Maps of extreme-value geoelectric amplitude and polarization for the Northeast United States

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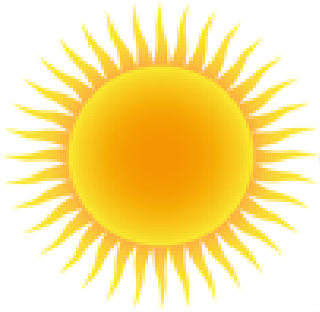
Concepts

- Storm-time induction of geoelectric fields in the conducting solid Earth.
- Combined use of monitoring and survey data.
- Physically motivated extreme-event analysis.
- Extrapolation to 100-year hazardous values.
- Error analysis.
- Interpretation in terms of regional geological structure.

Input signal time series → Convolution through a filter → Output signal time series



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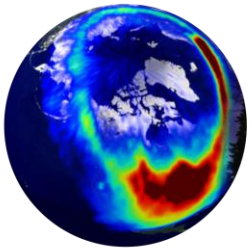
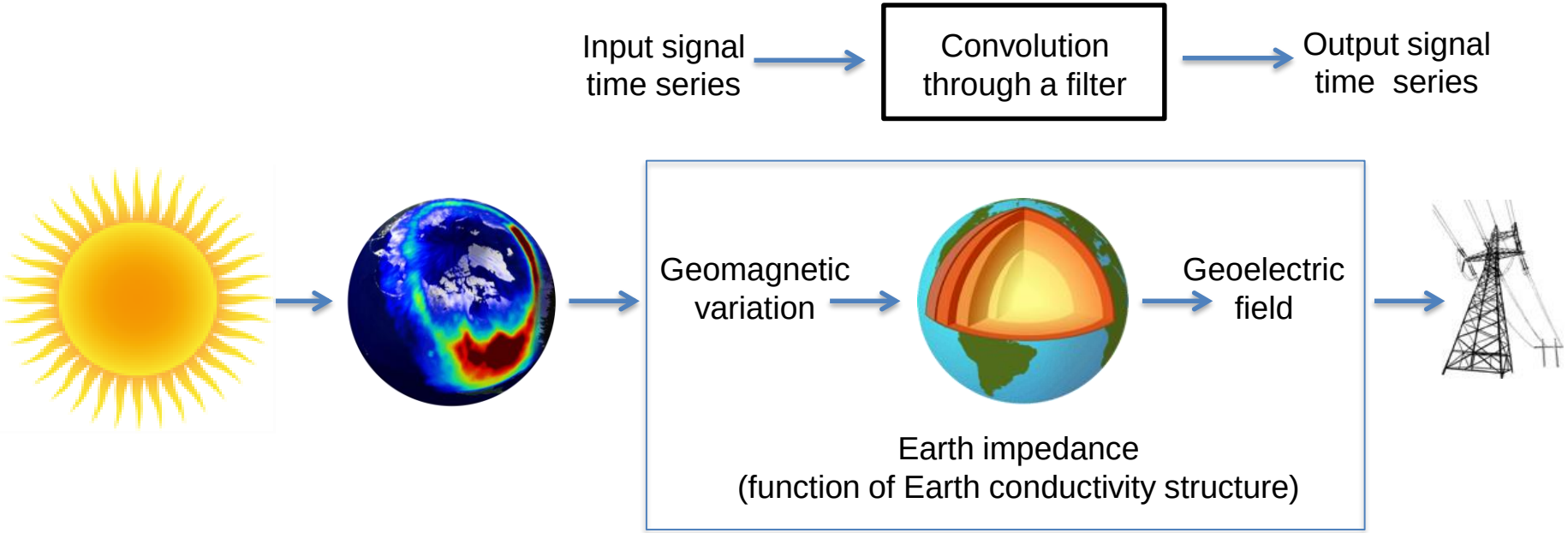


→ Geomagnetic variation →

→ Geoelectric field →

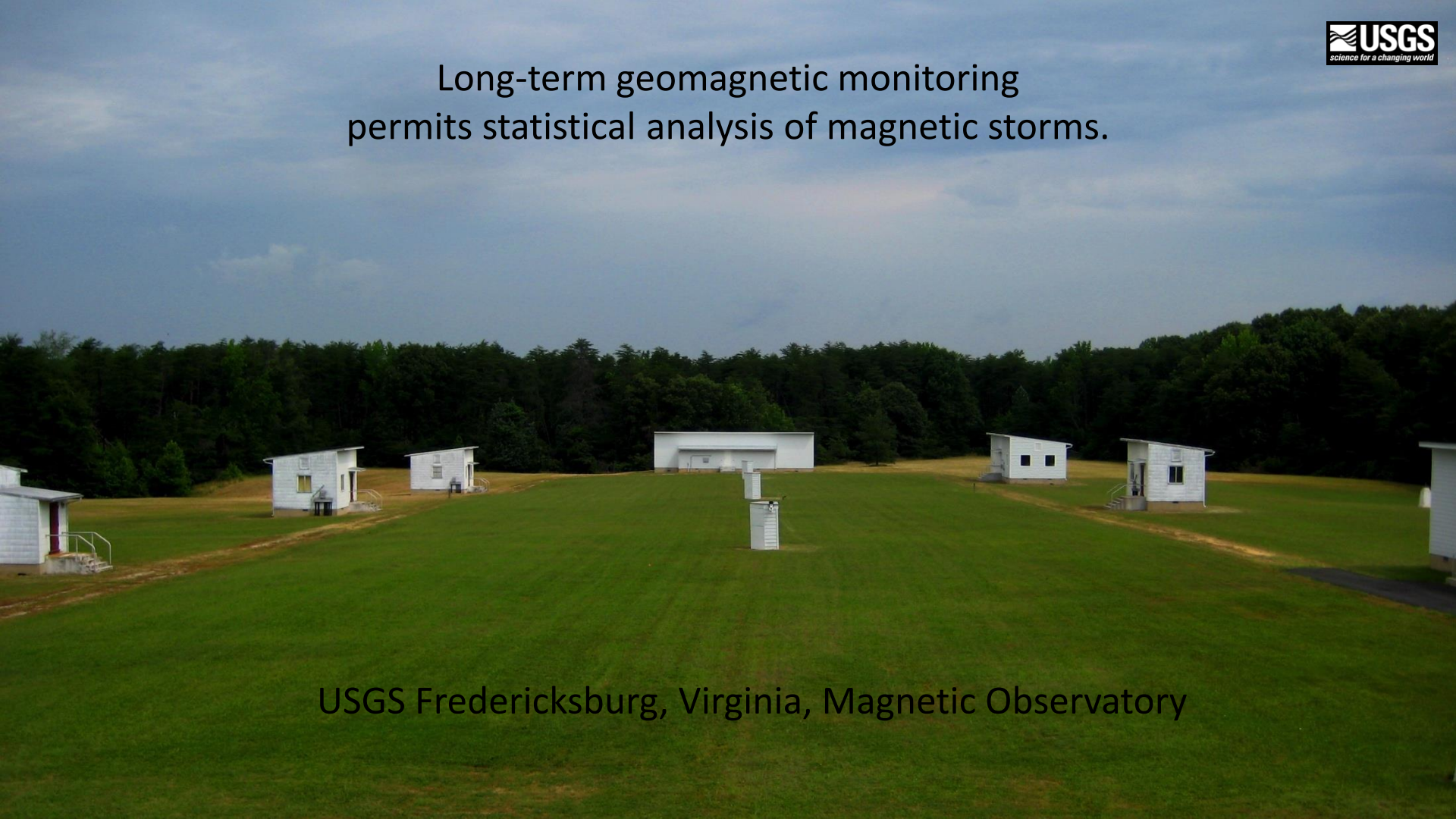
Earth impedance
(function of Earth conductivity structure)

Love, J. J., Rigler, E. J., Pulkkinen, A., Balch, C. C.,
2014. Magnetic storms and induction hazards, Eos, Trans. AGU, 95(48), 445-446, doi10.1002/2014EO480001.

