Estimating the Geoelectric Field and Transmission Line Voltages During a Geomagnetic Storm in Alberta, Canada Using Magnetotelluric Impedance Data

October 12 Aurora, Edmonton, AB, Canada
©2021 Chong Wei

Darcy Cordell[1,2], Martyn J. Unsworth[1], Benjamin Lee[1], Cedar Hanneson[1], David K. Milling[1], Ian R. Mann[1]

[1] University of Alberta

[2] Georgia Tech

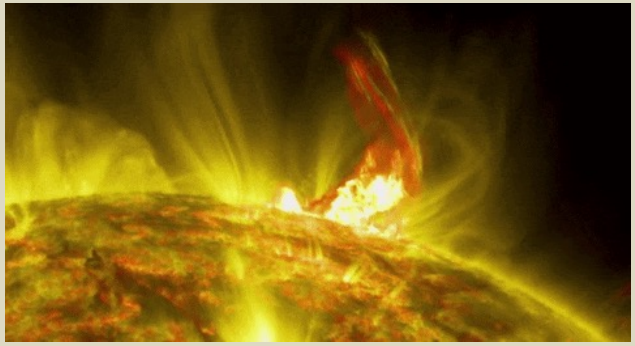
American Geophysical Union Fall Meeting, New Orleans, LA, USA
December 15, 2021

NSERC CRSNG

Background Information: Space Weather Hazards

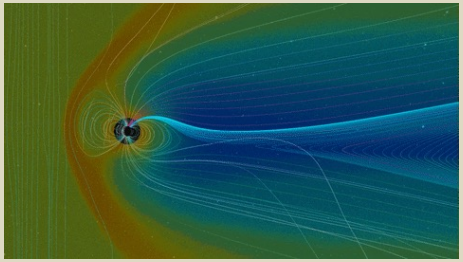
CME

Coronal Mass Ejections
Where: Sun
Who: Heliophysics



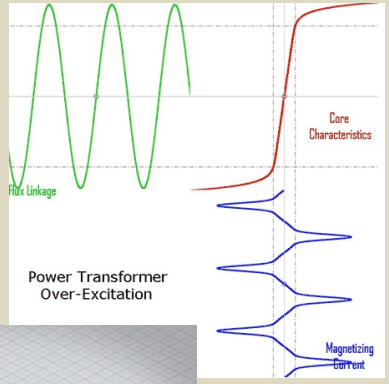
GMD

Geomagnetic Disturbance
Where: Sky
Who: Space Physics



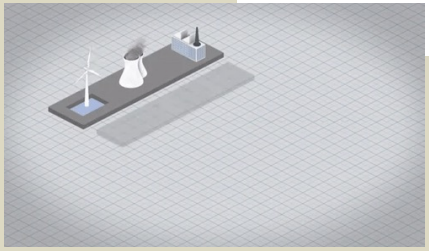
Geoele c Fields

The Induction
Where: Earth
Who: Geophysics



GIC

Geomagnetically-Induced Currents
Where: Power Transmission Networks
Who: Electrical Engineering

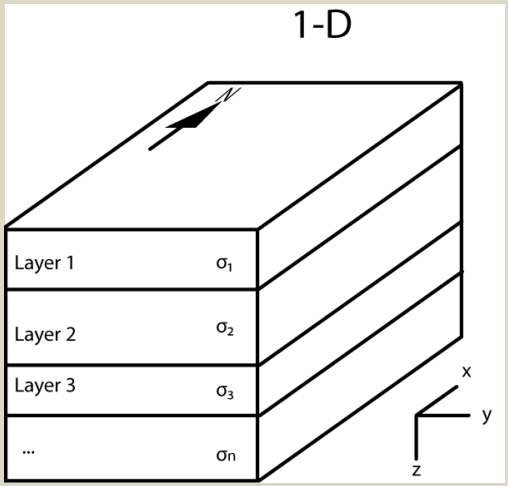


Background Information: Geoelectric Field Modelling

"1-D Model-Space Method"[1]

Common assumption: Locally 1-D Earth

$$\begin{bmatrix} E_x(\omega) \\ E_y(\omega) \end{bmatrix} = \begin{bmatrix} 0 & Z(\omega) \\ -Z(\omega) & 0 \end{bmatrix} \begin{bmatrix} H_x(\omega) \\ H_y(\omega) \end{bmatrix}$$

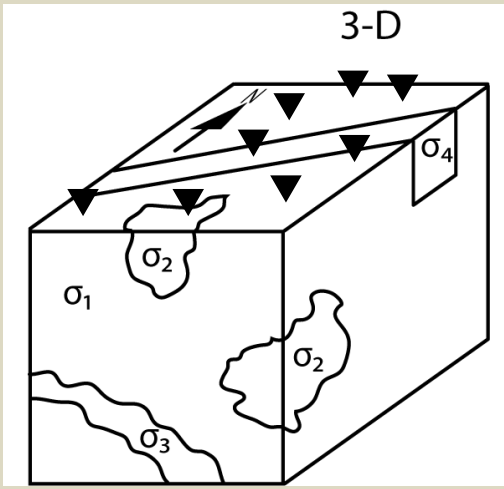


Impedance is calculated using *a priori* 1-D conductivity model

"Data-Space Method"[1]

Ability to Capture 3-D Earth Structure

$$\begin{bmatrix} E_x(\omega) \\ E_y(\omega) \end{bmatrix} = \begin{bmatrix} Z_{xx}(\omega) & Z_{xy}(\omega) \\ Z_{yx}(\omega) & Z_{yy}(\omega) \end{bmatrix} \begin{bmatrix} H_x(\omega) \\ H_y(\omega) \end{bmatrix}$$

