GIC Observations and Modeling: From the Solar Wind to Power System Impacts

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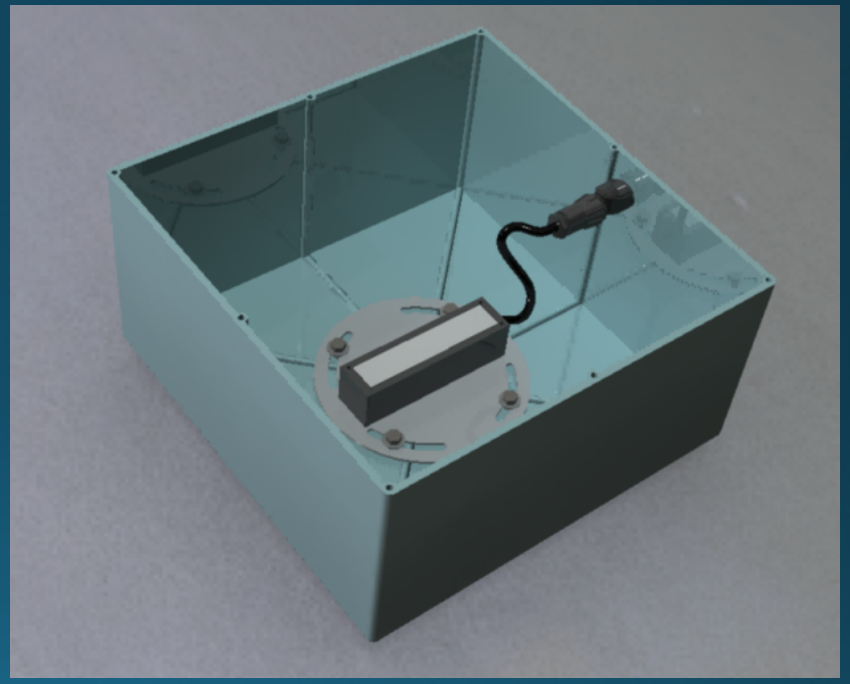
NSF Hazards GMD Project

- NSF award EAR-1520864, focus is on better understanding of GMD impacts on the power grid
- Interdisciplinary
- Academic, Industry and Government partners
- Strongly desire utility participation!
  - One activity is the deployment of four magnetic and electric field monitors with one second resolution
  - At Odessa TX, Univ. Illinois, Leyden CO, Hennepin County MN, Columbus OH, Connecticut and Maine!



Thank you: NSF, EarthScope, USGS, Carisma, McMac

NSF Project Team

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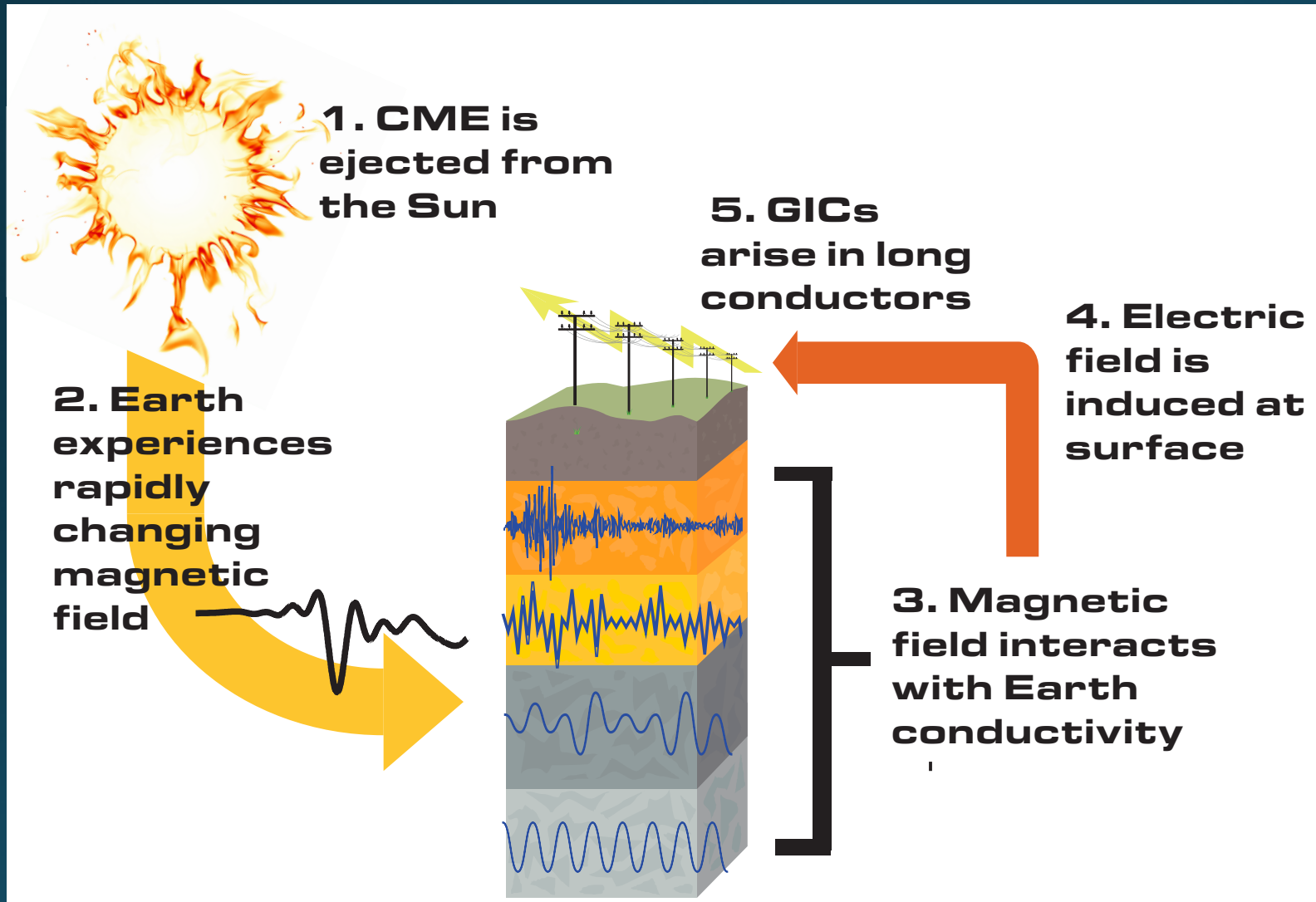
Advisors/Consultants : Chris Balch (NOAA-SWPC), Michael Henderson (GICMagnetics)

