Aquifers, Faults, Subsidence and the Lightning Data Base

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Dynamic Measurement, LLC

…..and Lagniappe

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Aquifers, Faults, Subsidence, and Lightning Databases

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OUTLINE

1. Introduction and Theory
2. Geologic Setting in Texas Study Area
3. Aquifers / Earth Tides / Geothermal Gradient
4. Conclusions

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Lightning Theories and Facts

- Lightning occurs everywhere.
- Cloud to cloud lightning travels up to about 150 miles (250 km).
- Cloud to ground lightning follows terralevis/shallow earth currents which reflect geology. Some strikes do hit topography, vegetation, and infrastructure, but can be edited out from location and attribute data.
- Lightning Attributes contain data from various depths and image subsurface features and lineaments such as transforms, faults, drainage basins, and paleo channels.

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

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Main lightning bolt tied to geology

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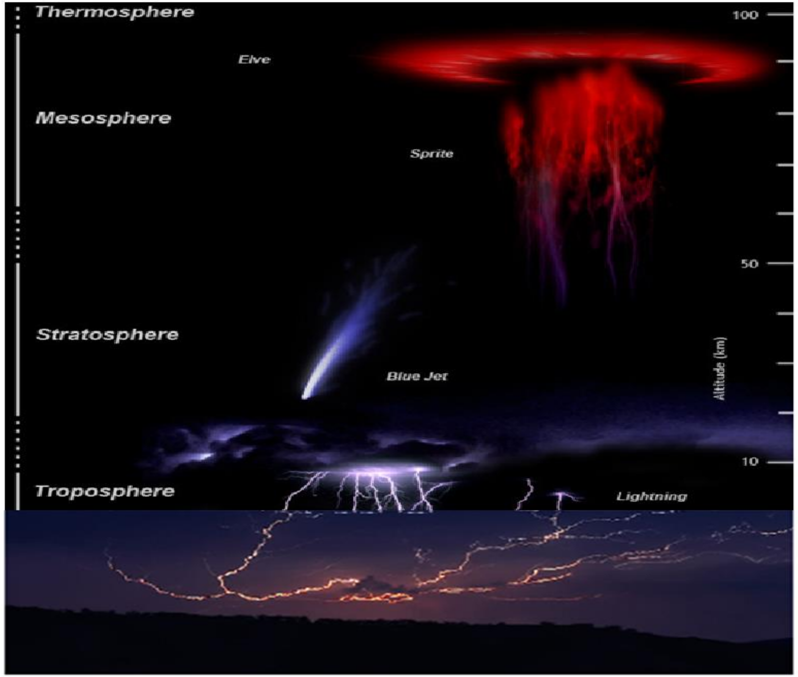
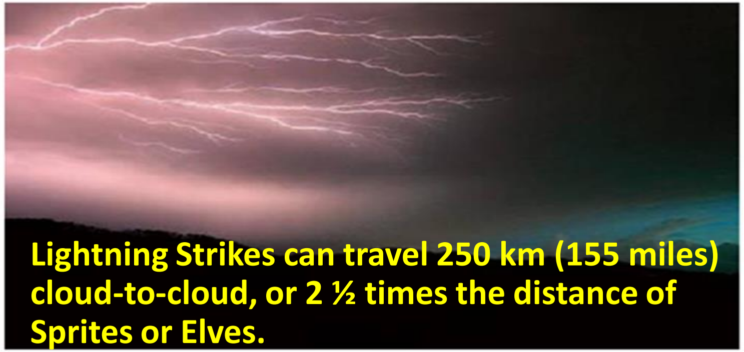
350 million annual Lightning Strikes - a rich database to mine





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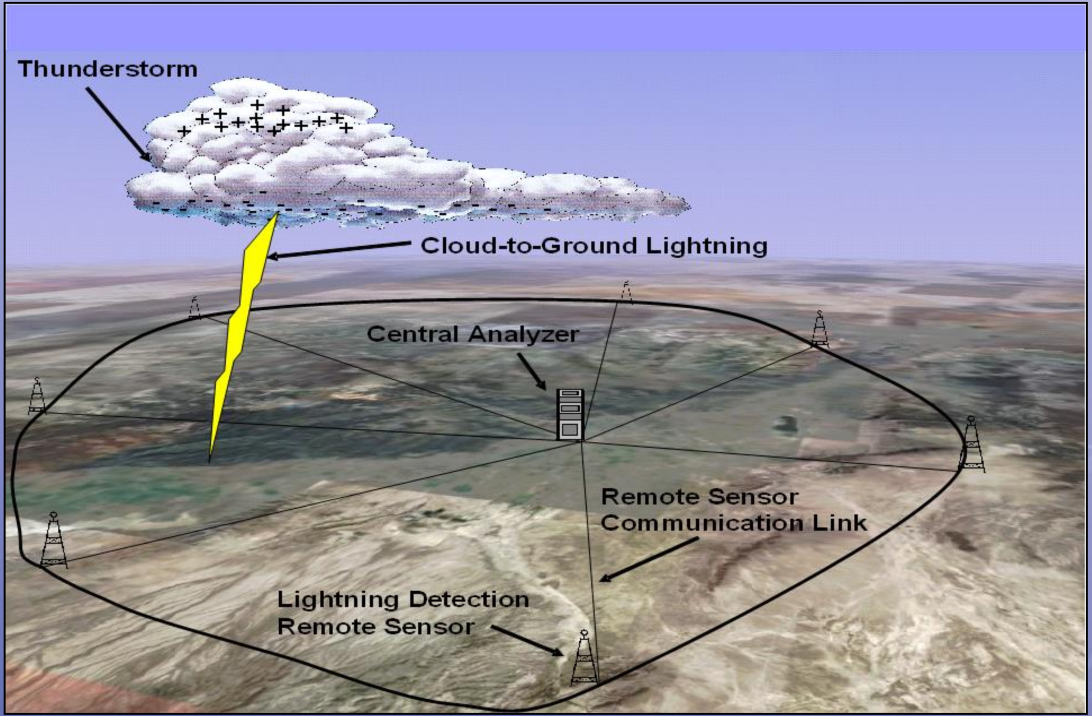
330 Sensors record U.S. lightning strike locations with 100-500 feet (30-150 meter) horizontal resolution



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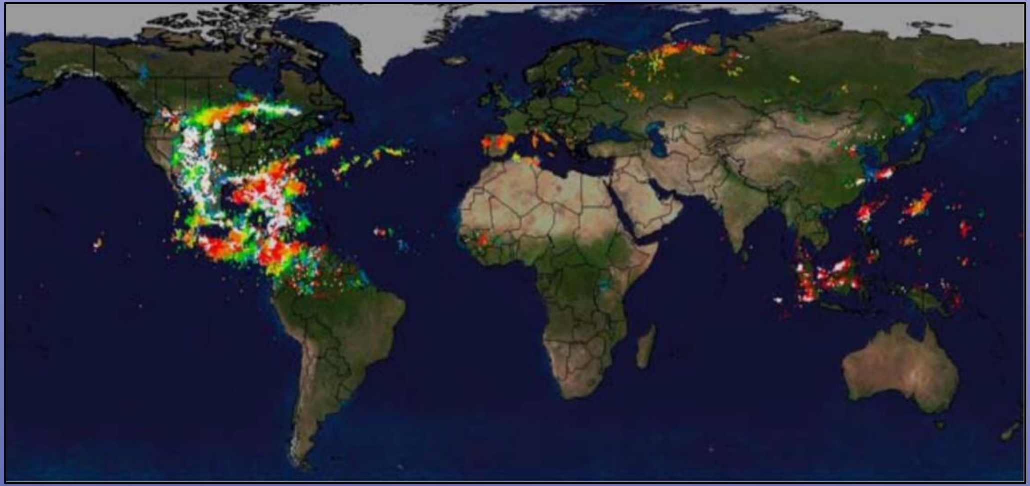
Vaisala Partnership

Exclusive worldwide license with Vaisala of Finland to use their data in the NLDN and GLD-360 for natural resource exploration.



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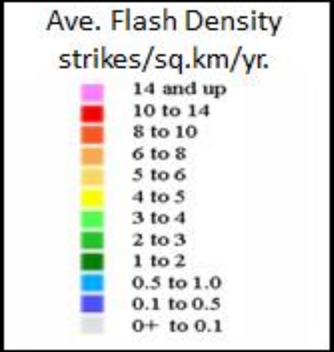
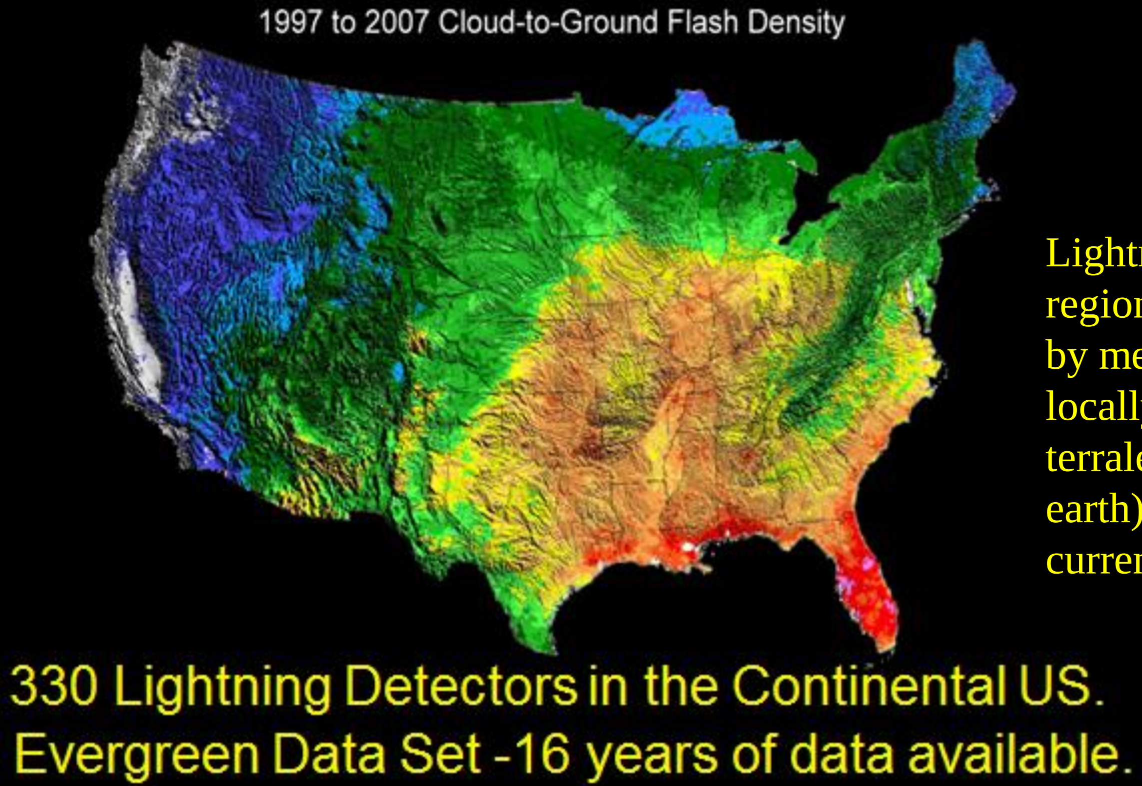
Strike Density (NLDN) and Topography





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

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Proven and Patented Technology

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**

(75) Inventors: **H. Roice Nelson, Jr.**, Houston, TX (US); **Joseph H. Roberts**, Houston, TX (US); **D. James Siebert**, Katy, TX (US); **Wulf F. Massell**, Conroe, TX (US); **Samuel D. LeRoy**, Houston, TX (US); **Leslie R. Denham**, Houston, TX (US); **Robert Ehrlich**, Salt Lake City, UT (US); **Richard L. Coons**, Katy, TX (US)

(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

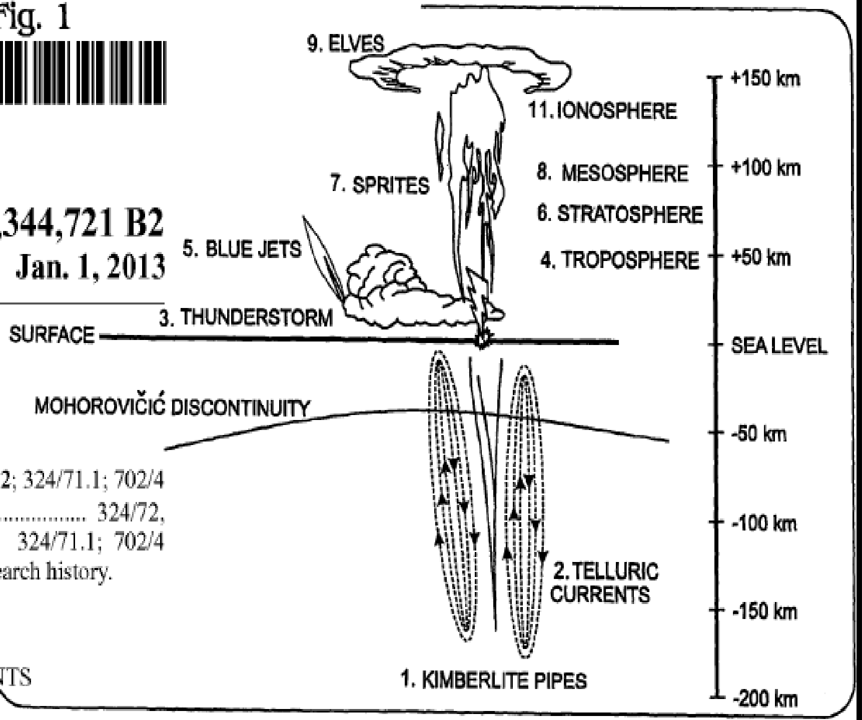
(58) **Field of Classification Search** 324/72, 324/71.1; 702/4

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

Fig. 1



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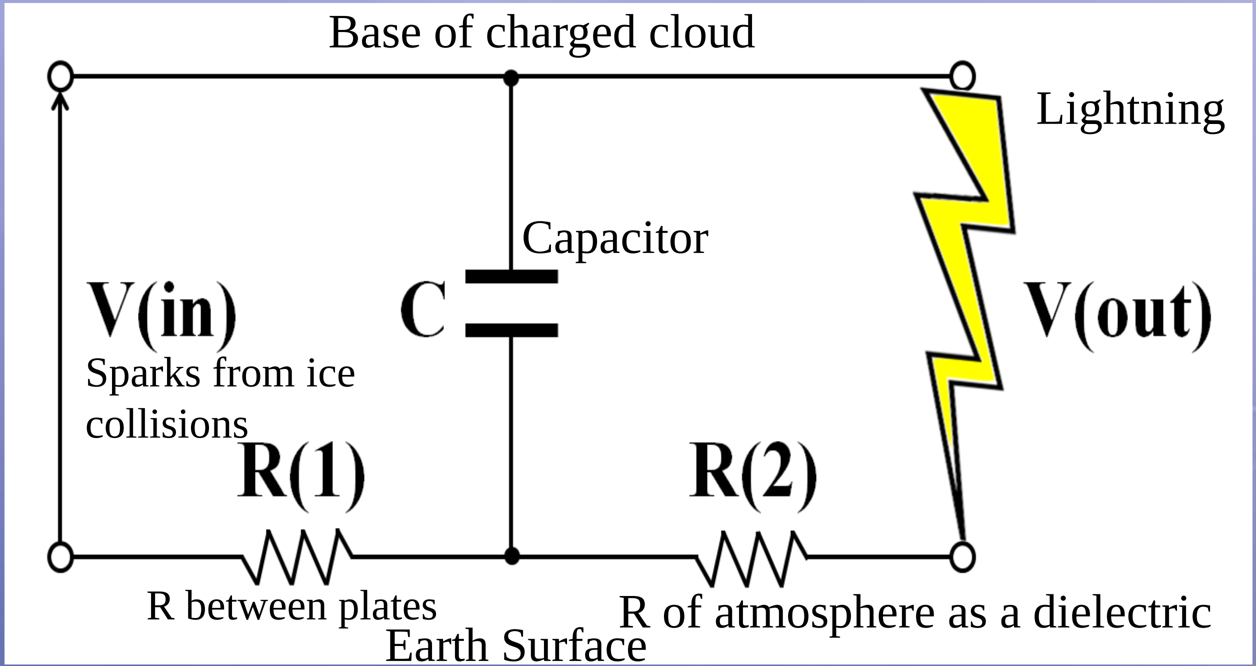
Lightning

Two conducting plates, the storm cloud and the earth, are separated by an insulating dielectric, the atmosphere. Voltage is created by collision of ice within the cloud and lightning bolts rebalance the charge between the plates.



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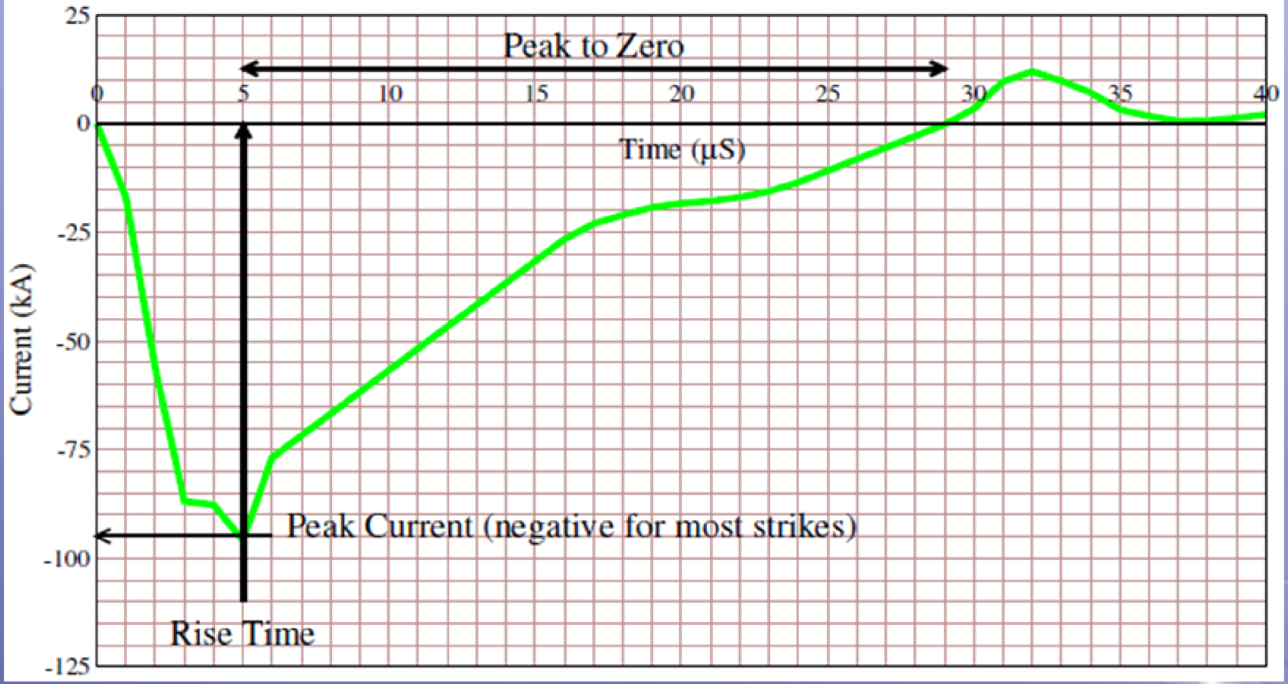
Lightning Measurements/Attributes, & Wave Form

- Location / Time and Duration / # of Sensors
- Rise Time
- Peak Current
- Peak to Zero
- Polarity
- Chi Squared
- Number of Sensors



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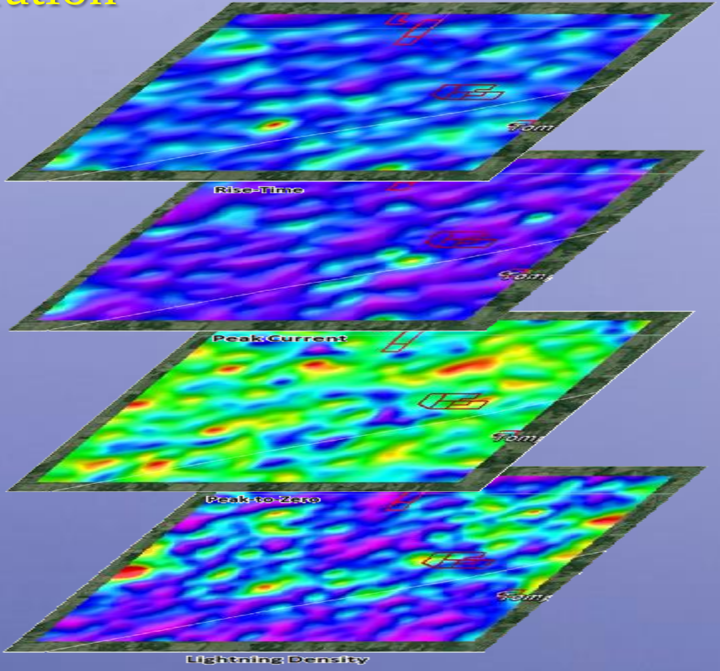
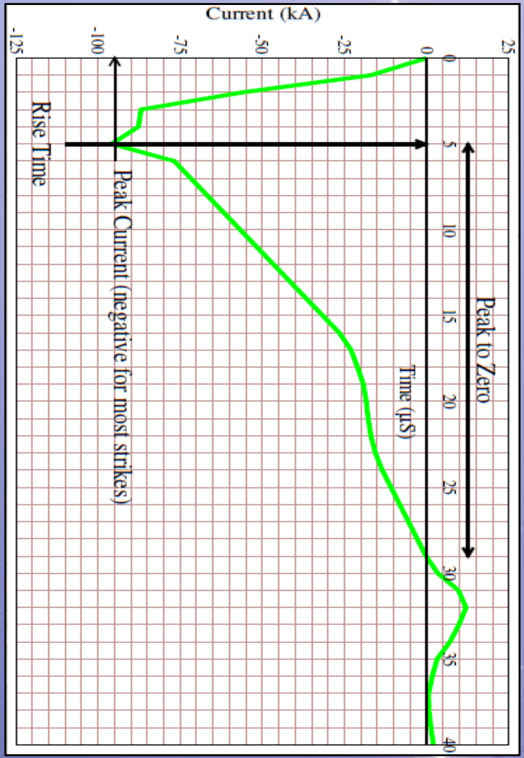
Lightning Strike Measurements

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





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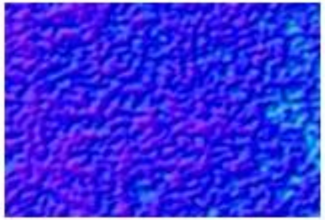
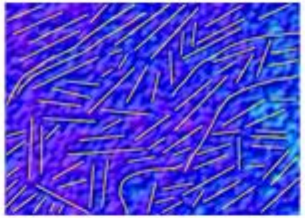
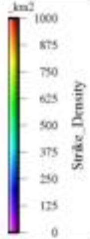
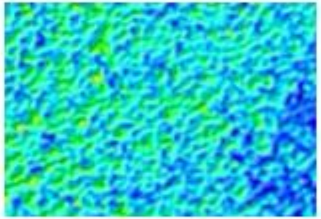
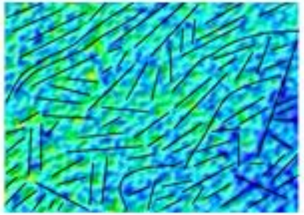
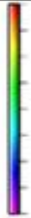
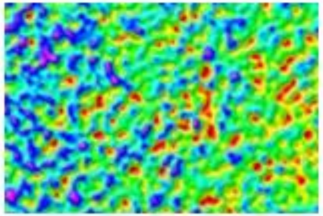
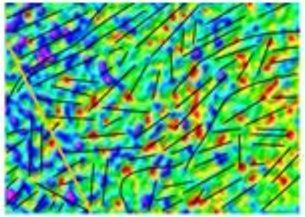
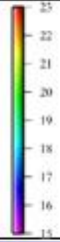
Geological Significance of Lightning Attributes

Lightning Attribute	Definition	Geological Attributes	Example	Interpretation	Color Bar
Density	The average number of lightning strikes located in an IG-6 cell (269 x 153 meter or 881 x 503 feet cells at 30° Latitude).	Used to define lineaments which are associated with faulting. Minor topographic effects are distinguished from geologic influences during interpretation.			
Rise-Time	The time to go from background electrical noise to Peak Current in microseconds, averaged over IG6 cells.	Sees areas with higher resistance such as salt domes and fresh water associated with ponds, rivers, and aquifers. In this example, the blue region in the east, suggests the presence of shallow fresh water.			
Peak Current	The average Peak Current in kiloamps of lightning strikes falling in an IG6 cell.	Sees subsurface resistivity and is largely impacted by the negative lightning strikes. Voltage must be higher to get through depth.			

