Deriving Exploration Maps and Rock Property Volumes from Lightning Databases

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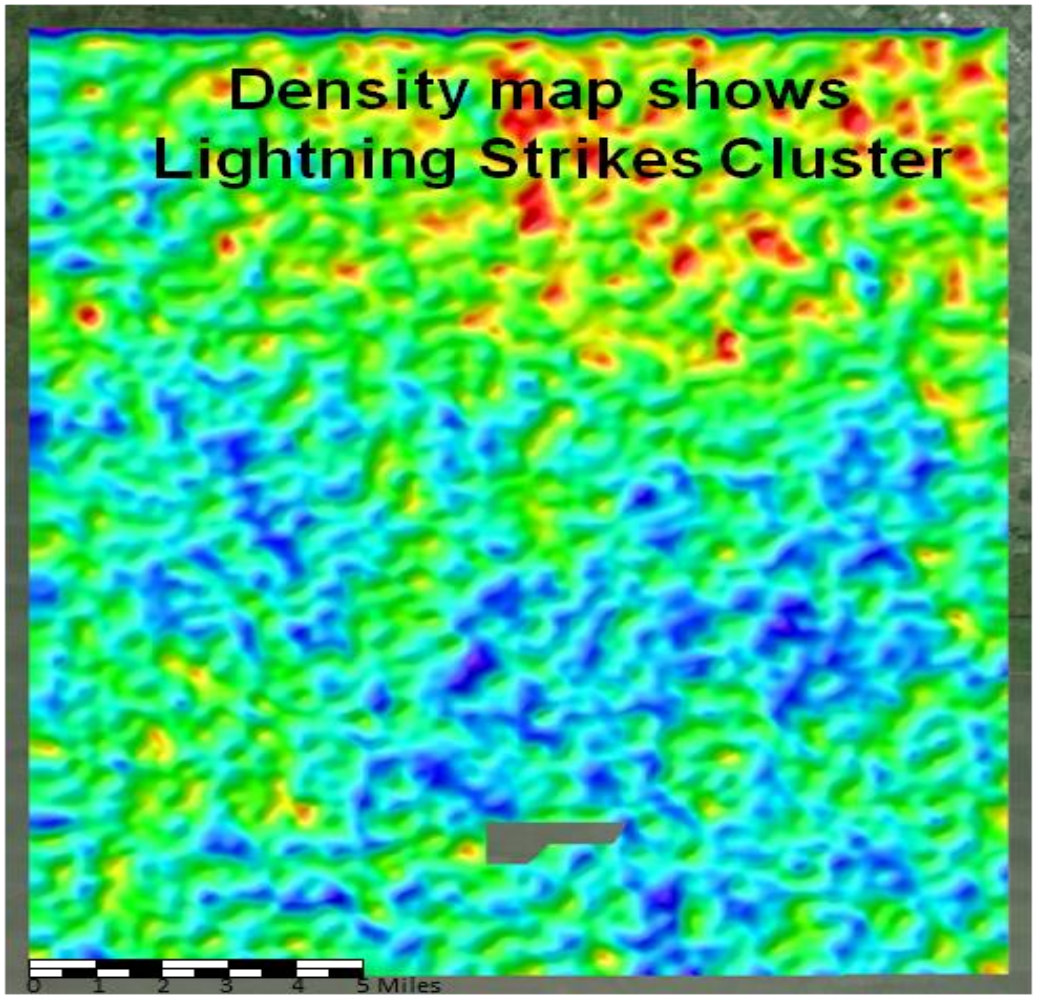
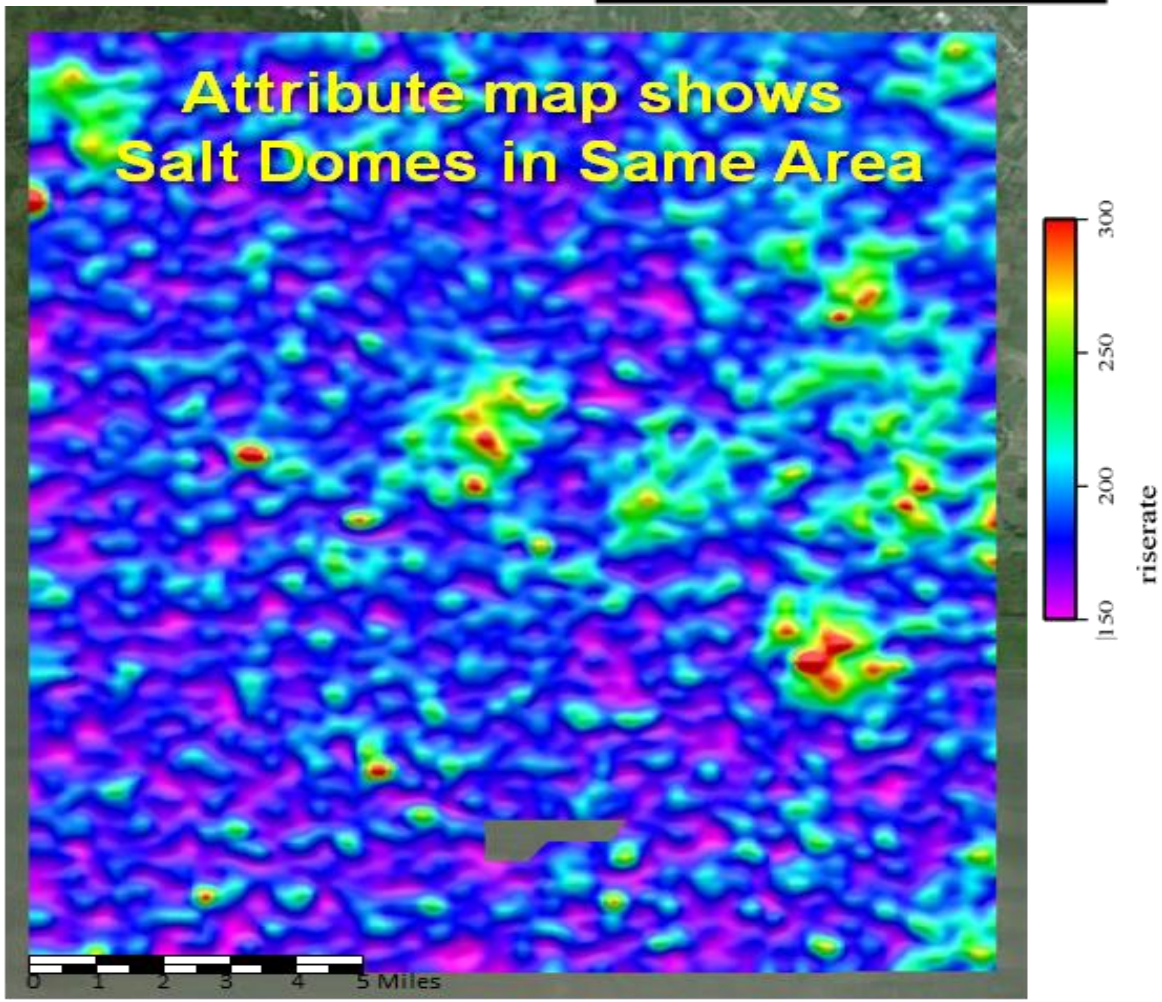
Outline

1. NSEM - A new geophysical data type
2. The meteorology behind lightning databases
3. Calculating rock property volumes from lightning databases
4. Examples of using lightning databases to map geology

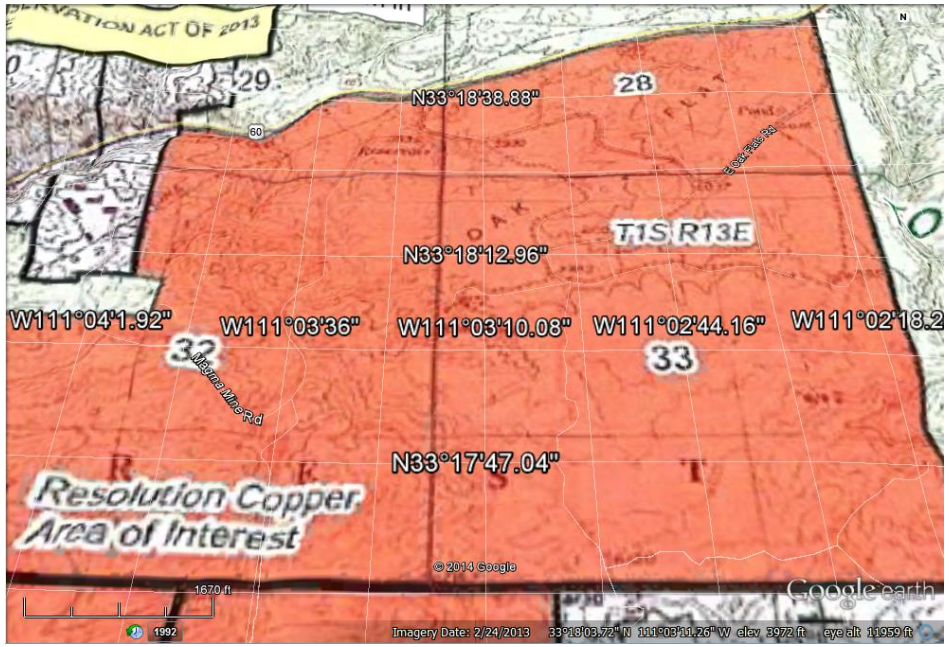
1. NSEM – (Natural Source ElectroMagnetics) – a new geophysical data type

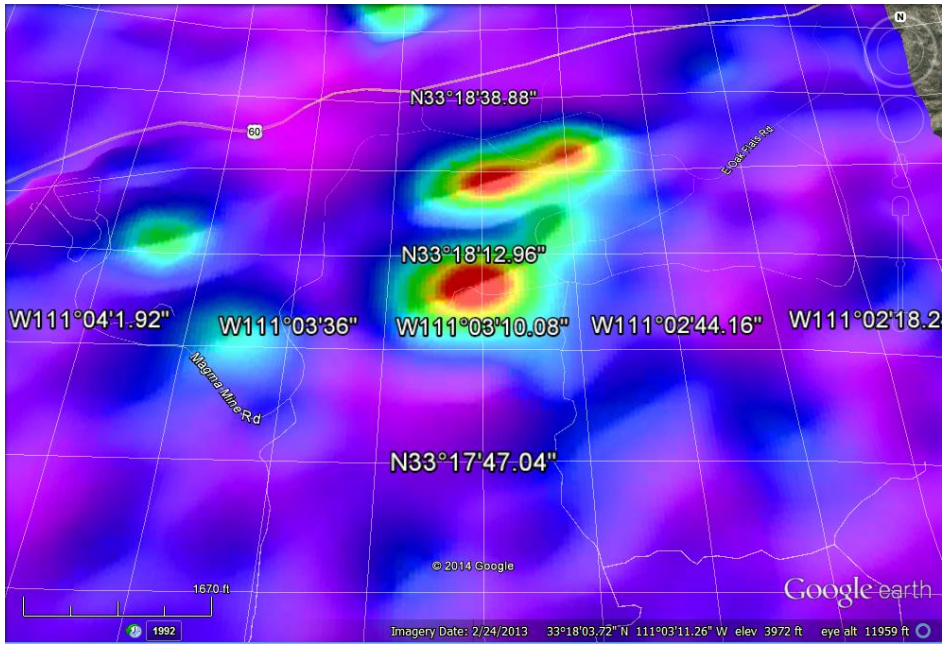
Lightning Data Analysis
demonstrates strikes are tied to geology

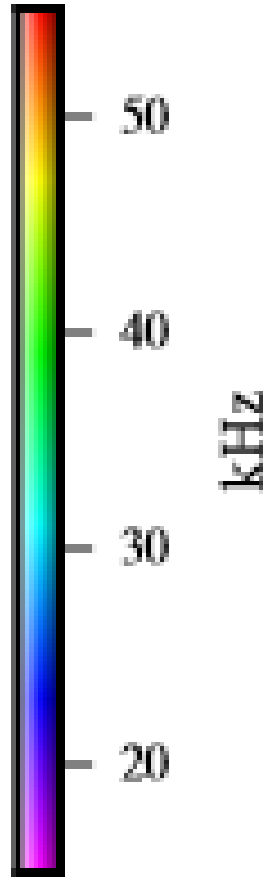




Attribute Maps related to major copper mine being developed in Arizona



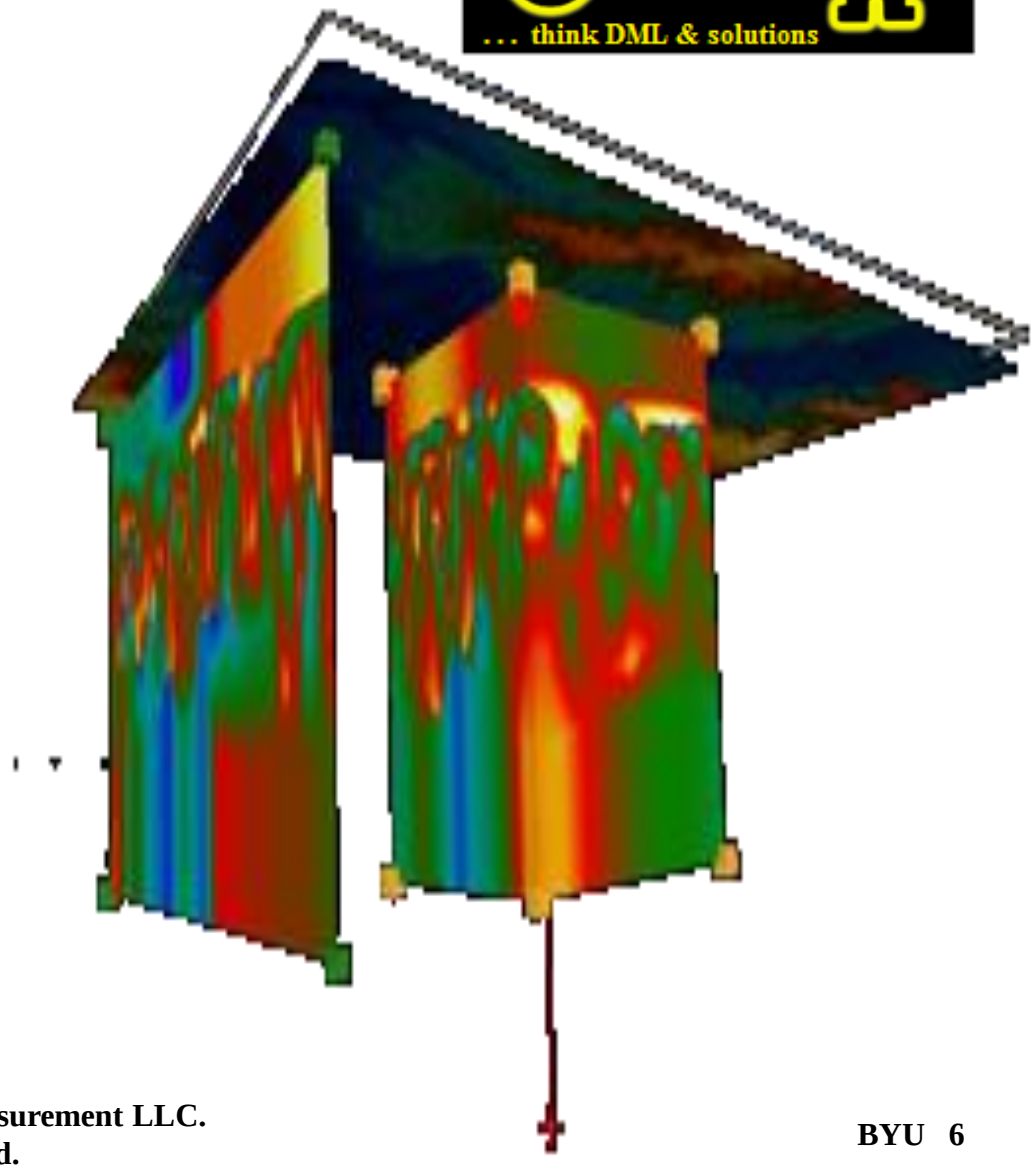




Technical Merit & Economic Benefits

- Maps, Sections, and Volumes
- Evergreen Data
- 17 year database US & Canada
- 4 year database worldwide
- Integrates with other data
- Simple Solution
- Patented, & Patent Pending

- 2 month project turnaround
- Larger Area – Less Expense compared to 3-D seismic

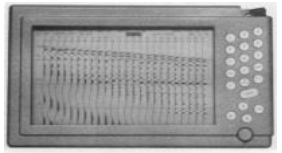


A time-line of new Geophysical Data Types

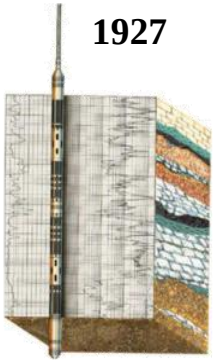
1752

1833

1920s

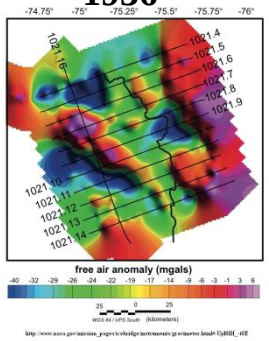


1927



1931

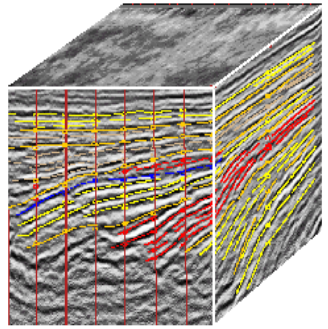
1936



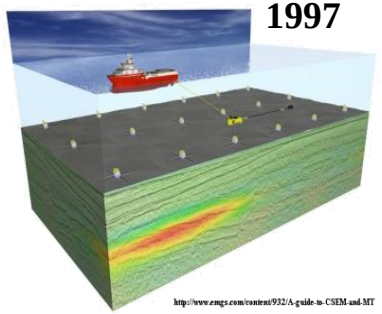
1950s

1960s/70s

1974

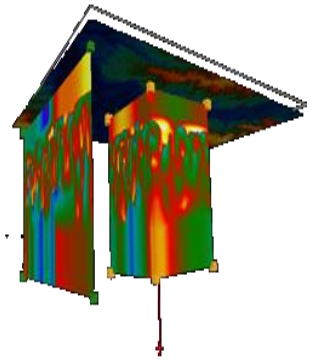


1997



2008

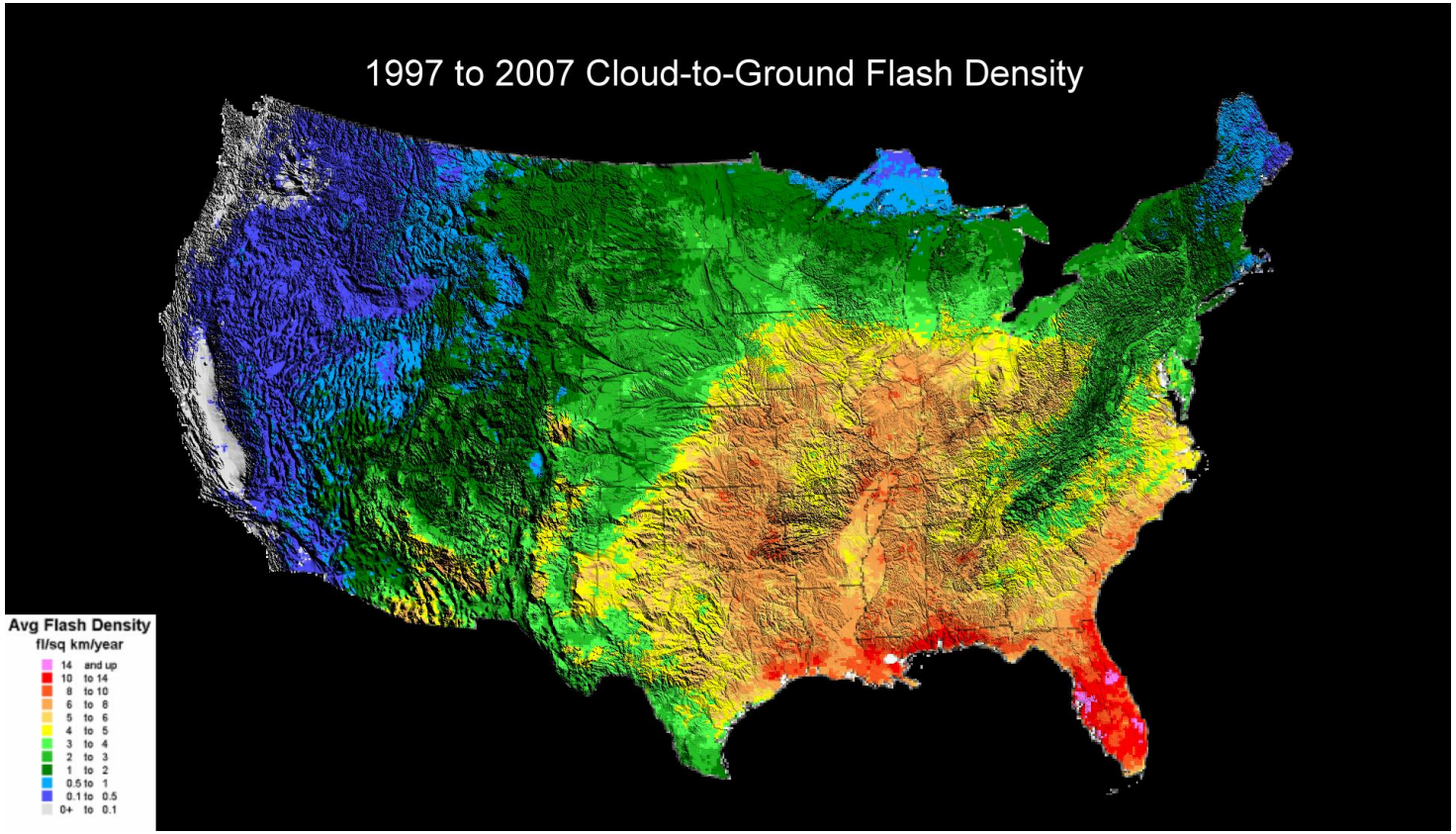
2015



Each new data type has sparked a step change in new revenues and cost avoidance for upstream oil and gas companies

