

On the Role of Earth Conductivity in Driving Geomagnetically Induced Currents: Three Examples on the Alberta Electric Power Network

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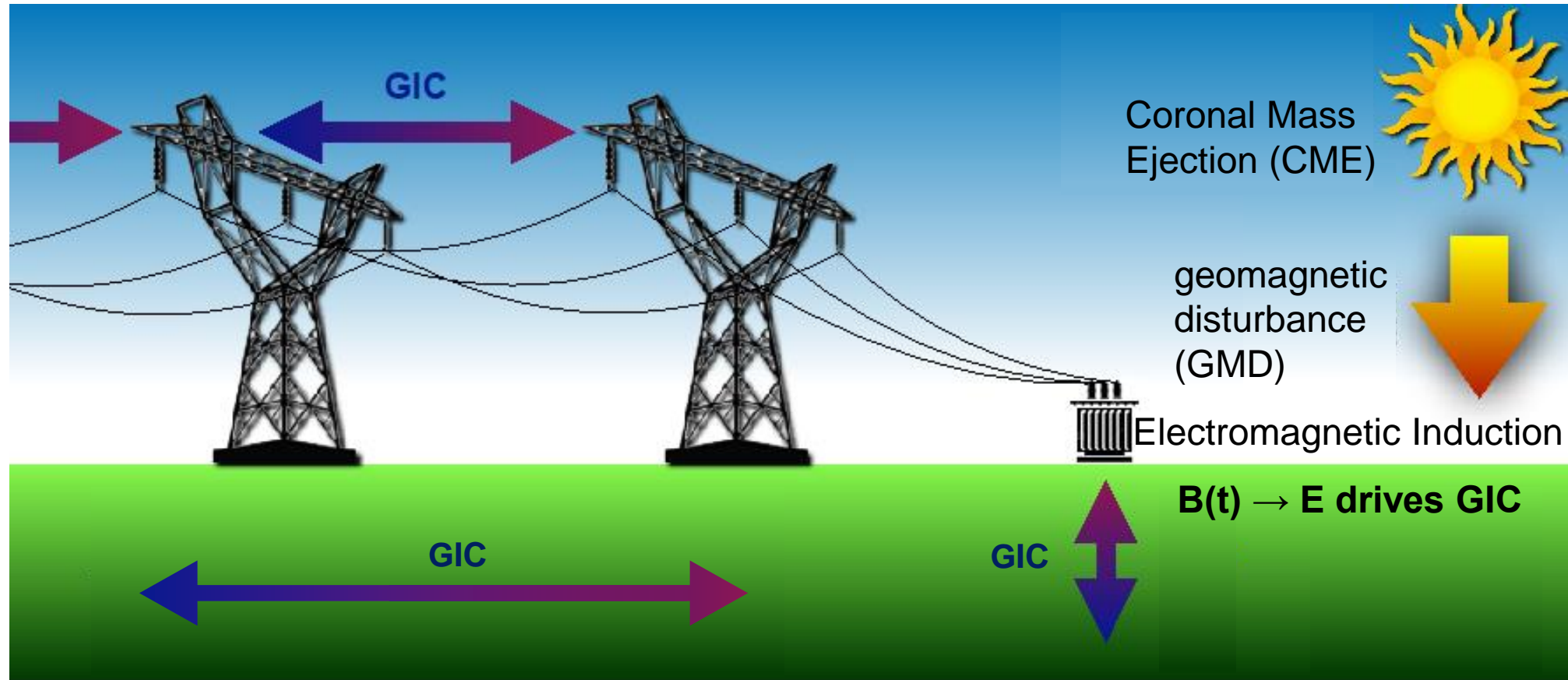
(²)AltaLink L.P.

DASP 2024 – February 20th, 2024

Overview

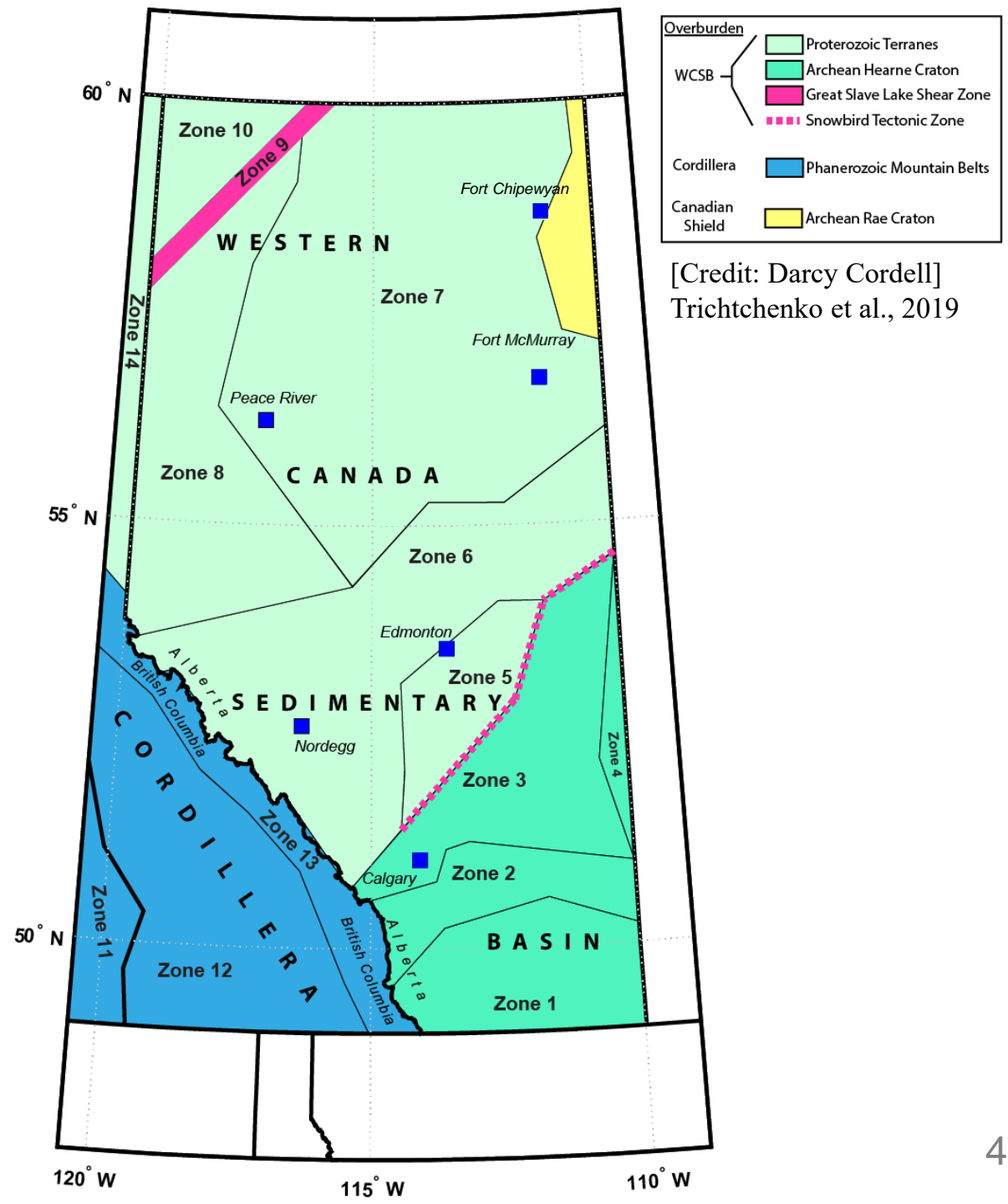
1. Space Weather Hazards: Geomagnetically Induced Currents (GIC)
2. Studying GICs in Alberta
 - Industry Collaboration
 - Data and Methods
3. Phase and Polarization Characteristics of Geoelectric Field
4. Conclusions + Future Work
 - Proposed research involving industry collaboration

Geomagnetically Induced Currents (GICs)



Adapted from www.swico.it/category/geo-mag/

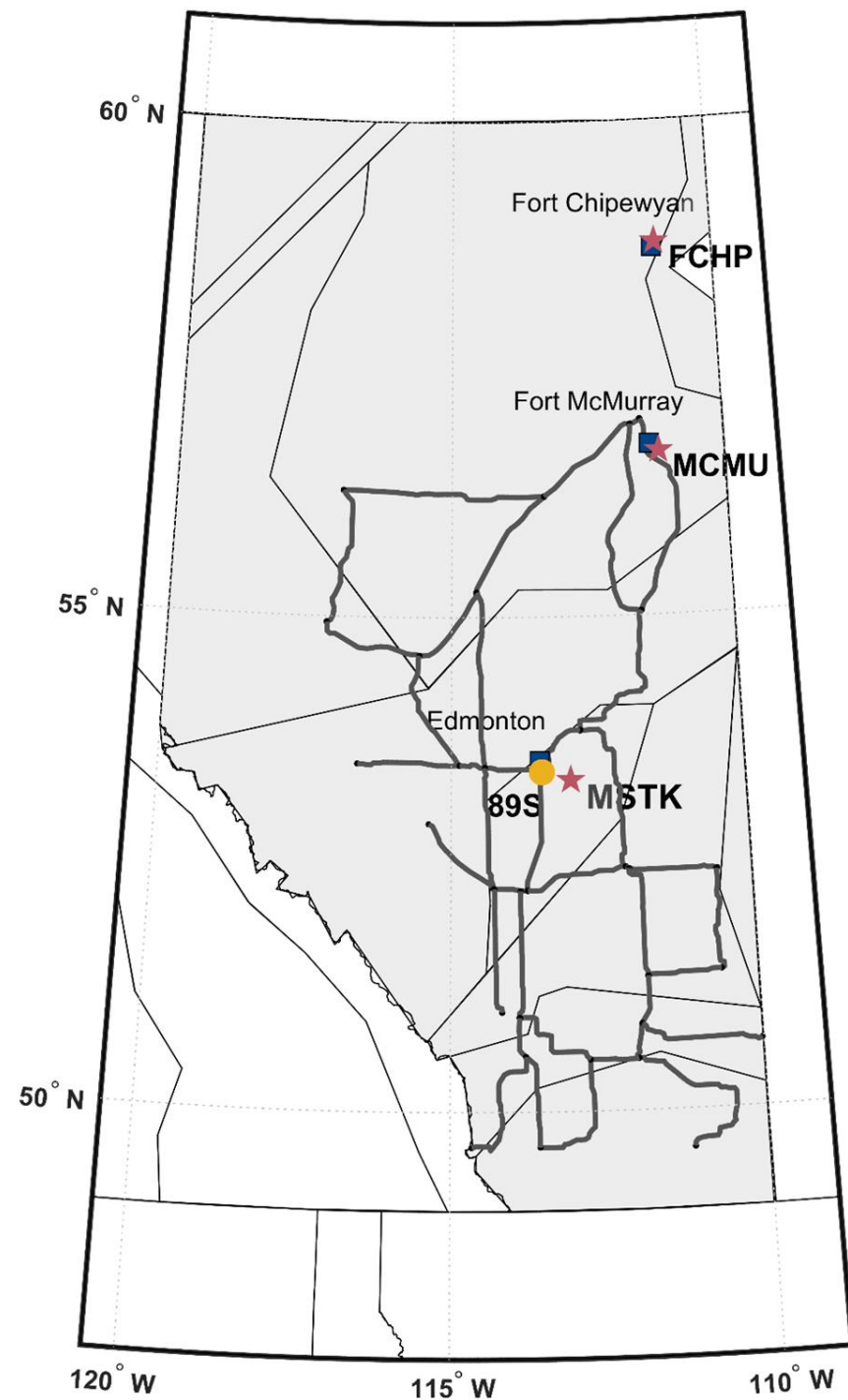
Studying GICs in Alberta, Canada: Importance of Earth Conductivity



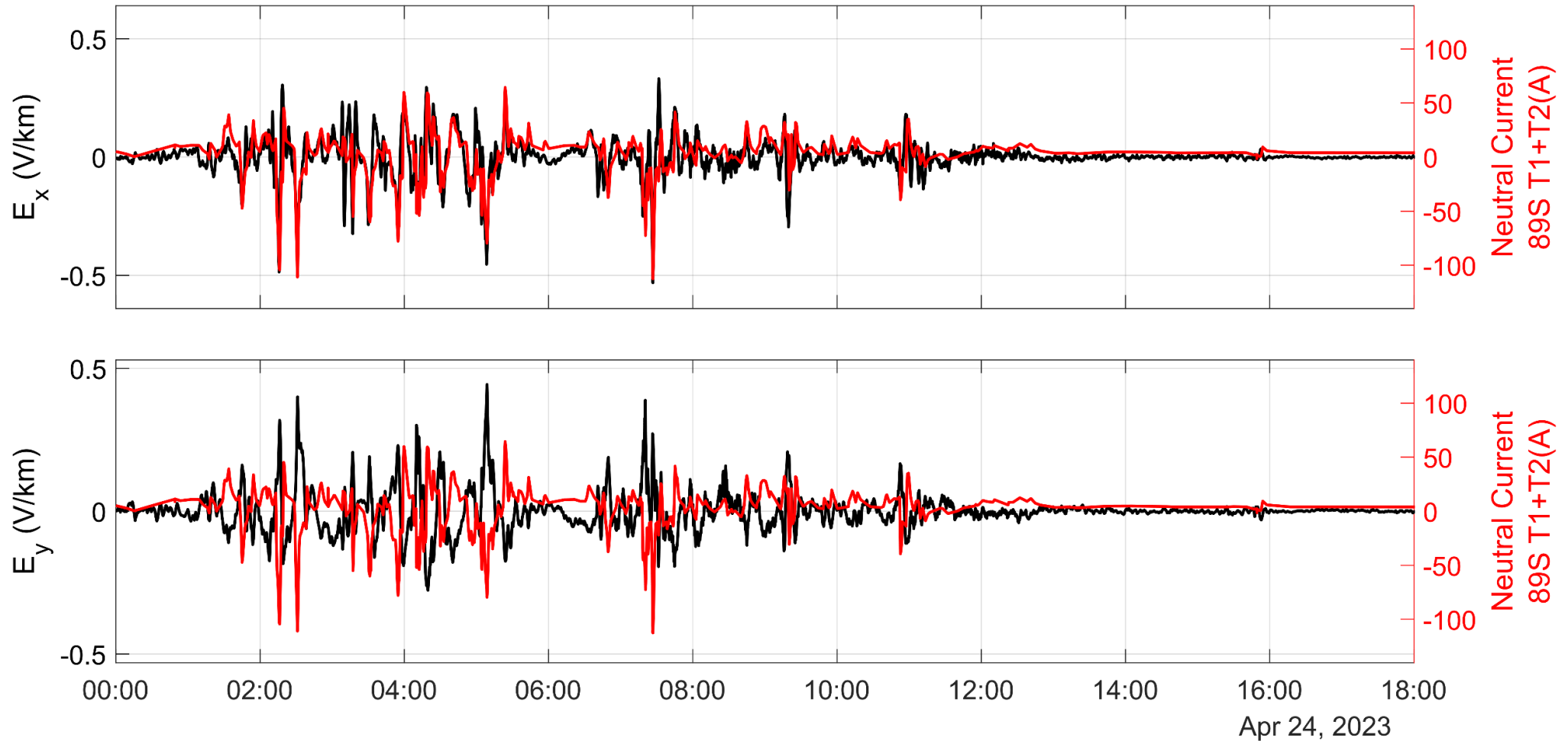
Studying GICs in Alberta, Canada: Importance of Earth Conductivity

Sensor Locations and the Alberta Interconnected Electric System (AIES)