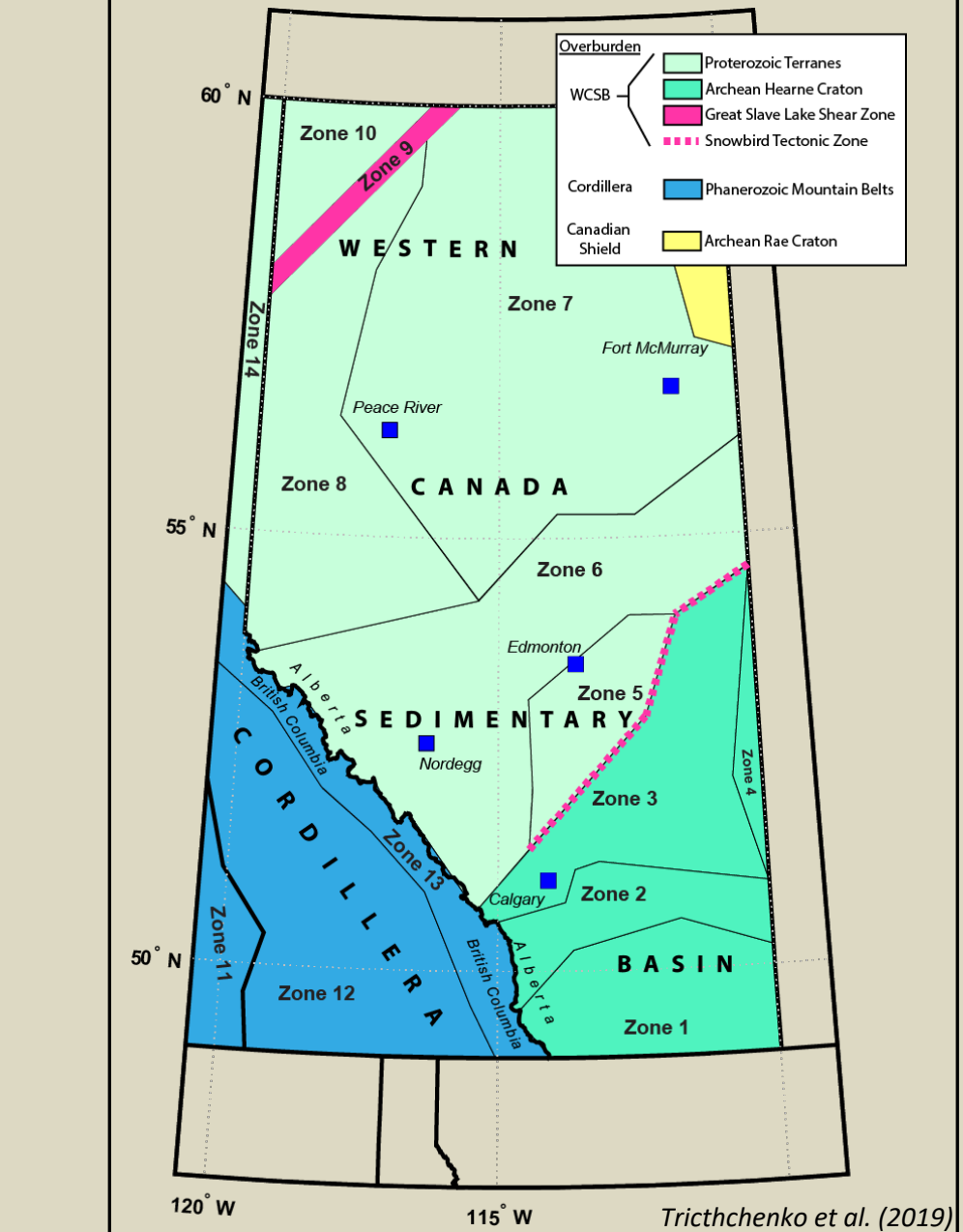


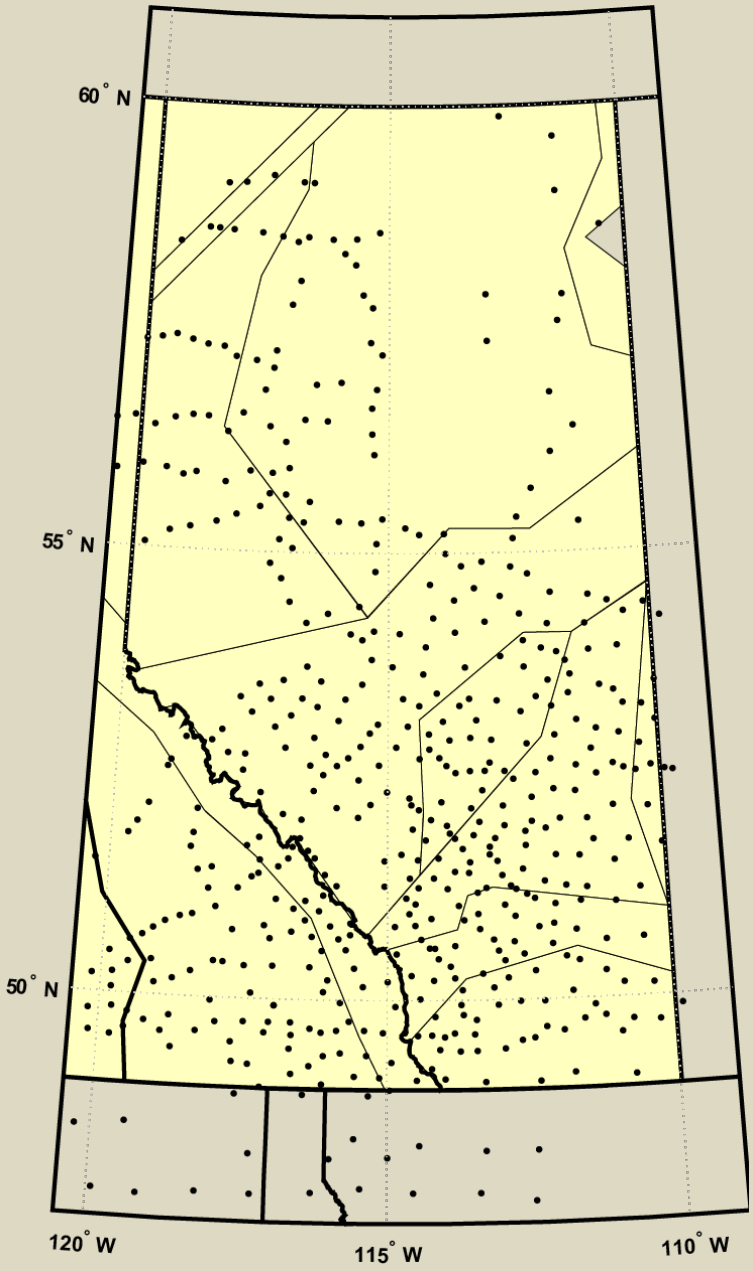
Impedance is measured using magnetotelluric instruments in the field

Question: Are there significant differences depending on the method you use?

