USGS Geomagnetism Program Electric Field Estimates

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Mission of USGS Geomagnetism Program

- Monitor Earth's magnetic field using ground-based magnetic observatories
- Provide continuous, high temporal resolution, accurate data recording magnetic field variations in real-time and covering long timescales
- Disseminate magnetic data to governmental, academic, and private institutions, NOAA, USAF, NASA
- Conduct research for scientific understanding and hazard mitigation
- 14 observatories, all collecting 1-second data in real-time
- 12 full-time operational staff,
  3 research staff

Electric Field: Spatial vs temporal variations

- Magnetic field varies with time and location
- Conductivity varies with depth and location => Surface Impedance varies with input frequency
- Electric field => Can be very different at different locations, even with the same B

Electric Field calculations

Conductivity Profiles
- Vary with location and geology
- Static with time

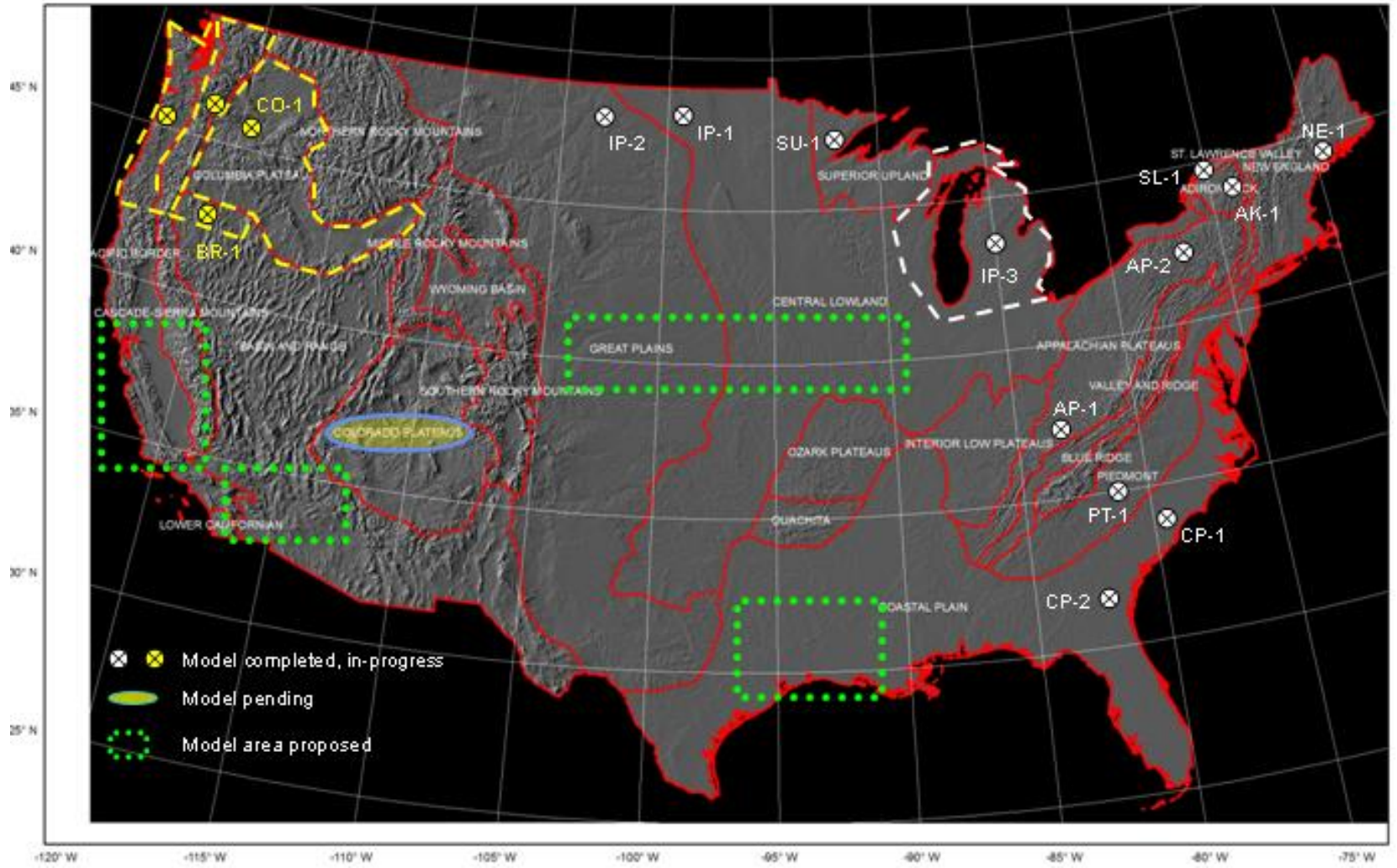
Surface Impedance
- Calculate using plane wave assumption at different freq.

