THE POWER OF DATA: A GRID ANALYSIS

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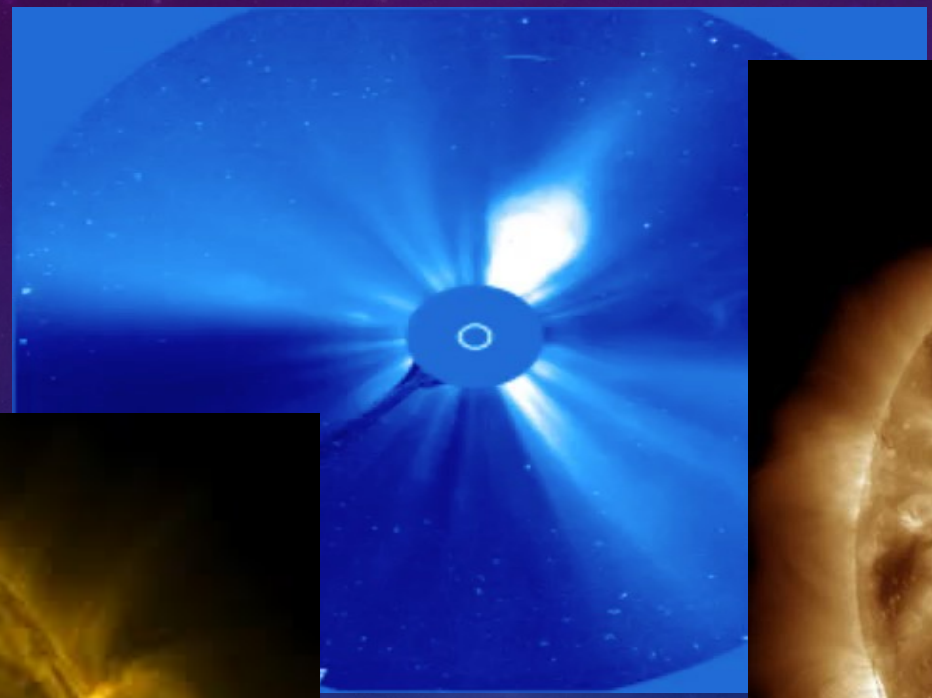
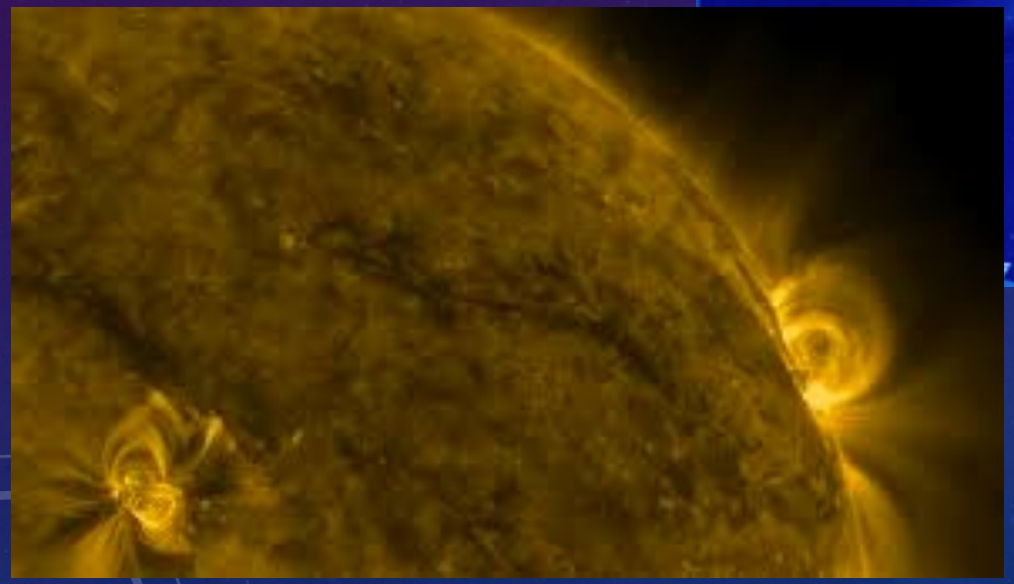
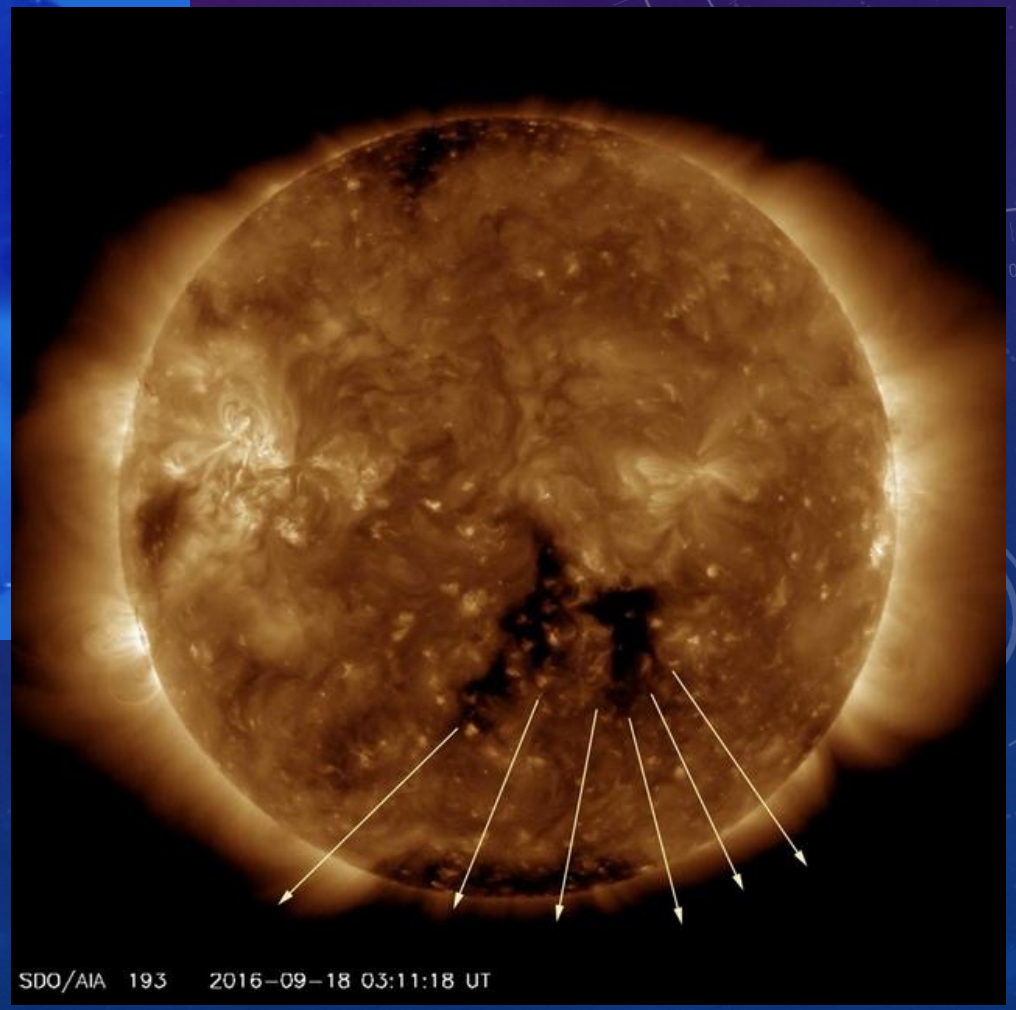
(WITH D. KNIPP/CU-BOULDER AND C. MACCORMACK/NASA)

IN SPACE WEATHER, WE TEND TO FOCUS ON THE EXTREME EVENTS

Coronal Mass Ejections (CMEs) aimed towards the earth can create extreme geomagnetic conditions.