[1]*Kelbert (2020)*

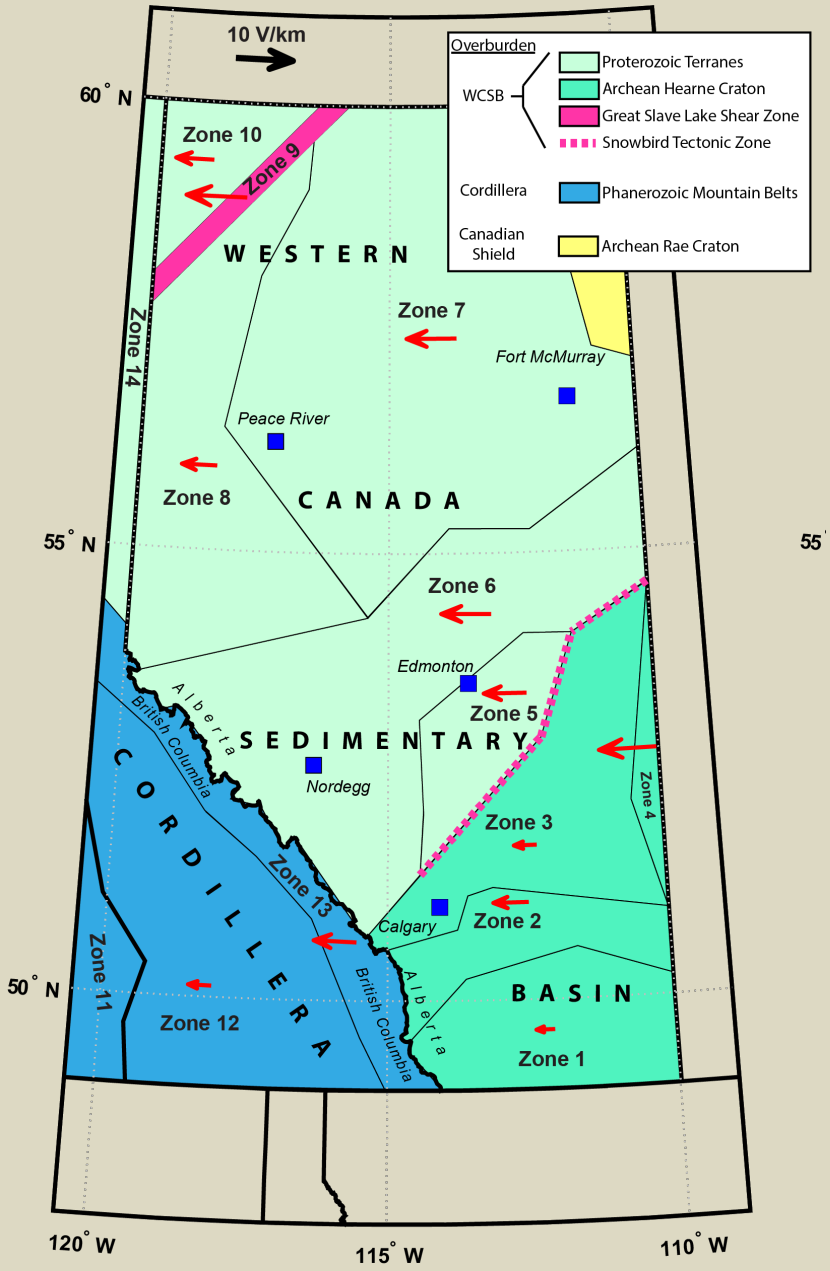
Background Information: Alberta Geology

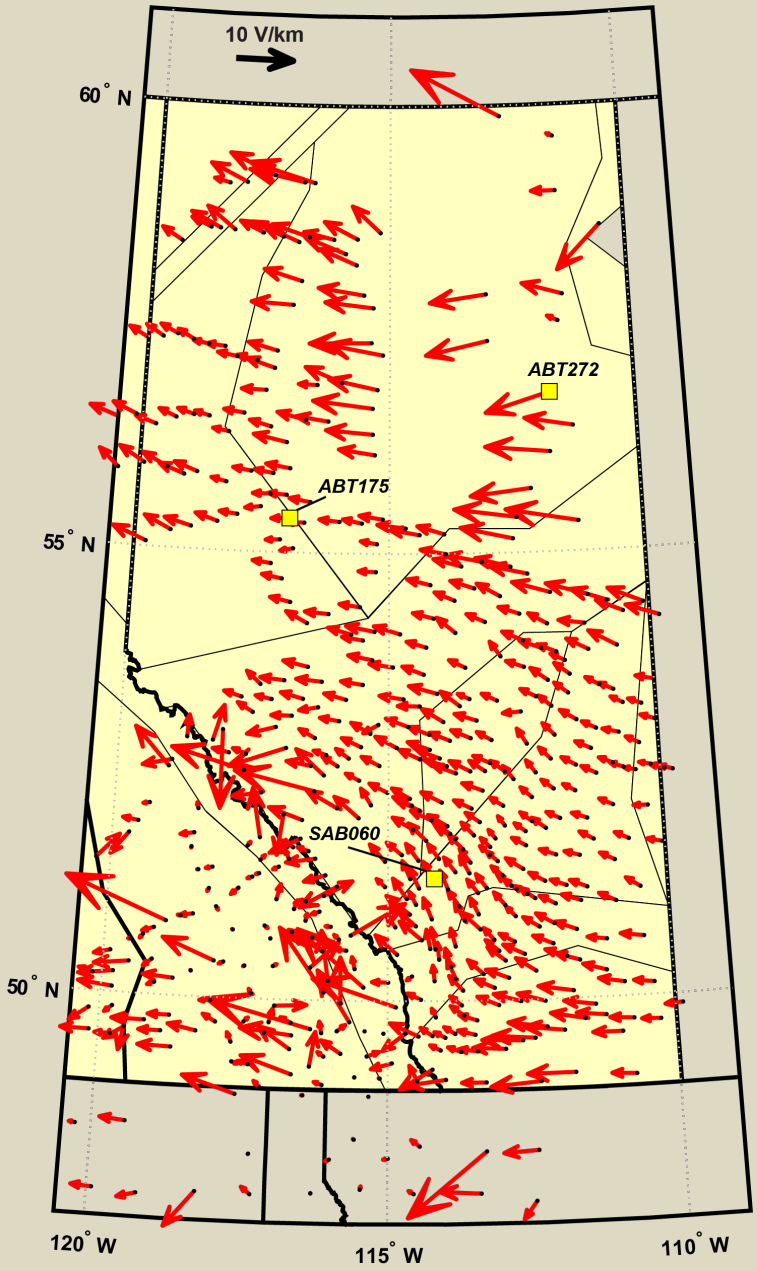




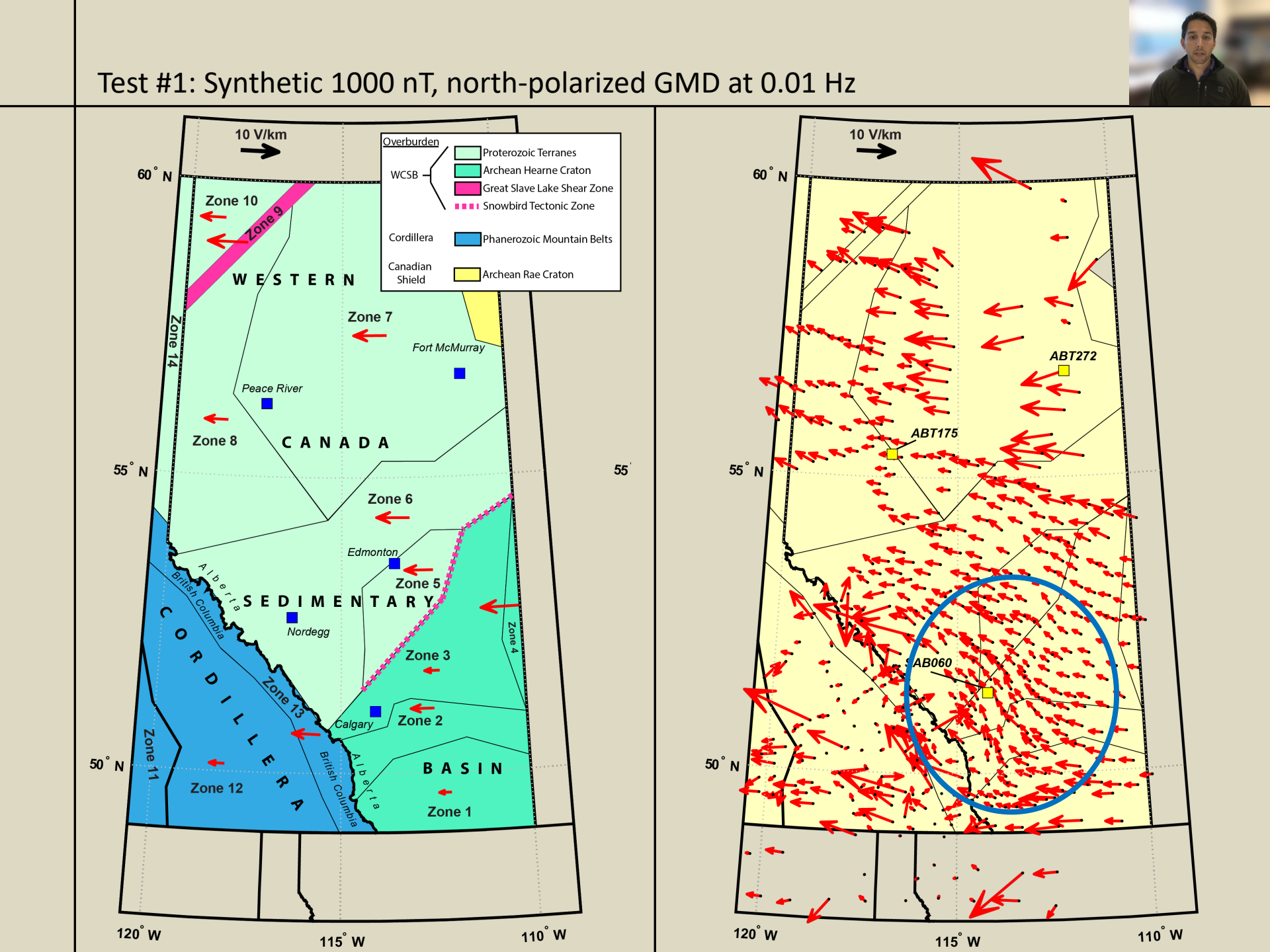
Tricthchenko et al. (2019)