Magnetic Field
- At least 10-sec data require for full resolution
- 1-minute data used for historical reanalysis

Electric Field
-Convolution of Z and B in time domain= multiplication in frequency domain

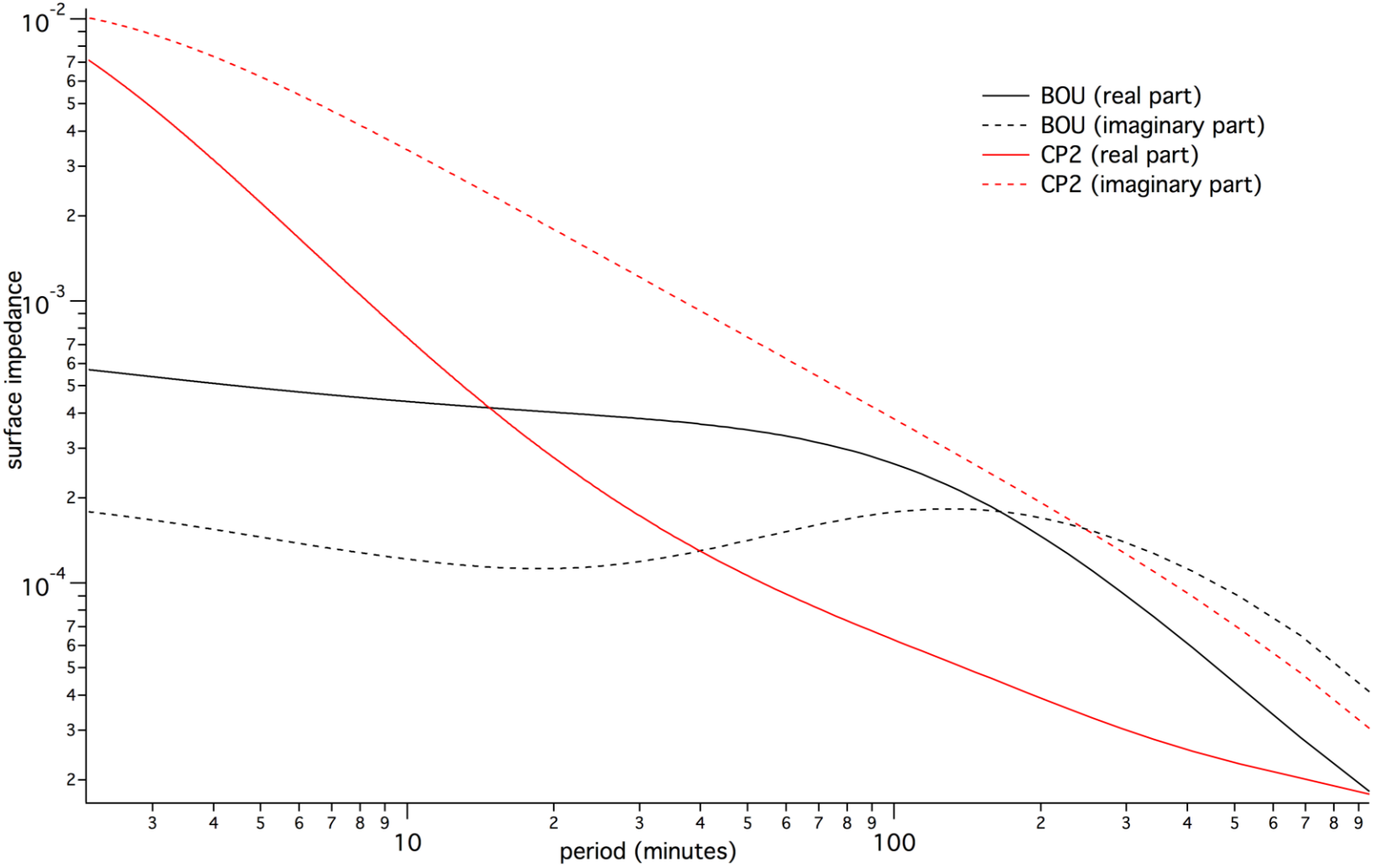
$$E(w) = B(w) * Z(w)$$
$$\Rightarrow$$
$$E(t) = FFT^{-1}(FFT(B(t)*Z(w)$$