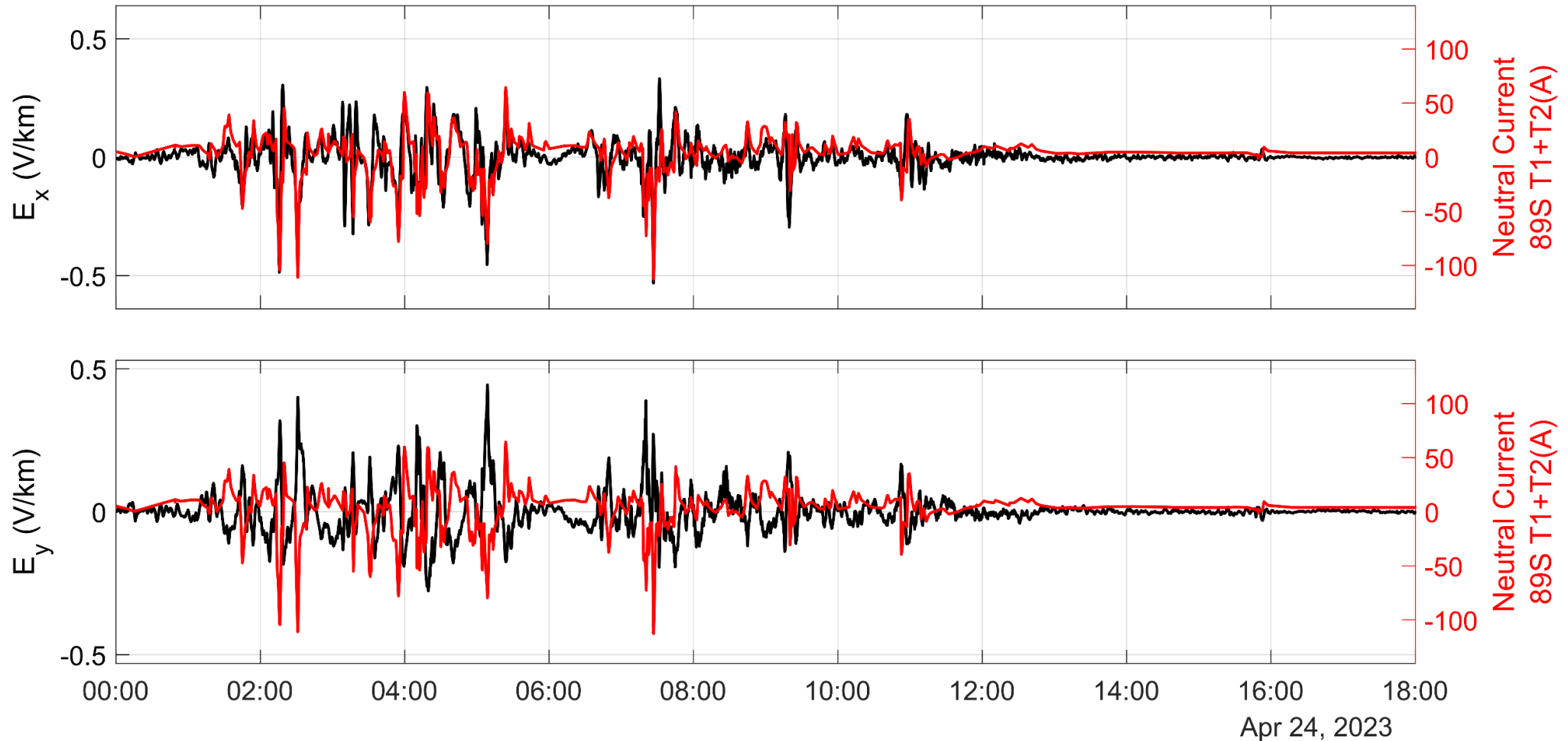
- AIES >240 kV transmission lines
- AltaLink substation with GIC data
- Ellerslie (89S)
- ★ CARISMA FGM station
- GMD → Geoelectric Field
- Nearby Cities and Towns



Geoelectric Field Validated by Hall Probe GIC

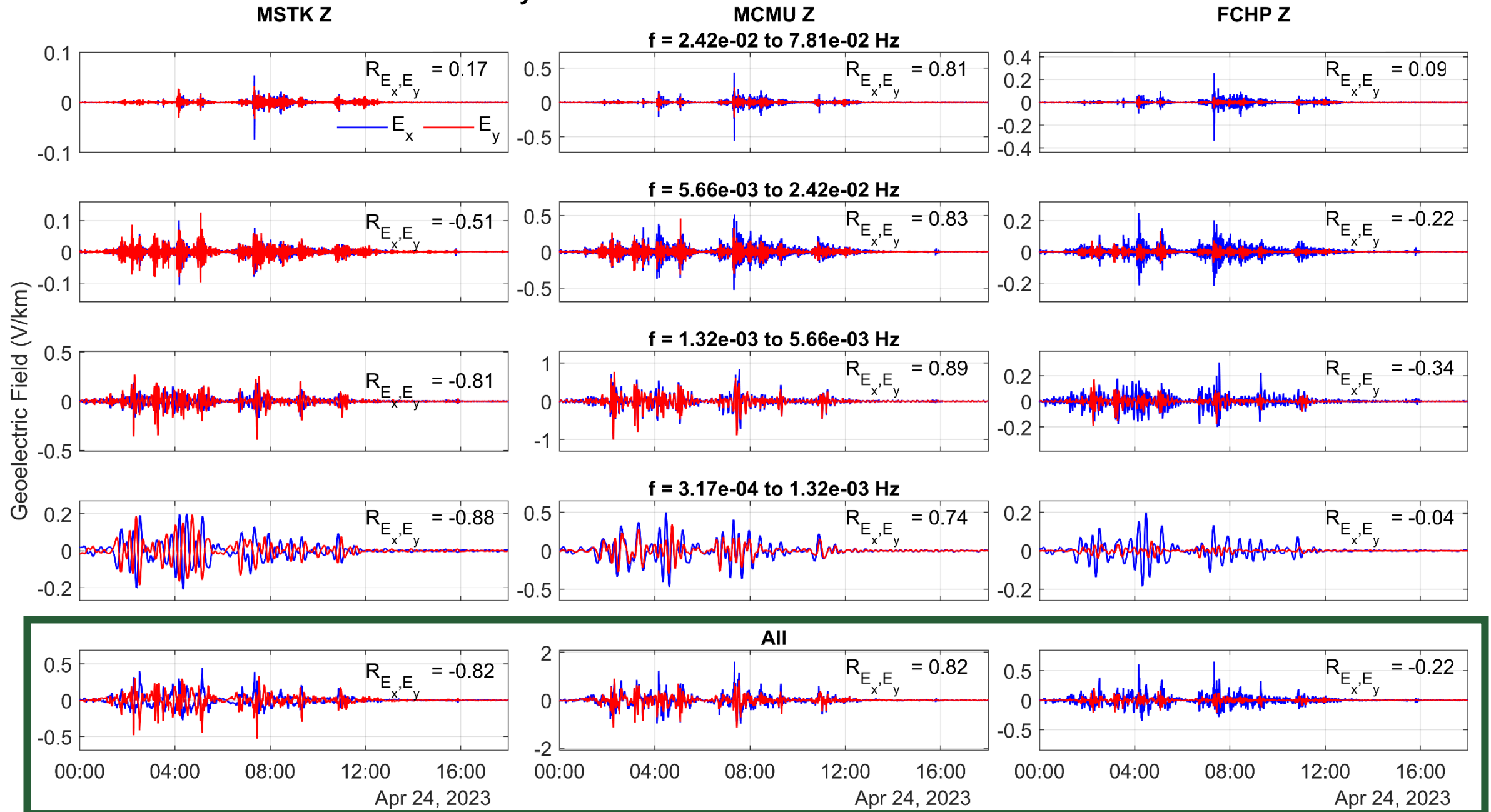


Geoelectric Field Validated by Hall Probe GIC



Role of 3D Earth conductivity on the phase and polarization characteristics of geoelectric field?

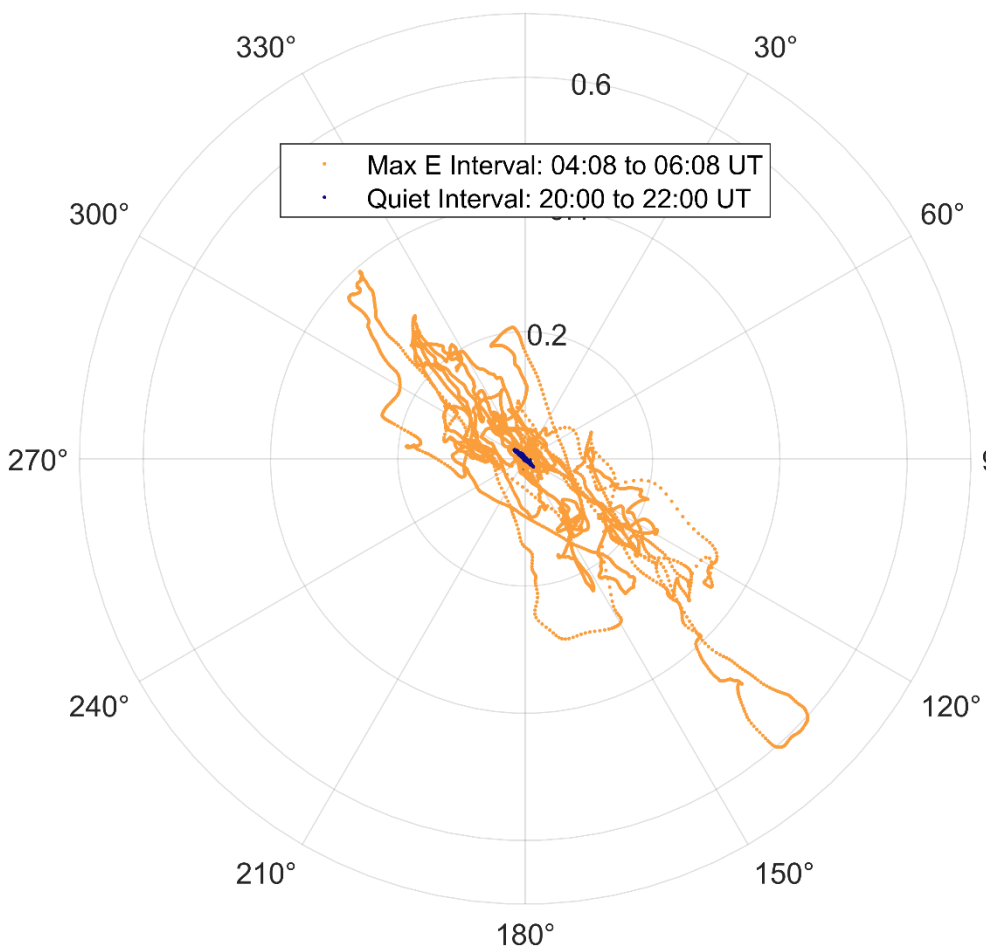
Correlation between E_x and E_y from Same Driving dB – Different Location Dependent Z



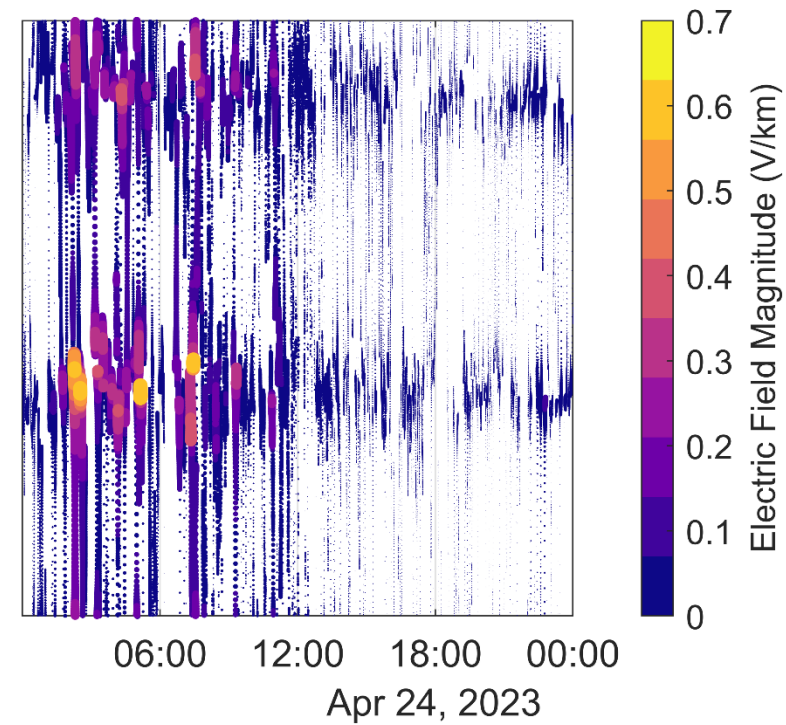
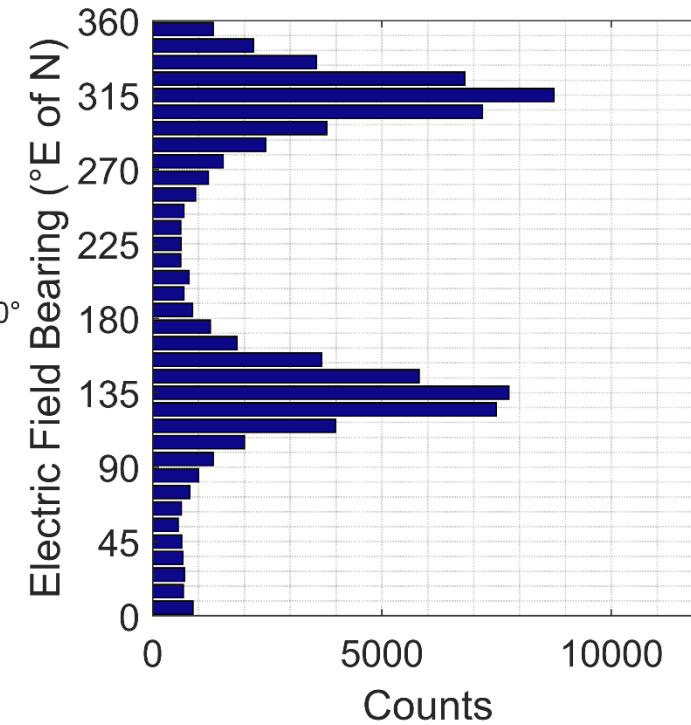
Electric Field Bearing: April 24th, 2023 – MSTK



E Field bearing ° E of N in V/km @ MSTK Z



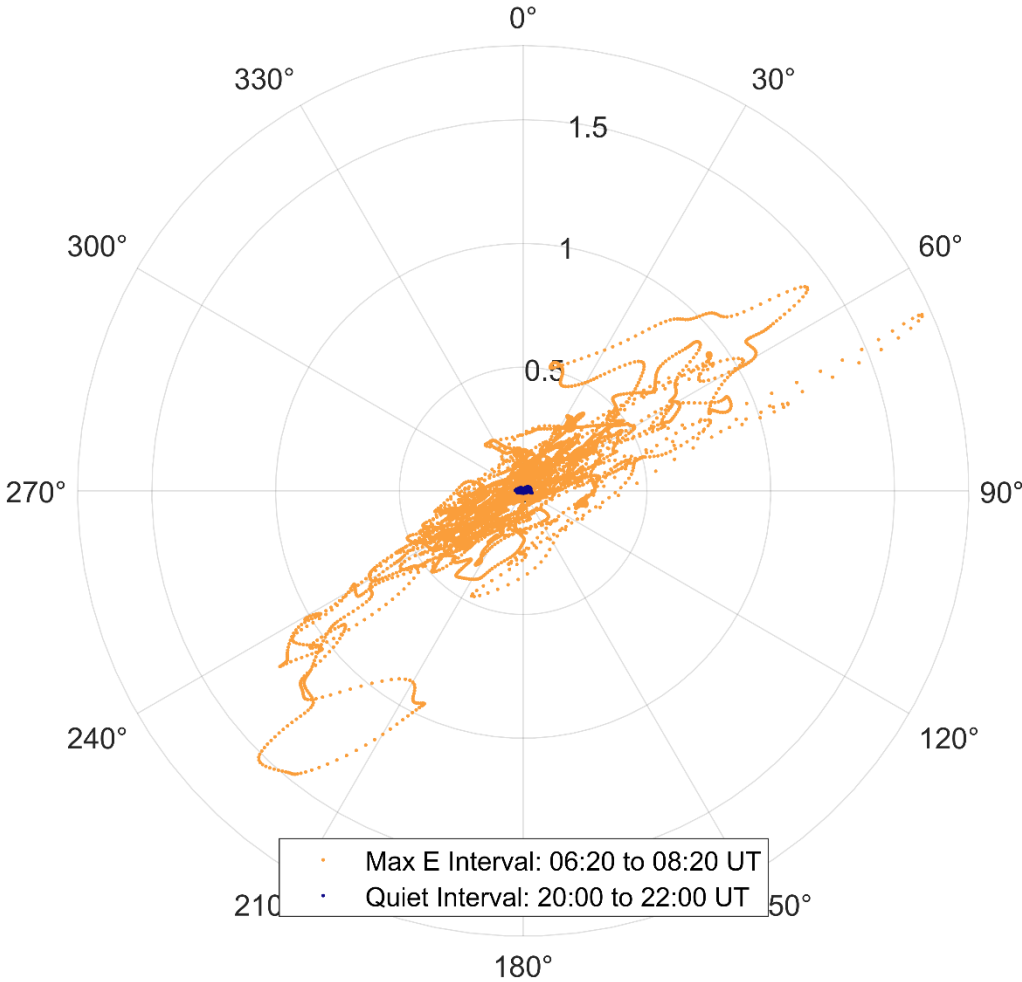
Max E field of 0.608 V/km @ MSTK on 24-Apr-2023 05:08:42 with bearing 134.6961° E of N