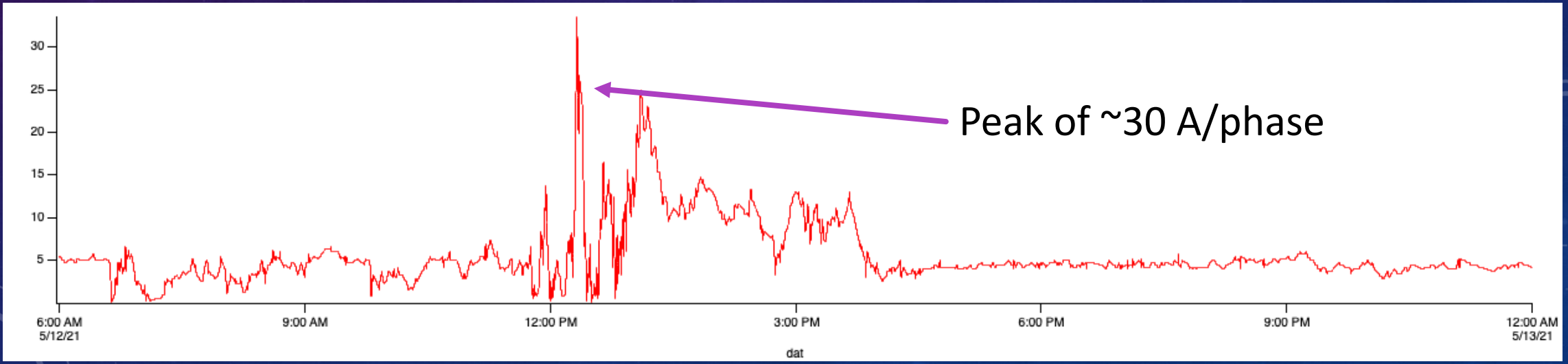


Images courtesty NASA

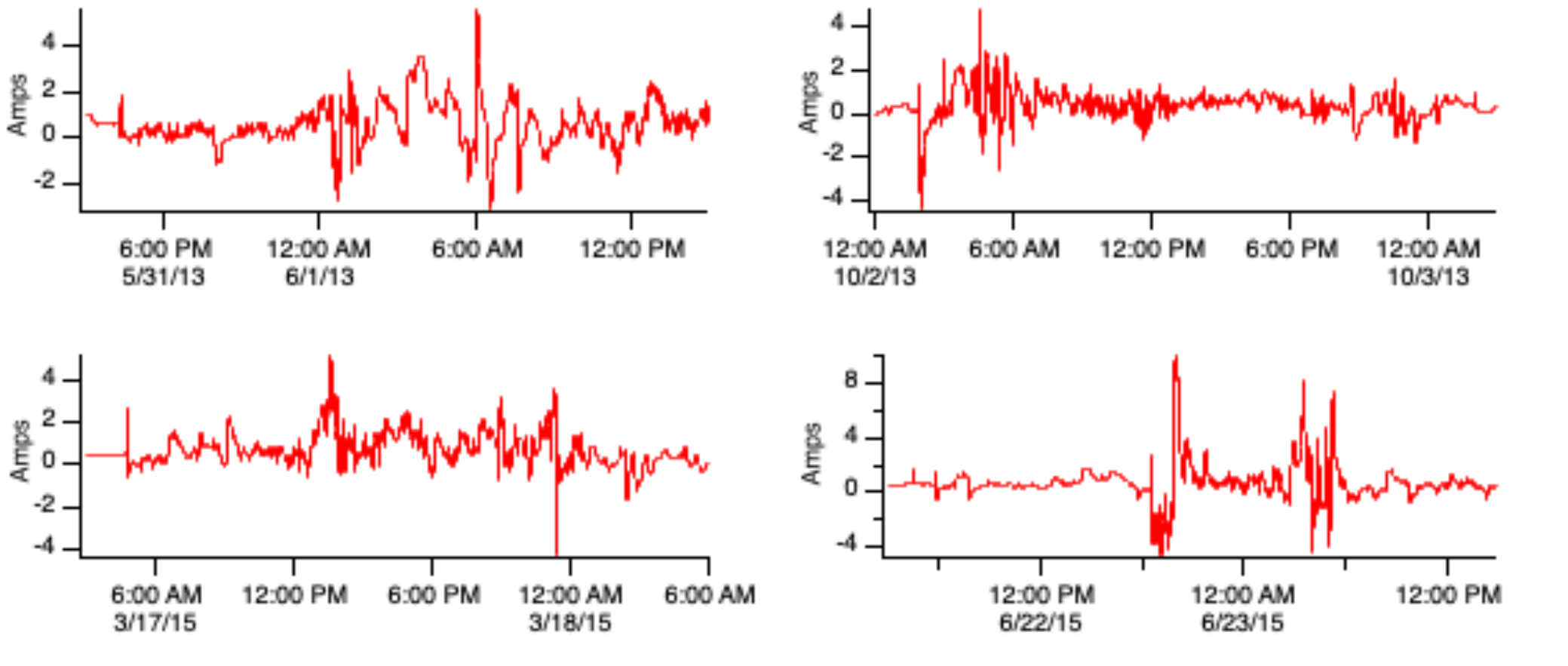
THE MAY 12-13, 2021 GEOMAGNETIC STORM SEEMED TYPICAL….

Classified as a G3, Kp = 7, BUT we have a new important data source in GIC (Geomagnetically induced current) data, provided by the US power utilities!

- Extended elevated GICs for 3-4 hours
- Note time of peak GIC => 12Noon



GIC LEVELS INCONSISTENTLY HIGH COMPARED TO EARLIER STORMS IN THE WASHINGTON, DC AREA

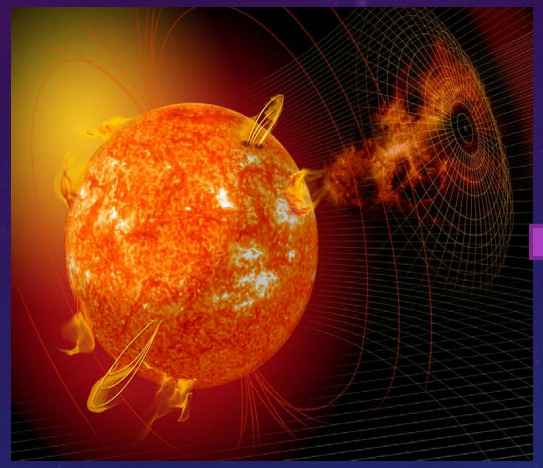


HISTORY OF GIC DATA AVAILABILITY

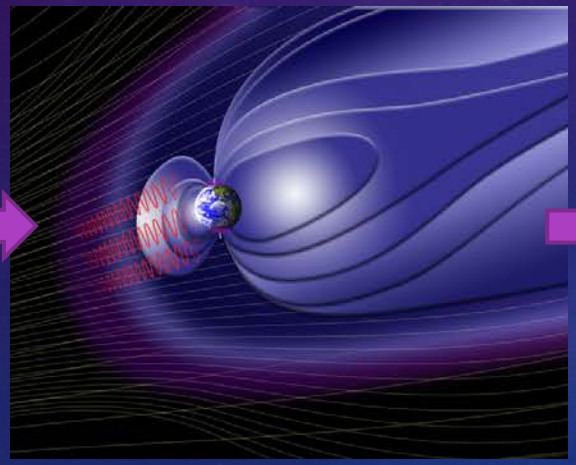
- 1989 geomagnetic storm leads to issues in the Quebec power grid
- FERC regulation directs NERC to assess needs for mitigation (TPL-007)
- TPL-007 directs power utilities to measure GIC
- Data request to utilities to update NERC data base yearly for storm periods indicated by SWPC

A GEOMAGNETIC STORM IS A RECONFIGURATION OF FIELDS.

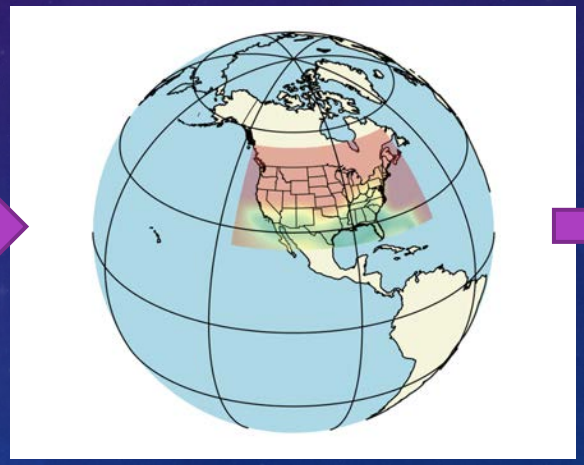
Solar Wind Drivers



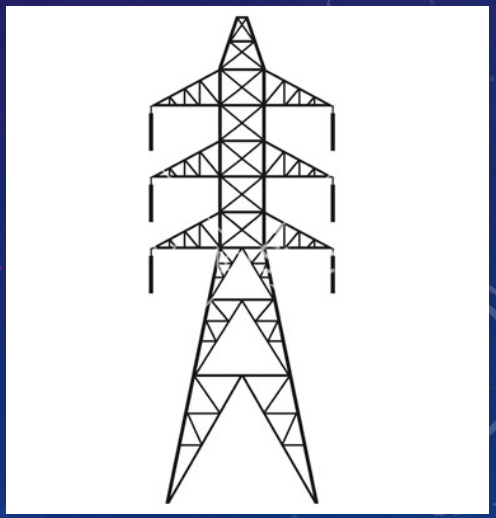
Currents in the Magnetosphere-Ionosphere System