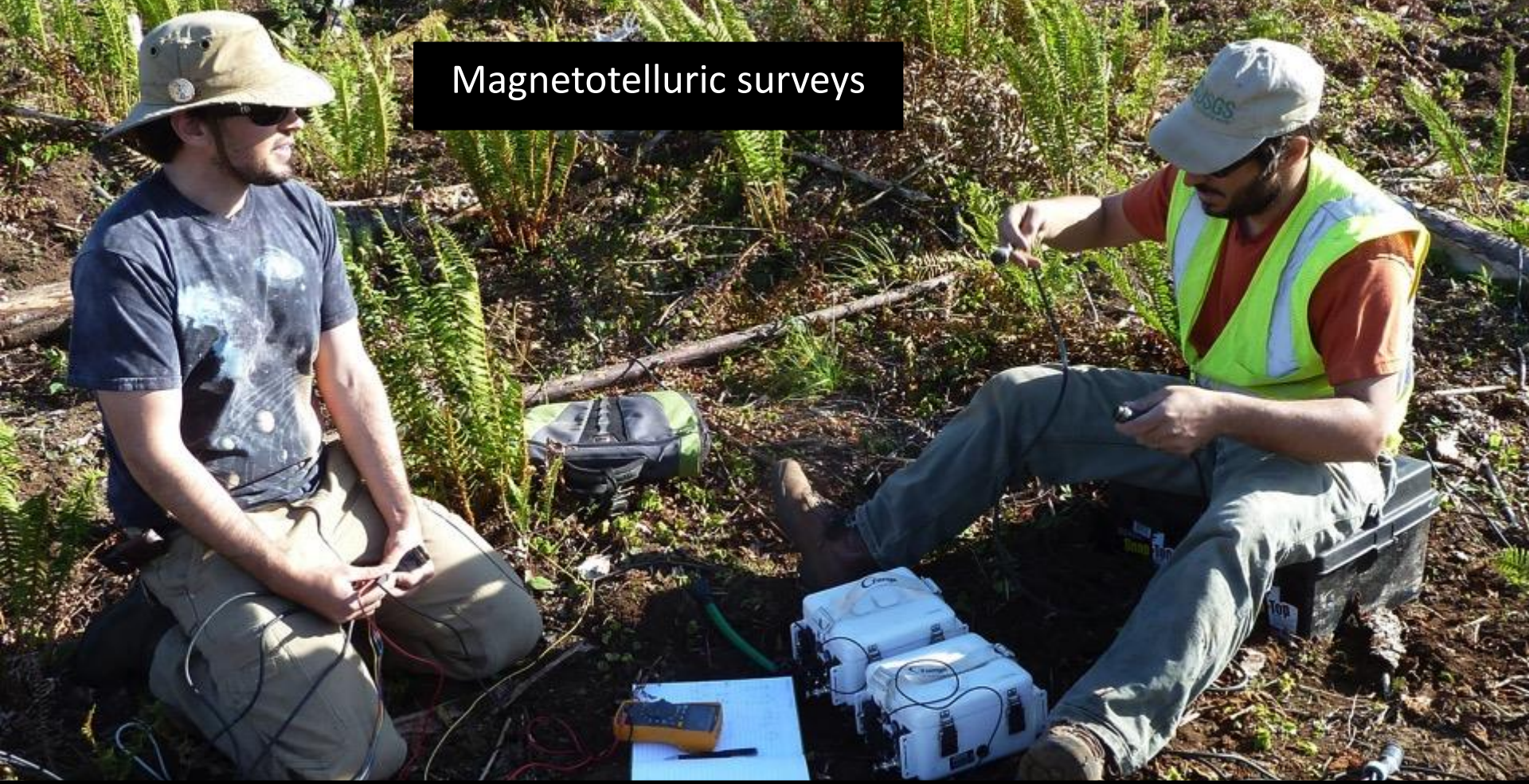


Love, J. J., Rigler, E. J., Pulkkinen, A., Balch, C. C.,
2014. Magnetic storms and induction hazards, Eos, Trans. AGU, 95(48), 445-446, doi10.1002/2014EO480001.

Long-term geomagnetic monitoring
permits statistical analysis of magnetic storms.