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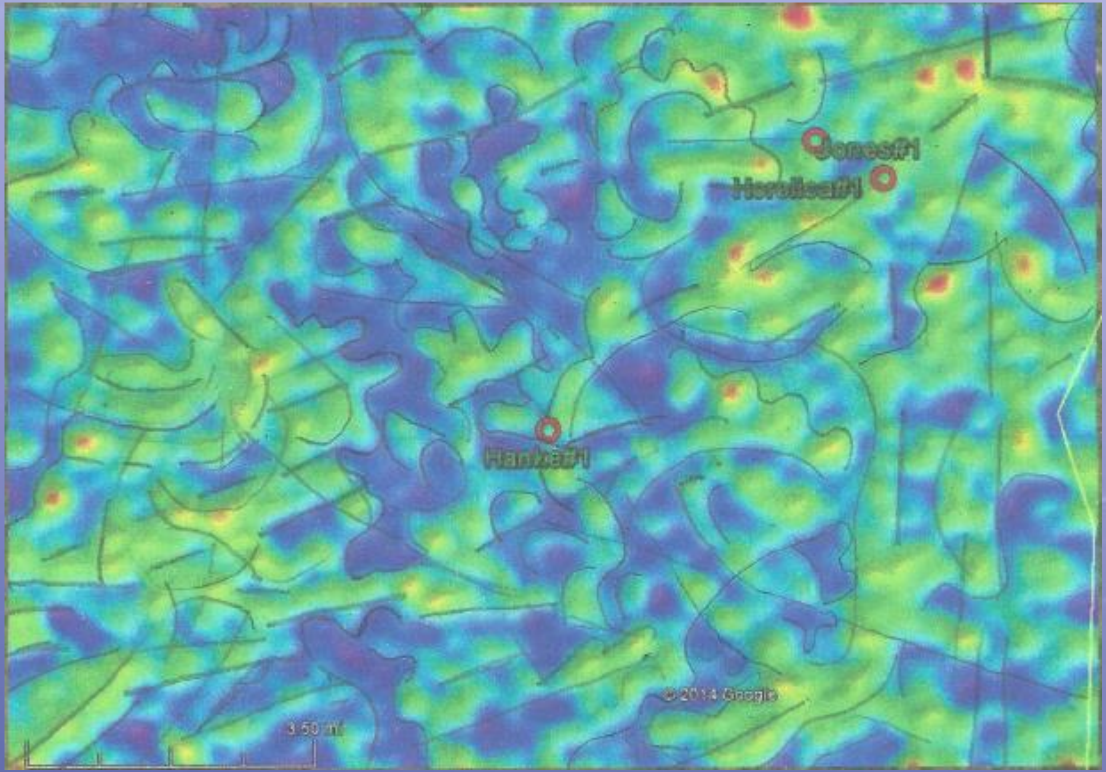
2. Geologic Setting in Texas Study Area
Aquifers / Faults / Stratigraphy / Subsidence

Rise-Time
Central Texas



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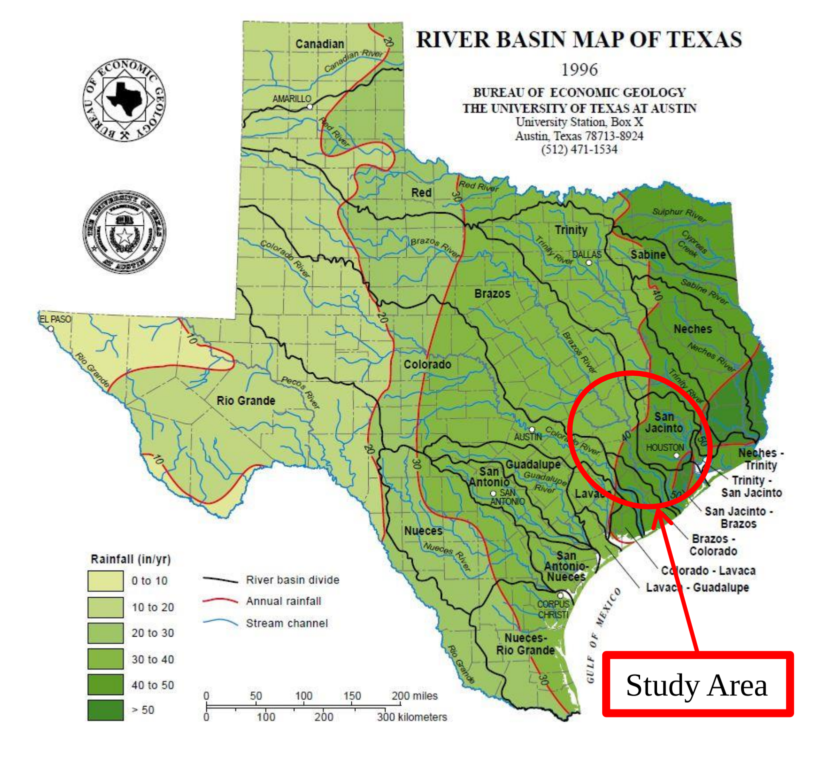
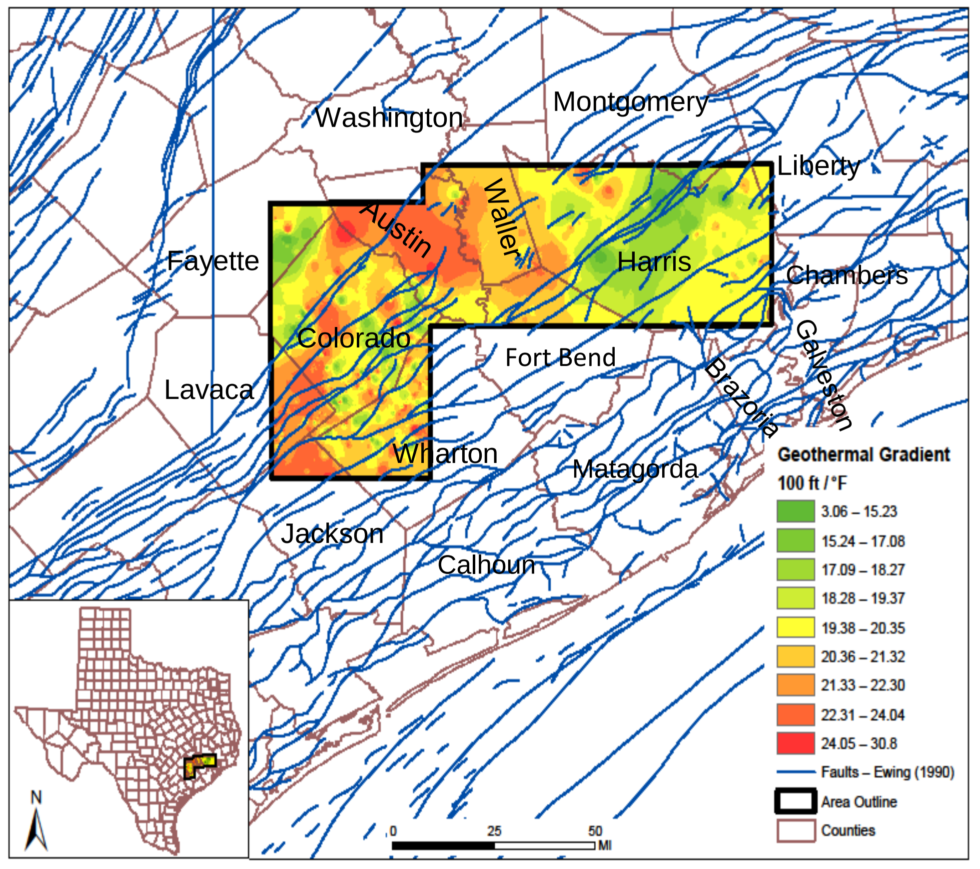
Fault Trends and Geothermal Gradient





Fault trends by Ewing 1990
Geothermal Gradient Map

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Aquifers

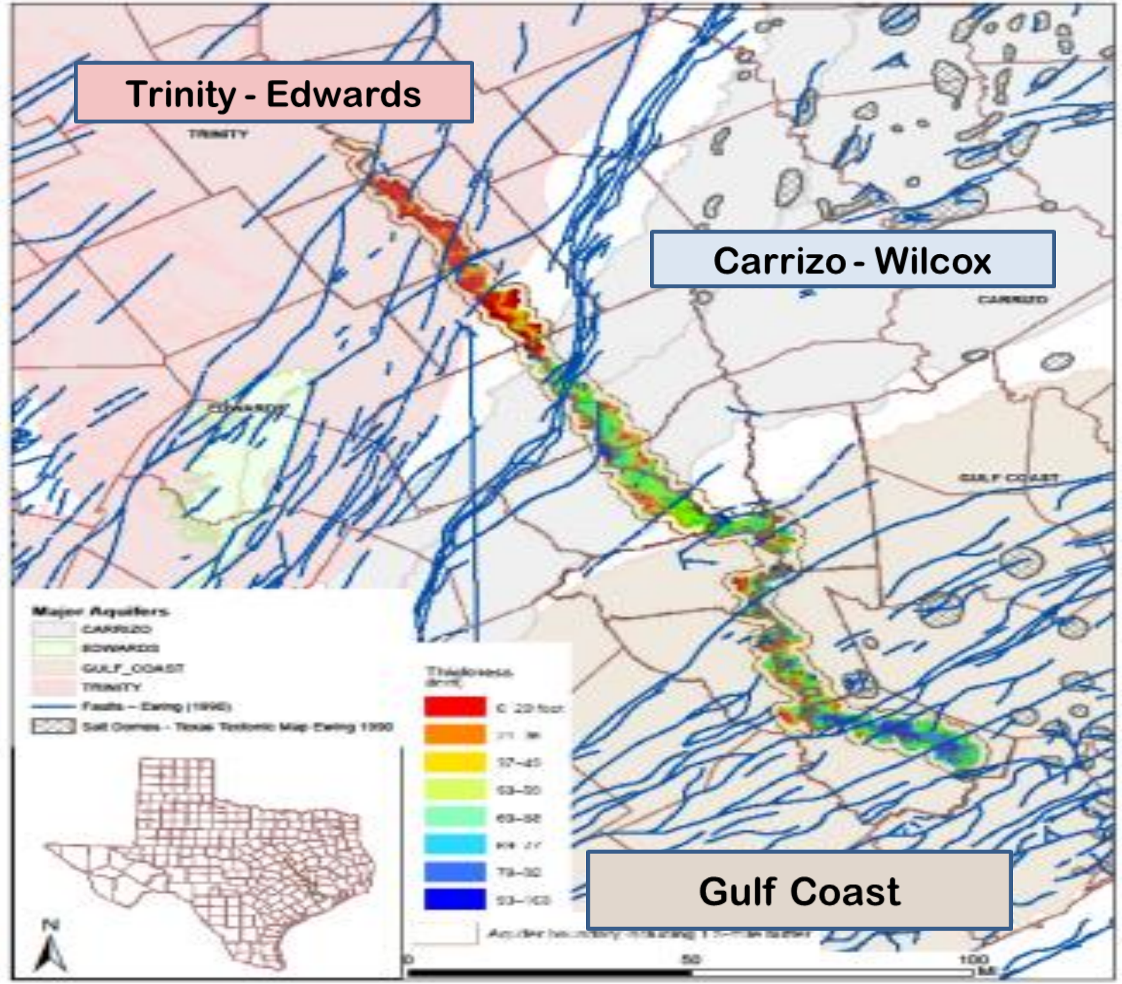
Brazos River Alluvium Aquifer

Trinity - Edwards

Carrizo - Wilcox

Gulf Coast

Aquifers from Texas Water Development Board Report 380.



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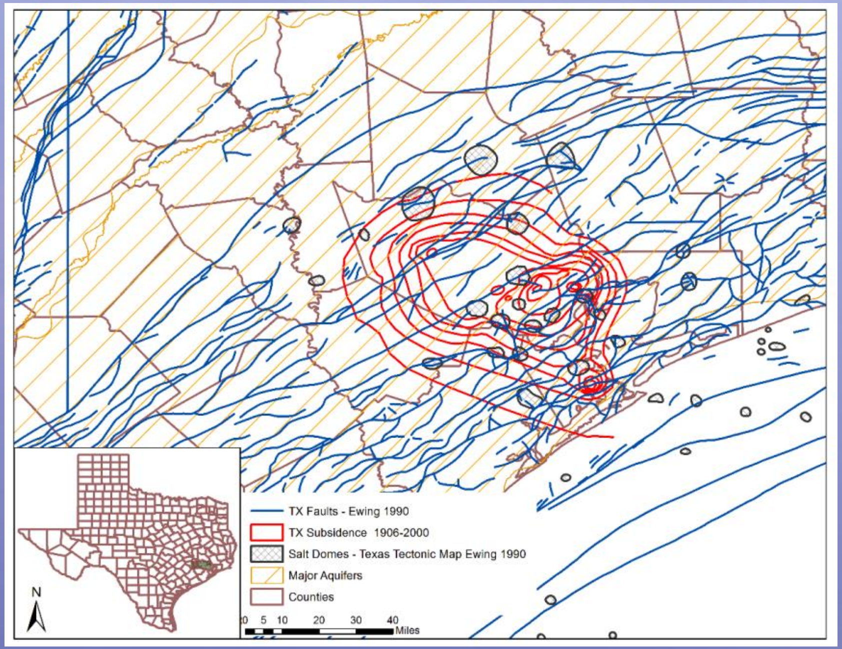
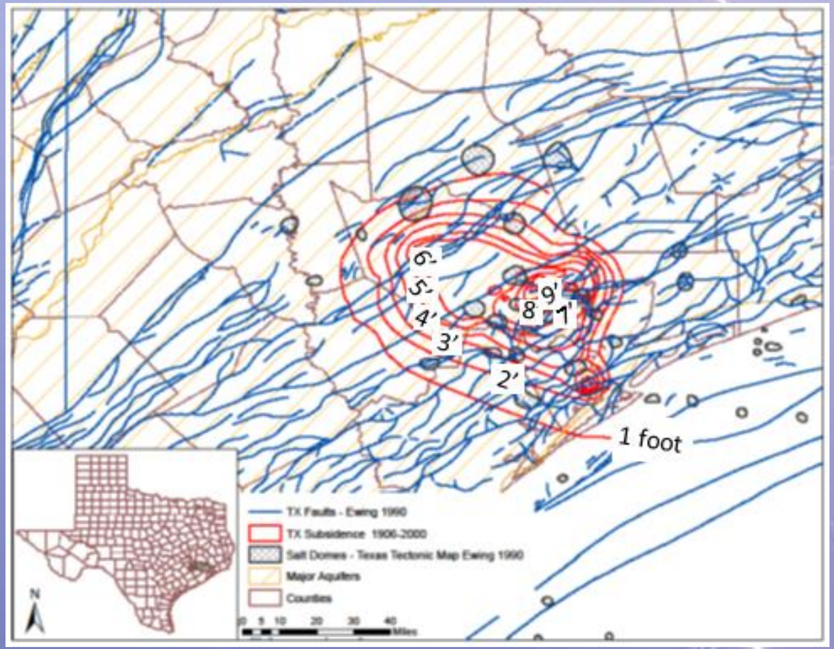
Houston – Galveston Area Subsidence in Gulf Coast Aquifer





From Houston Galveston Subsidence District 1906-2000 with permission

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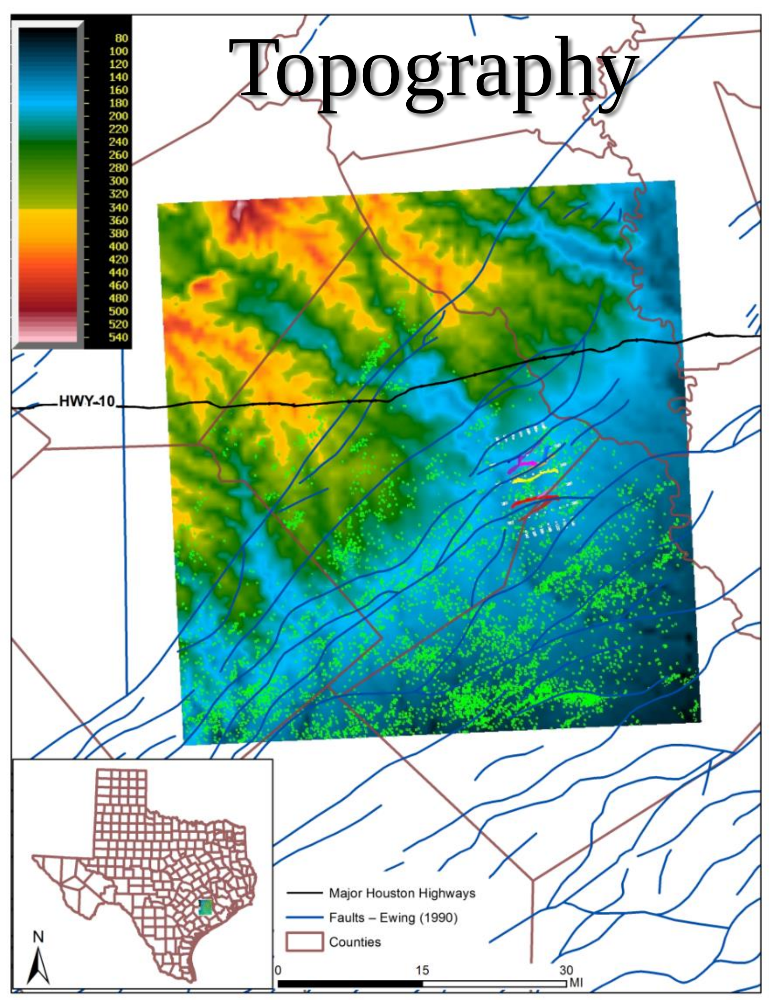
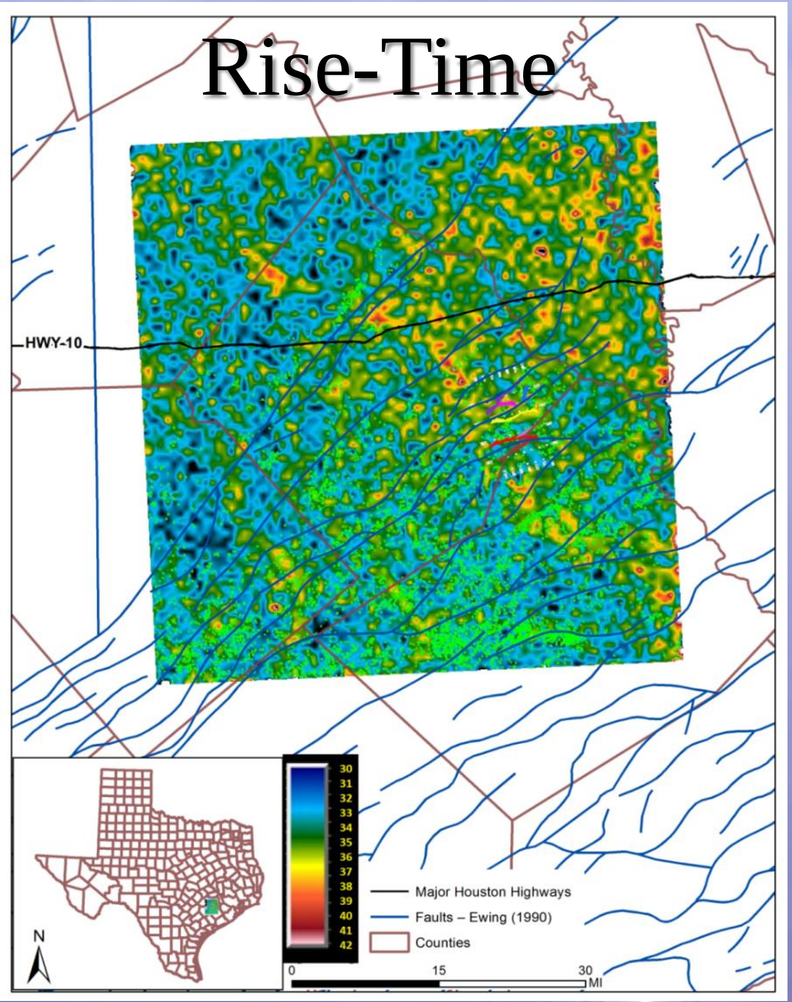