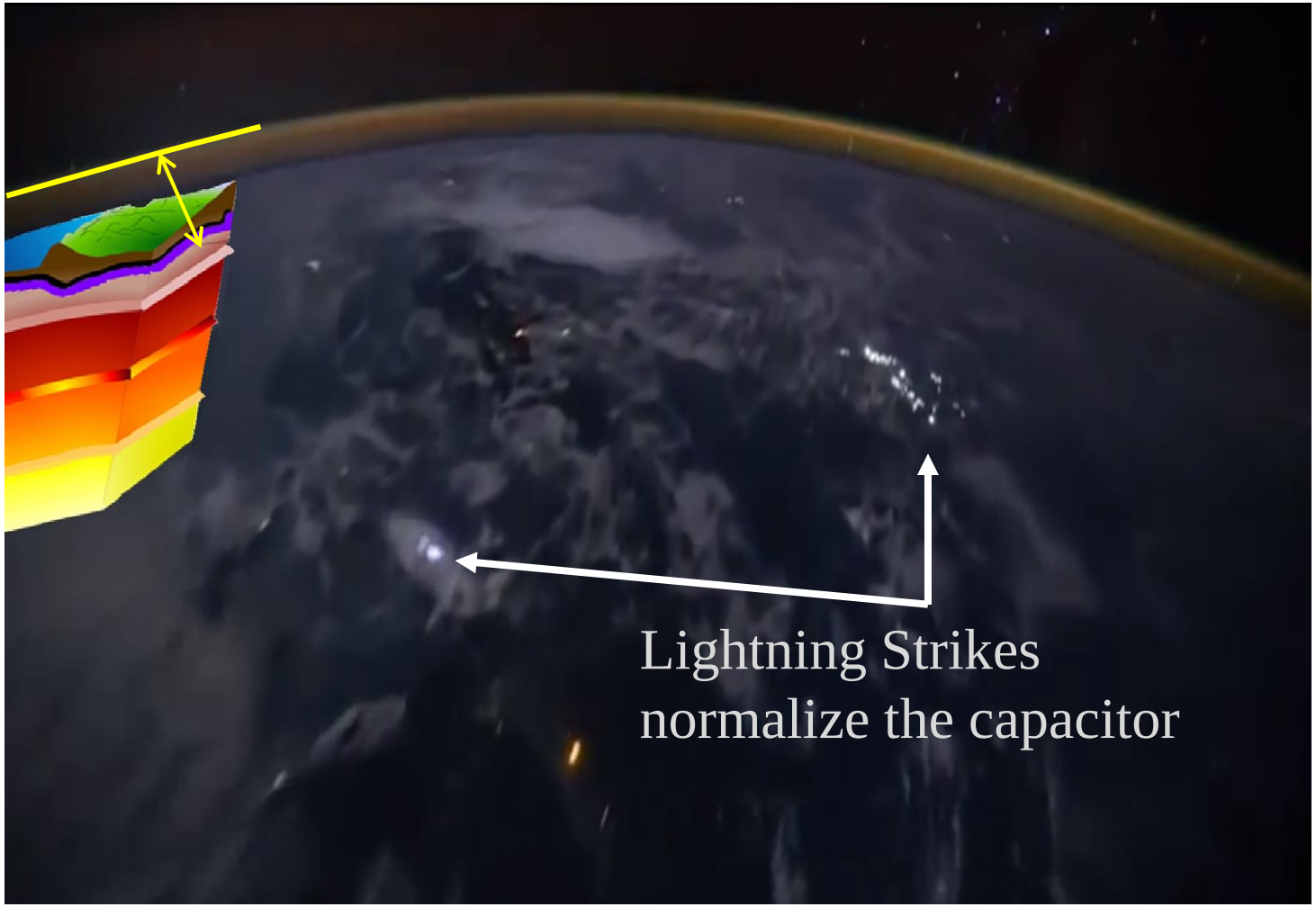
2. The meteorology behind lightning databases

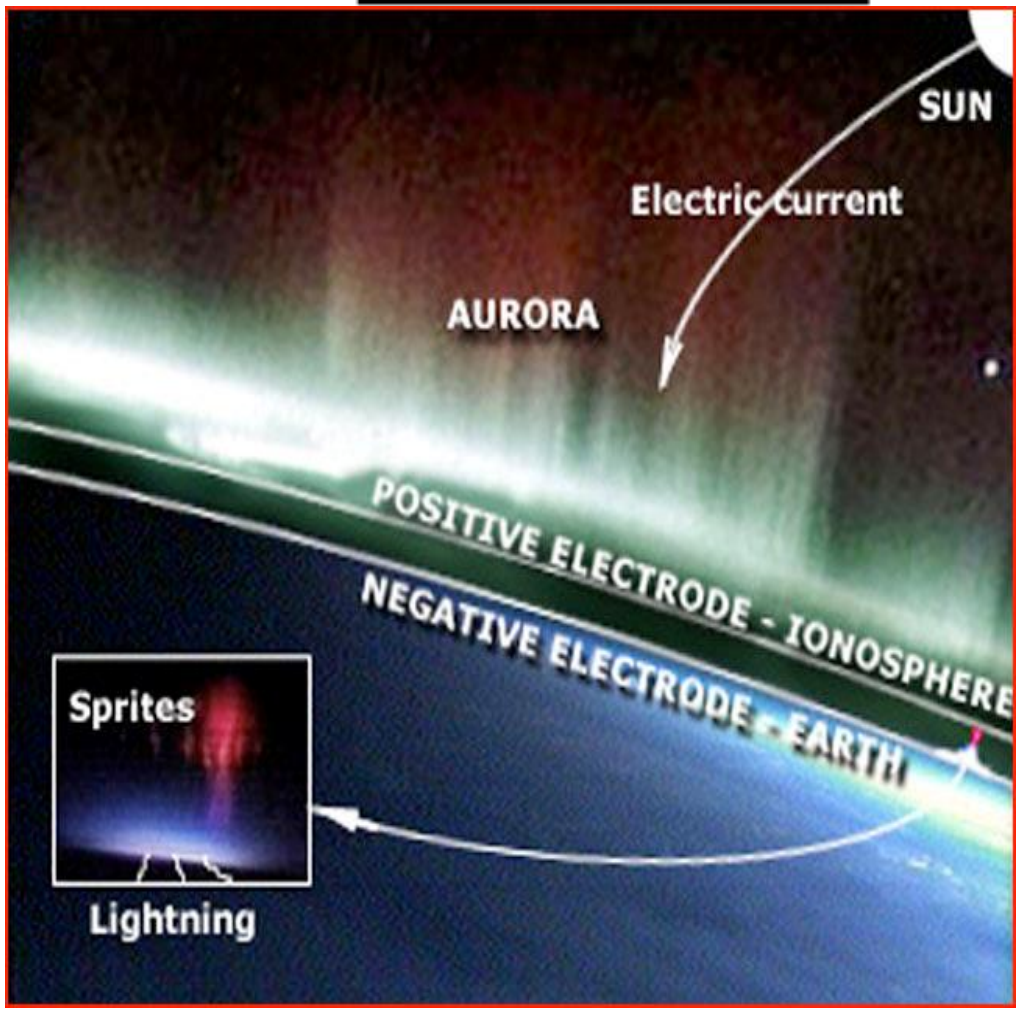
Lightning Maps and Natural Resources



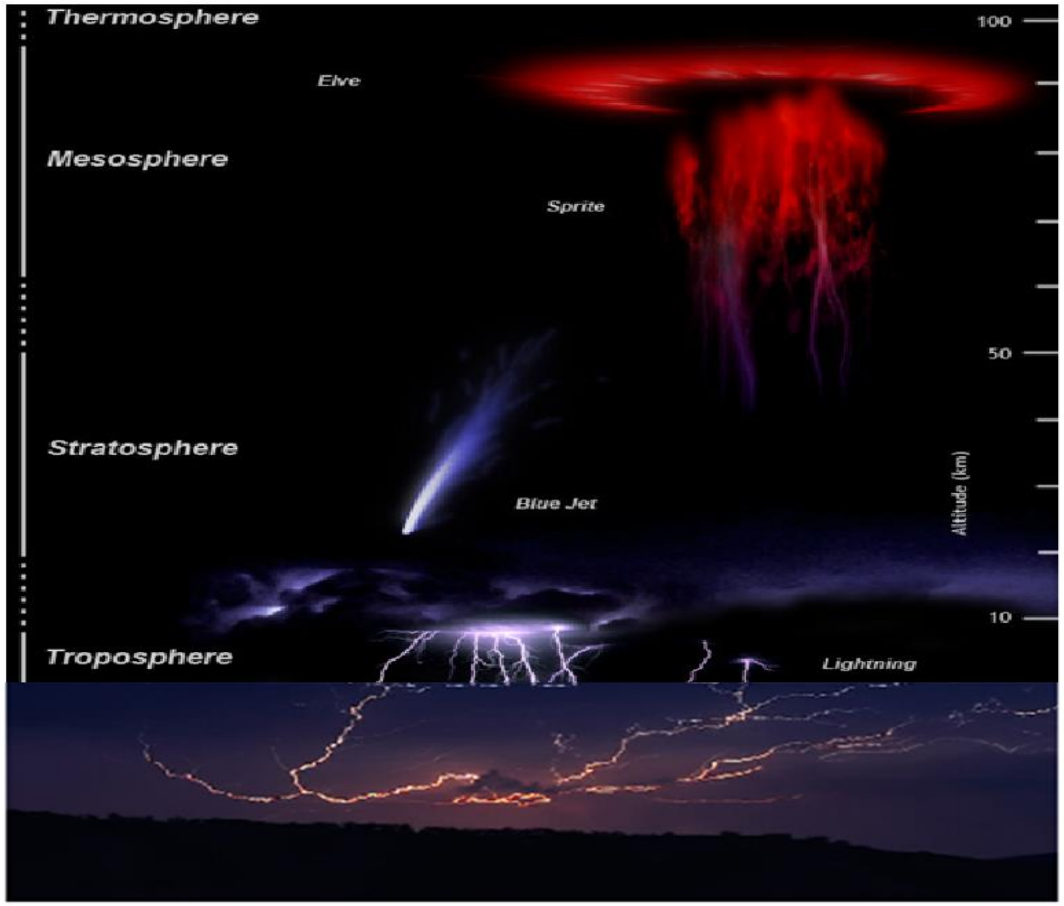
Lightning density regionally controlled by meteorology, and locally controlled by terralevis (shallow earth) currents.

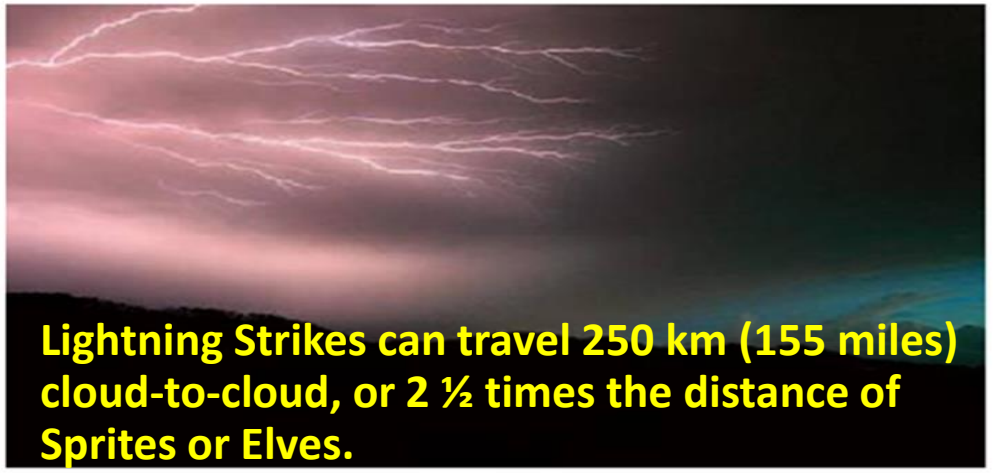
Earth: A Self-Repairing Capacitor





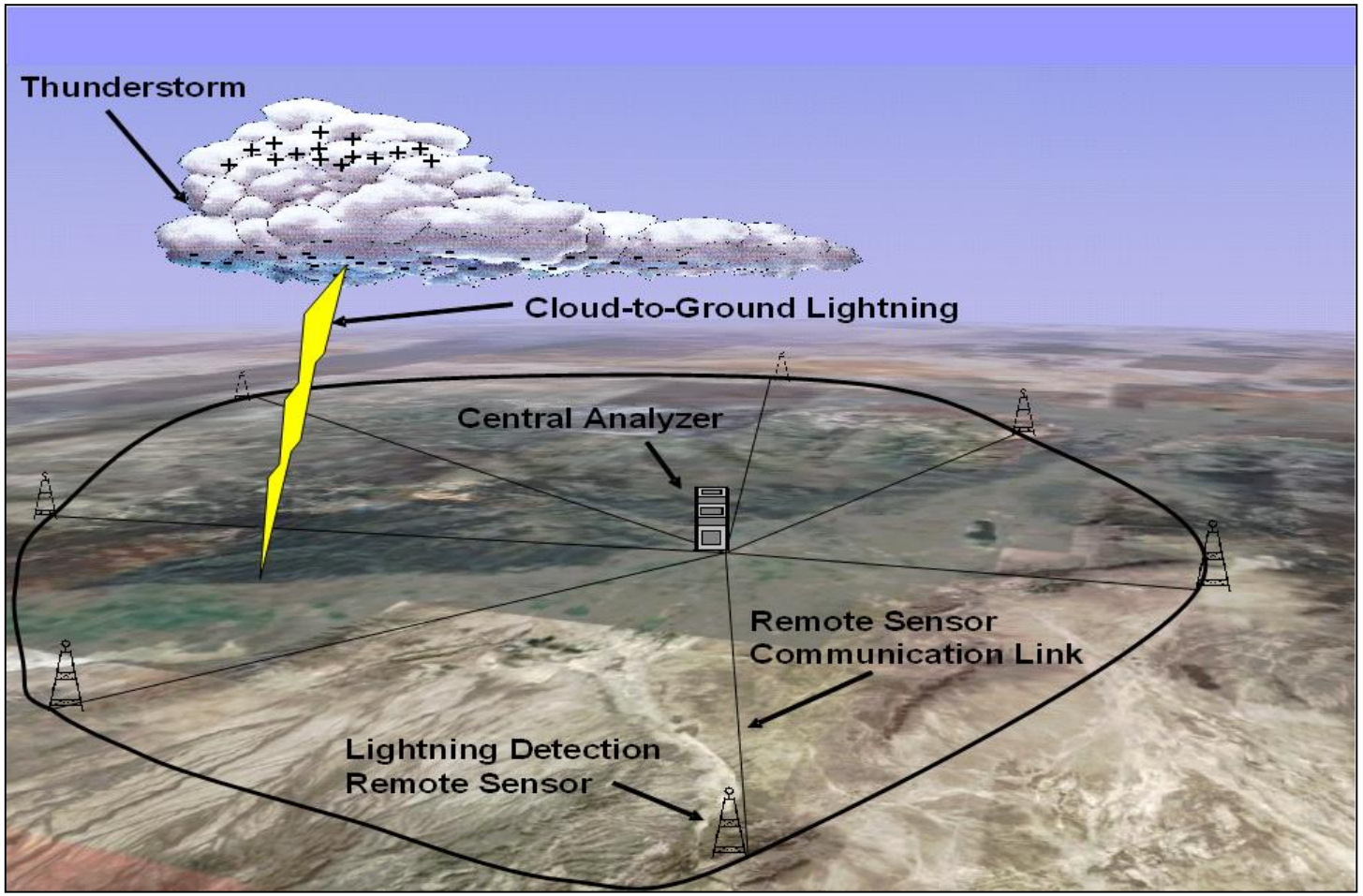
350 million annual Lightning Strikes - a rich database to mine





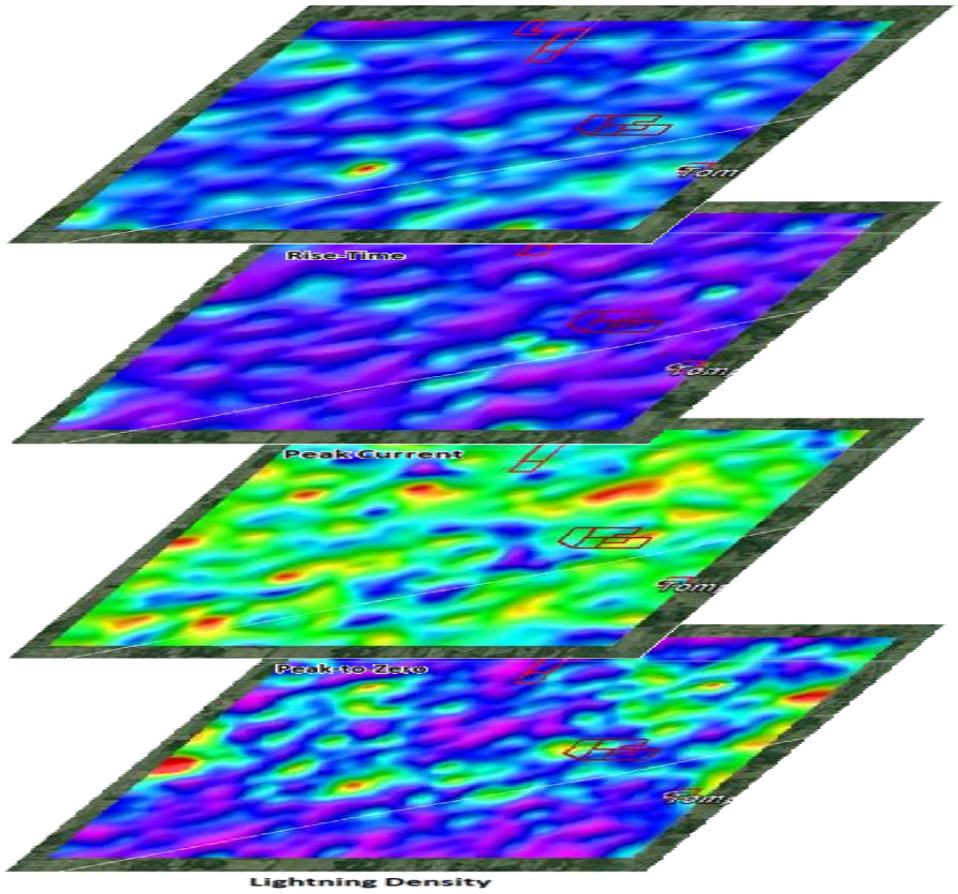
Lightning recorded for early storm warning, safety, **insurance**, and meteorological purposes