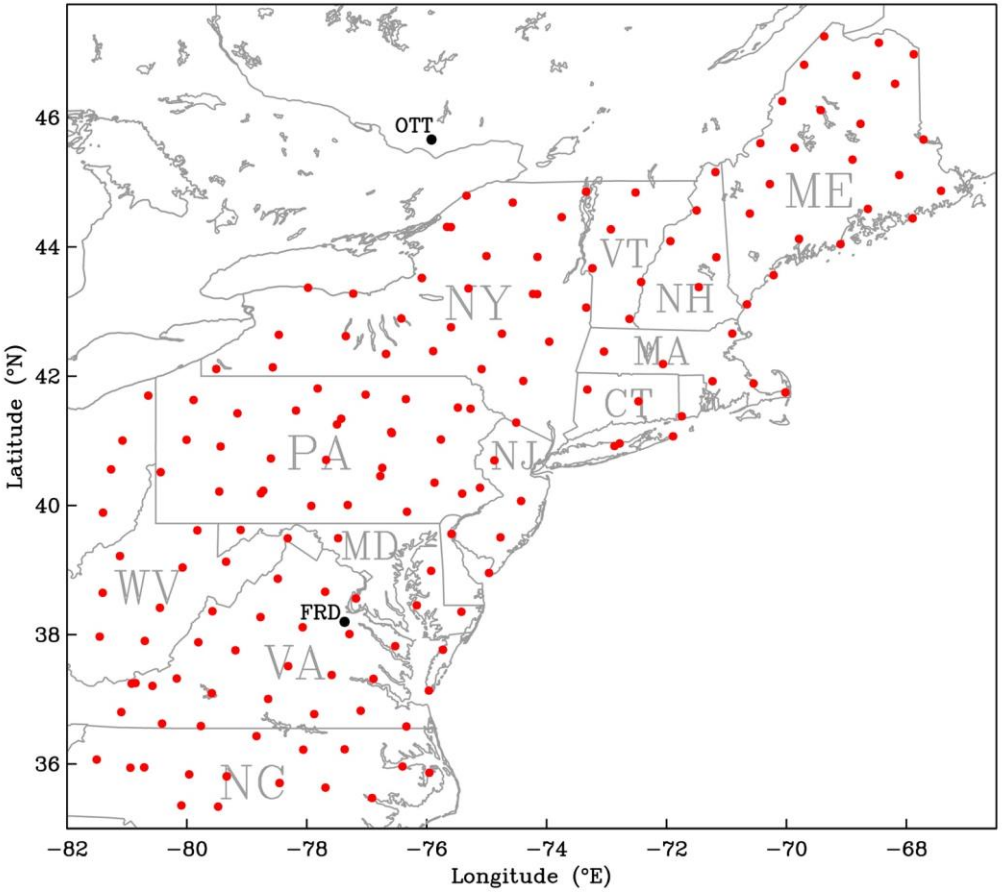


USGS Fredericksburg, Virginia, Magnetic Observatory

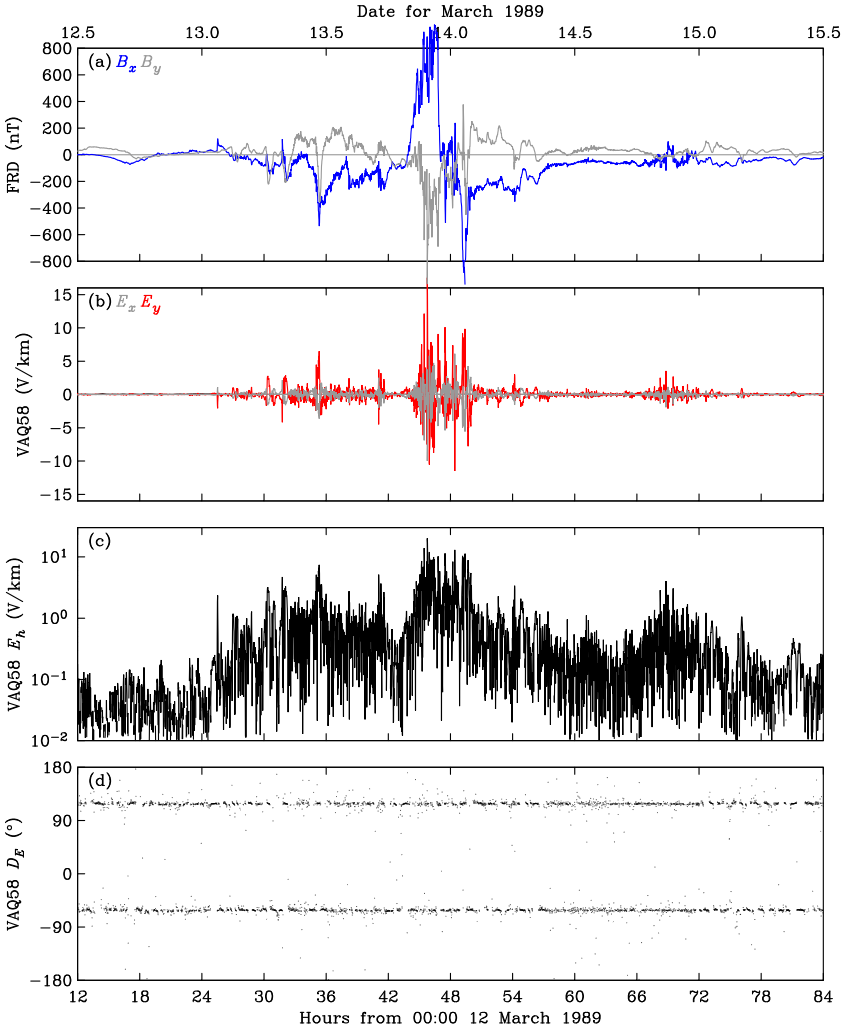


Measurement of surface impedance permits inference of Earth conductivity structure.

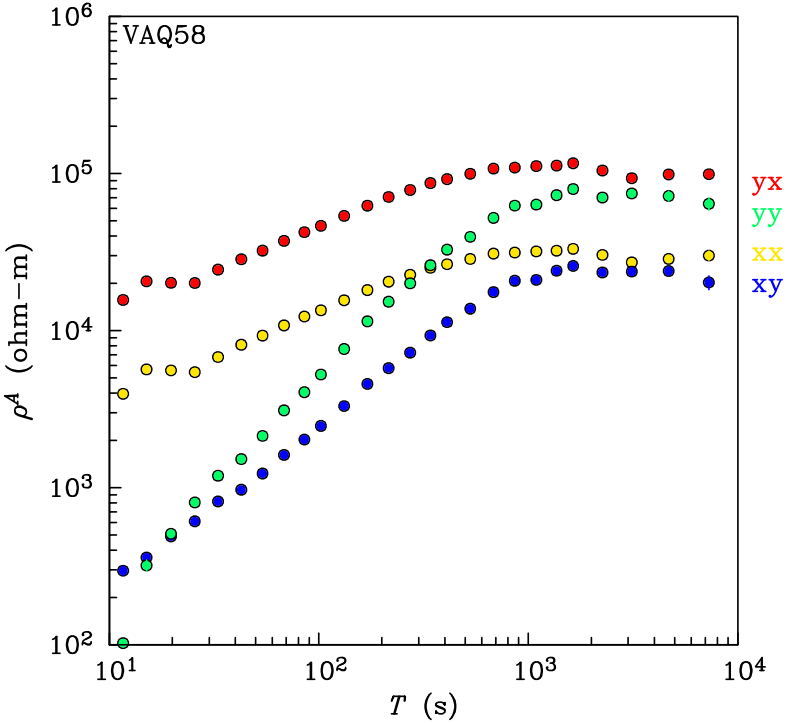
Observatories and magnetotelluric survey sites