Drivers of GIC



This project incorporates cross-disciplinary studies spanning the solar wind drivers through direct system impacts.

Four project components: Geophysical Analysis, Instrumentation, Predictive Studies, and System Modeling

Space Hazard Monitor (SHM)

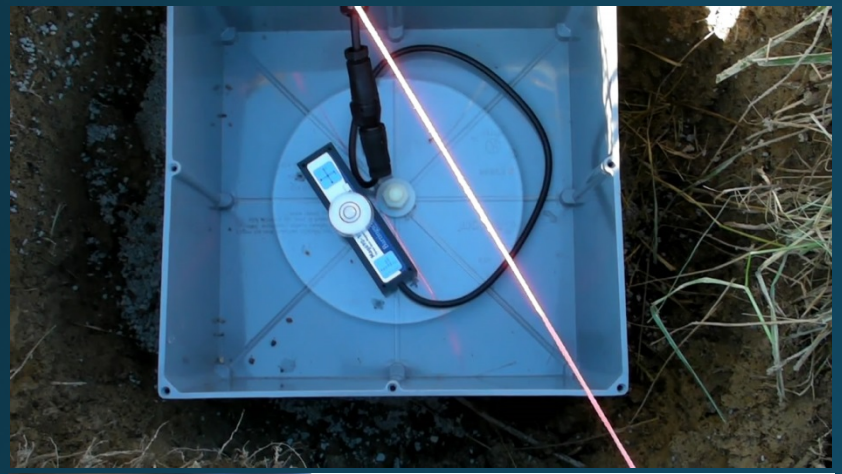
Magnetic field and electric field sensors.

Design emphasis on real-time stability and reliability (< 1 second data latency), with specific application to power grid hazard monitoring.