1-D Conductivity

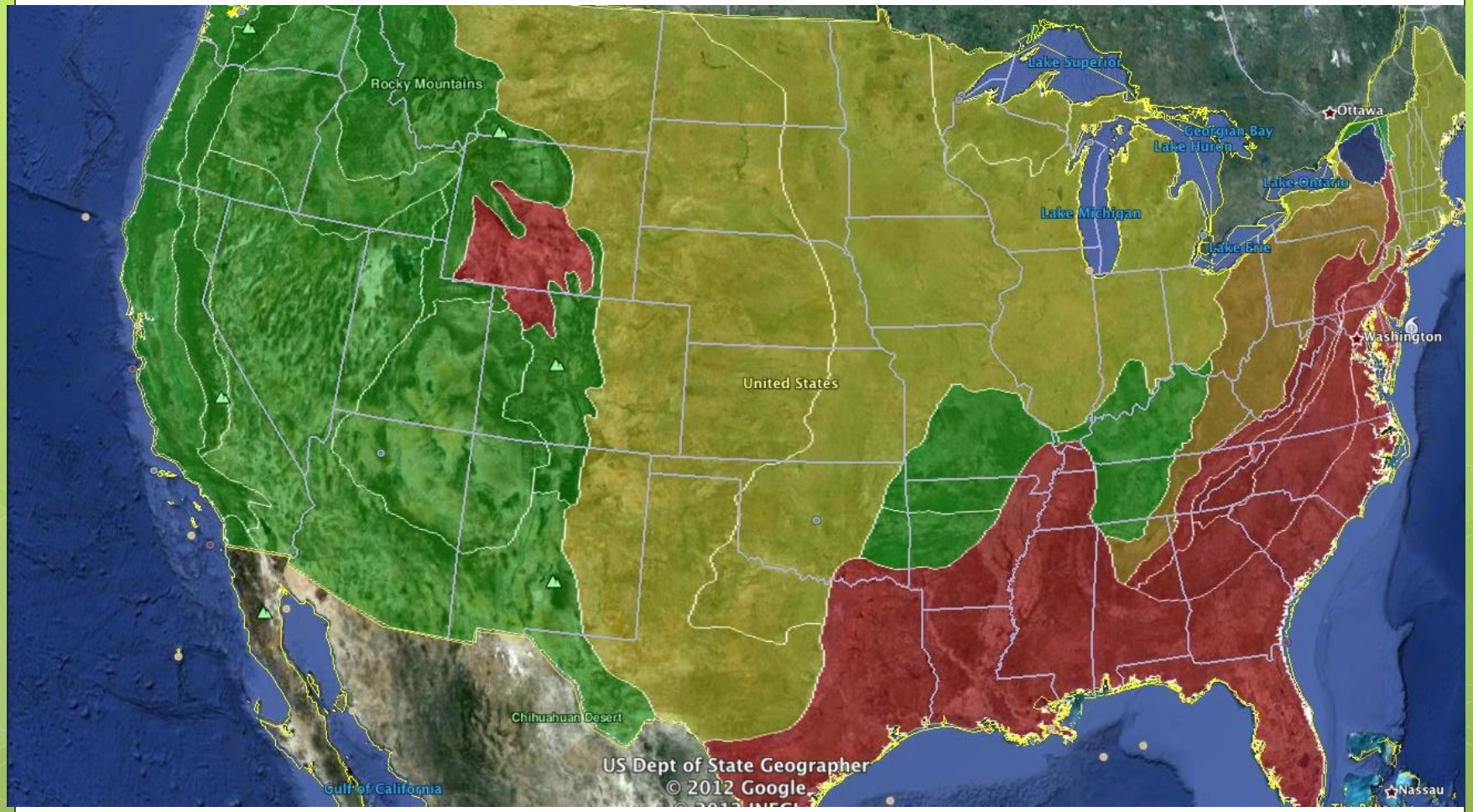


Fernberg, Gannon and Bedrosian, USGS OFR 2013, under review

Surface impedance vs frequency



Efield Response to Conductivity



Electric Field: Spectral content of a storm

- At least 10 second time resolution required to resolve full response of Electric field