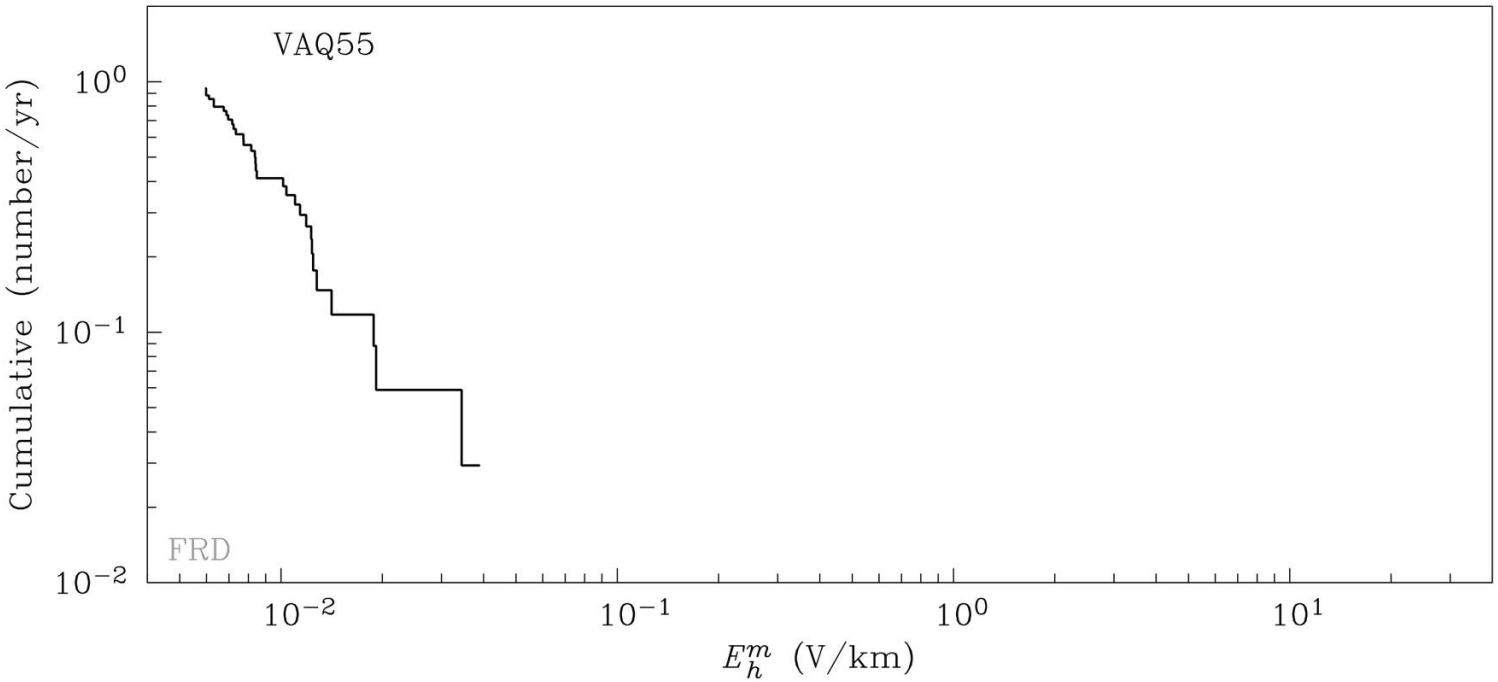


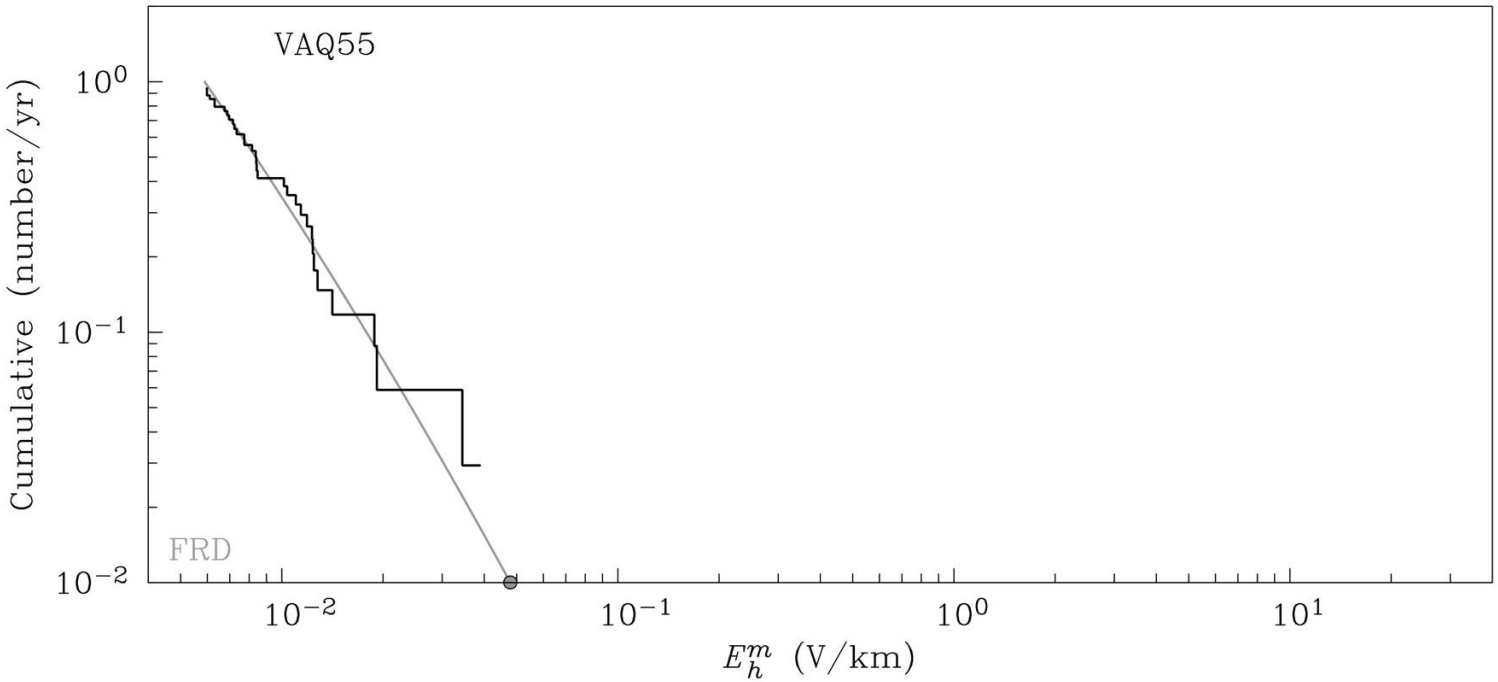
Natural Resources Canada

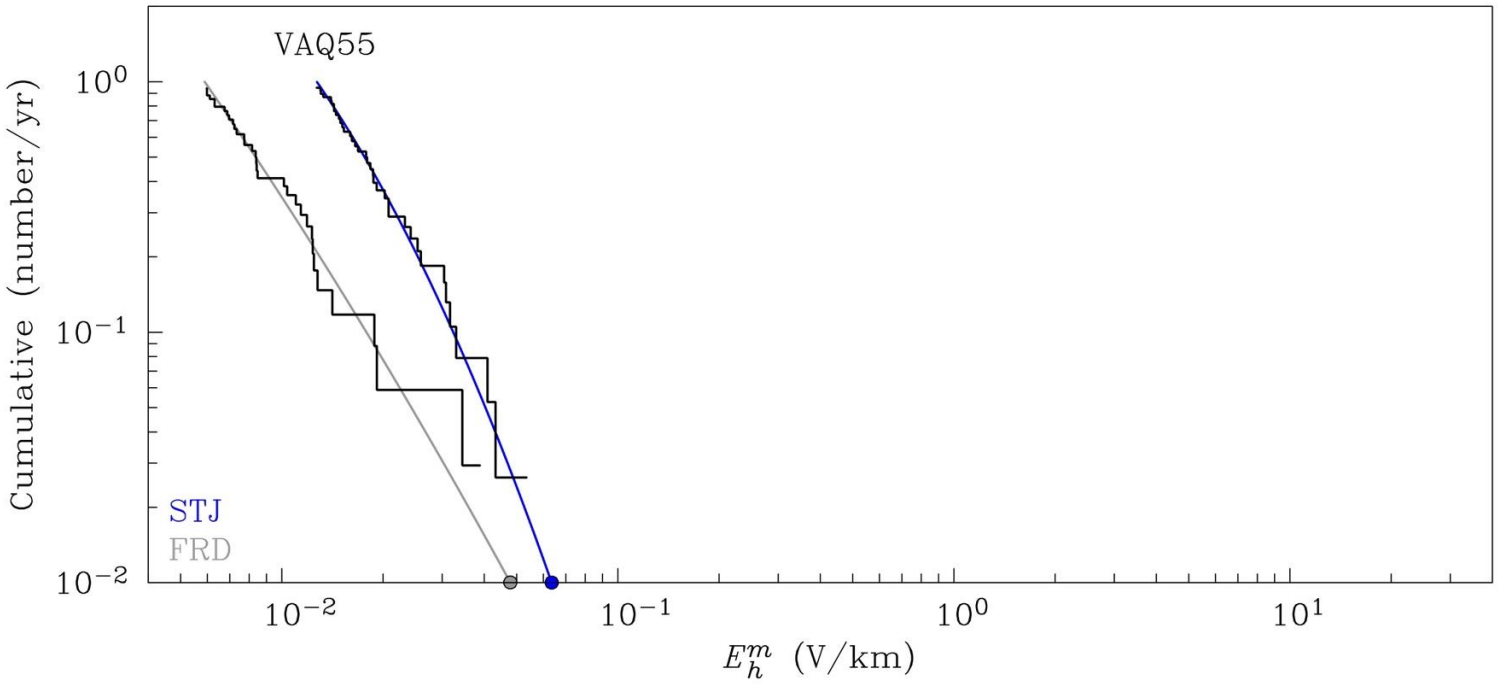


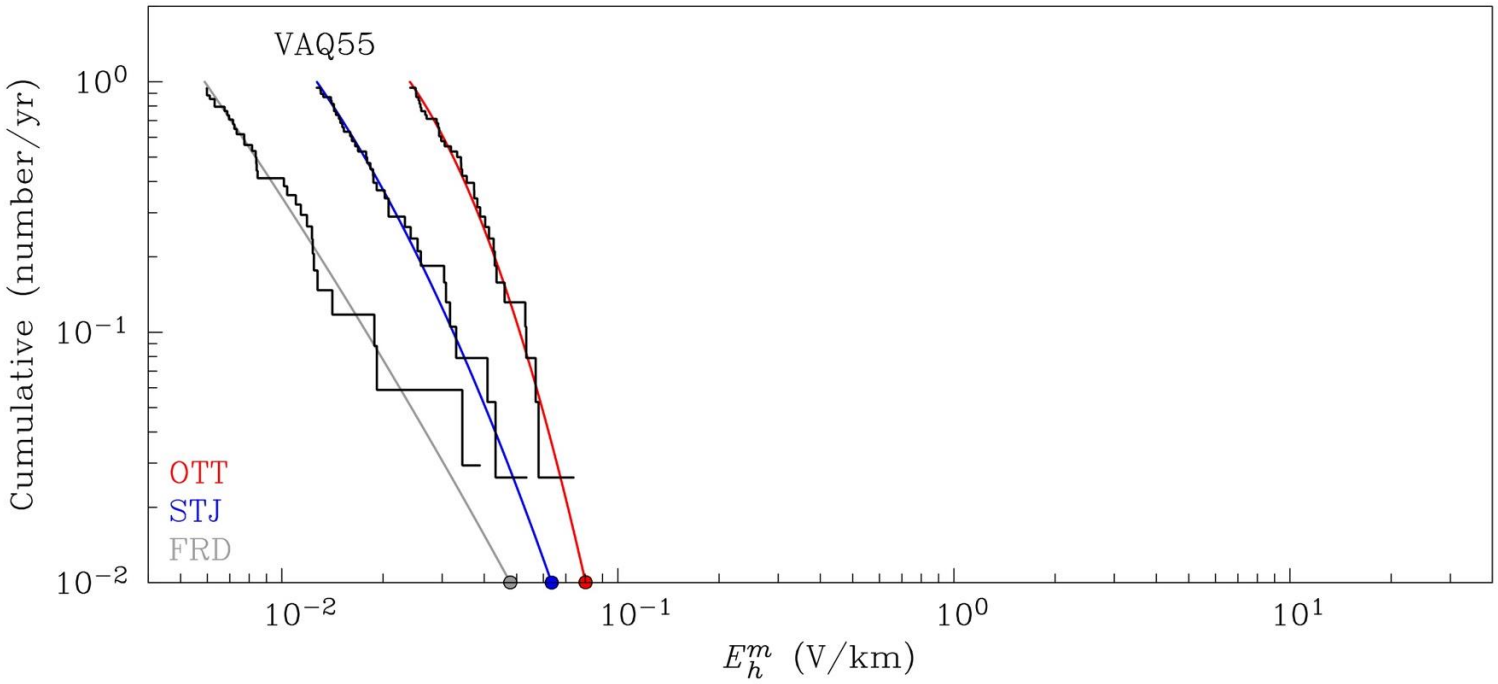
Geomagnetic time series for the March 1989 storm recorded at the USGS Fredericksburg observatory, convolved with EarthScope impedance tensor VAQ58 to obtain geoelectric time series:

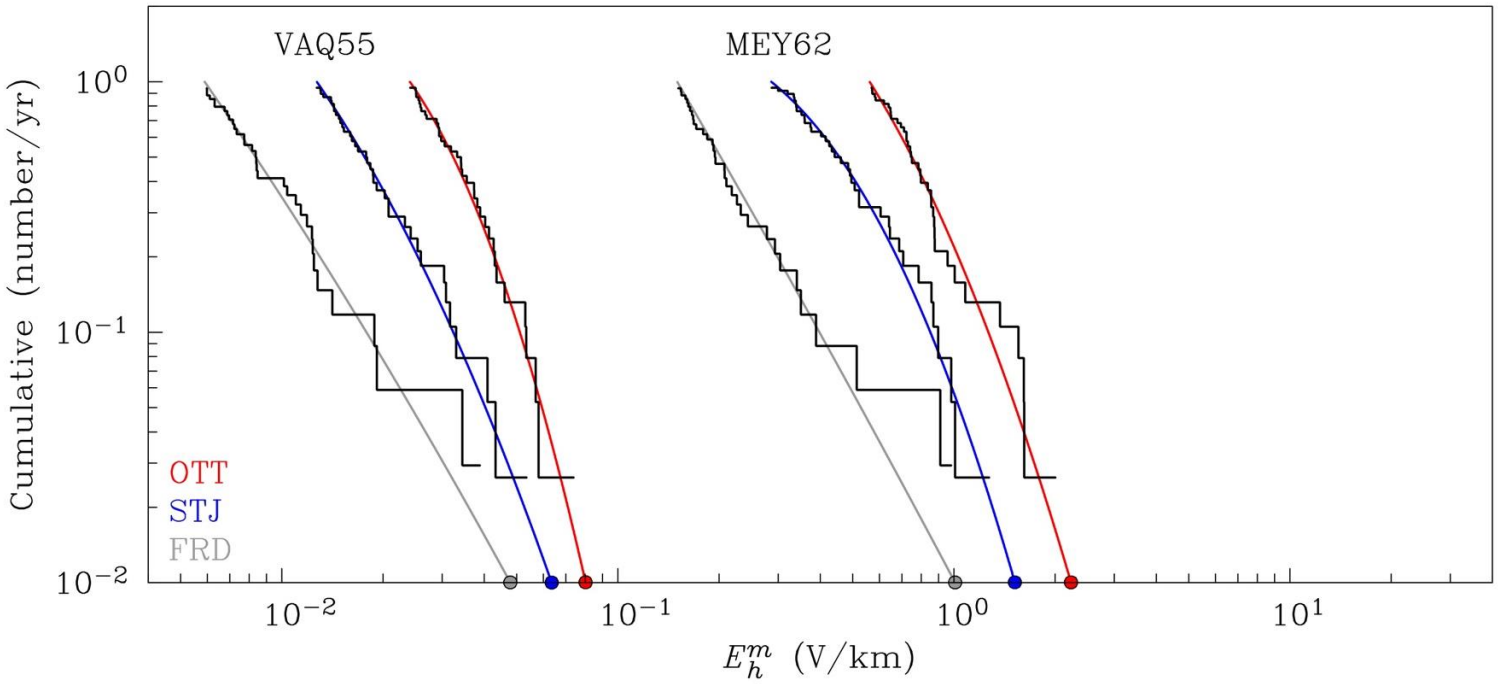


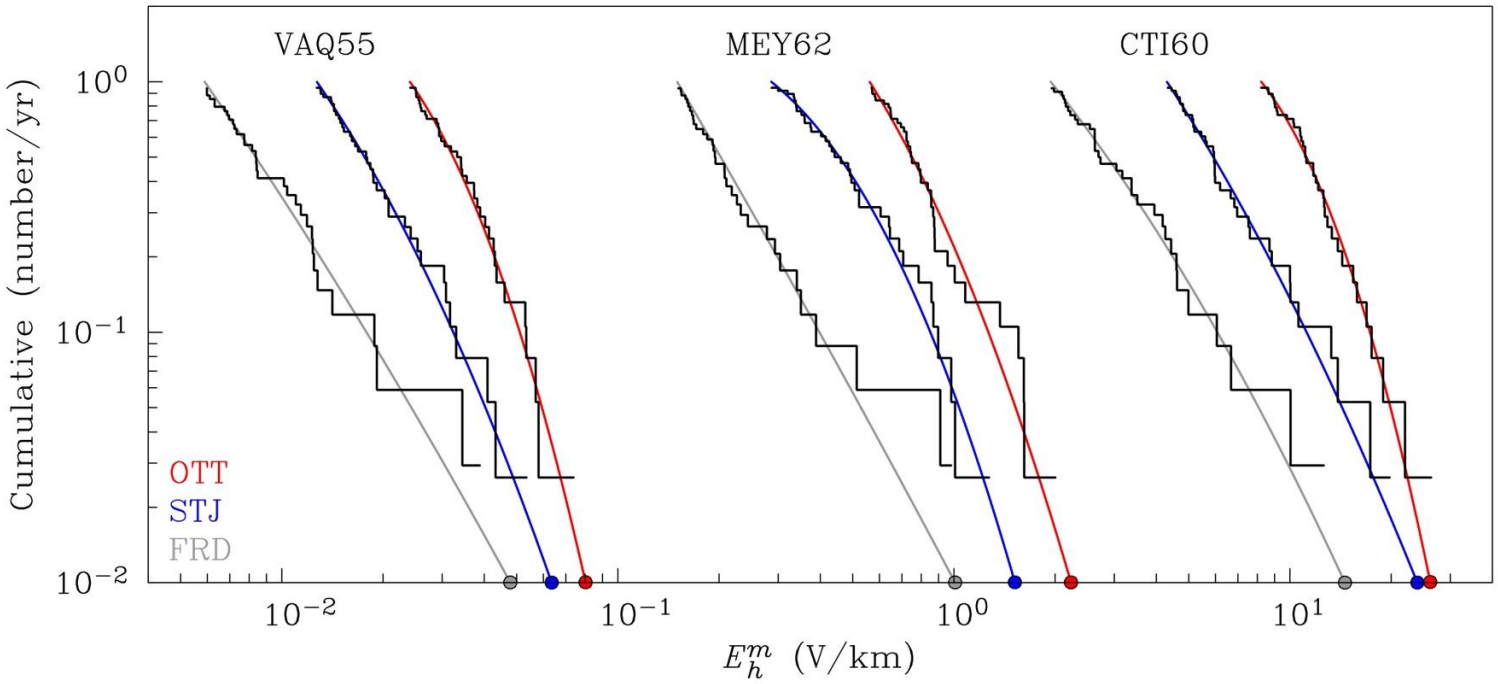

VAQ55
FRD
Cumulative (number/yr)
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
E_h^m (V/km)