Off-grid power and
Communications

Integrates with CPI's AVERT GIC Hazard and equipment monitoring tools

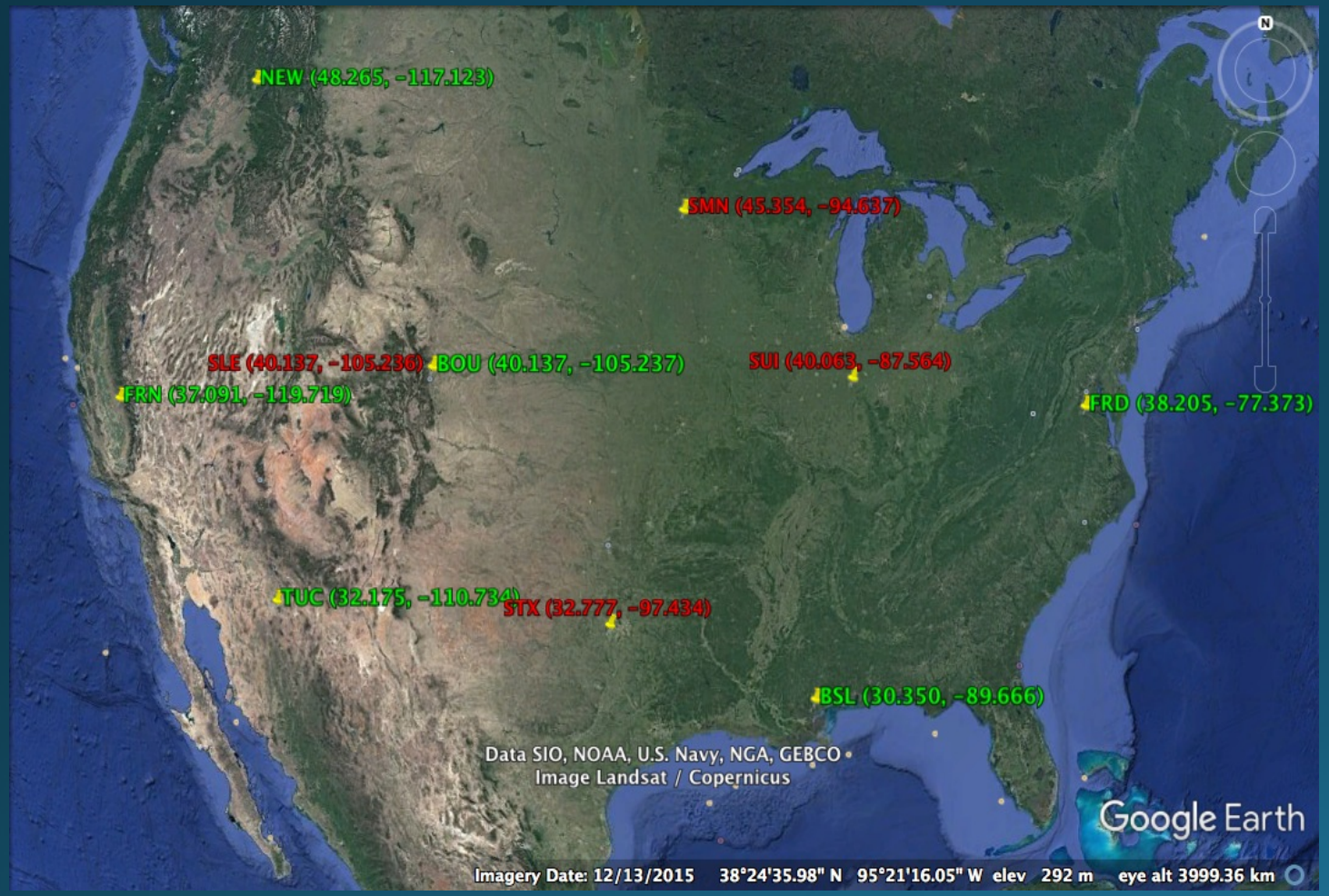
SHM Sensors



Bartington Fluxgate magnetometer

Lemi electrodes

SHM Installation Sites



Locations of SHMS and USGS stations

Leyden
(40.137 N, 105.236W)

Minnesota
(45.354 N, 94.657W)

Odessa
(32.777 N, 97.434 W)

UIUC
(40.063 N, 87.564 W)

First Installation: Ector County, Odessa, Texas

.

First installation near Odessa, TX on May 7-8, 2016.

1. Magnetic and electric field sensors
2. Installation will be on-site at utility partner location; ~300m from transformer assets.
3. Also performing secondary validation measurements at a very magnetically quiet site ~25 miles away; This will