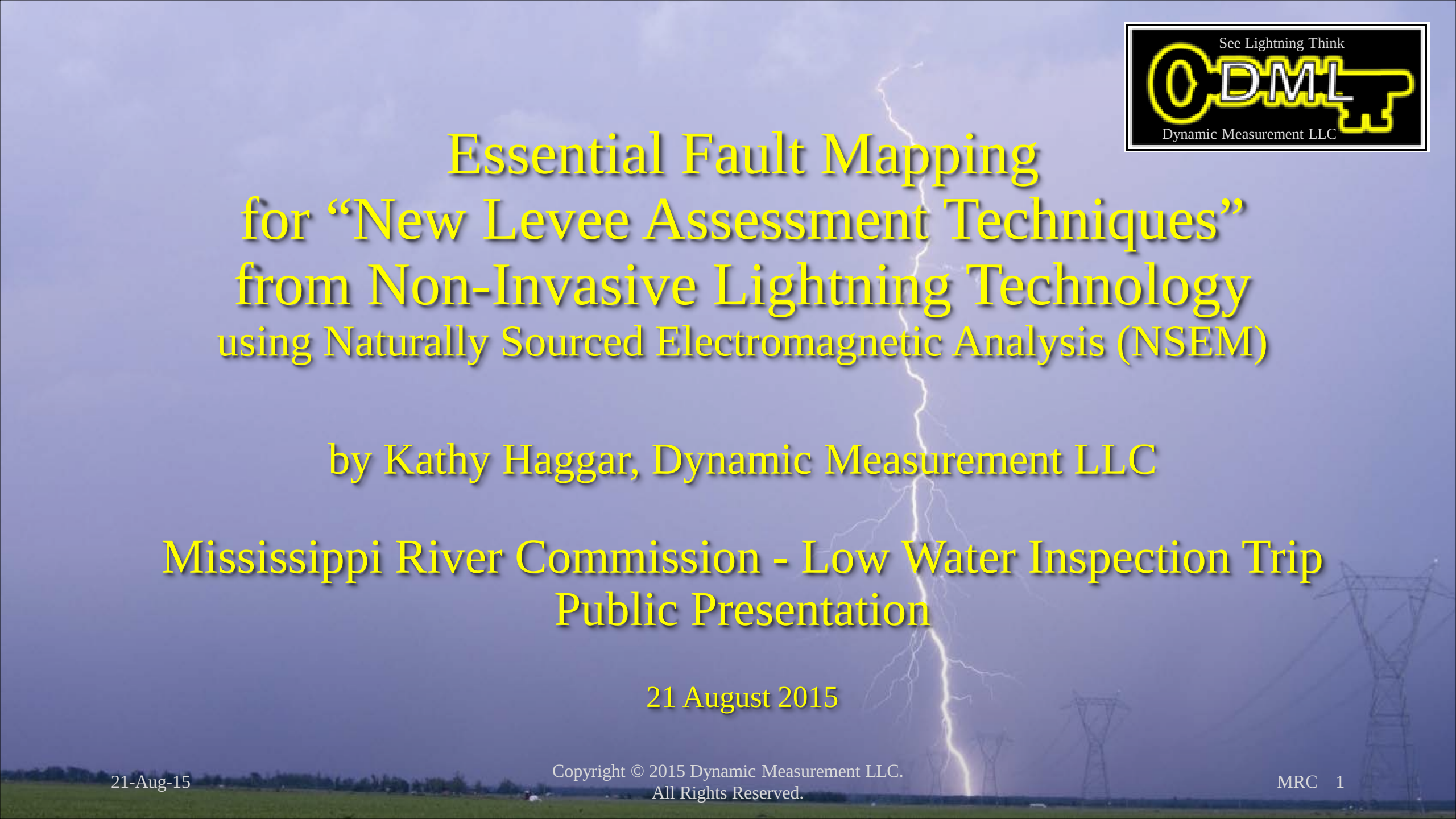

Essential Fault Mapping for "New Levee Assessment Techniques" from Non-Invasive Lightning Technology

using Naturally Sourced Electromagnetic Analysis (NSEM)

by Kathy Haggar, Dynamic Measurement LLC

Mississippi River Commission - Low Water Inspection Trip
Public Presentation

21 August 2015

Regional Geology – MS Delta and Faults

Mississippi Delta Cycle by Penland

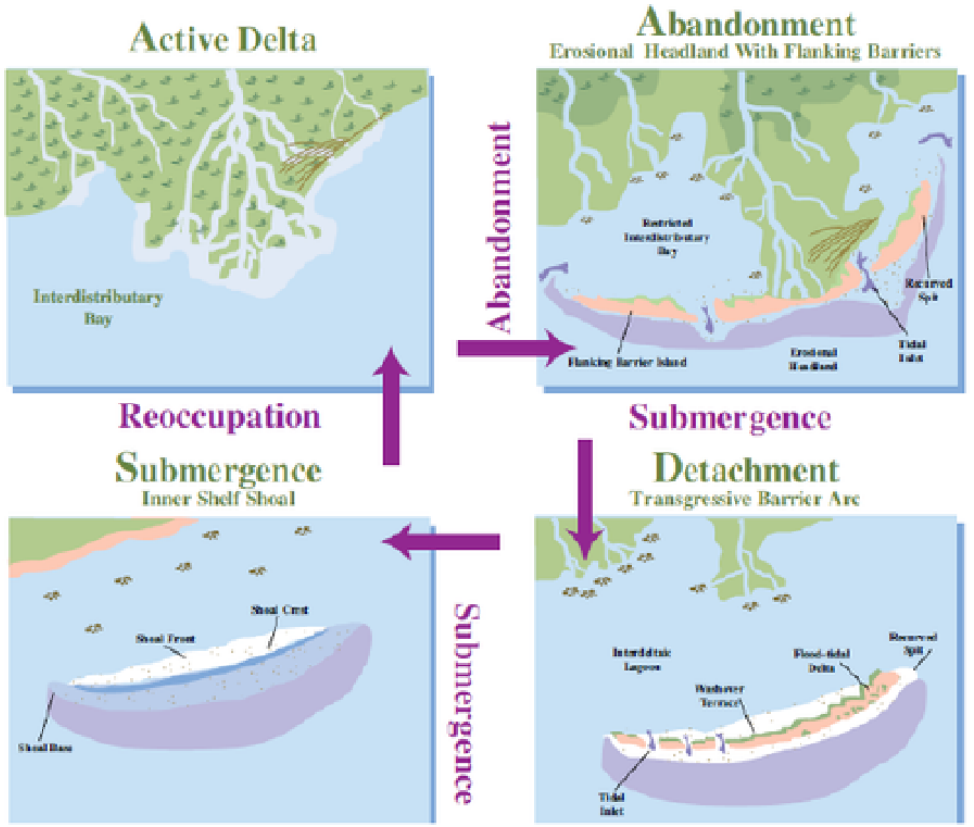

Figure 2. Three stage evolution of a deltaic barrier island. (Barrier Islands Educators Guide: model from Penland and Boyd, 1981.)

Penland, S., Boyd, R., 1981. Shoreline changes on the Louisiana barrier coasts. IEEE Oceans, Marine Technology Society. pp. 209-219.