Well Data, Faults, and 3-D Seismic

Green Dots are Well Locations



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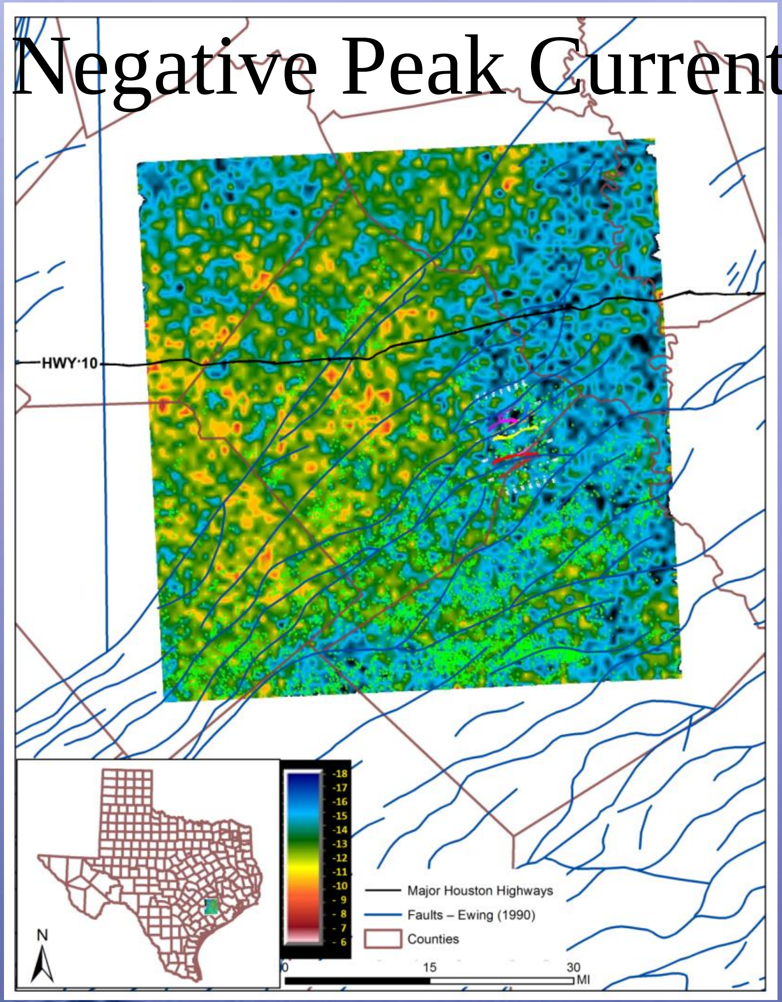
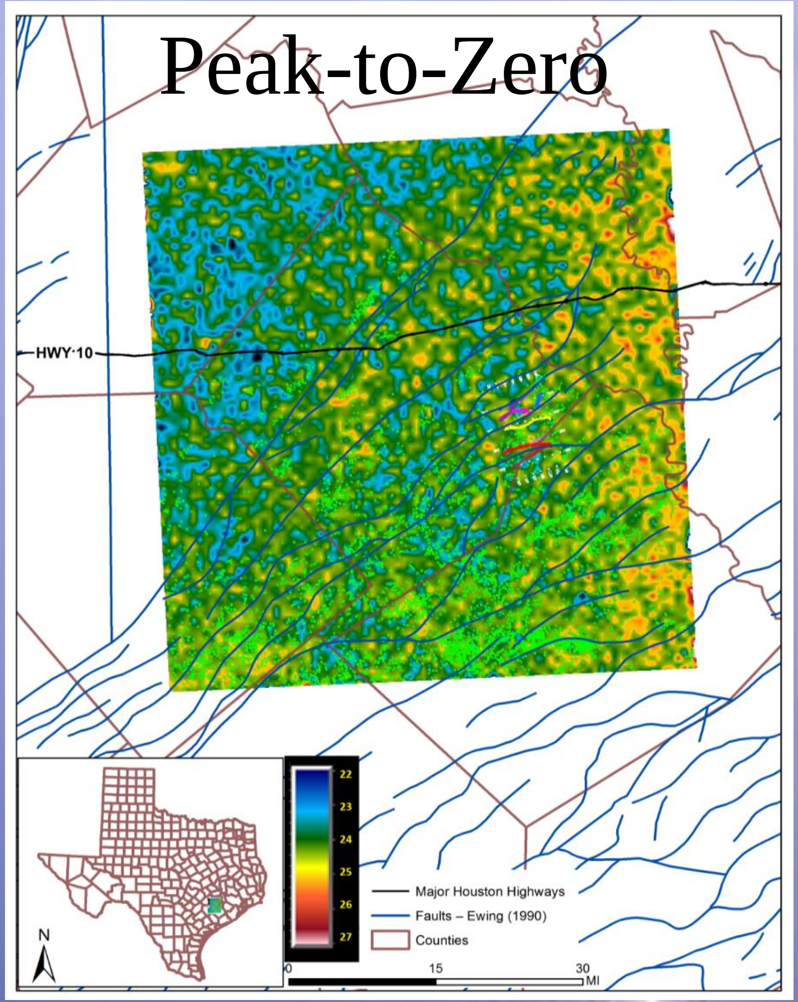
Negative Peak Current



Peak-to-Zero



Regional Scale

Colorado County, Texas

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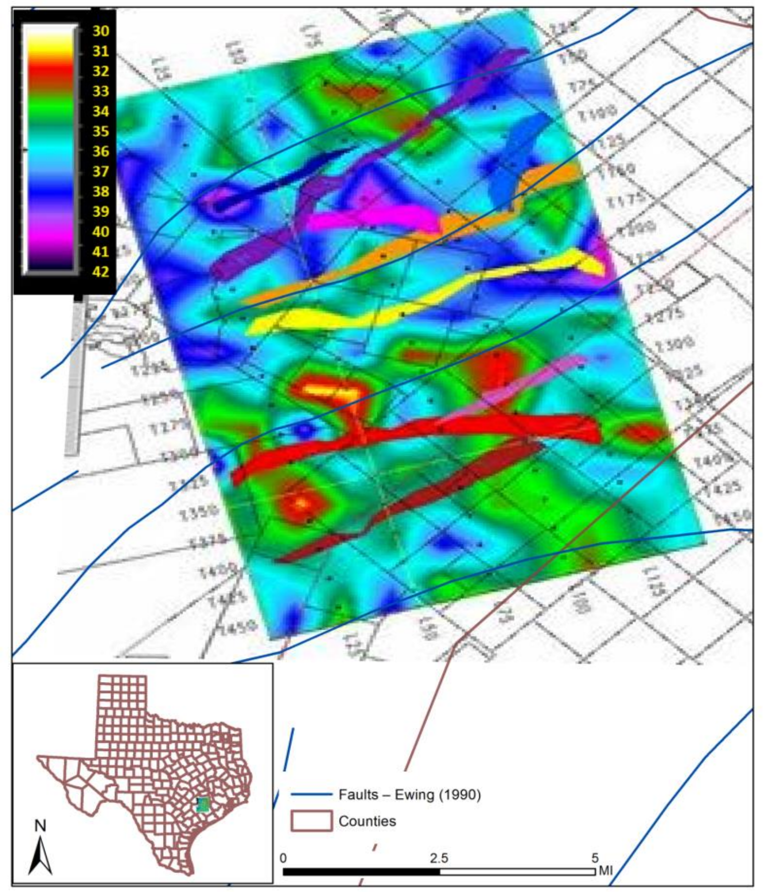
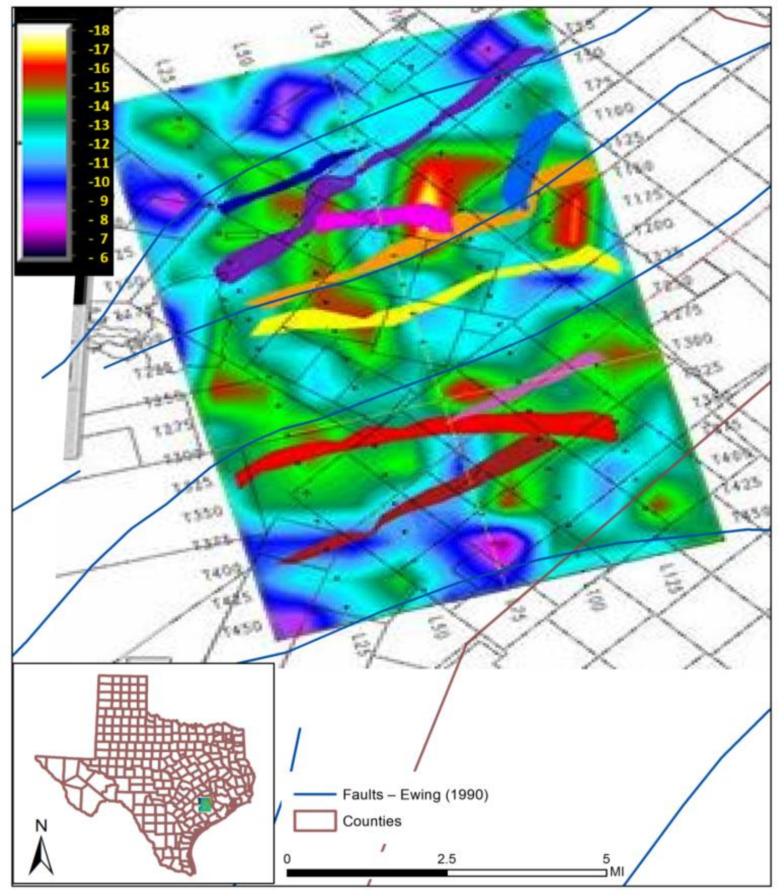
Rise-Time



Peak Current



Prospect Scale

Colorado County, Texas

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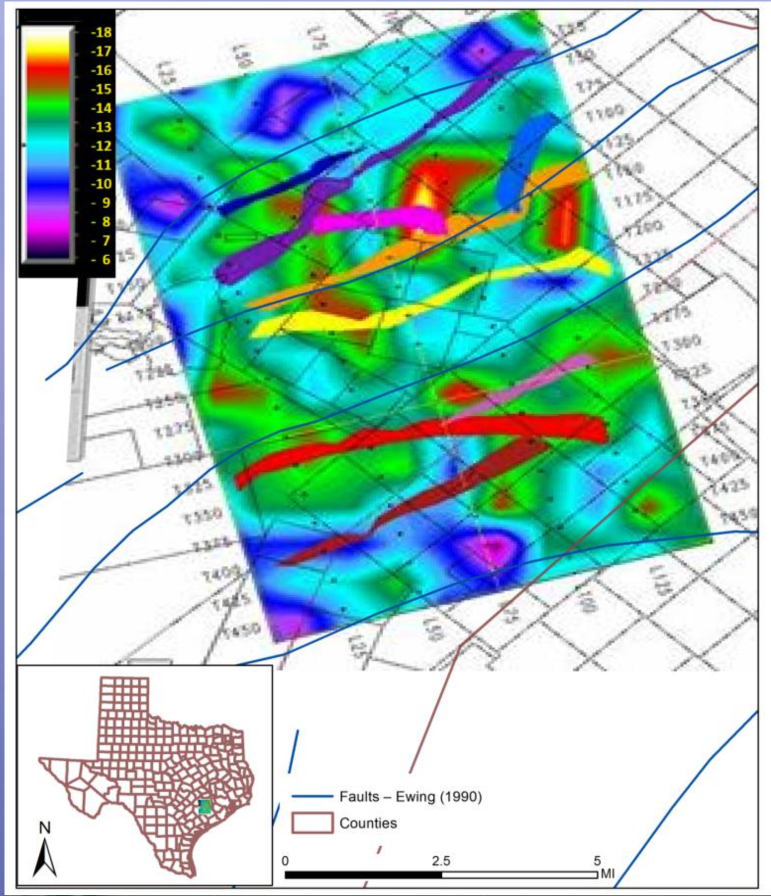
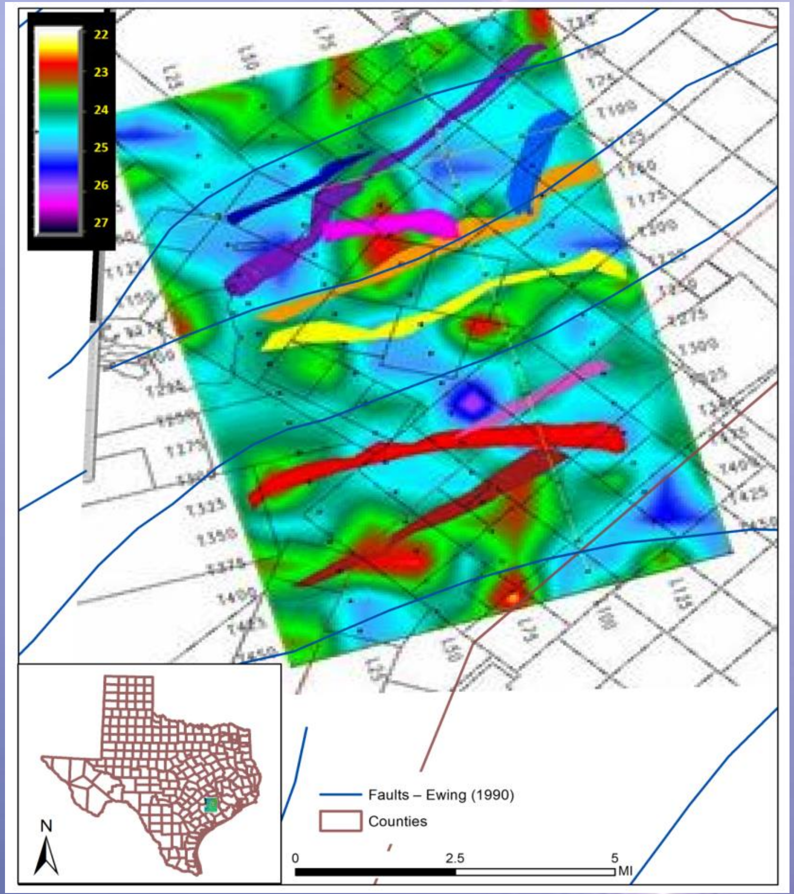
Peak Current



Peak-to-Zero



Prospect Scale

Colorado County, Texas

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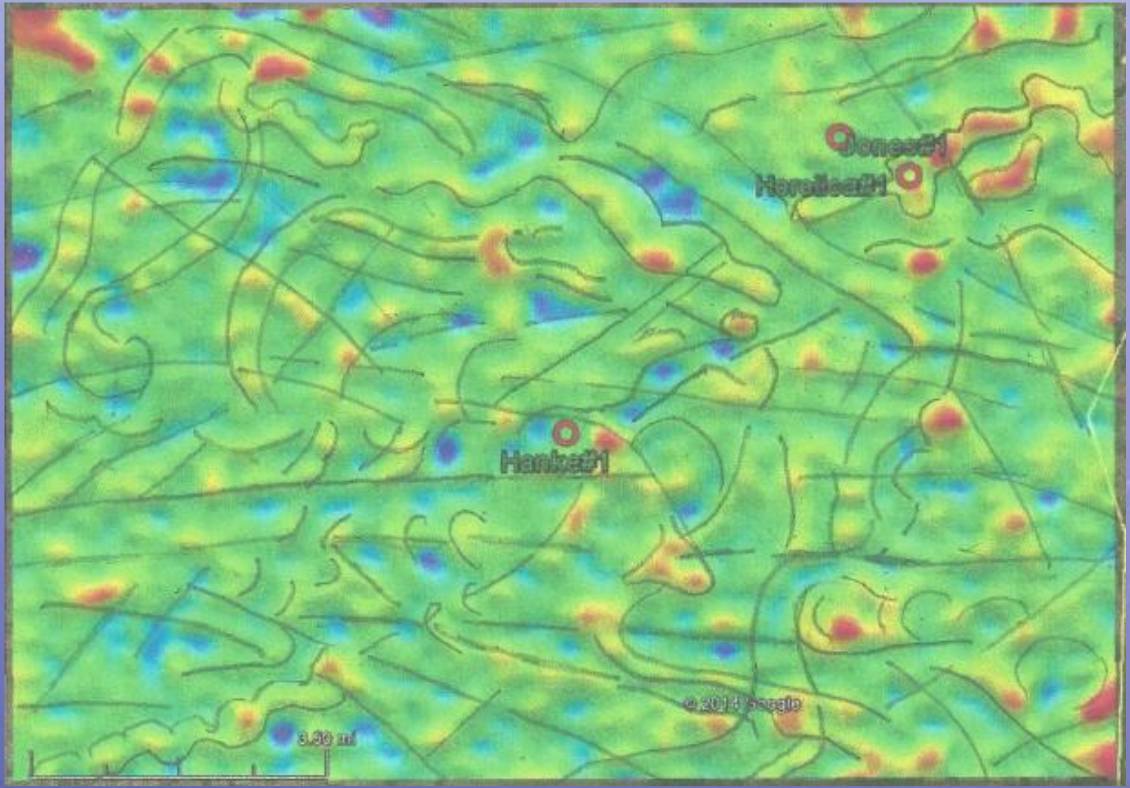
3. Applied Lightning Data in Texas Study Area

Earth Tides / Geothermal Gradient

Peak-to-Zero
Central Texas



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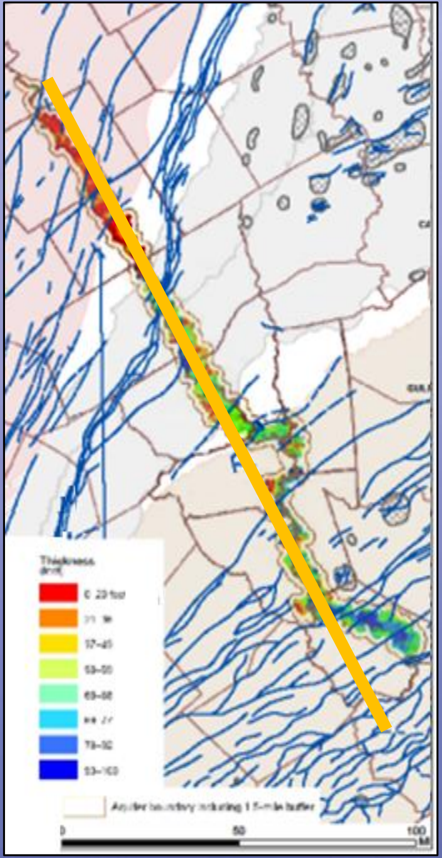
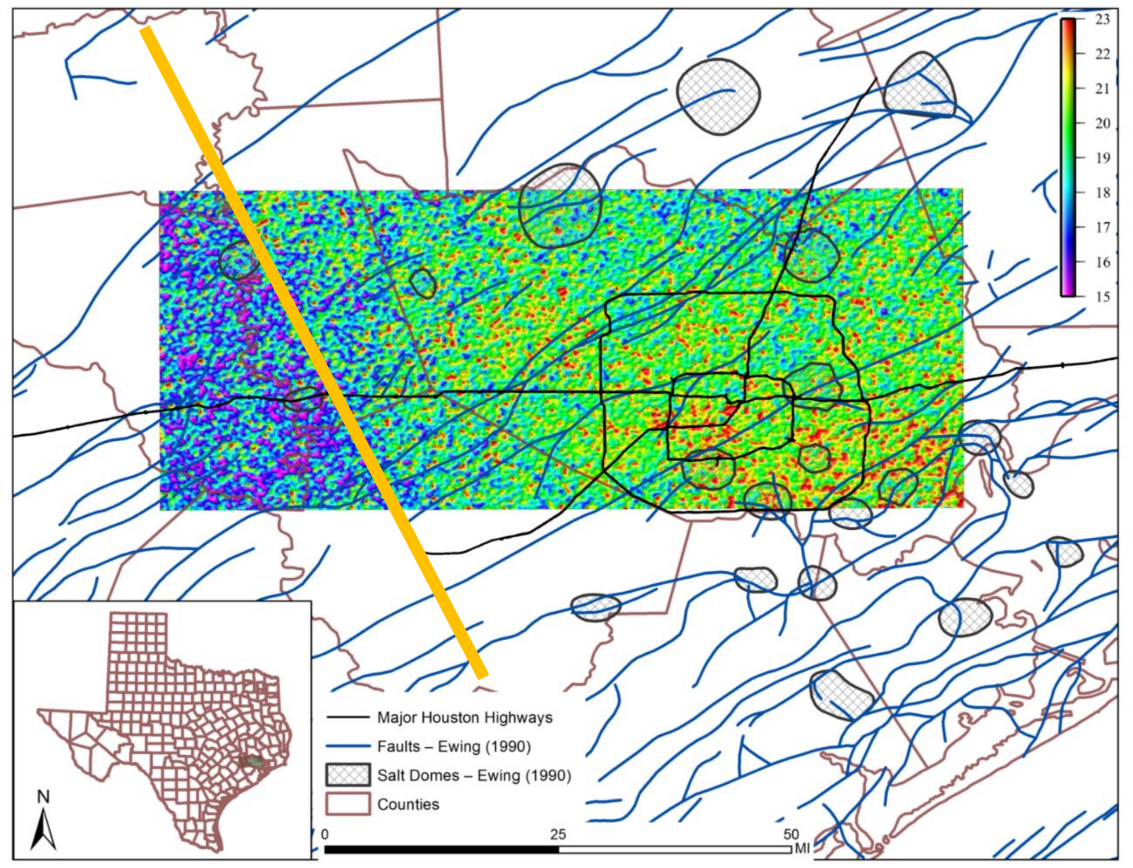
Brazos Aquifer



Absolute Peak-Current



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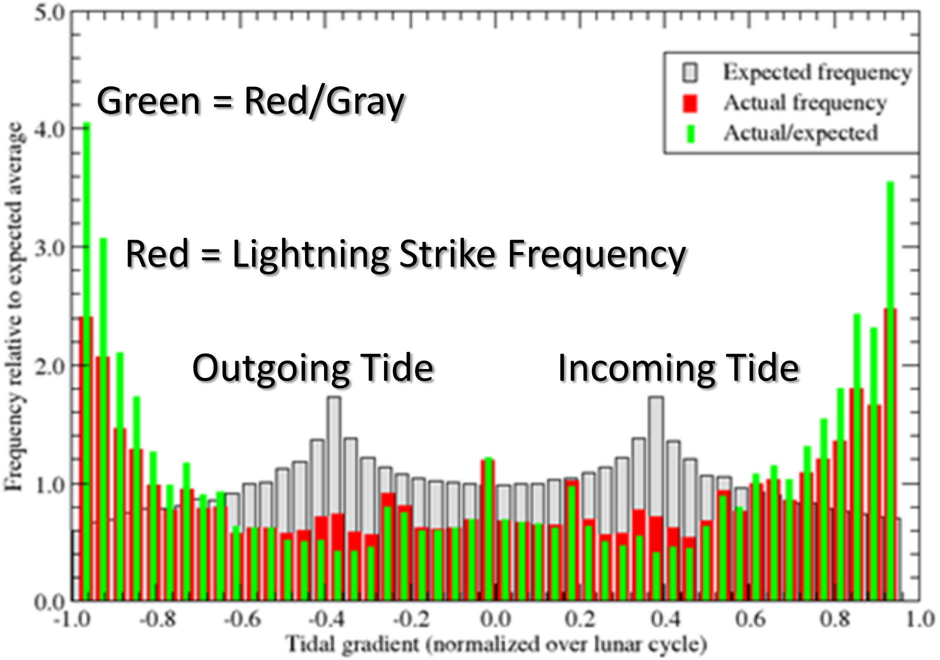
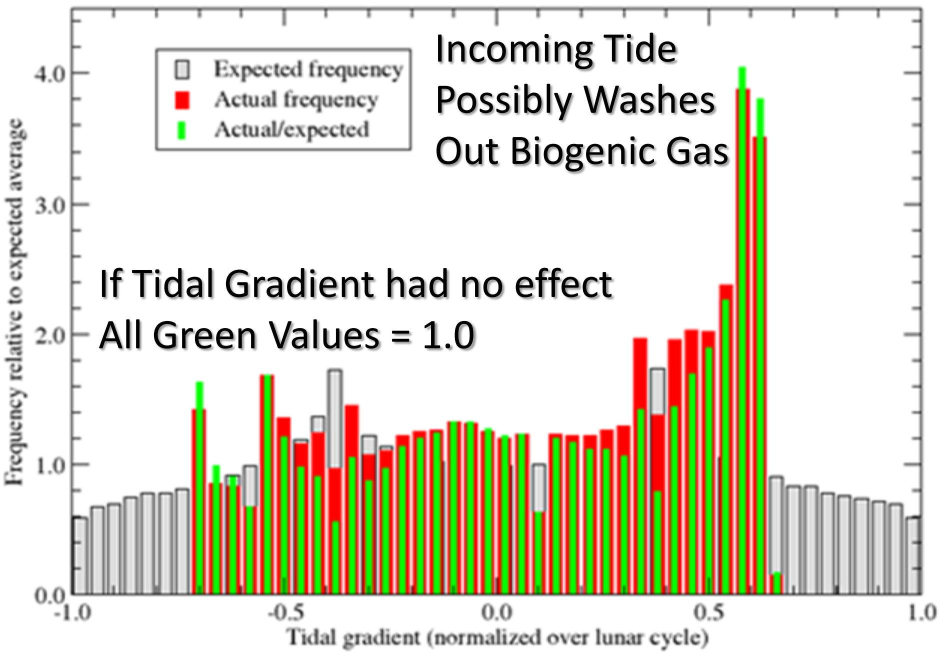
Rate of Change of Lunar/Solar Tides

(Normalized Over Lunar Cycle)