provide validation of measurements from primary installation, as well as magnetotelluric (MT) information for conductivity models.

Potential issues:

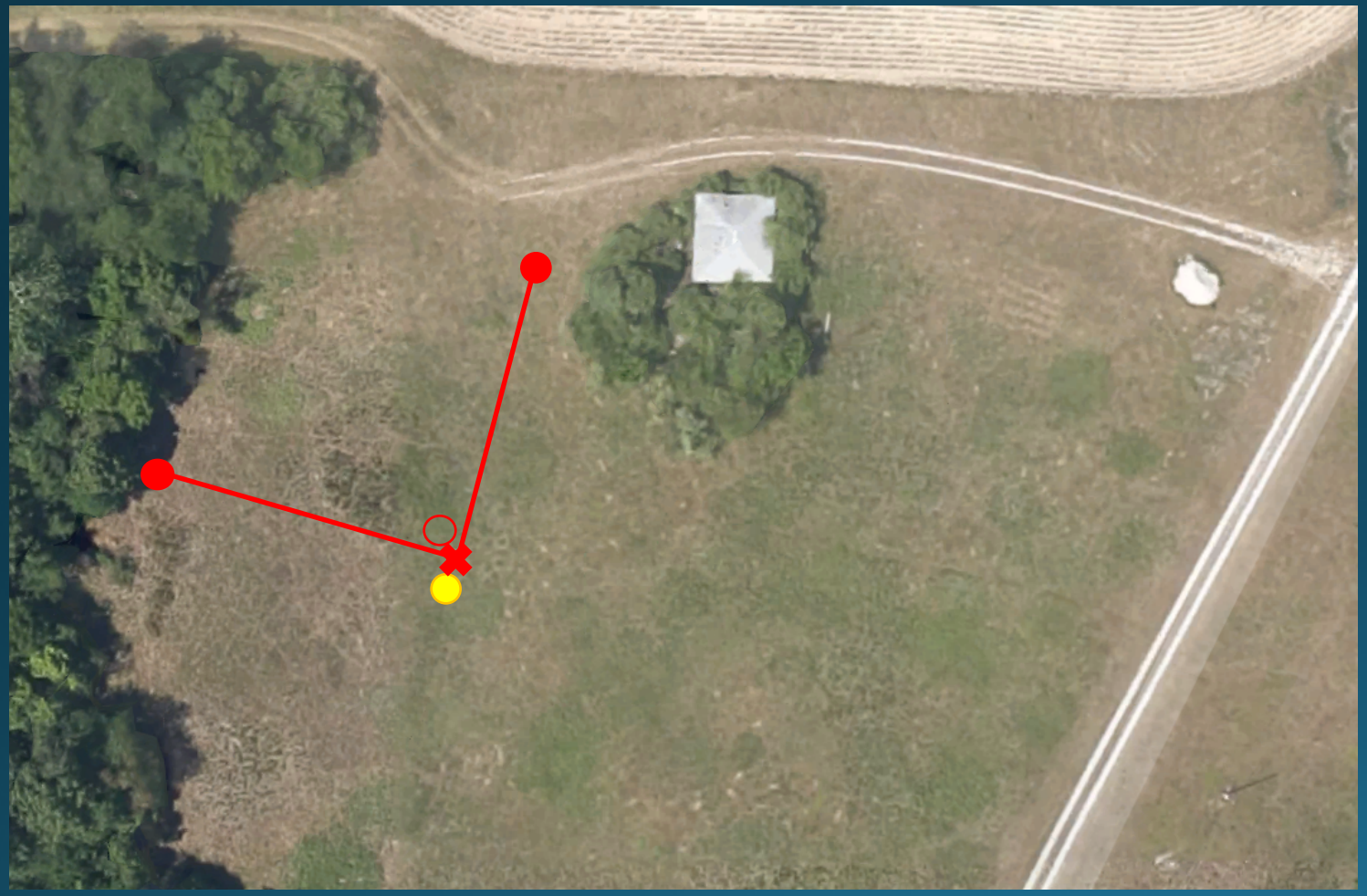
1. We expect noise in the magnetic field time series due to proximity to transformers. HydroQuebec has successfully placed magnetometers this close to substations, but it is not for detailed or scientific level analysis. It is unknown how accurate the electric field measurements will be this close to a substation.
2. There may be difficulties in the long-term deployment of electrodes in very dry locations. For proper functioning and electrode contact with the soil, moisture is required. We will be testing methods of maintaining proper conditions.