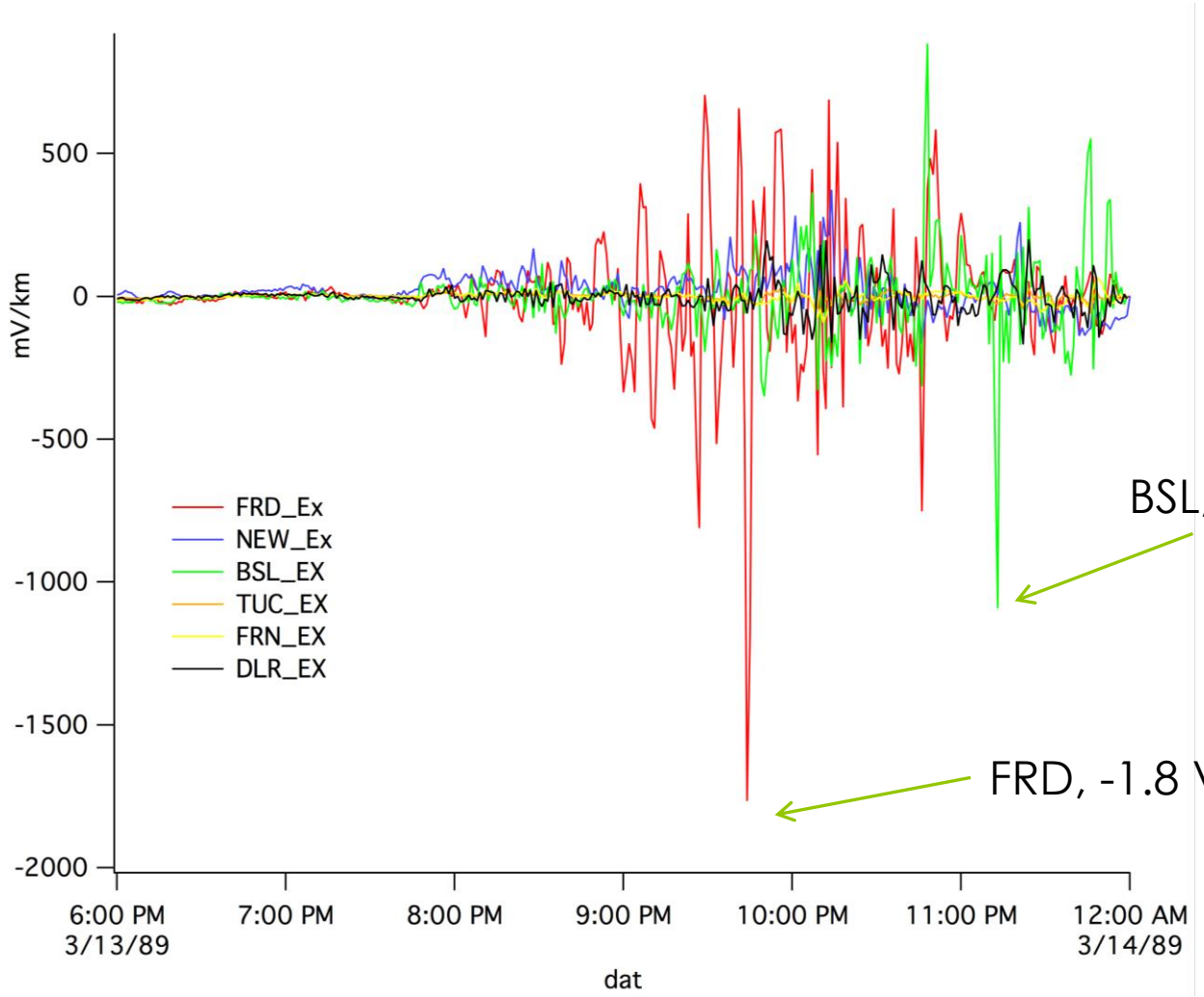
  (1-second data available at http://geomag.usgs.gov/data)

- Individual storms have