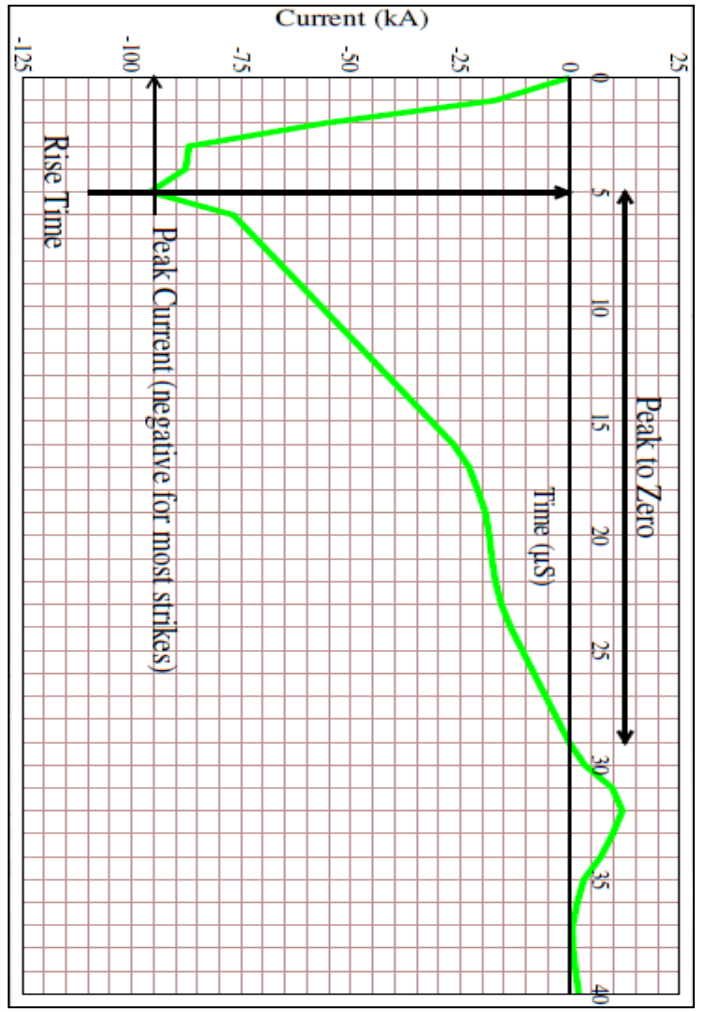
330 Sensors record U.S. lightning strike locations
with 650-980 feet (200-300 meter) horizontal resolution



Lightning Strike Measurements

- Location
- Time and Duration
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density





Upward Lightning tied to geology

Main lightning bolt tied to geology

Proven and Patented Technology

Fig. 1

US008344721B2

(12) **United States Patent**
Nelson, Jr. et al.

(10) **Patent No.: US 8,344,721 B2**
(45) **Date of Patent: Jan. 1, 2013**

(54) **METHOD FOR LOCATING SUB-SURFACE NATURAL RESOURCES**

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(51) **Int. Cl.**
G01R 31/02 (2006.01)
G01N 27/00 (2006.01)
G01W 1/00 (2006.01)

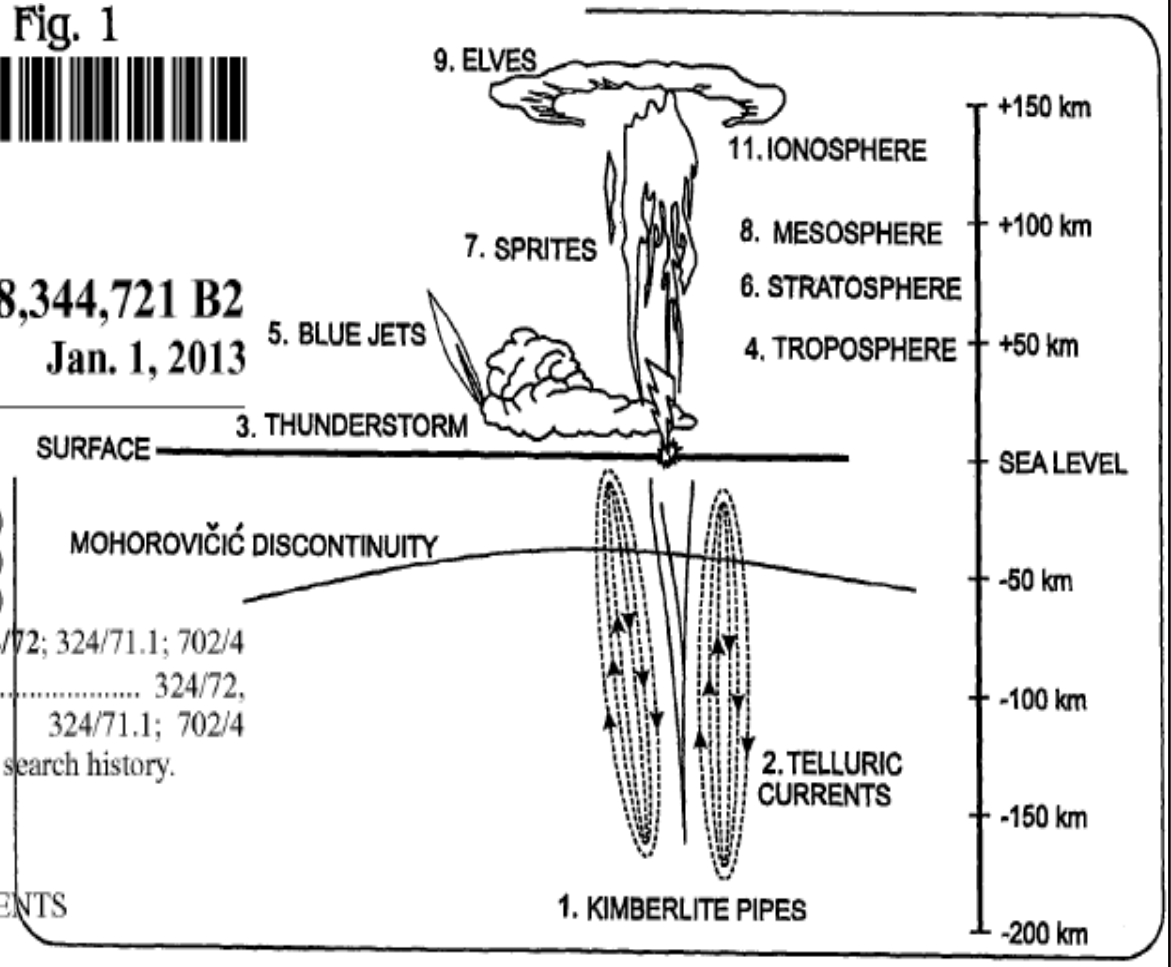
(52) **U.S. Cl.** **324/72**; 324/71.1; 702/4

(58) **Field of Classification Search** 324/72, 324/71.1; 702/4

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS



GULF COAST ASSOCIATION OF GEOLOGICAL SOCIETIES

www.gcags.org

Dear Kathleen,

Congratulations! You have been selected to receive the First Place Grover E. Murray Best Published Paper Award for your paper, "Aquifers, Faults, Subsidence, and Lightning Databases" published in the 2014 GCAGS *Transactions*.

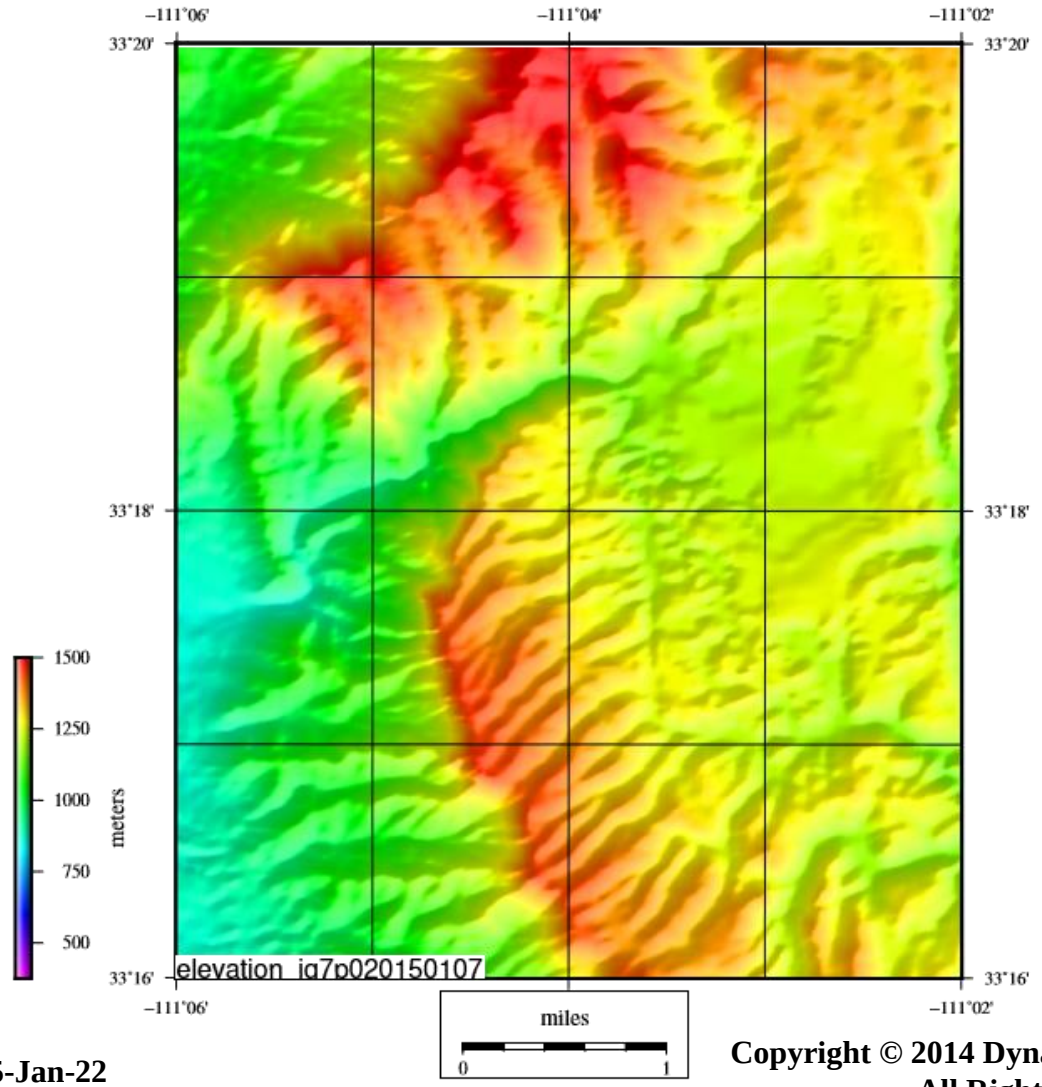
• • •

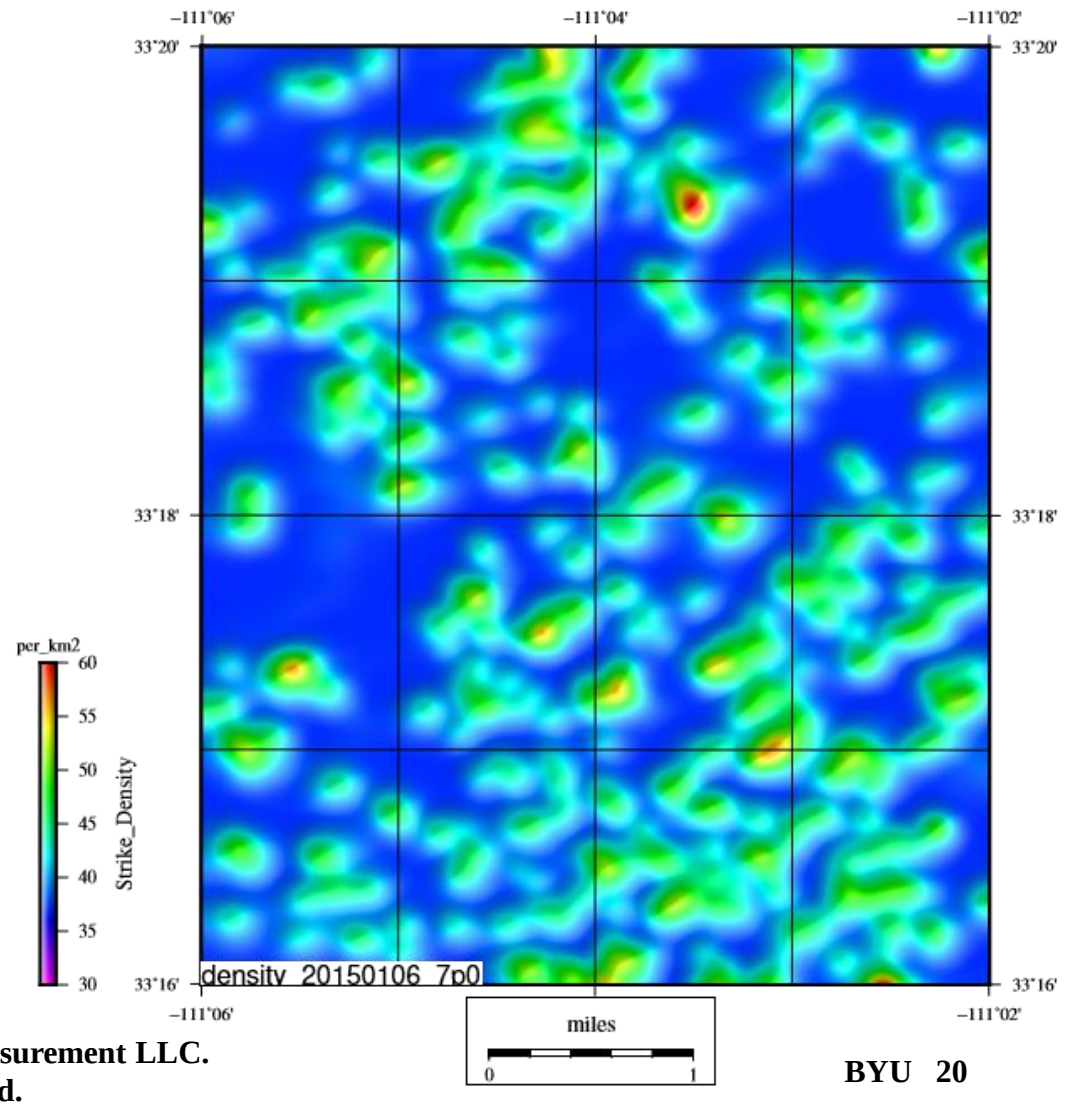
Mary Broussard
2013-2014 GCAGS President
Email: Mary_Broussard@fmi.com

"Aquifers, Faults, Subsidence, and Lightning Databases"

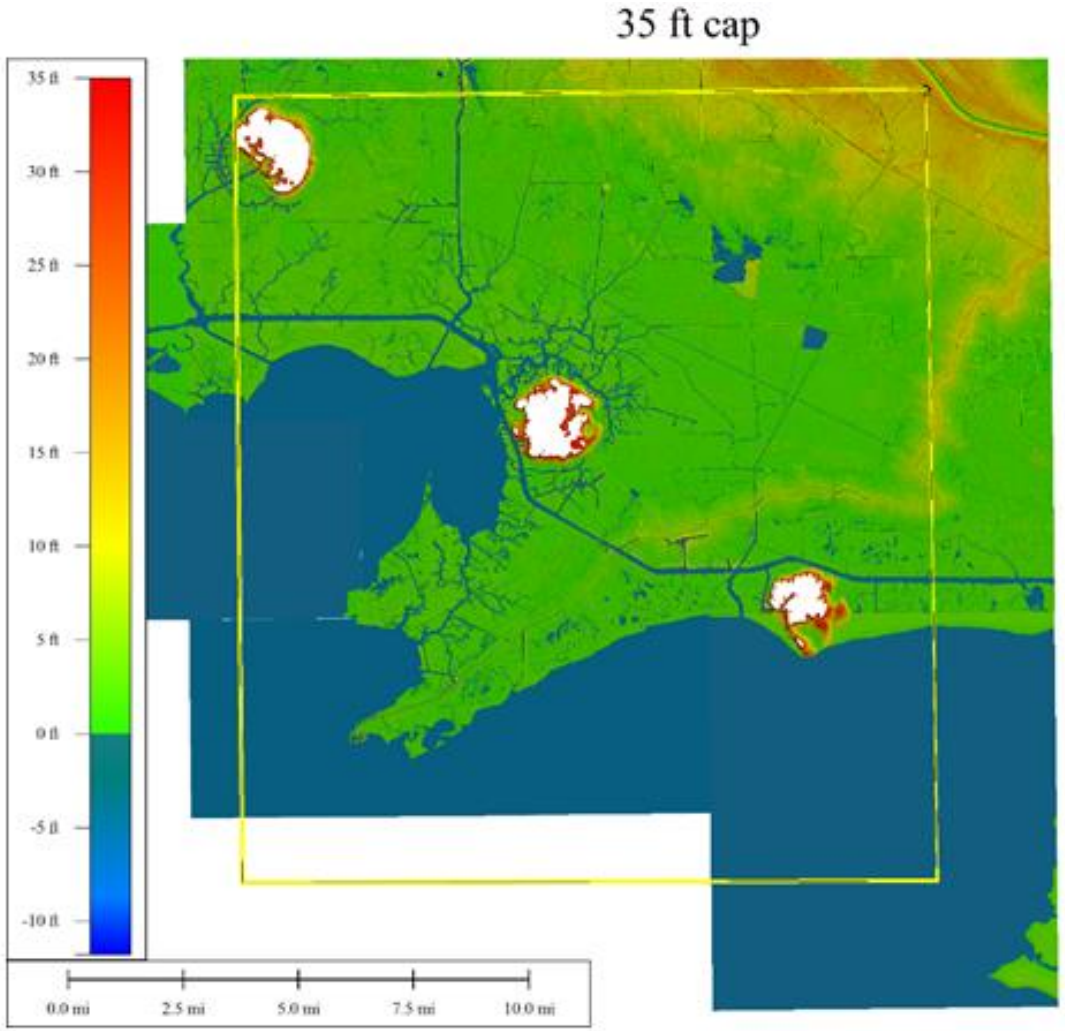
3. Calculating rock property volumes from lightning databases