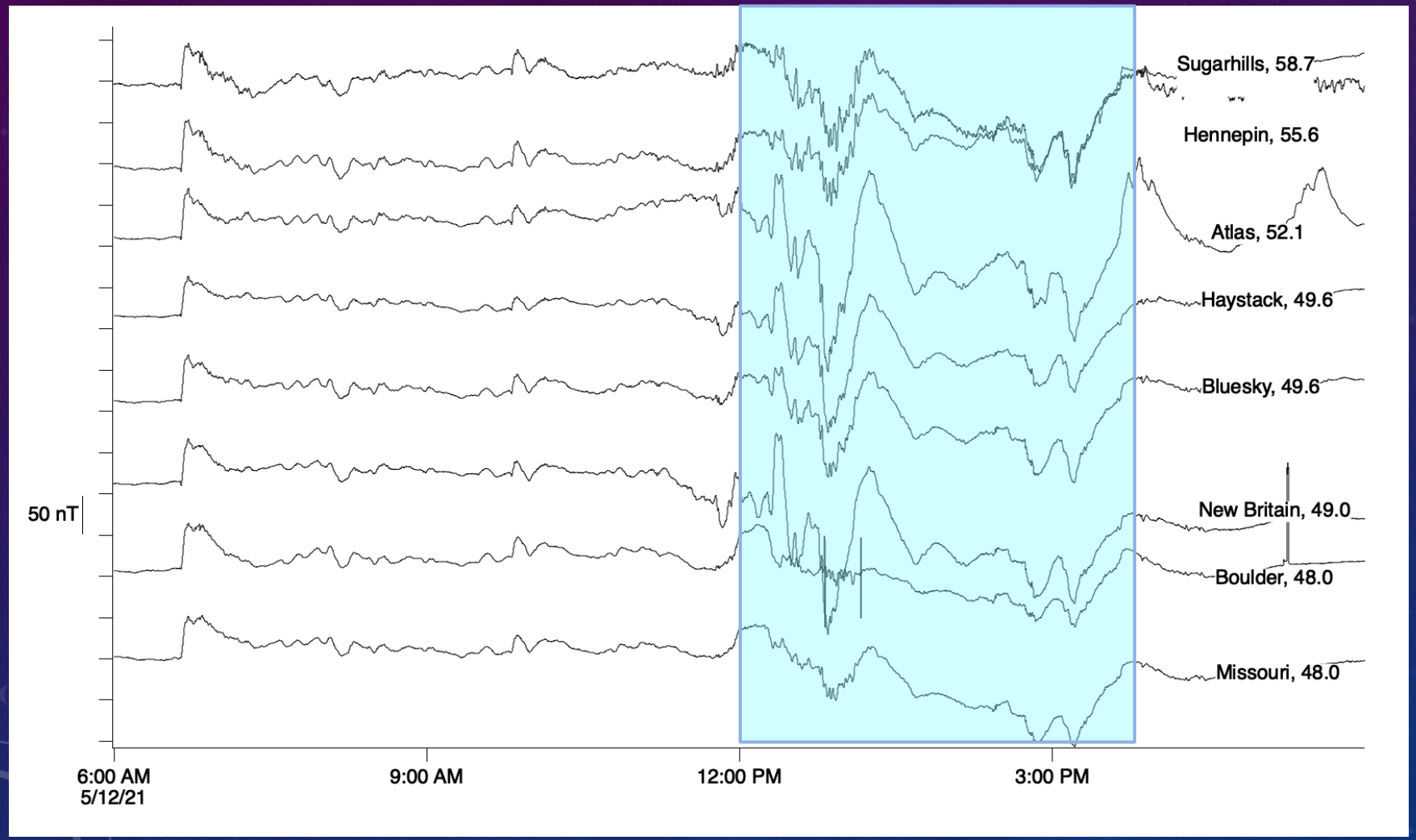
Geomagnetic Fields and Induced Electric Fields at Ground-Level



GICs induced in long conductors

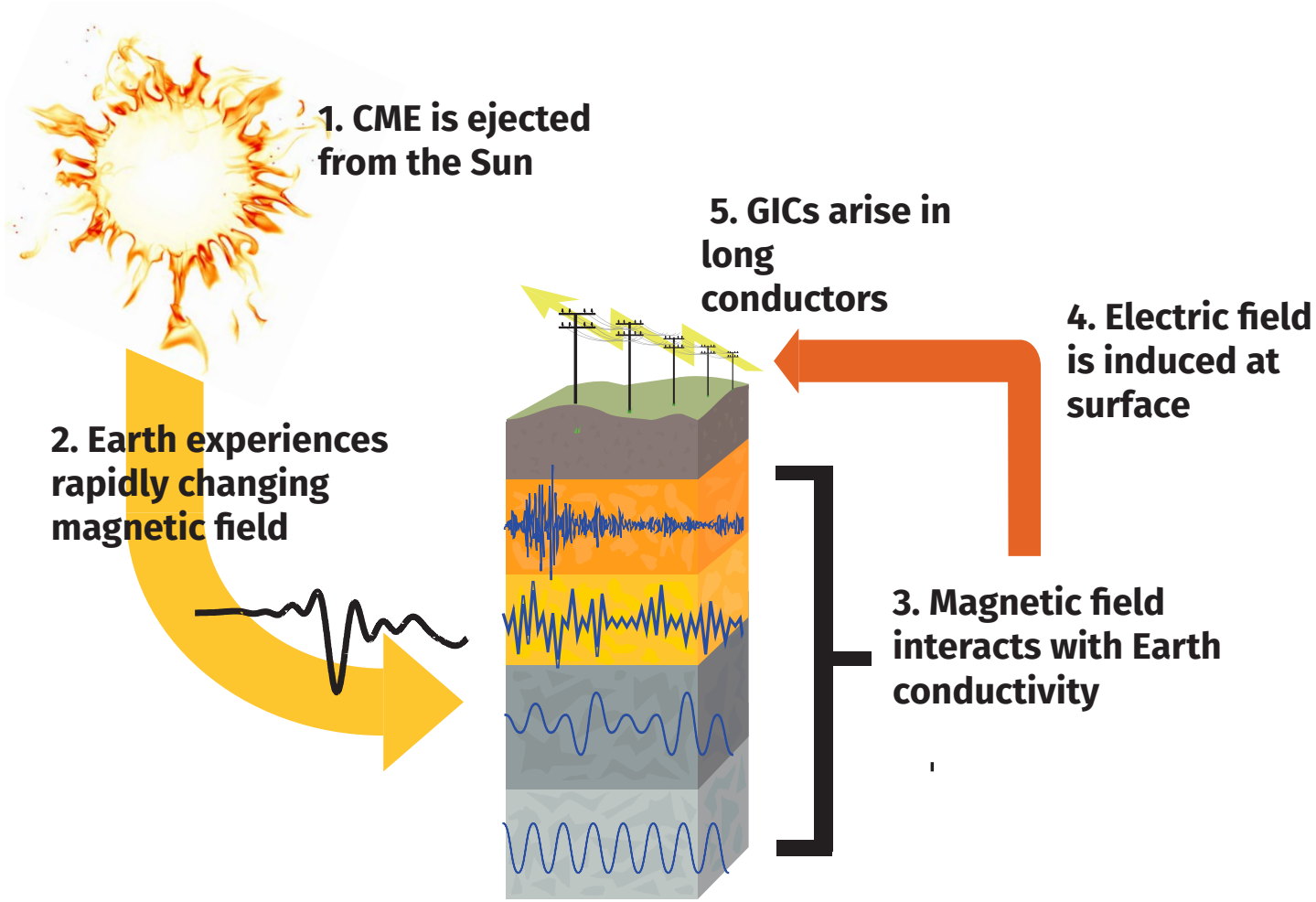


MAGNETIC FIELD DATA WAS ALSO AVAILABLE.