http://mississippidelta.wmwikis.net/Isles+Dernieres+-+Trinity+Island

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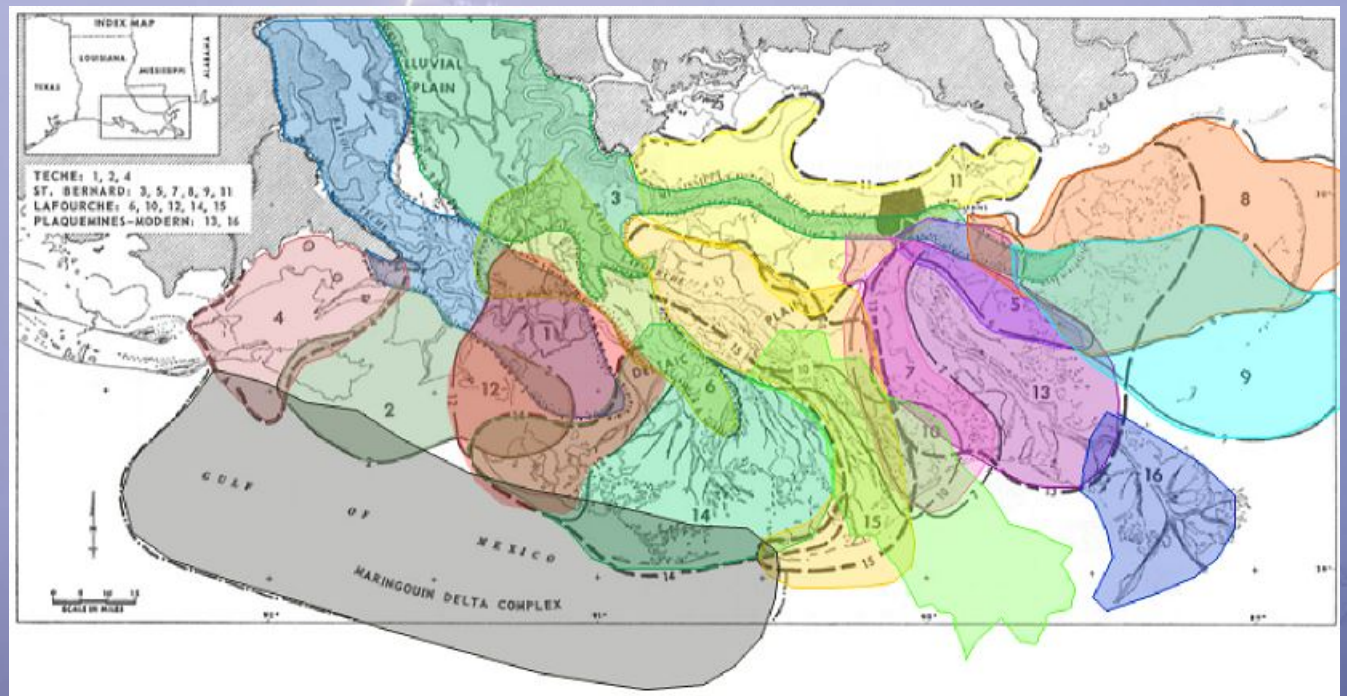
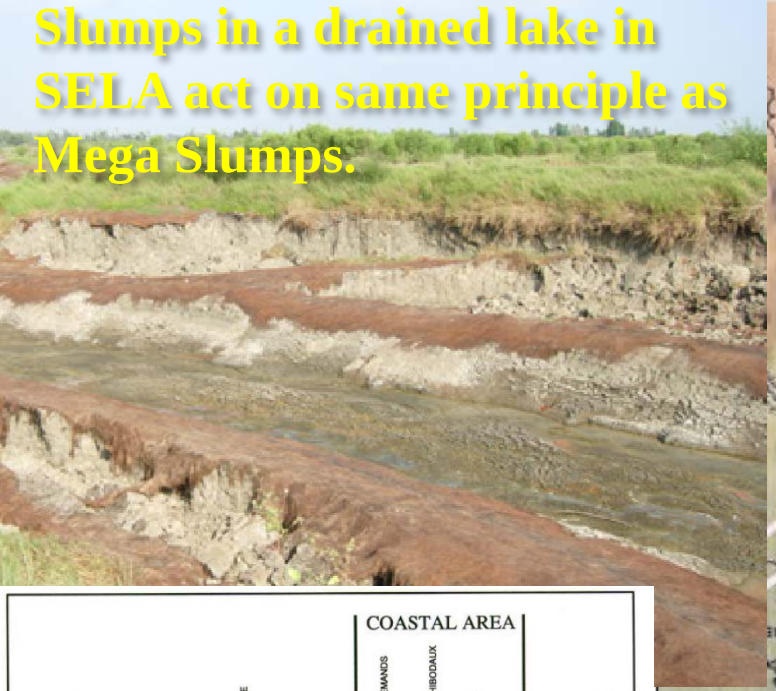
Mississippi Deltas by Frasier



Recent Deltatic Deposits of the Mississippi River: Their development and chronology, by David E. Frazier, Gulf Coast Association of Geological Societies, *Transactions*, 1967

Mega Slumps in the Northern Gulf of Mexico

Slumps in a drained lake in SELA act on same principle as Mega Slumps.



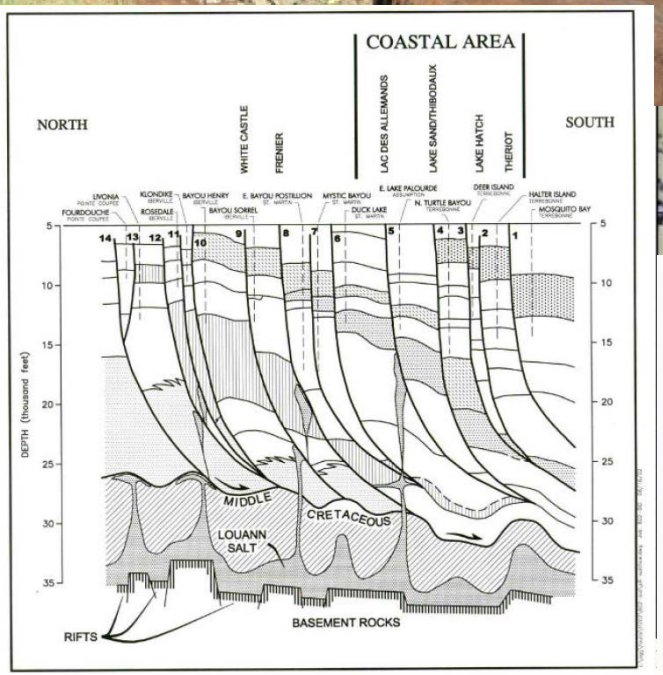
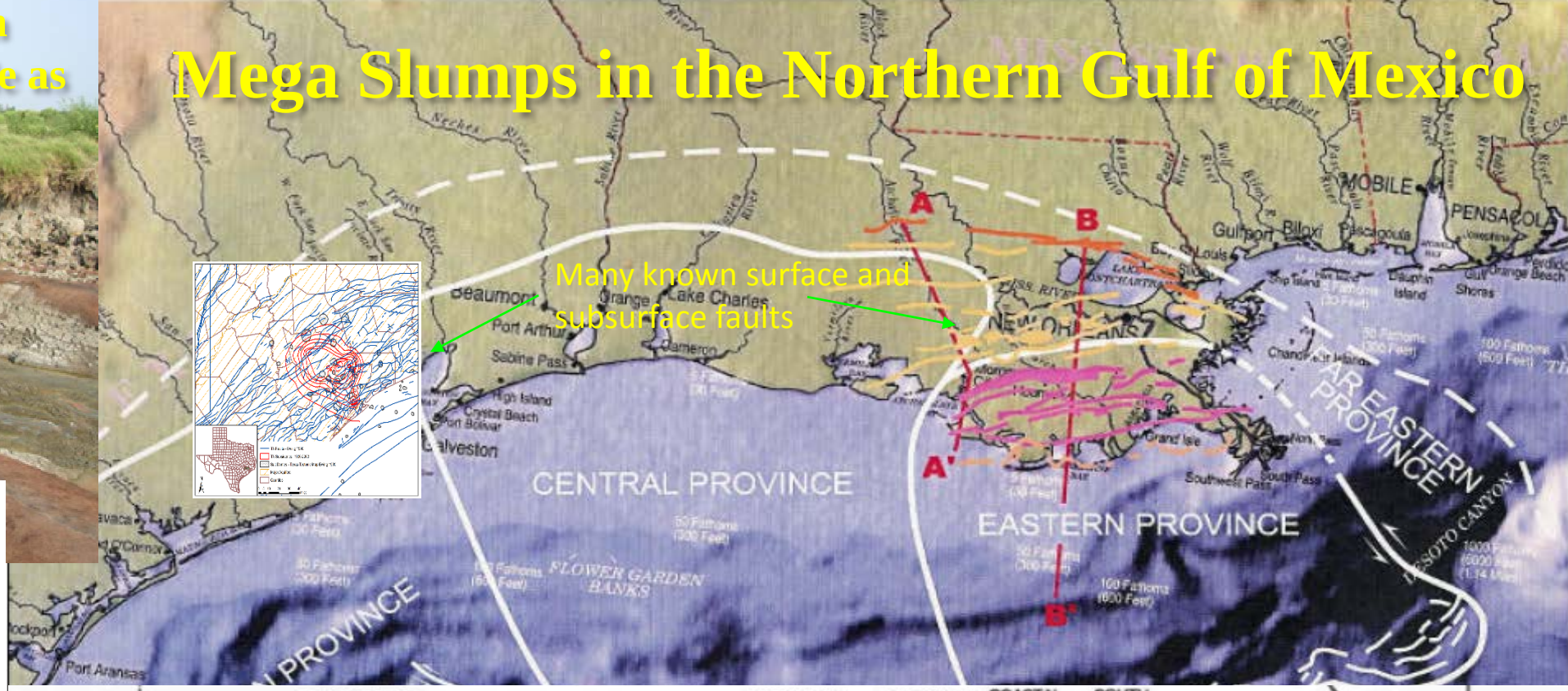
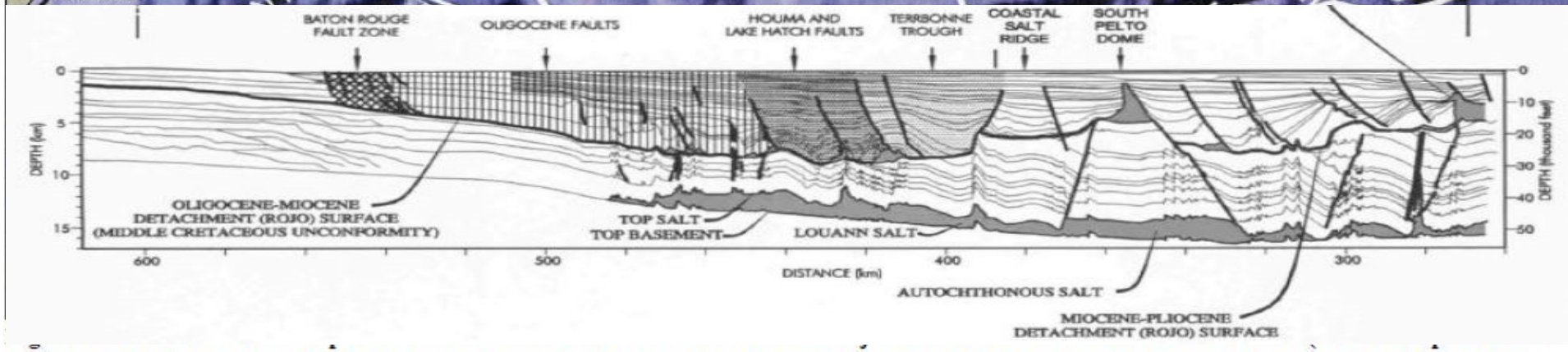