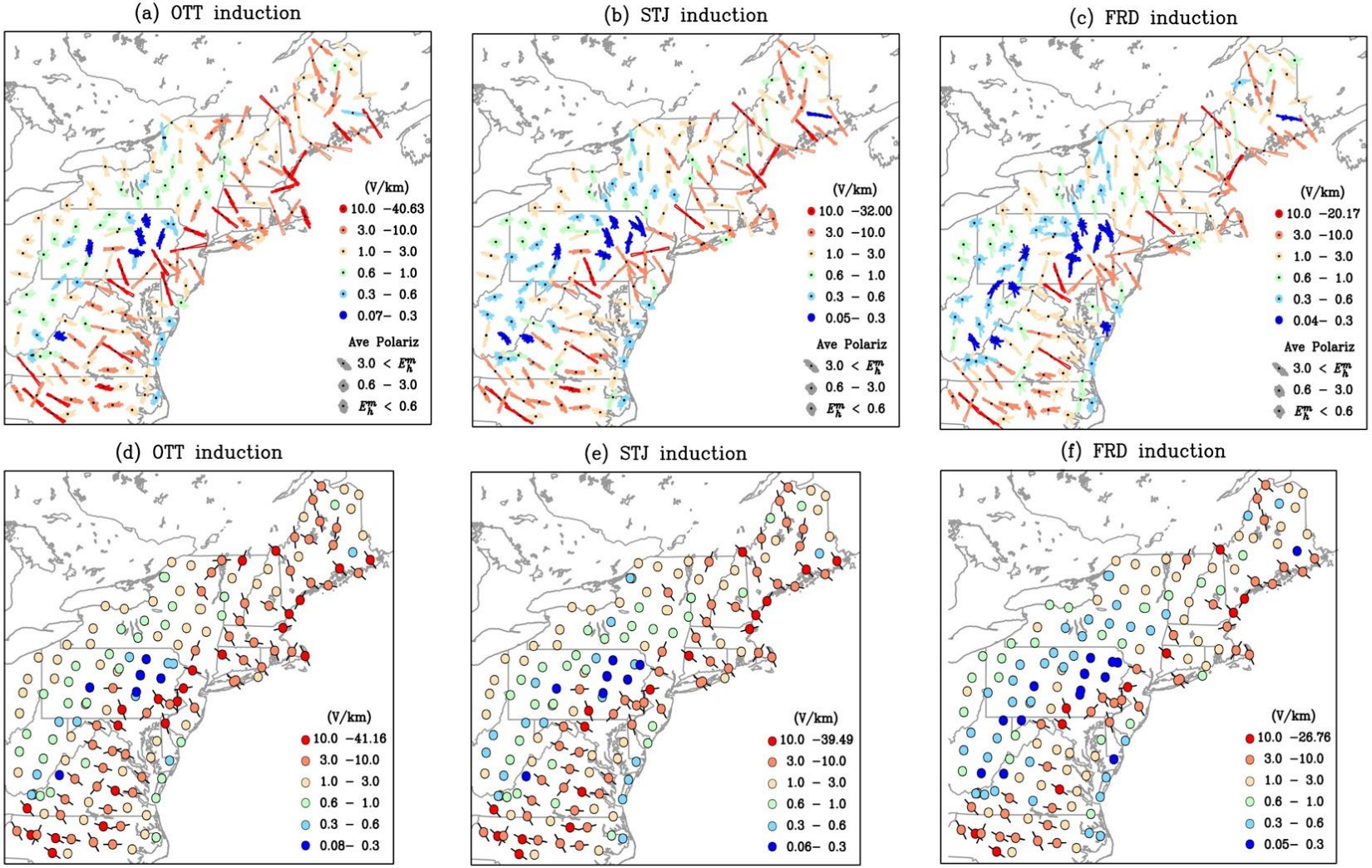

VAQ55
FRD
Cumulative (number/yr)
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
E_h^m (V/km)

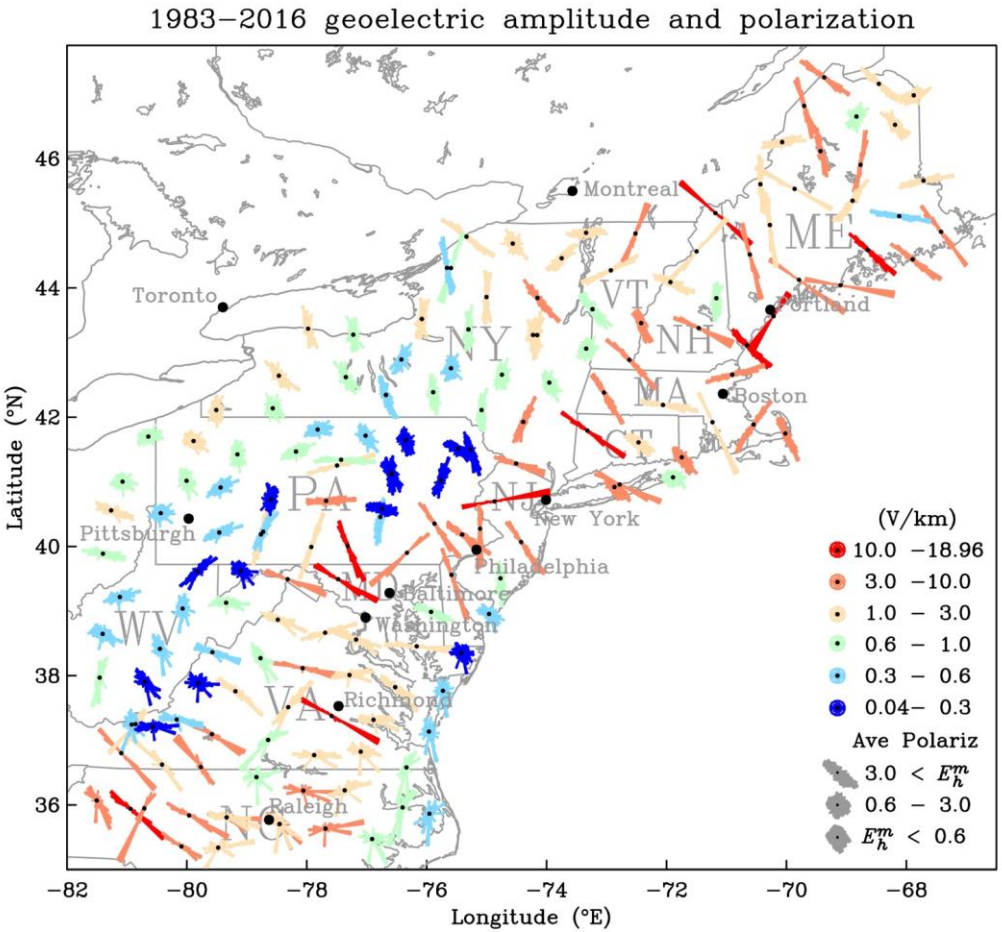

VAQ55
STJ
FRD
Cumulative (number/yr)
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
E_h^m (V/km)


VAQ55
OTT
STJ
FRD
Cumulative (number/yr)
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
E_h^m (V/km)

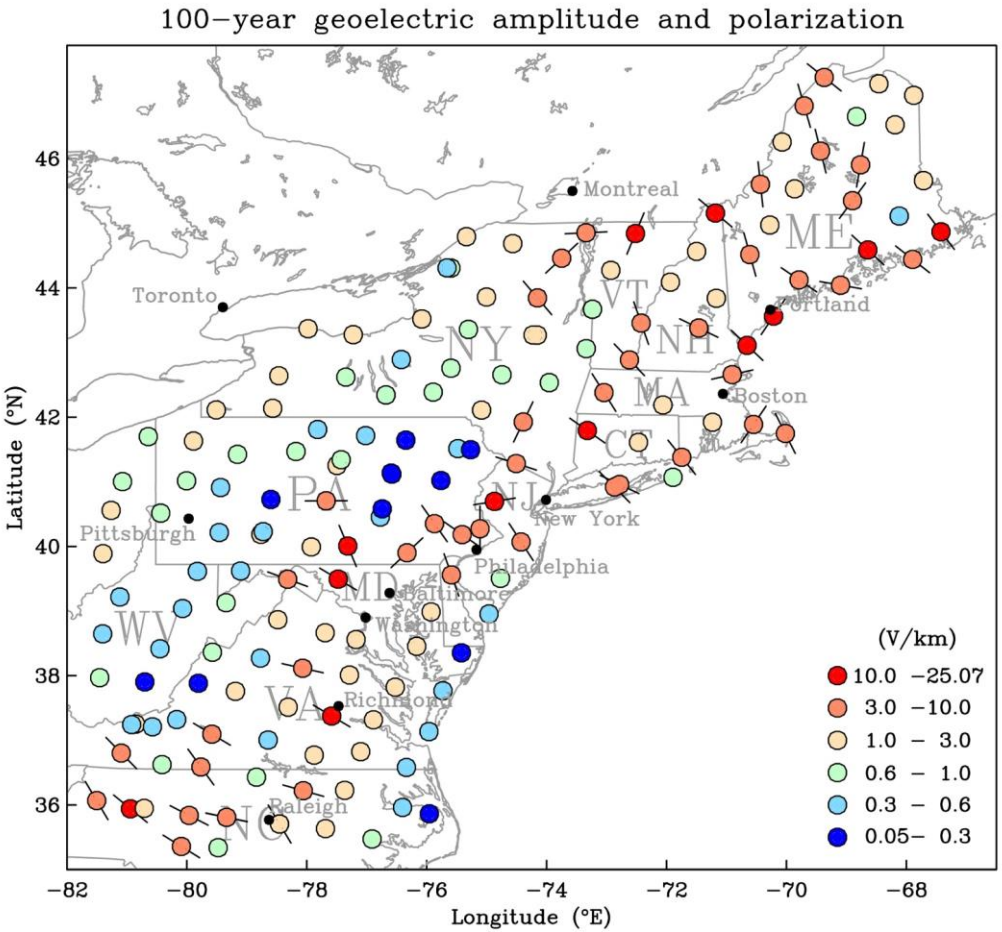

VAQ55
MEY62
OTT
STJ
FRD
Cumulative (number/yr)
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
E_h^m (V/km)


