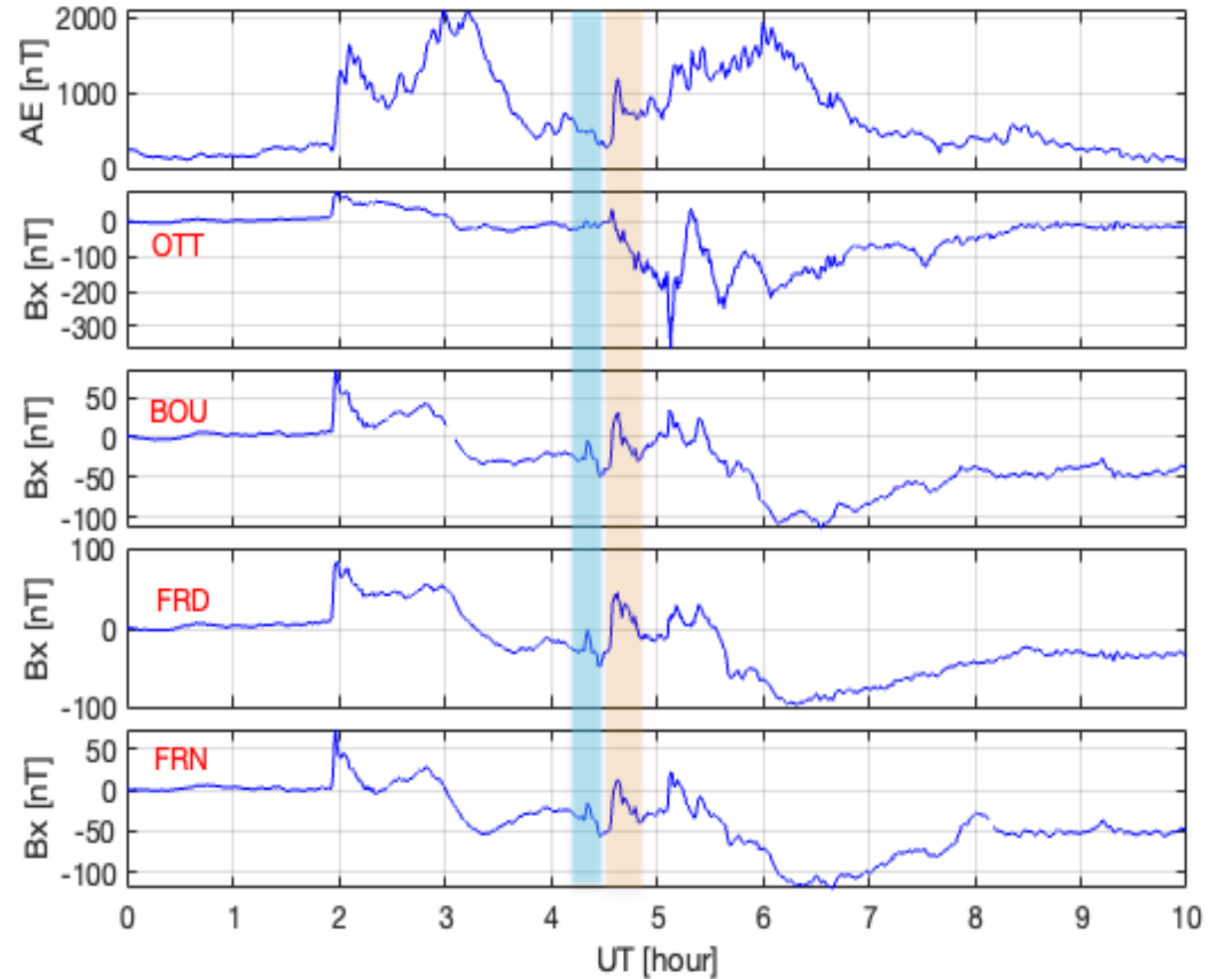
