Benchmarks for Induced Geo-Electric Fields

Current Status and Next Steps

Pete Riley, on behalf of the “Induced Geo-Electric Fields” Working Group:

Pete Riley (PSI)

Jeff Love (USGS, jlove@usgs.gov)

Antti Pulkkinen (NASA/CCMC, antti.a.pulkkinen@nasa.gov)

Adam Schultz (OSU, Adam.Schultz@oregonstate.edu)

Emanuel Bernabeu (PJM, Emanuel.Bernabeu@pjm.com)

Alan Thomson (BGS, awpt@bgs.ac.uk)

Background

- During an intense geomagnetic storm, time-varying magnetic fields can induce electric fields within the Earth's conducting interior, driving quasi-direct currents that may interfere with power-grid operation.
- If sufficiently strong, they may damage transformers and/or cause blackouts.
- Consequences of even more extreme events explored in a number of reports, which, in the worst case may lead to prolonged periods without power, water, or food.
- So, identifying the appropriate benchmark(s) to capture these possibilities is important!

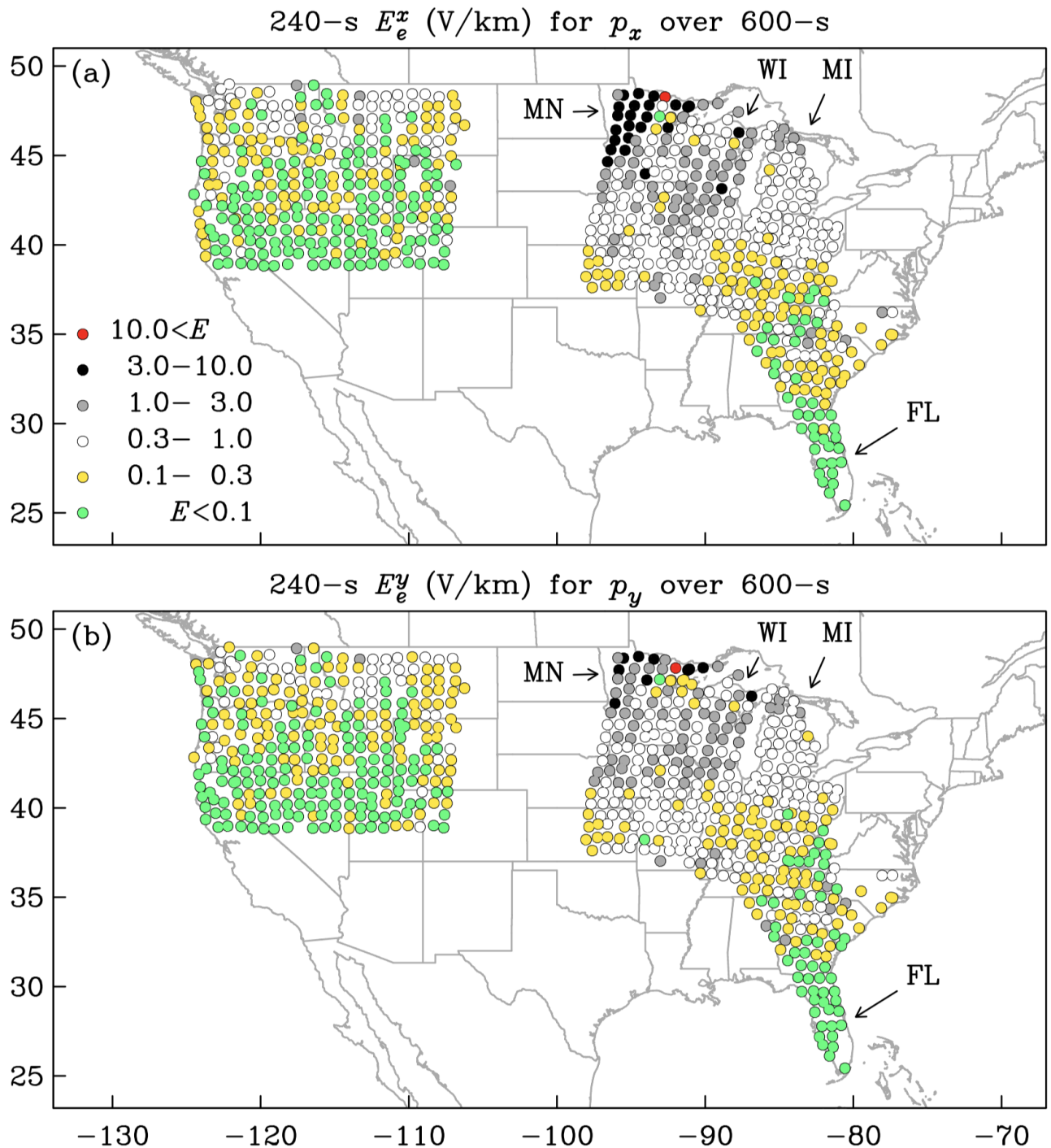
Objectives of Phase I “Induced Geo-Electric Fields”