VAQ55
MEY62
CTI60
Cumulative (number/yr)
10^0
10^{-1}
10^{-2}
OTT
STJ
FRD
10^{-2}
10^{-1}
10^0
10^1
E_h^m (V/km)


(a) OTT induction
(V/km)
10.0 −40.63
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.07− 0.3
Ave Polariz
3.0 < E_h^m
0.6 − 3.0
E_h^m < 0.6
(b) STJ induction
(V/km)
10.0 −32.00
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.05− 0.3
Ave Polariz
3.0 < E_h^m
0.6 − 3.0
E_h^m < 0.6
(c) FRD induction
(V/km)
10.0 −20.17
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.04− 0.3
Ave Polariz
3.0 < E_h^m
0.6 − 3.0
E_h^m < 0.6
(d) OTT induction
(V/km)
10.0 −41.16
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.08− 0.3
(e) STJ induction
(V/km)
10.0 −39.49
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.06− 0.3
(f) FRD induction
(V/km)
10.0 −26.76
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.05− 0.3



Related work: Love, J. J., Lucas, G. M., Kelbert, A. & Bedrosian, P. A., 2018.
Geoelectric hazard maps for the Mid-Atlantic United States: 100 year extreme values and the 1989 magnetic storm, Geophys. Res. Lett., 45(1), 5-15, doi:10.1002/2017GL076042.



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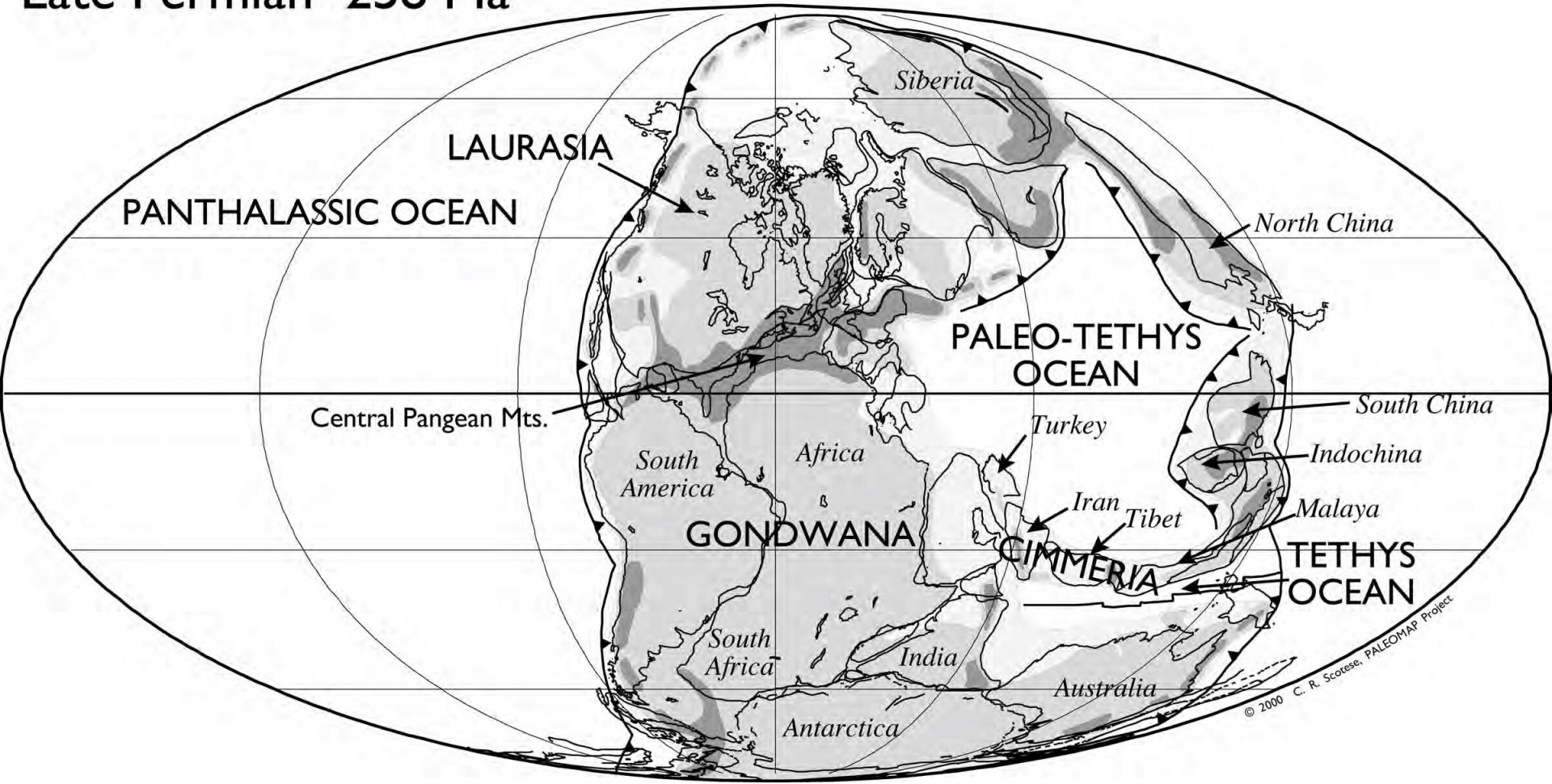
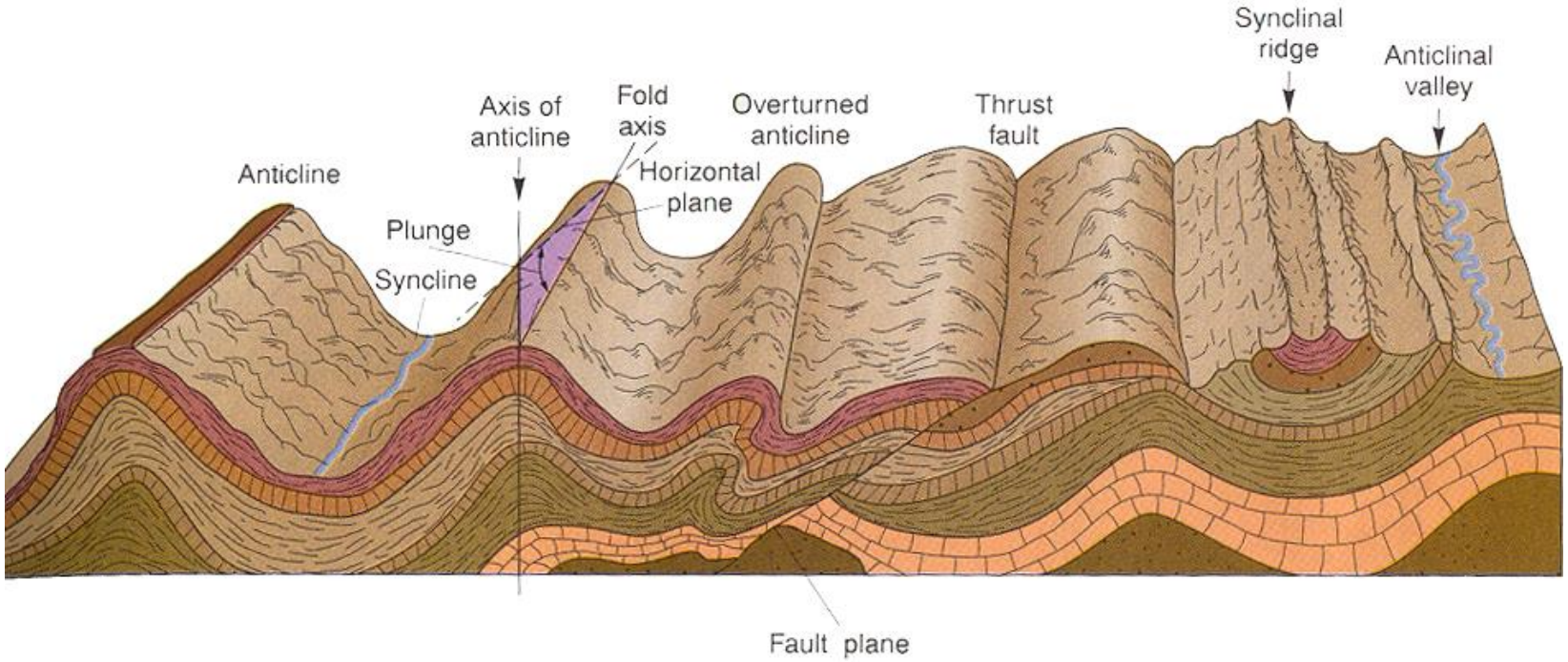
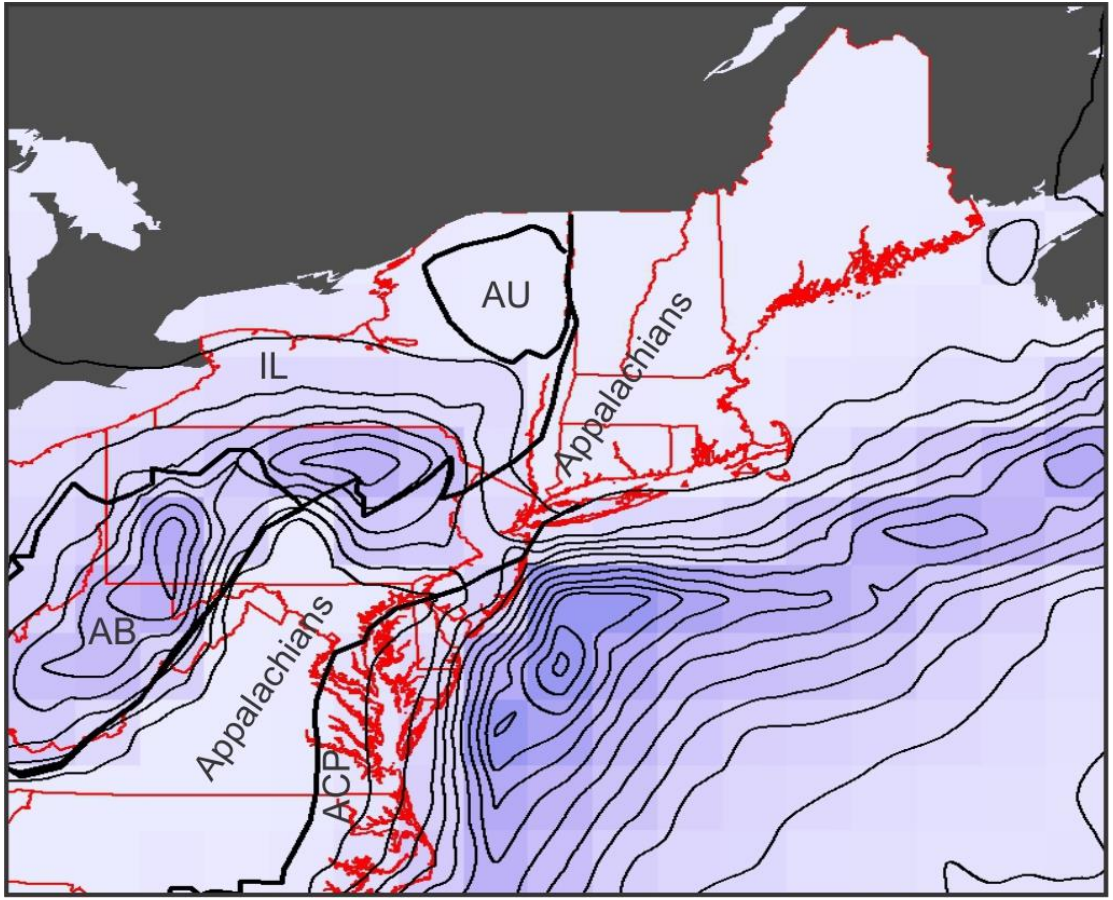
Geoelectric hazard maps for the Mid-Atlantic United States: 100 year extreme values and the 1989 magnetic storm, Geophys. Res. Lett., 45(1), 5-15, doi:10.1002/2017GL076042.