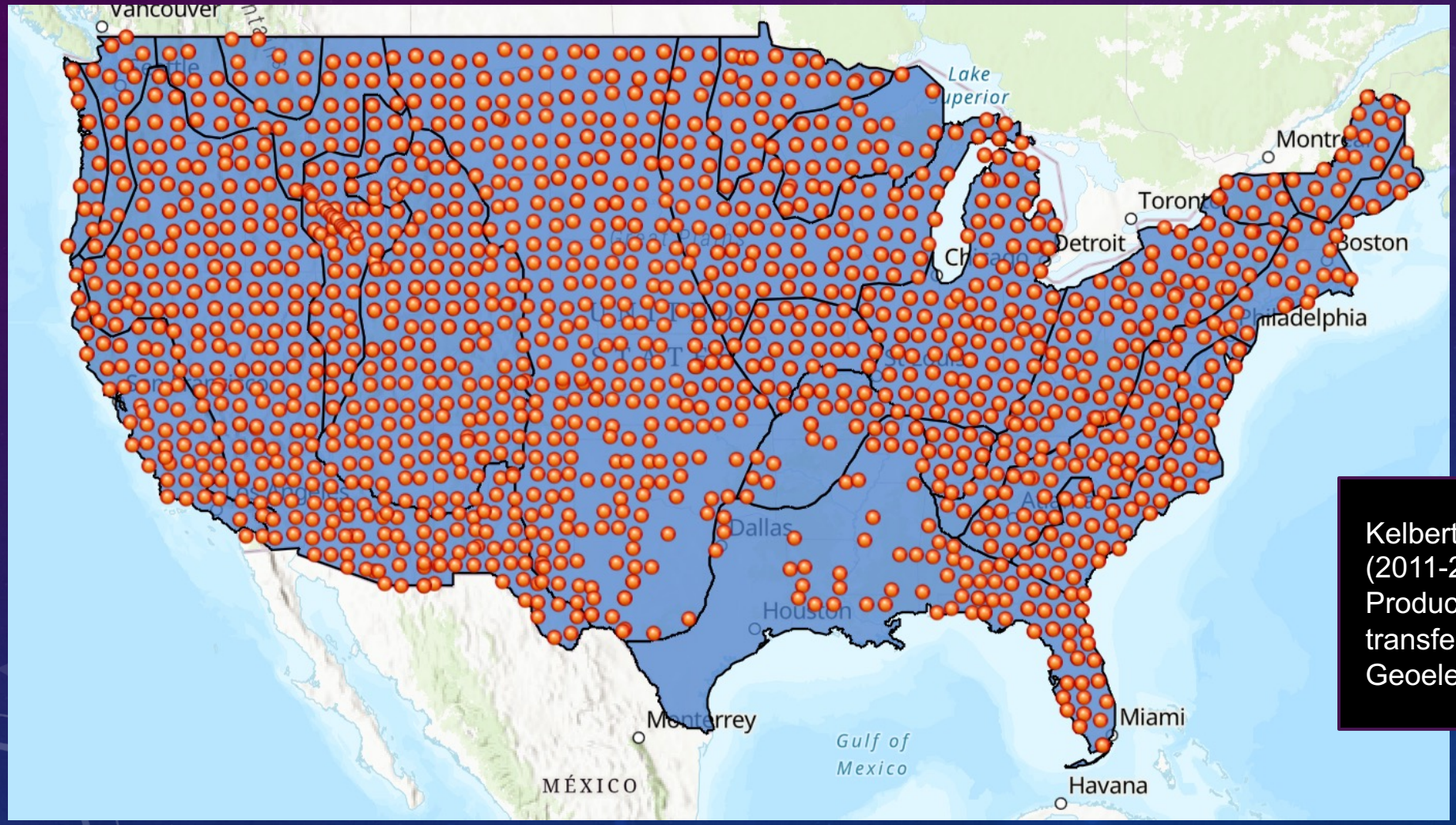
- Horizontal intensity in magnetic field shown here
- Sharp sudden commencement observed at all 8 MagStar installations just after 6UT
- Remarkably smooth field orientation during storm main phase.
- Note 12:00 time period.

THE EARTH IS A NON-UNIFORM CONDUCTOR.



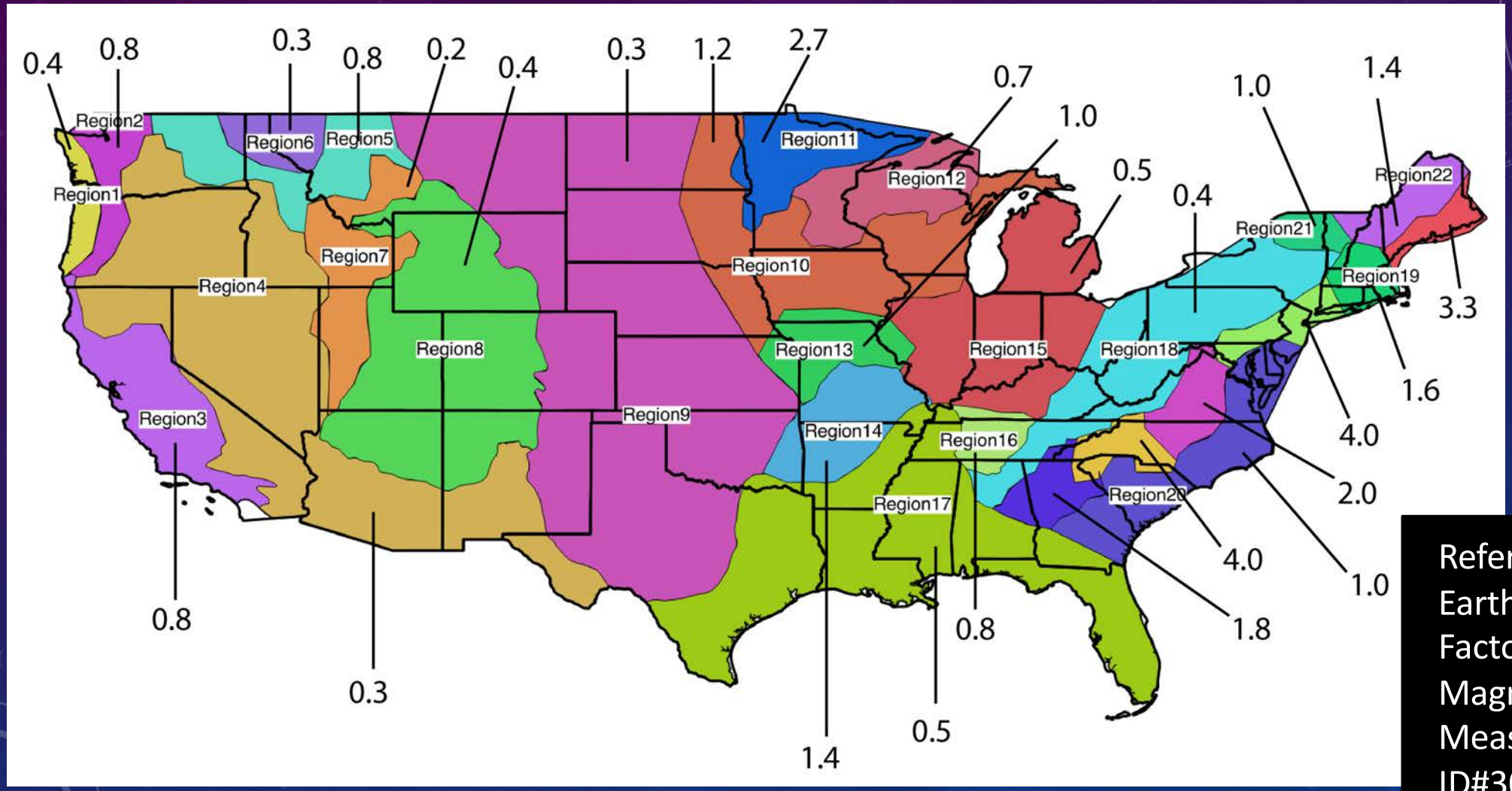
- Changing magnetic field produces an electric field.
- Conductivity varies with depth (and also laterally)
- Skin depth is frequency dependent