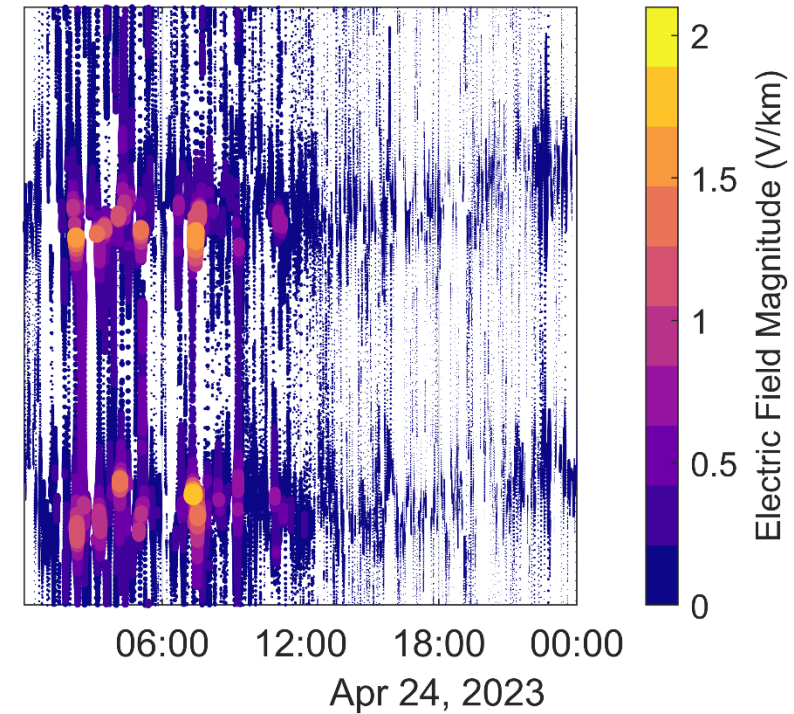
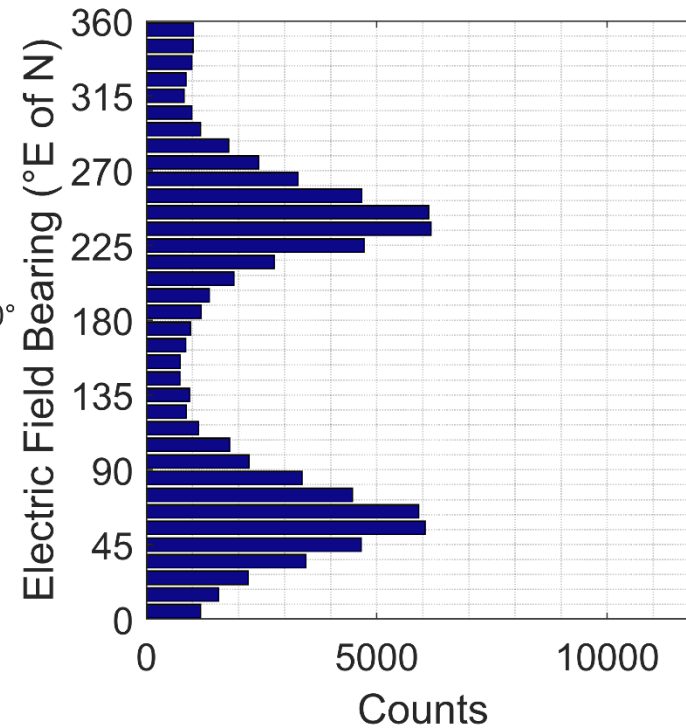
Electric Field Bearing: April 24th, 2023 – MCMU



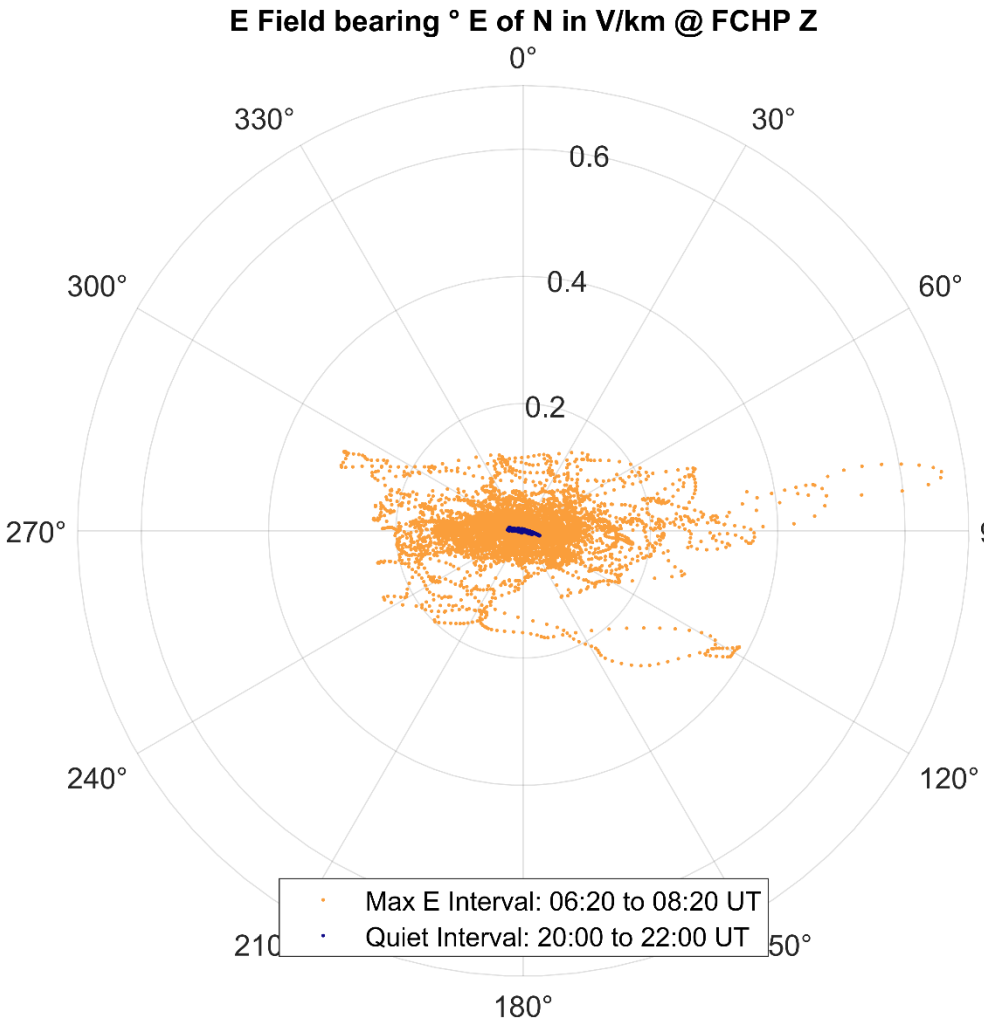
E Field bearing ° E of N in V/km @ MCMU Z



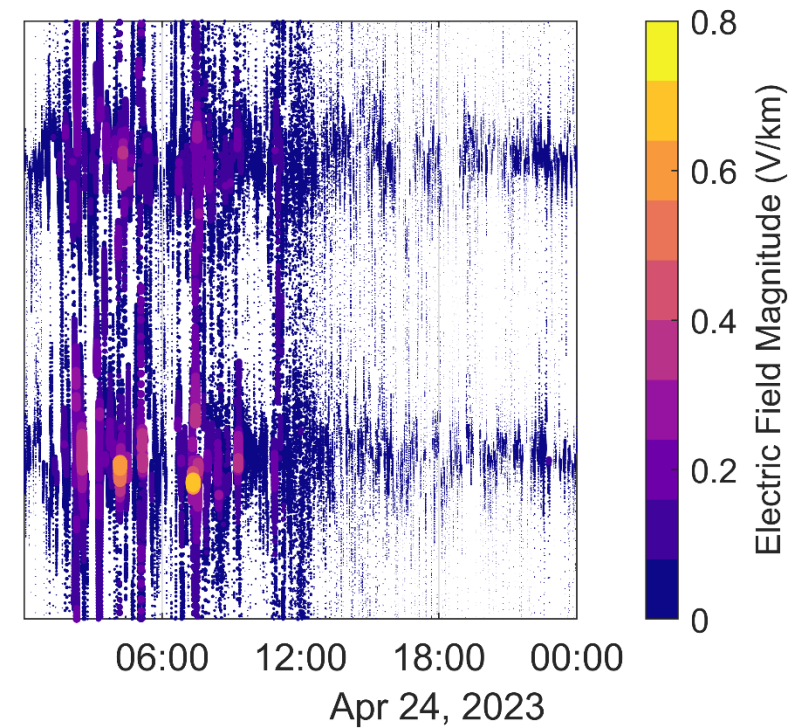
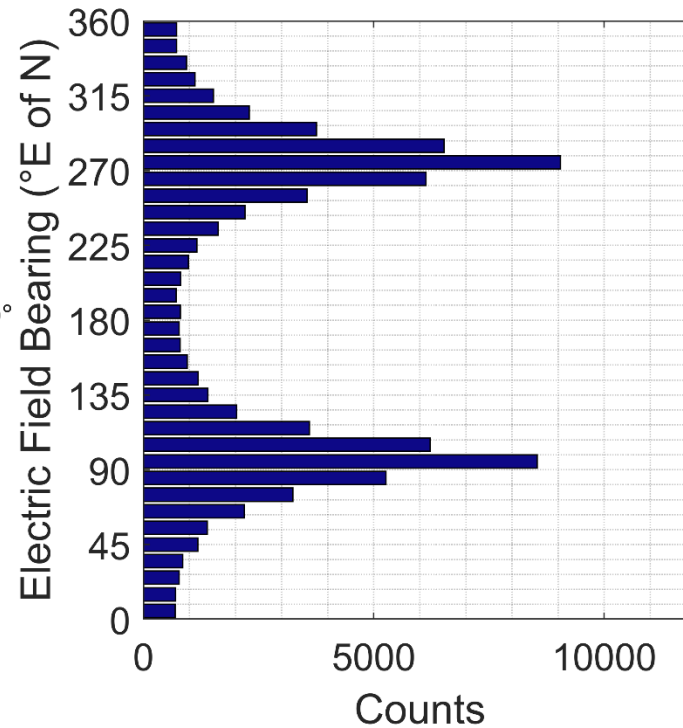
Max E field of 1.76 V/km @ MCMU on 24-Apr-2023 07:20:32 with bearing 66.1432° E of N



Electric Field Bearing: April 24th, 2023 – FCHP



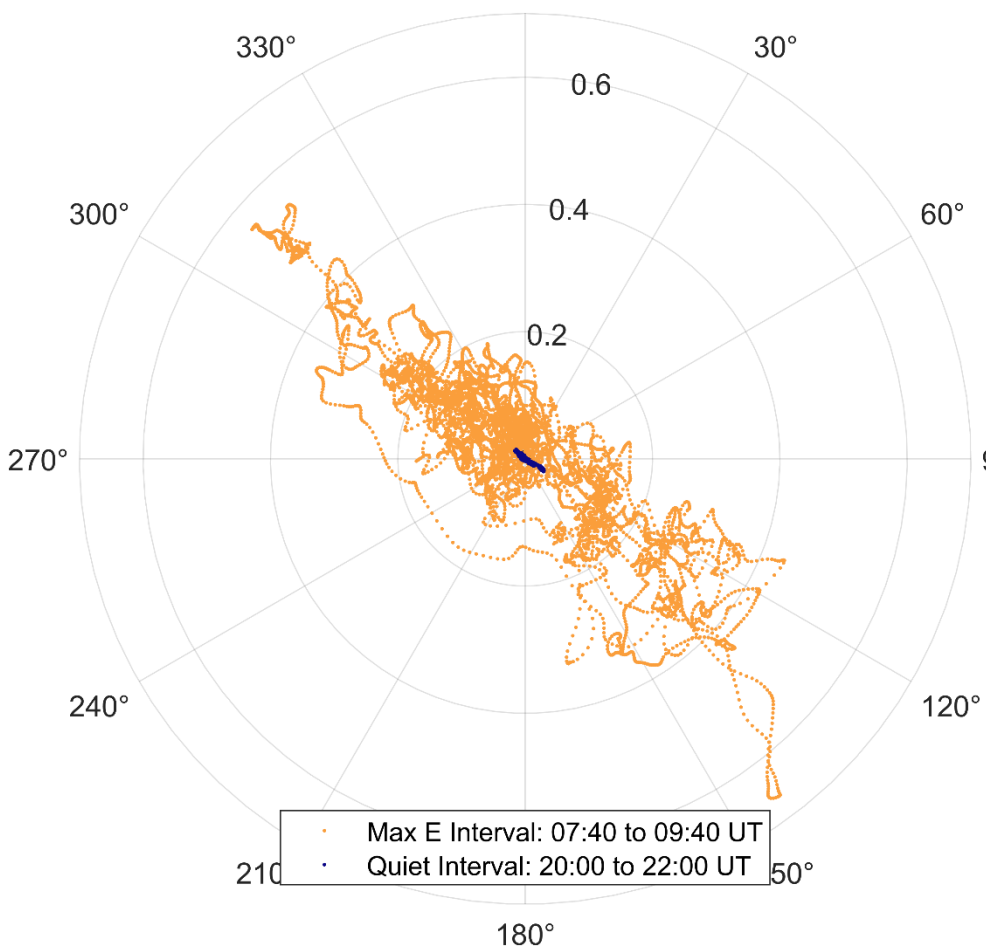
Max E field of 0.663 V/km @ FCHP on 24-Apr-2023 07:20:26 with bearing 81.9483° E of N



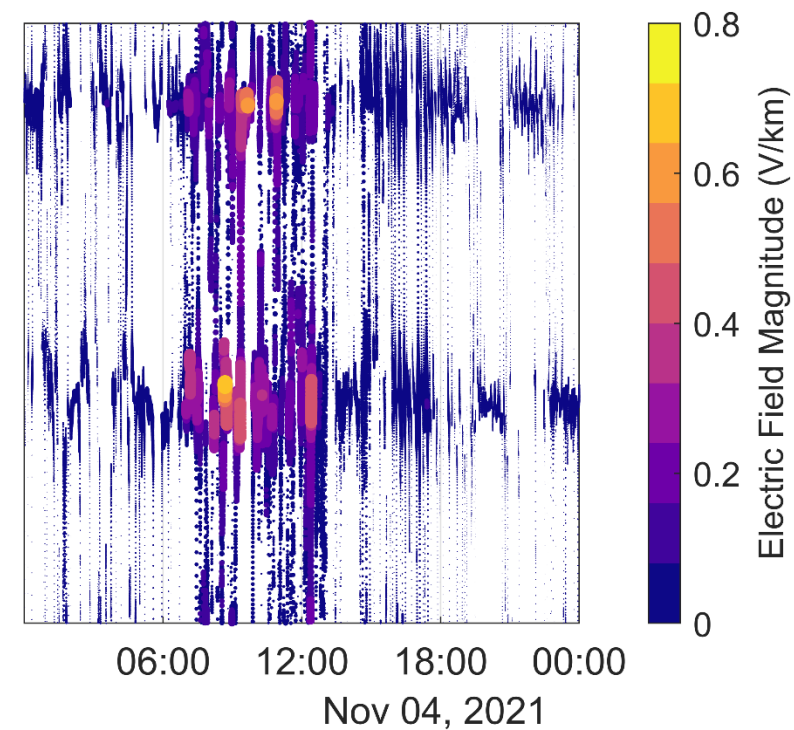
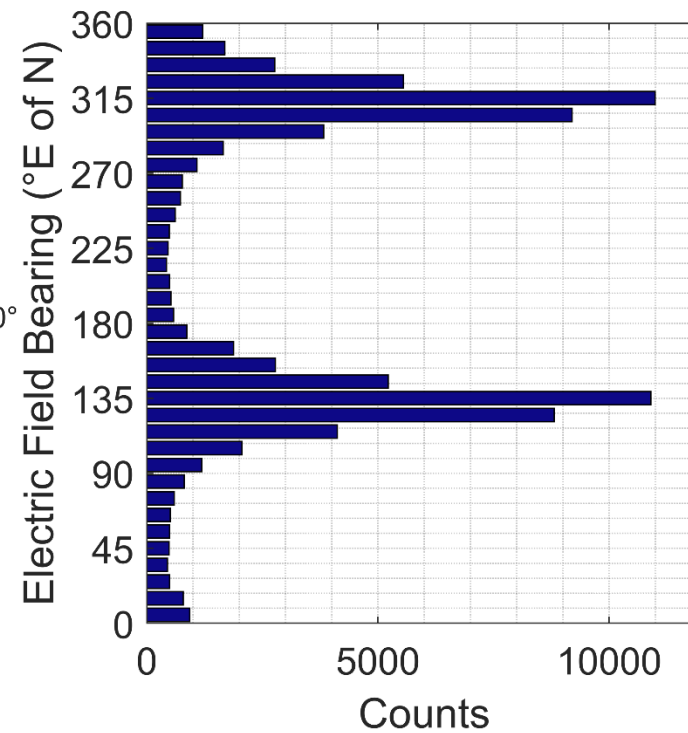
Reproducible results: Nov 4th, 2021 – MSTK