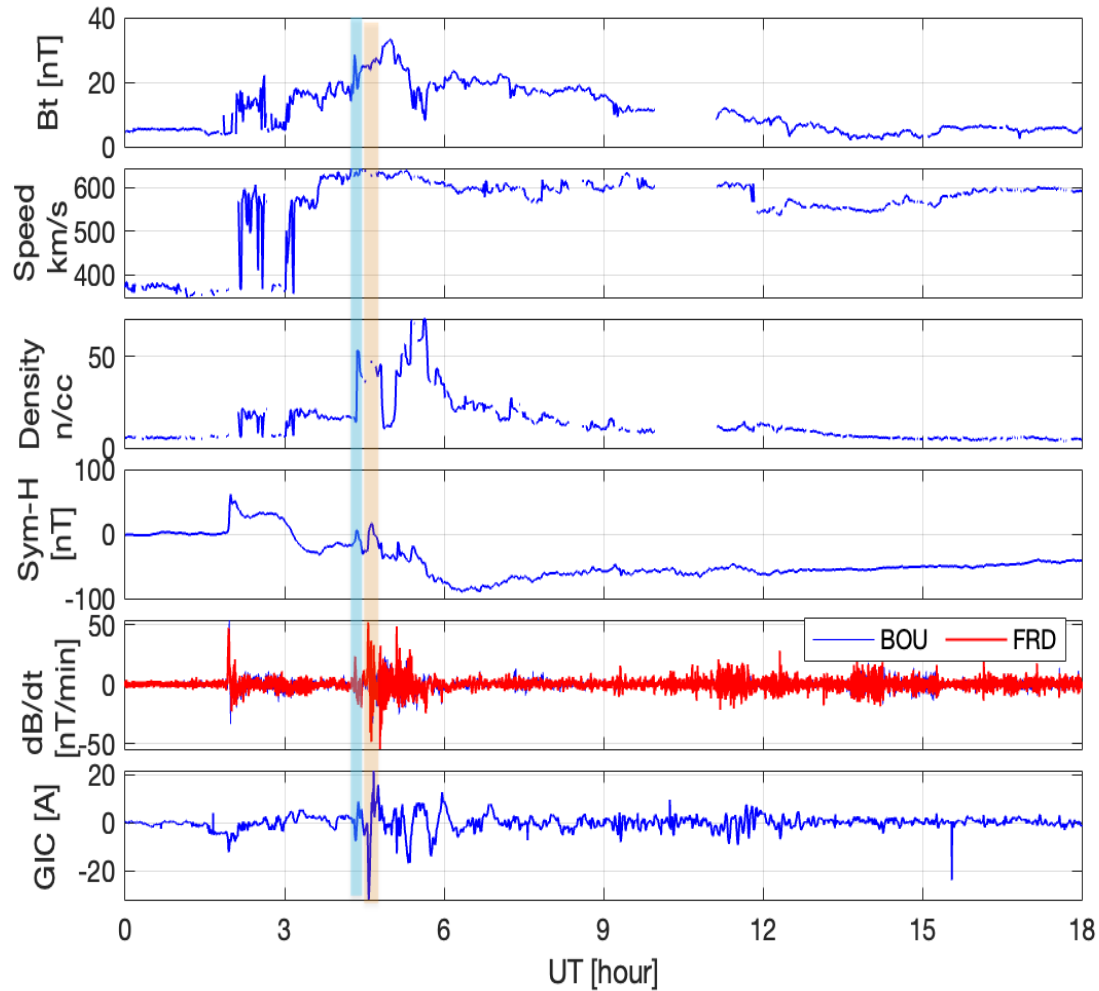