MORE DATA AVAILABLE!! MEASUREMENTS OF DEEP EARTH CONDUCTIVITY – EARTHSCOPE MAGNETOTELLURICS

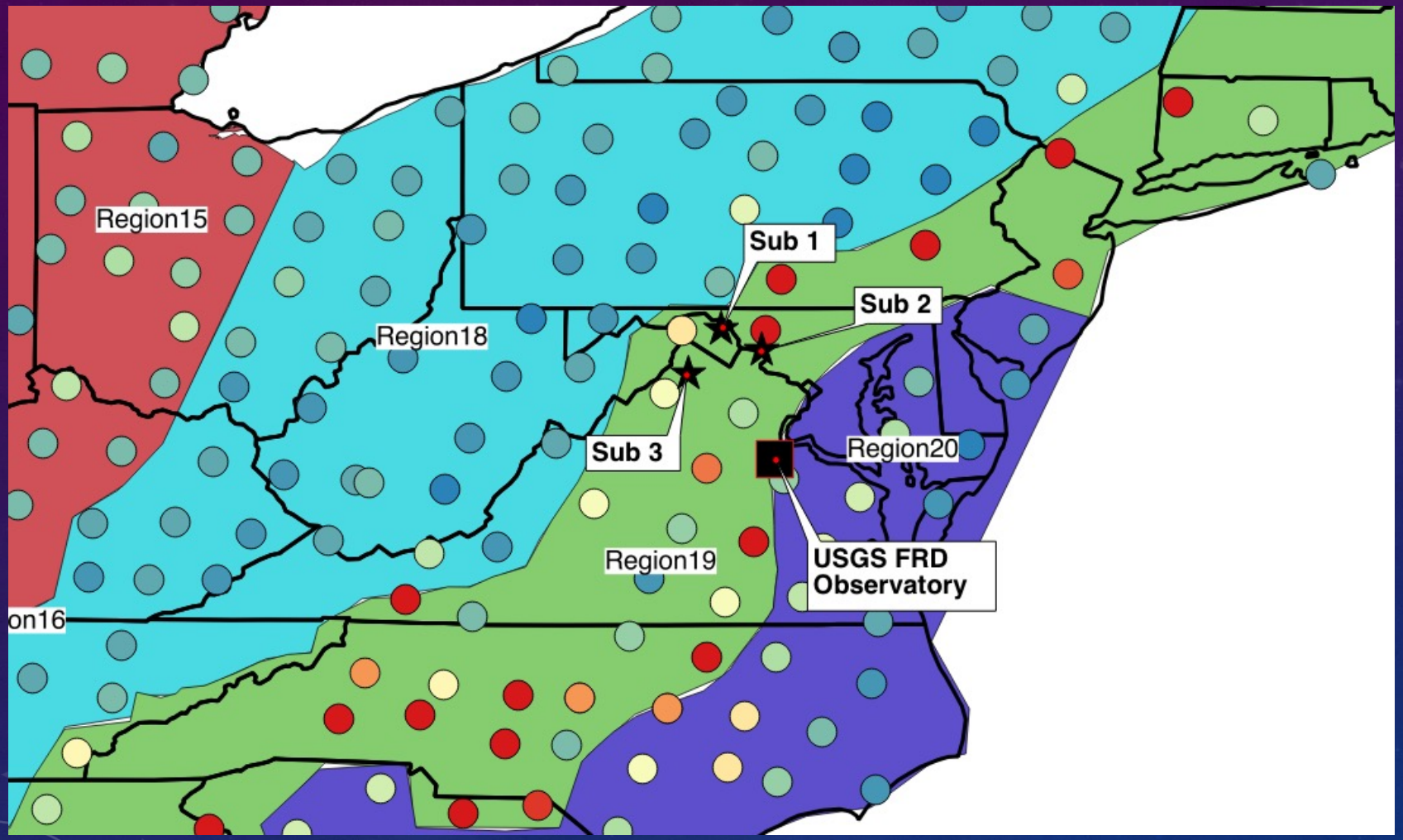


Kelbert, A., G. Egbert, and A. Schultz (2011-2023), IRIS DMC Data Services Products: EMTF, the magnetotelluric transfer functions, Tech. rep. National Geoelectromagnetic Facility.

FROM THE MT DATA, WE KNOW WHICH PARTS OF THE US HAVE THE HIGHEST GIC HAZARD.



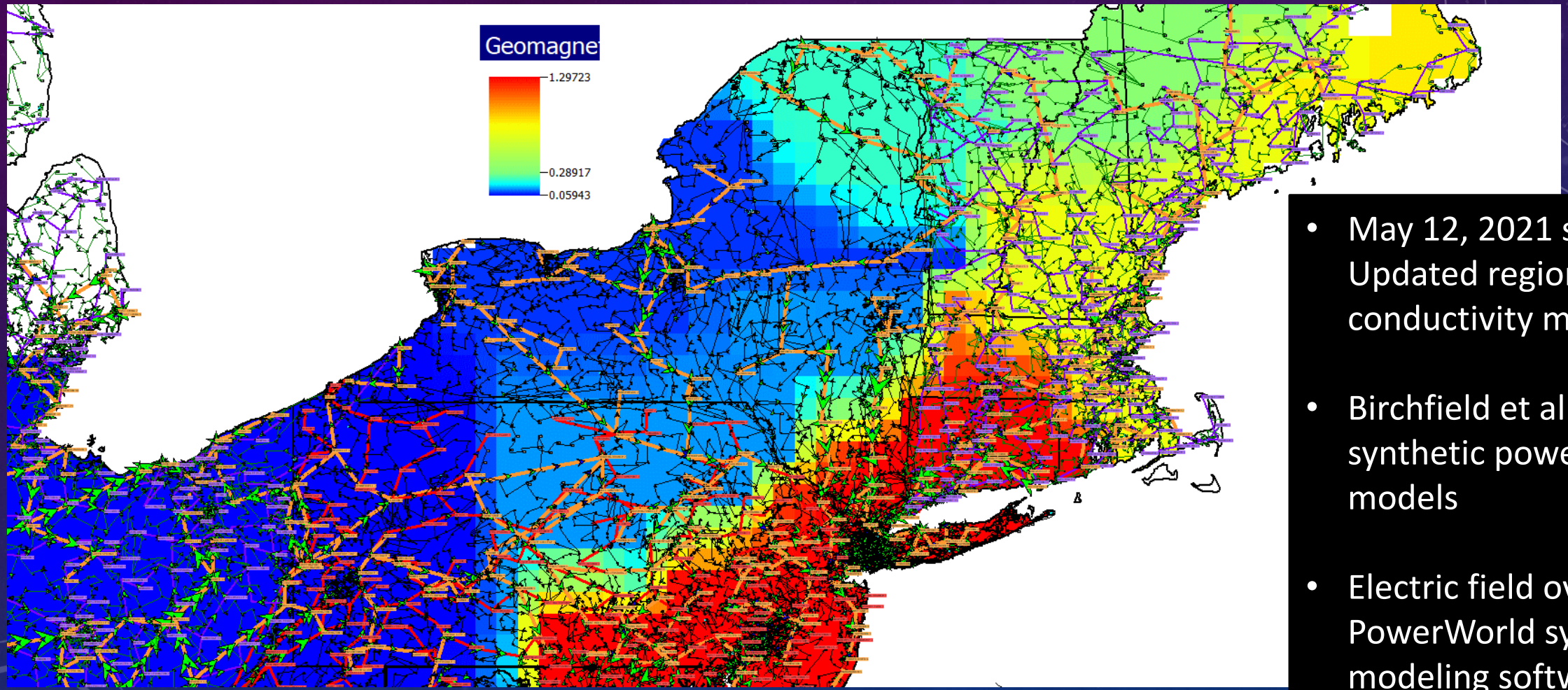
Reference: Update of Earth Response Scaling Factors Using Magnetotelluric Measurements, Product ID#3002017899, 2020.



FROM THESE DATA WE ALSO KNOW THAT THERE ARE AREAS THAT ARE PARTICULARLY COMPLEX

FIELDS VARY\ IN ORIENTATION AND INTENSITY

THE POWER SYSTEM IS ALSO VERY COMPLEX. SYSTEM MODELS ARE USED TO ANALYZE GRID RESPONSE.