Second Installation: UIUC (Urbana-Champaign, IL)

Second installation near Urbana-Champaign, IL in September, 2016.

Magnetic and electric field sensors

UIUC Site Layout



Post

Sensor(Electrodes)

Sensor(FGM)

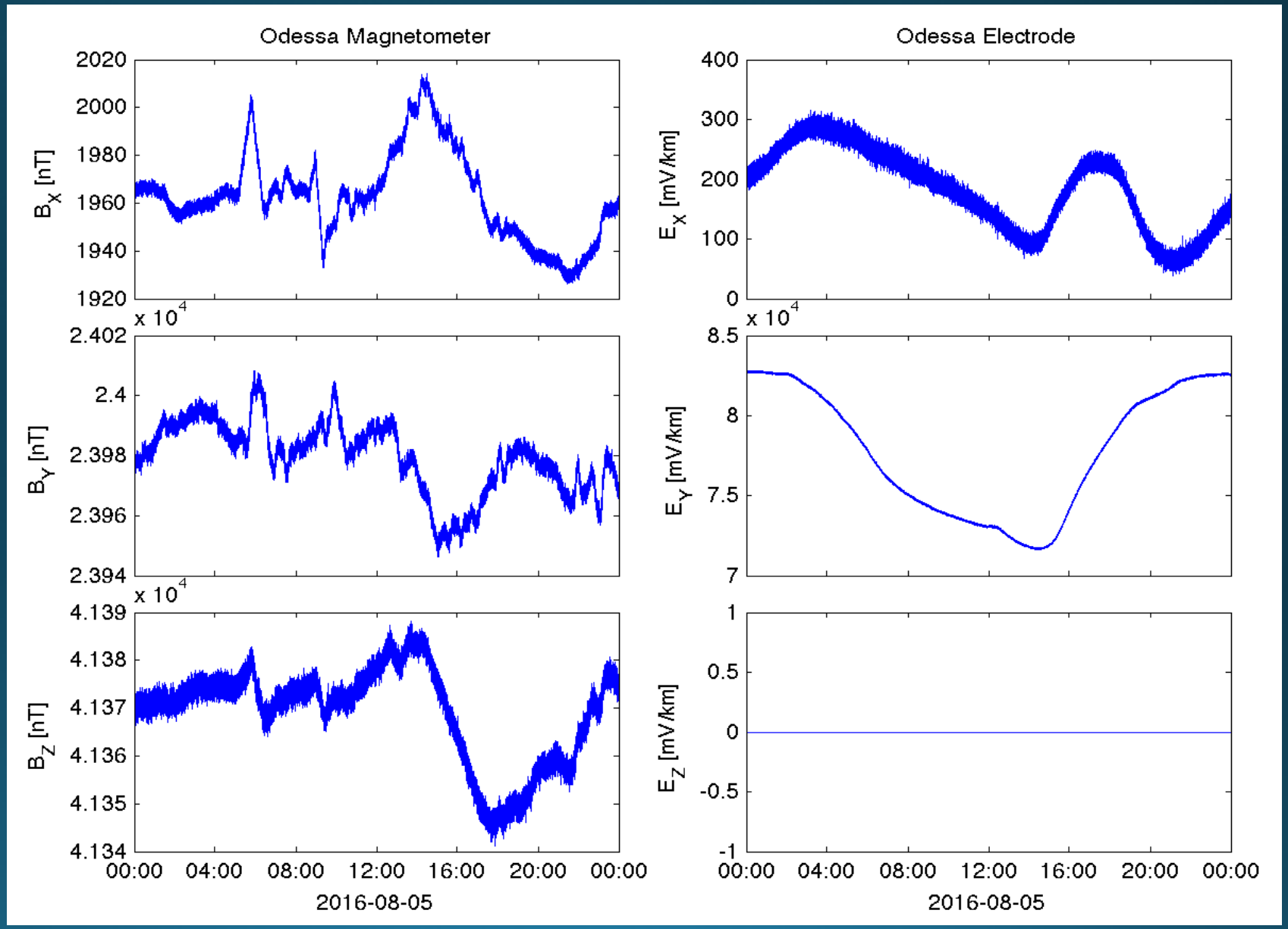
GPS location is 40.06N, 87.56W.