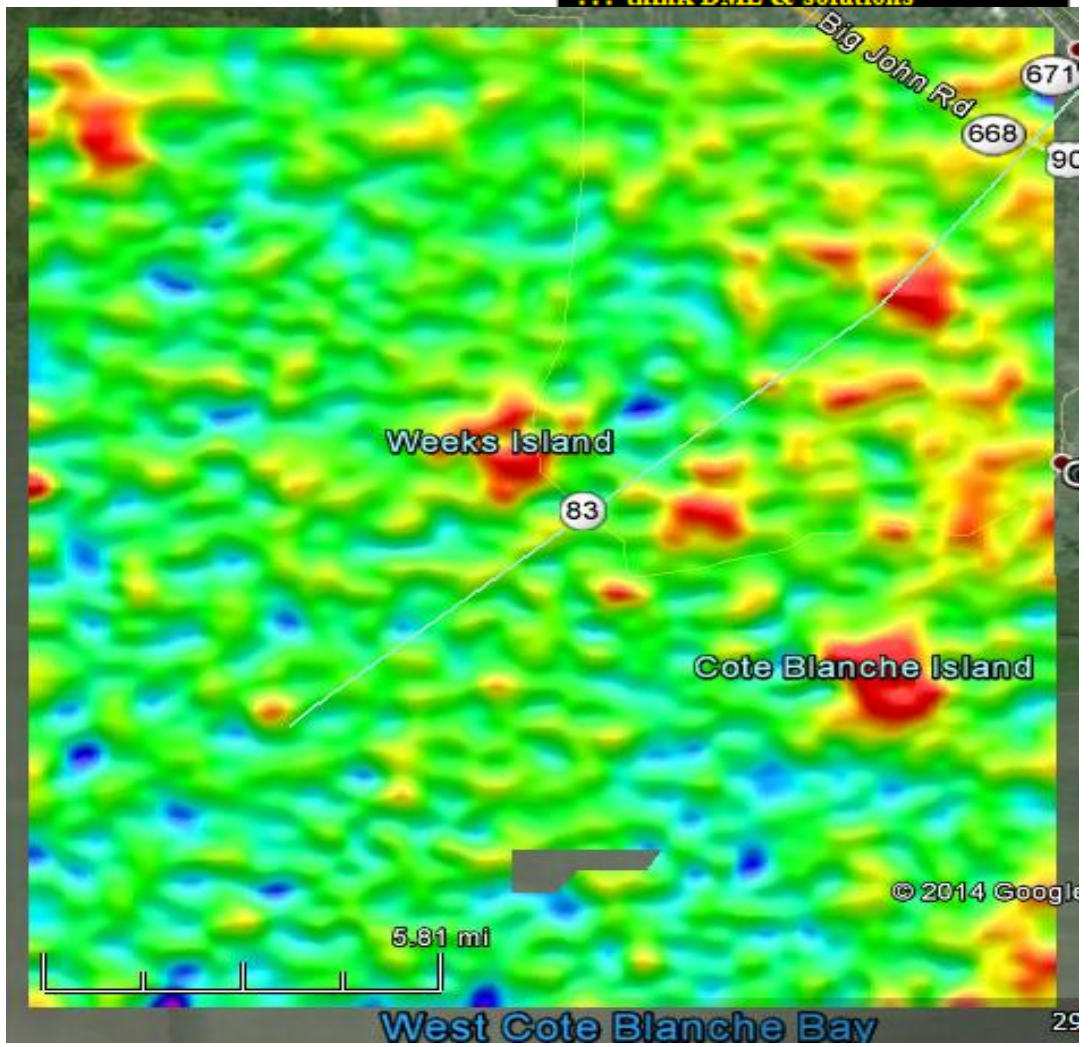
Topography and Lightning Density Arizona



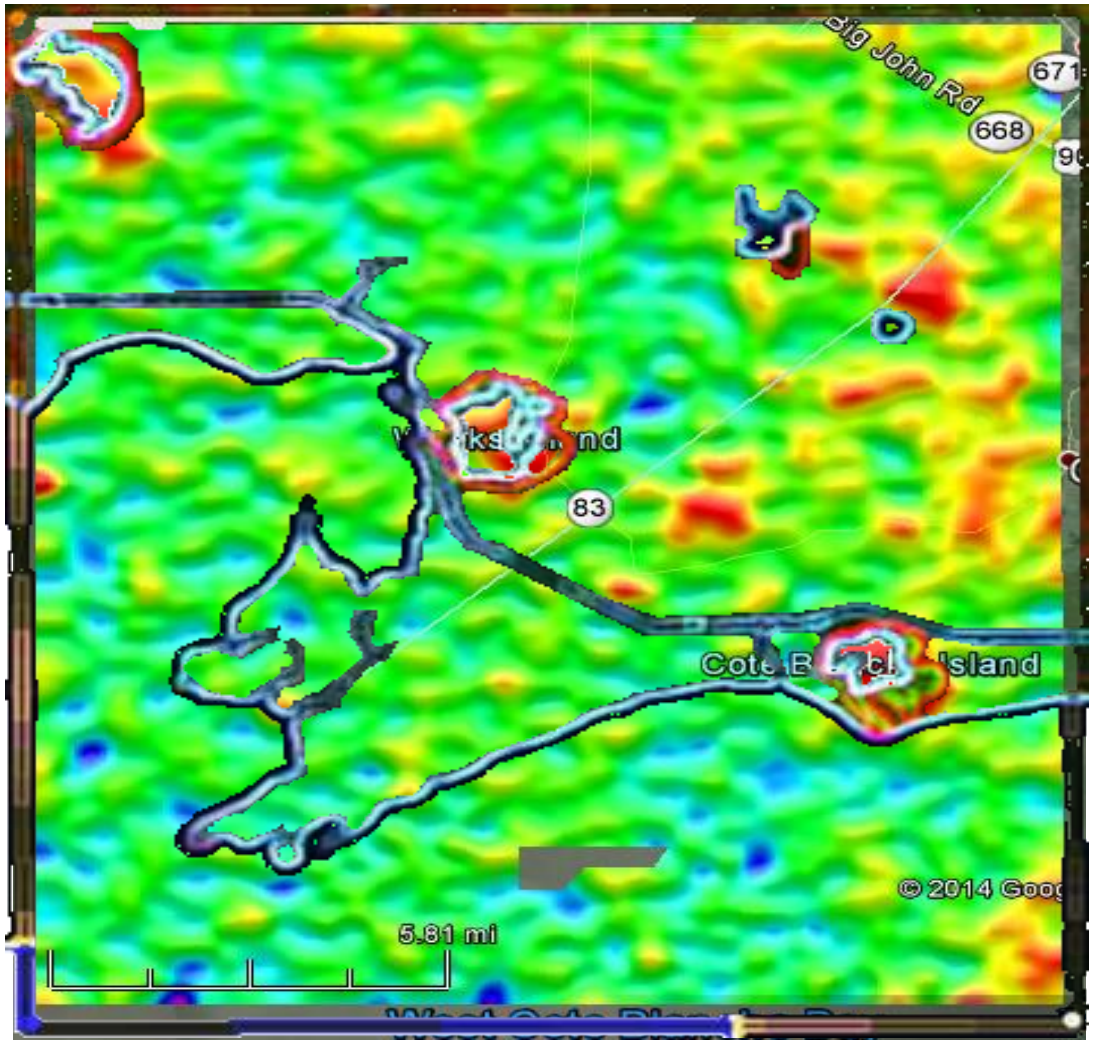


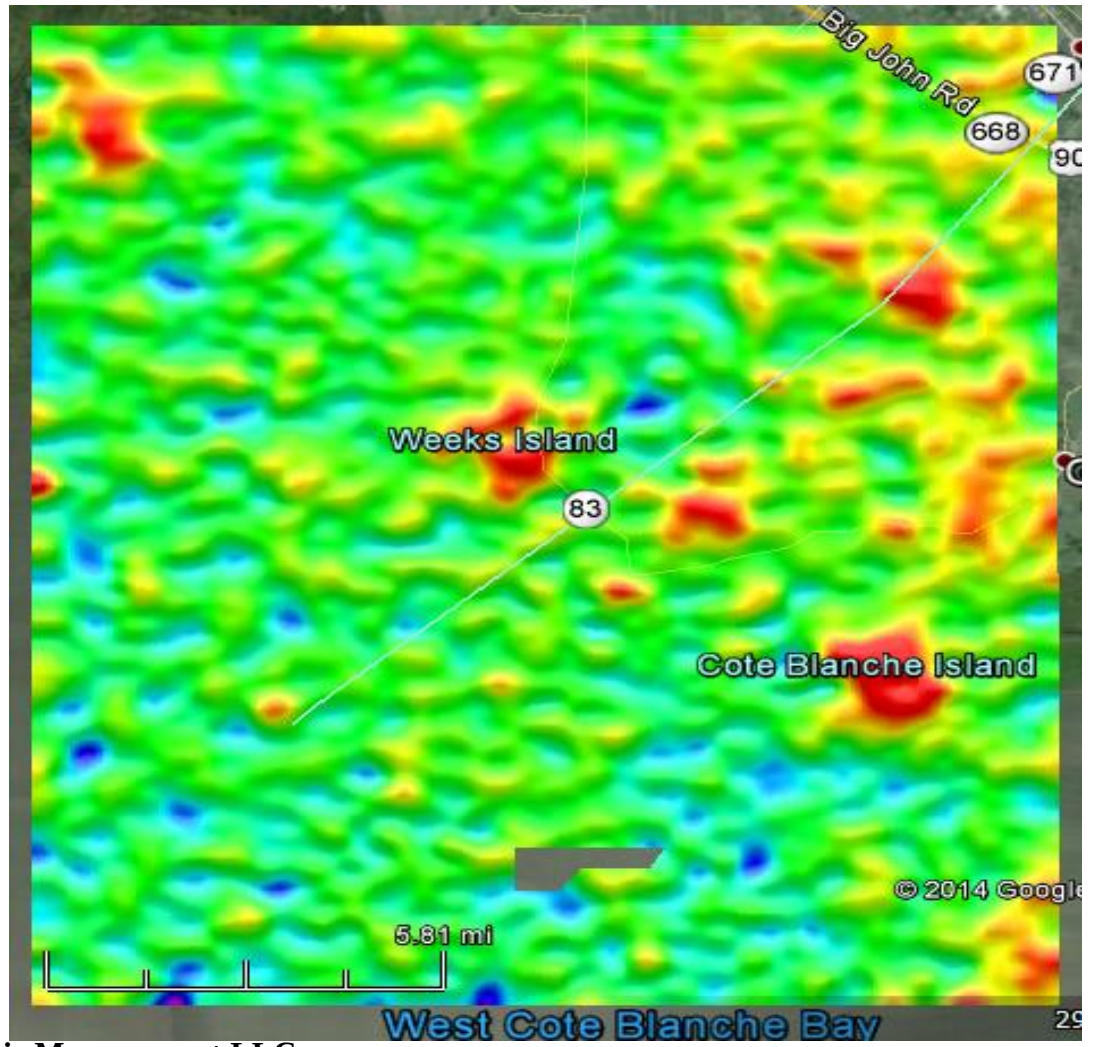
LIDAR Extended with NSEM Analysis





Lateral Strike Resolution 200-300 meters





The Atmospheric Capacitor

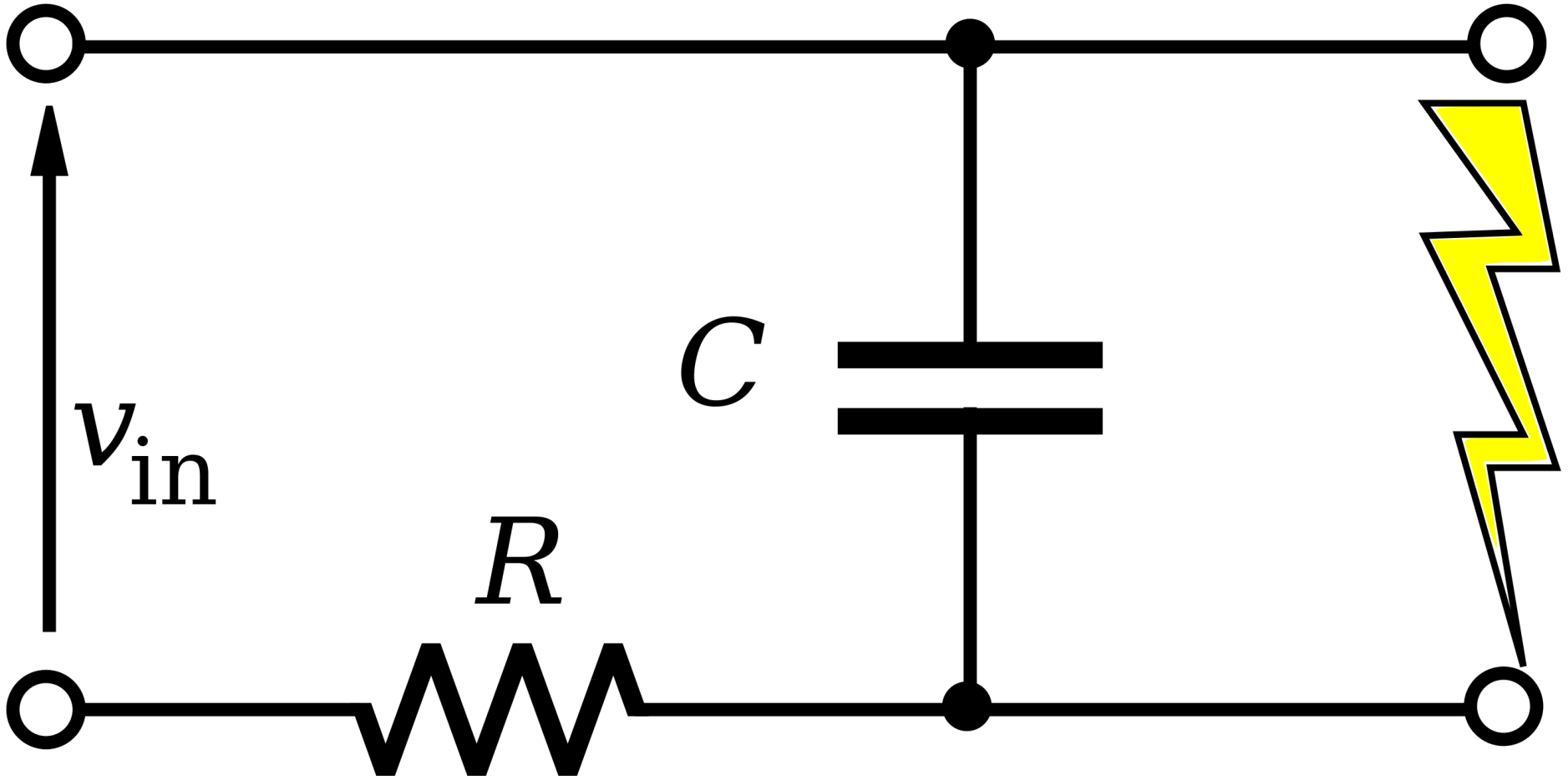
Plate 1

- The charged thundercloud is one plate of a capacitor
- The other plate of the capacitor is the earth underlying the charged cloud
- The dielectric is the air
- Energy from a lightning strike is converted to heat, partly in the air, but largely in the subsurface

Dielectric

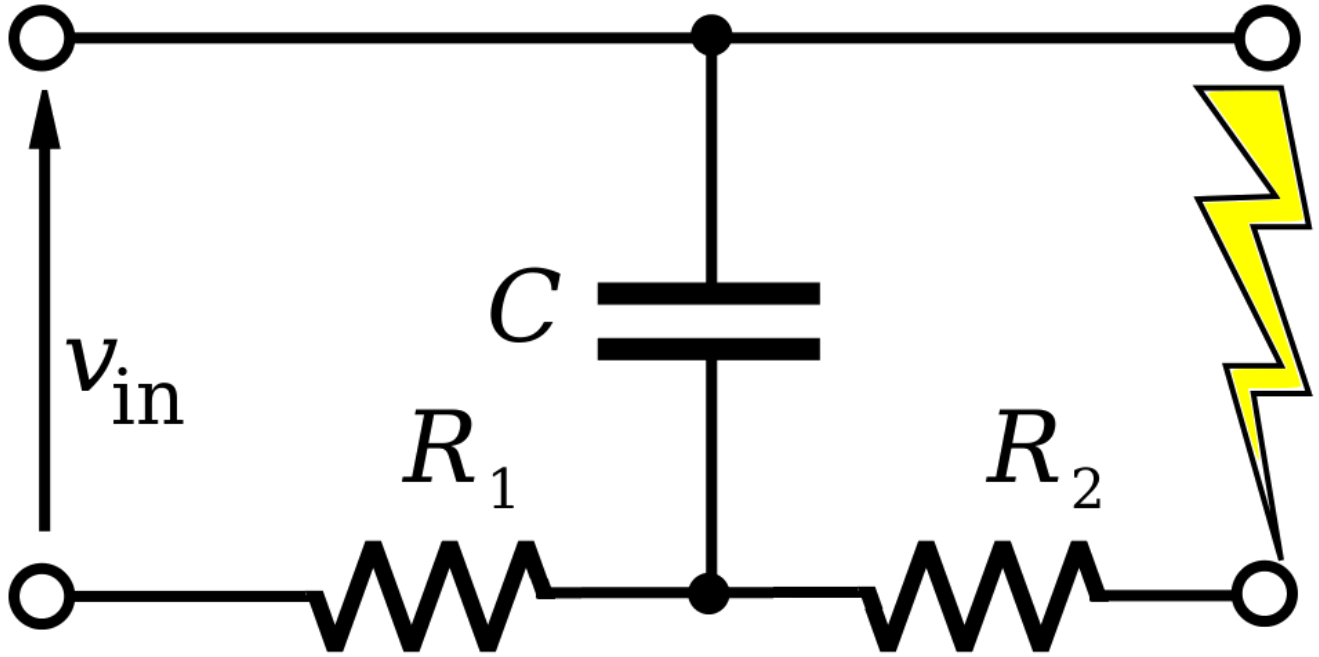
Plate 2

Relaxation Oscillator



Lightning

- The atmospheric capacitor is nearly the same
- Just an additional resistance (R_2) limiting the current
- R_2 is the resistance between the lightning strike point and the bottom plate of the capacitor

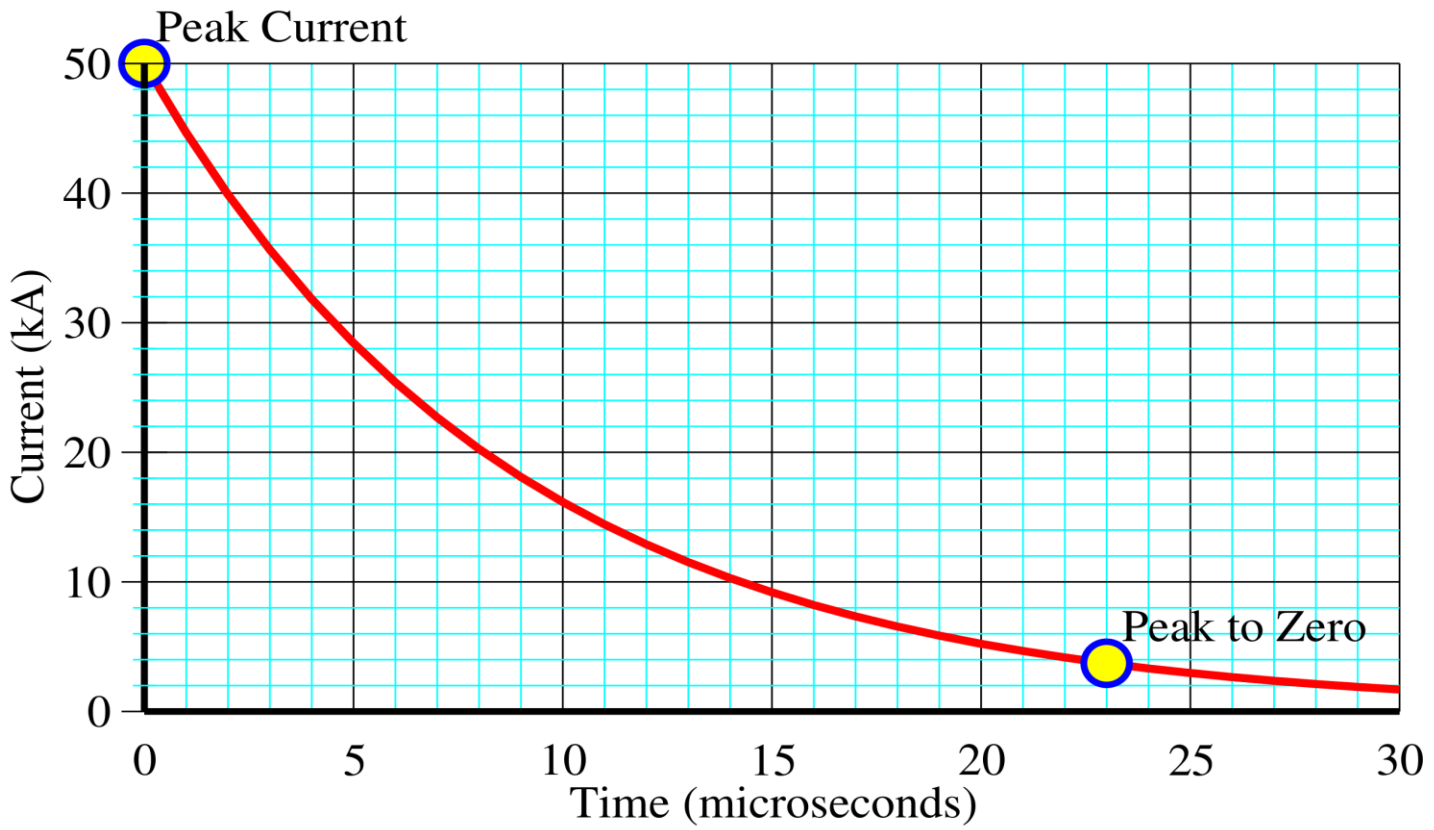


Relaxation Oscillator Physics

- When a relaxation oscillator triggers, the discharge current decays exponentially
- The rate of decay is given by $I_t = I_0 e^{-t/RC}$
- If lightning is similar, can we use the decay to measure resistance?
  - This equation can be rearranged to $ln(\frac{I_t}{I_0}) = -\frac{t}{RC}$ or $R = -\frac{t}{ln(\frac{I_t}{I_0})C}$
  - All we need is the current at two times (I_0 and I_t), and the capacitance (C) to get the resistance R