- May 12, 2021 storm, Updated regional conductivity models (EPRI)
- Birchfield et al., 2016 synthetic power system models
- Electric field overlaid in PowerWorld system modeling software

GIC MODEL VALIDATION ASSESSMENT

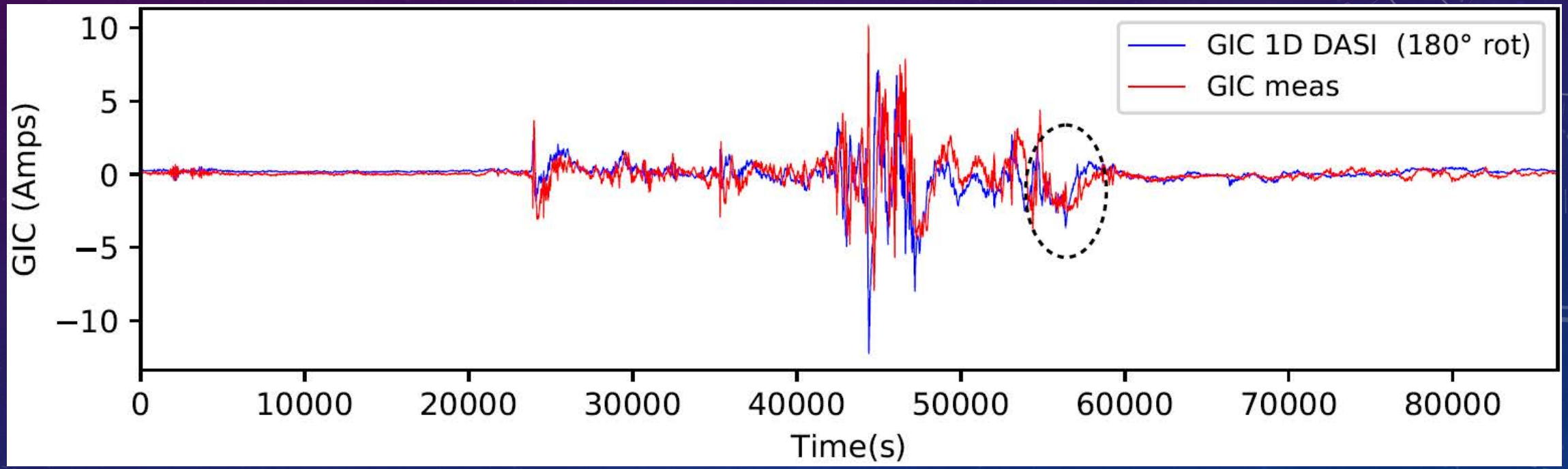
Step 1: Measure magnetic field and GIC

Step 2: Calculate geoelectric field (or line voltages) using magnetic field and earth response model

Step 3: Use geoelectric field with system model to estimate GIC

Step 4: Compare estimated and measured GIC

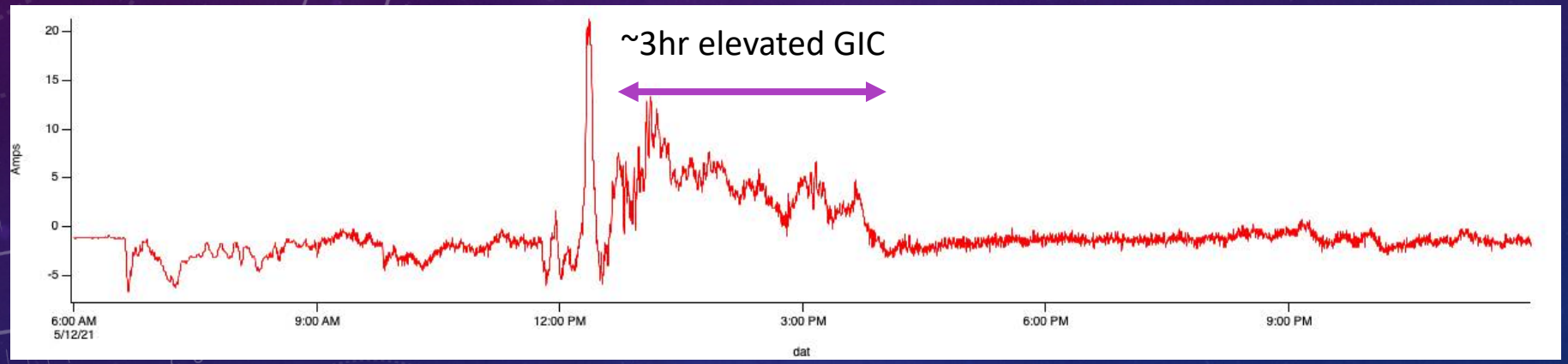
WE USE DATA TO ENSURE MODEL RESULTS ARE ACCURATE

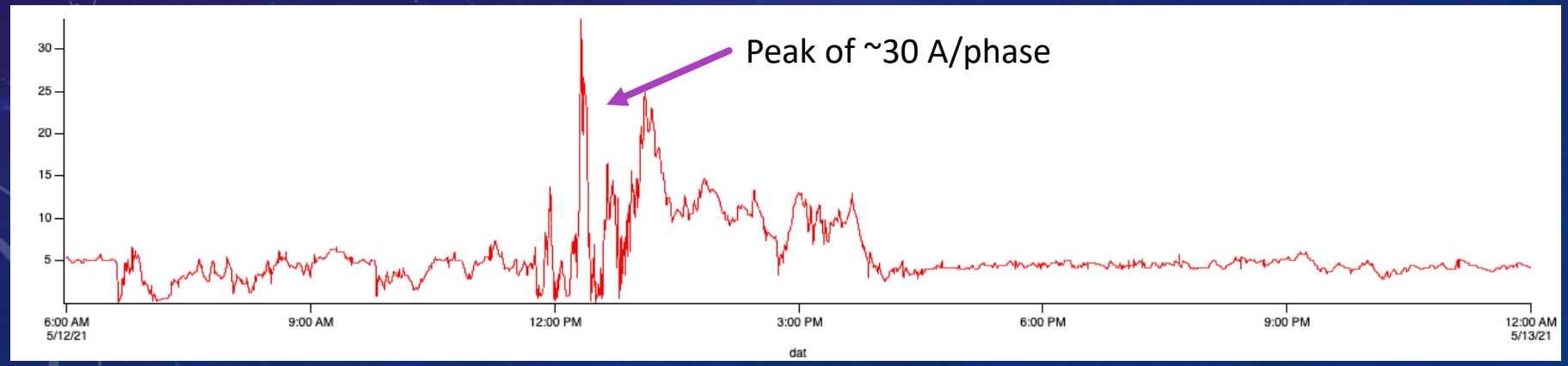


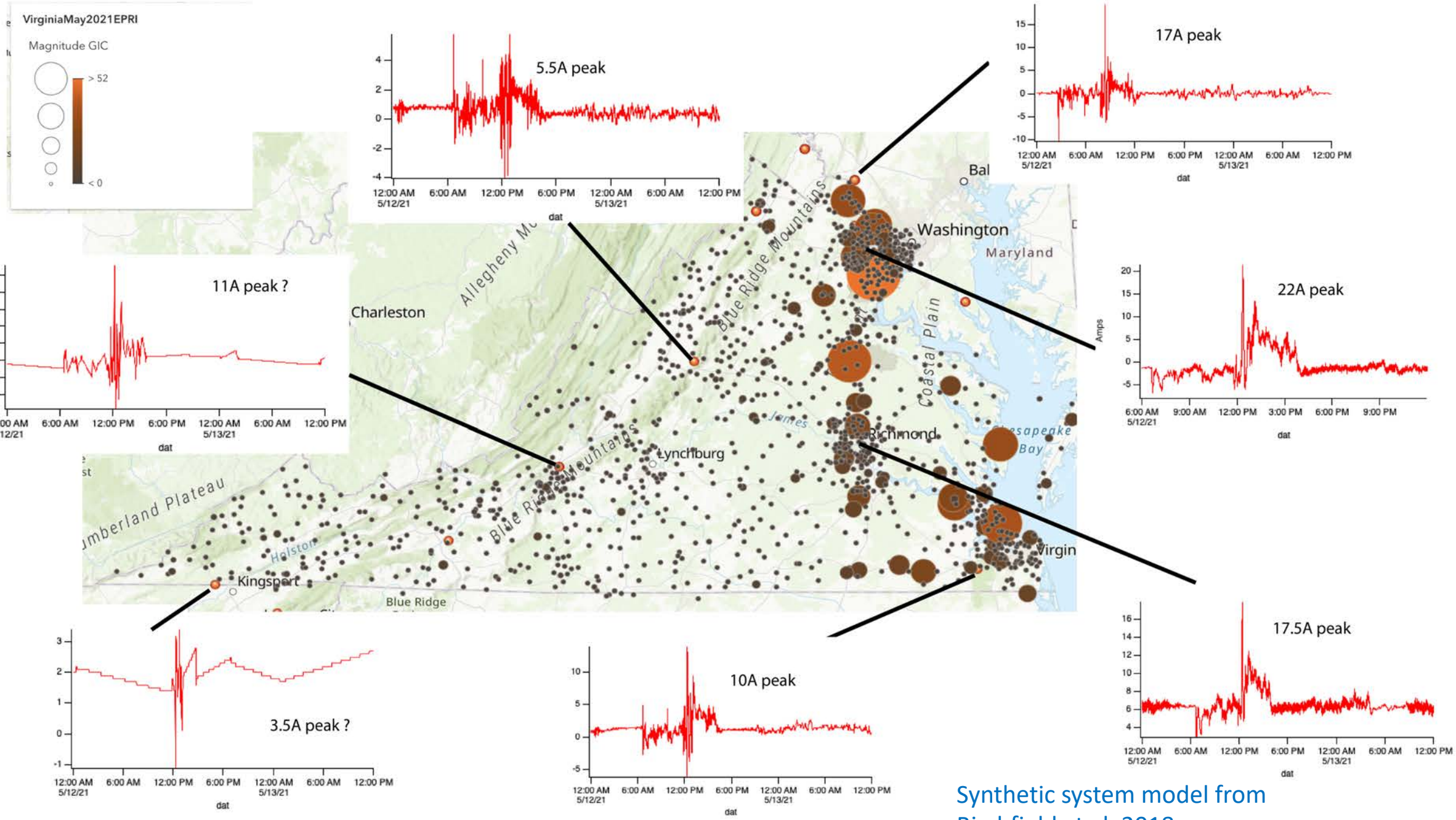
Courtesy: B. Arritt (EPRI)