North Texas Example



Florida Example



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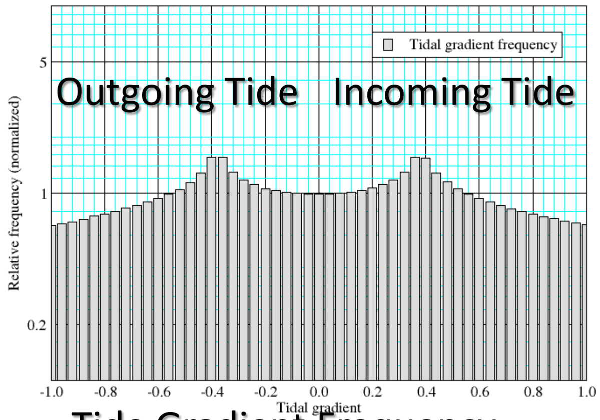
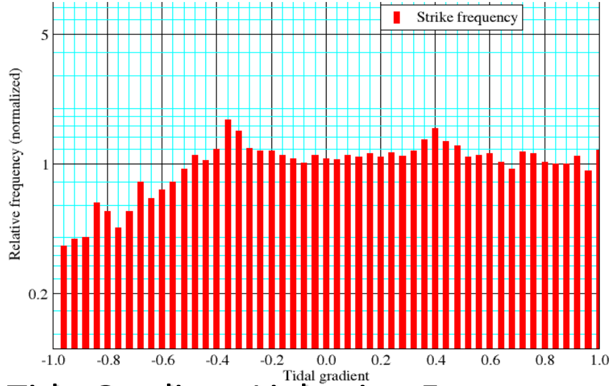
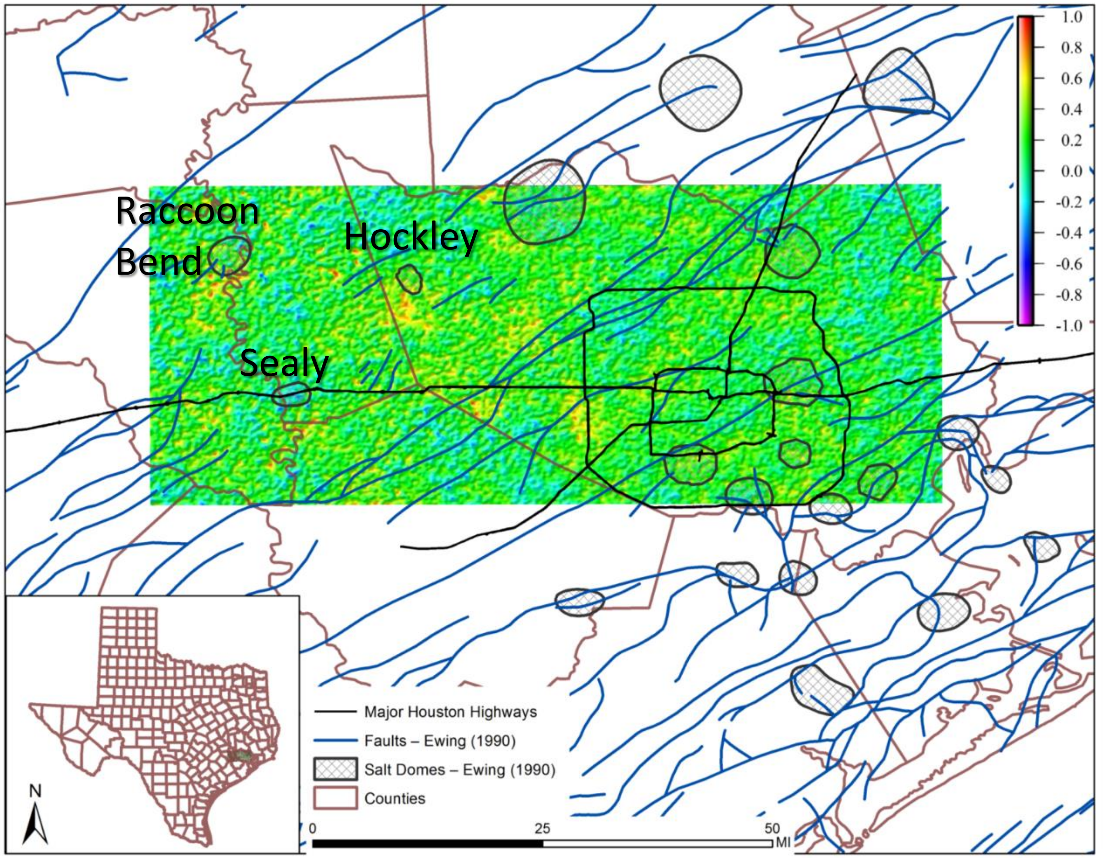
Tidal Gradient when Strikes Occur



Tide Gradient Frequency



Tide Gradient Lightning Frequency



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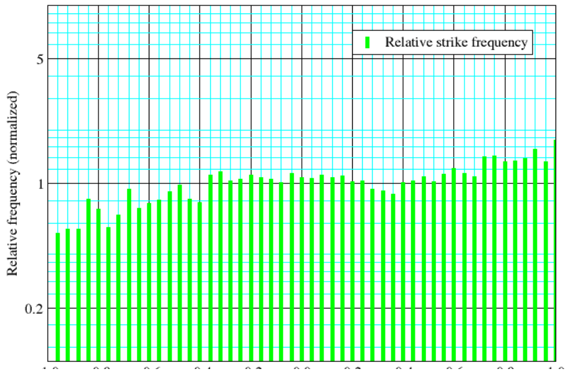
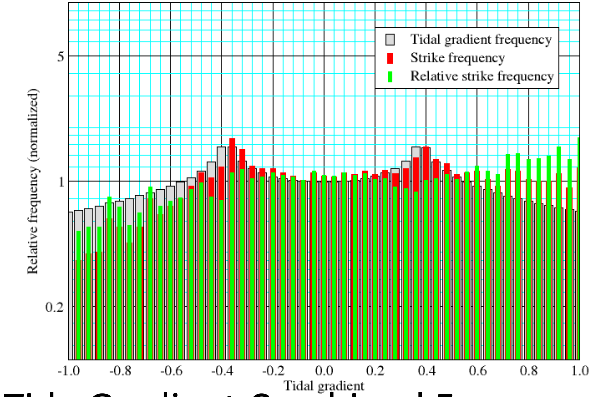
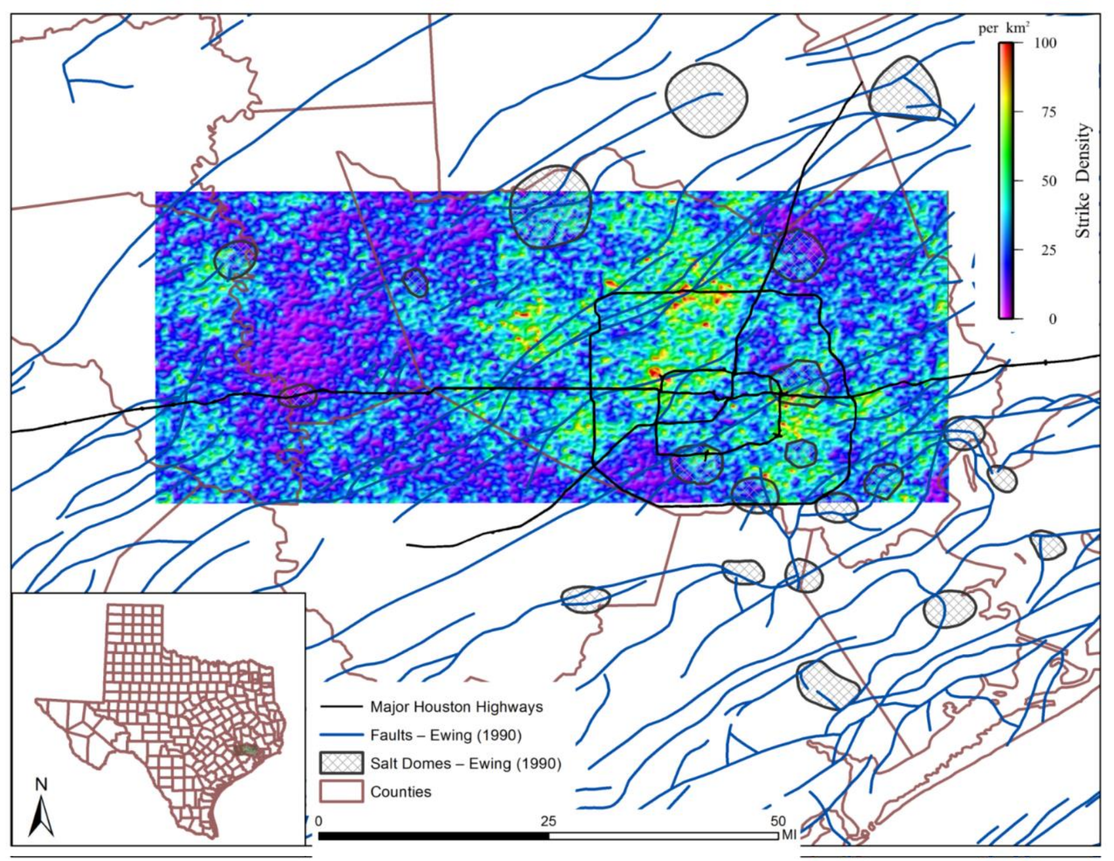
Strike Density at High Tidal Gradient



Tide Gradient Normalized Lightning Frequency



Tide Gradient Combined Frequency



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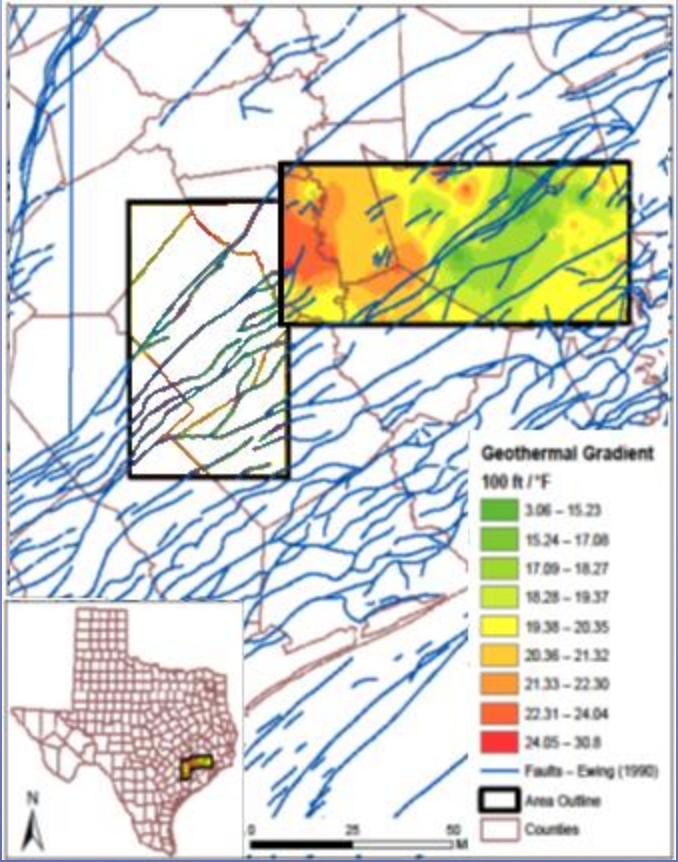
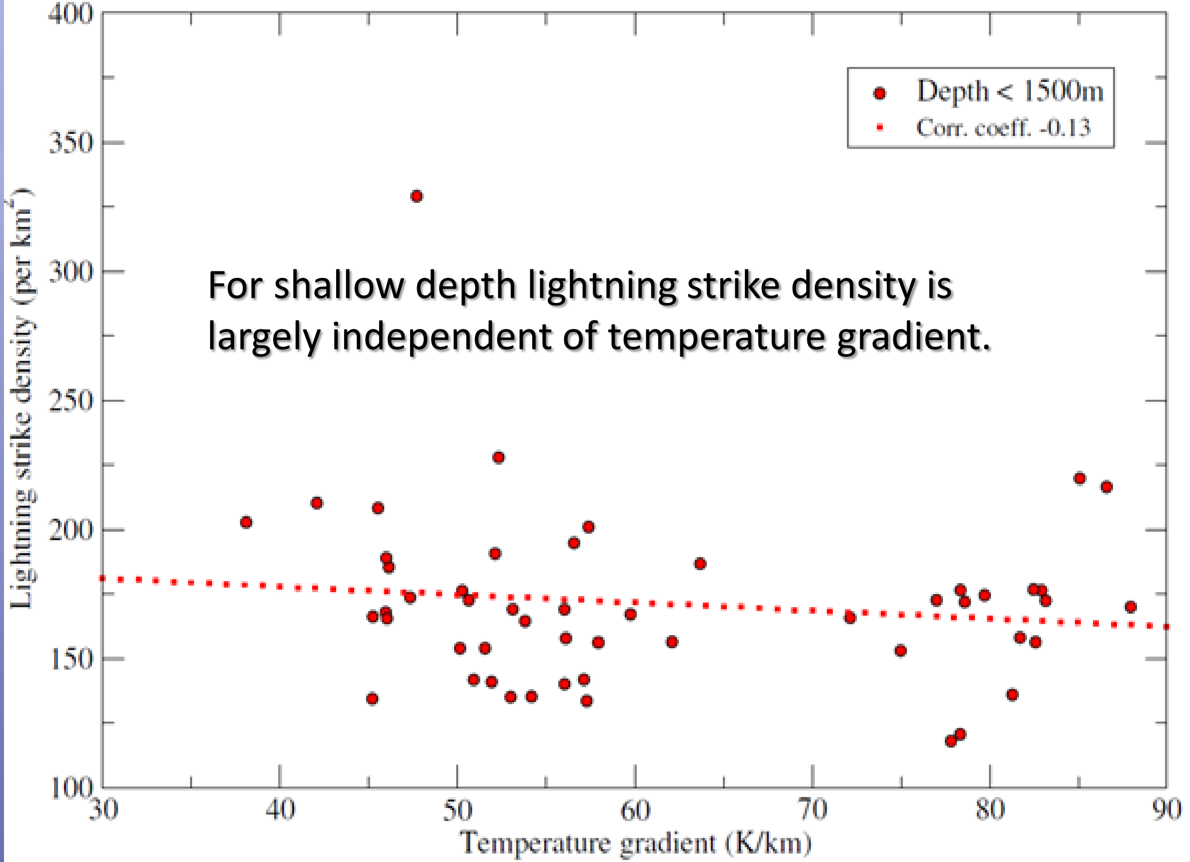
Strike Density Wells <1,500 m (4,920 Feet) Vs. Geothermal Gradient





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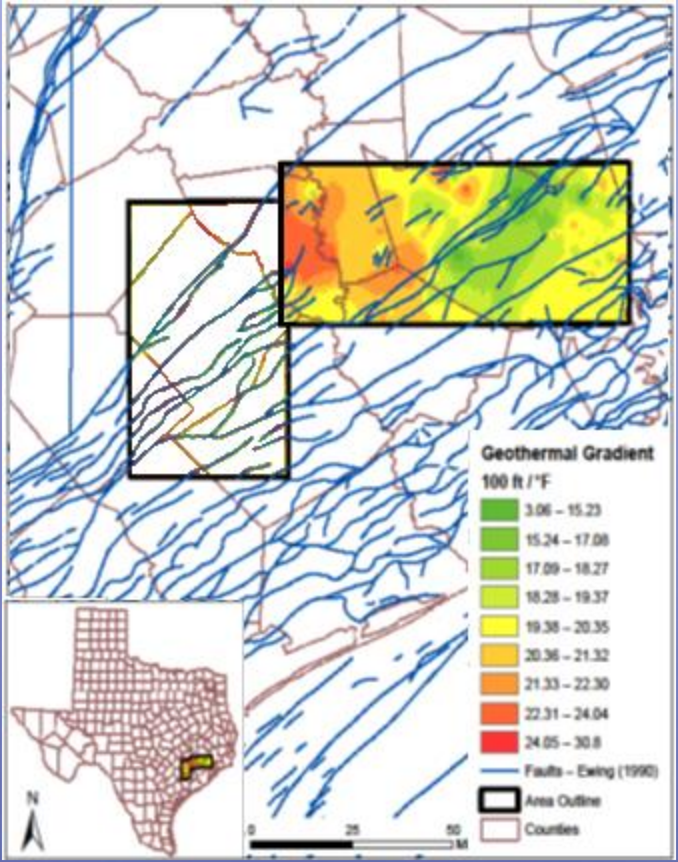
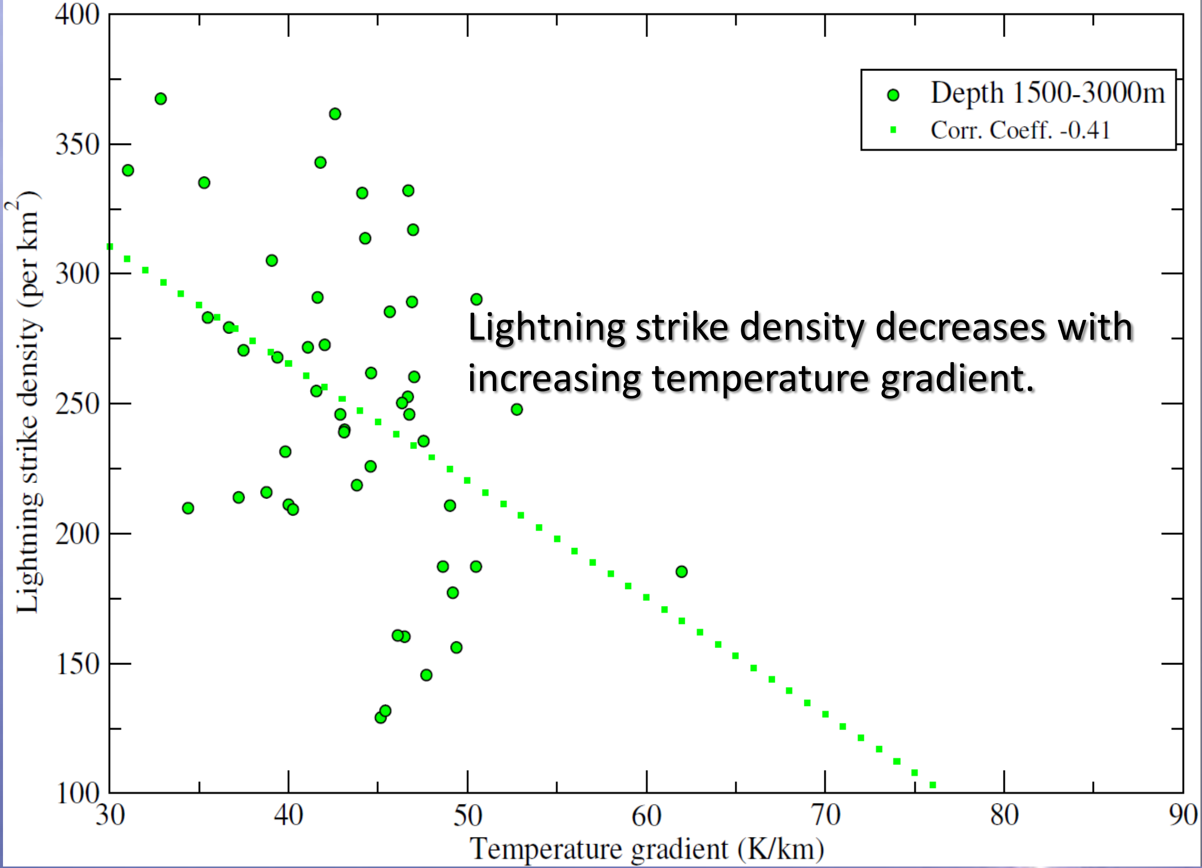
Strike Density for Wells 1500-3000m (4920-9843 feet) Vs. Geothermal Gradient





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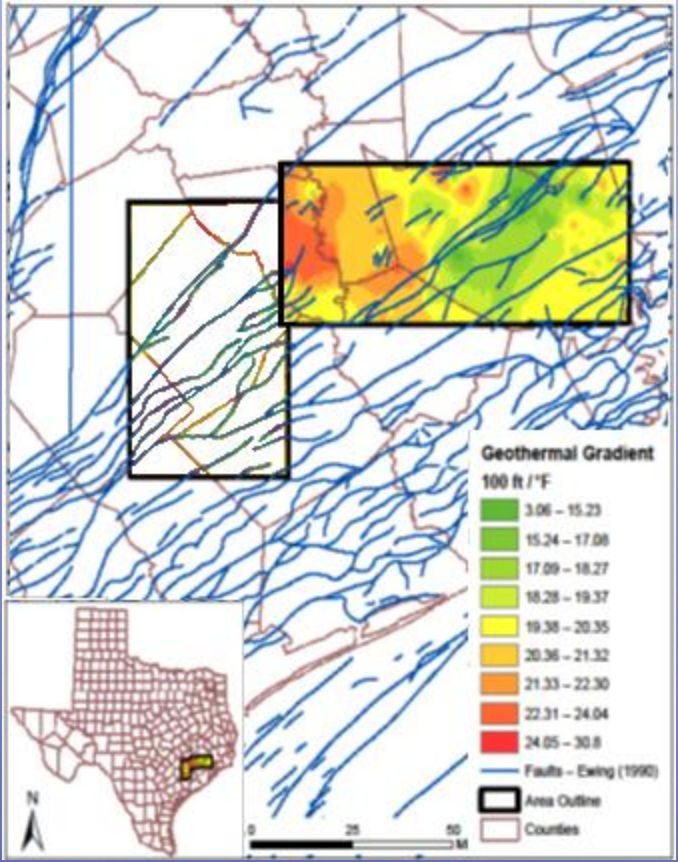
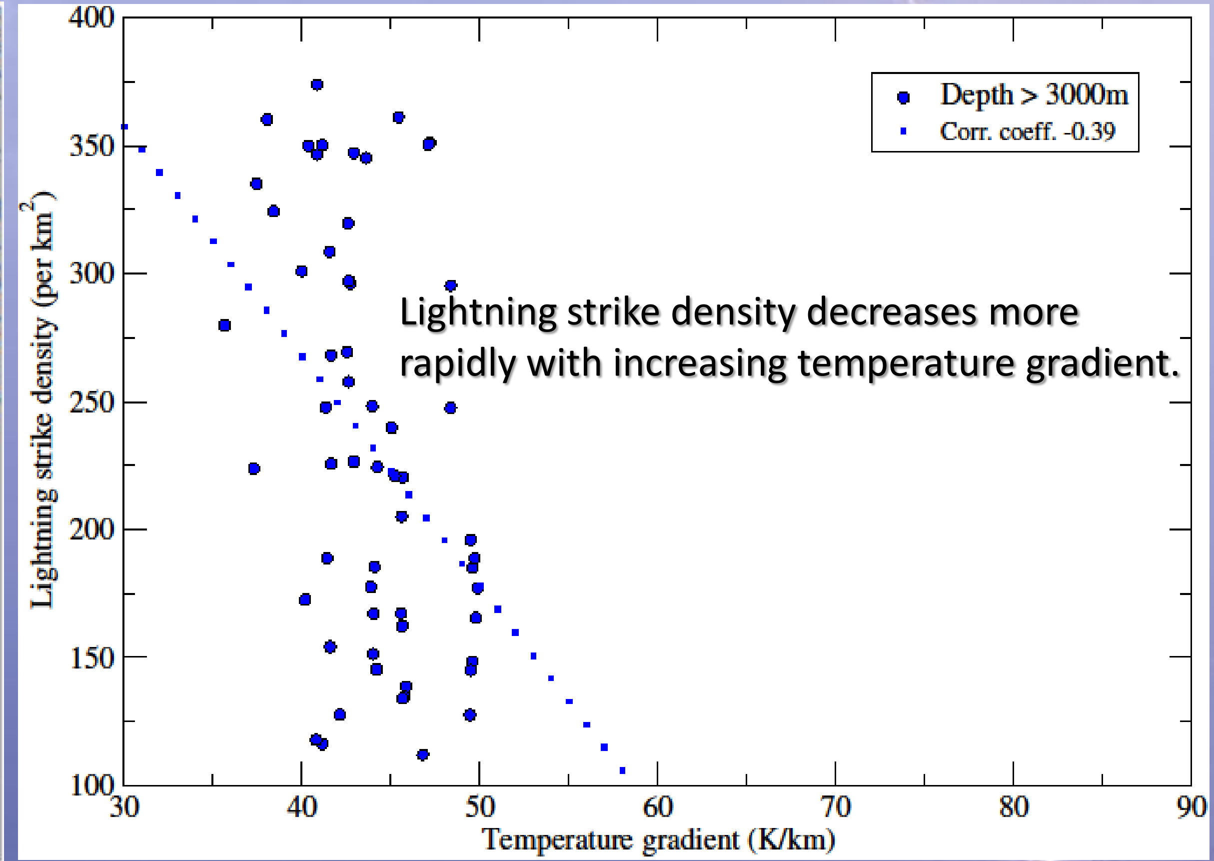
Strike Density for Wells >3000 m (>9,843 Feet) Vs. Geothermal Gradient