How do we measure Decay

- Lightning measurements do not give this kind of continuous decay.
- We have two values:
  - Peak current
  - Peak to zero time

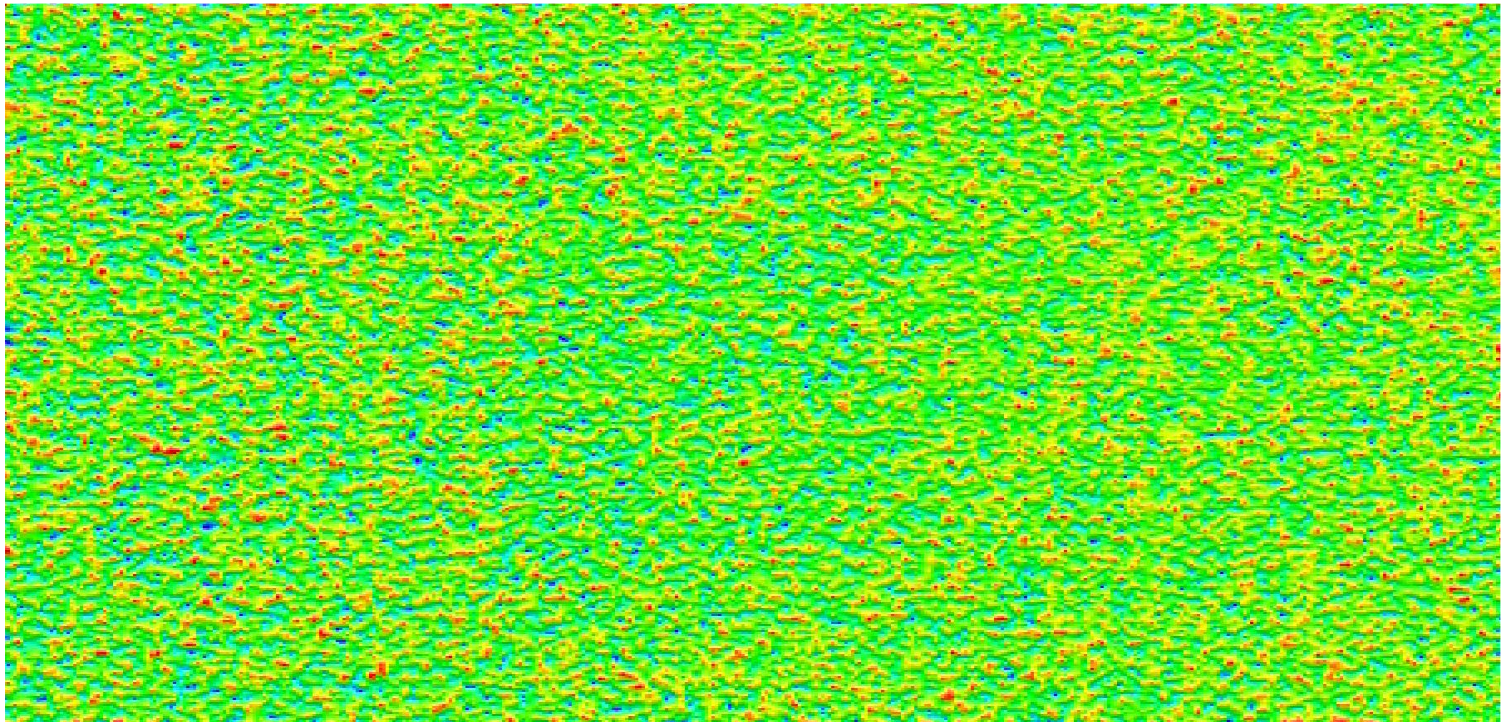


The Assumptions

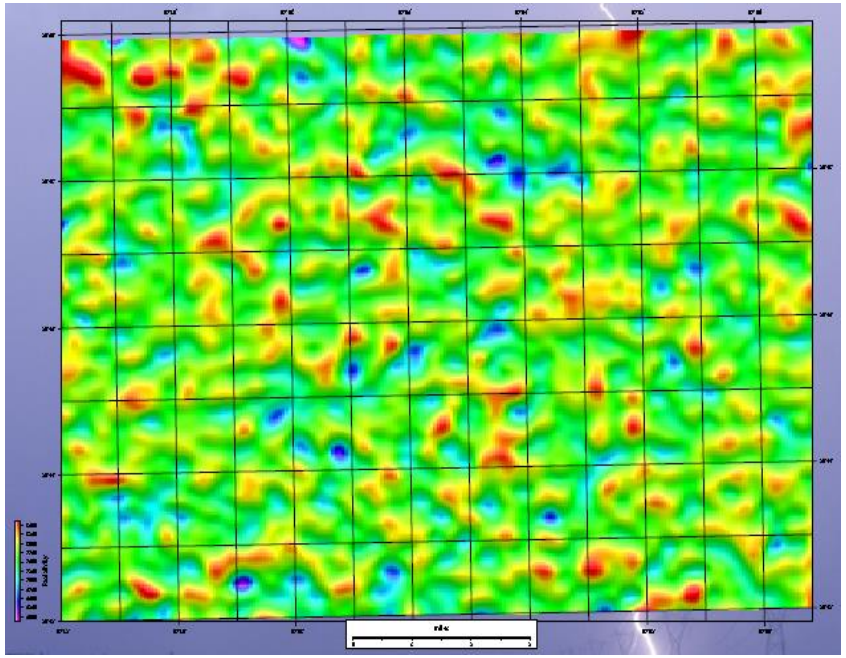
1. Voltage is proportional to peak current (within a local area).
2. Cloud height is proportional to voltage because the dielectric strength of air is more or less constant.
   - This gives plate separation for the atmospheric capacitor
3. The effective capacitor is circular, with a radius proportional to cloud height.
   - This gives plate area for the capacitor
4. With over 100 lightning strikes per square kilometer in the database in many areas, we can stack results to improve signal-to-noise ratio

Resistivity Maps

Houston Area



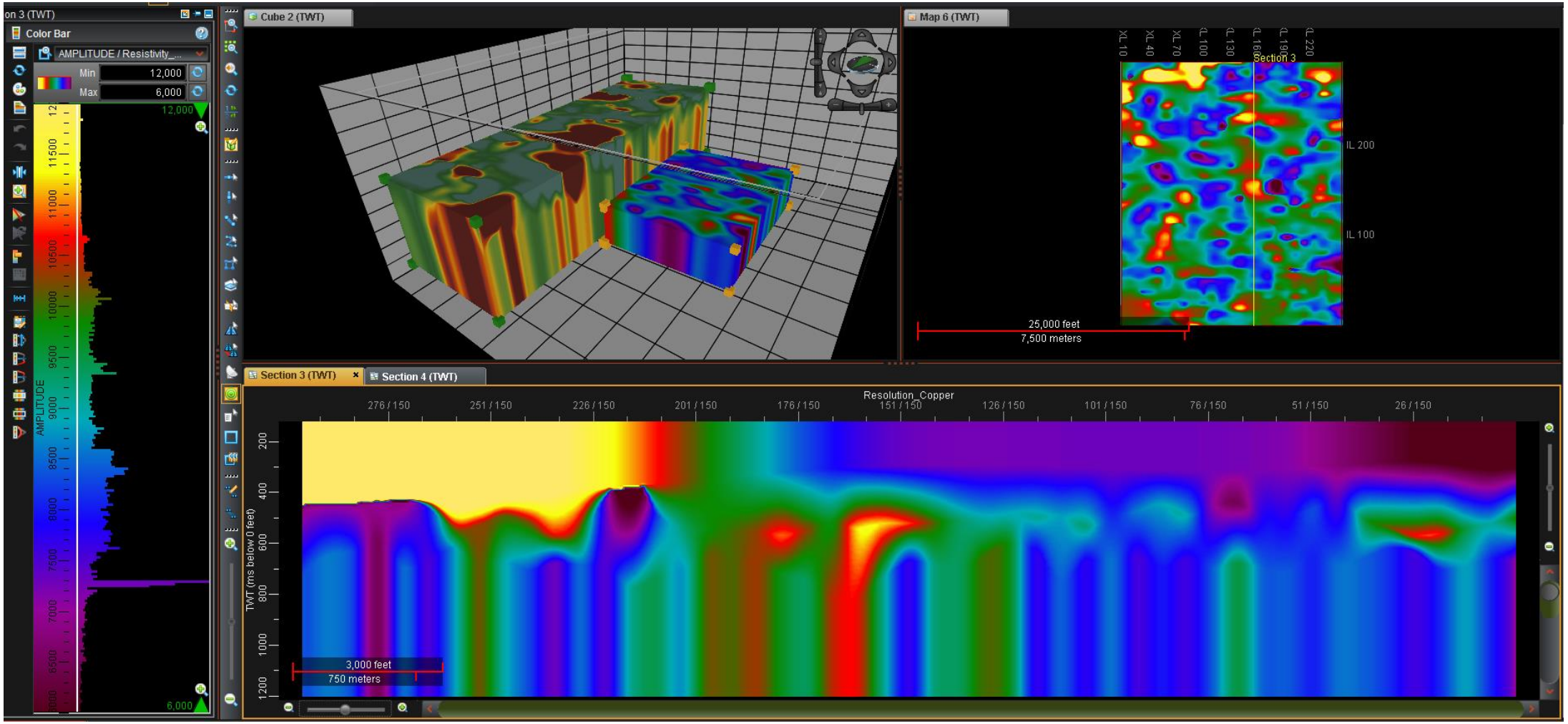
Milam County



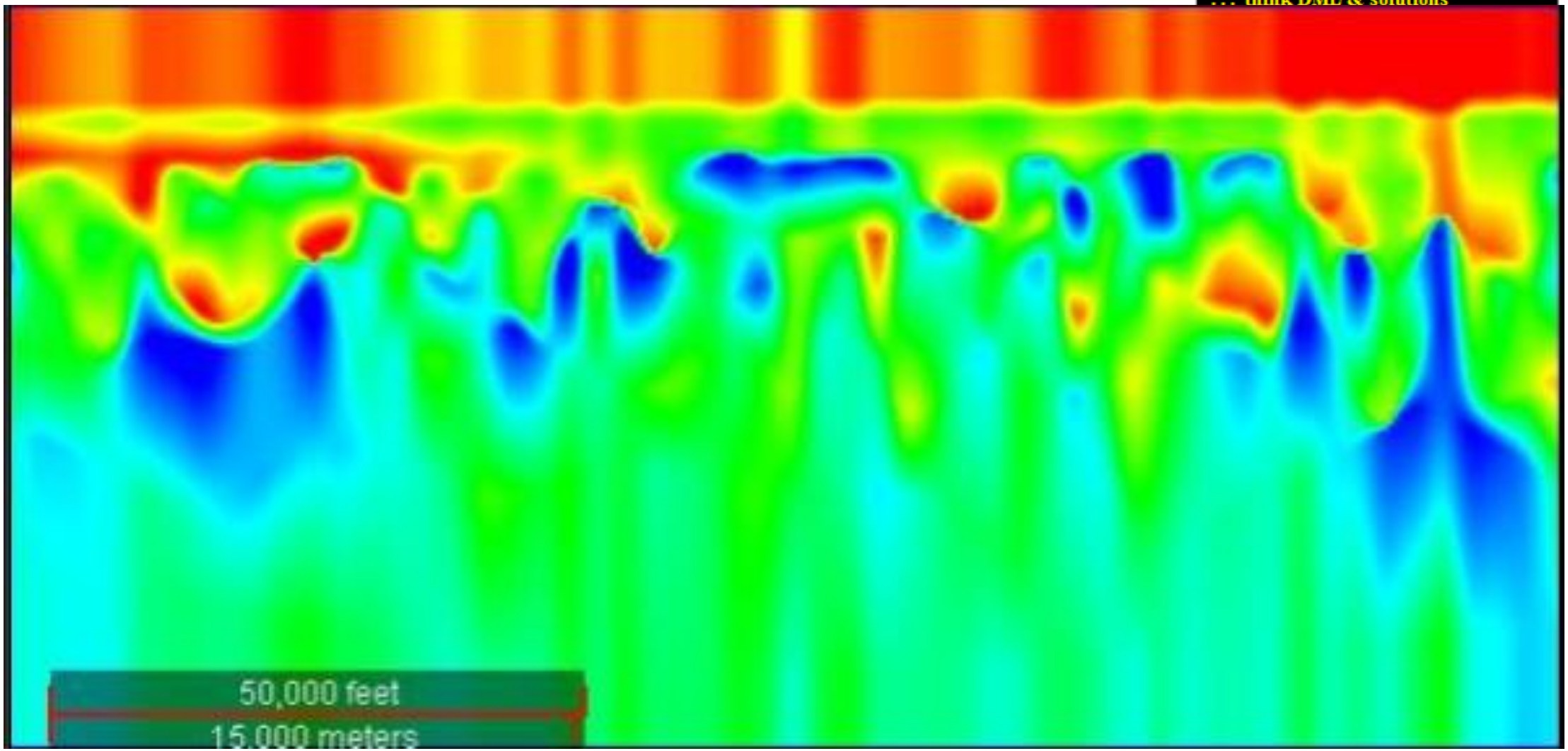
A Resistivity Trace

- For standard seismic interpretation software, data traces need to be uniformly sampled in time or depth, with the same number of samples in each trace
  - At latitude and longitude for the trace, each depth grid is sampled and each resistivity grid is sampled.
  - Resistivity values are interpolated with depth between these points to give samples at uniform intervals.
- Typical sample interval is 48 meters.
- Typical trace length is 125 samples.
- There is no restriction in sample interval or length beyond those imposed by the SEG-Y format.

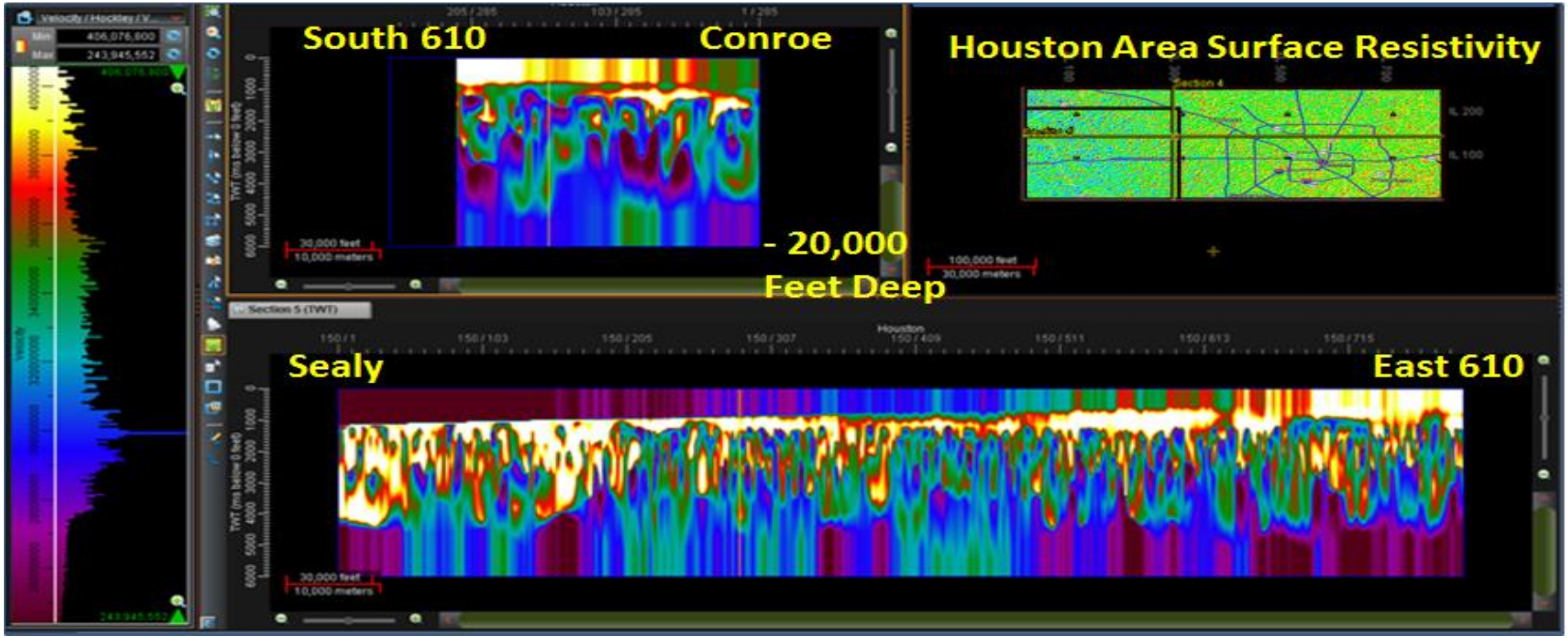
Resistivity Volume Arizona



Resistivity Volume Cross-Section



Houston Area Resistivity Volume Example



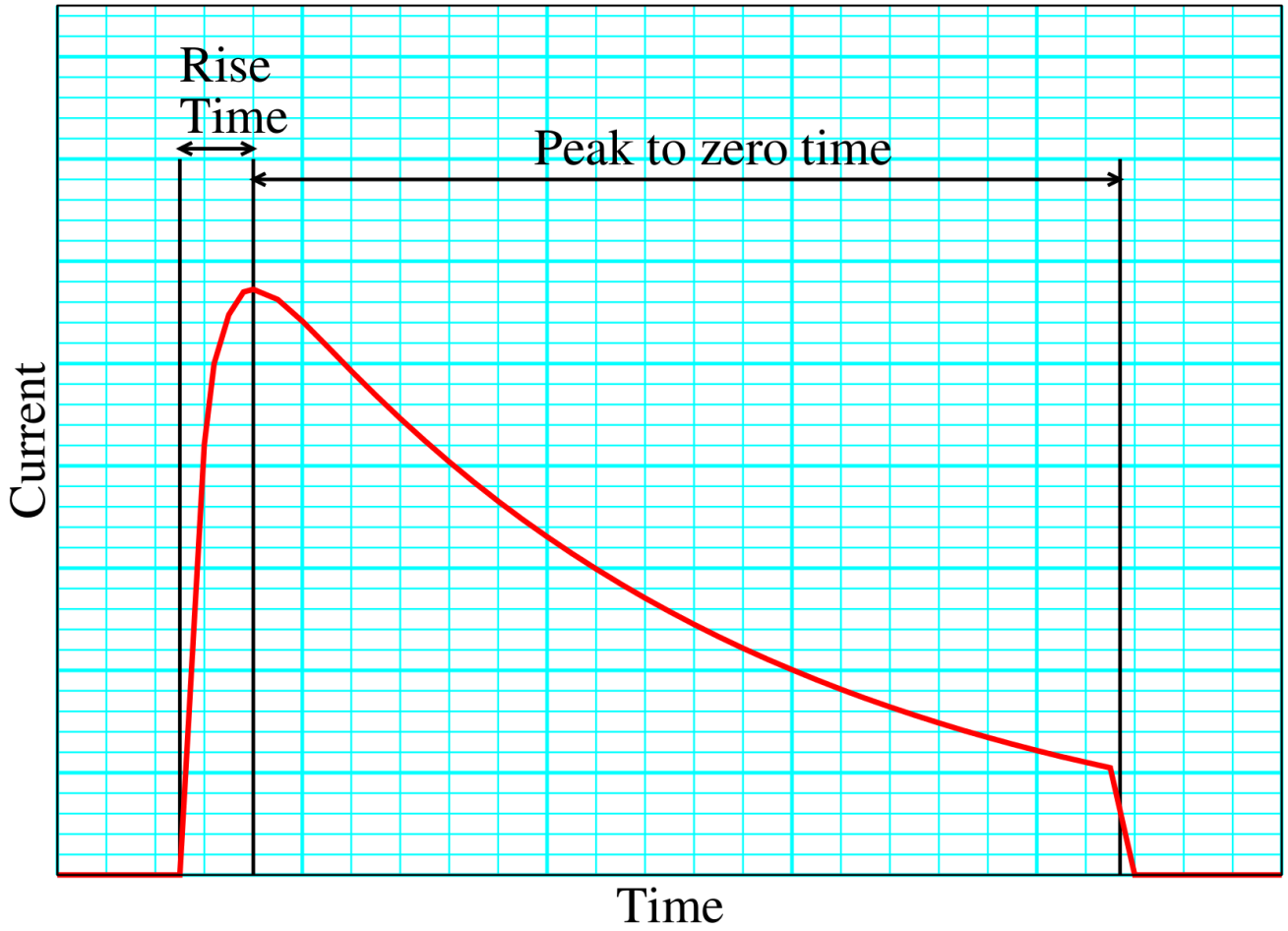
IP (Induced Polarization) Effect

- IP Effect is the departure of measured voltage from the square wave input current