E Field bearing ° E of N in V/km @ MSTK Z



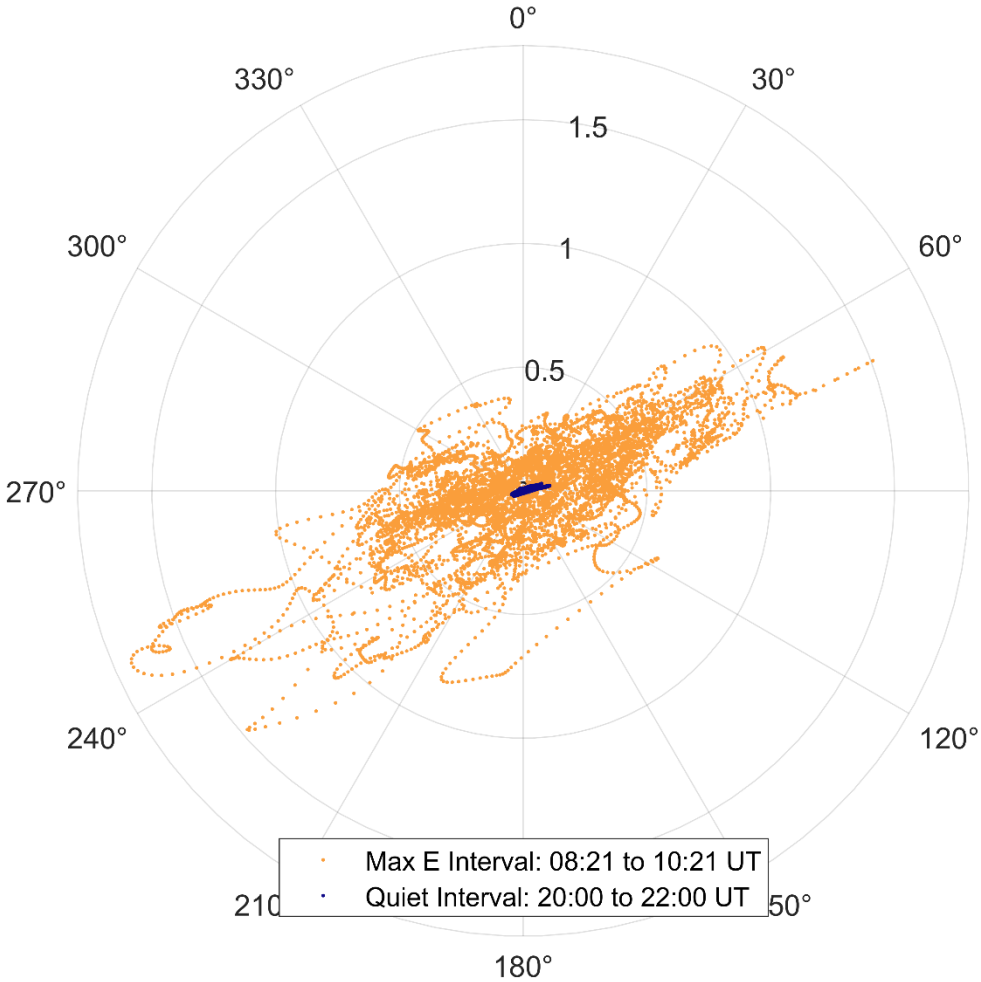
Max E field of 0.663 V/km @ MSTK on 04-Nov-2021 08:40:28 with bearing 142.957° E of N



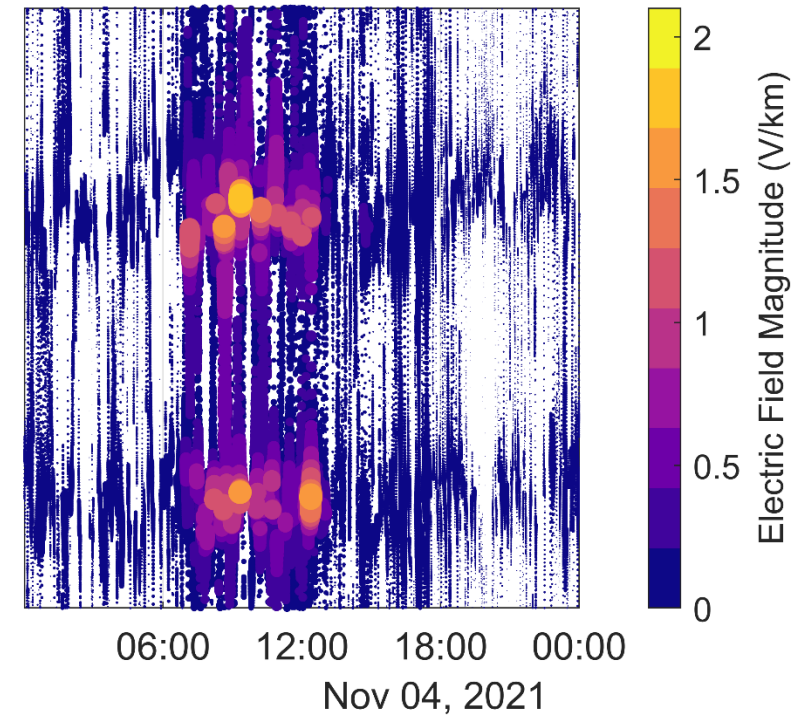
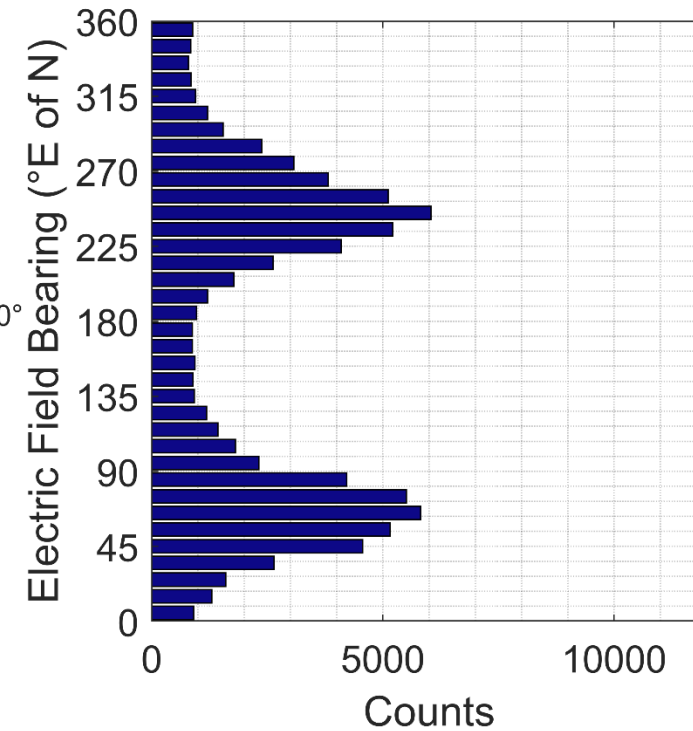
Reproducible results: Nov 4th, 2021 – MCMU



E Field bearing ° E of N in V/km @ MCMU Z



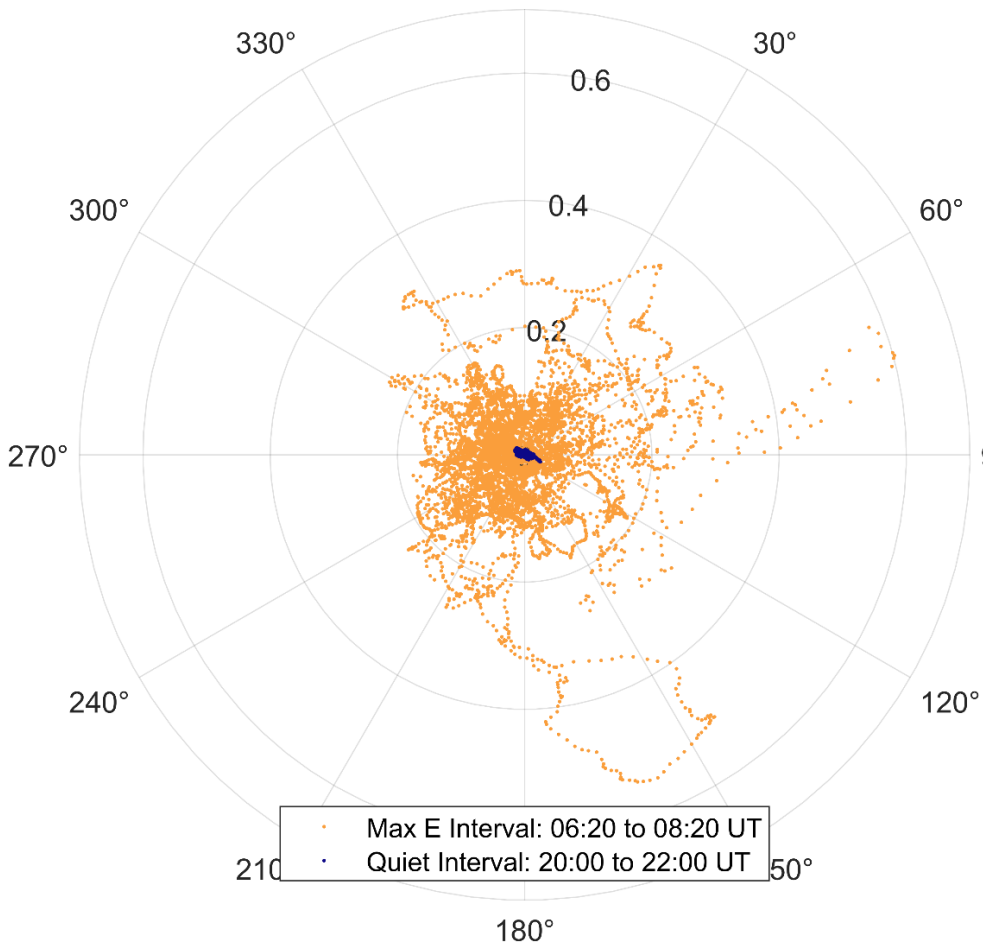
Max E field of 1.73 V/km @ MCMU on 04-Nov-2021 09:21:25 with bearing 246.2525° E of N



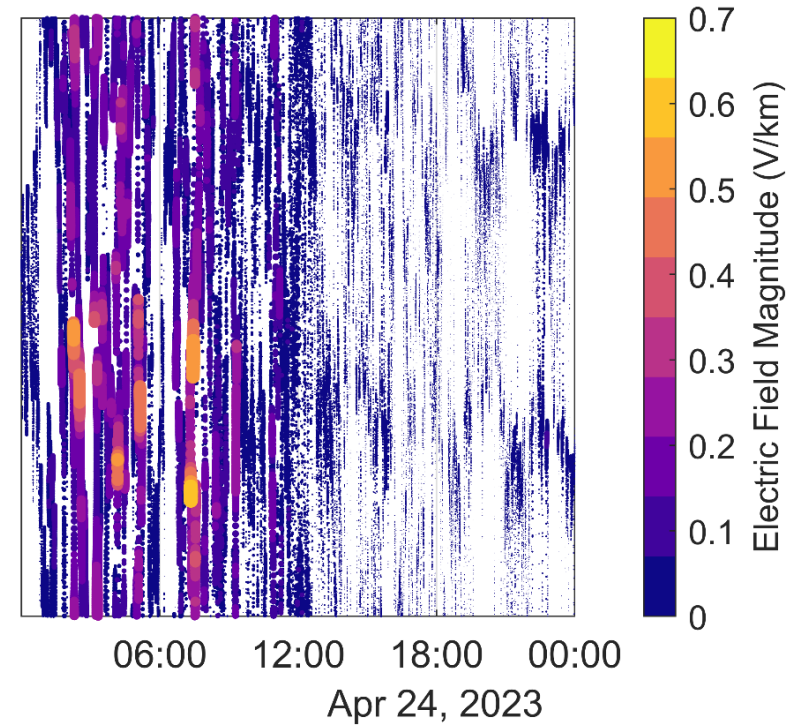
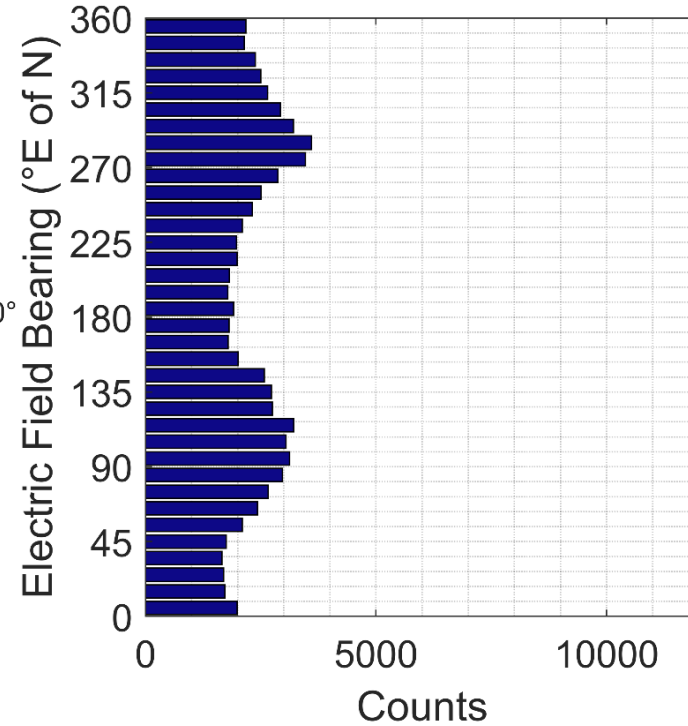
Synthetic Z: 100 Ω m Halfspace (1D)



E Field bearing ° E of N in V/km @ 1 Z



Max E field of 0.602 V/km @ 1 on 24-Apr-2023 07:20:28 with bearing 74.9439° E of N





Validate that large GIC is being driving in the Alberta network during moderate GMD events

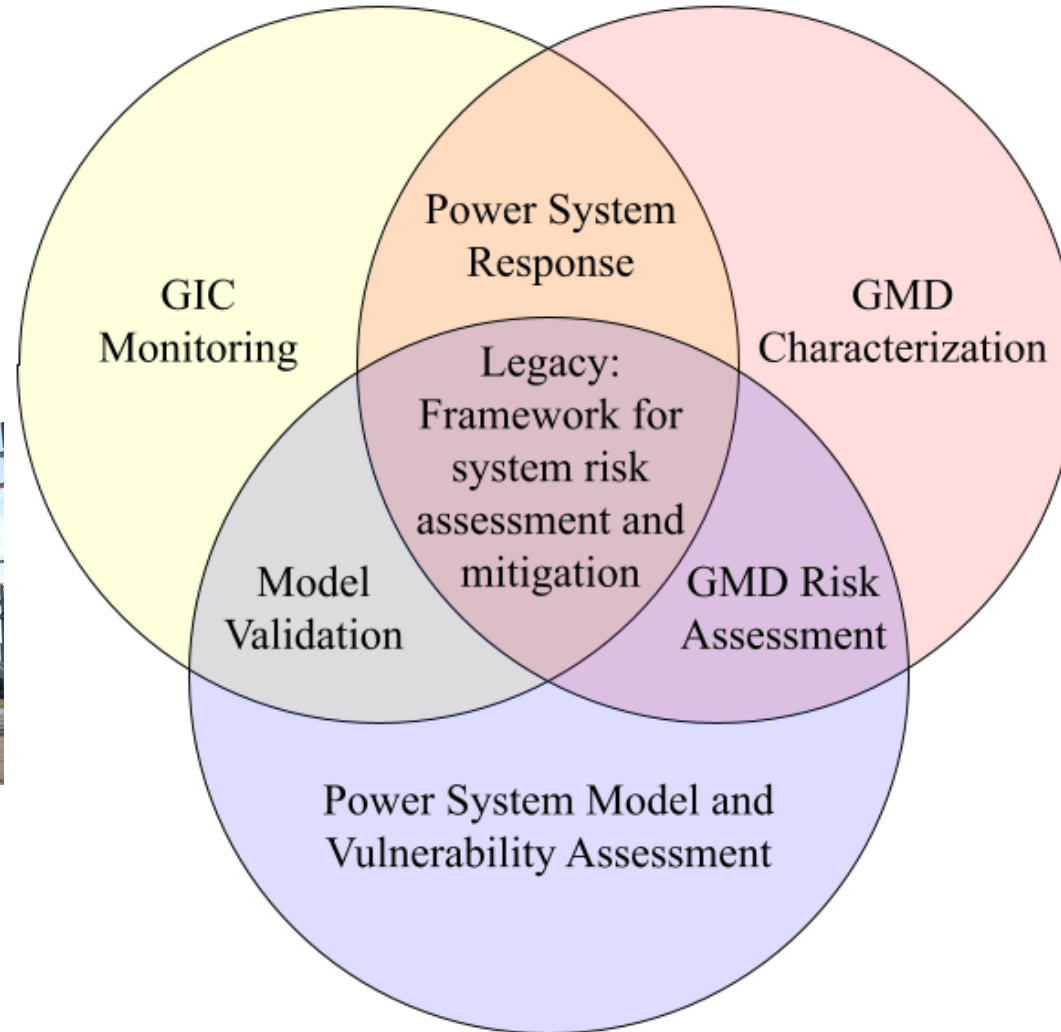
Phase and polarization characteristics of E is greatly influenced by the 3D impedance tensor, such that in a specific geological region E_x and E_y may be highly correlated

Implies that polarized E creates large GIC by adding together or cancelling based on the topology of the network

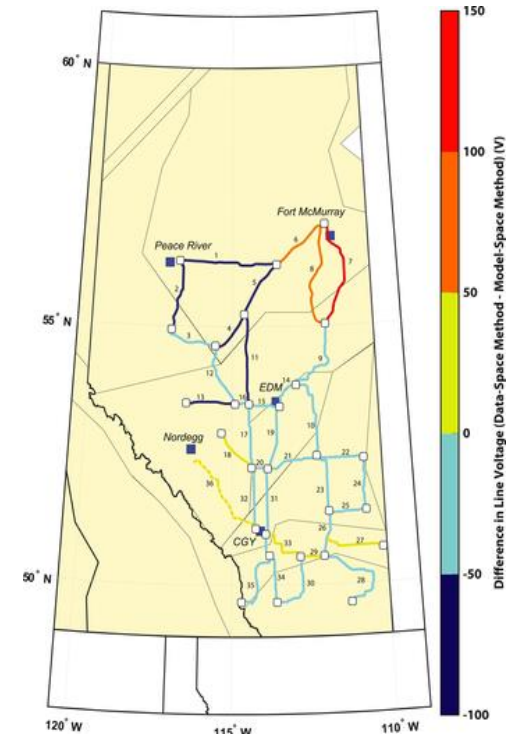
Proposed Project with Power Industry Collaboration



[www.auc.ab.ca]



[www.carisma.ca]



[Cordell et. al, 2021]

Relationship of research objectives categorized within three research themes.