Late Permian 258 Ma



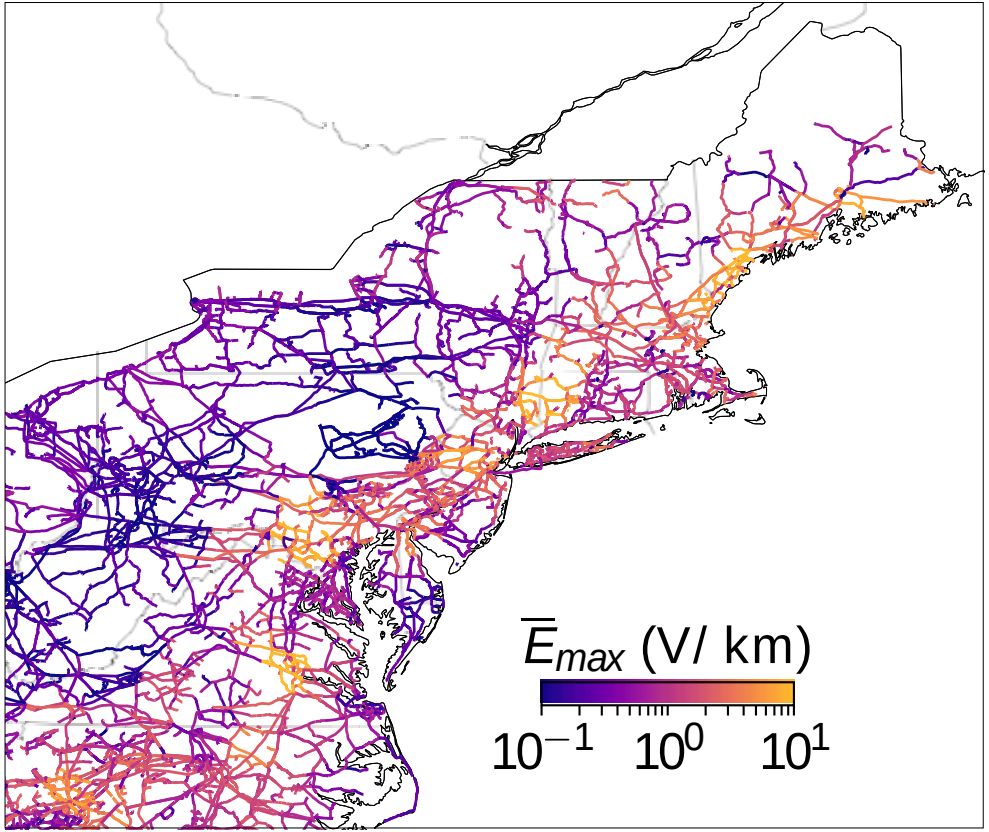

Synclinal ridge
Anticlinal valley
Axis of anticline
Fold axis
Overturned anticline
Thrust fault
Anticline
Horizontal plane
Plunge
Syncline
Fault plane


AU
IL
Appalachians
AB
Appalachians
ACP

Conclusions

- Storm-time geoelectric amplitude and polarization show significant geographic granularity that is related to local geological structure.
- 100-year geoelectric amplitudes across the Northeast United States range from 0.05 to 25.07 V/km.
- High amplitude geoelectric fields tend to be polarized in a direction orthogonal to the strike of the Appalachians

Maximum geoelectric amplitude on power-grid lines realized during the March 1989 storm:



Related work: Lucas, G. M., Love, J. J. & Kelbert, A., 2018.
Calculation of voltages in electric power transmission lines during historic geomagnetic storms: An investigation using realistic Earth impedances, Space Weather, 16(2), 185-195, doi:10.1002/2017SW001779.