Test #1: Synthetic 1000 nT, north-polarized GMD at 0.01 Hz

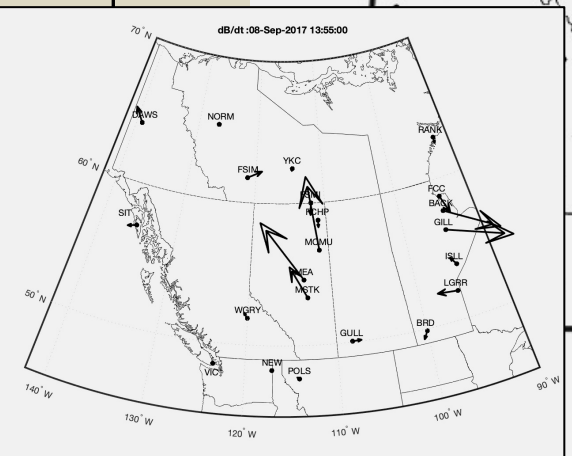




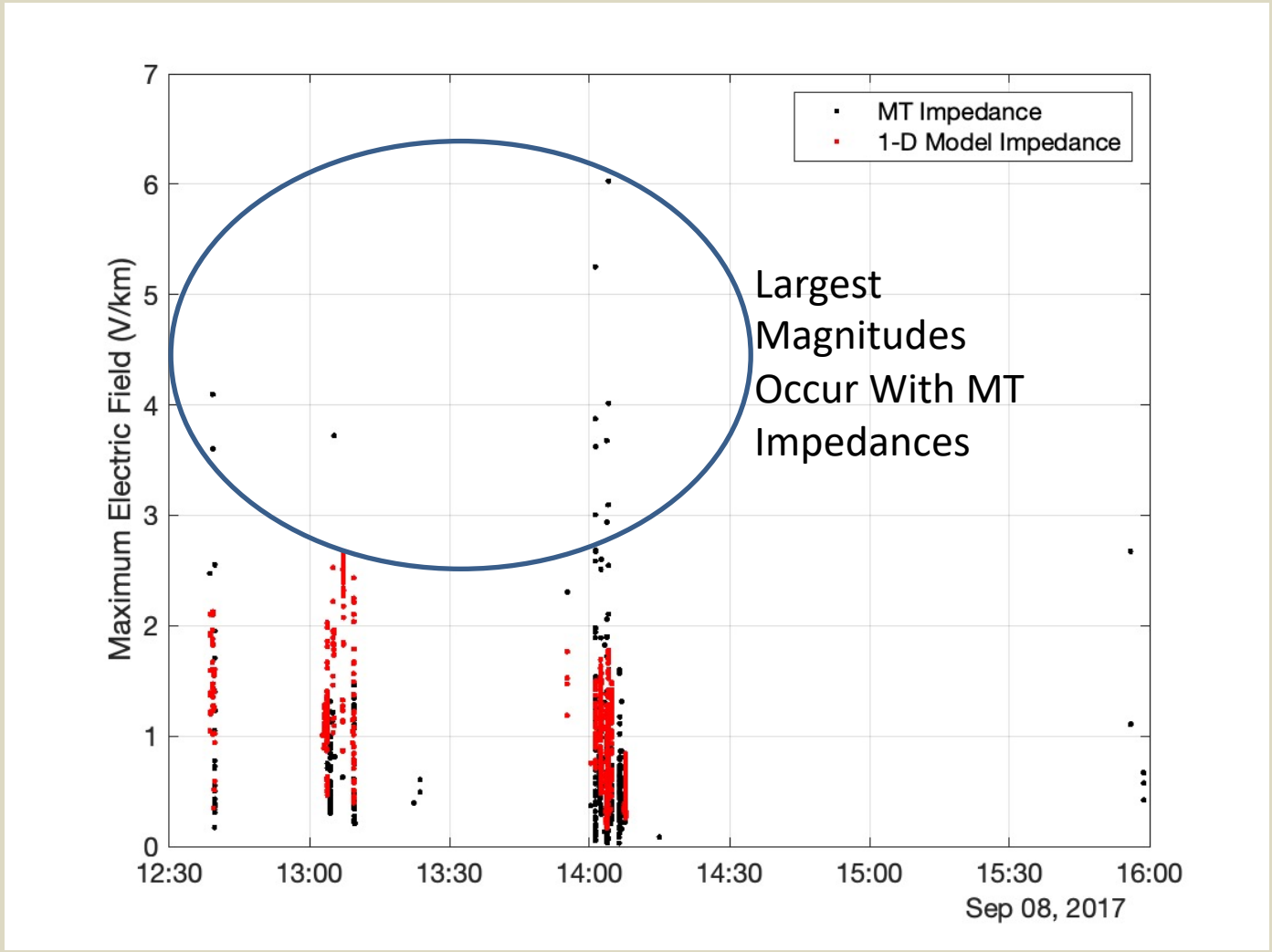
Test #1: Synthetic 1000 nT, north-polarized GMD at 0.01 Hz



Test #2: Real Storm from September 8, 2017 in Time-Domain

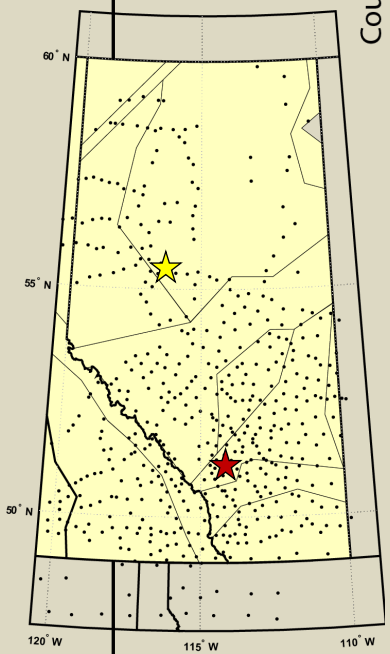


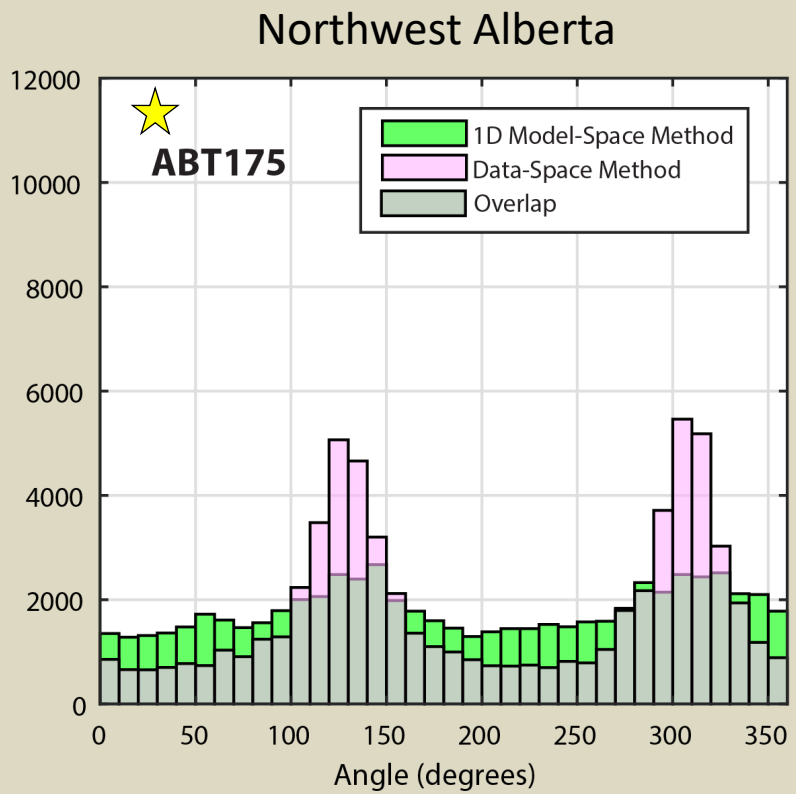
Test #2: Peak Geoelectric Field Magnitude