Power and GPS antenna

Data: Validation and Analysis

Summary plot of Magnetometer and Electrode data at Odessa, Tx

(Plot courtesy of Dong Lin, Virginia Tech)



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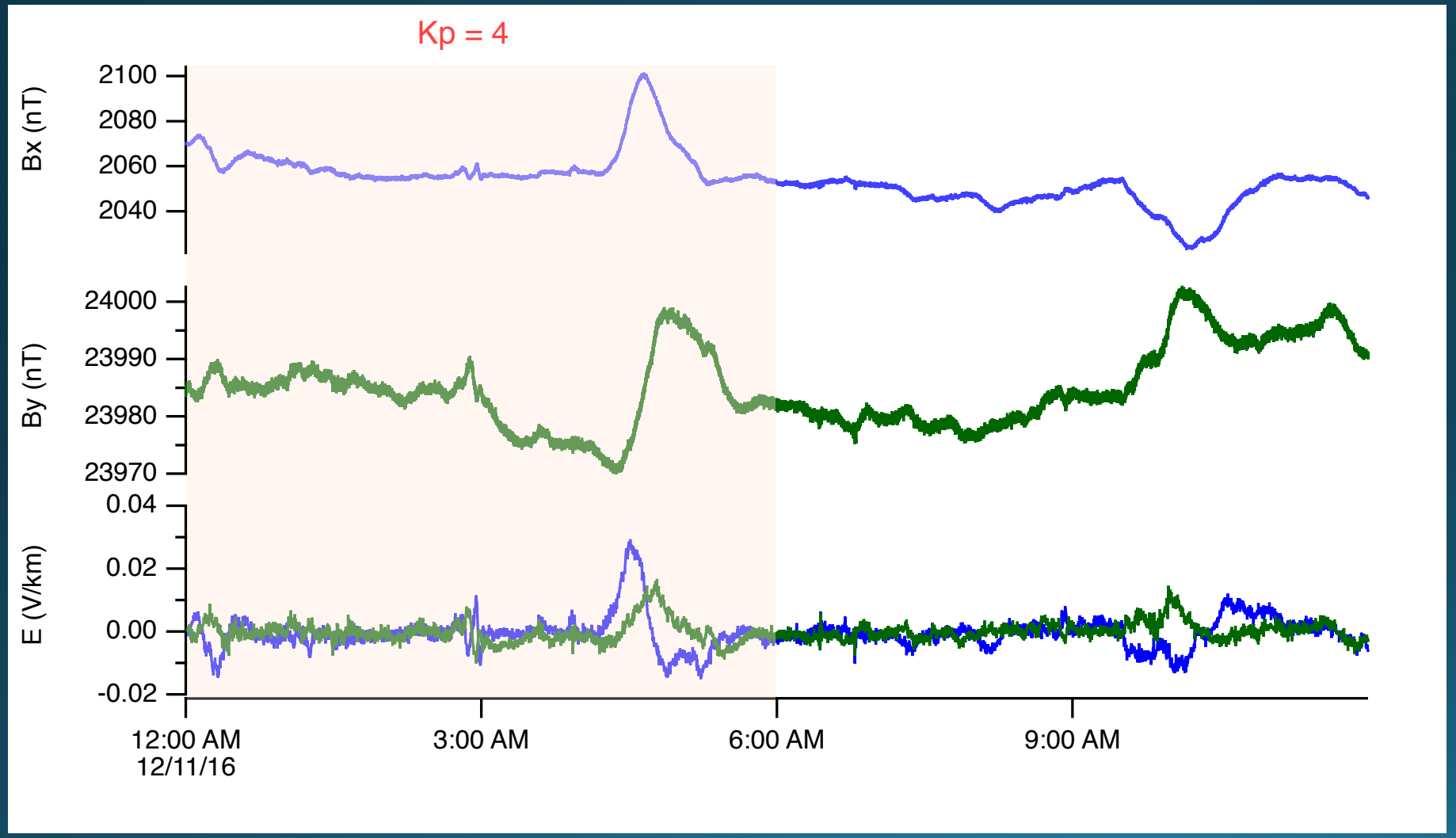
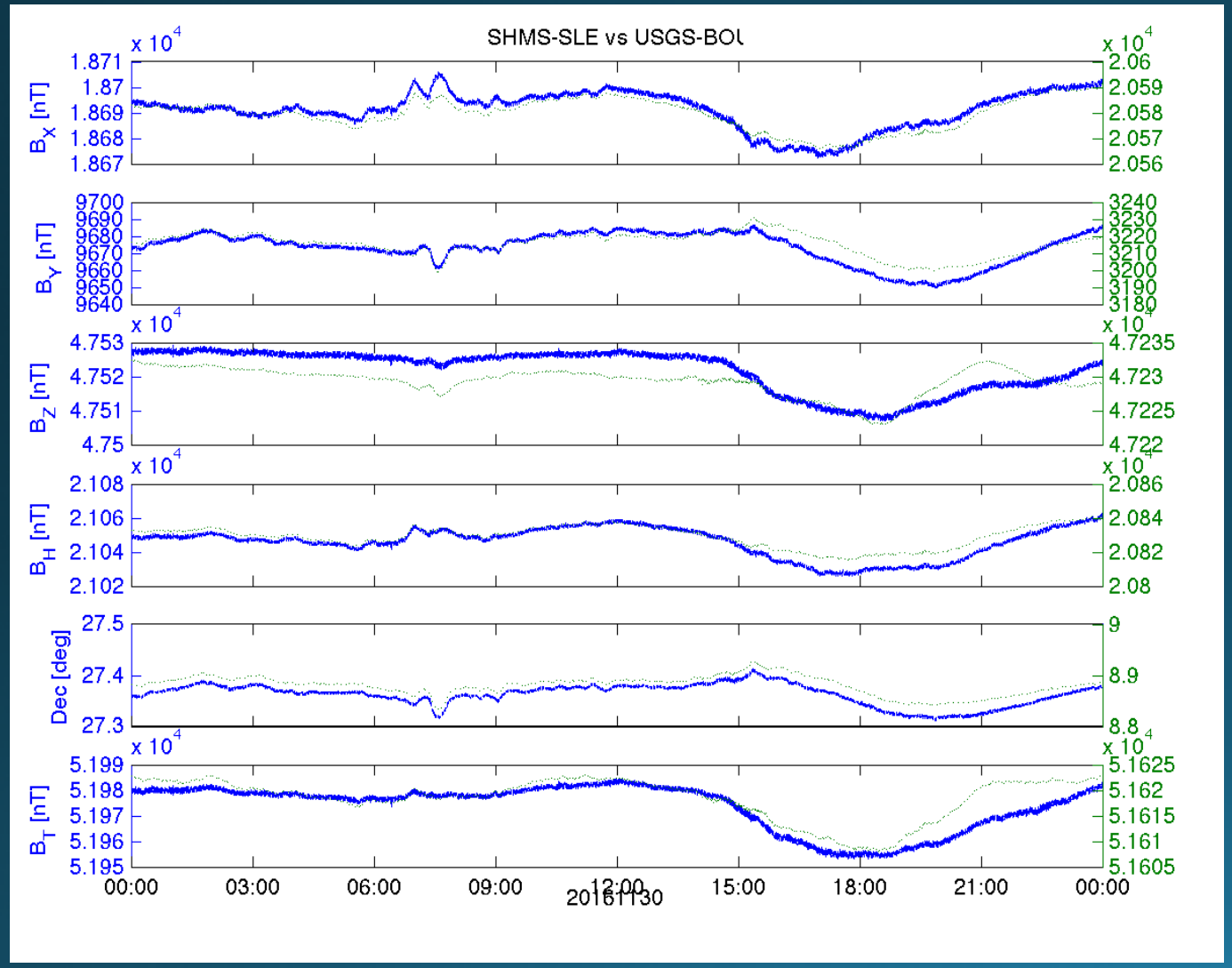