unique spectral content

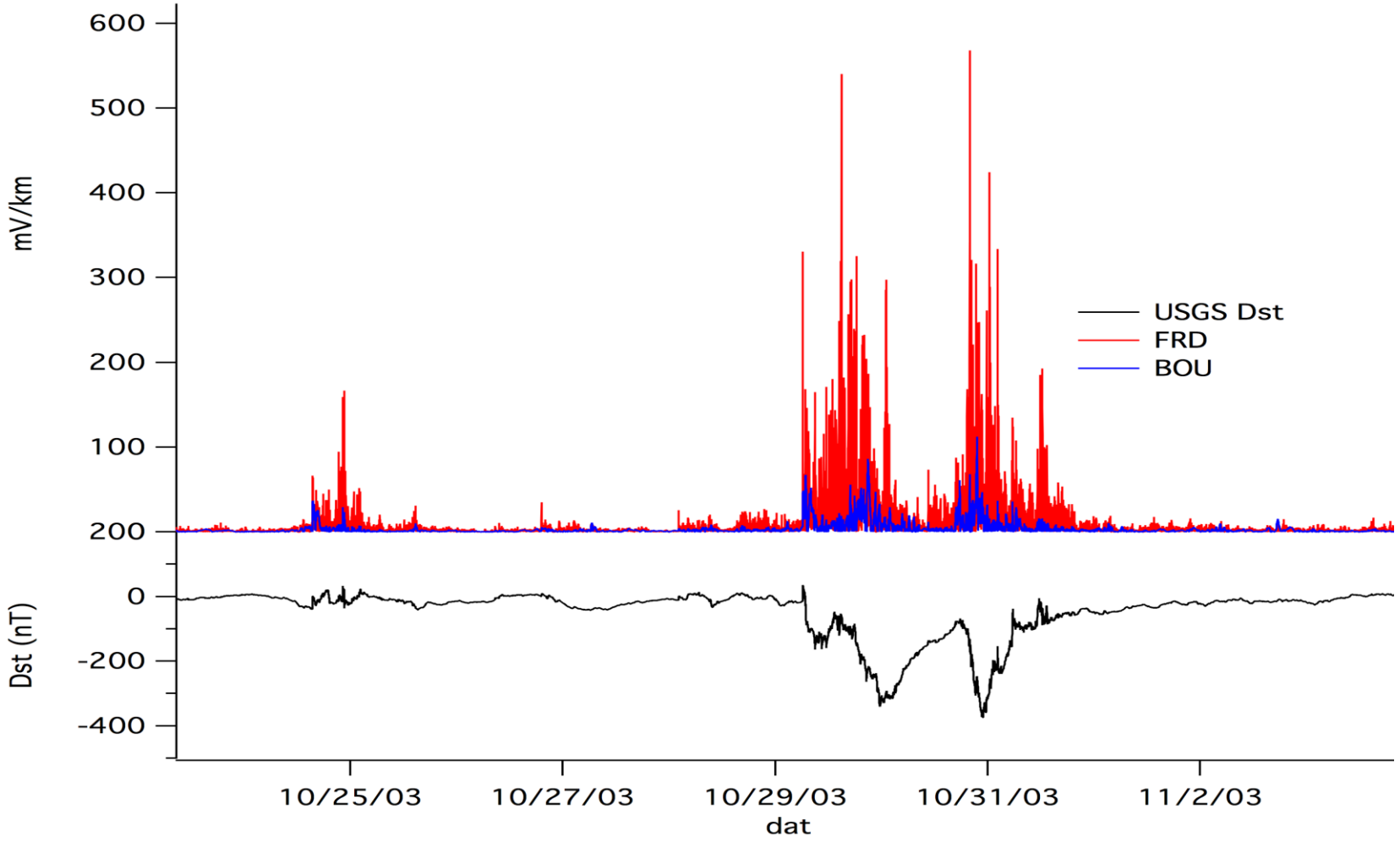
- Electric field response very sensitive to local geology