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Contributors and Partnership: Ian Mann, David Milling, Andy Kale, and the CARISMA team, Colin Clark, AltaLink L.P (Ryan Cui, Ryan MacMullin, Eva Kelemen), Darcy Cordell, Martyn Unsworth, the AESO

Funding: NSERC Discovery Grant

Data Acknowledgement:

- Magnetic field data was provided by CARISMA, operated by the University of Alberta and funded by the Canadian Space Agency.
- Transformer neutral-to-ground current data and 500 kV transmission line information was provided by AltaLink LP, and the Alberta Electric System Operator (AESO).
- 3D impedance tensor data was provided by Dr. Darcy Cordell and Prof. Martyn Unsworth

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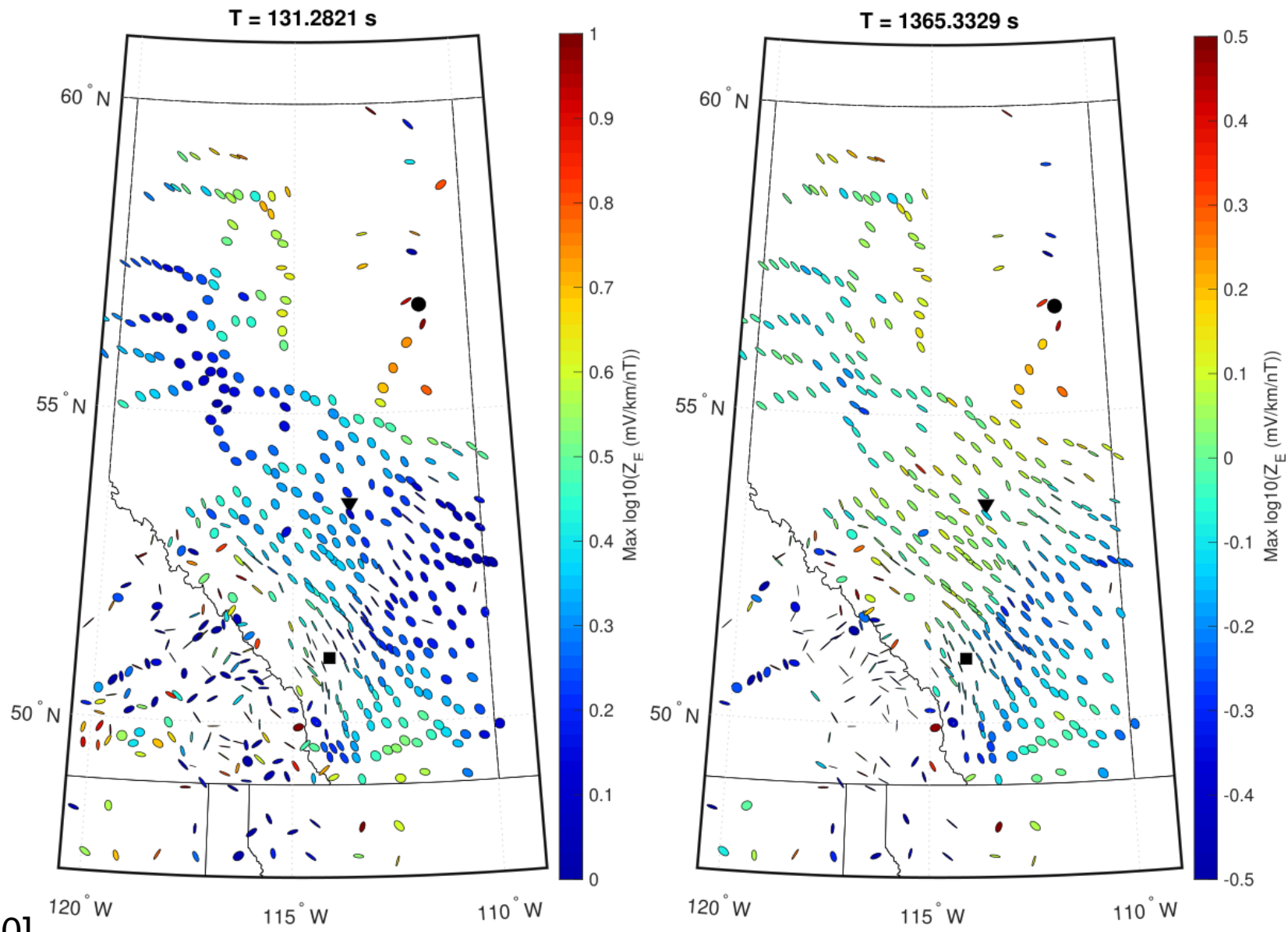
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Questions?

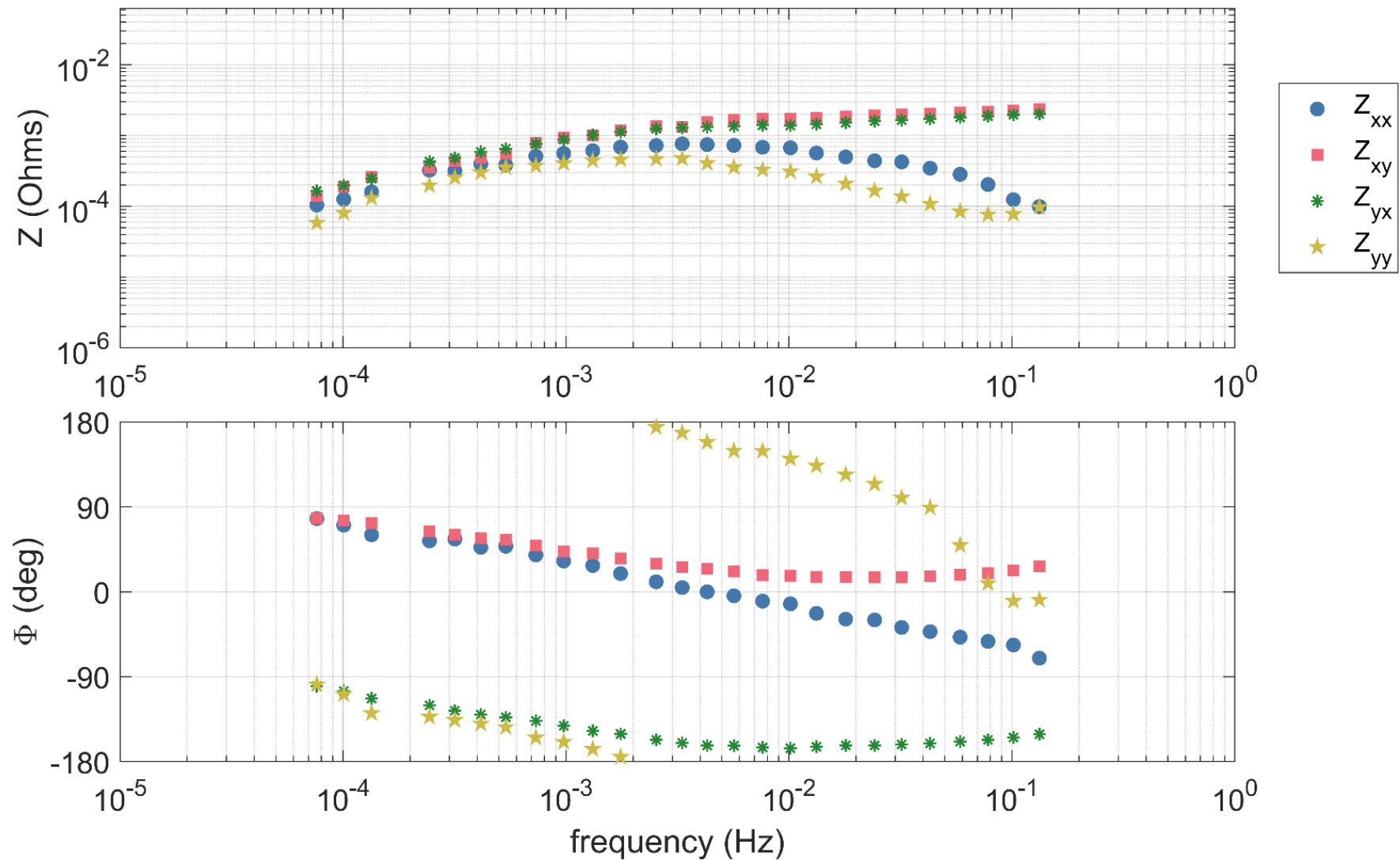
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Surface Impedance Measurements

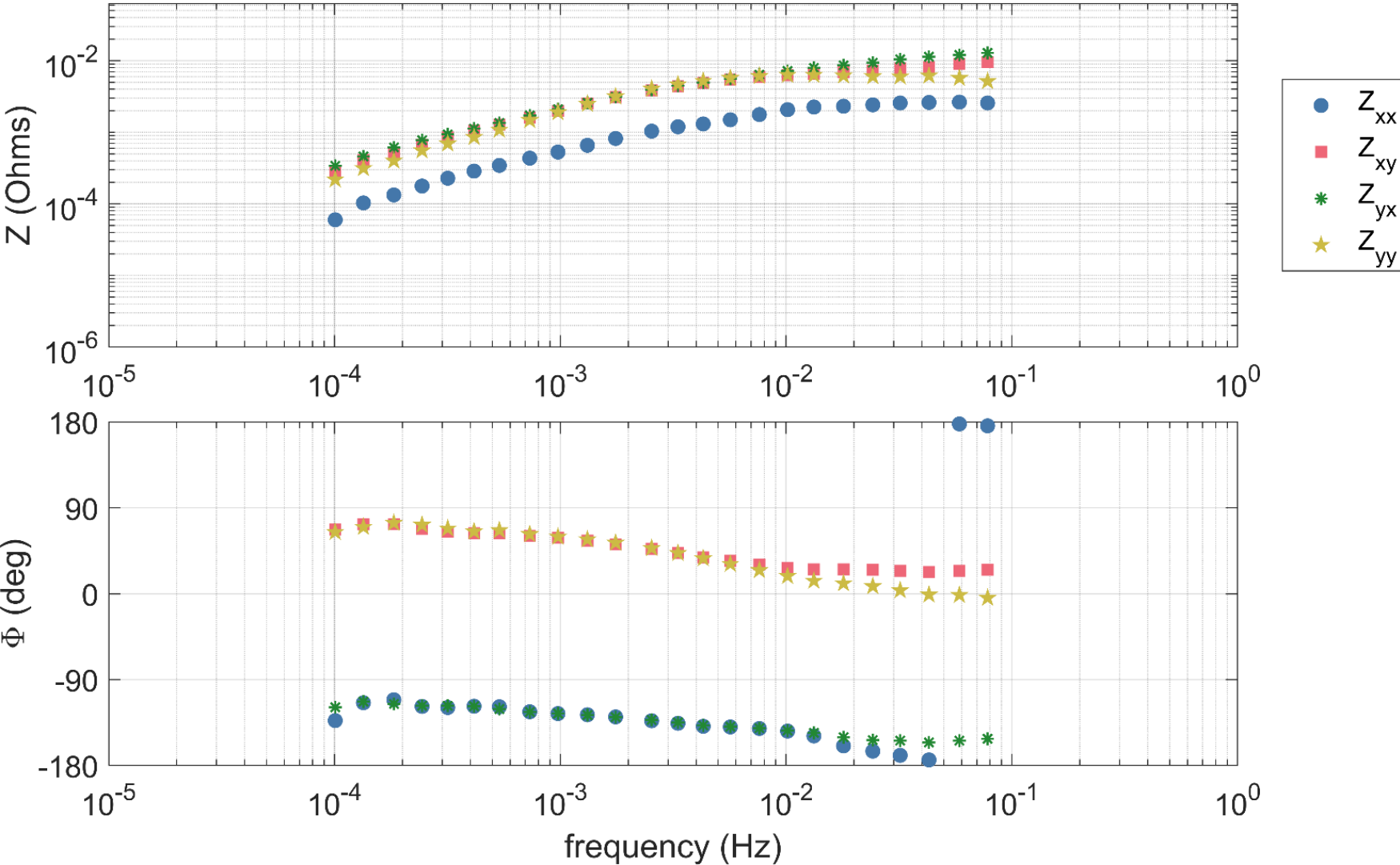


[After Love, et al 2020]