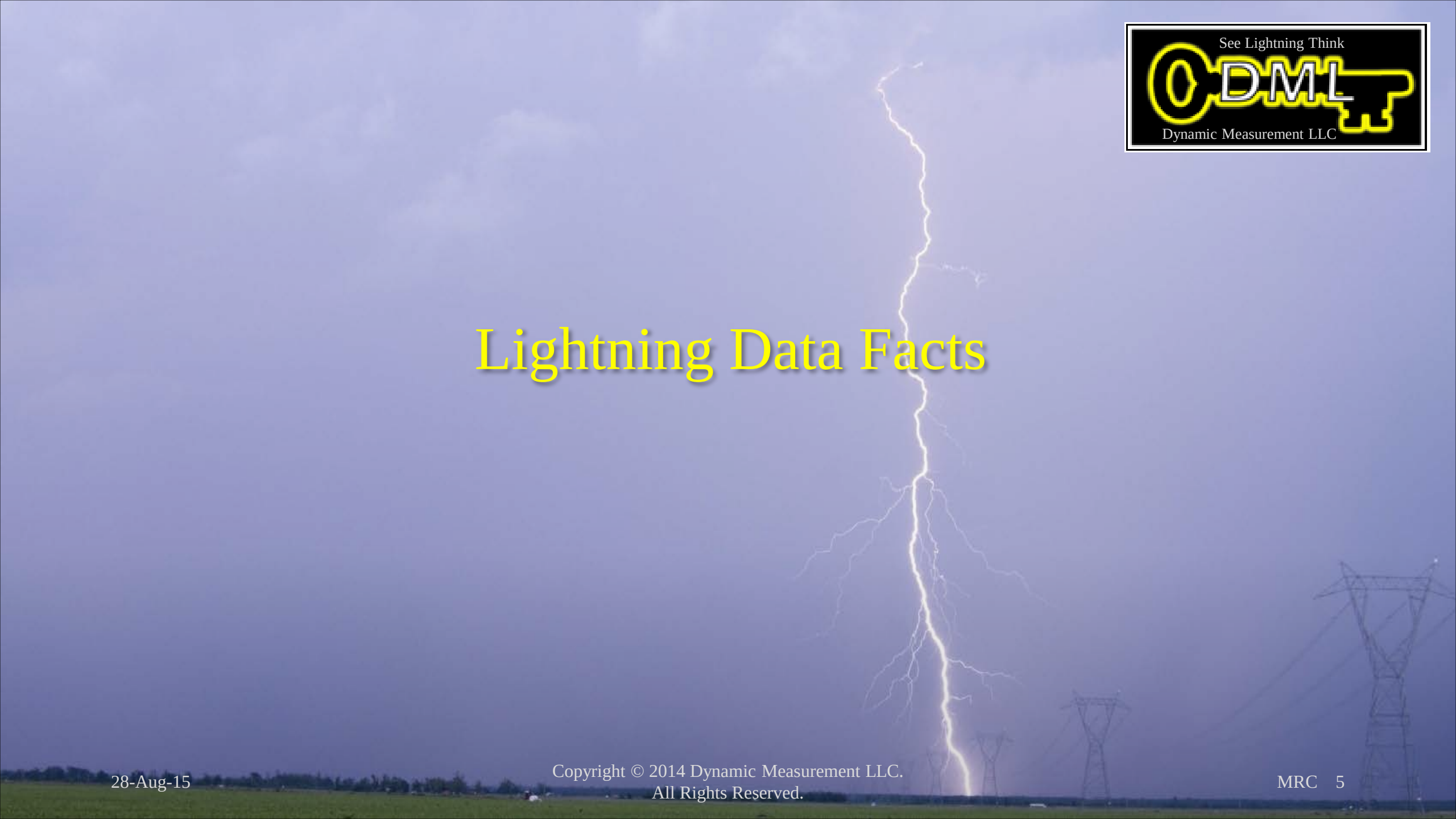
Figure 8. North-South cross-section through the Gulf Coast Salt Dome Basin showing stratigraphy and geological structures (after Adams 1997). Extensional section with progressively younger listric faults from north to south. Section also shows inferred basement-salt-decollement surface relationships. Subsurface faults shown in Figure 6 are identified on the section.