SURPRISES FROM THE MAY 12, 2021 STORM

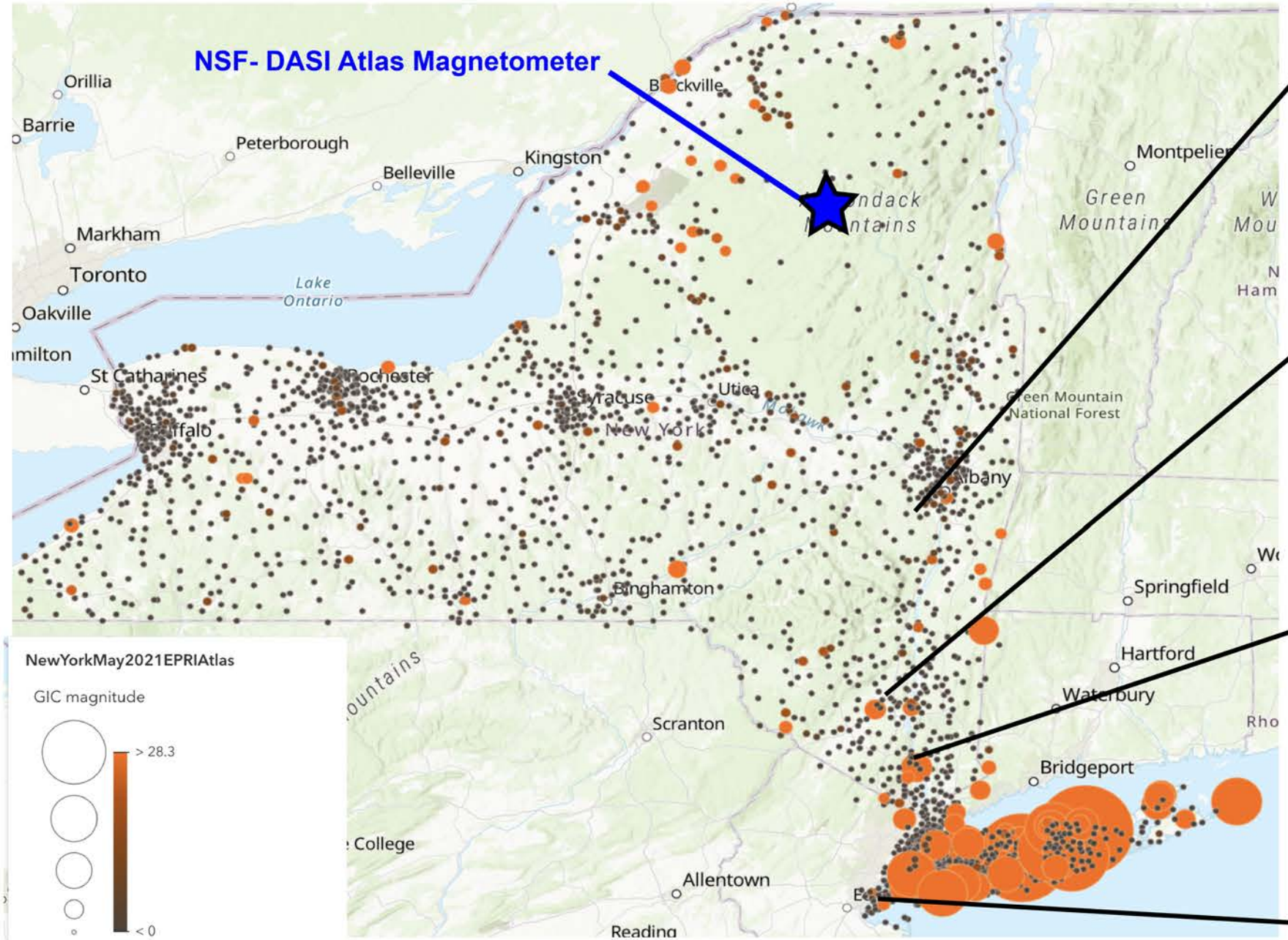
- Larger than expected GICs in the DC/Northern Virginia area (no data available from highest hazard regions in US).
- GIC spiked, then maintained elevated levels for 3-4 hours.
- ***This effect was observed over a large area of the US, from Kansas to DC area (~20 locations from available dataset).***

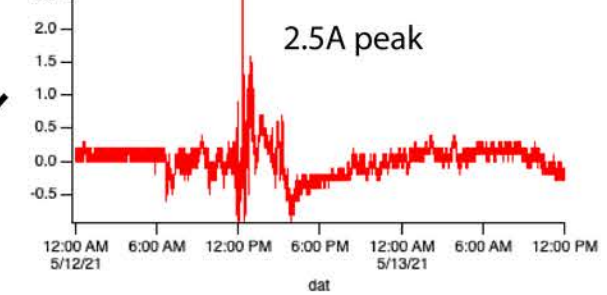


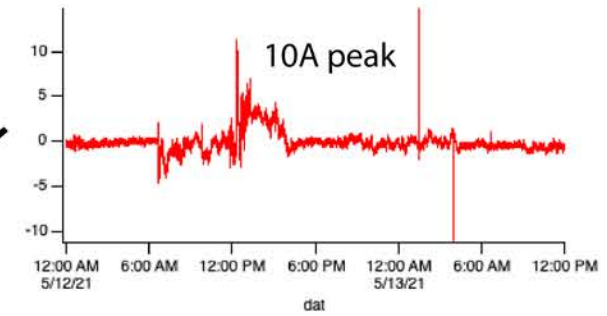


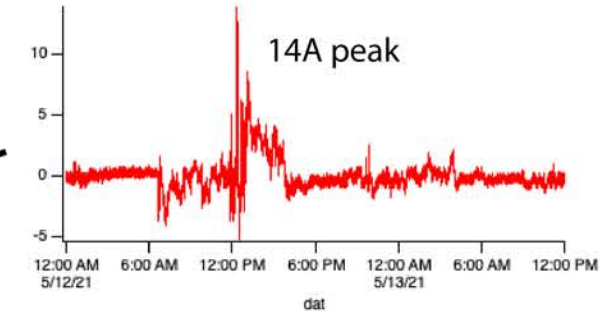


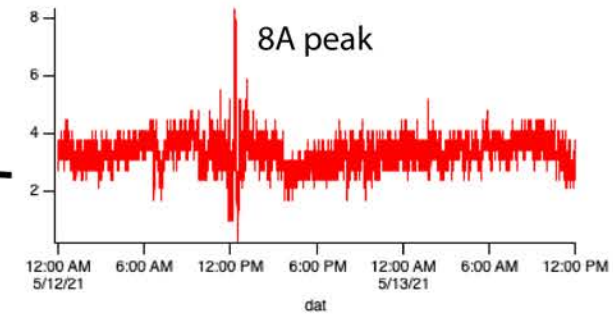
Synthetic system model from Birchfield at al, 2018.