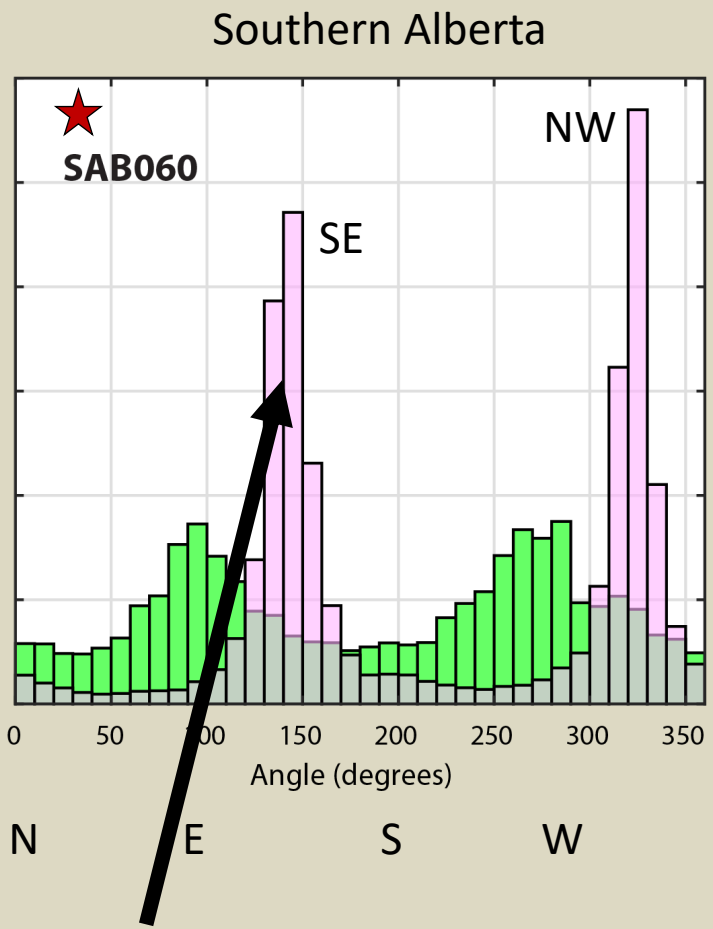


Test #2: Direction

- Direction of the E-field computed at all times (06:00:00 to 23:59:59) for 2 locations