Many known surface and subsurface faults



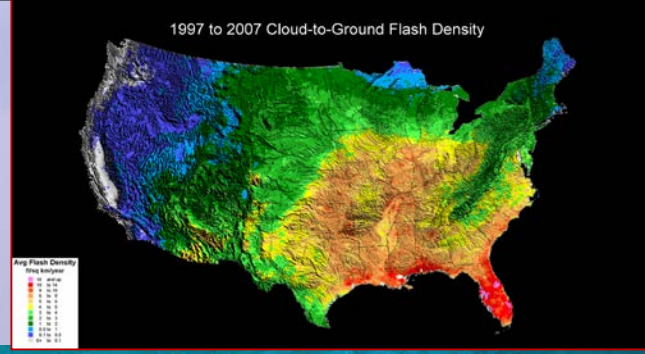


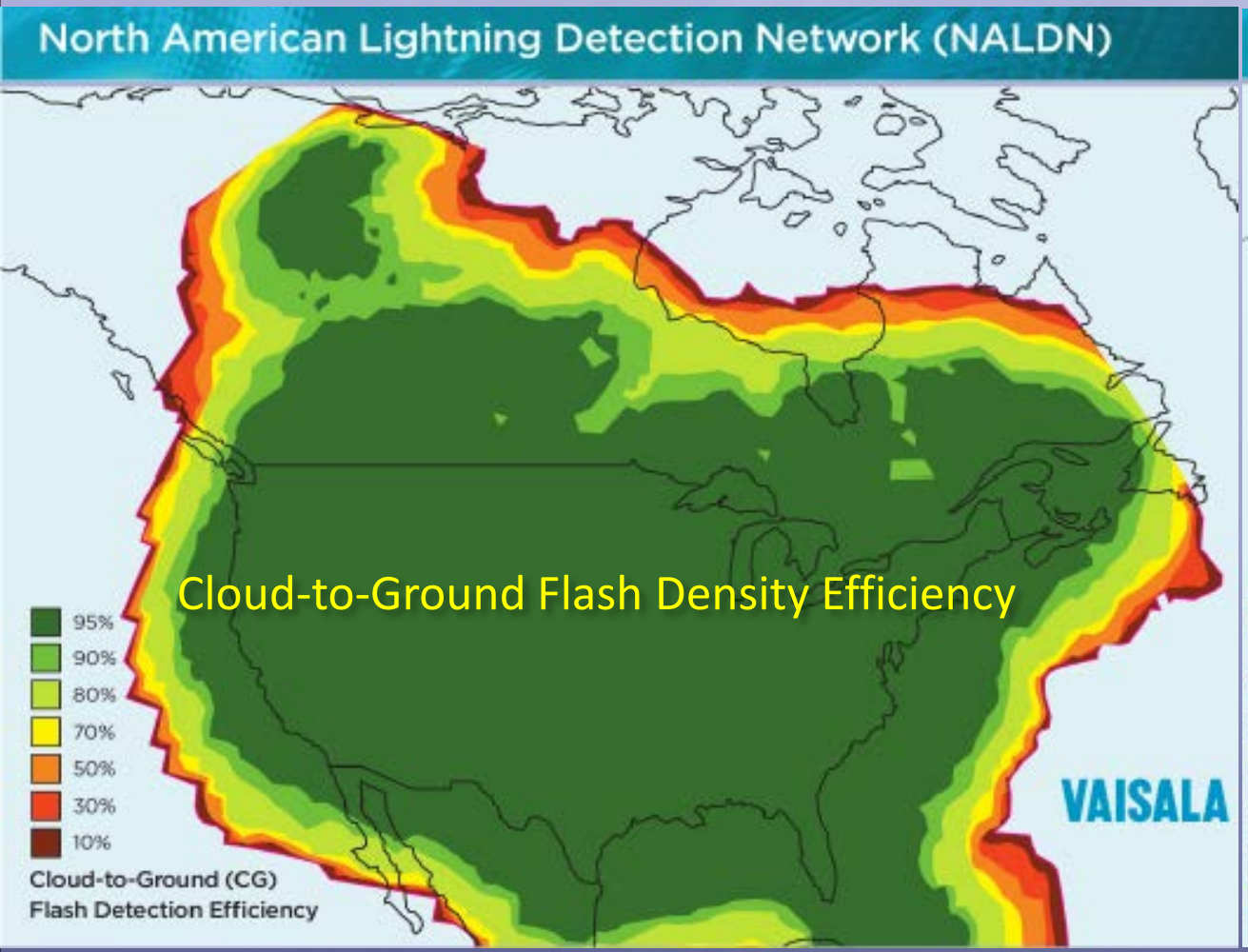
after Peel et al. 1995; base map with permission of Port Publishing Co., Houston, TX; fault zones reported). Color patterns correspond to those in Figure 6. Note apparent massive slumping of continental slope in the Central Province

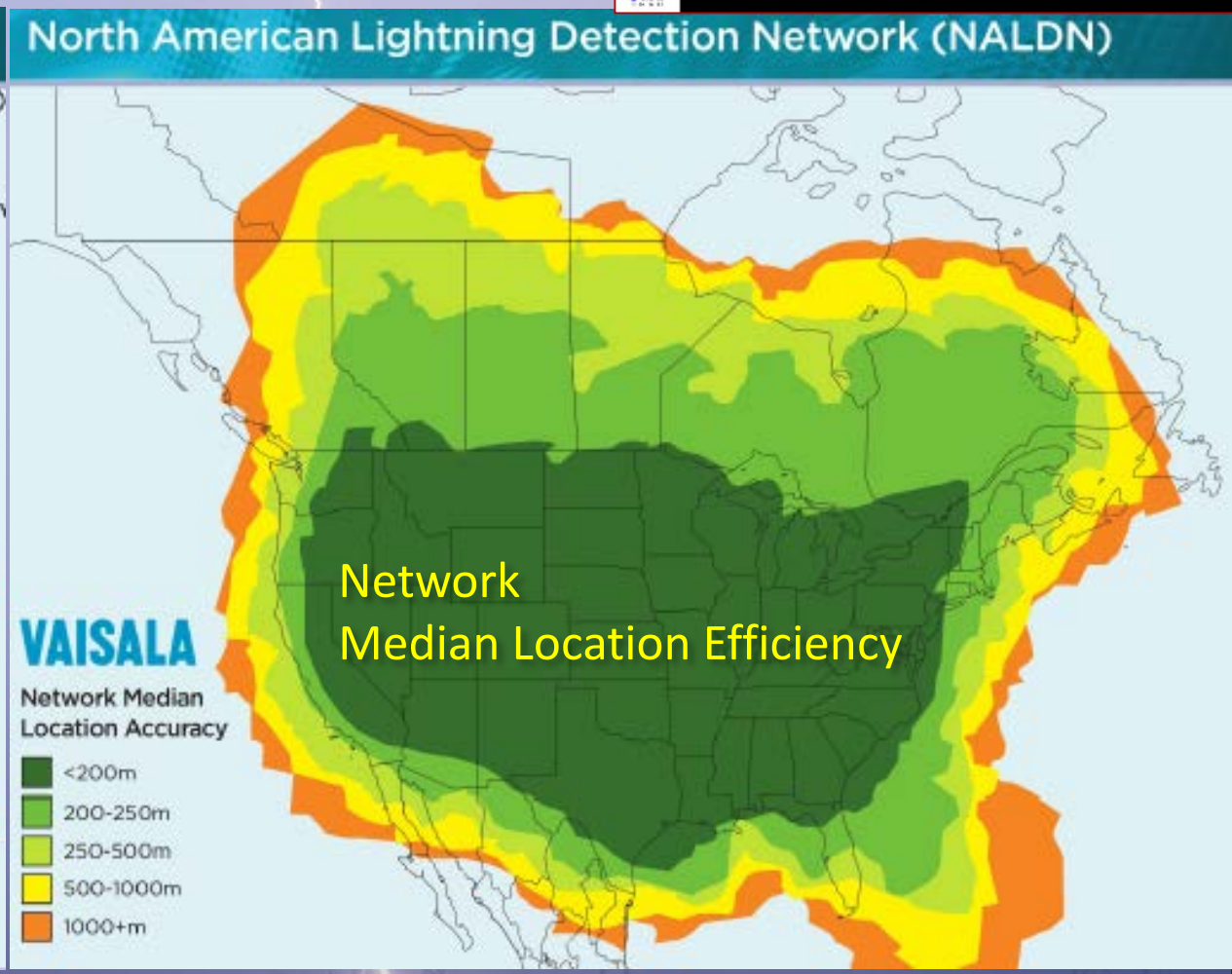


Lightning Data Facts

17 years of digital lightning strike data available!







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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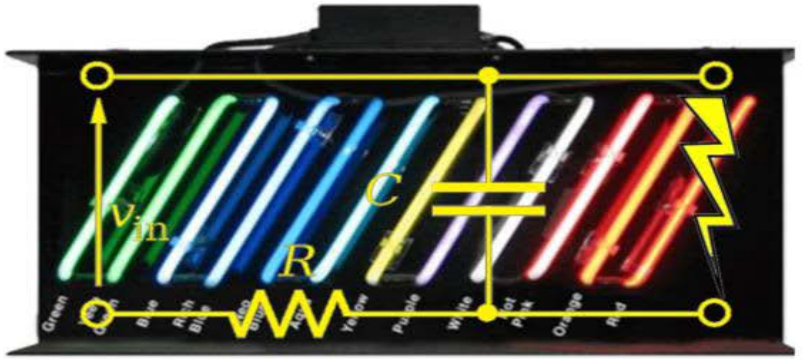
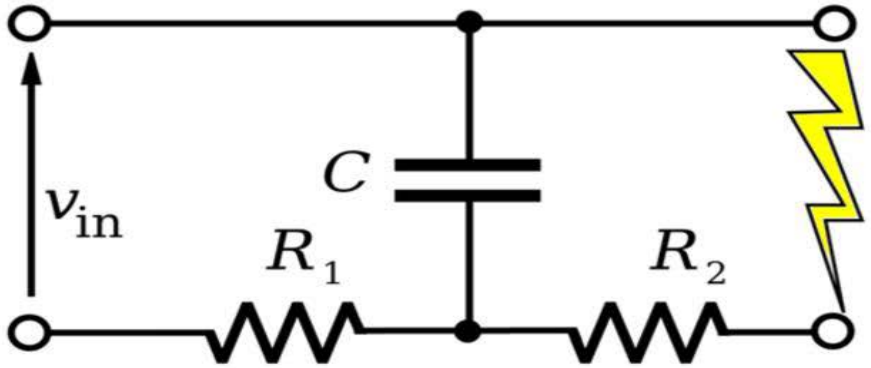
Lightning Physics is analogous to Relaxation Oscillator Physics





- The atmospheric capacitor is nearly the same physics
- 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