- It can be measured on either the decay curve or on the charging curve

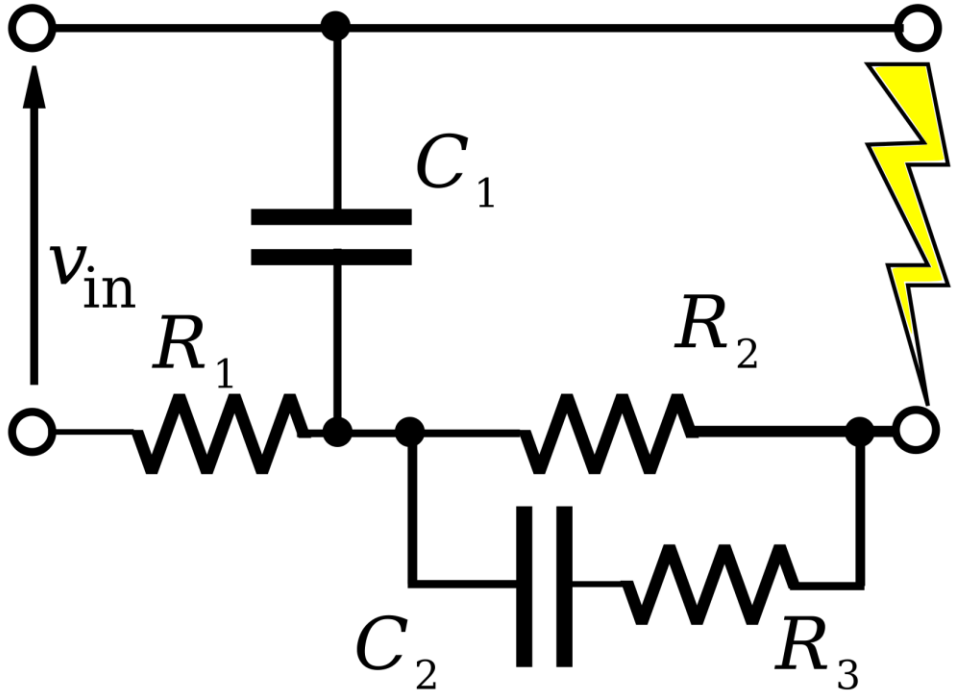
Lightning and the IP Effect

- Lightning does not have a square waveform
- But it does have a very steep onset
- Variations in the onset as measured (rise-time) show the IP Effect

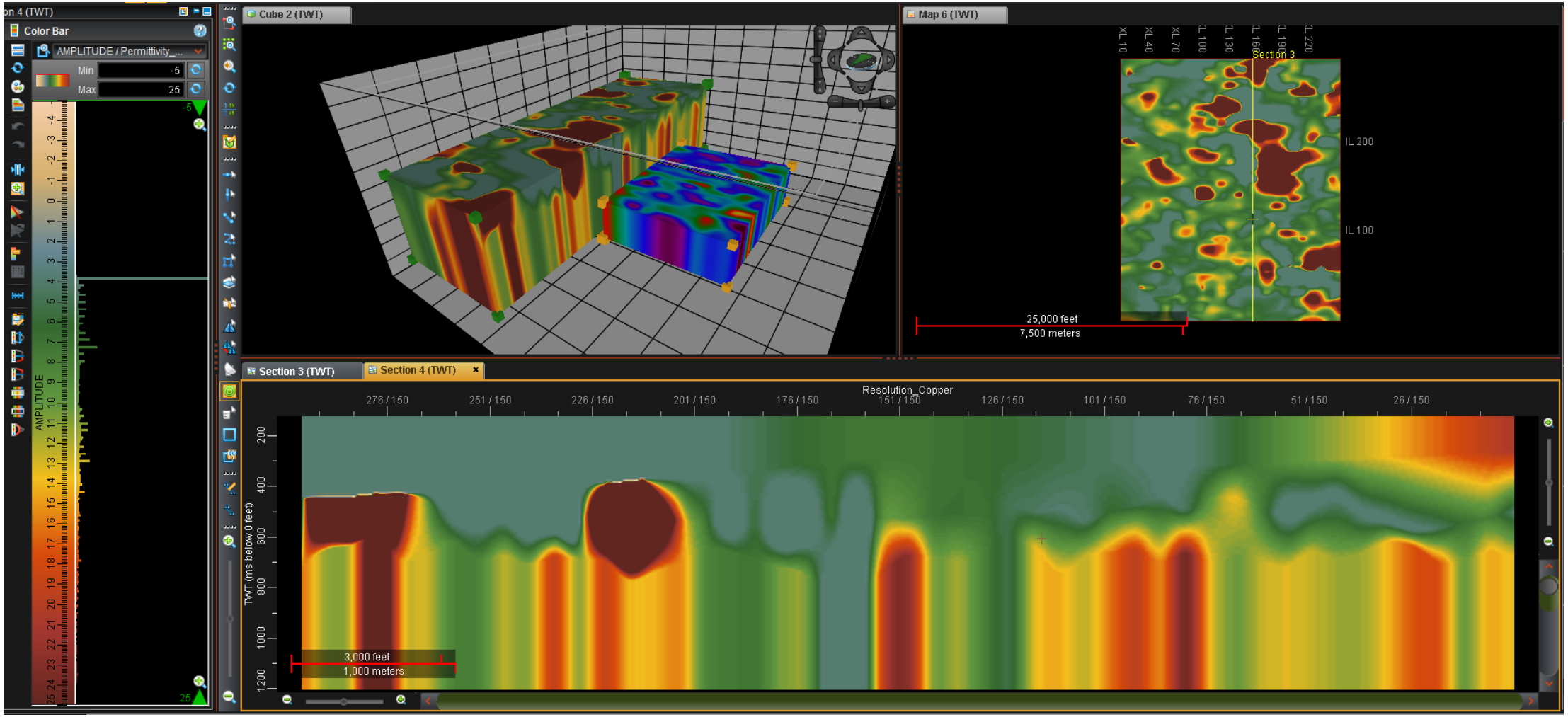


The equivalent circuit

- By treating this as charging a capacitor (C_2) through a resistor (R_3), an apparent capacitance can be calculated
- From apparent capacitance a value for average permittivity can be calculated

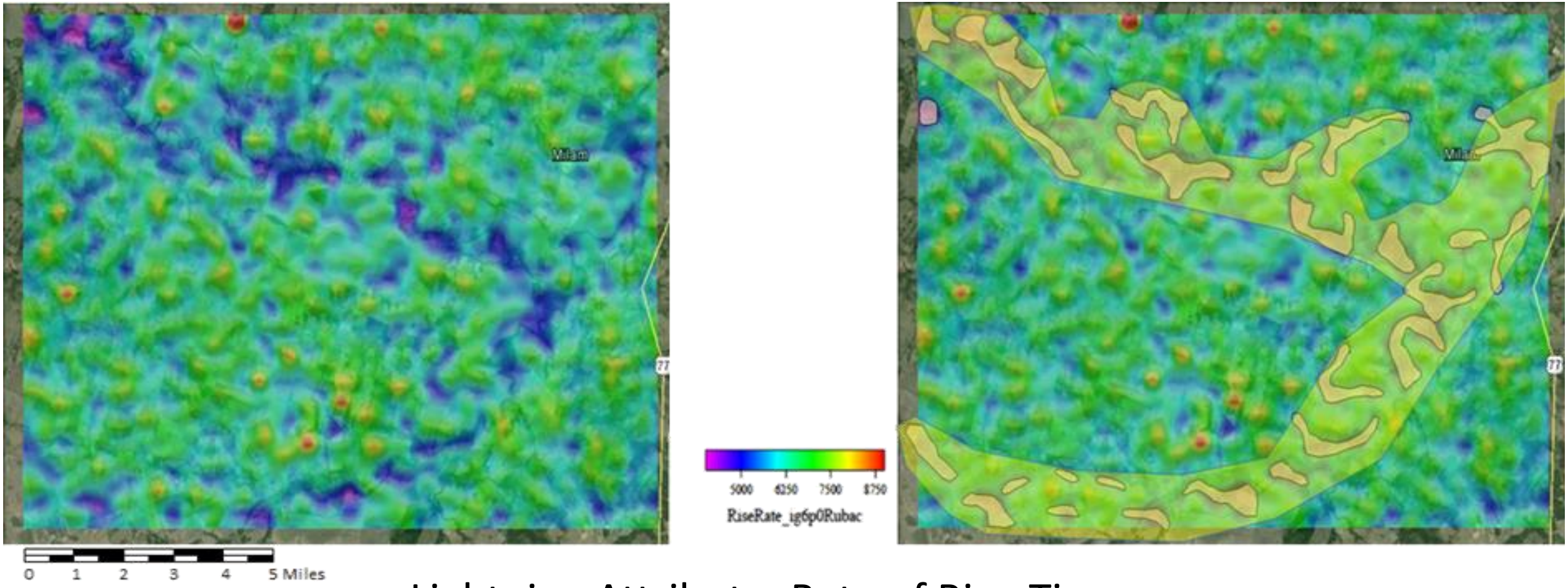


Permittivity Volumes Arizona



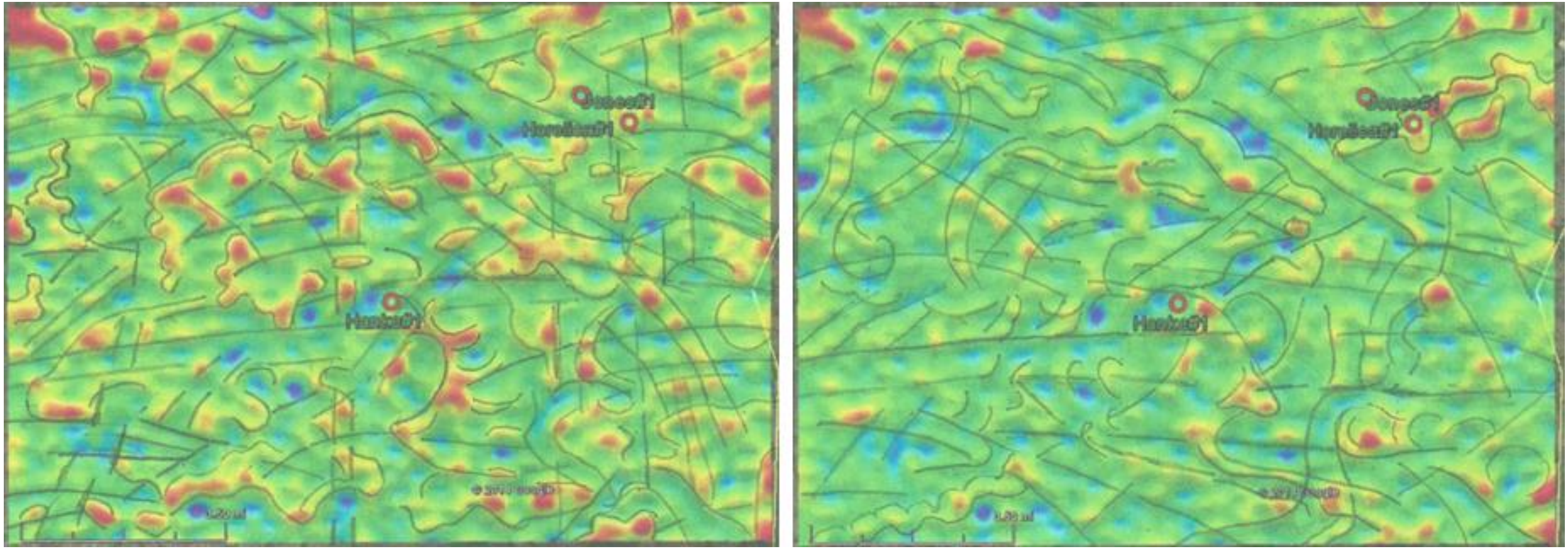
4. Examples of using lightning databases to map geology

Lightning Analysis
Defines Stratigraphy



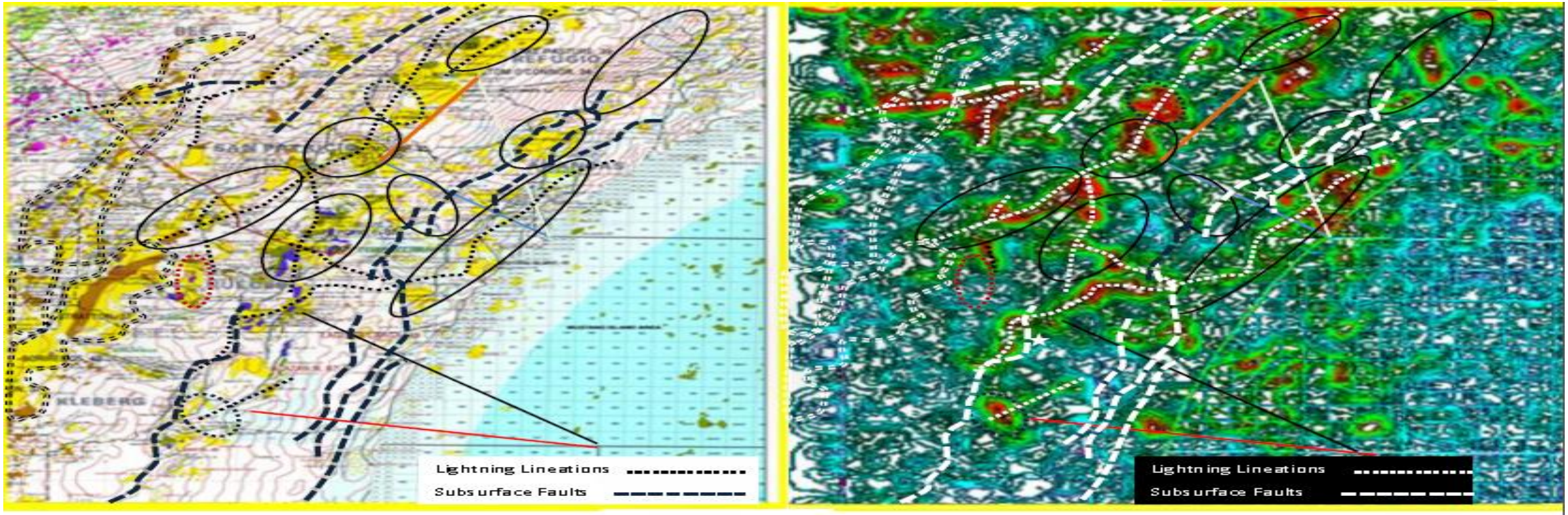
Lightning Attribute: Rate of Rise-Time

Lightning Analysis
Interprets Paleochannels and Meander Schrolls



Lightning Attributes: Surface Resistivity (left) Peak-to-Zero (right)

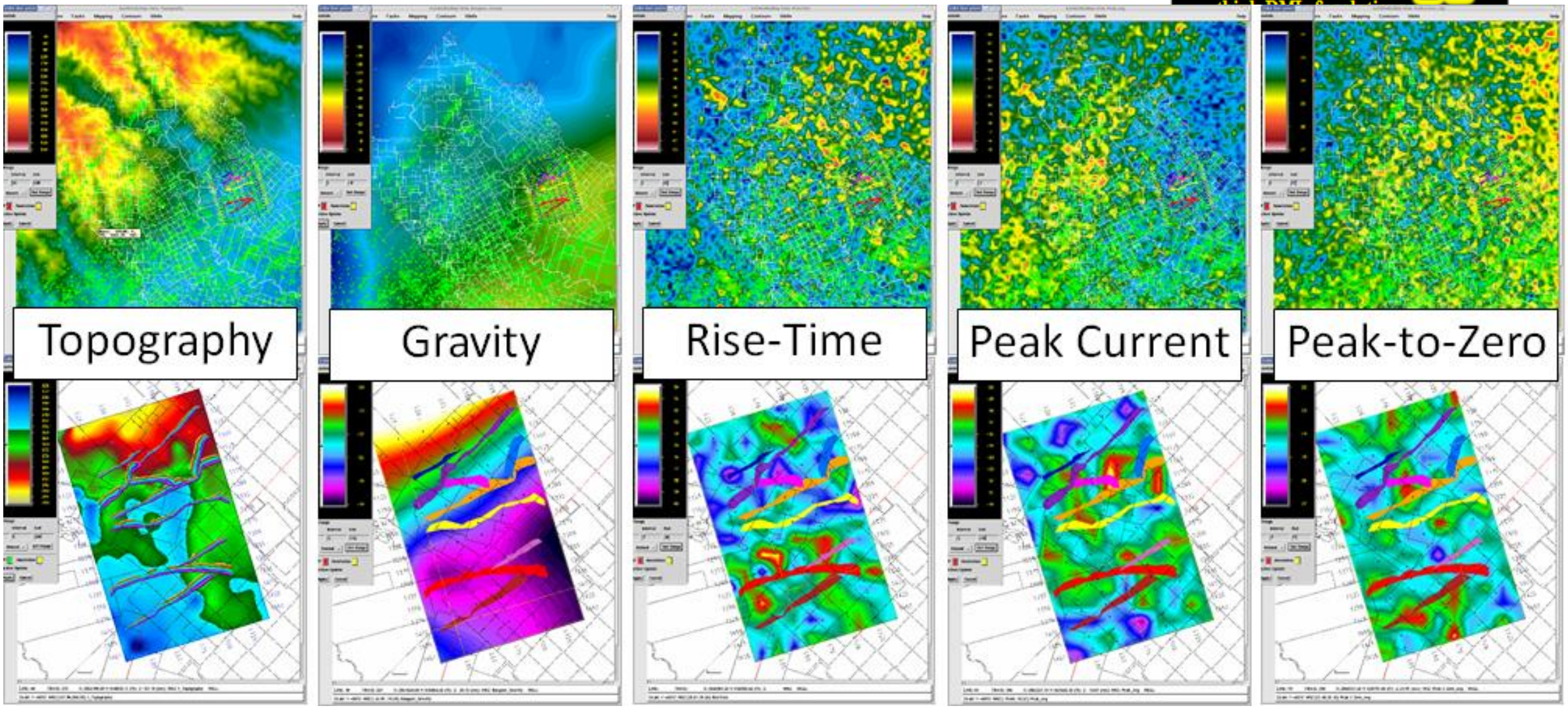
Lightning Analysis
Correlates with Fields