  (Conductivity profiles available at http://geomag.usgs.gov/conductivity)

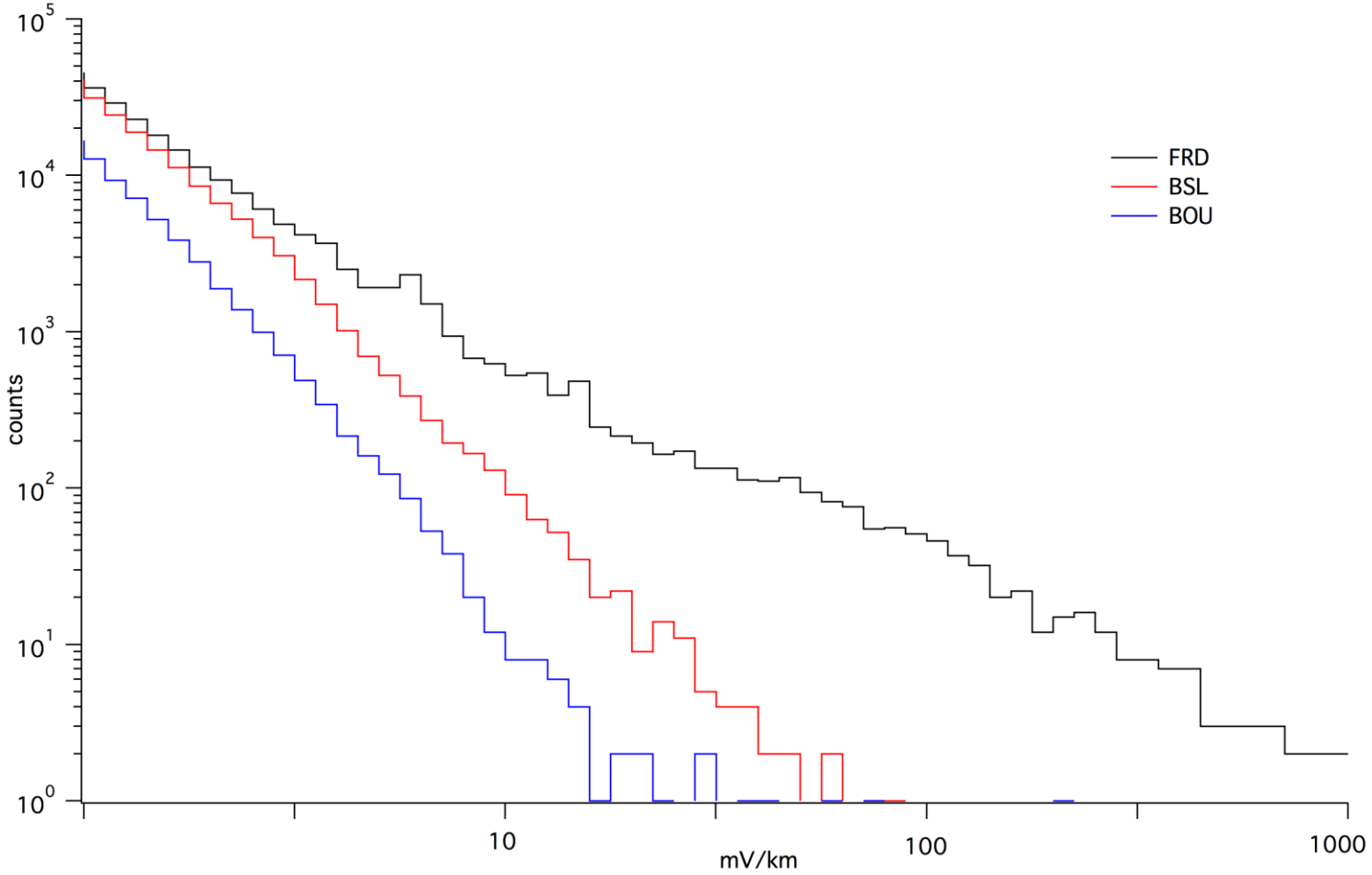
1989 Storm


500
0
-500
-1000
-1500
-2000
mV/km
FRD_Ex
NEW_Ex
BSL_EX
TUC_EX
FRN_EX
DLR_EX
6:00 PM
3/13/89
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
3/14/89
dat
BSL, -1.2 V/km
FRD, -1.8 V/km