GIC Hazard analysis using Odessa station measurements.

Collaborating with local utility to understand GIC impacts

Data: Validation and Analysis



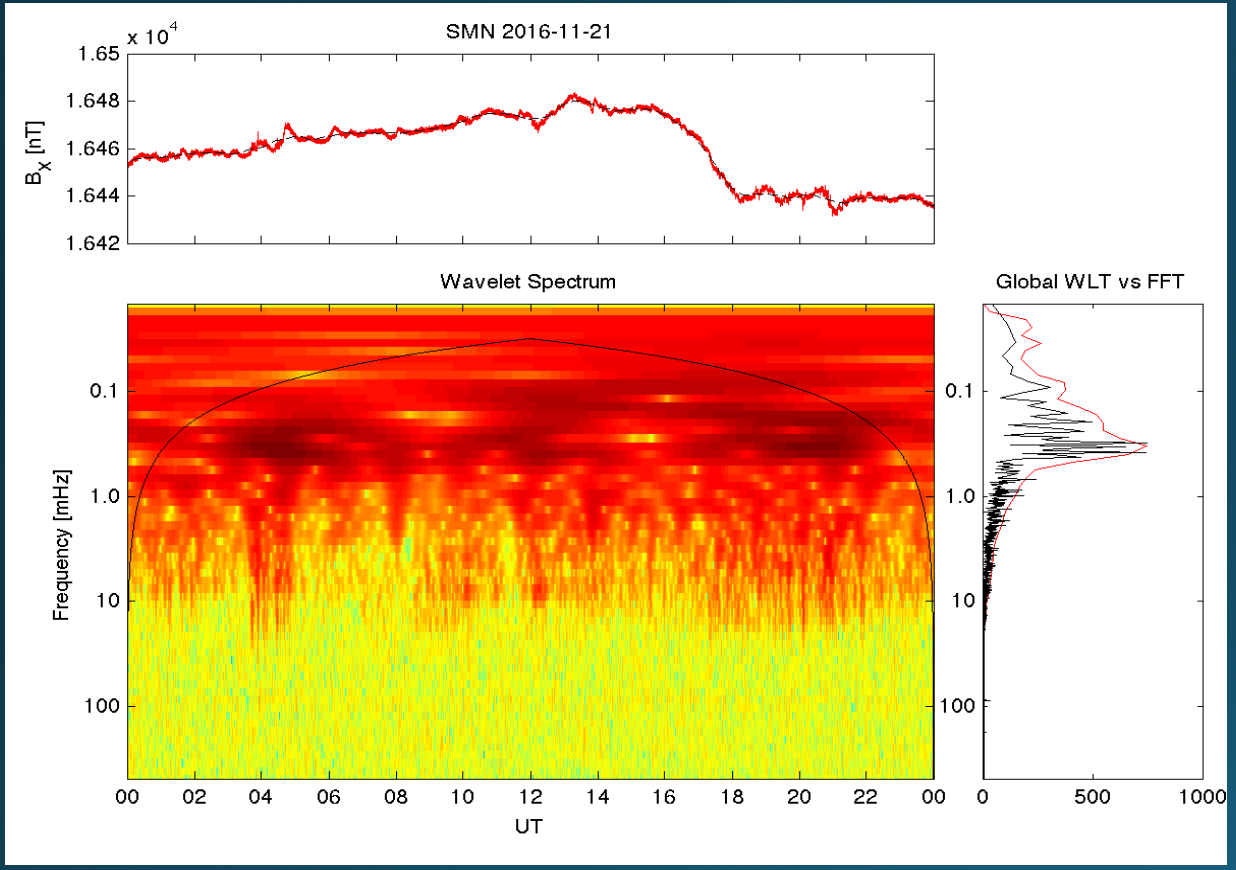
Comparison of Leyden station with USGS/BOU station

- Horizontal component is well consistent between SLE and BOU (40.137 N, 105.237 W).
- There seems to be a constant difference in declination atan(By/Bx) of about 18°.
- Bx and By difference should probably be attributed to declination.

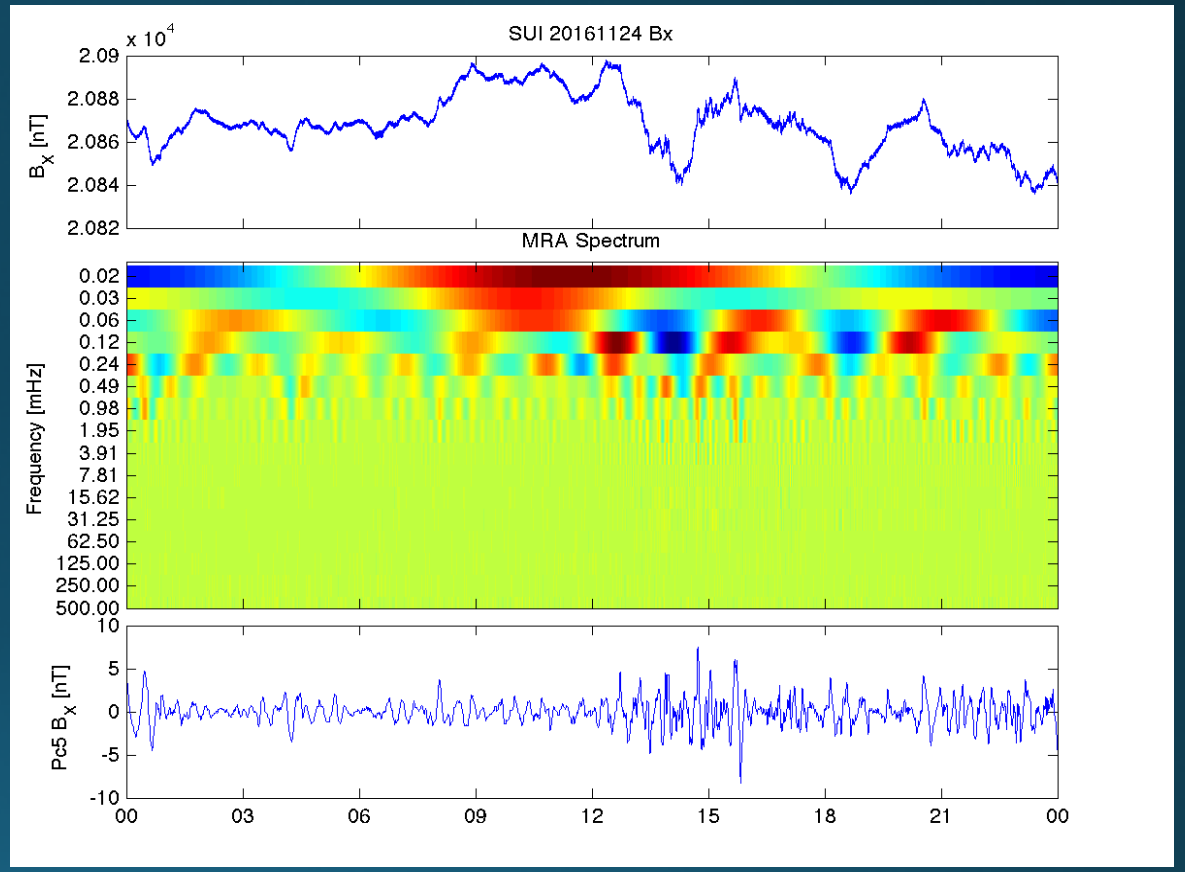
(courtesy of Dong Lin, Virginia Tech)