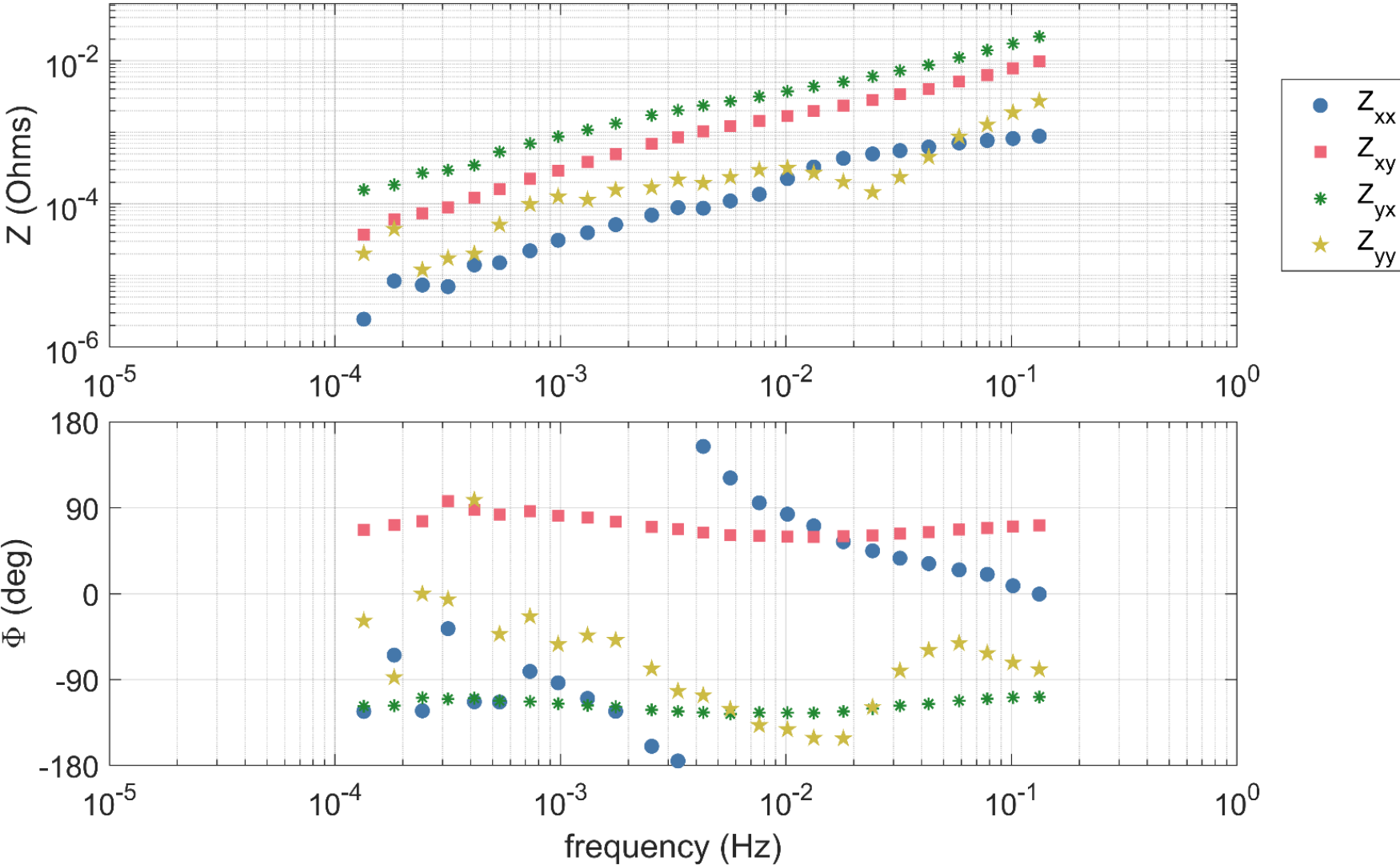
Surface Impedance and Phase: MSTK



Surface Impedance and Phase: MCMU



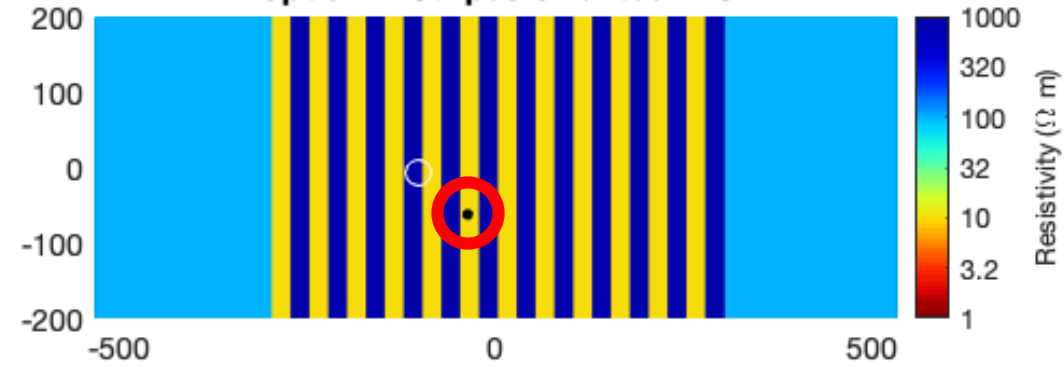
Surface Impedance and Phase: FCHP



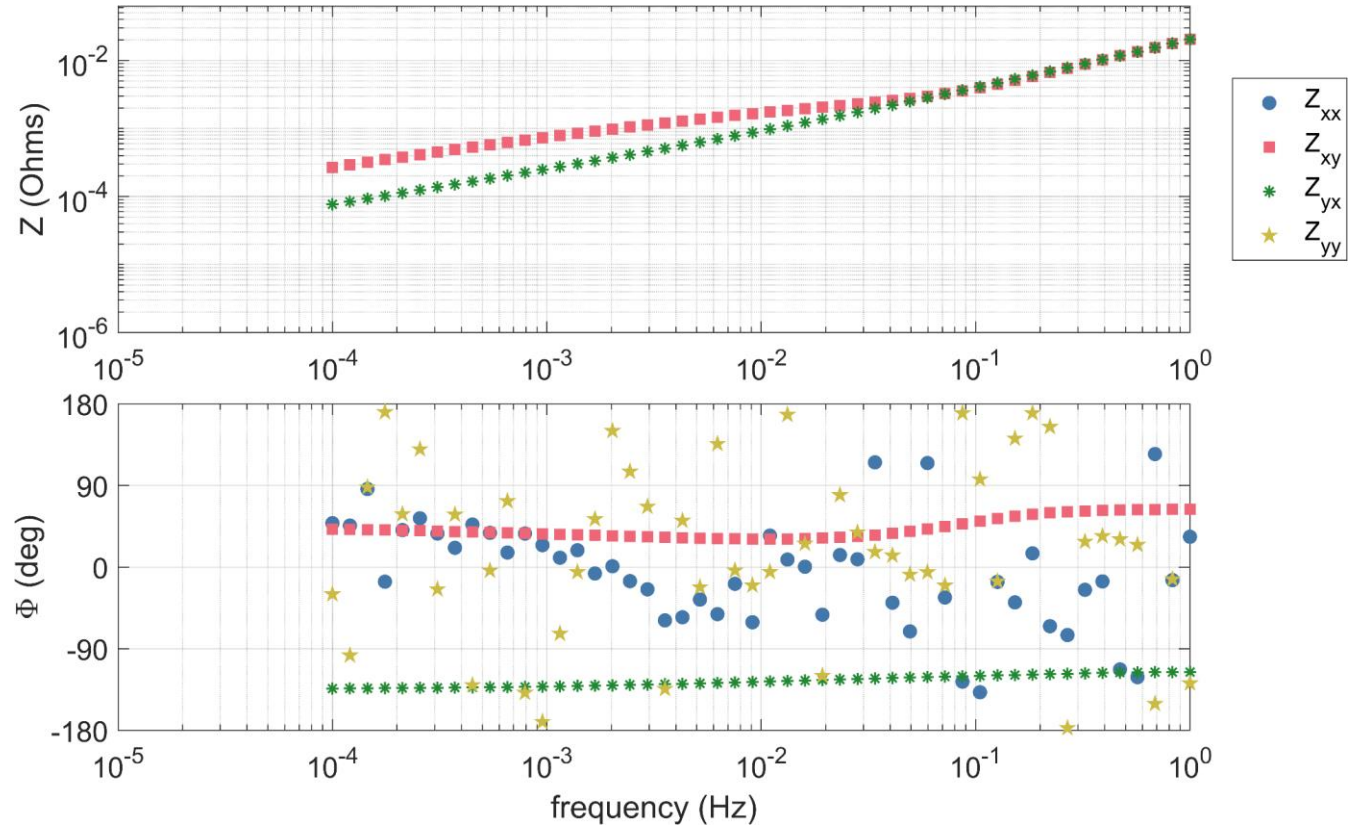
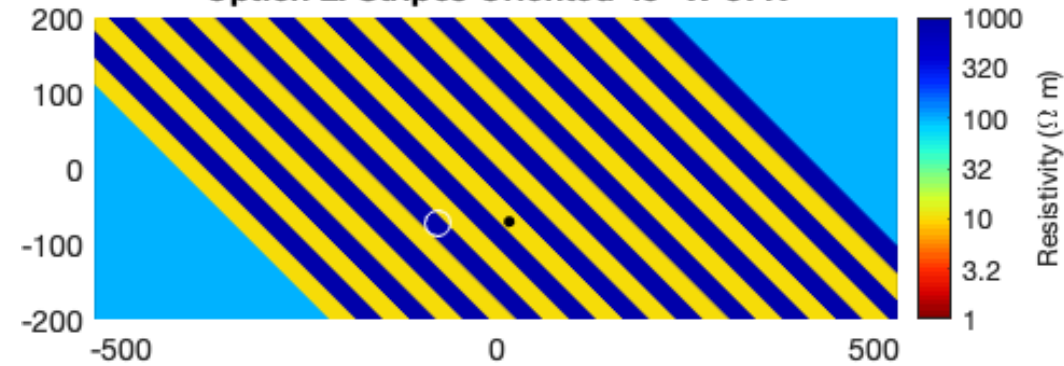
Synthetic Z: MT Site on N-S oriented conductor



Option 1: Stripes Oriented N-S



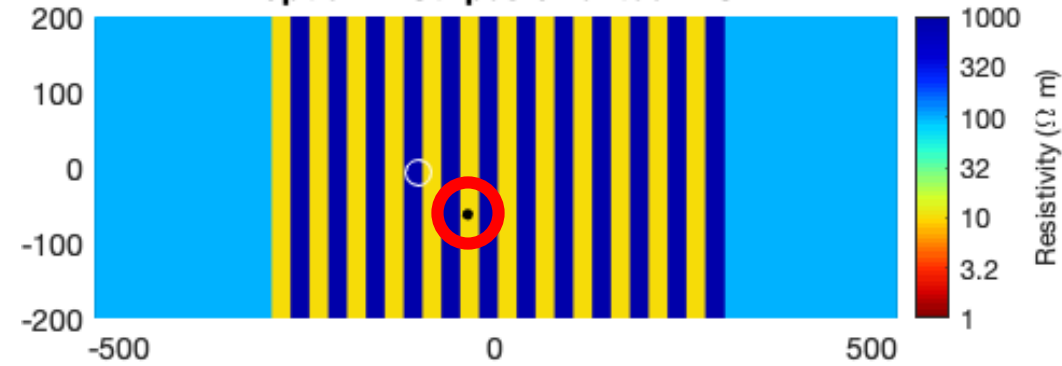
Option 2: Stripes Oriented 45° W of N



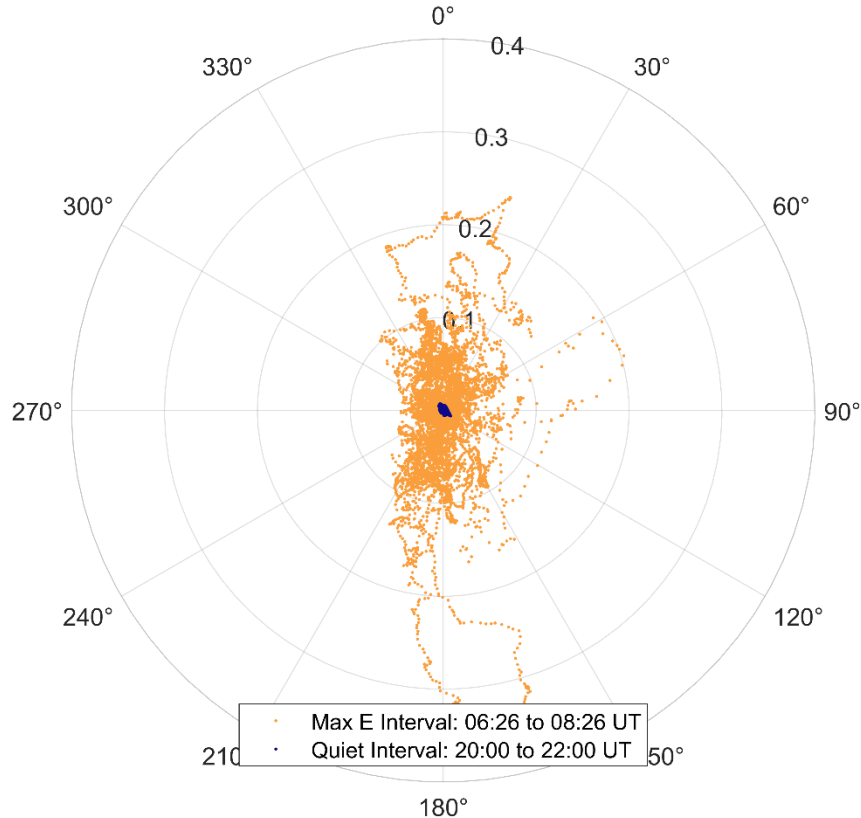
Synthetic Z: MT Site on N-S oriented conductor



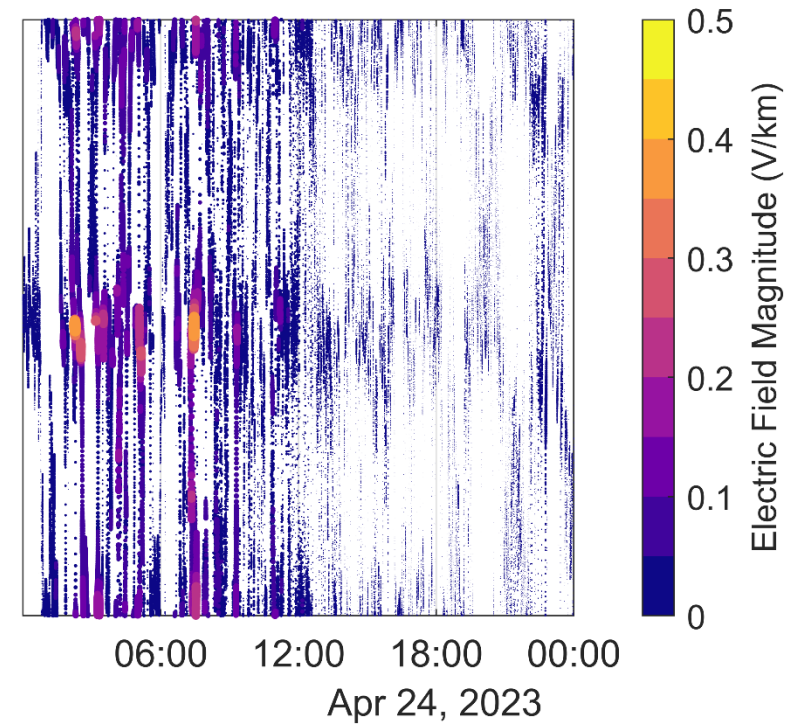
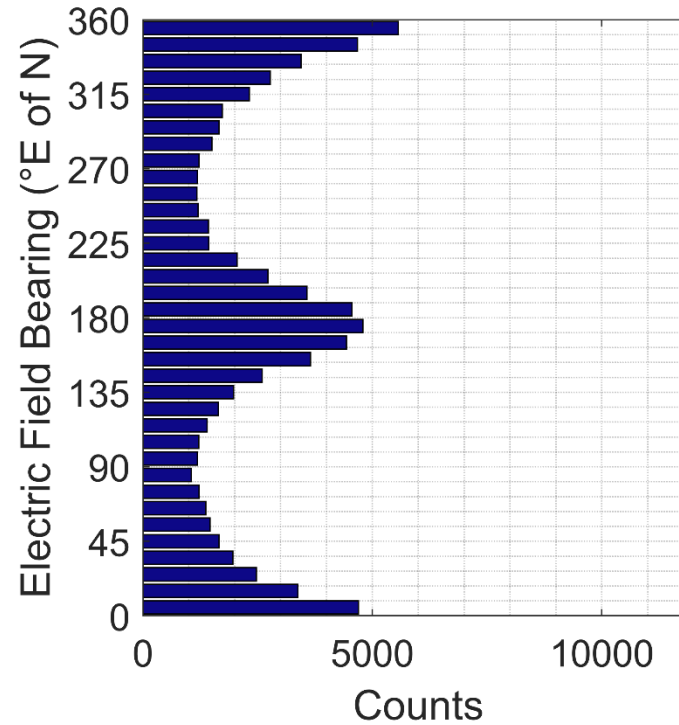
Option 1: Stripes Oriented N-S



E Field bearing ° E of N in V/km @ 7 Z



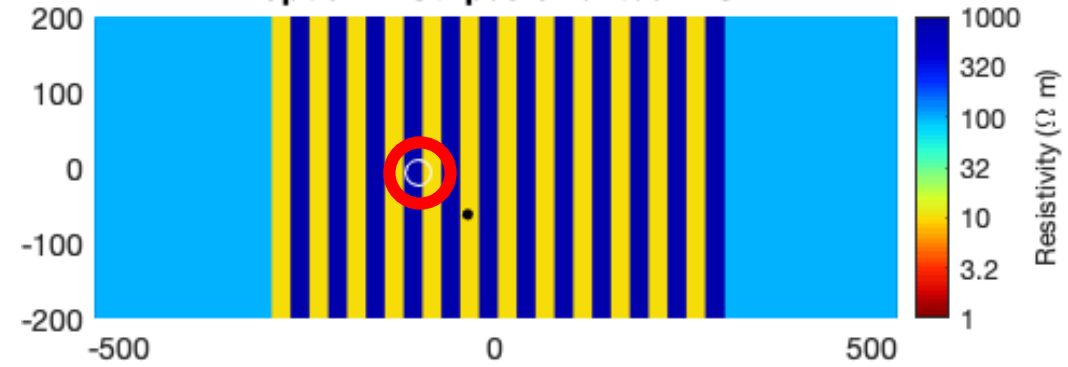
Max E field of 0.384 V/km @ 7 on 24-Apr-2023 07:26:47 with bearing 174.2517° E of N