Substorm onset key to the localization



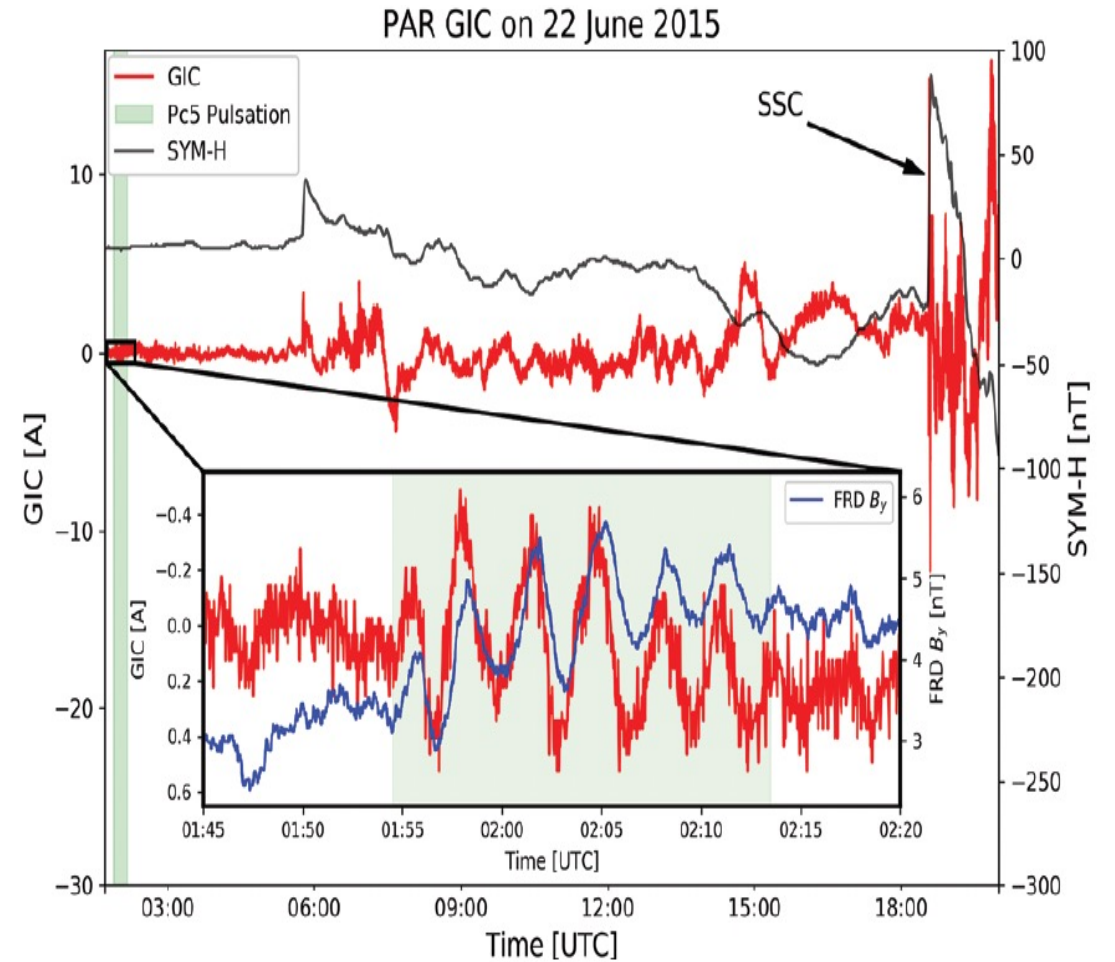
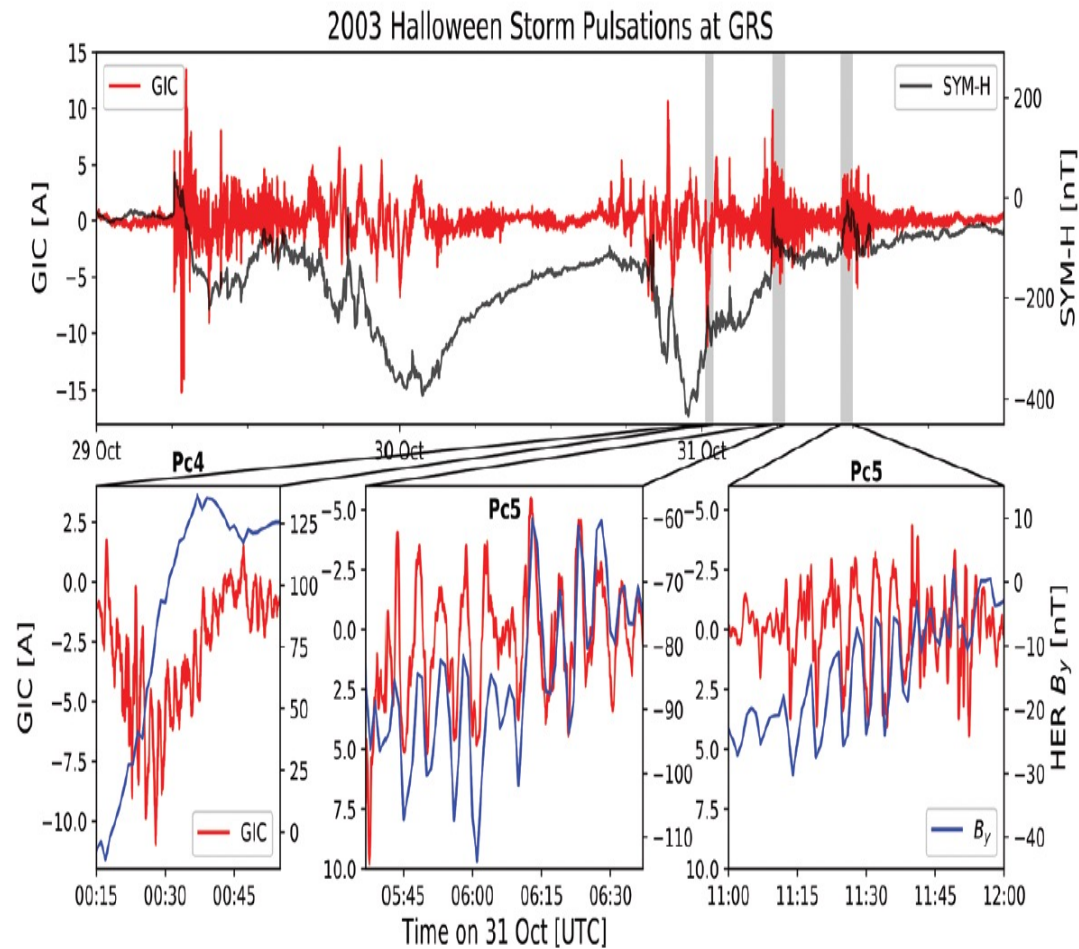
[Ngwira et al., In preparation, 2023]