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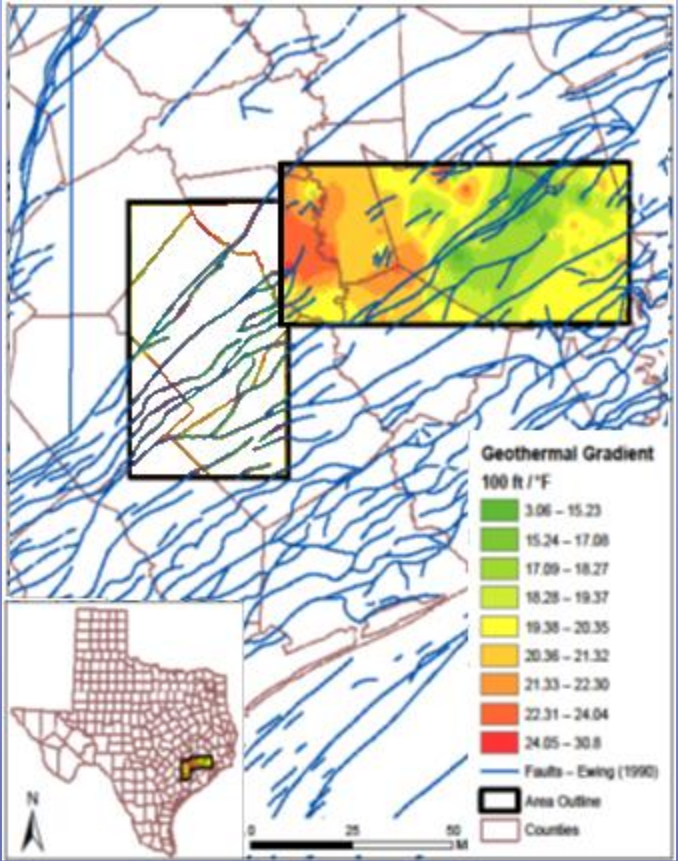
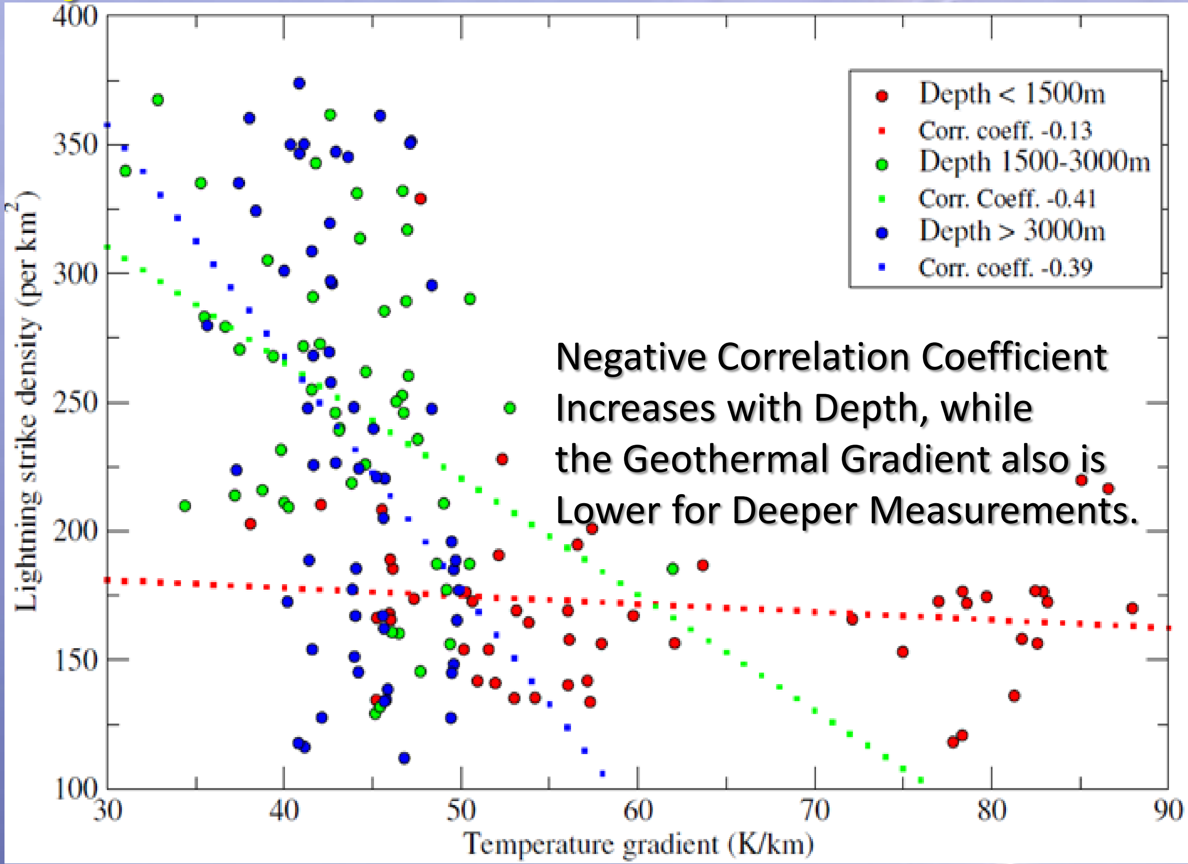
Lightning Strike Density for All Wells Vs. Geothermal Gradient





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Conclusions and Lagniappe…

- Lightning is a new geophysical data type.
- Strike locations and attributes primarily controlled by earth currents and geology.
- Lightning strikes highlight geological features and sediment/rock characteristics.
- Integration of lightning data provides a better understanding of the subsurface.

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Lagniappe

1. Southeast LA – Vermillion Bay Area
2. Goose Point Lightning Study
3. Advanced Lightning Analysis

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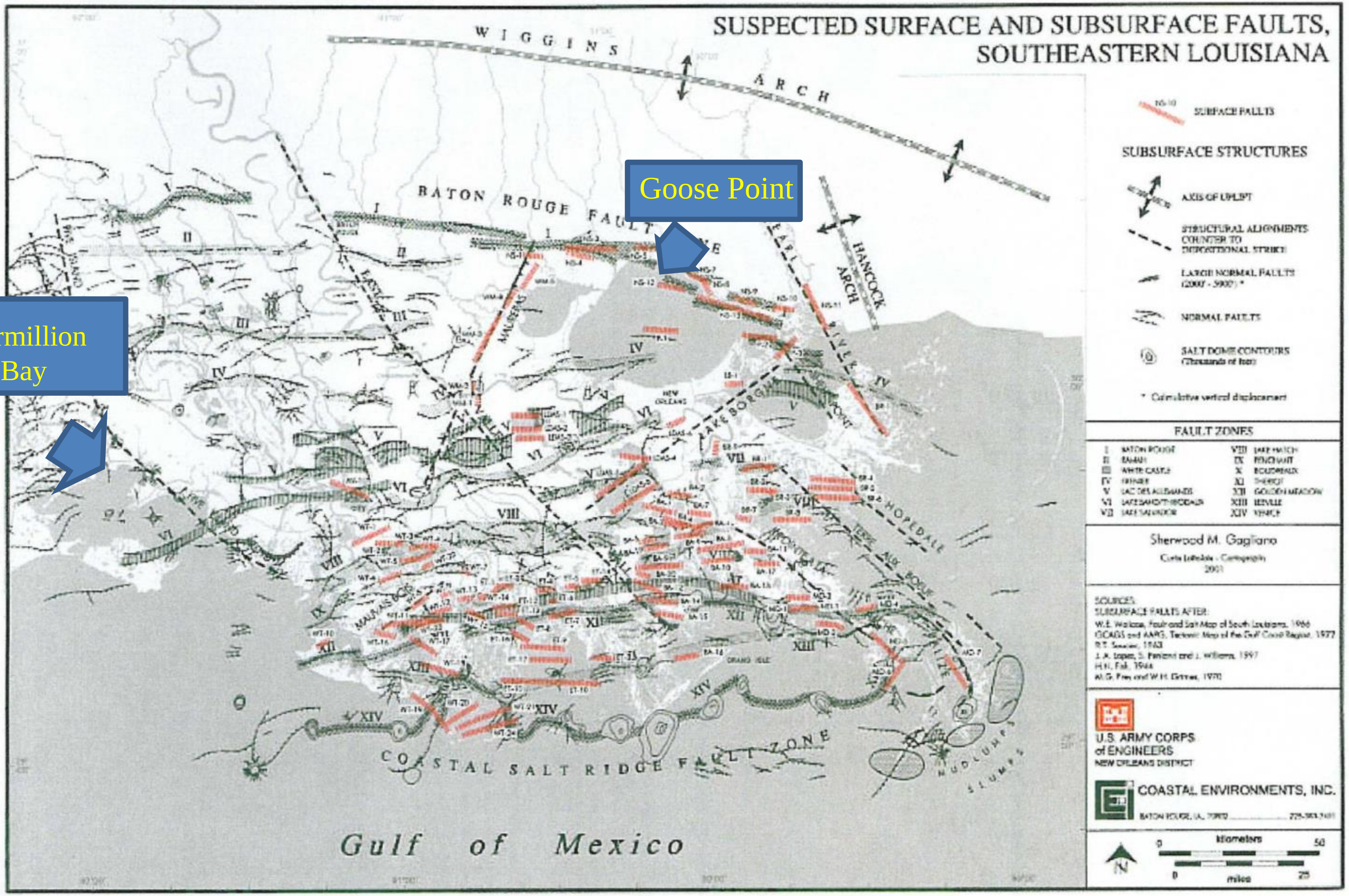
Goos
Poin

Coastal Environments, Inc./20008



Page 34

Figure 19. Map showing the relationship between suspected surface and subsurface faults. (See Table 1).

From Gagliano et al, 2003

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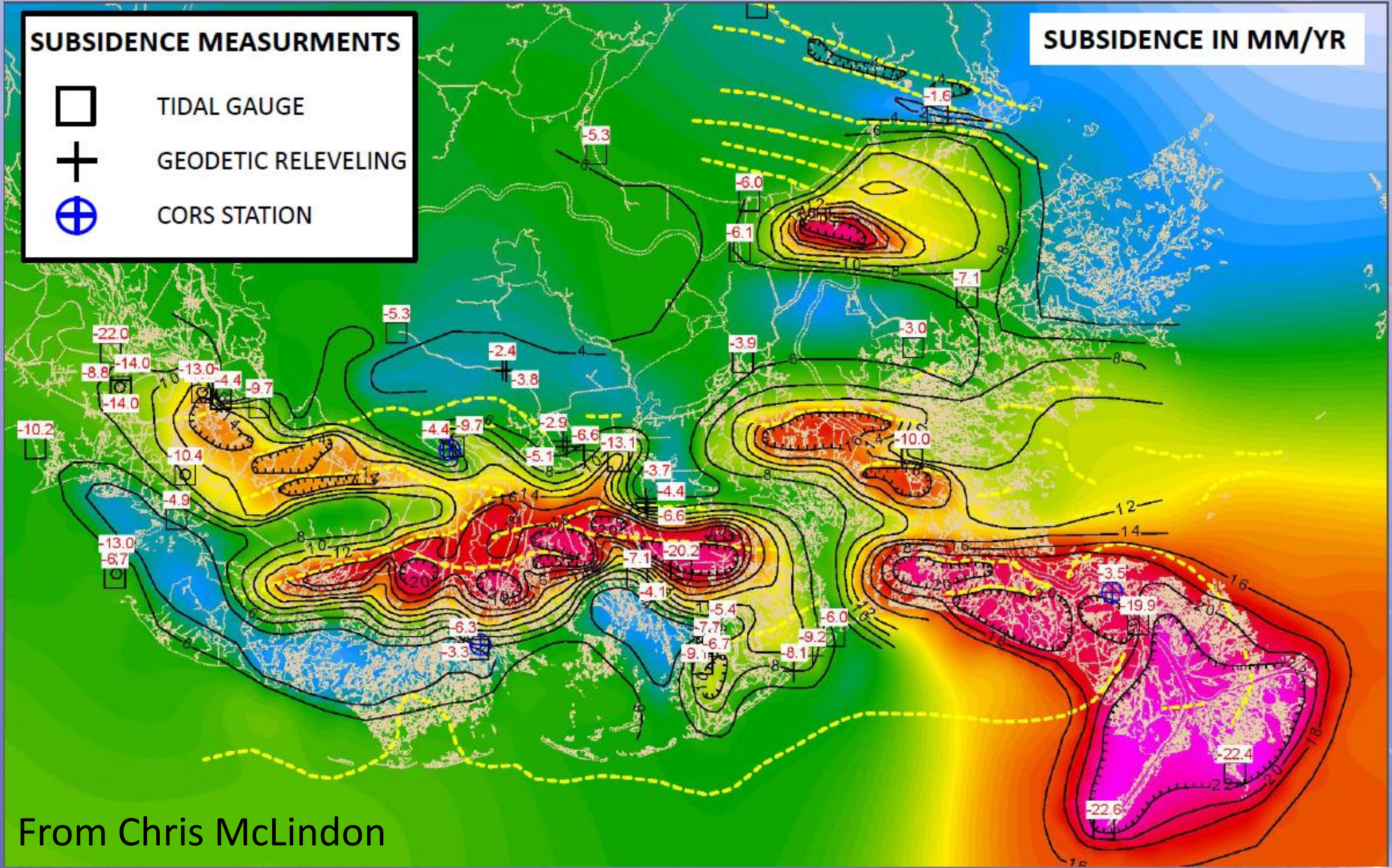

From Chris McLindon

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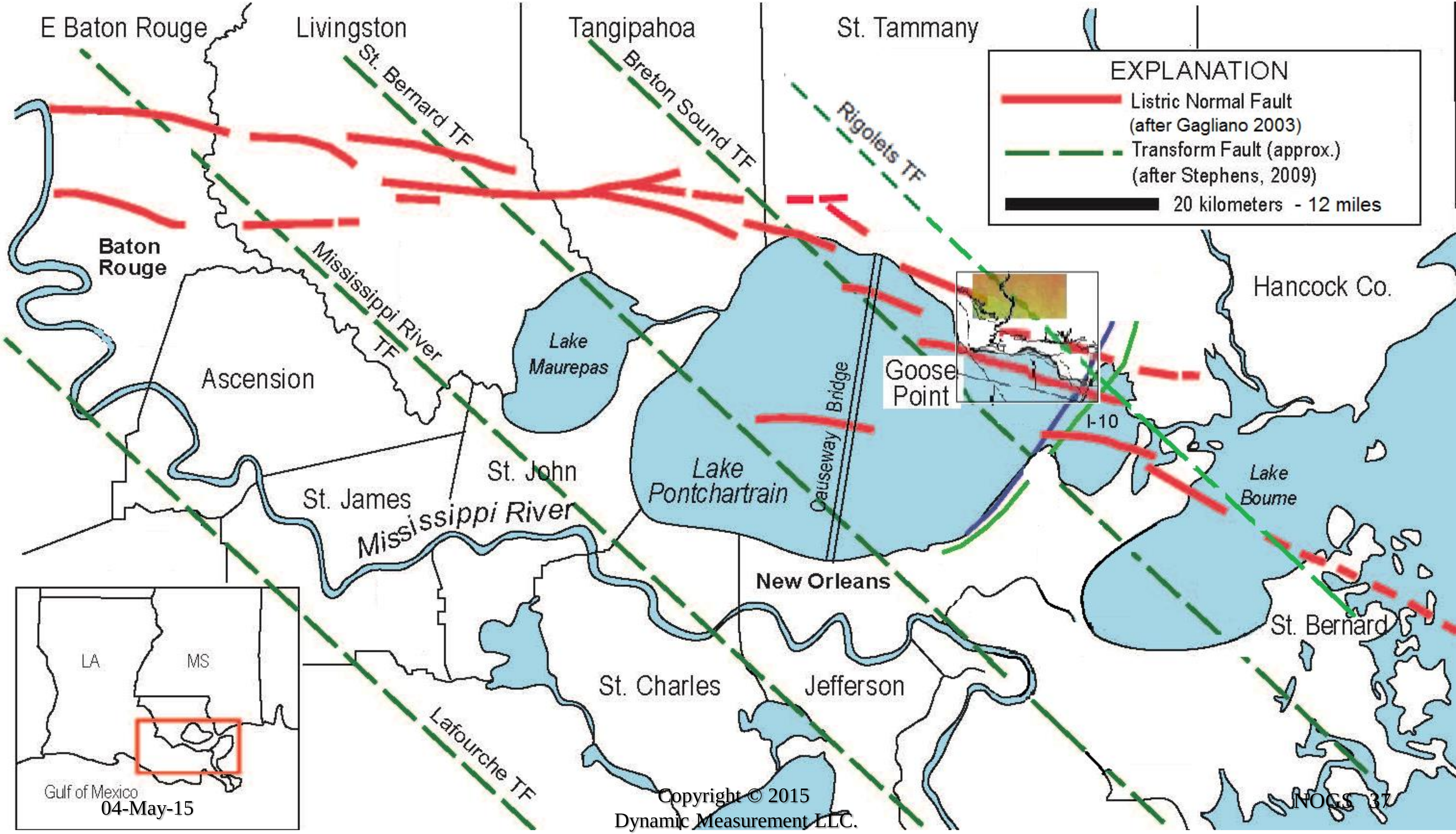

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Lightning Data Analysis
demonstrates strikes are tied to geology

See Lightning Think
DML
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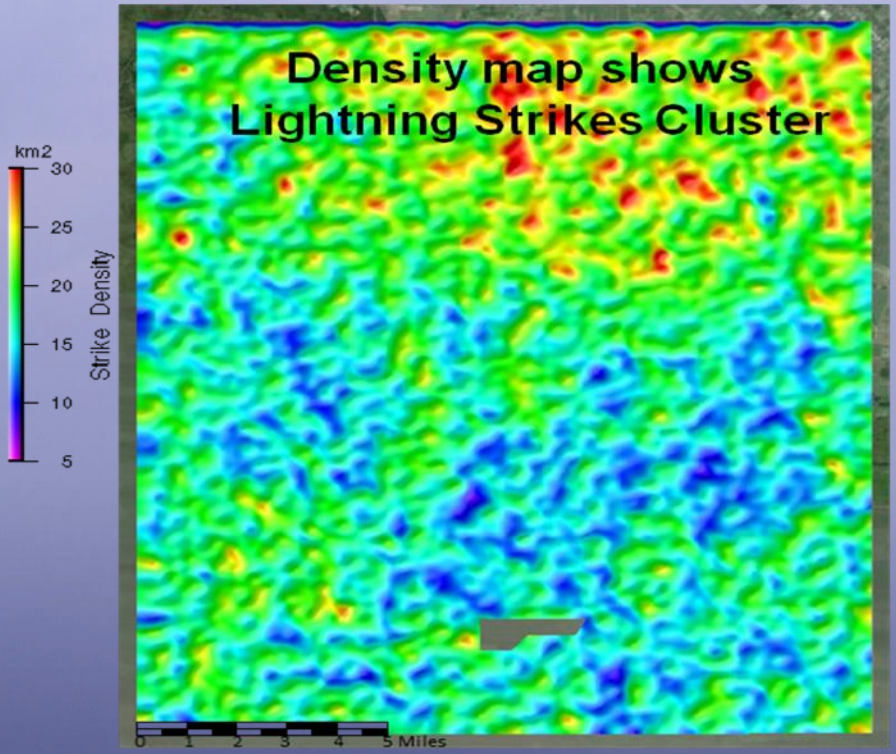