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Lightning

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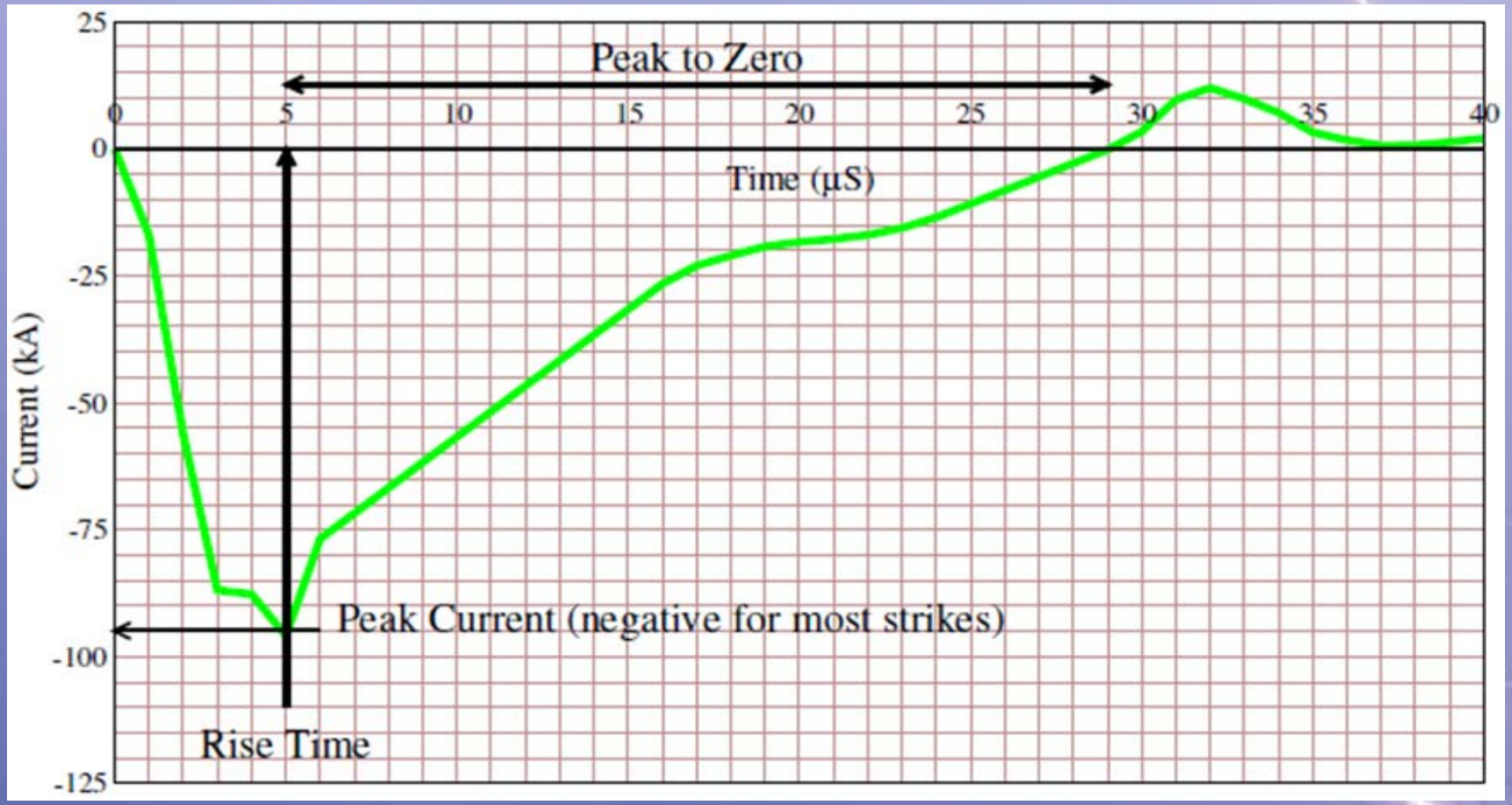
Lightning Measurements/Attributes, & Wave Form

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



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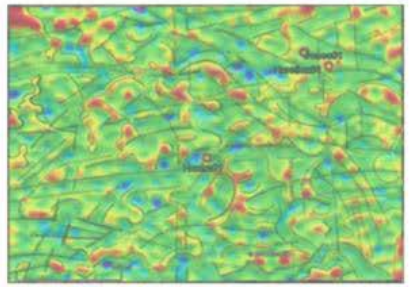
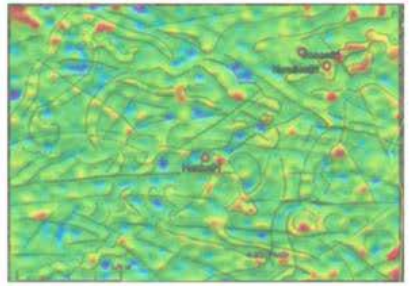
Attributes Calculated or Displayed with DecisionSpace®

Surface Resistivity:



Peak-to-Zero:



Seismic Attributes

- Instantaneous
- Wavelet
- Geometrical
- Reflective
- Curvature
- Dip
- Semblance/Coherence
- AVO / AVA
- Derivatives

Lightning Map Attributes

- Rise-Time
- Peak Current
- Peak-to-Zero
- Total Wavelet Time
- Symmetry
- Density
- Rise-Time-Rate
- Temporal Versions
- Tidal Gravity

Lighting Volume Attributes

- Resistivity
- Instantaneous Resistivity
- Curvature Resistivity
- Permittivity
- Wavelet Permittivity
- Dip Permittivity
- Temporal Versions:
- Before Event
- After Event

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7

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There are more lightning attributes than seismic

Lightning Interpretation

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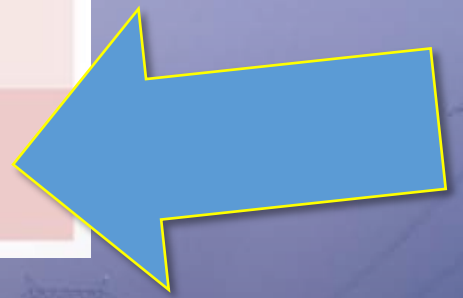
Rock Property Specifics

Method	Type of measurement	Physical property detected
Gravity	Spatial variations in the strength of the Earth's gravitational field	Density
Magnetic	Spatial variations in the strength of the Earth's magnetic field.	Magnetic susceptibility
Seismic	Travel times of seismic waves	Density and elastic moduli
Electrical Resistivity	Electrical resistance	Electrical conductivity
Electromagnetic	Response to electromagnetic radiation	Electrical conductivity and Inductance
Ground Penetrating Radar (GPR)	Travel time of radar pulses	Dielectric constant
Lightning	Location, Time, Rise-Time, Peak Current, Peak-to-Zero	Resistivity and Permittivity



The Dutch, Germans, and Belgians have published extensively on new shallow levee assessment techniques –EM, GPR, Sparker, LIDAR, SAR, and Gravity.