- Assess the feasibility of establishing functional benchmarks for geo-electric fields using currently available storm data sets, existing models, and published literature; and
- Use the existing body of work to produce benchmarks for induced geo-electric fields for specific regions of the United States.

Methodology used by the “Induced Geo-Electric Fields” WG

- Focused on developing (1) maps of geo-electric hazard, (2) a formal statistical product from them (*Love et al*., 2016).
- Developed maps of extreme-value geo-electric amplitudes over ~1/2 continental U.S.
  - built by combining estimates of surface impedance (from magnetotelluric survey data) with statistical maps of extreme-value geomagnetic activity, to produce estimates of geo-induced electric fields.
- Estimates for likelihood of extreme geomagnetic activity based on extrapolation of quasi-power-law distributions.

Benchmarks for Induced Geo-Electric Fields	
Environmental parameter	Intense magnetic storms may induce geo-electric fields of sufficient strength to drive quasi-direct currents in electric power grids, sometimes causing blackouts and damaging transformers.
Methodology for determining benchmarks	Benchmarking for induced geo-electric field amplitudes used two geophysical quantities: the surface impedance relationship between geomagnetic variation and the induced geo-electric field, as well as a measure of geomagnetic activity at Earth's surface. Surface impedance values are obtained by magnetotelluric surveys, which have been completed for about half of the continental United States. Surface geomagnetic activity is routinely measured at magnetic observatories and variometer stations, and geomagnetic variations during a once-per-century event are estimated by a statistical analysis.
1-in-100-year benchmarks	The median once-per-century geo-electric exceedance amplitude among surveyed sites (see Figure 1) is 0.26 volts per kilometer (V/km), with amplitudes exceeding 14 V/km in Minnesota. One standard-deviation error, the result of statistical variance in the geomagnetic data, is estimated to be about 30 percent, which is small compared to the site-to-site differences. The full benchmark of once-per-century geo-electric amplitudes across the United States, where data is available, is displayed in Figure 1.
Theoretical maximum benchmarks	Not feasible to compute benchmarks. Higher frequency amplitudes cannot be reasonably estimated from the observatory data, and while lower frequency harmonics generally yield smaller geo-electric amplitudes, additional investigation would help inform this issue.



Love et al. (2016)

Main points from “Induced Geo-Electric Fields” WG in the Phase I report

- Products from WG were:

1. Well-defined and could be quantified, including their uncertainties;
2. Described a significant fraction of the U.S., with plans to complete mapping for other geographical areas; but
3. Focused, and not necessarily the most useful for some stakeholders

Next steps?

- Review studies completed/started since the writing of the Phase I Report, e.g.,
  - *Love et al.* (2019)
  - *Lucas et al.* (2018)
- Solicit input from “stakeholders” about how Phase II should be undertaken
- Different or additional benchmarks?
  - Wave shapes?
- Funding to support spatial mapping efforts?

Concluding Remarks

- First meeting of this “next steps” working group: April 23-25, 2019 (Denver).
  - Everyone welcome (at least for first day)
- Formally, submit ideas by 12th April to:
  - https://www.ida.org/STPI/ExploreSTPIResearch/SpaceWeather
- Informally, inputs/suggestions for this WG accepted anytime prior to, or at plenary session on the 23rd.
- Inputs after 25th may be considered if possible.