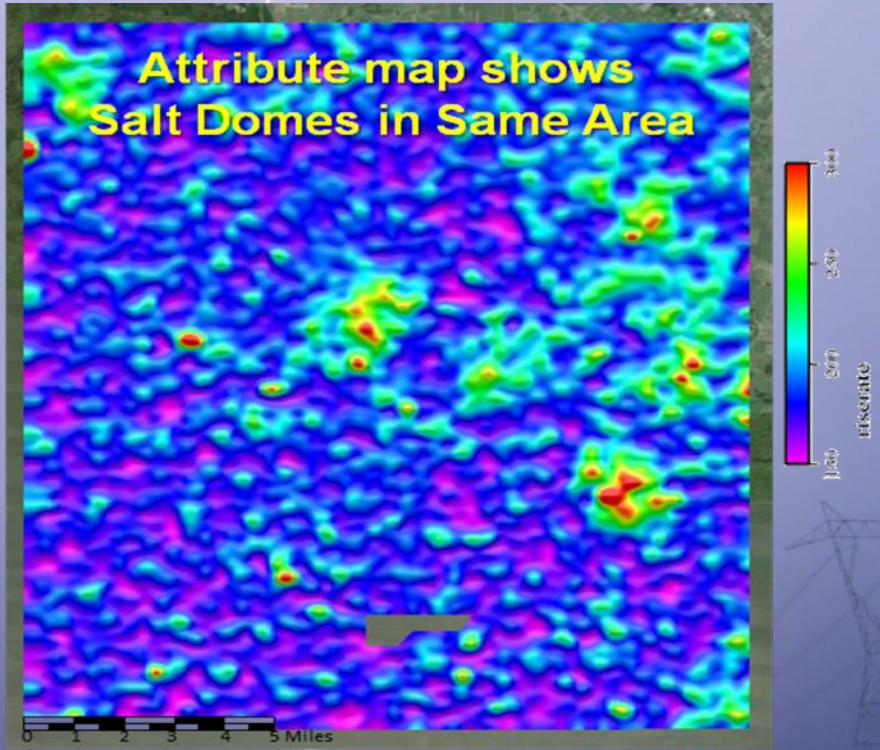

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See Lightning Think
DML
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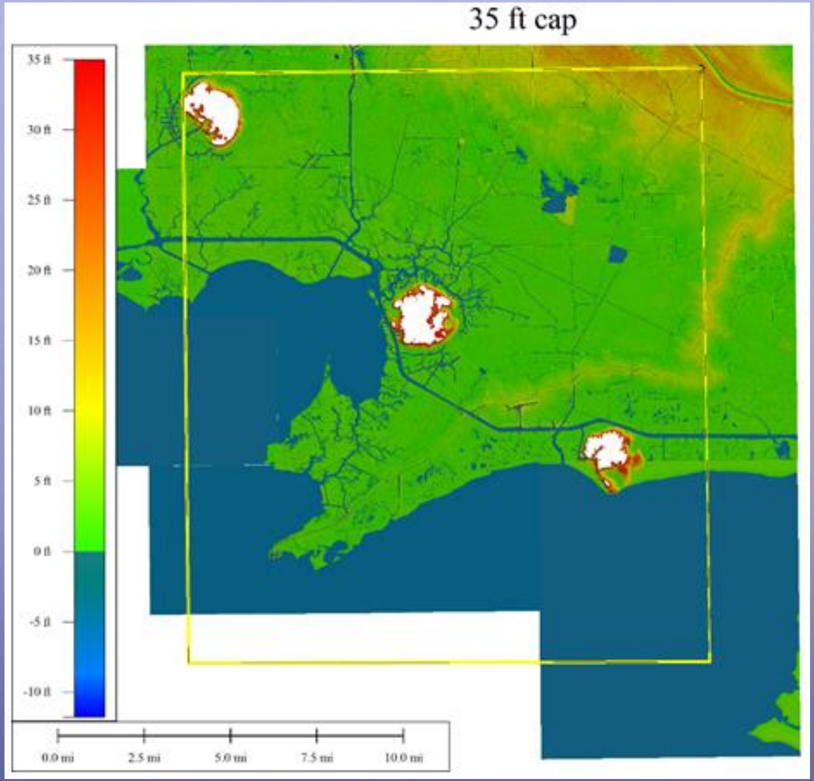
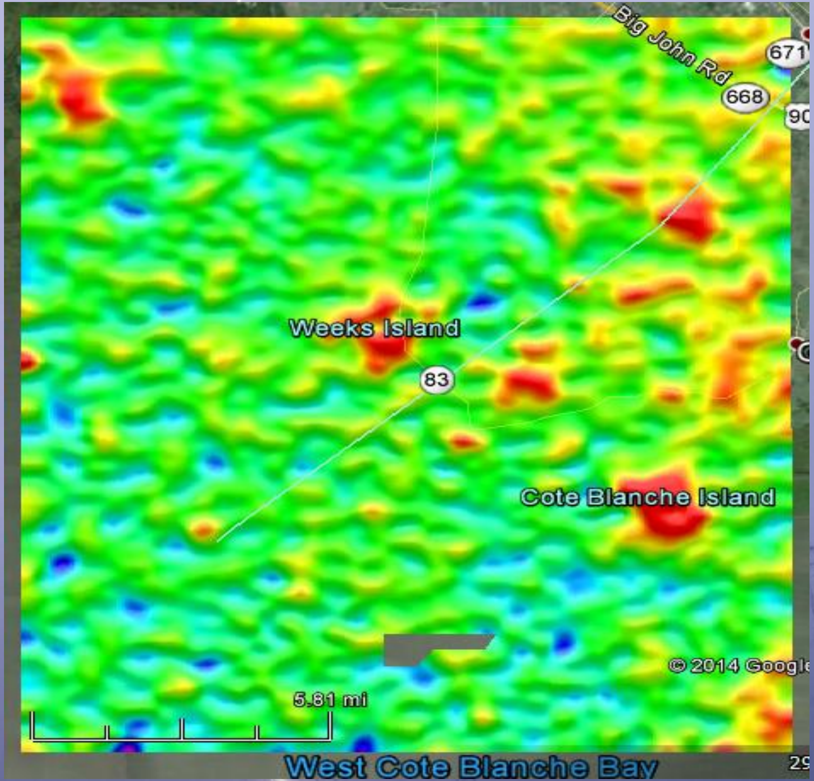
LIDAR Extended with NSEM Analysis





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Google Earth

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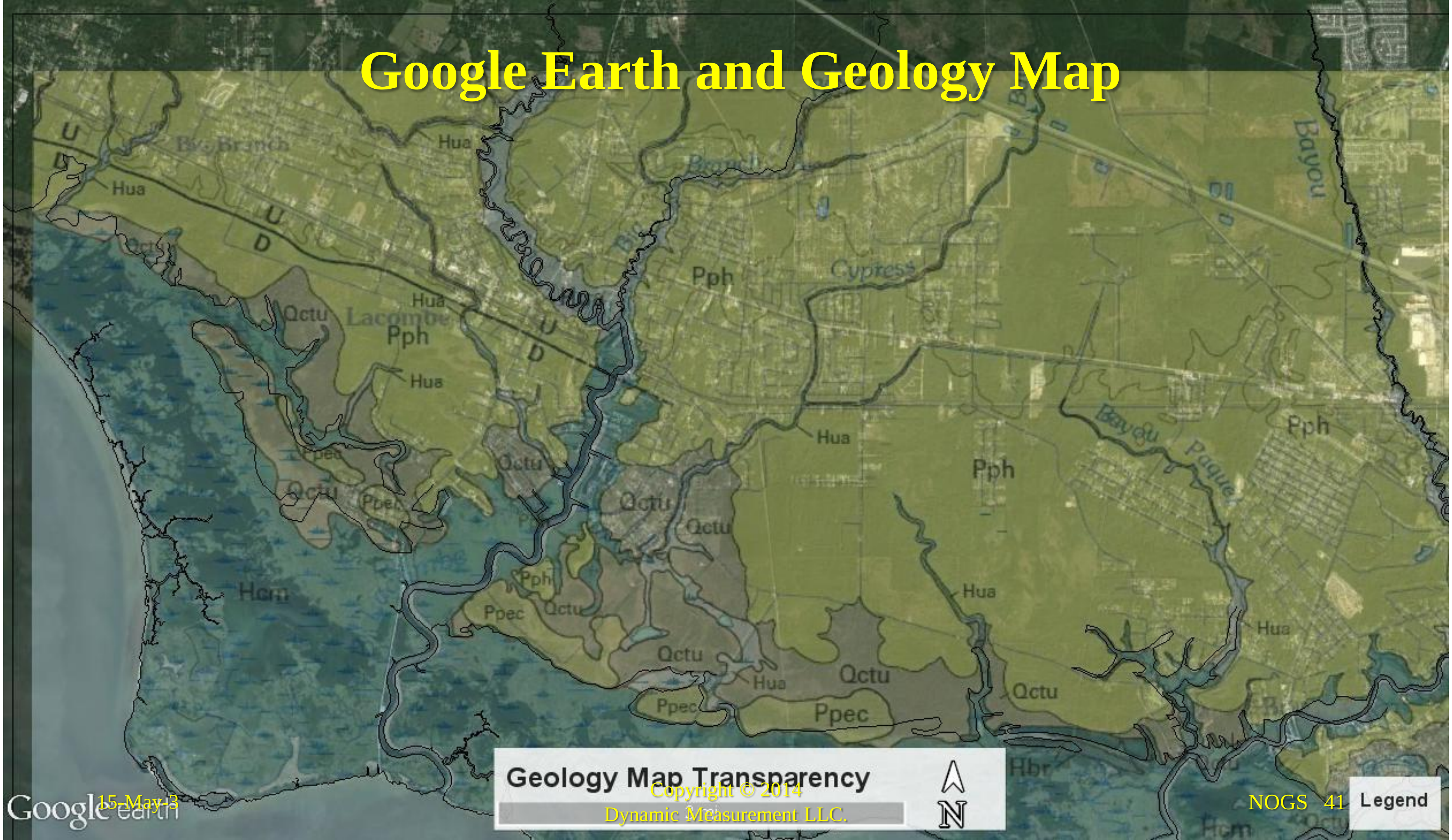
Google Earth and Geology Map



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Google Earth and LIDAR

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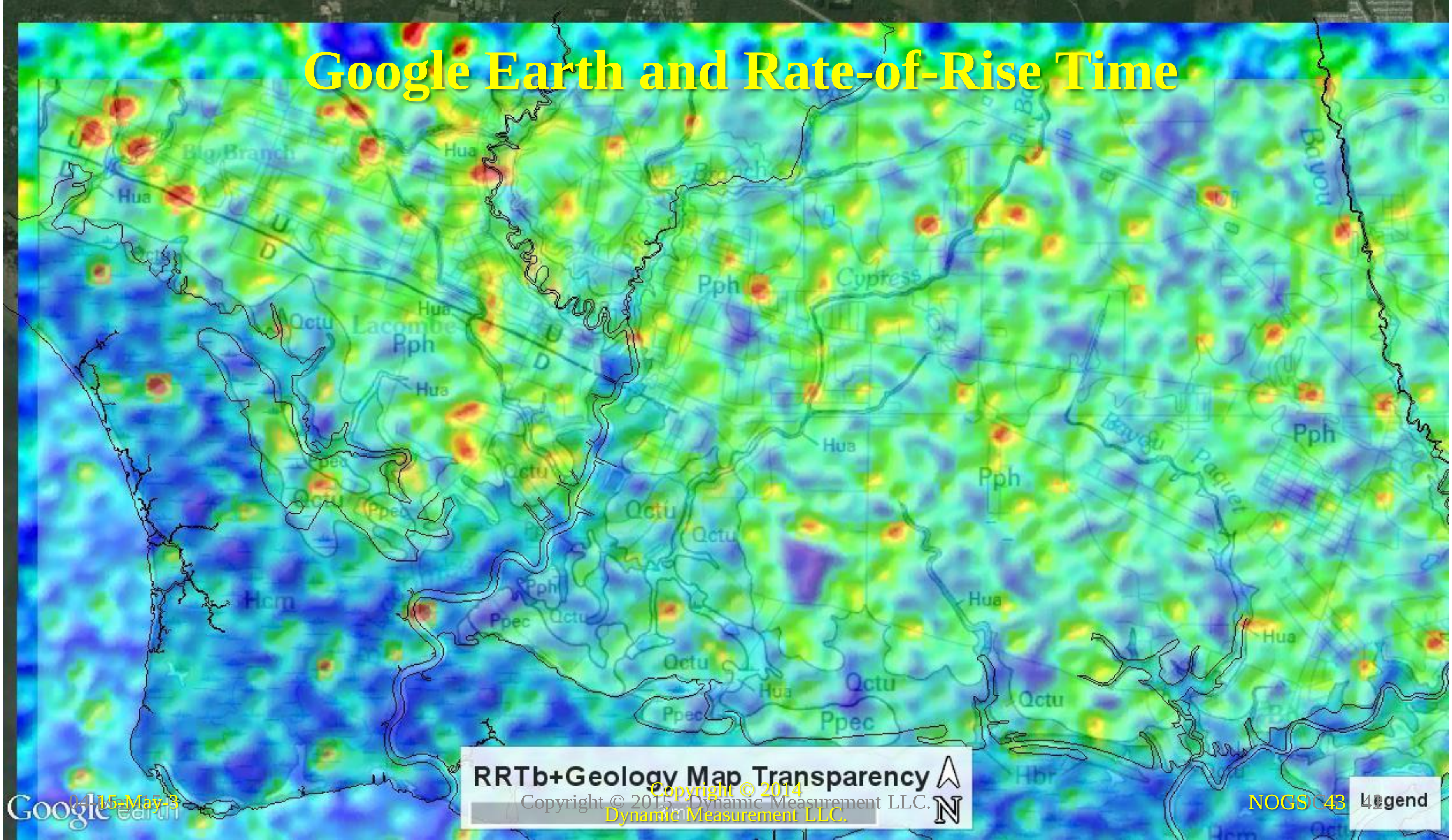
Google Earth and Rate-of-Rise Time



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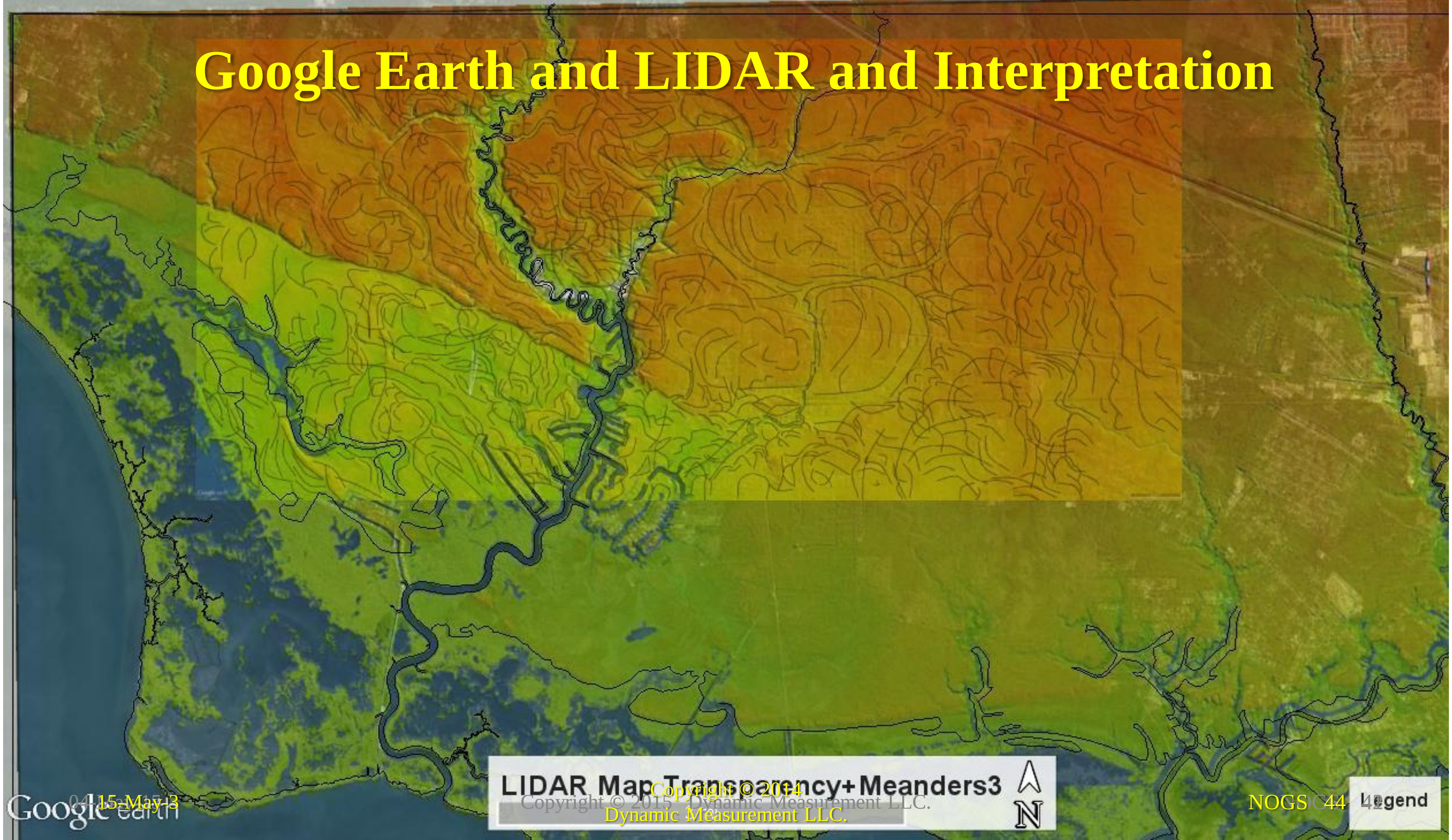
Google Earth and LIDAR and Interpretation



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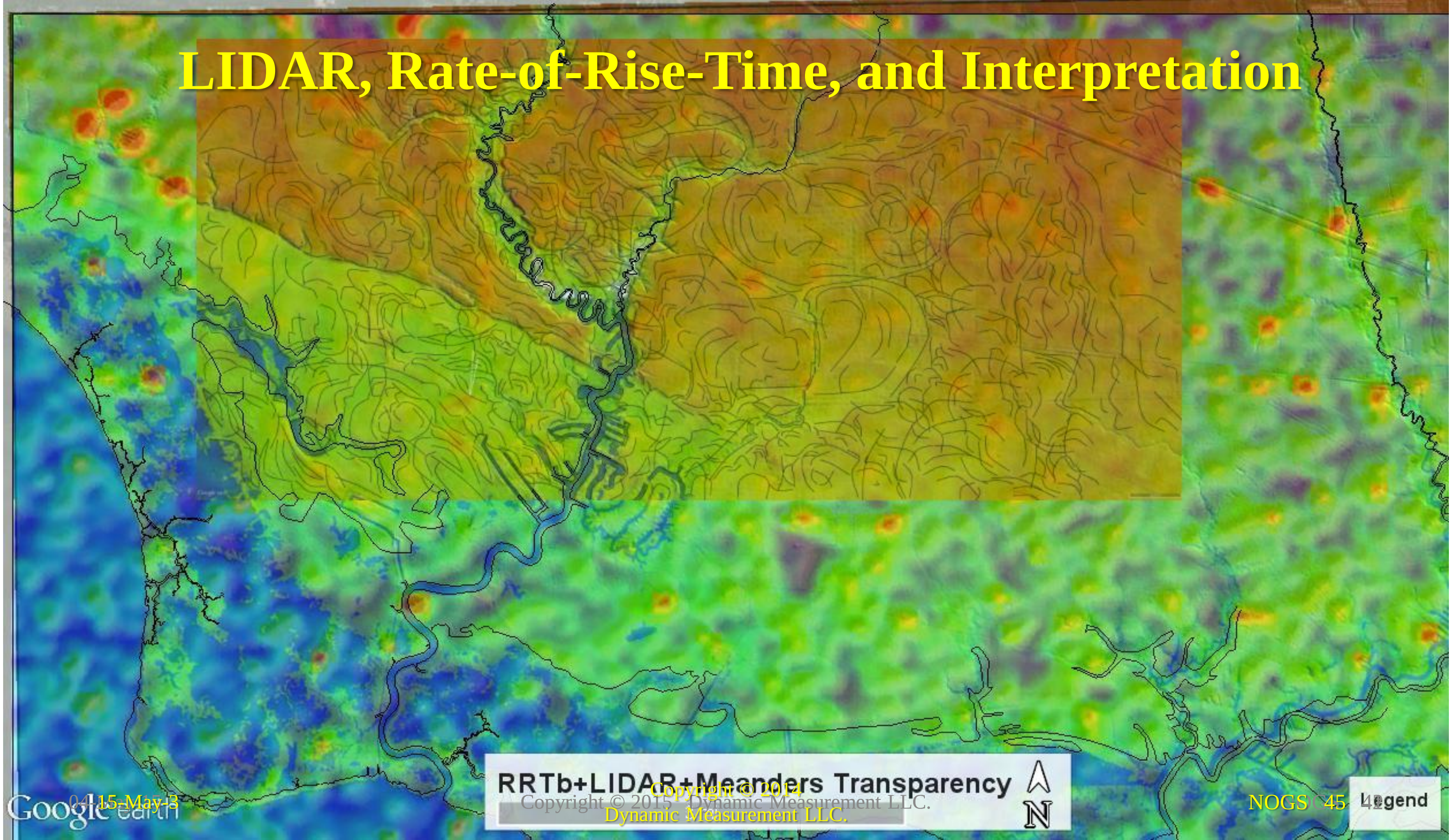
LIDAR, Rate-of-Rise-Time, and Interpretation



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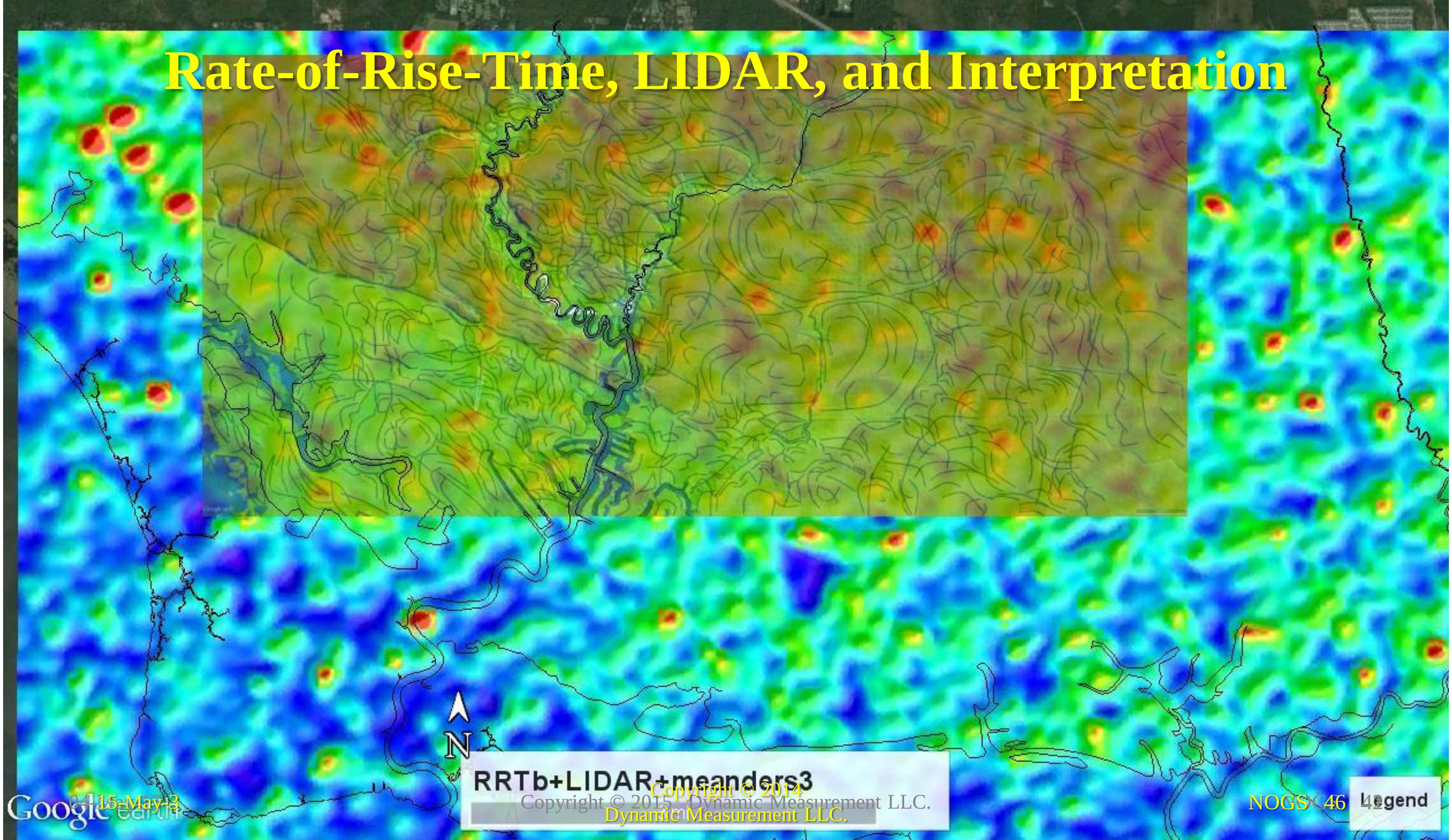
Rate-of-Rise-Time, LIDAR, and Interpretation