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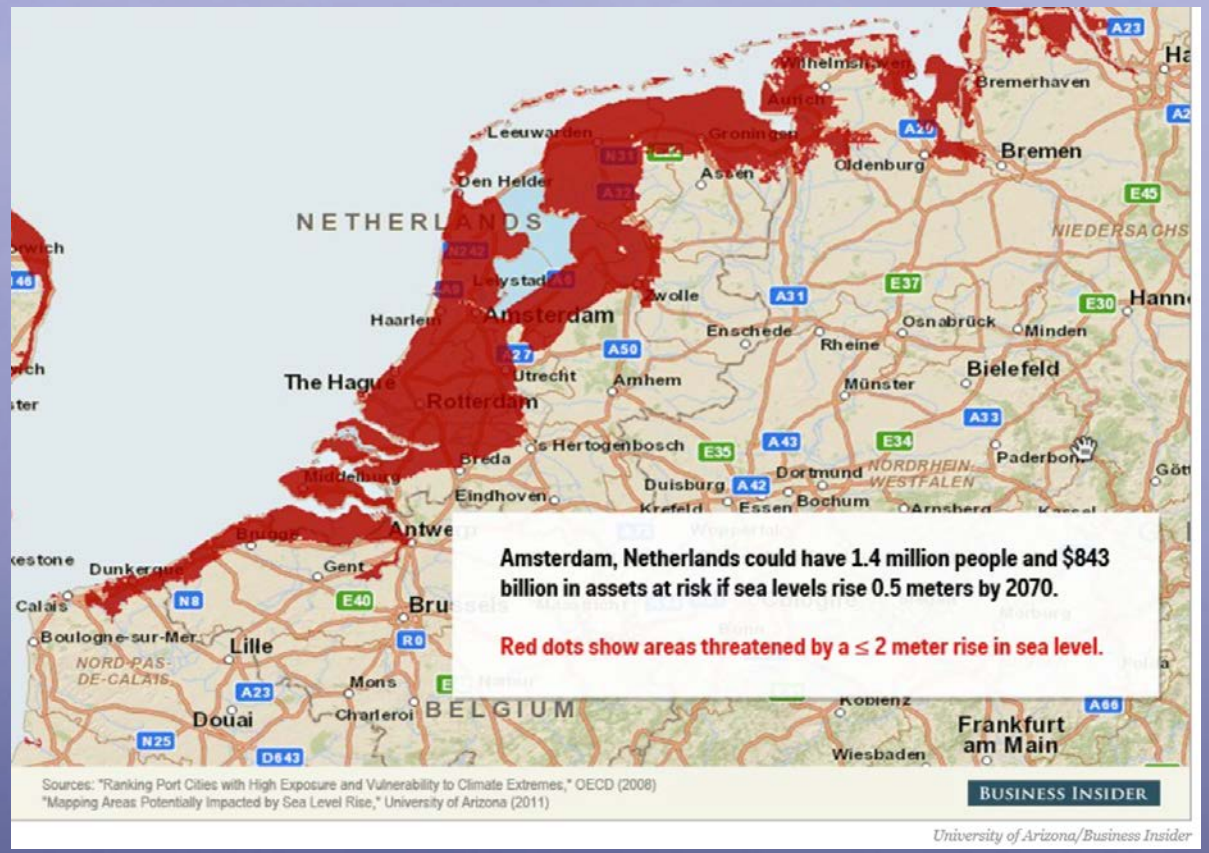
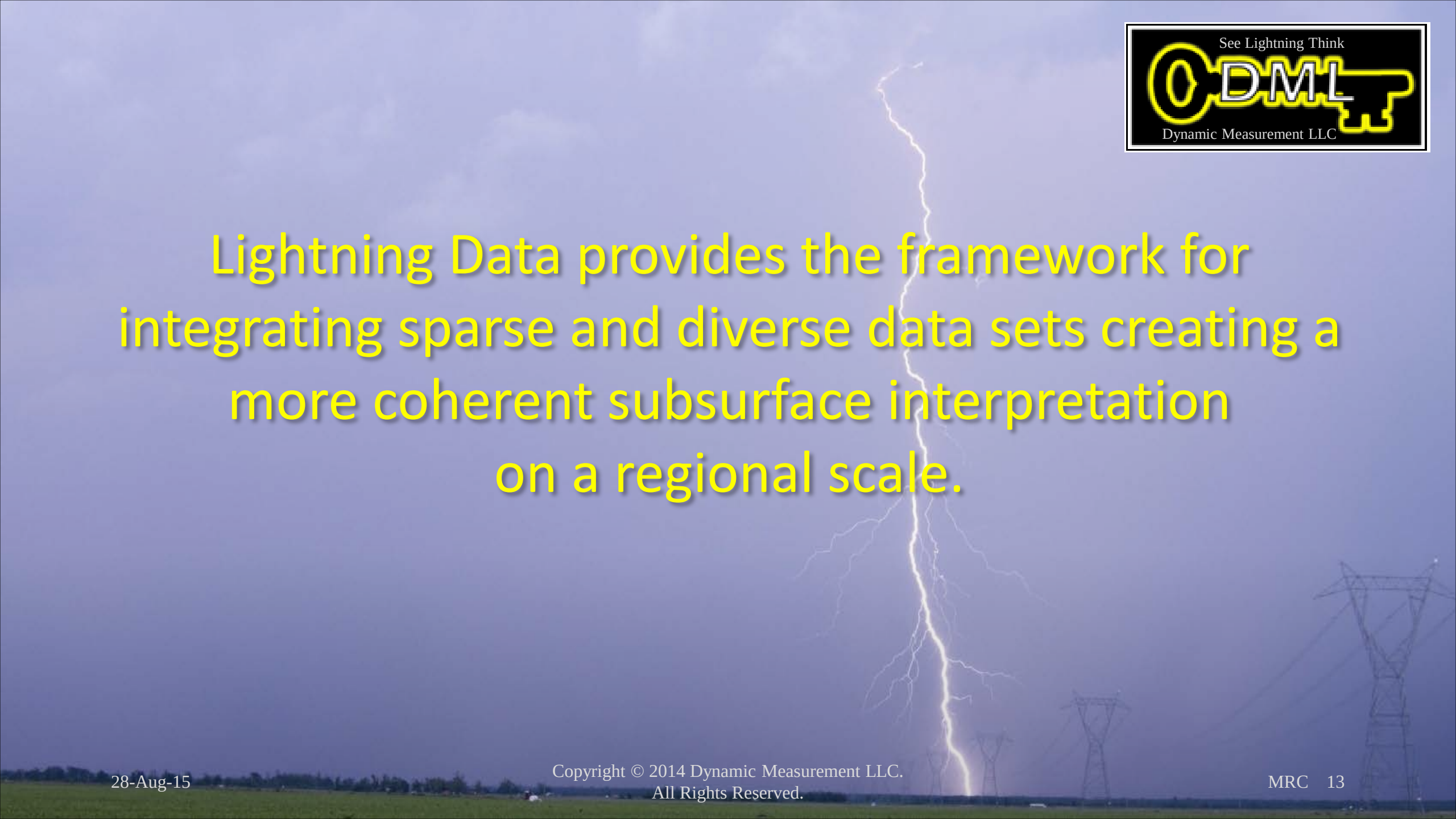


Task/problem	resistivity	electro-magnetics	GPR	seismics	radiometric sounding
Global delineation of homogeneous areas (levee and subsoil)	+	O	-	-	-
detection of structural anomalies (e.g. repaired areas)	O	O	O	O	-
localisation of manmade objects	O	O	+	-	-
identification of levee structure	+	O	O	-	+
characteristic layer boundaries	O	O	O	O	+
impermeable layers (subsoil, existence and thickness)	+	O	O	-	+
water level	-	-	O	O	+
petrophysical/geotechnical properties	-	-	-	O	+

+ : application recommended
O : application recommended with restrictions
- : application not recommended



Lightning Data provides the framework for integrating sparse and diverse data sets creating a more coherent subsurface interpretation on a regional scale.

Integrating sparker with resistivity volumes and fault picks at Goose Point, LA for interpretation

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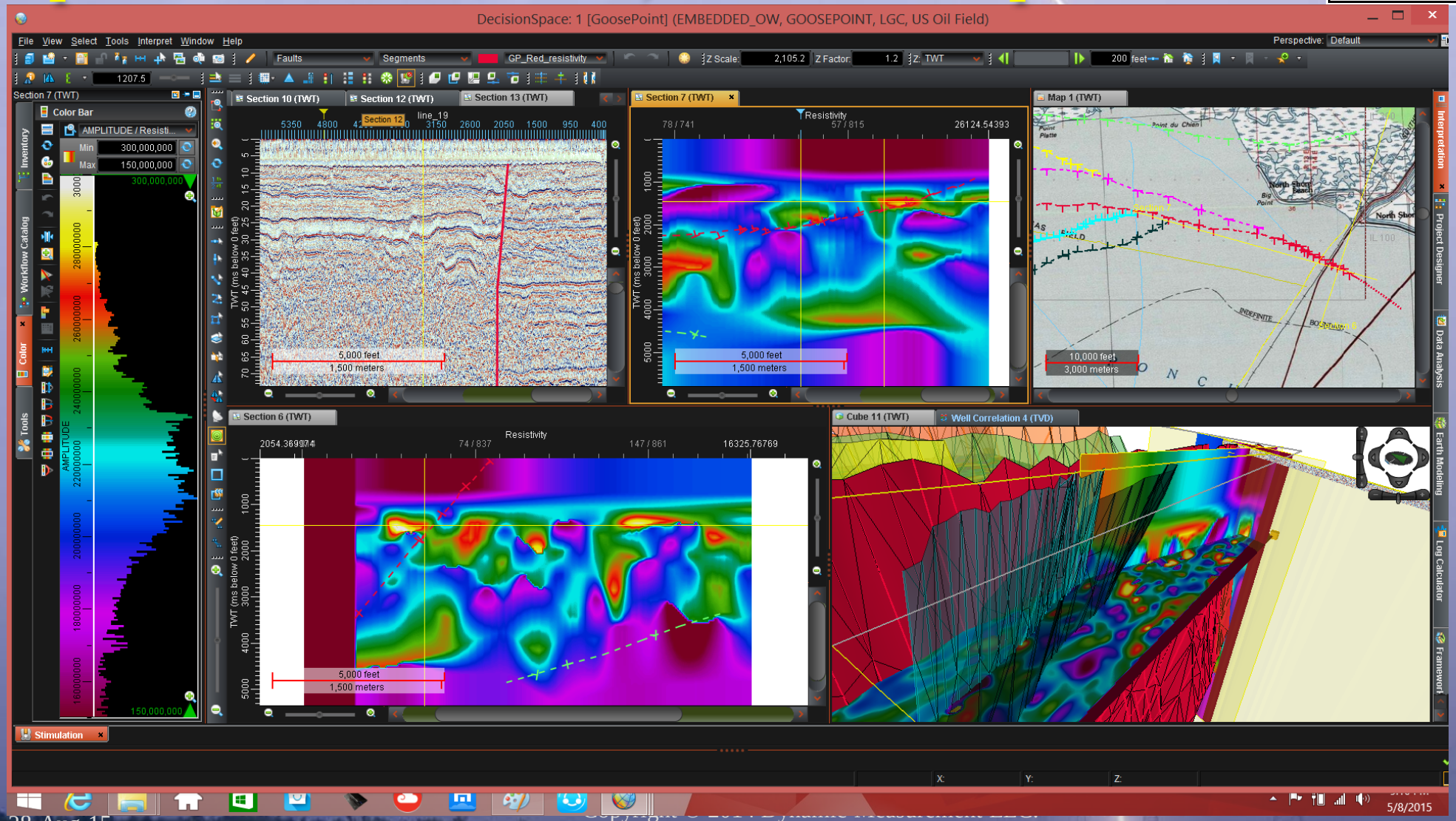