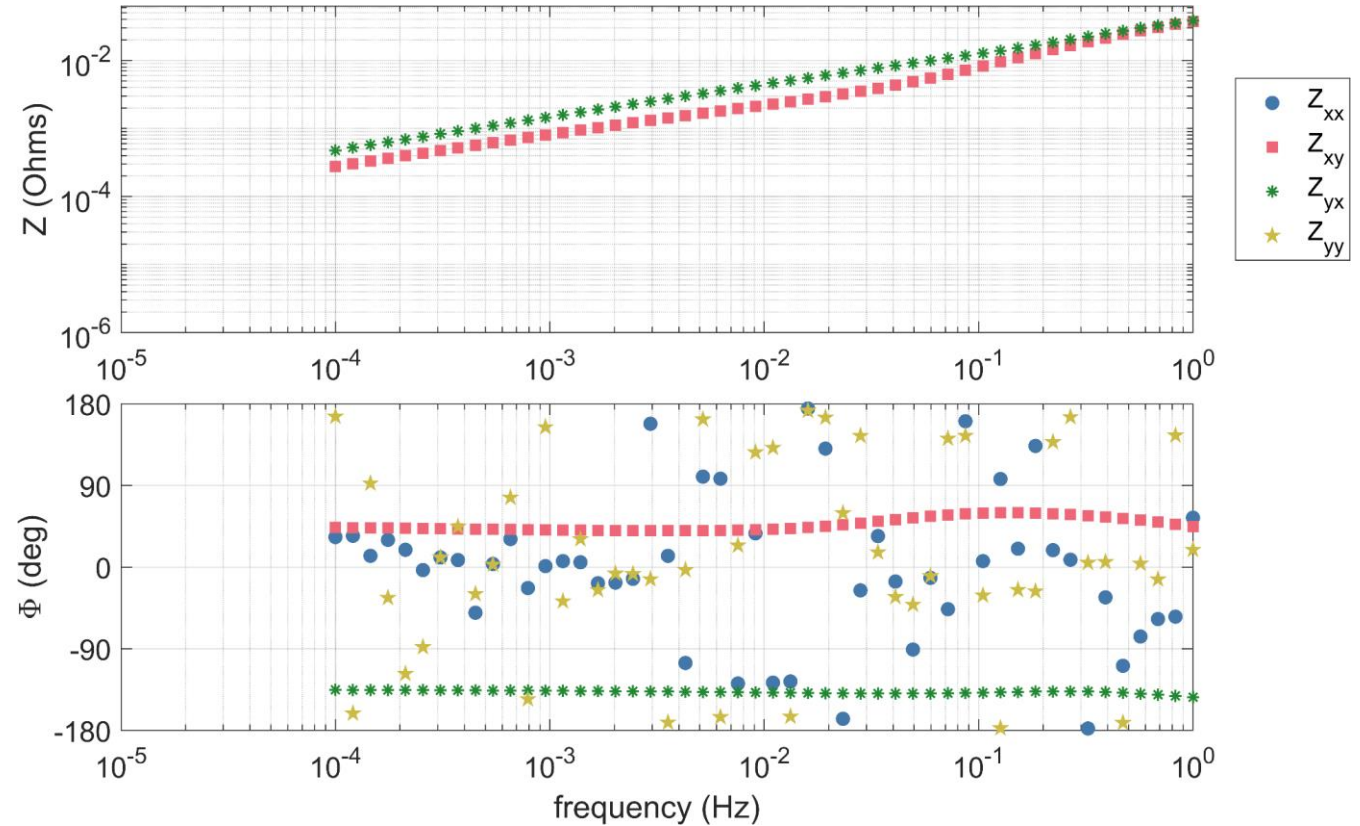
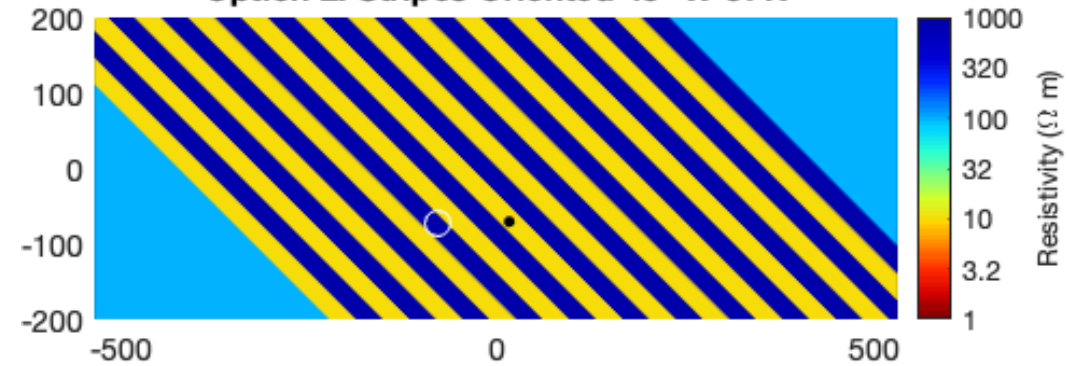
Synthetic Z: MT Site on N-S oriented resistor



Option 1: Stripes Oriented N-S



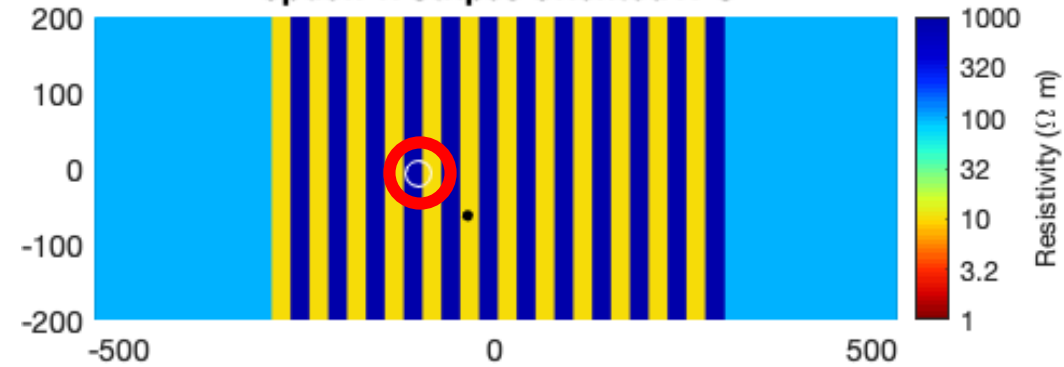
Option 2: Stripes Oriented 45° W of N



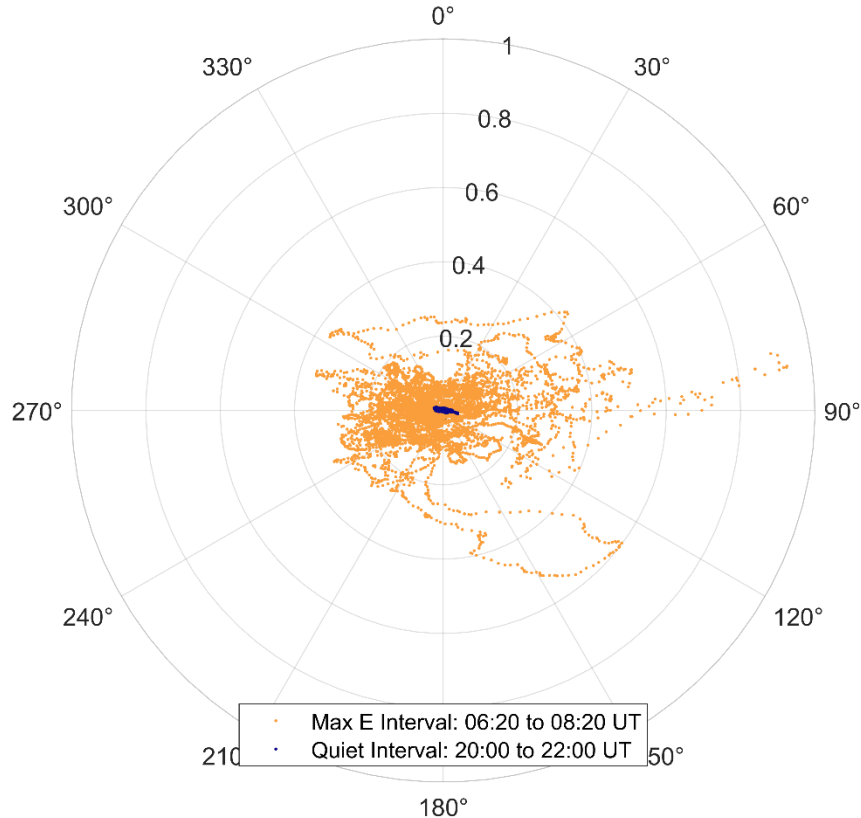
Synthetic Z: MT Site on N-S oriented resistor



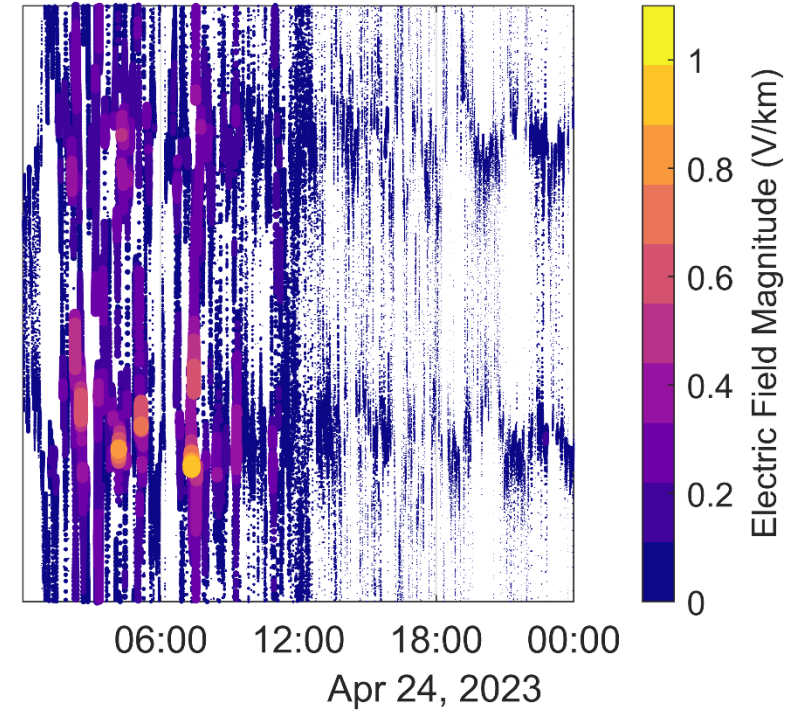
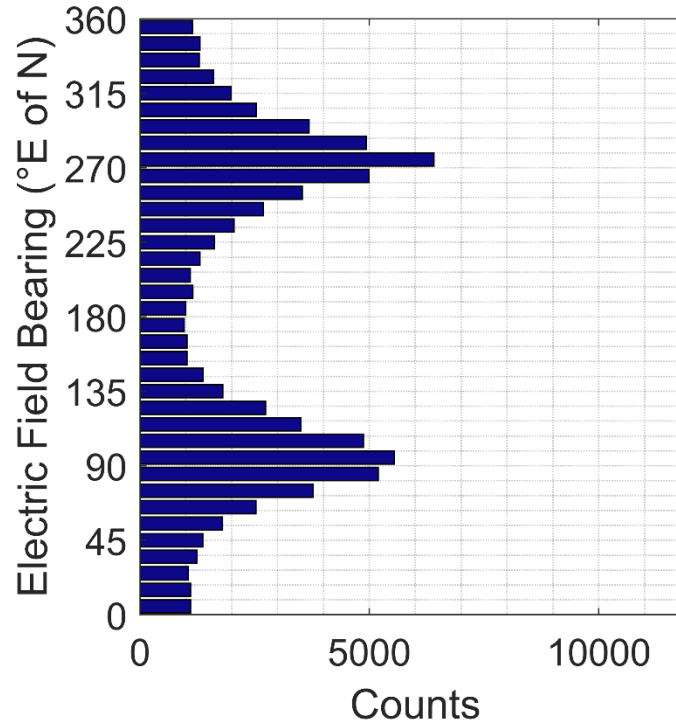
Option 1: Stripes Oriented N-S



E Field bearing ° E of N in V/km @ 8 Z



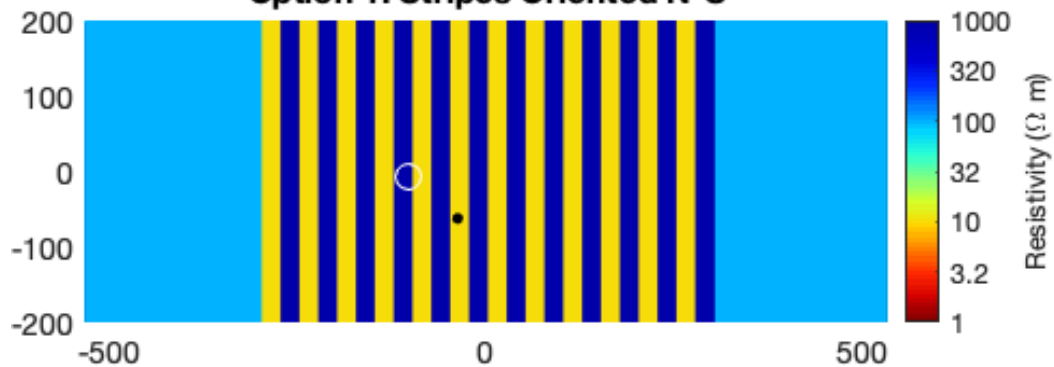
Max E field of 0.932 V/km @ 8 on 24-Apr-2023 07:20:29 with bearing 82.6598° E of N



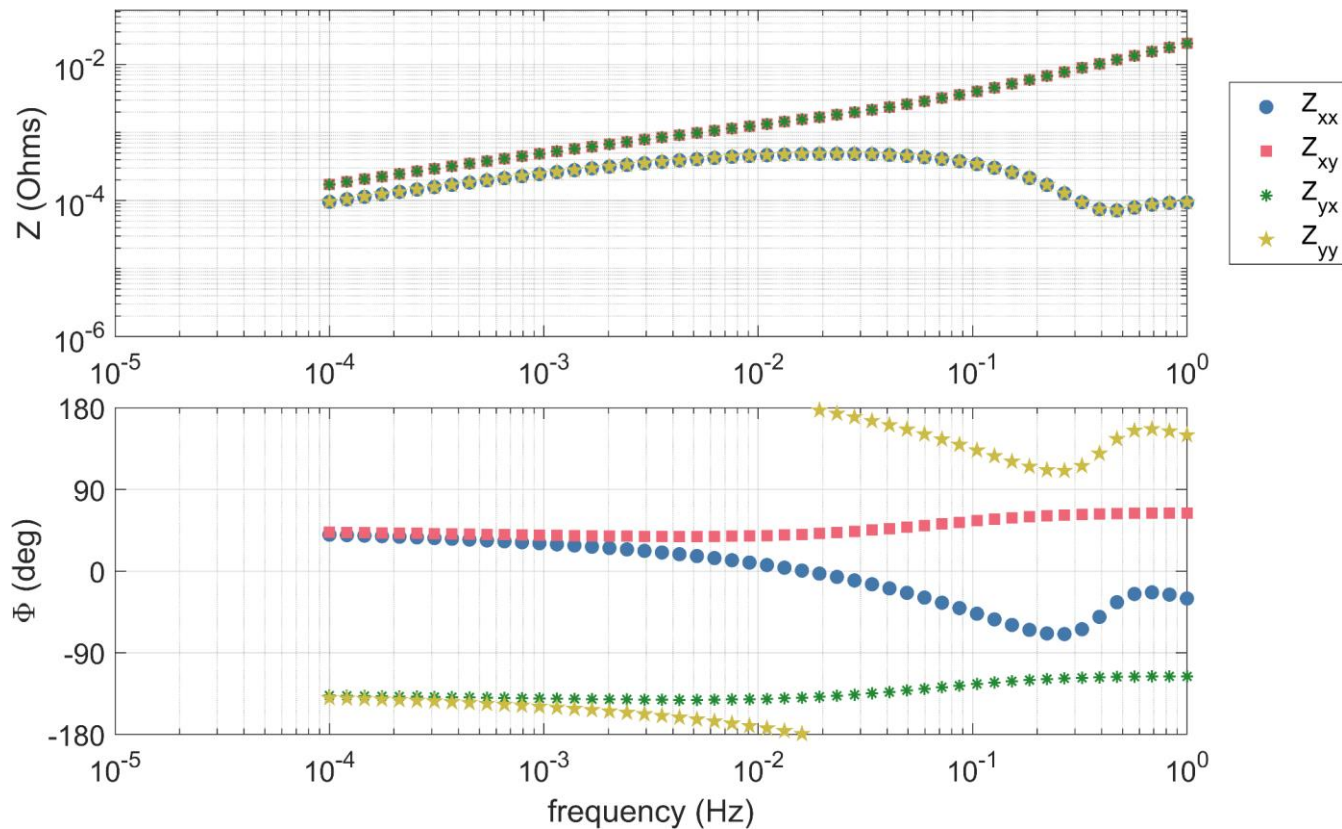
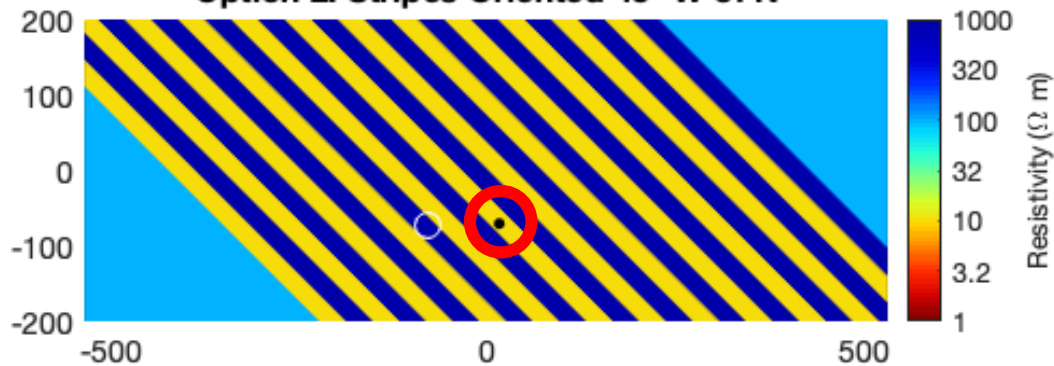
Synthetic Z: MT Site on conductor oriented 45° W of N