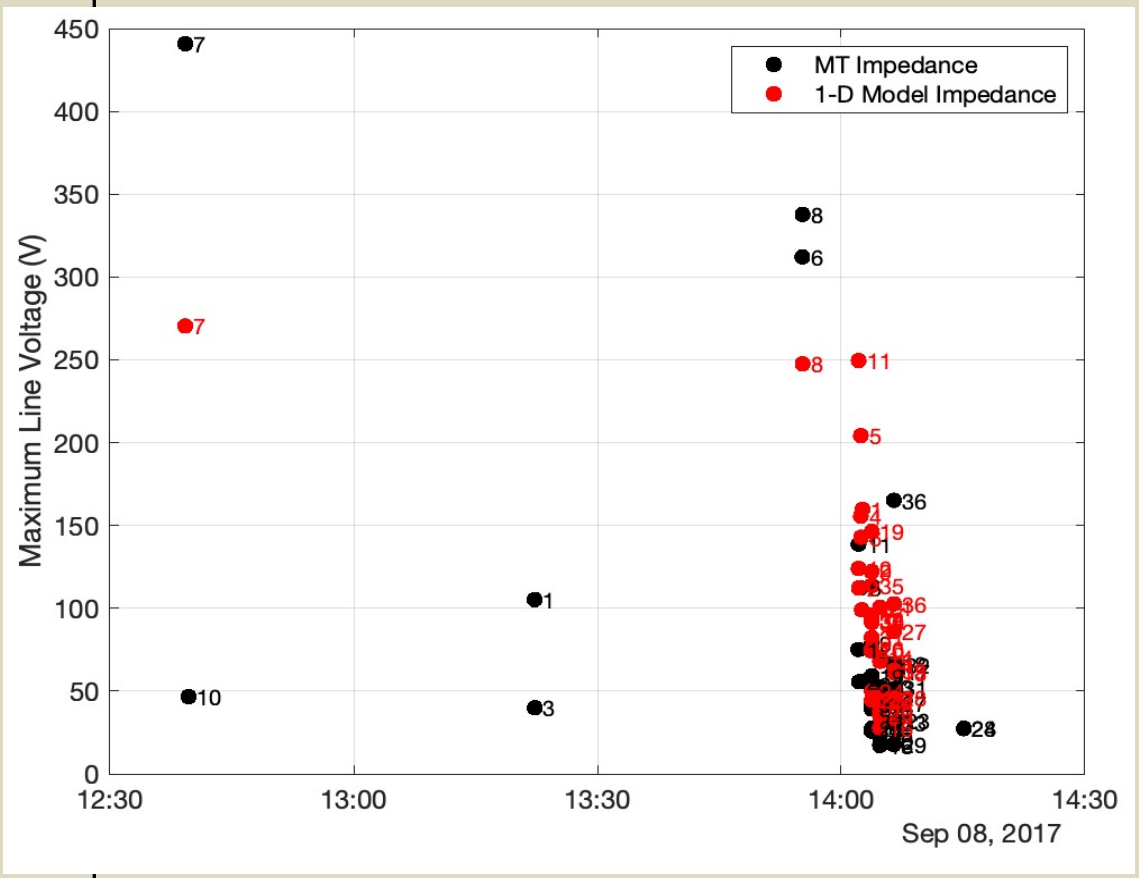


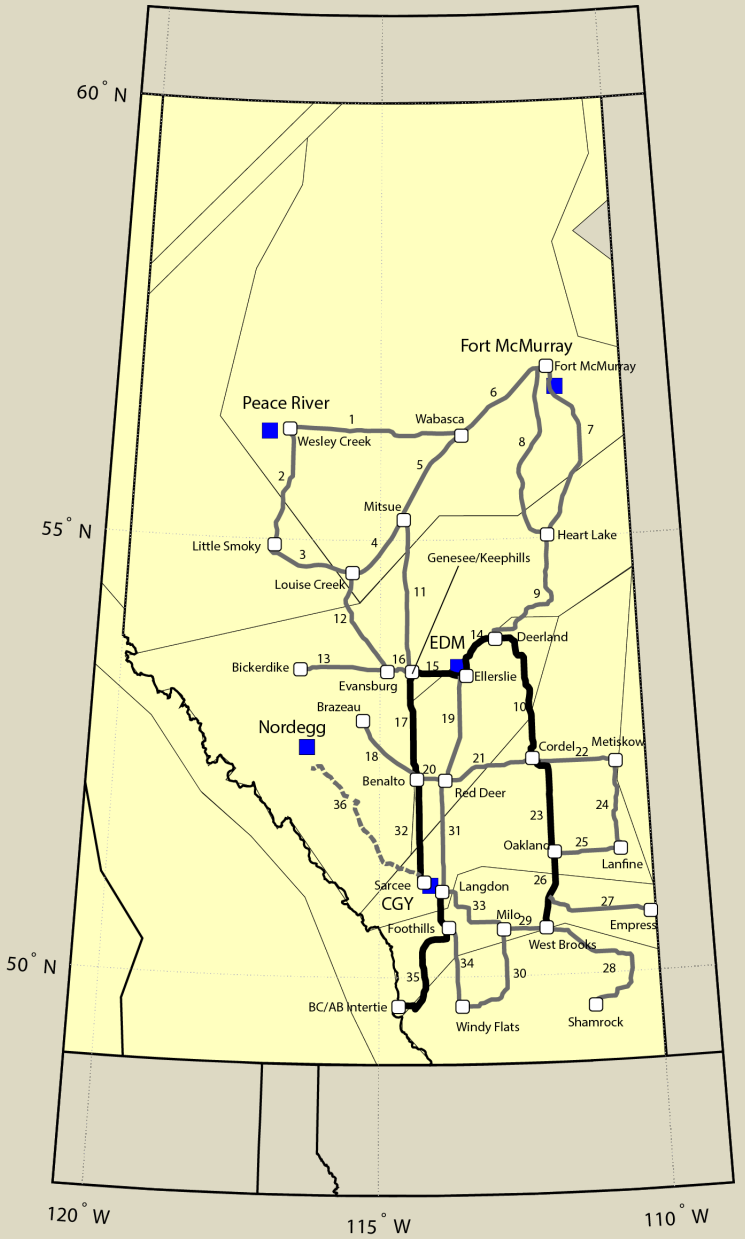




Partially-polarized geoelectric field is most apparent in southern Alberta

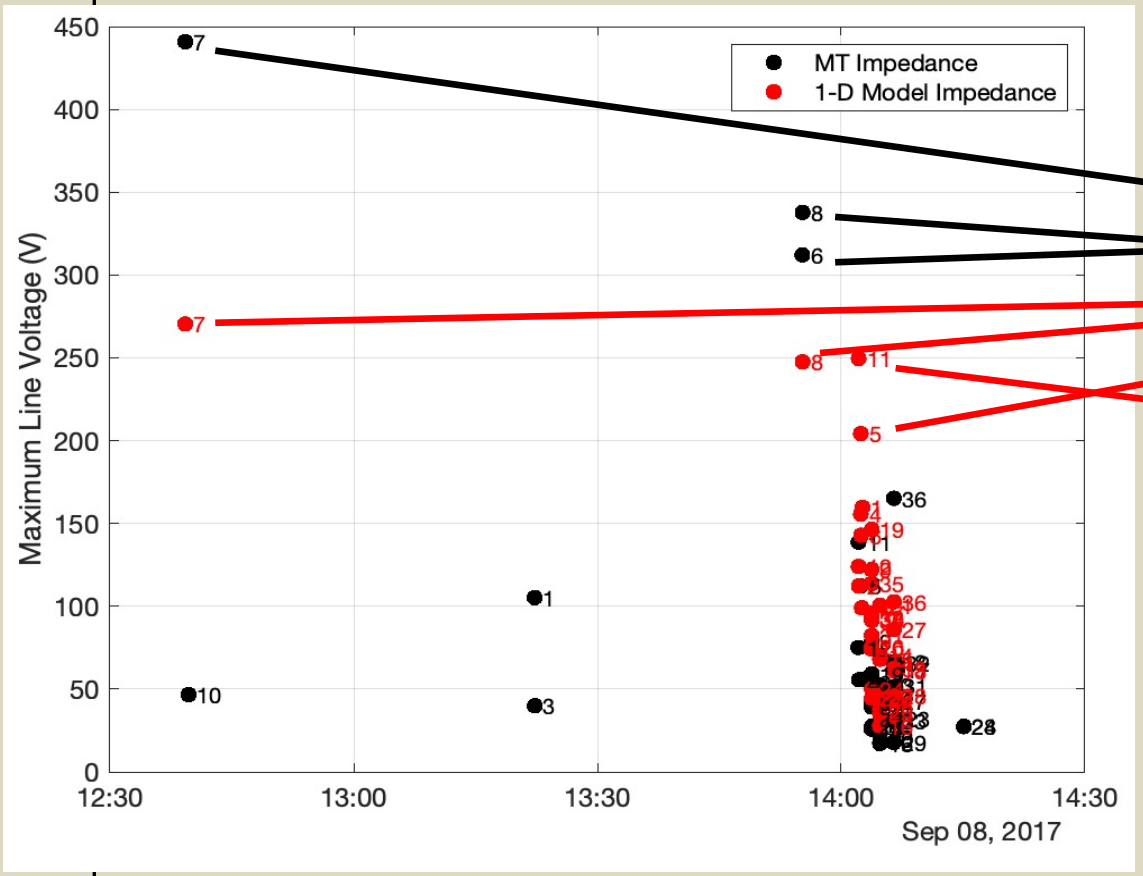
Test #3: Line Voltages

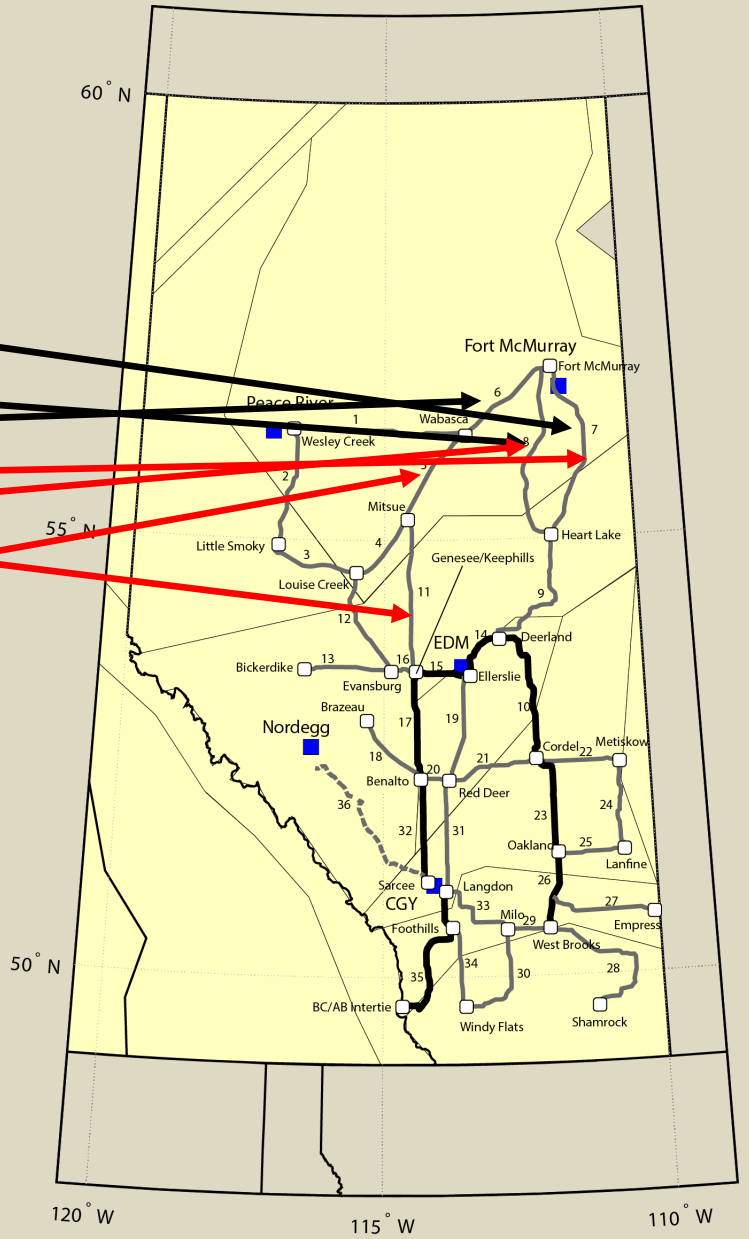




Test #3: Line Voltages

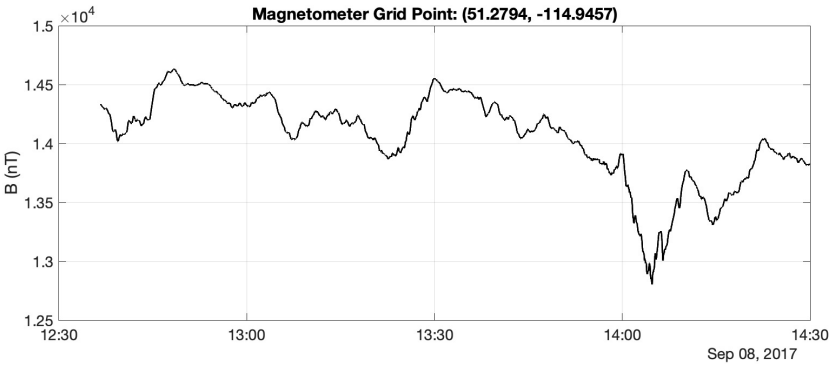
- MT impedance results in larger peak voltages in northern Alberta