Data: Validation and Analysis

Comparison of Global Wavelet and Fourier Spectrum



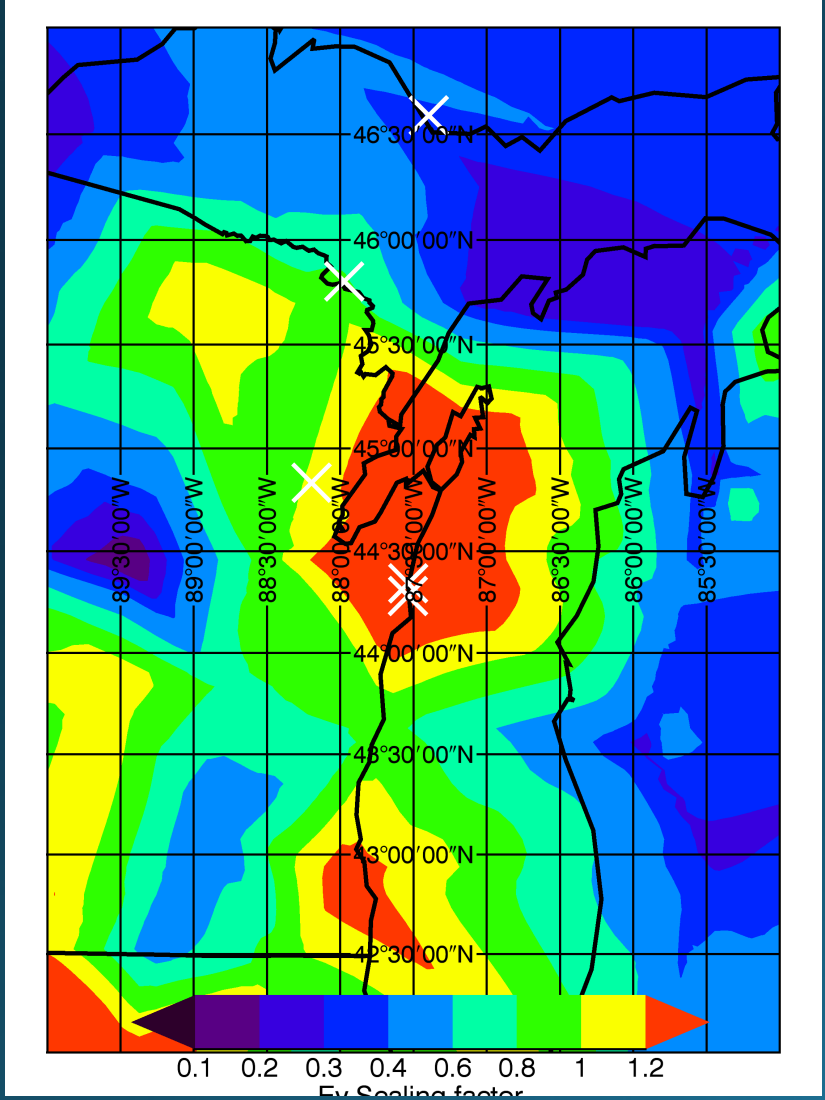
Multiresolution analysis (MRA)



- Wavelet spectrum based on algorithm of Torrence and Compo [1997].
- Global wavelet spectrum (summation over time) is consistent with Fourier spectrum (red curve).
- Multiresolution analysis is capable of decomposing the geomagnetic signal into a single or combination of individual frequencies (e.g. Pc5 between 1 and 10 mHz).

Courtesy Dong Lin , Virginia Tech

System Models: Wisconsin example



Calculation of electric field using modeled magnetic fields and 3D Earthscope impedance tensor transfer functions.

GIC data shows anomalous readings at one station.

Combining electric field simulations with system models to assess impacts.

➔ Magnetometer data of the appropriate characteristics can improve GIC hazard analysis within 100 miles

Summary

- NSF award EAR-1520864, focus is on better understanding of GMD impacts on the power grid
- 6 magnetometers (SHMs) deployed across the US by project completion
- Real-time data available
- Support of GIC and space weather hazard analysis

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