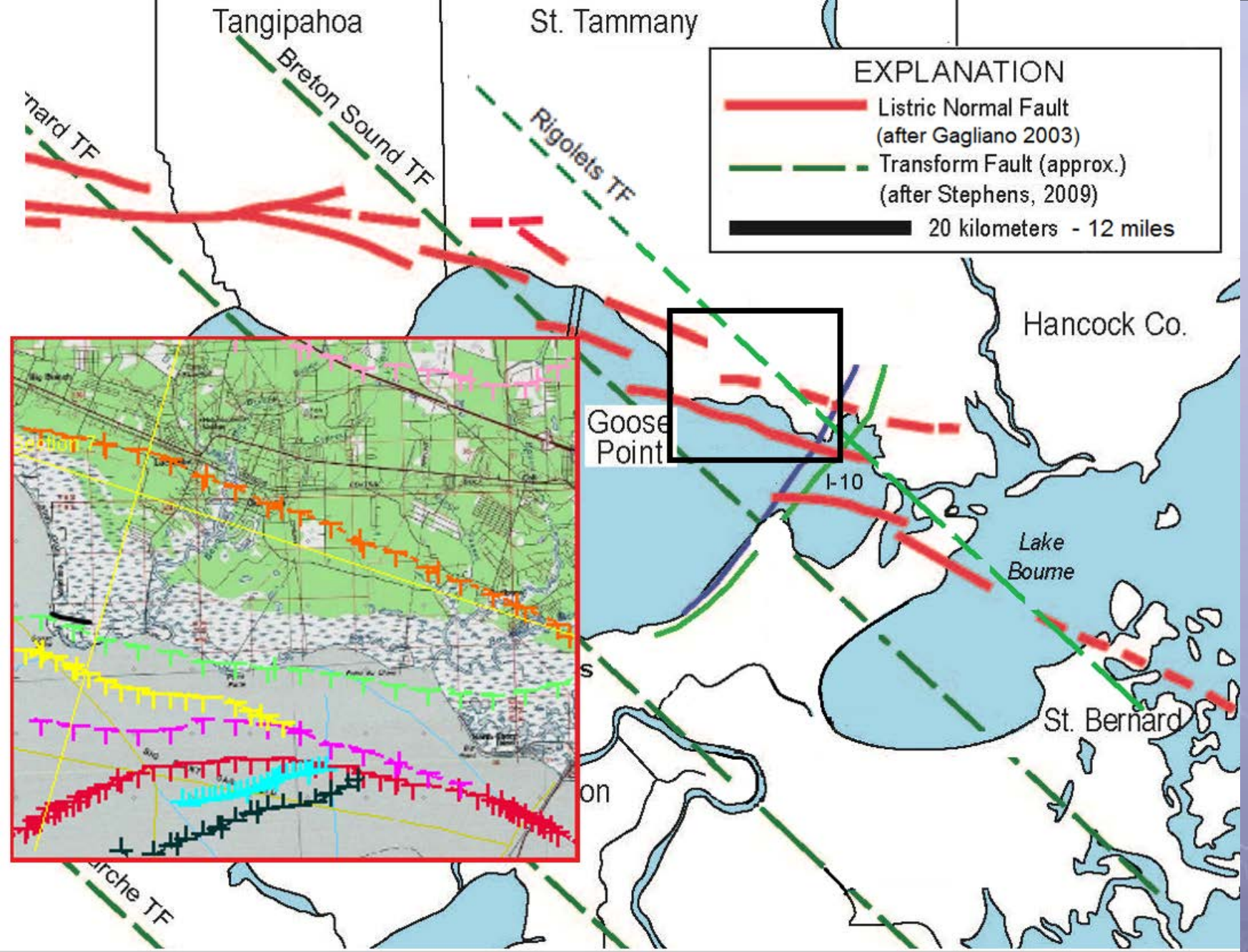

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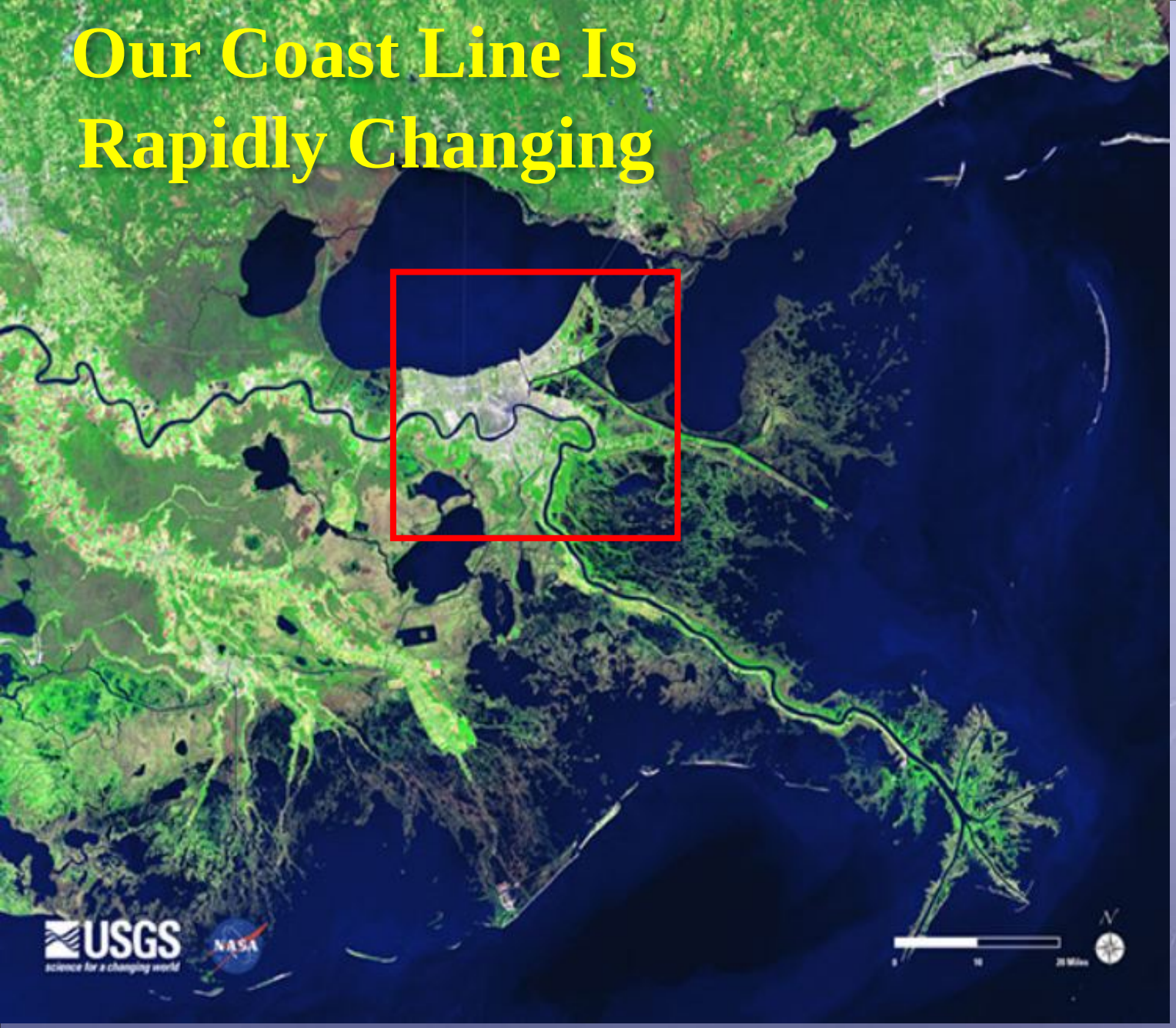
Regional interpretation integrates:

- sparker seismic
- core data
- well data
- surface fault offsets
- LIDAR

into a lightning data framework

Our Coast Line Is Rapidly Changing



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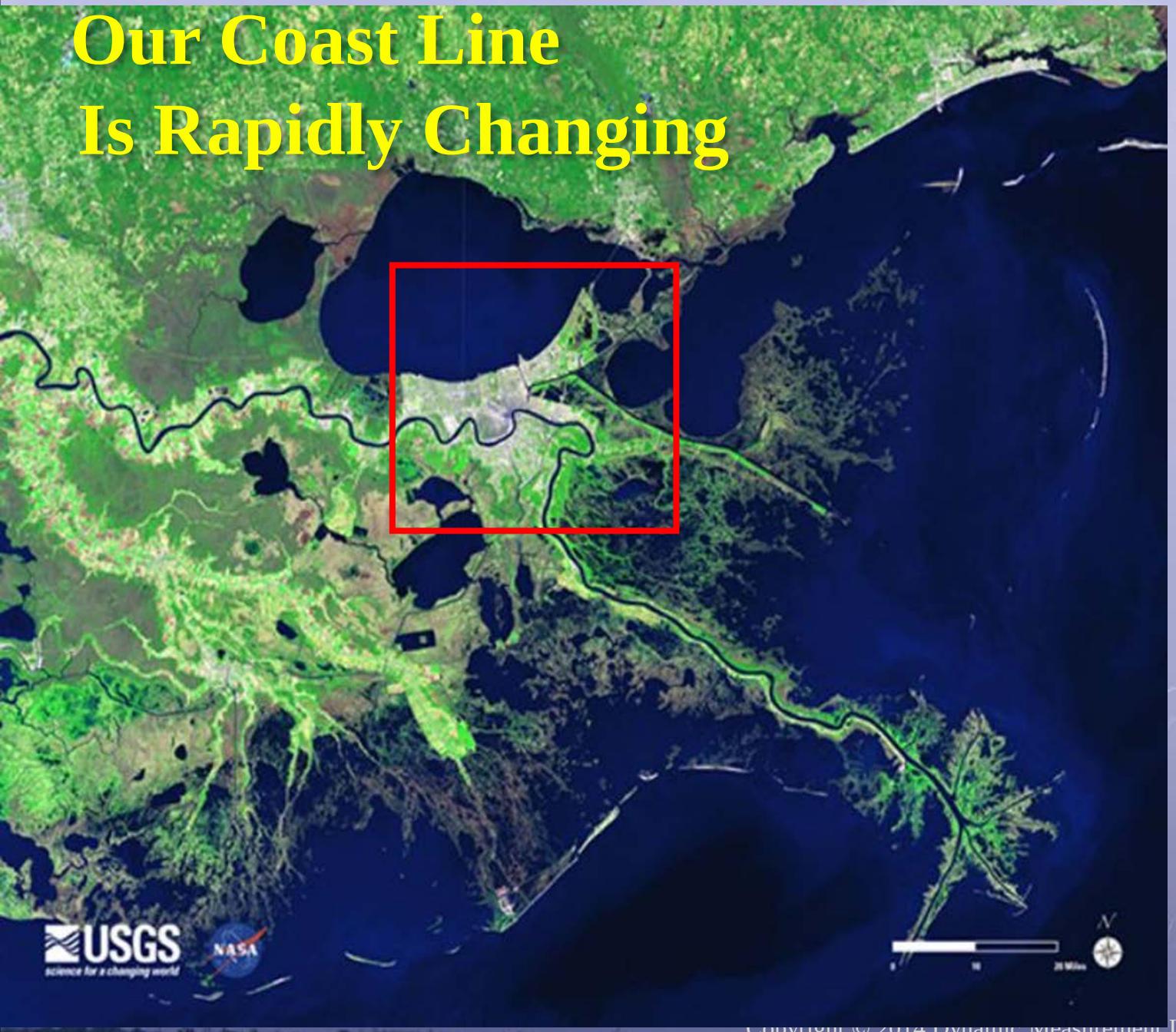
This red box is about 860 sq. miles.

Can't shoot seismic over a major metro area … Marsh 3-D seismic average cost to shoot is $120,000+/- per sq. mi. !

Our Coast Line Is Rapidly Changing



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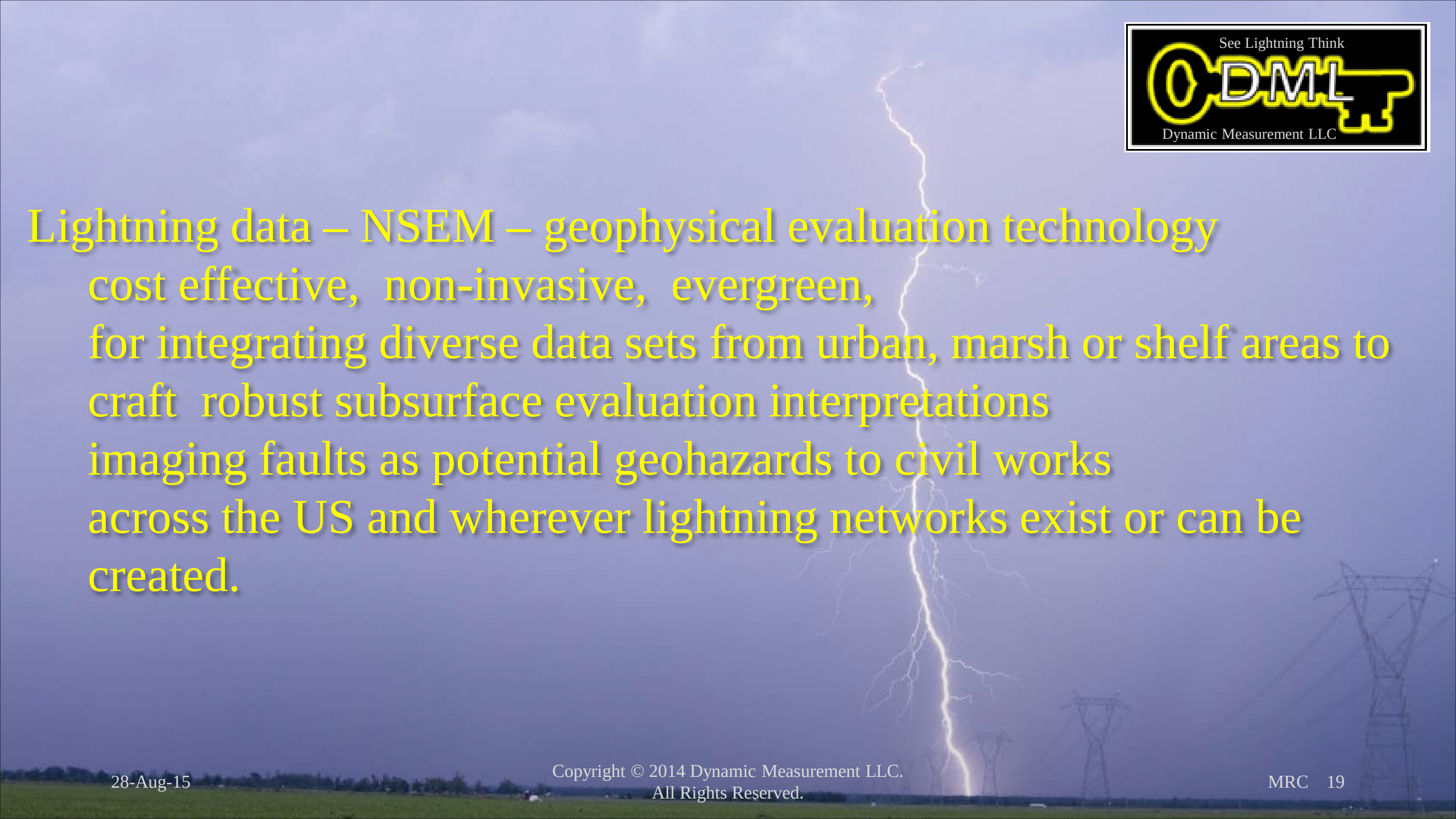
Lightning data - Already collected & increasing daily

Processed and delivered in about 2 months

Costs less than 2 squares of seismic data.

Conclusion



Lightning data – NSEM – geophysical evaluation technology

cost effective, non-invasive, evergreen,

for integrating diverse data sets from urban, marsh or shelf areas to craft robust subsurface evaluation interpretations

imaging faults as potential geohazards to civil works

across the US and wherever lightning networks exist or can be created.

Thank you for the opportunity to present our new geophysical lightning data - NSEM - to the Mississippi River Commission

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