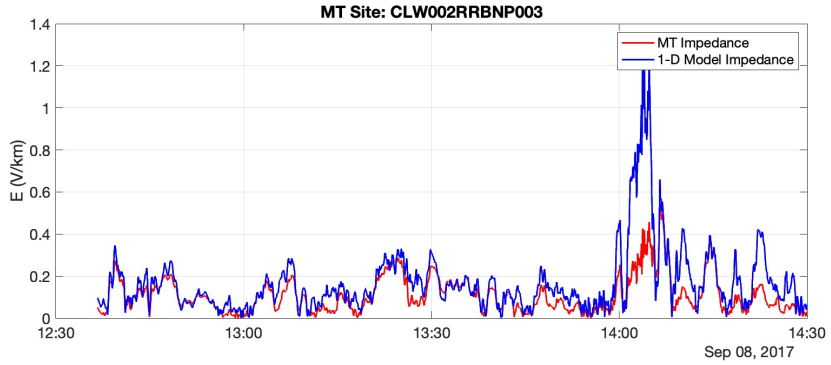


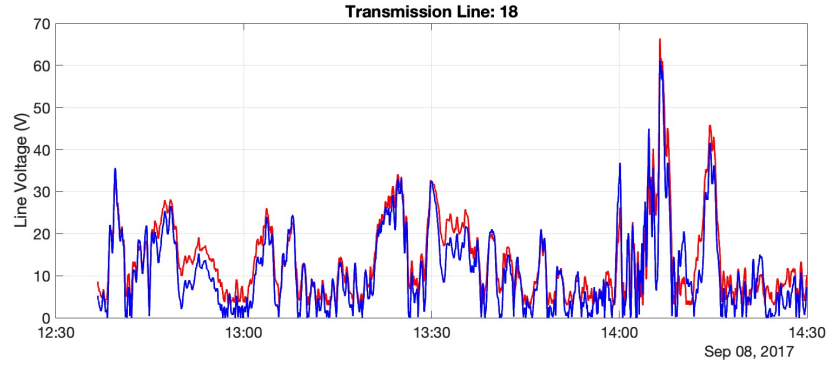


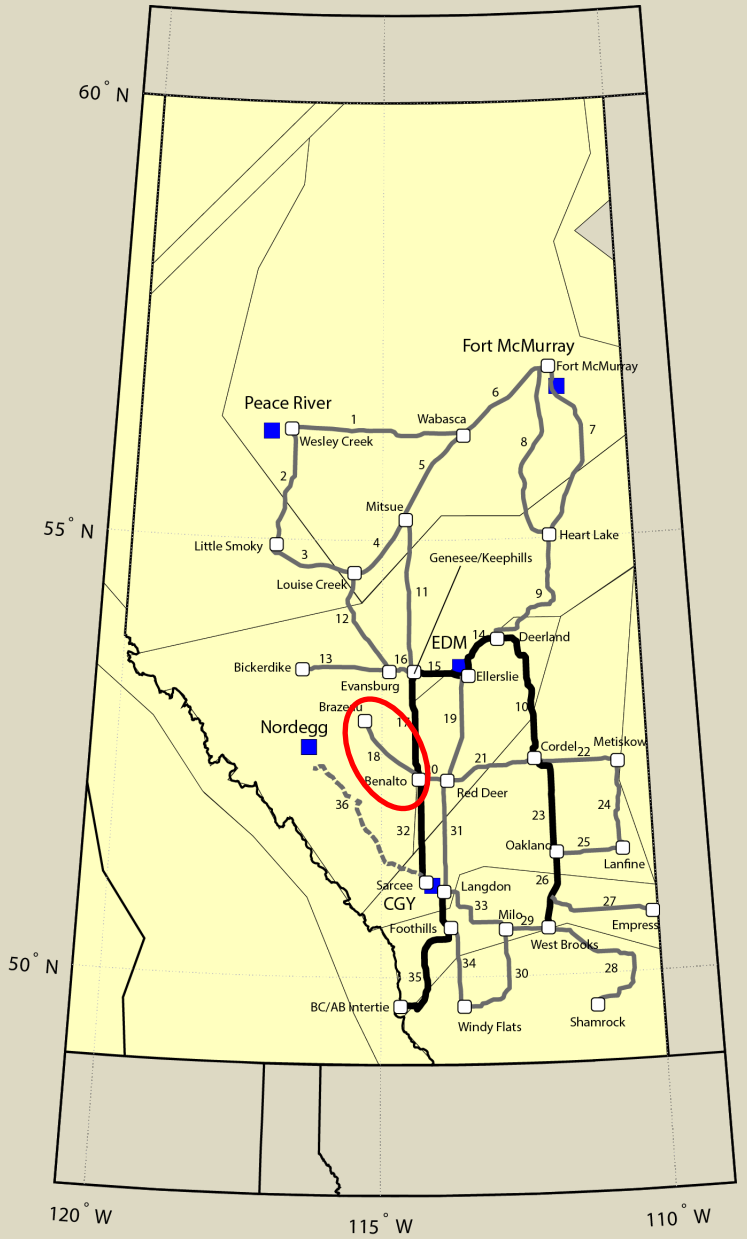
Test #3: Line Voltages

What about the polarization?