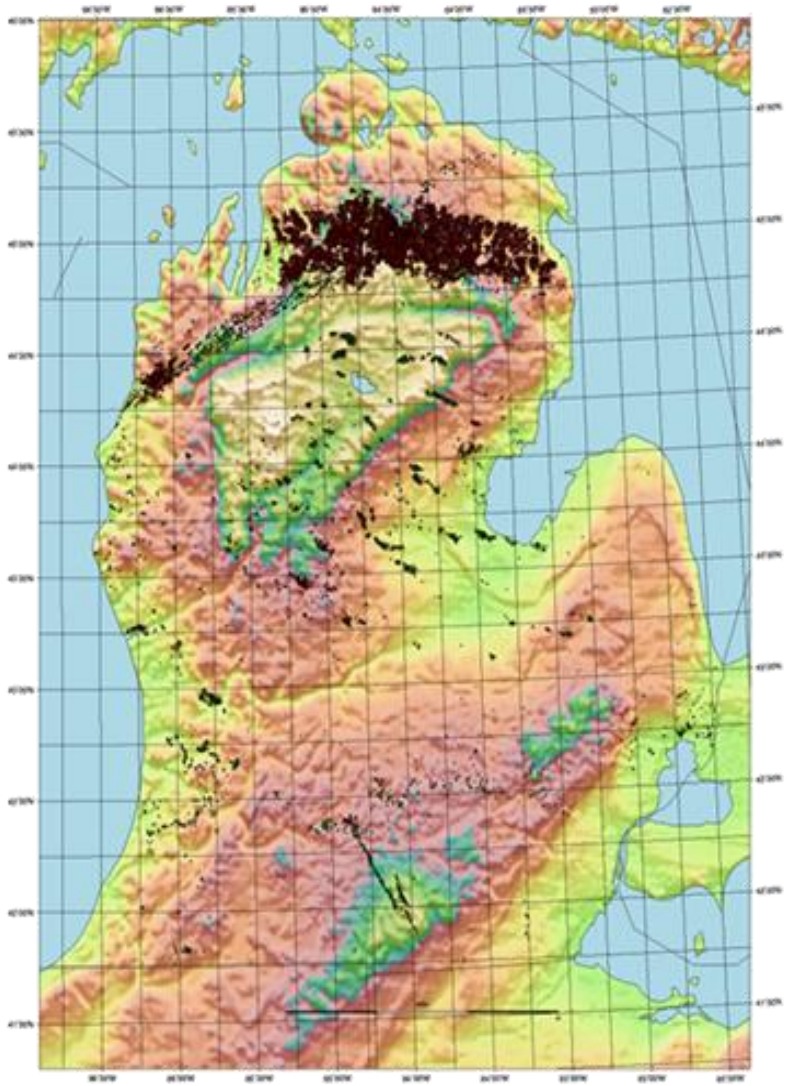
Second Pass

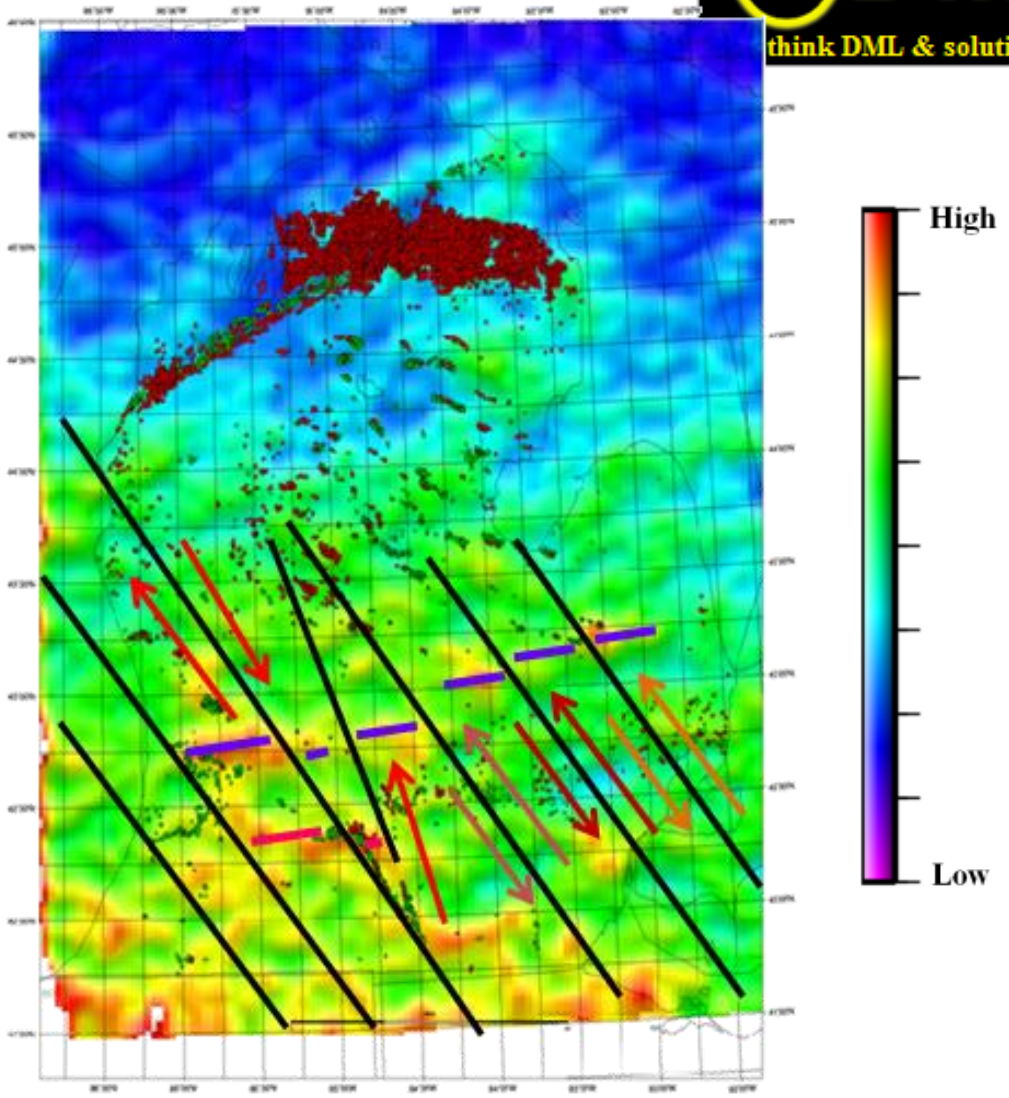
Dark Red	Production but no anomaly.	
Black	Anomaly correlates to production.	
Red Black Dark Blue Olive Green	Location Line Aids	
		Excellent Examples
		Dark Blue — Anomaly but no production.
		Black — Production with partial to no anomaly.
		Black & White — Field alignment, minimal correlation.