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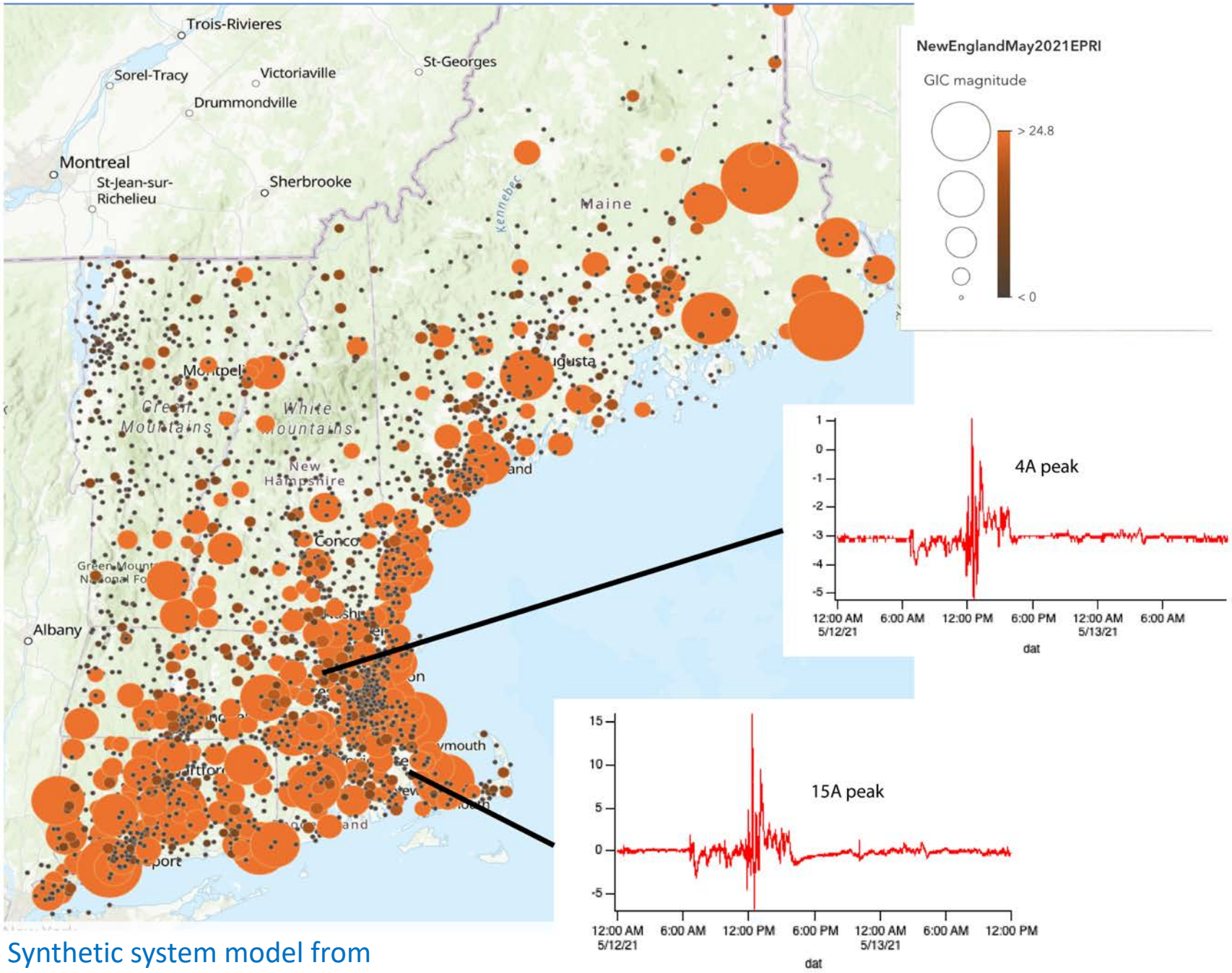
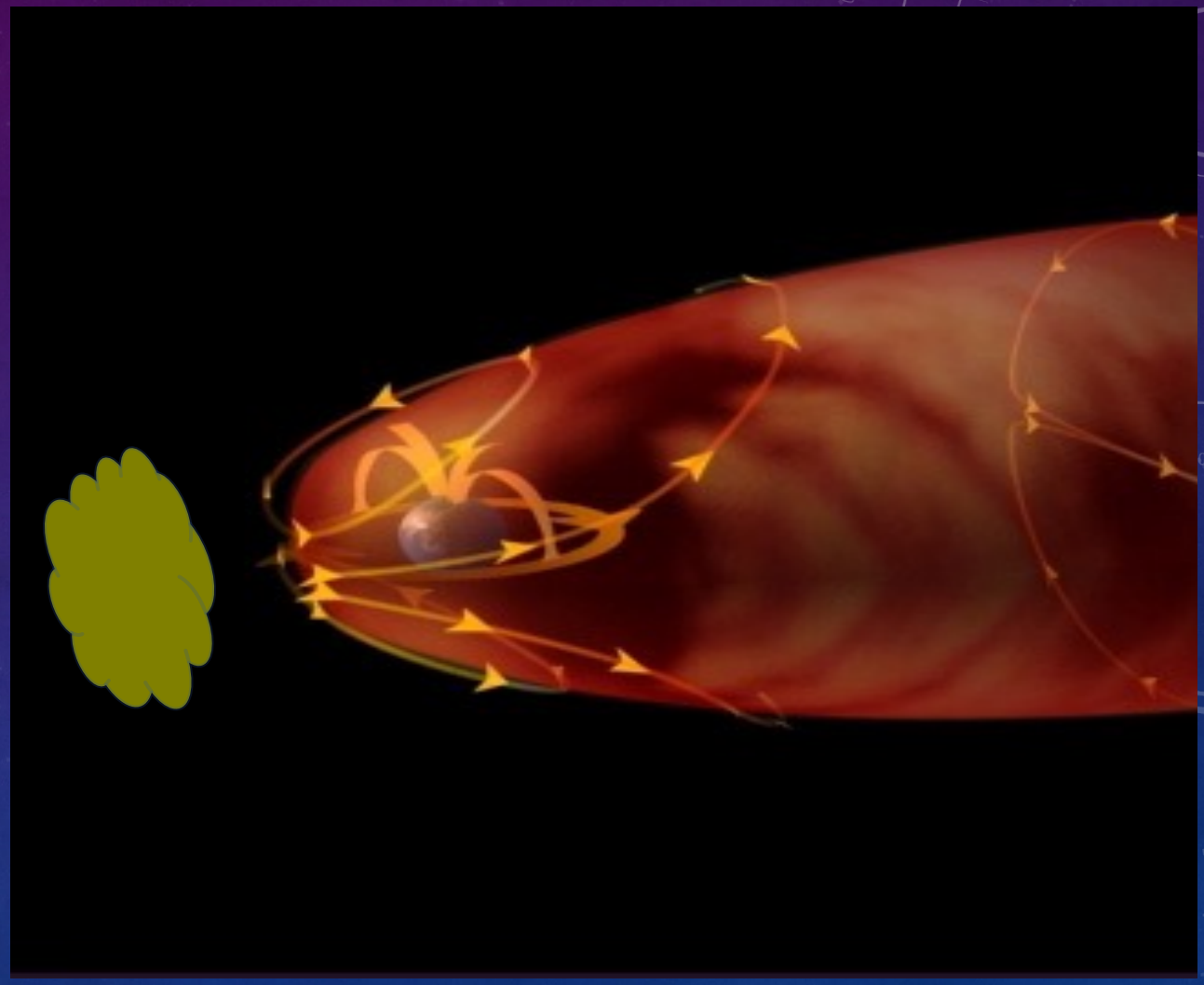


Synthetic system model from Birchfield at al, 2018.

SO WHAT HAPPENED DURING THE MAY 12 EVENT?

Work in progress with CU-Boulder!

- Earth's magnetosphere shields us from most solar wind
- Currents on/in magnetosphere organize to shield
- Mid- and low-latitudes *usually* well-shielded



Courtesy, D. Knipp/COMET

GROUND-BASED DATA

- Magnetic field measurements (NSF-funded, CPI operated)
- MT measurements (NSF-funded, Oregon State)
- GIC data (Power utility owned)
- Power grid models (Power utility owned)

THERE ARE COMPLEXITIES IN MAKING COMMERCIAL DATA OPEN AND PUBLIC

- Where is the funding for the data coming from?
- Data acquisition and management takes a lot of time and knowledge.
- There are very real sensitivities associated with data.

THERE ARE BENEFITS TO SCIENCE AND TO END USERS

Sharing data between sectors requires collaboration, communication and trust.

- How can we as scientists make the lives of end users easier?
- What can each sector do best?
- Am I improving collaboration, communication and trust?
- Are both sides benefitting?

SUMMARY

- Local (ground-based) data are important to understanding the atypical cases. (Not all large storms have large impacts, or occur during solar max, and not all impacts happen during large events.)

- Commercial data sources provide an opportunity for both researchers and end users to benefit.

Image from www.9news.com.au, courtesy of Thurein Kyaw (@thurein_k on Instagram)

May 12, 2023
Victoria, Australia