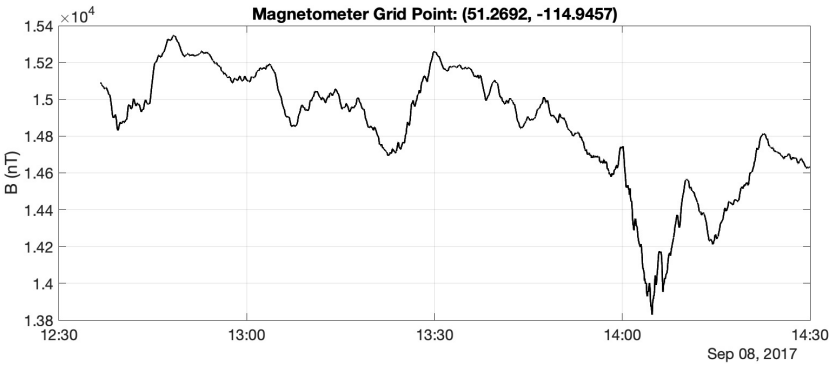


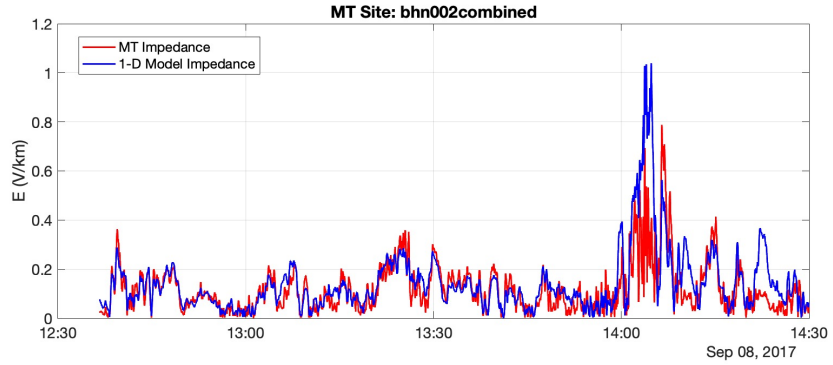


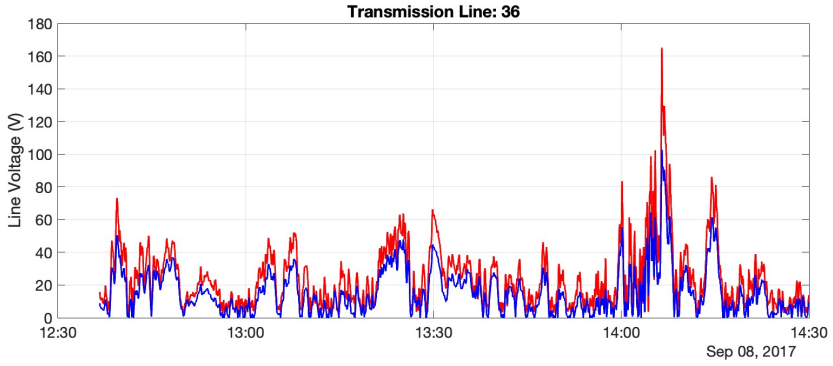


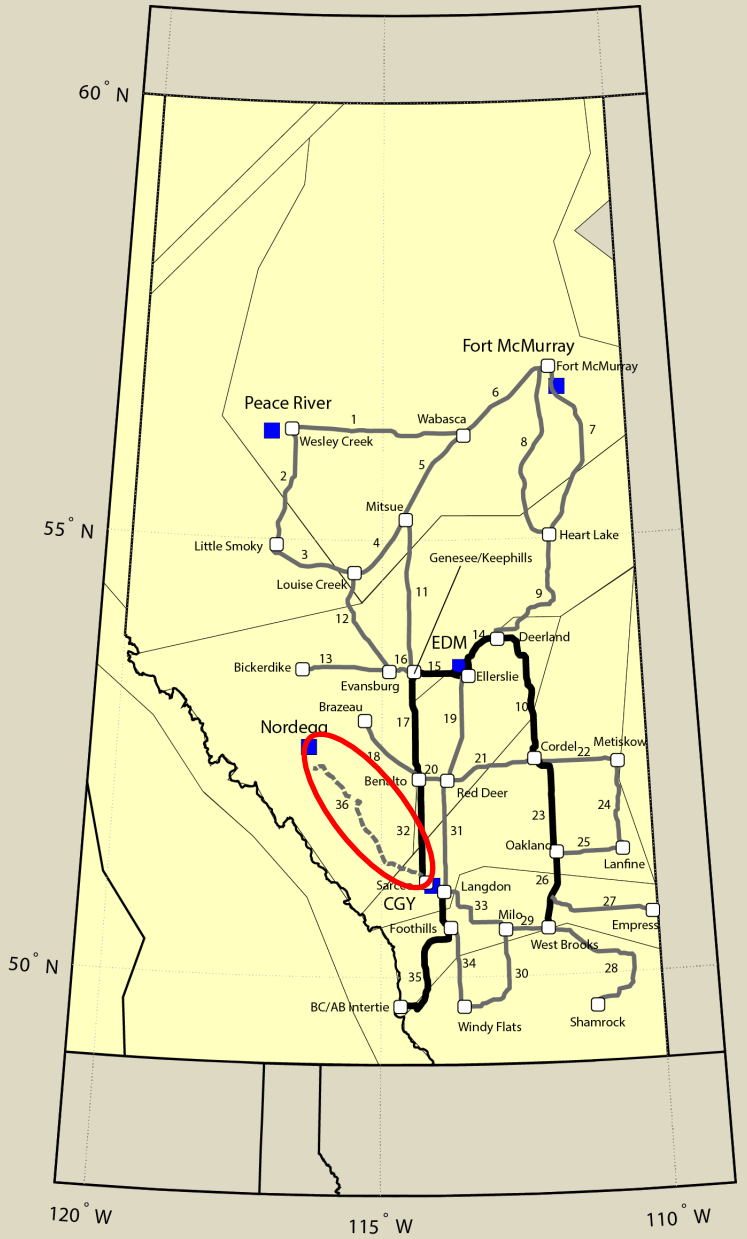


Test #3: Line Voltages

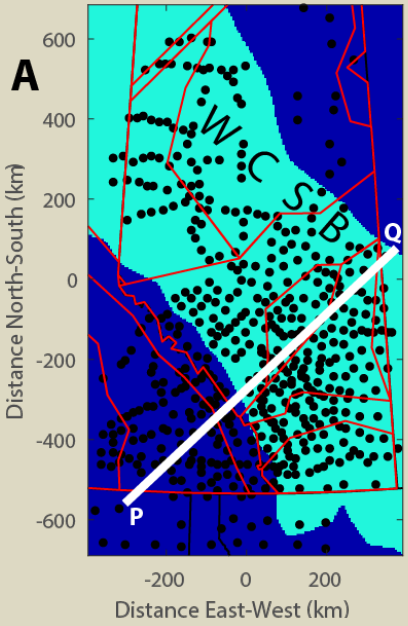


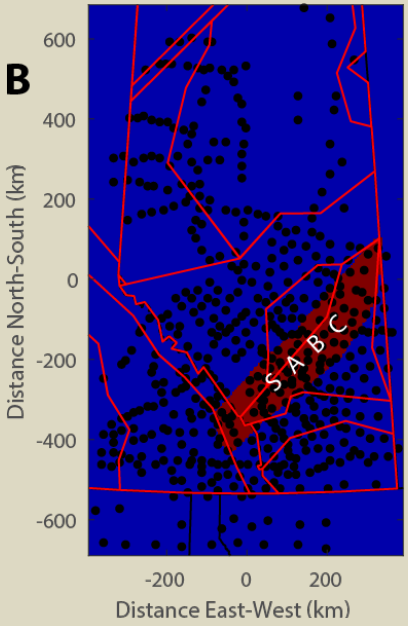


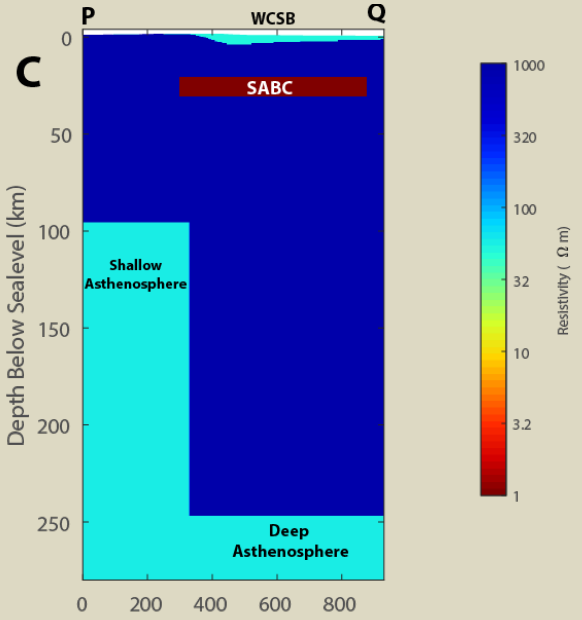


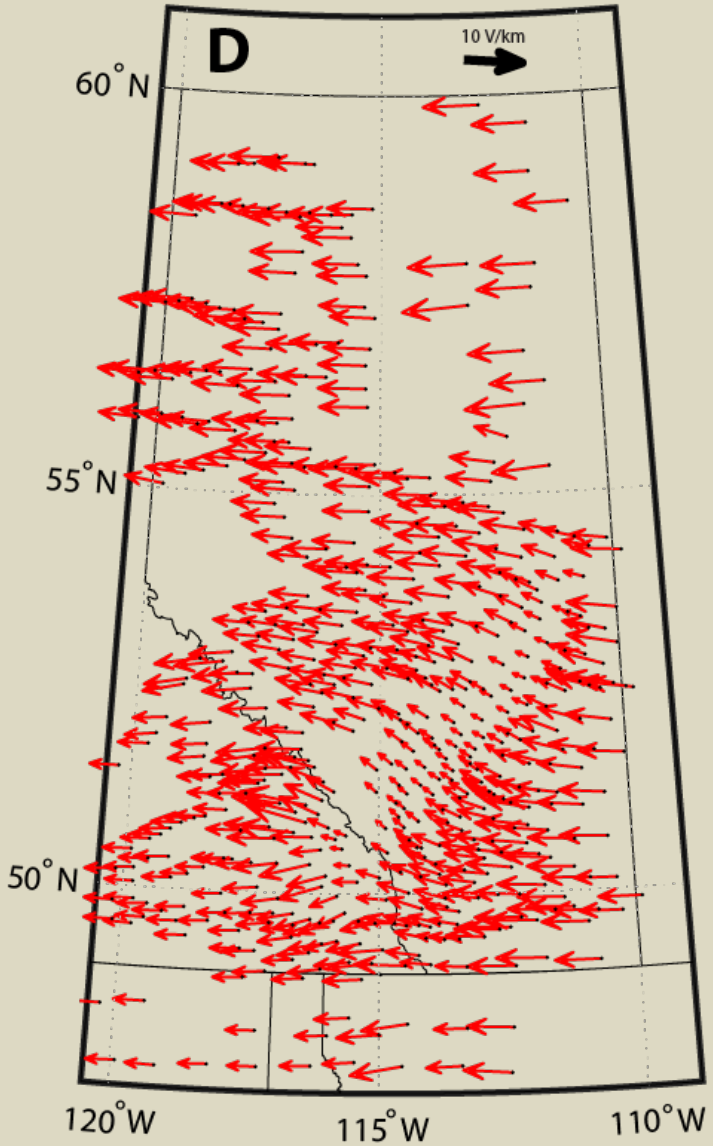


Geological Explanation









Conclusions and Future Directions

- NE Alberta has largest discrepancies and largest magnitudes
- Transmission line voltages can be >100 V larger depending on method
- Partial polarization of the geoelectric field in southern Alberta has subtle effect
- Different geology, different GMD, or different transmission networks could magnify this effect
- Ancient tectonics on stable continents can play a role in influencing space weather hazards today