A New Potential Fields Method,
Supplementing Gravity & Magnetics

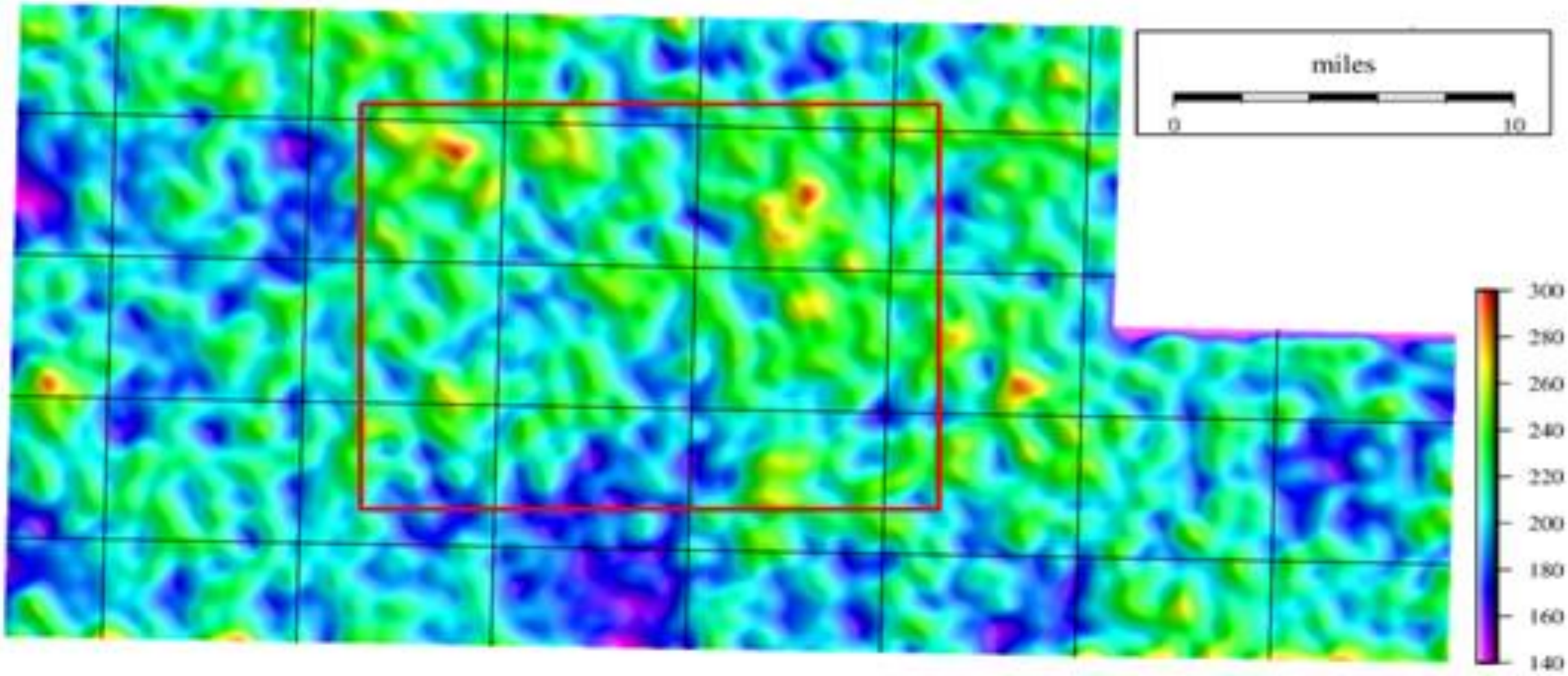


Michigan Basin Topography & Strike Density

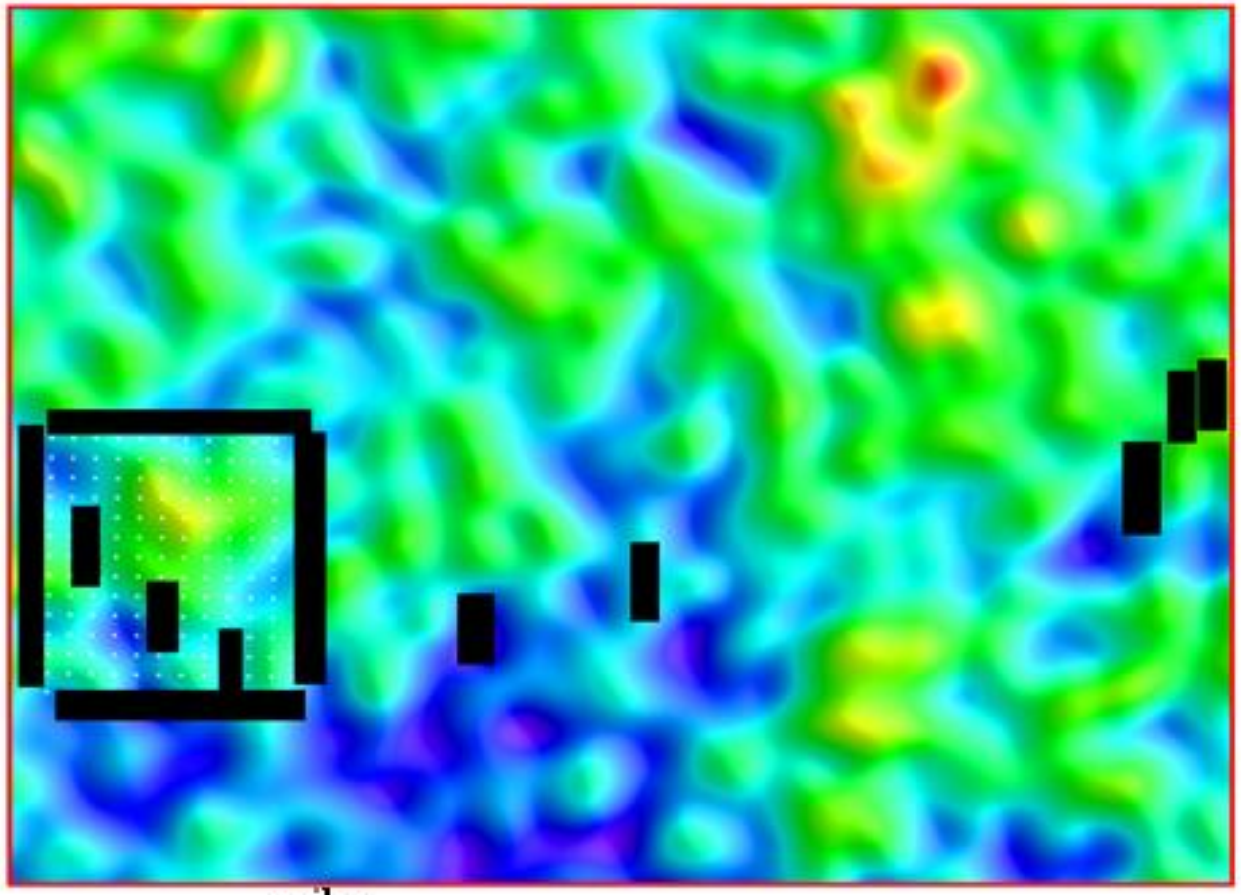


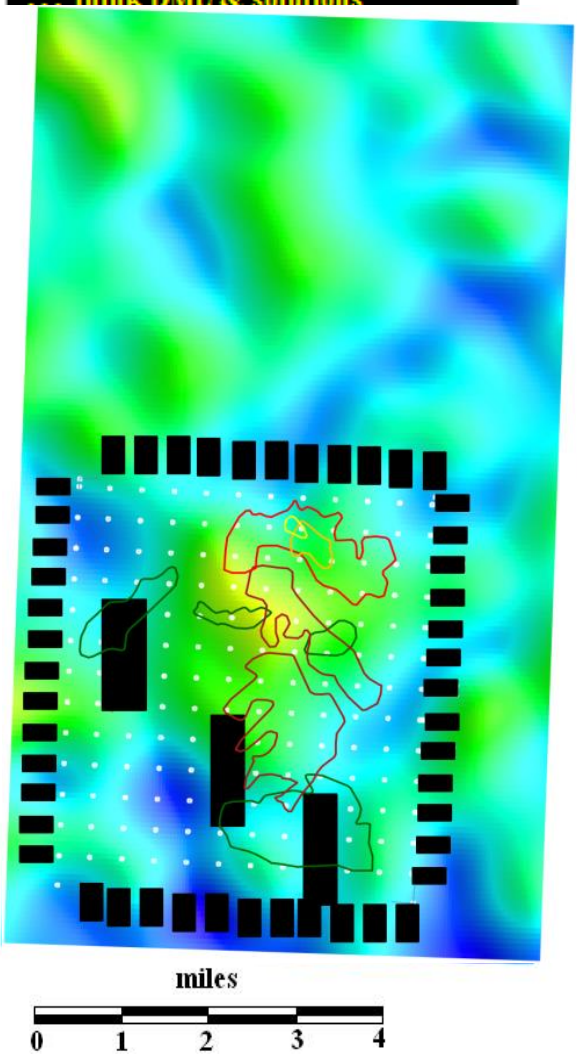


Lightning Analysis - Quicker Regional Overviews

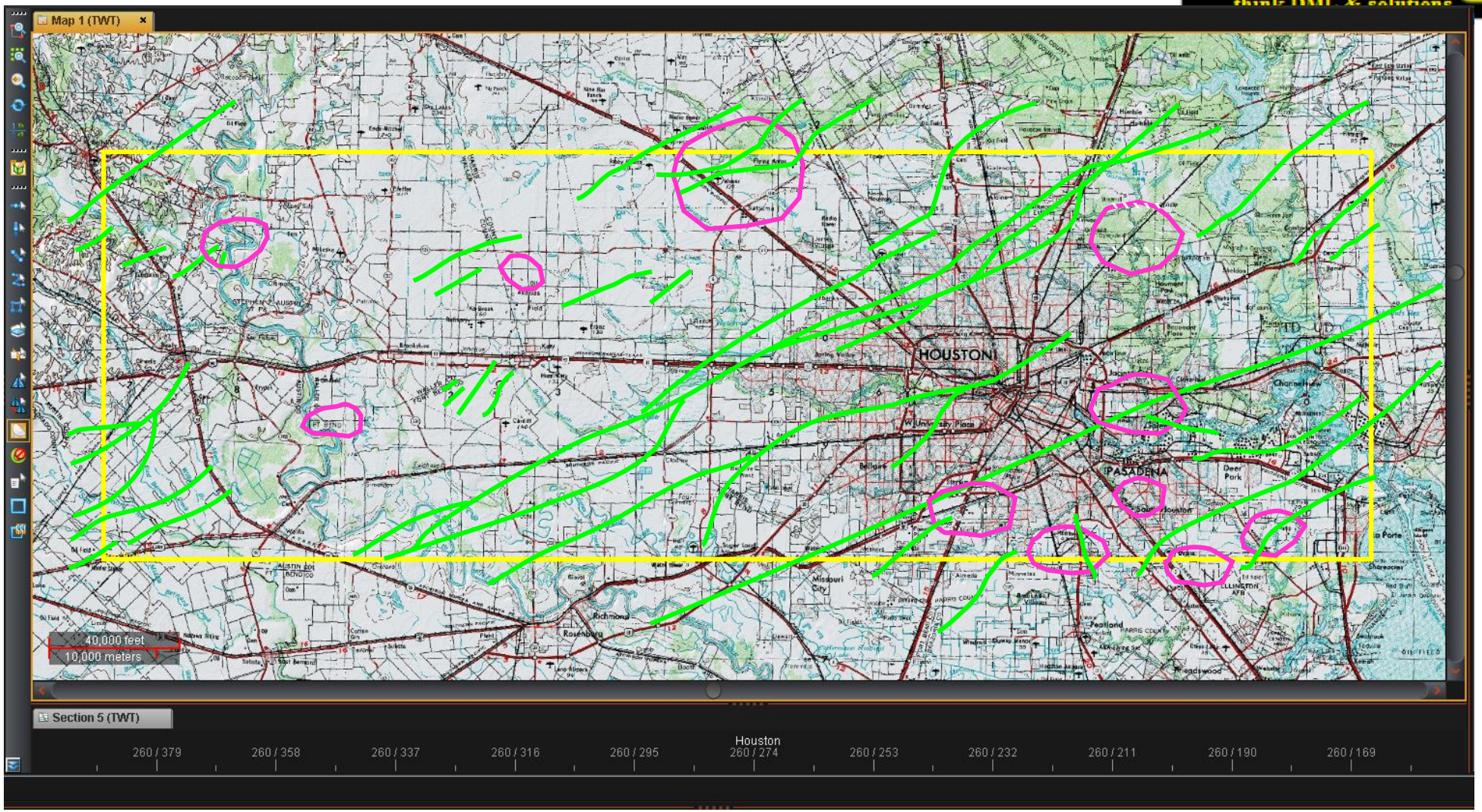


More details at Play Fairway & Prospect Scales

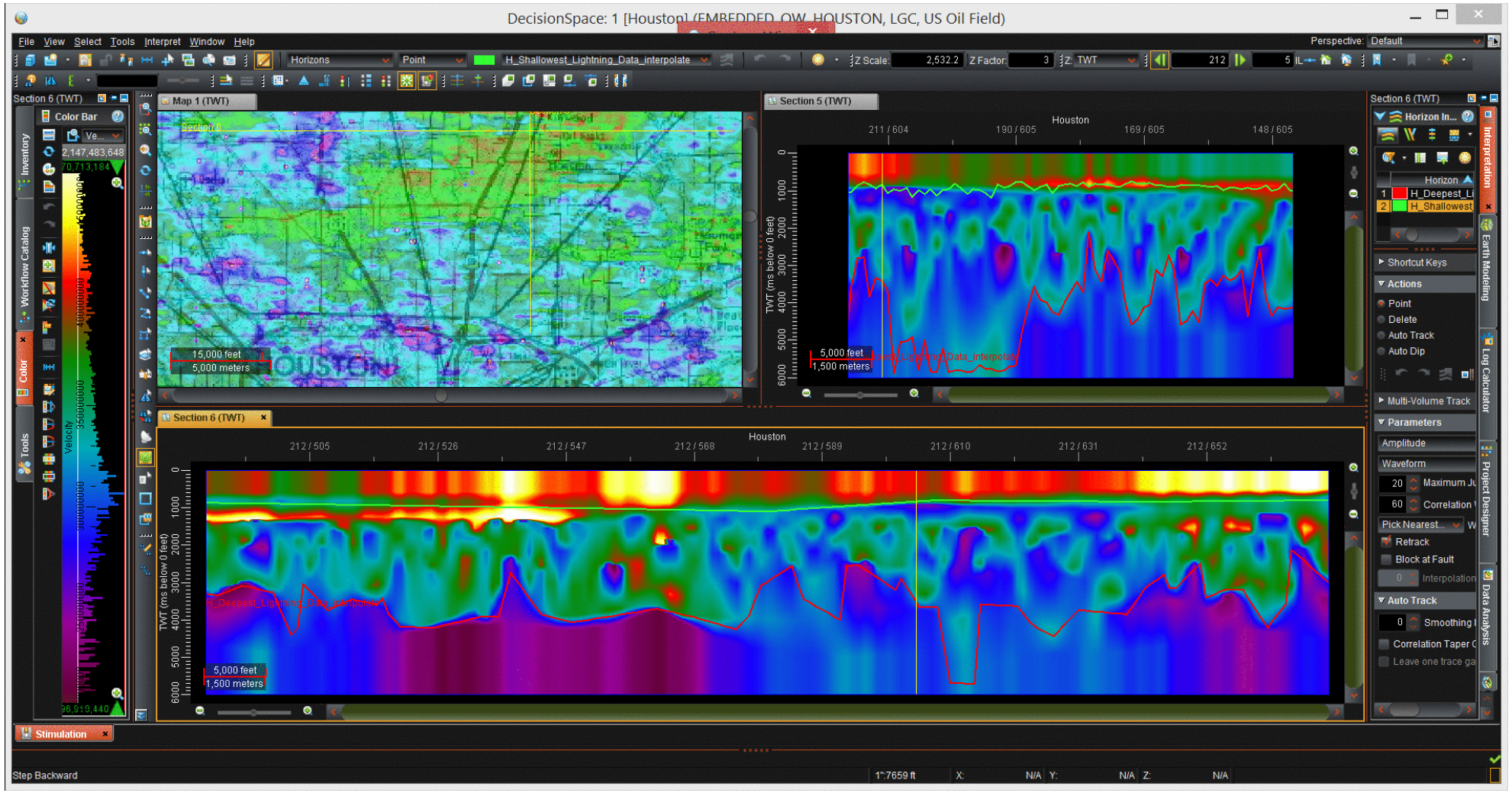




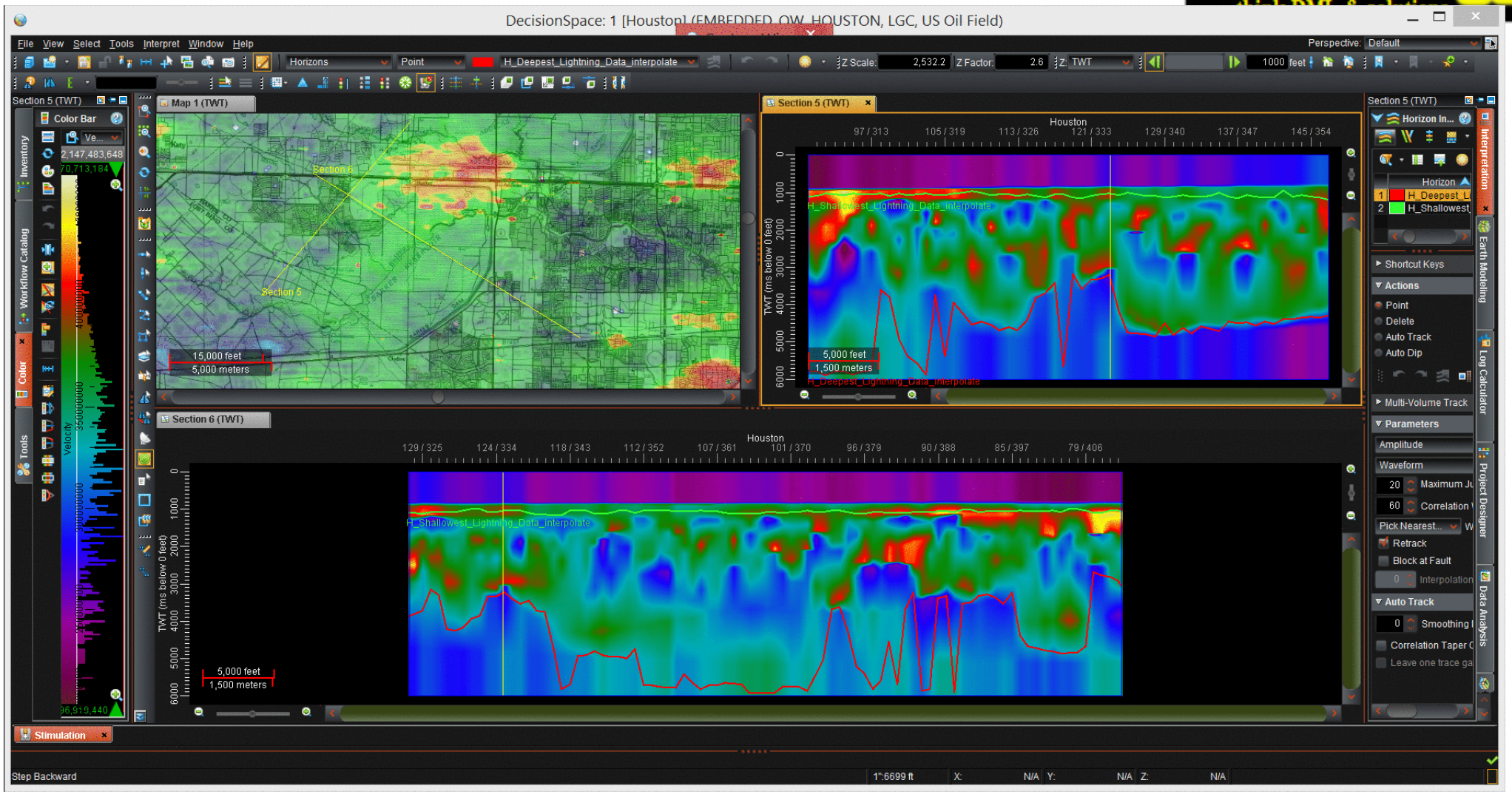
Imagine collecting a 3-D seismic survey here!



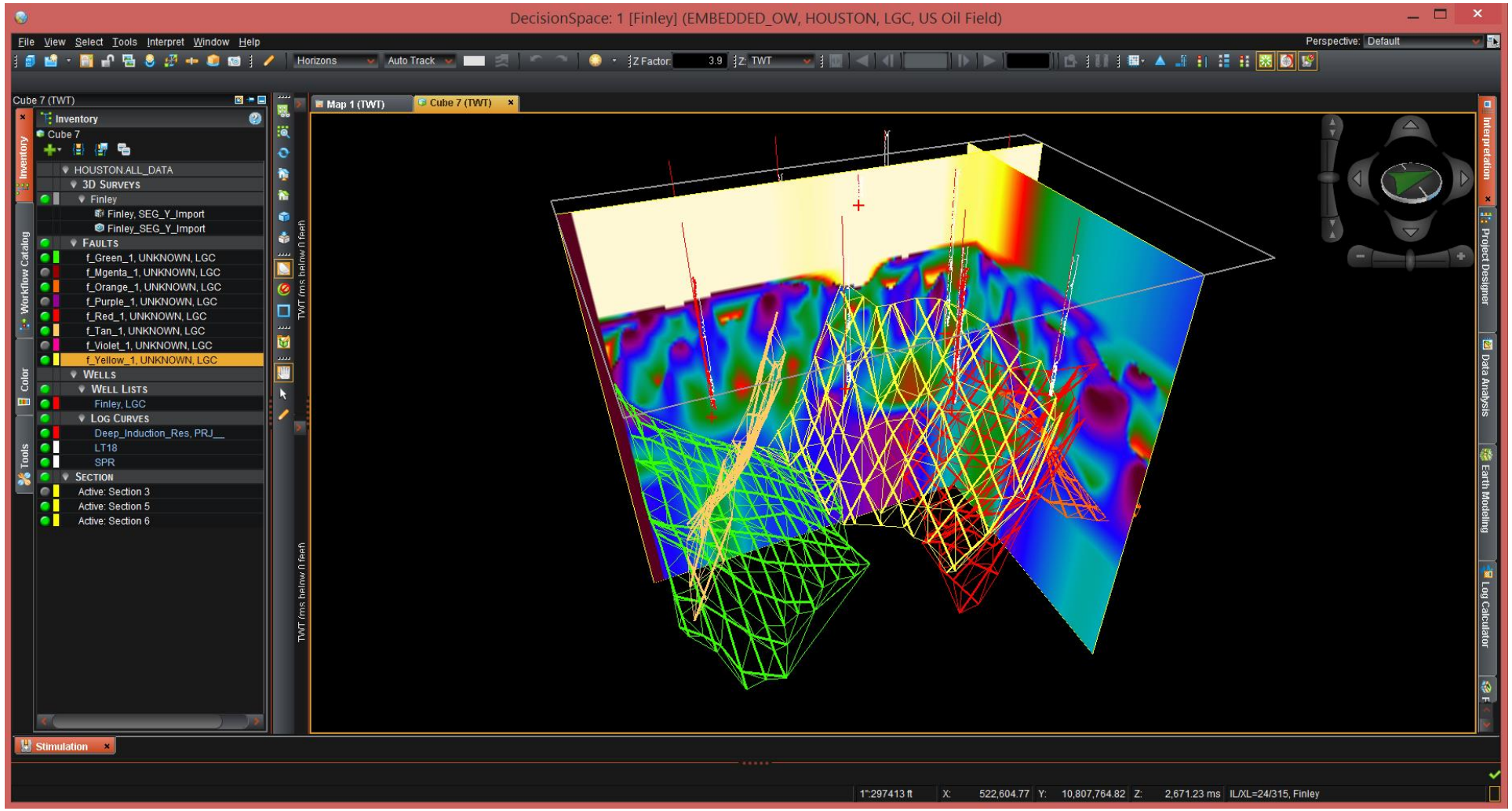
North Houston In-Line Animation



USACE George Bush Park Pipeline Animation



Texas Resistivity Fault Interpretation - 1



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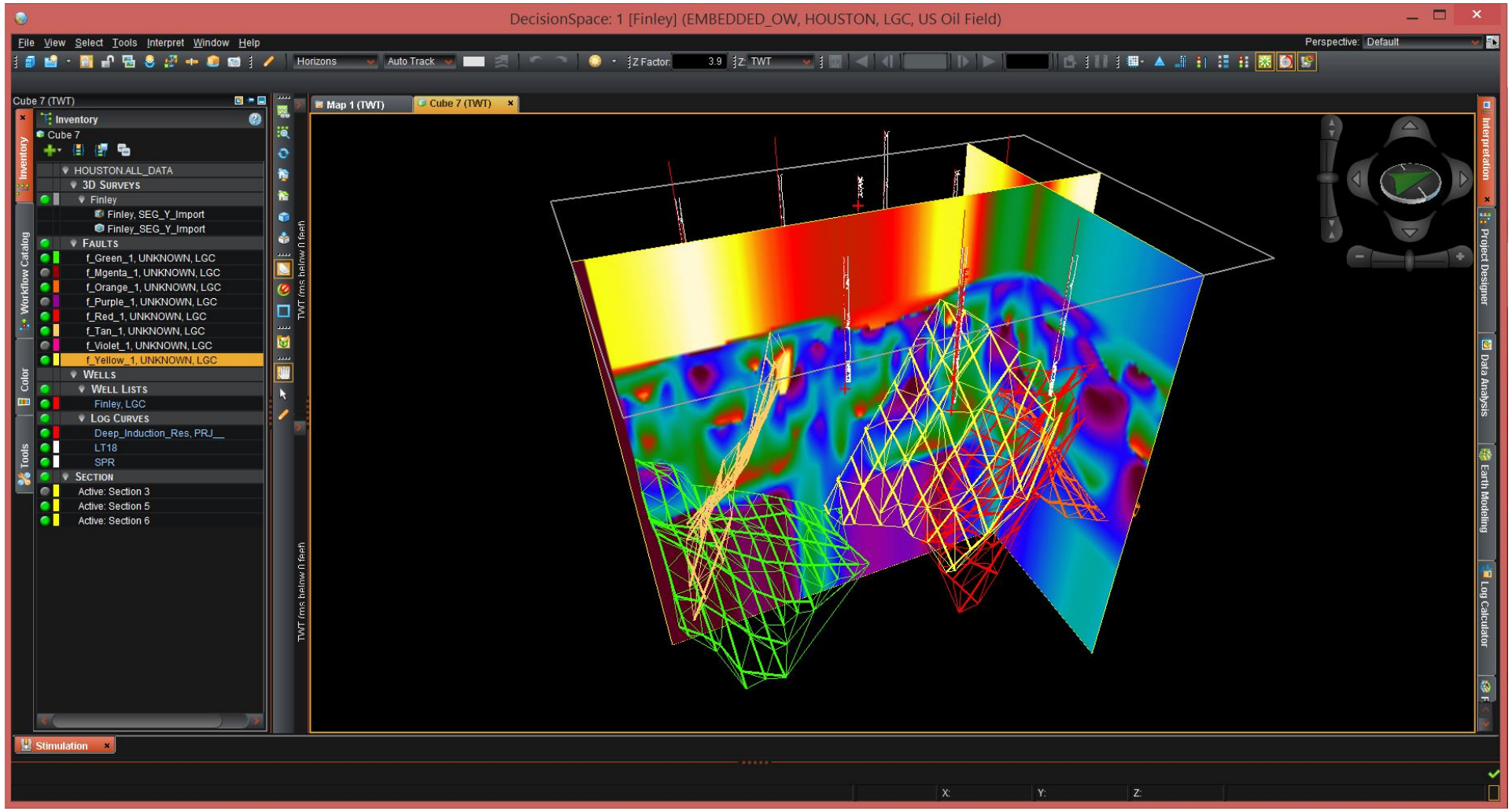
Texas Resistivity Fault Interpretation - 2



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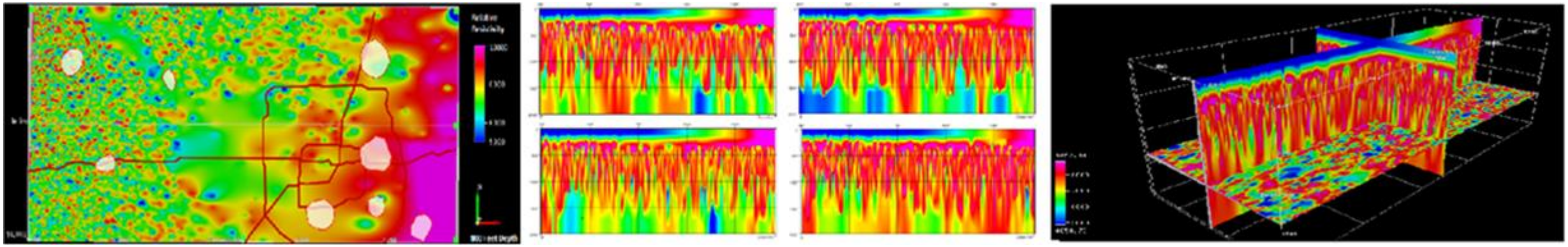
NSEM and Resistivity Volumes are a Technology Breakthrough



- Attribute maps identify lineaments related to faulting
- Resistivity and Permittivity volumes provide an independent view of geology
- Resistivity & Permittivity volumes can be created to match 3-D geometry
- Expect merger of resistivity & Permittivity volumes and lithology predictions

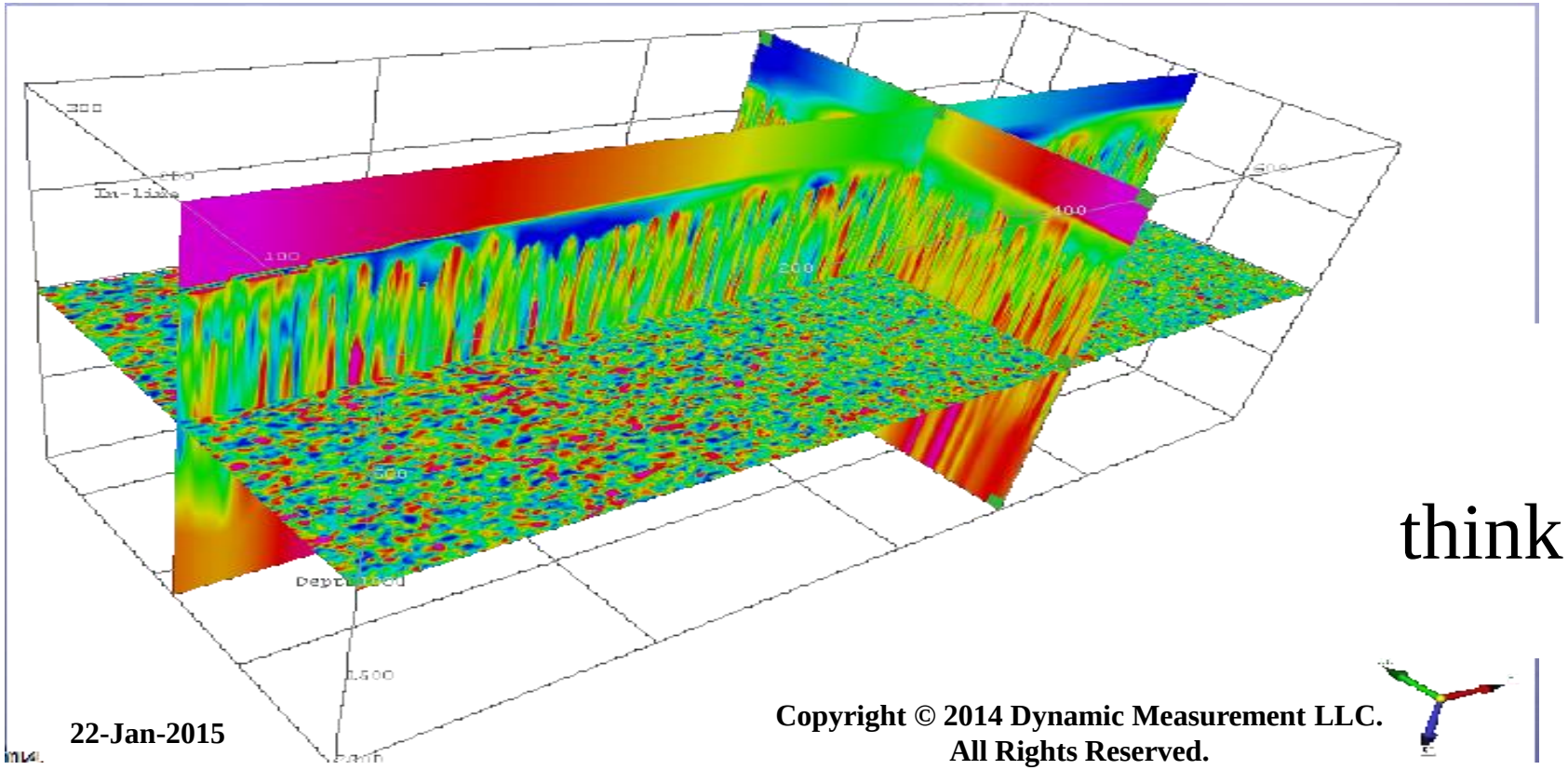
What we have covered:

1. NSEM - A new technology to identify geologic hazards
2. The meteorology behind lightning databases
3. Calculating resistivity volumes from lightning databases
4. Examples of using lightning databases to map geology

Find out more at

http://www.dynamicmeasurement.com/TAMU
http://www.dynamicmeasurement.com/TAMU/150122_BYU
http://www.dynamicmeasurement.com/TAMU/150122_BYU_Expanded_Presentation

Thank You!



See Lightning,
think DML & solutions!

See Lightning, Think DML

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Discussion