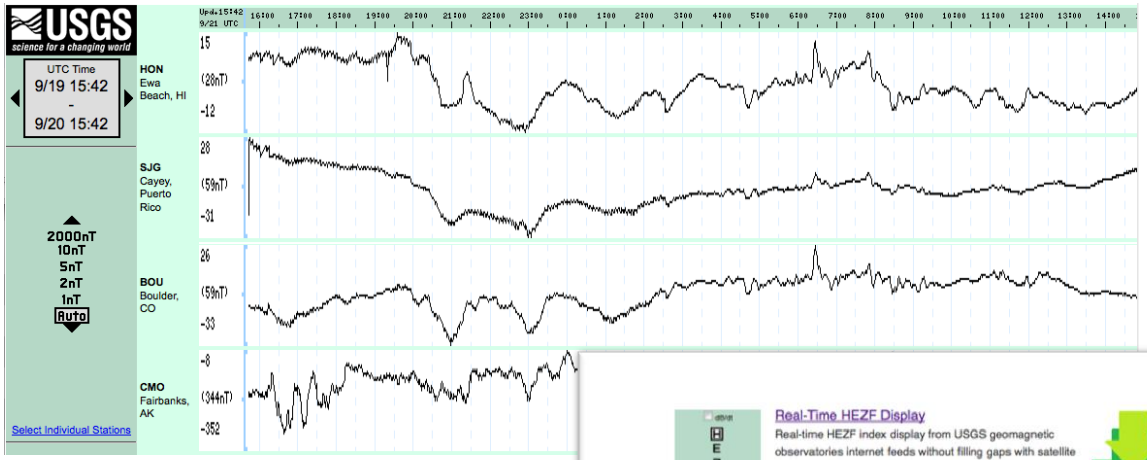
Halloween Storm

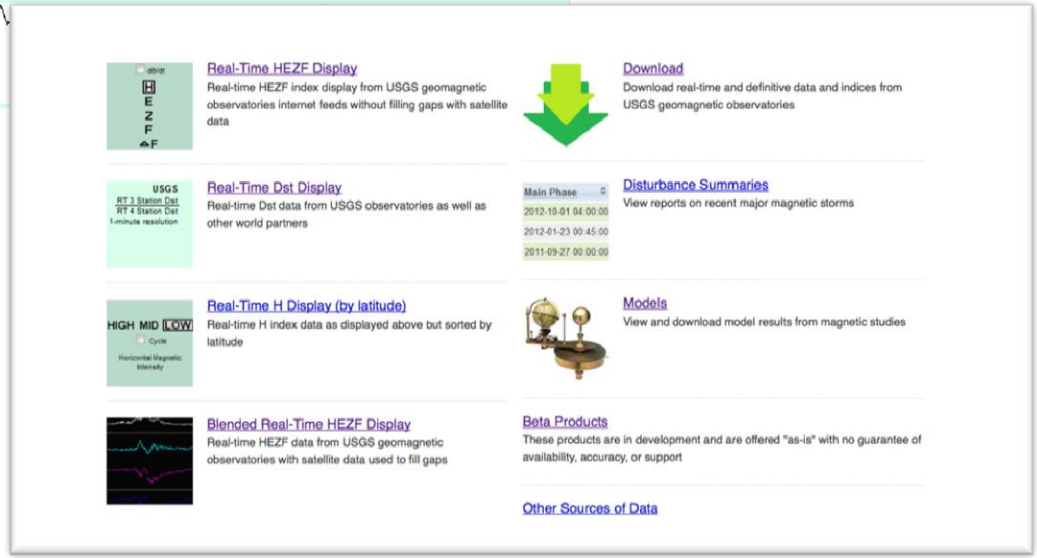


Historical Analysis- 1985-2010



Real-time products





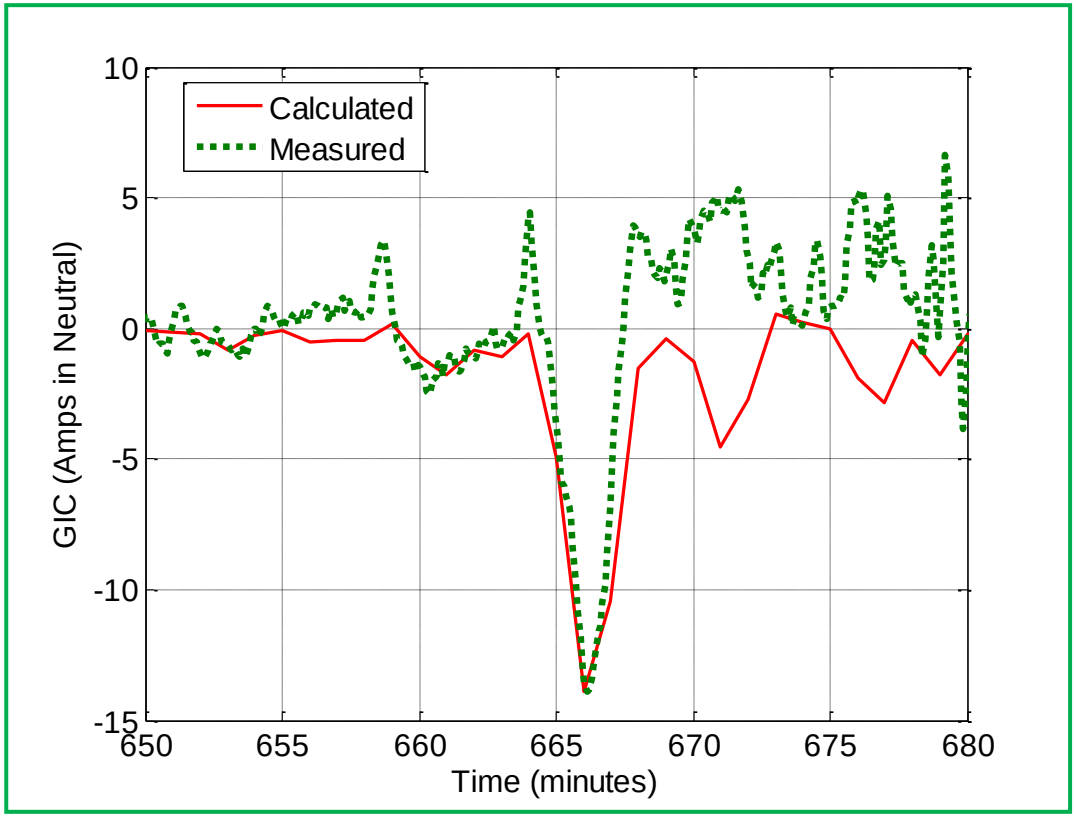
Real-time plots and text file download: http://geomag.usgs.gov/products

Validation of conductivity models

Use conductivity maps and magnetic field measurements (and models) to produce electric field input to system models

Working in collaboration with several utilities and researchers

Shorter period fluctuations (period < 1 min) may require more sophisticated methods than FFT



Courtesy of R. Horton (Southern Power)

Continuing Research

- Magnetic Field Interpolation for regional specification
- Wavelet analysis techniques to resolve higher frequency magnetic field drivers
- Observatory spacing/correlation lengths