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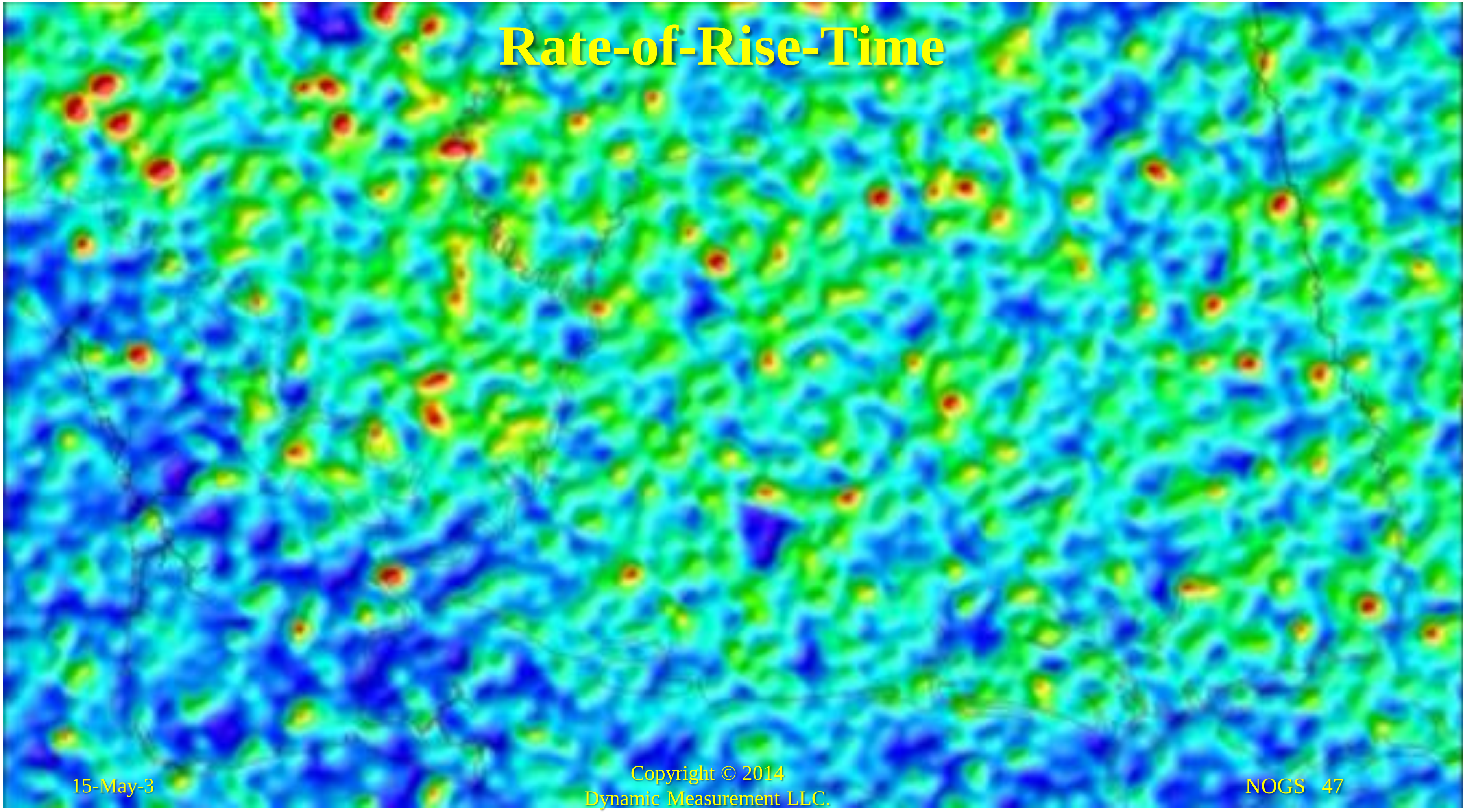
Rate-of-Rise-Time



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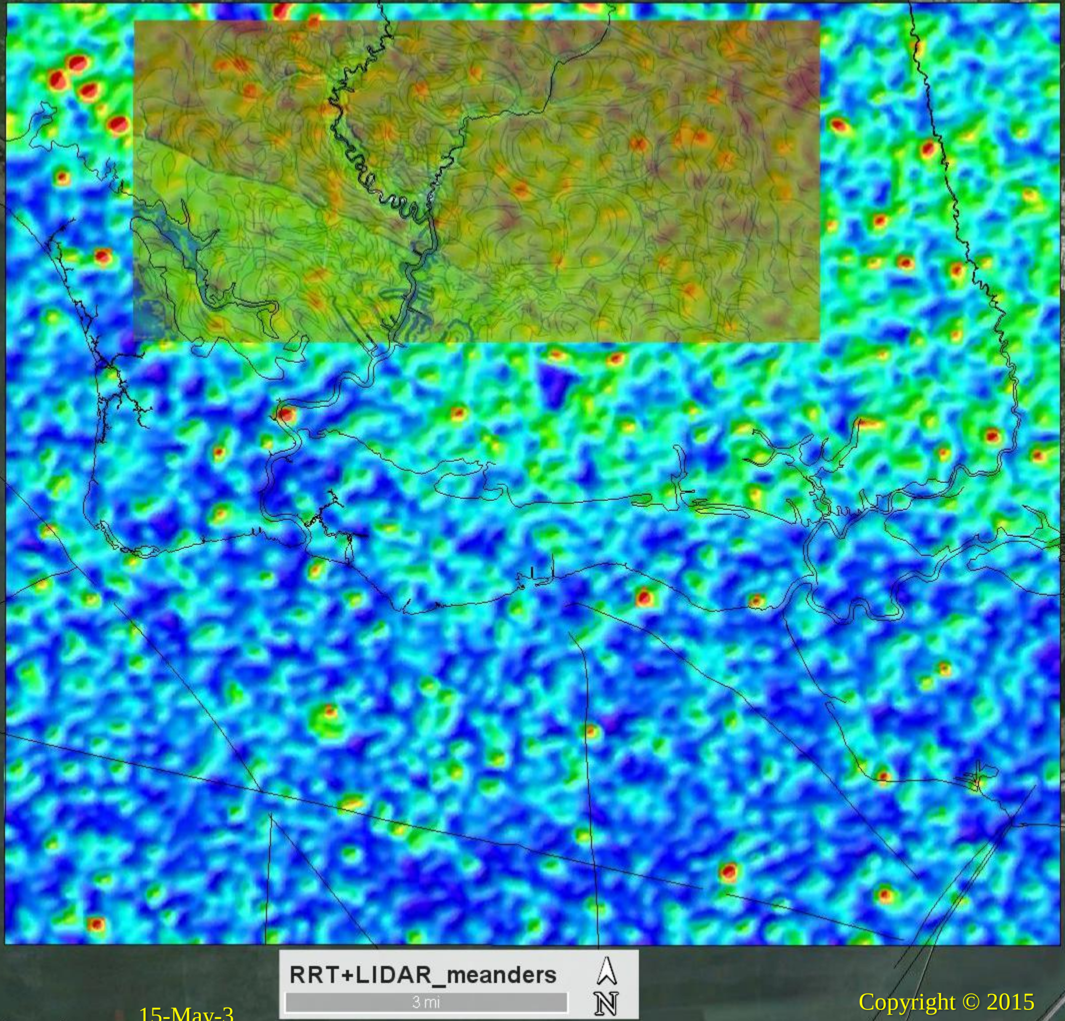
Rate-of-Rise-Time with LIDAR and meanders overlaid



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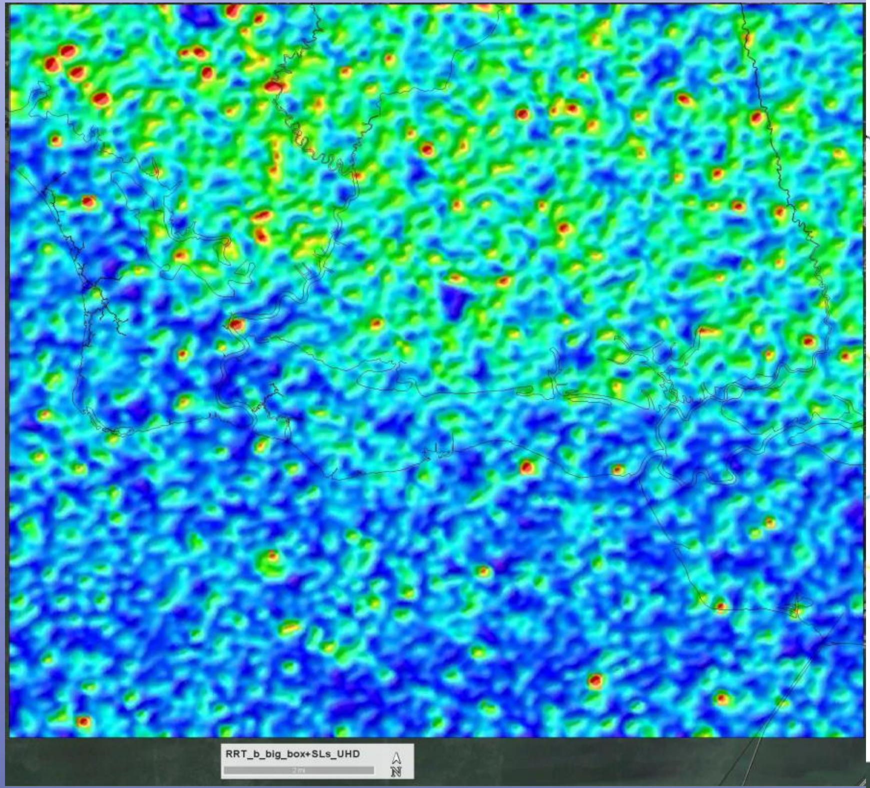
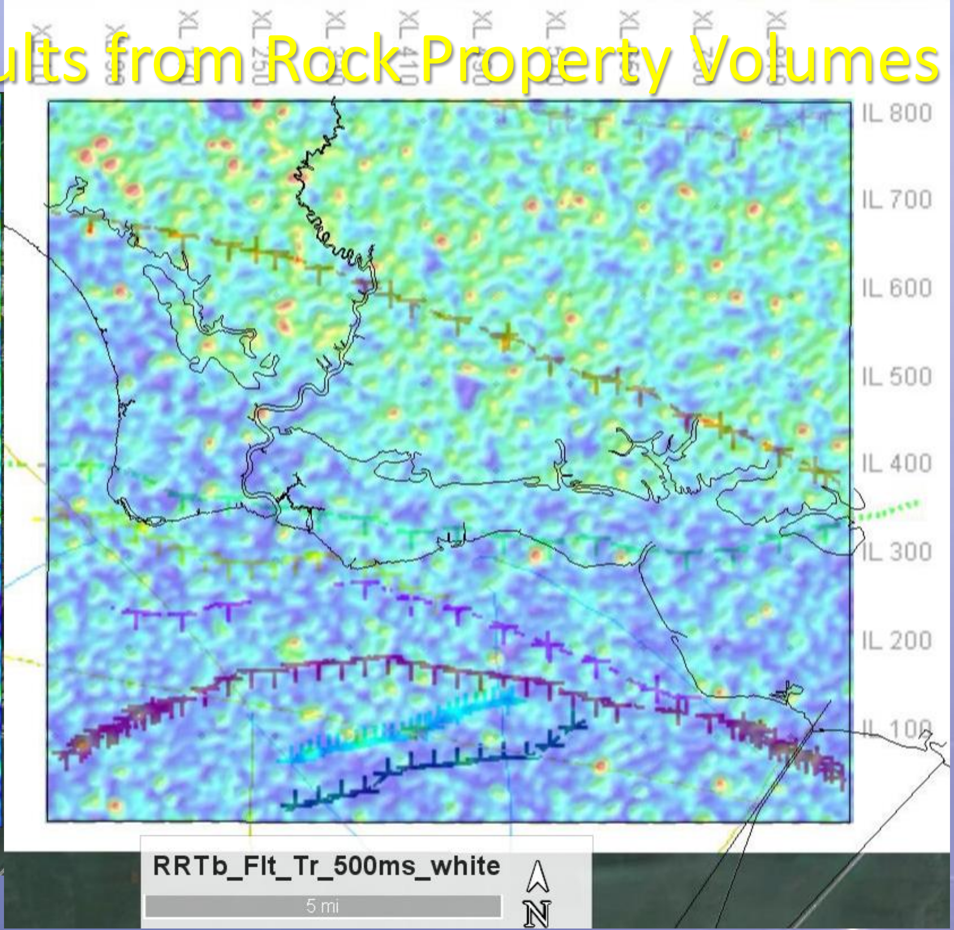
Rate-of-Rise-Time with Faults from Rock Property Volumes



Rate of Rise Time



Rate of Rise Time + Poss. Flts. from Resistivity

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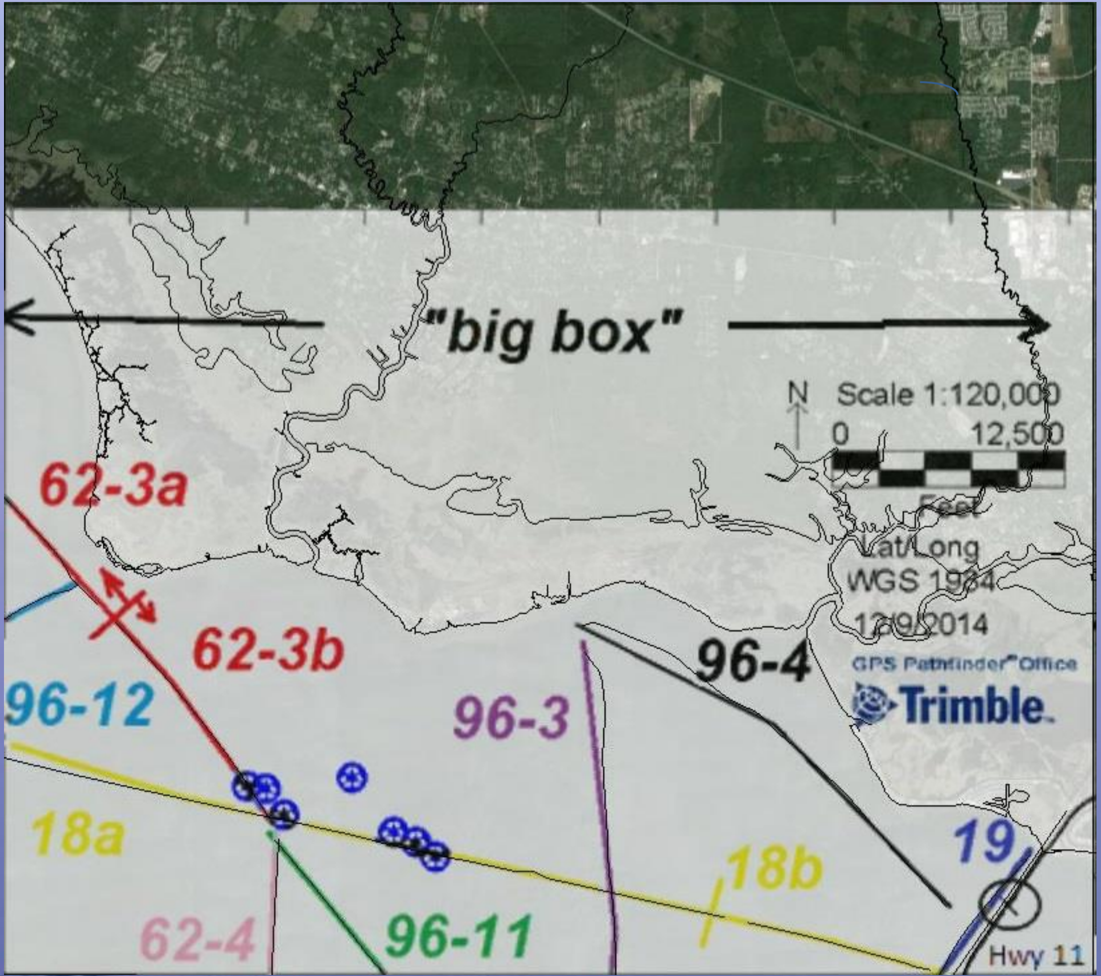

Goose Point Lightning Study Area

110 Square Miles

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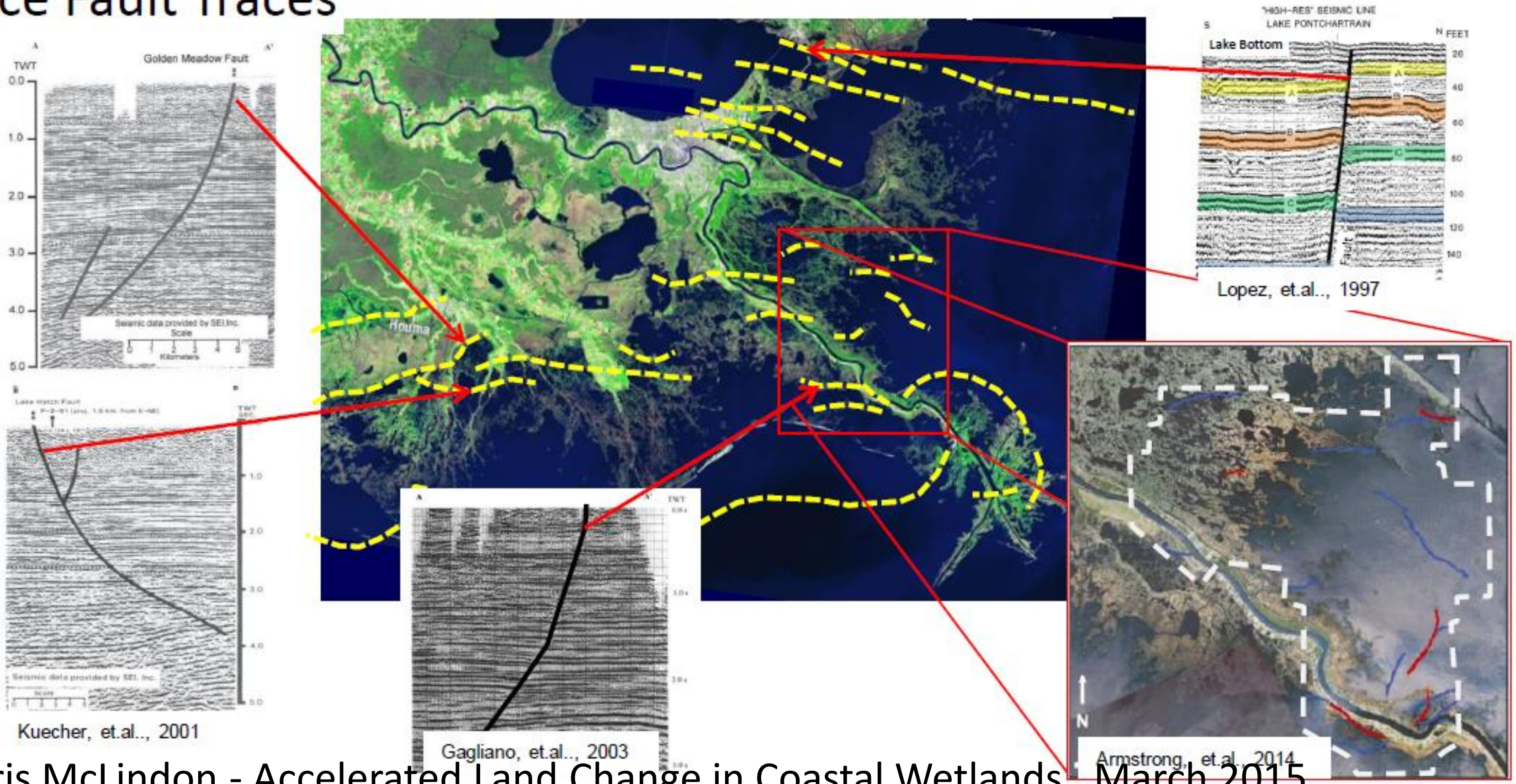
Surface Fault Traces



From Chris McLindon - Accelerated Land Change in Coastal Wetlands, March 2015

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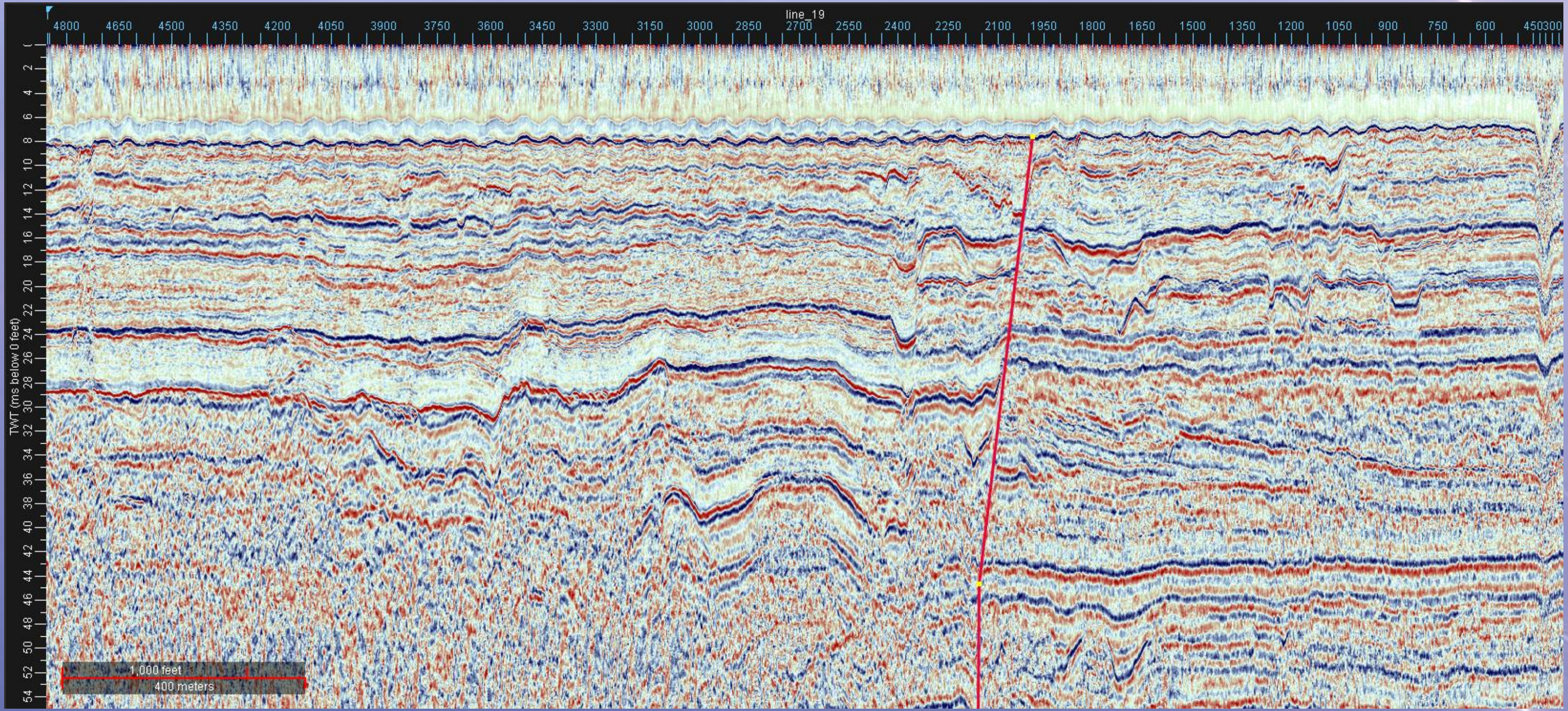
Reprocessed Sparker Line 19