What about the Mid-latitudes



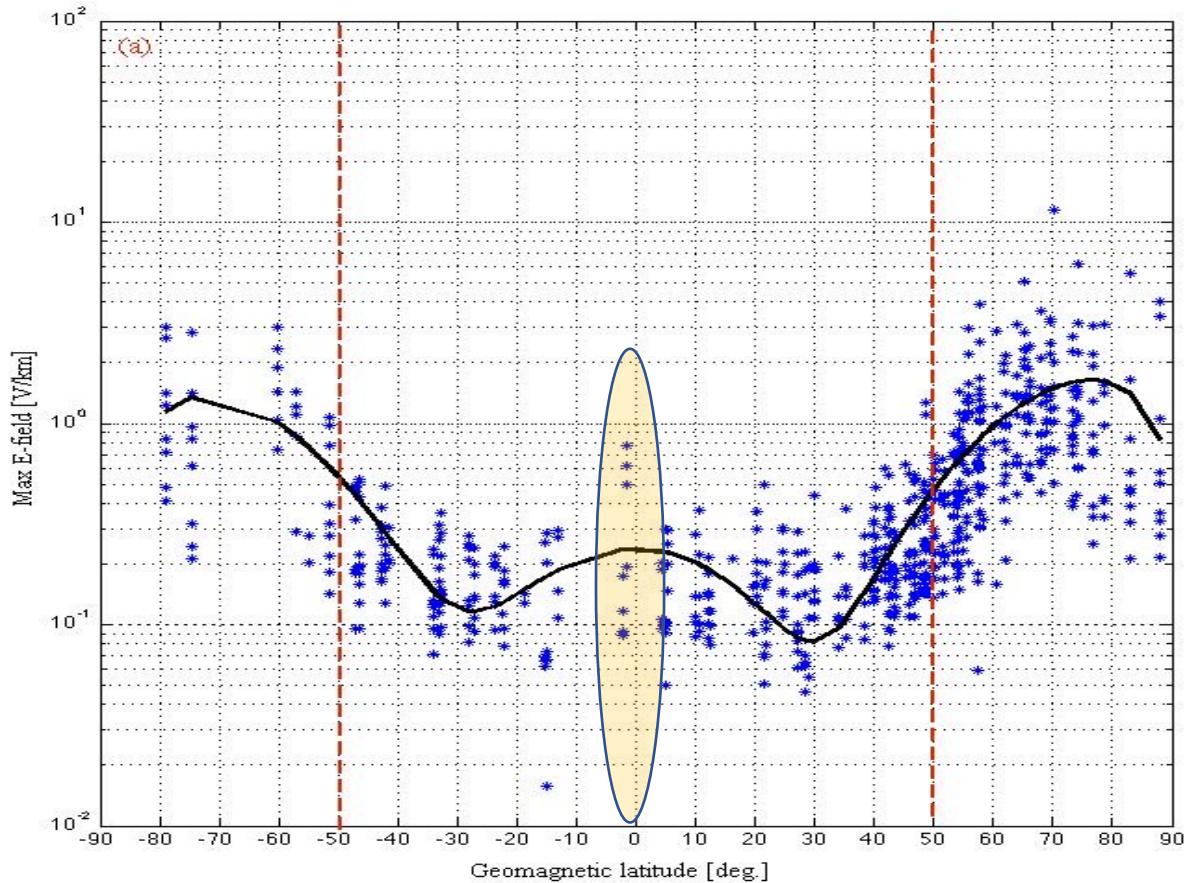
*First direct evidence of mid-latitude positive bay driving large GICs [Ngwira et al., under review, 2023]