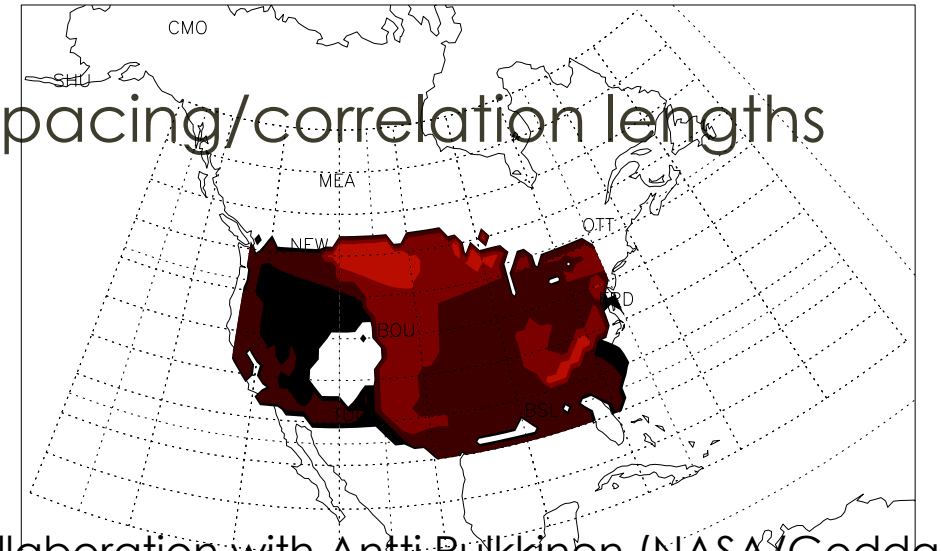
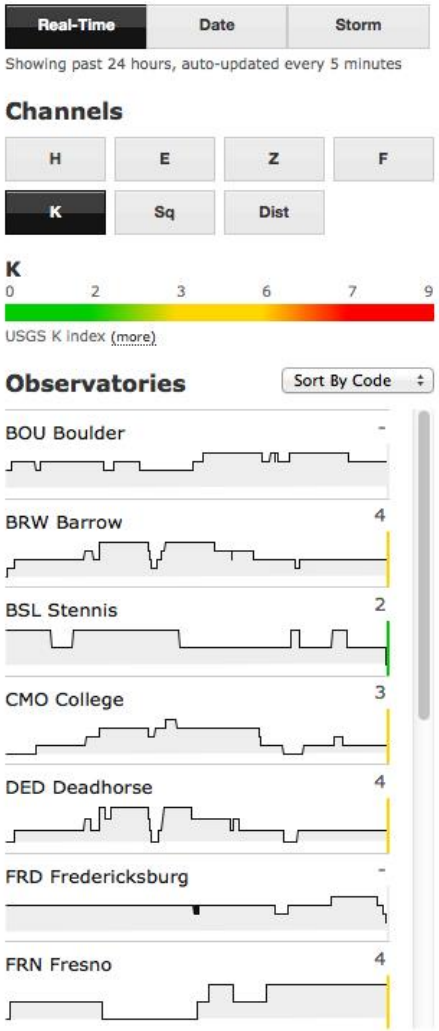
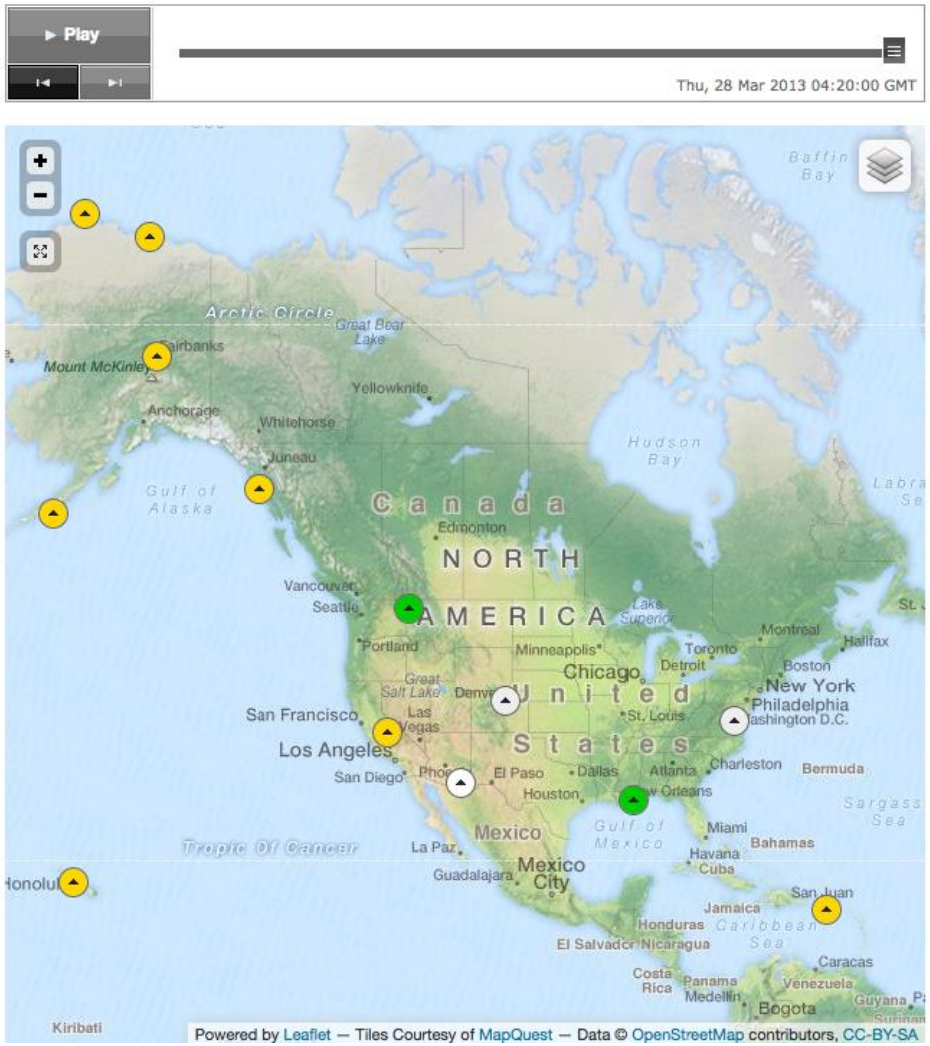


Image produced in collaboration with Antti Pulkkinen (NASA/Goddard)

USGS Real-time hazard maps





http://geomag.usgs.gov/map

Partnerships

- Industry: ISTI, EPRI, NERC, Markant, AER, GE, Southern Co, Schlumberger
- Government: NOAA, NASA
- Academia: CUA, UCLA, CU-Boulder, Oregon State

Summary

- Electric field estimates calculated for 1985-2010 at observatory locations
- Real-time electric field calculations available at observatory locations
- 1-D Conductivity profiles available
- Wavelet analysis and/or better conductivity mapping may be required to resolve pulsations with periods < 1 min
- Hazard mapping project and research underway!