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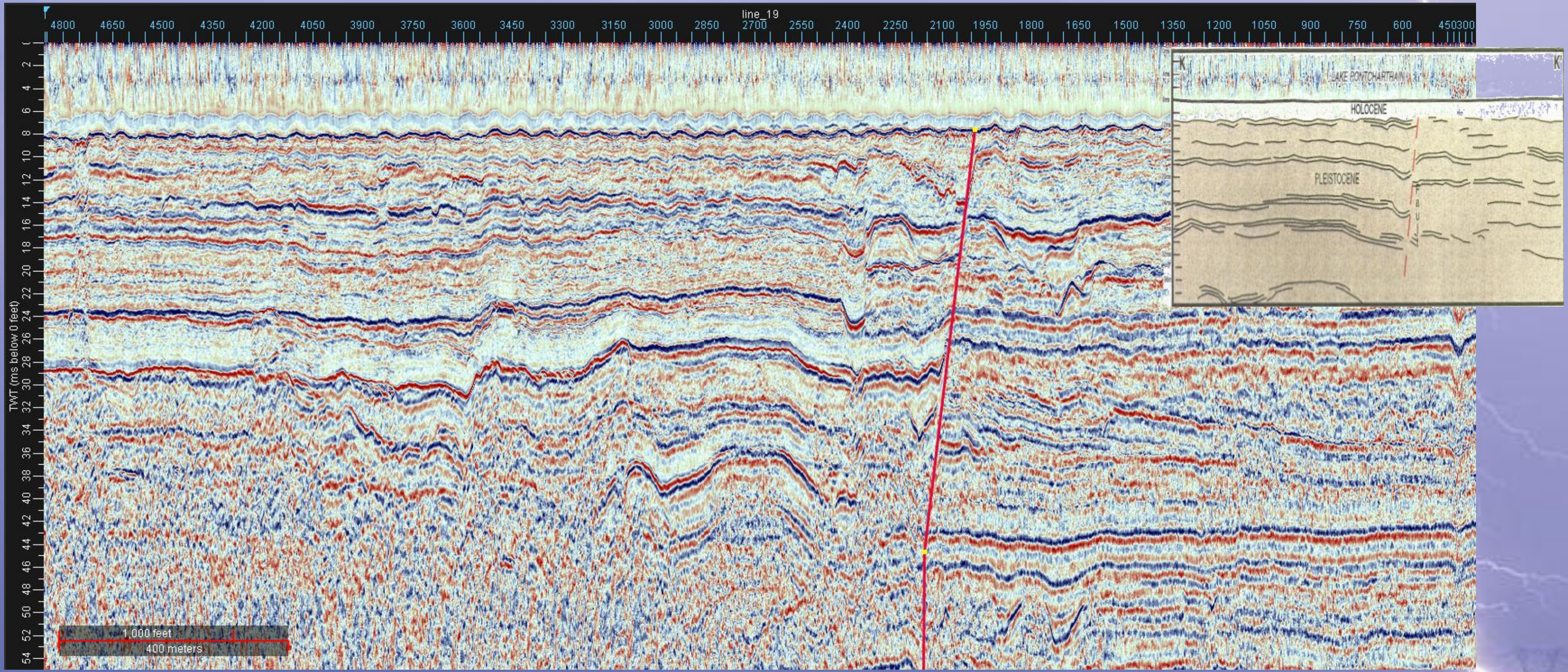
Approximate Integration with interpretation Shelly Roth - UNO MS Thesis 1999 (top right)



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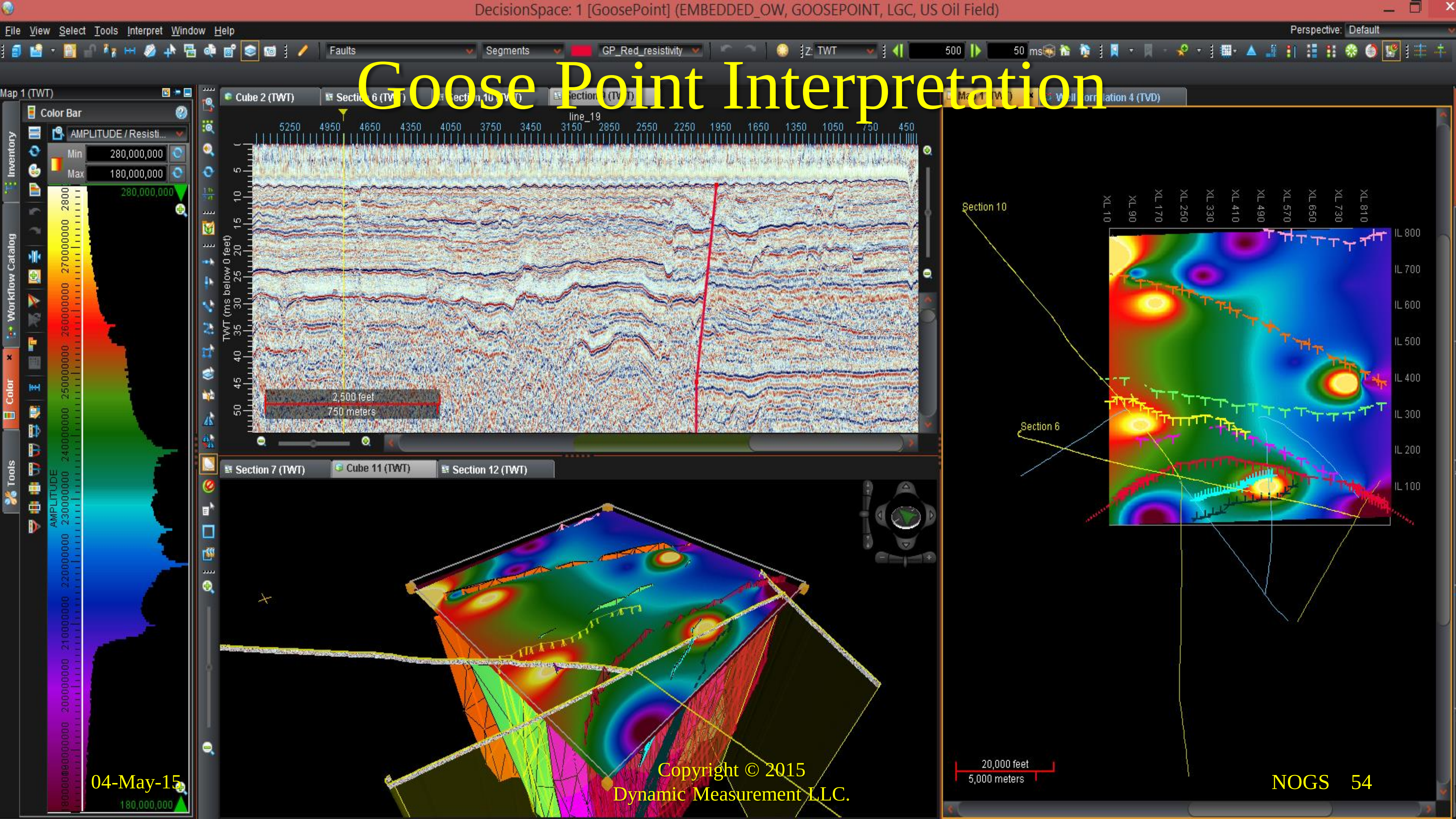
Goose Point Interpretation



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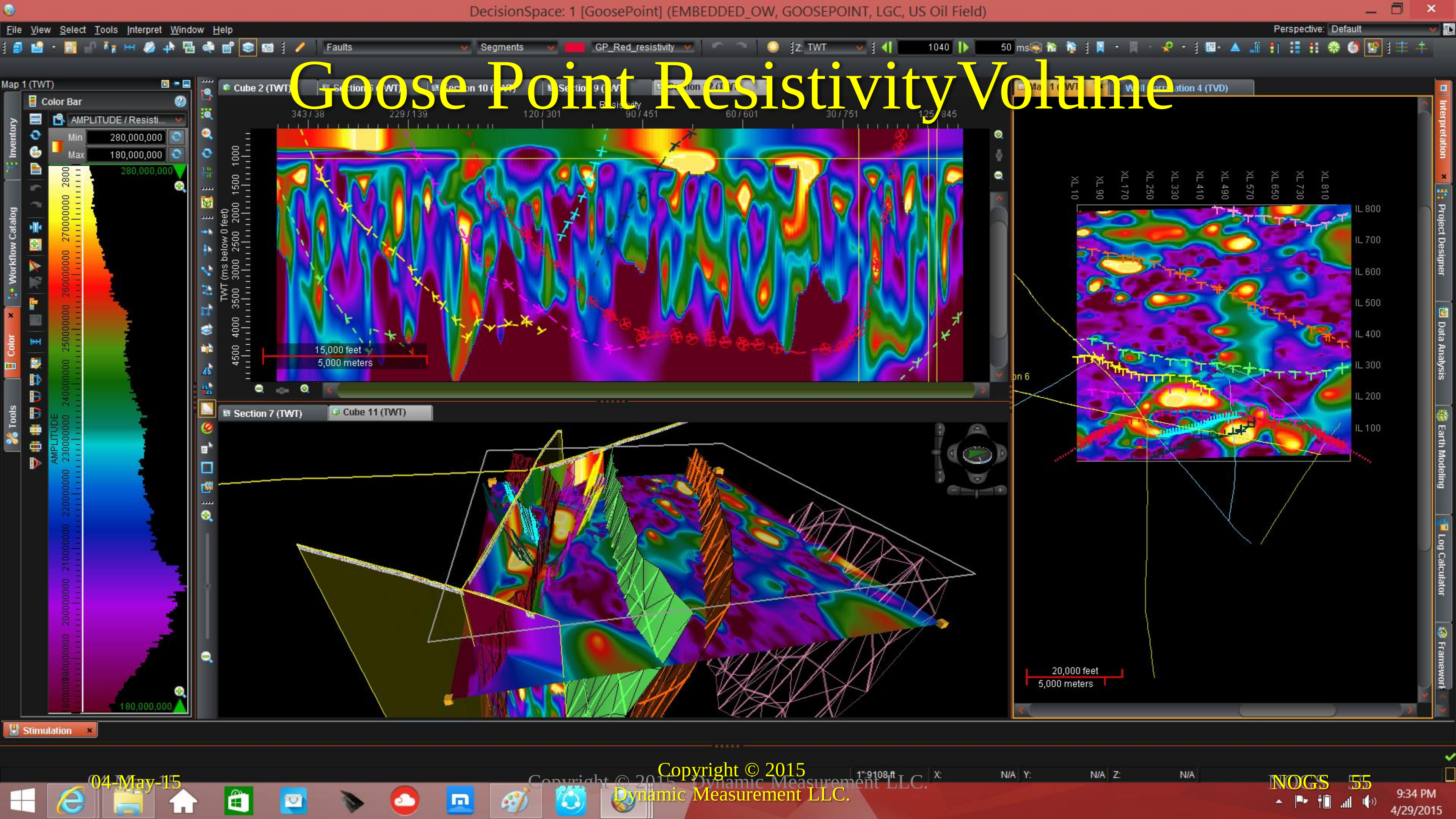
Goose Point Resistivity Volume



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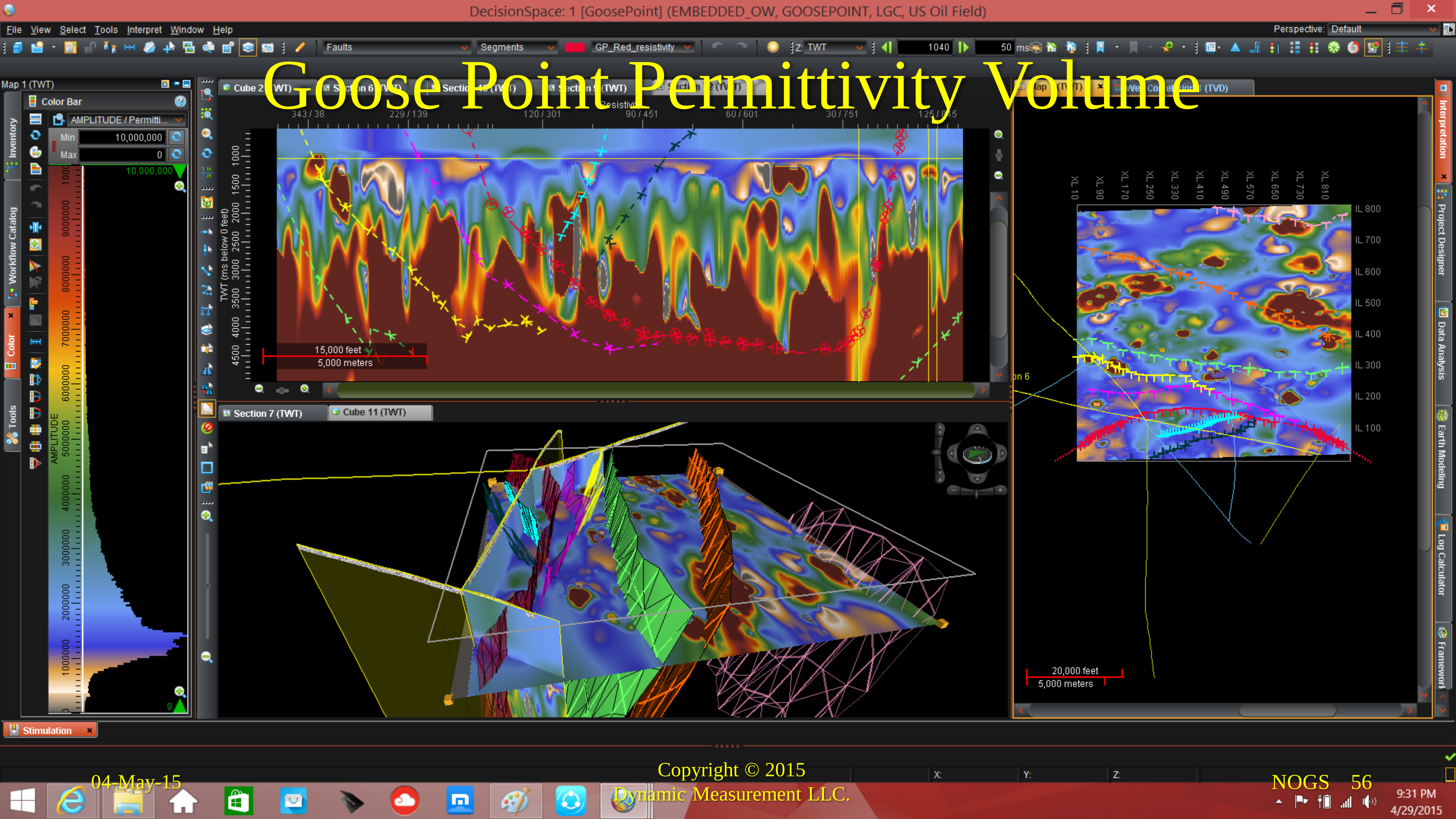
Goose Point Permittivity Volume



04-May-15

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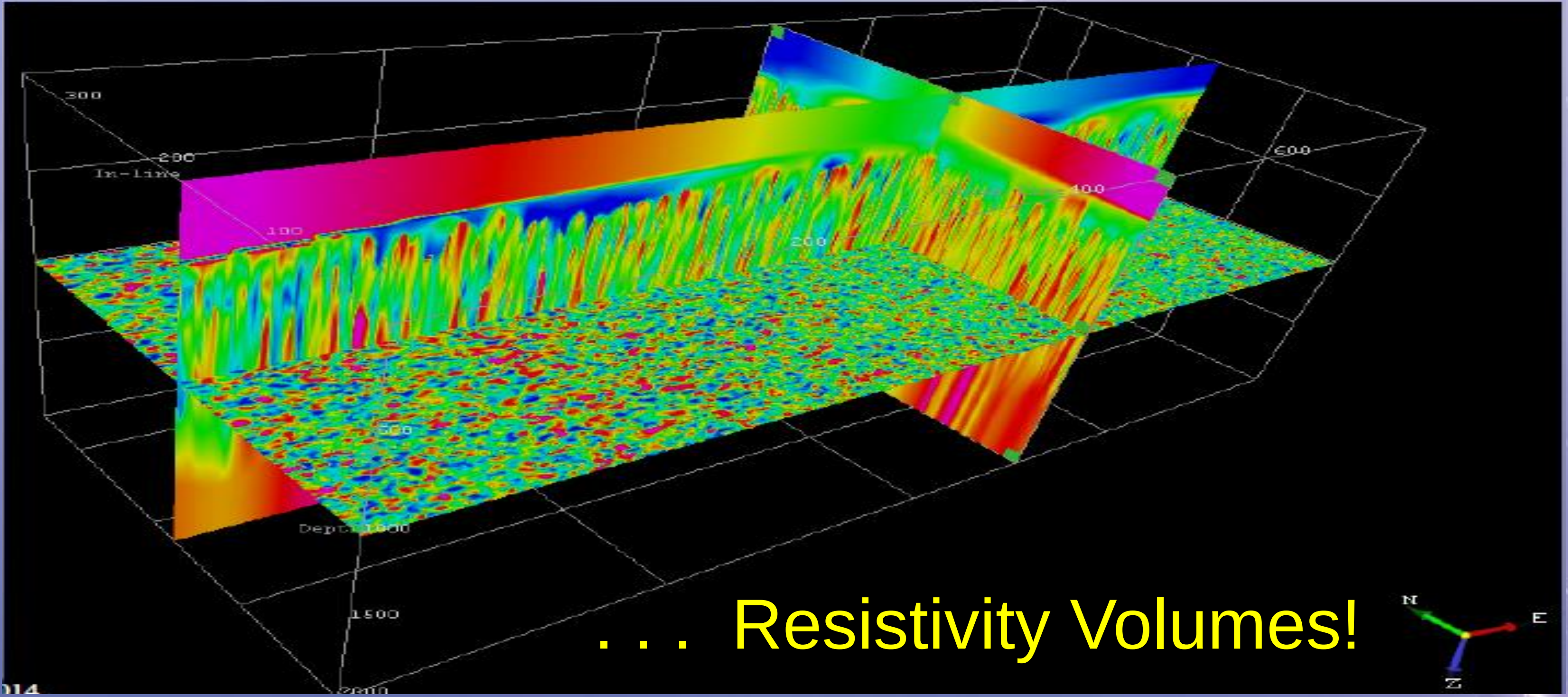
The Future of Lightning Analysis in Natural Resource Exploration . . .



. . . Resistivity Volumes!

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Conventional 2-D and 3-D Resistivity Images

over
Willow Creek Fault
in Tomball, TX

Figure 3. Willow Creek fault scarp across Highway 249. Note the several fractures and asphalt patches on the road. The picture was taken facing east. The car was going toward the bridge on the south (upthrown) side of the fault.

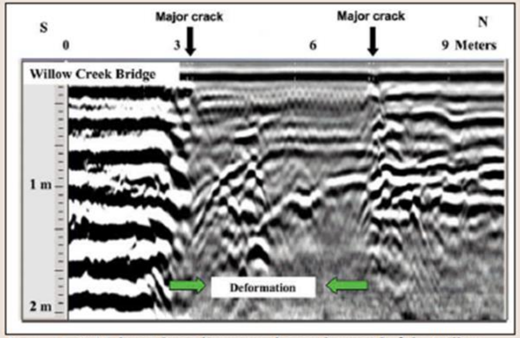

Figure 4. GPR data taken adjacent to the northern end of the Willow

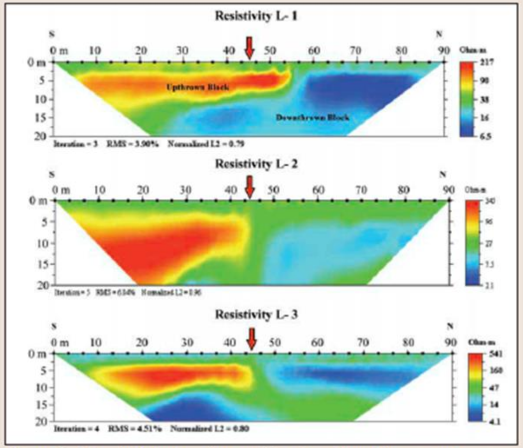

Figure 5. 2D resistivity imaging profiles taken along the east and west bounds of Highway 249 across Willow Creek fault.

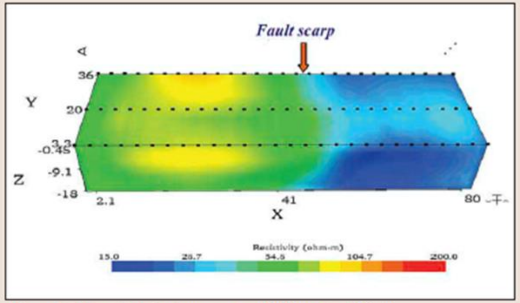

Figure 6. 3D resistivity image across Willow Creek fault.

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Willow Creek Resistivity Volume

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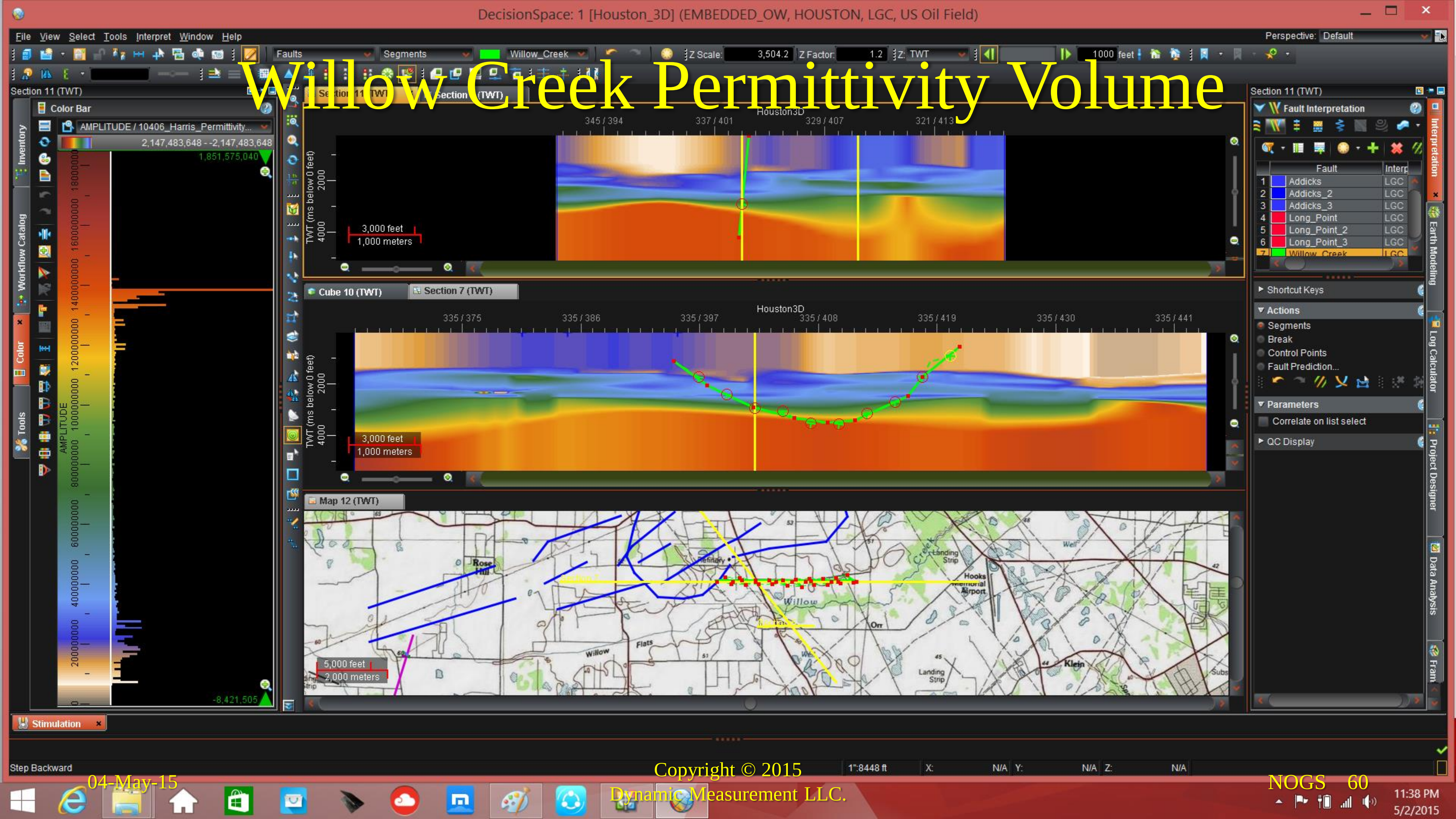
Willow Creek Permittivity Volume



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