Option 1: Stripes Oriented N-S



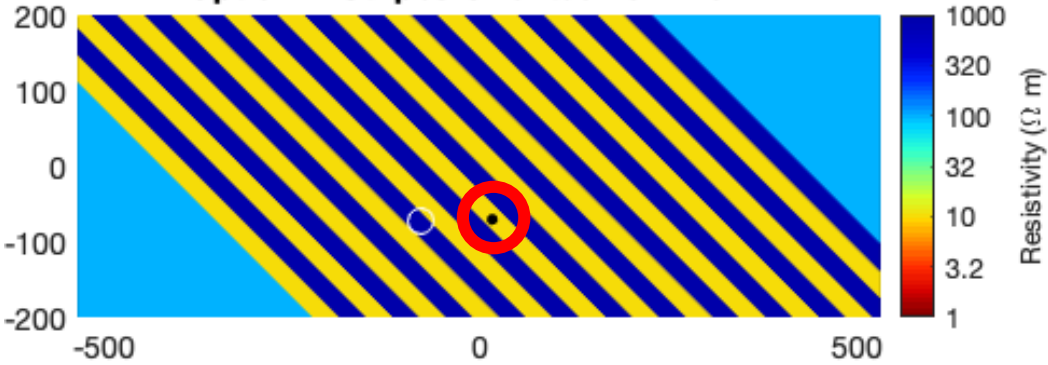
Option 2: Stripes Oriented 45° W of N



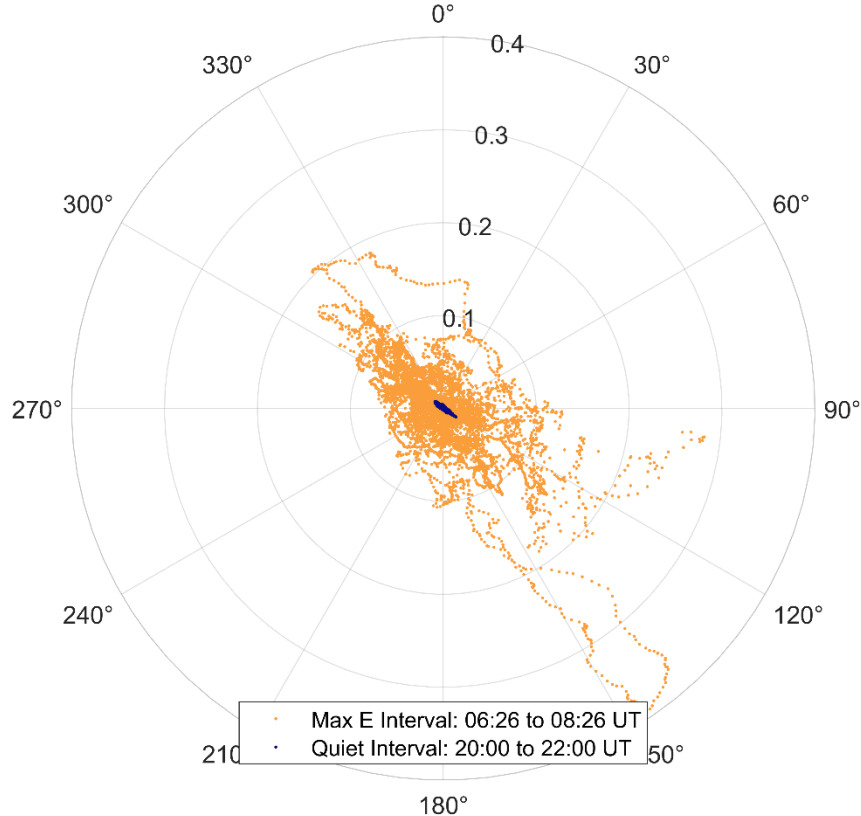
Synthetic Z: MT Site on conductor oriented 45° W of N



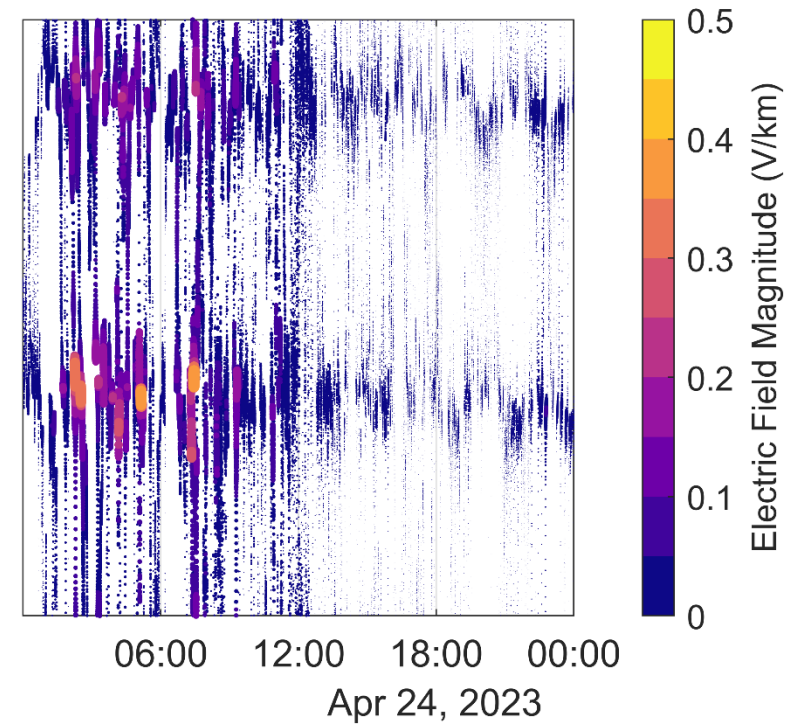
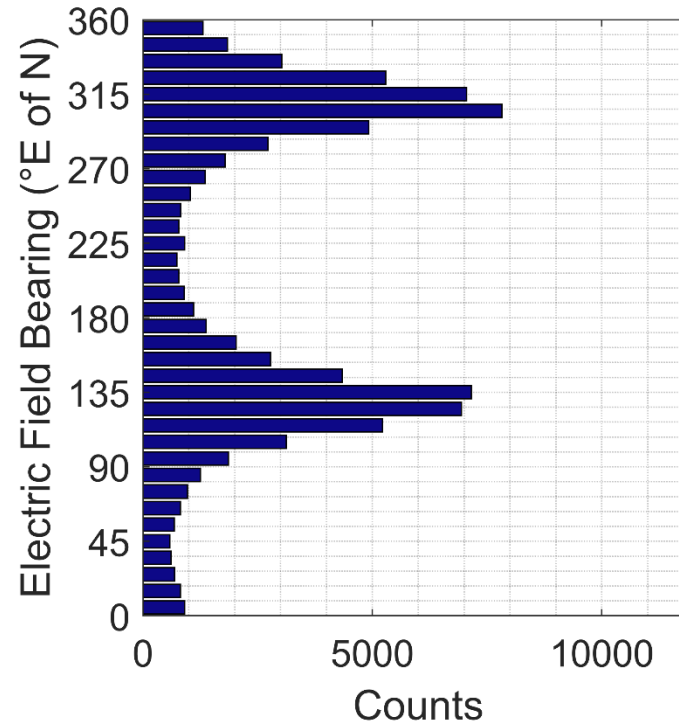
Option 2: Stripes Oriented 45° W of N



E Field bearing ° E of N in V/km @ 7 Z



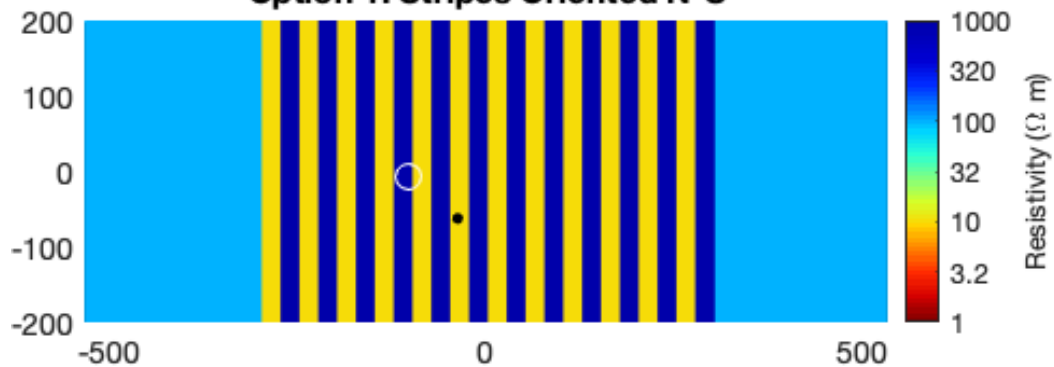
Max E field of 0.393 V/km @ 7 on 24-Apr-2023 07:26:39 with bearing 145.4788° E of N



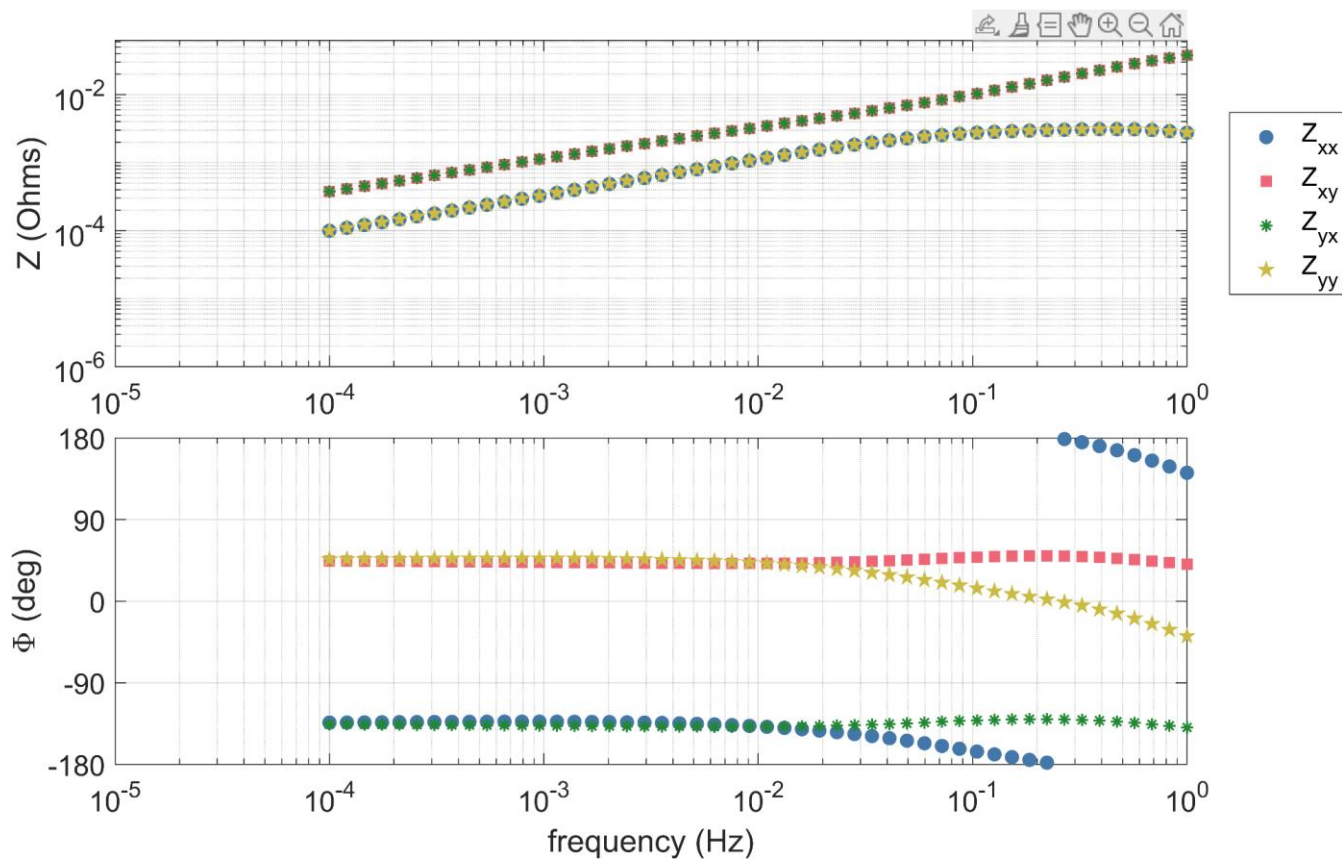
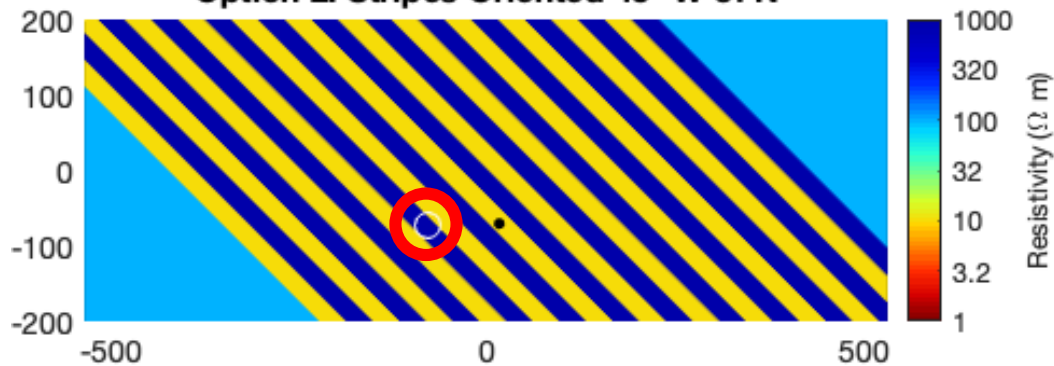
Synthetic Z: MT Site on resistor oriented 45° W of N



Option 1: Stripes Oriented N-S



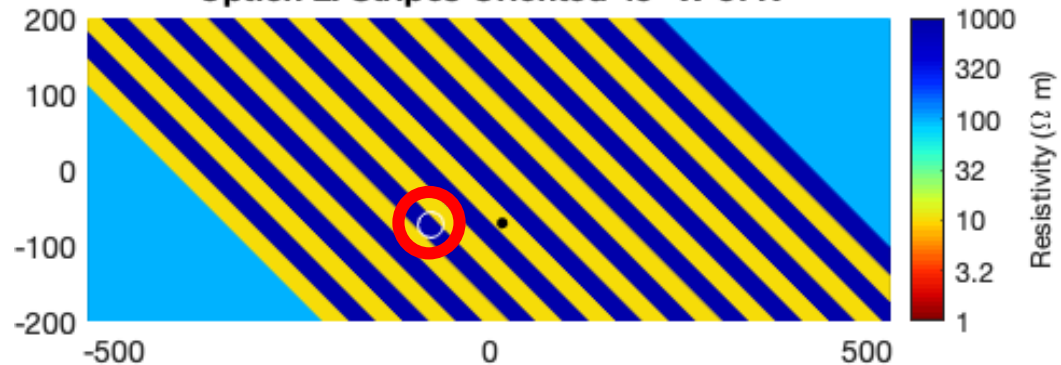
Option 2: Stripes Oriented 45° W of N



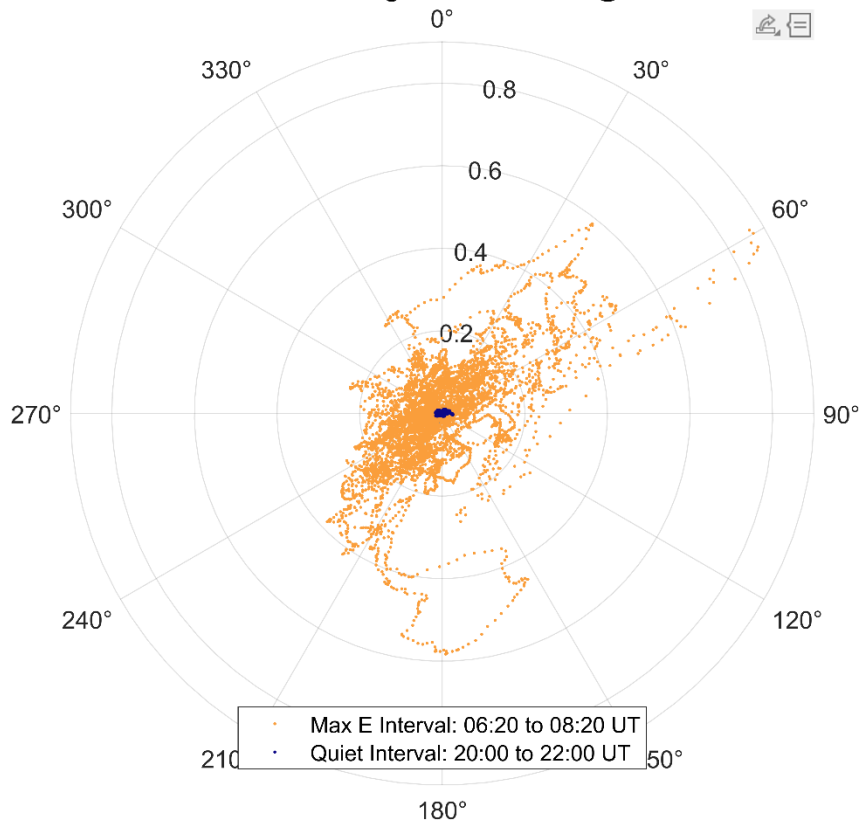
Synthetic Z: MT Site on resistor oriented 45° W of N



Option 2: Stripes Oriented 45° W of N



E Field bearing ° E of N in V/km @ 8 Z



Max E field of 0.87 V/km @ 8 on 24-Apr-2023 07:20:31 with bearing 59.9213° E of N