Geomagnetic Pulsations Driving GICs

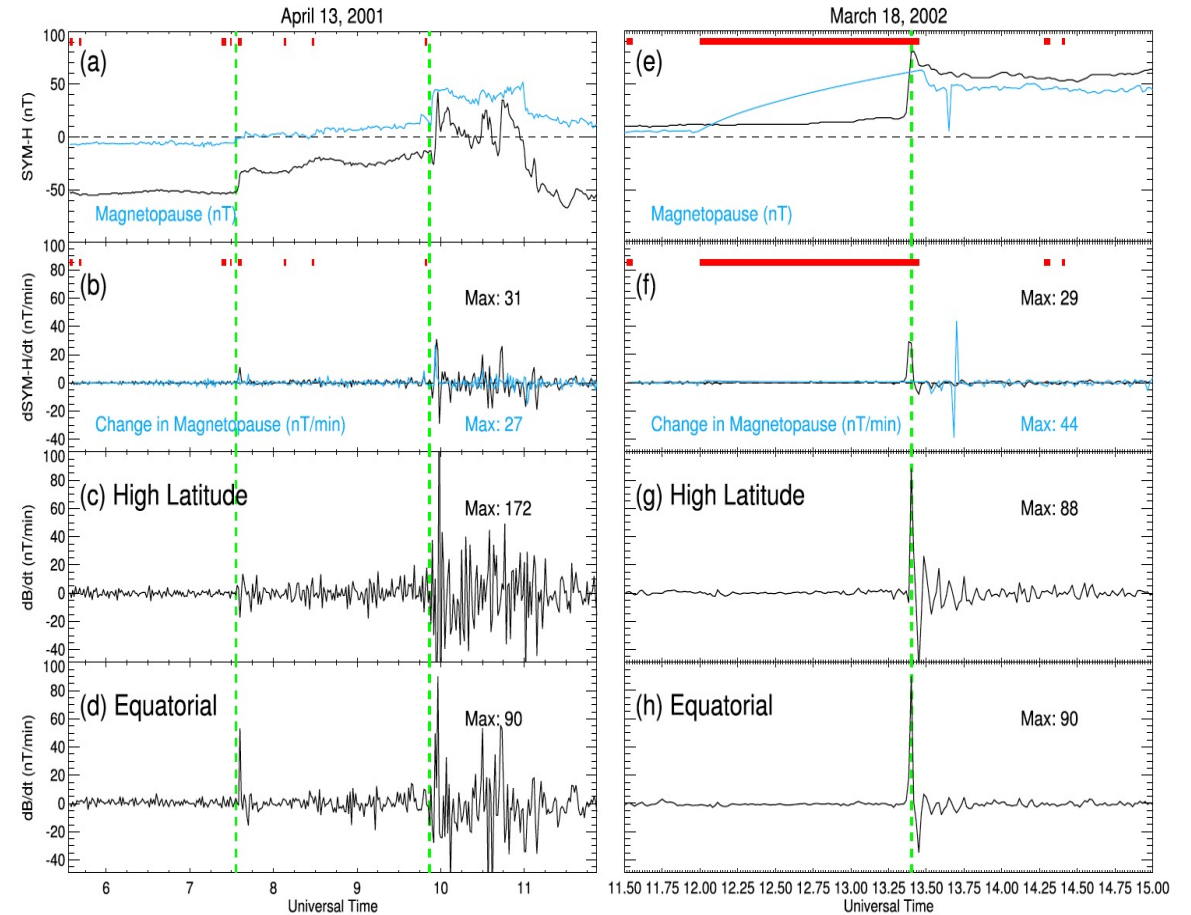


Extended Study of Extreme Events

Amplification by the equatorial electrojet current during Sudden Commencement



[Ngwira et al., SW, 2013]



[Carter et al., 2015]

Summary

- Space Weather is an important part of today's technology dependent society.
- GICs are interdisciplinary in nature and require joint effort.
- A solid understanding of the entire GIC chain is key to fully appreciate the GIC phenomena.
- From the space weather standpoint, GICs are driven by many different factors that depend on the M-I coupling process.
- Basic science research is the core to understanding GICs drivers to aid development of mitigation procedures.



Up Coming Events in Lusaka, Zambia

- **International Space Weather Initiative (ISWI) School**
 - September 26th to 30th 2023
 - Open to students/postdocs/early career at African institutions
 - Limited travel support available - Apply
- **African Geophysical Society Conference**
 - October 2nd to 4th 2023
 - Open to all Earth and Space science students and scientists
 - Limited travel support available - Apply

<https://afgps.org/conference>

