Remote Imaging and Lightning analysis

left panel

Abstract

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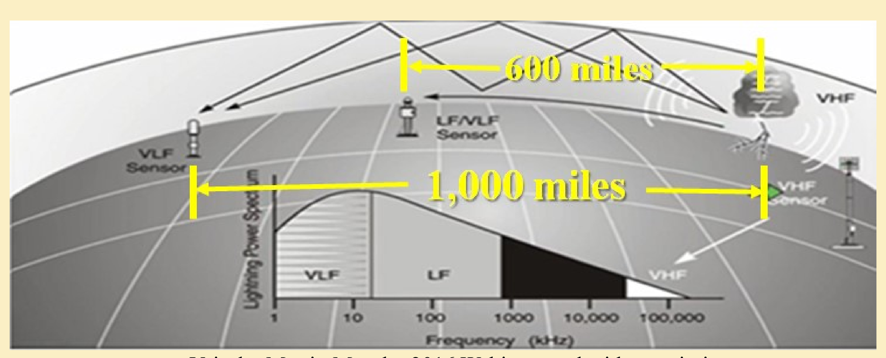
Lighting analysis is based on triangulating each lighting strike location and measuring time and electrical characteristics of each lightning strike by 5-30 sensors. These sensors can be 600+ miles away, or half the distance of a low-Earth orbit satellite. Lightning analysis is remote imaging too. The NSEM (Natural Sourced Electromagnetic Method) is based on passive remote sensing of the most powerful natural electromagnetic pulses on plant Earth. Sensors have been measuring lightning strikes since 1983, before widespread adoption of workstation technologies. Passive lightning strike measurement technology was initially developed for meteorological research by Dr. Richard Orville (https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-89-2-180). The data were quickly adopted by insurance companies, who did not want to pay claims on damages not caused by lightning. This business driver resulted in the privatization and commercialization of the NLDN about 20 year ago (National Lightning Detection Network: https://www.vaisala.com/en/products/data-subscriptions-and-reports/data-sets/nldn), and about six years ago the GLD-360 (Global Lightning Database – 360: https://www.vaisala.com/en/products/data-subscriptions-and-reports/data-sets/gld360). The primary commercial basis for these databases is insurance, safety, and meteorology (including television weather reporting of lightning storm locations).

Geophysical Service Technologies

Discipline	Technique	Source	Receiver	Power	Remote
PotentialFields	Gravity	Passive	Required	High	Some
PotentialFields	Magnetics	Passive	Required	High	Yes
ElectricalMethods	D.C. Resistivity	Required	Required	Low	No
ElectricalMethods	Electrical Resistivity Tomography (ERT)	Required	Required	Low	No
ElectricalMethods	Induced Polarization (IP)	Required	Required	Low	No
ElectricalMethods	Time-Domain IP	Required	Required	Low	No
ElectricalMethods	Magnetotellurics (MT)	Passive	Required	Low	No
ElectricalMethods	Audio-Frequency MT (AMT)	Passive	Required	Low	No
ElectricalMethods	Controlled Source Electromagnetics (CSEM)	Required	Required	Medium	No
ElectricalMethods	Transient Electromagnetic Time-Domain EM (TEM)	Required	Required	Low	No
ElectricalMethods	Controlled Source Audio Magnetotelluric (CSAMT) techniques	Required	Required	Low	No
ElectricalMethods	Frequency-Domain EM Induction	Required	Required	Low	No
ElectricalMethods	AquaTrack (leak detection at dams, mines, etc.)	Required	Required	Low	No
ElectricalMethods	Borehole Techniques like Self-Potential (SP)	Passive	Required	Low	No
ElectricalMethods	Ground Penetrating Radar (GPR)	Required	Required	Low	No
ElectricalMethods	Very Low Frequency Methods (VLF)	Required	Required	Medium	No
ElectricalMethods	High-Frequency Techniques (radar, etc.)	Required	Required	Low	No
ElectricalMethods	Airborne Electromagnetic Systems	Required	Required	Low	No
ElectricalMethods	Tipper	Passive	Required	Low	Some
ElectroSeis	ElectroSeis	Passive	Required	Low	No
Seismic	Micro-Seismic	Required	Required	Low	No
Seismic	Earthquake Seismology	Passive	Required	High	Yes
Seismic	Refraction Seismic	Required	Required	Medium	No
Seismic	Reflection Seismic	Required	Required	Medium	No
Satellite	Spatial, Spectral, Temporal, & Geometric Resolution	Passive	Database	Low	Yes
Satellite	Radiometric Resolution: Thermal, Reflectance, Elevation	Passive	Database	Low	Yes
Lightning	National Lightning Detection Network (NLDN)	Passive	Database	High	Yes
Lightning	Global Lightning Database (GLD-360)	Passive	Database	High	Yes

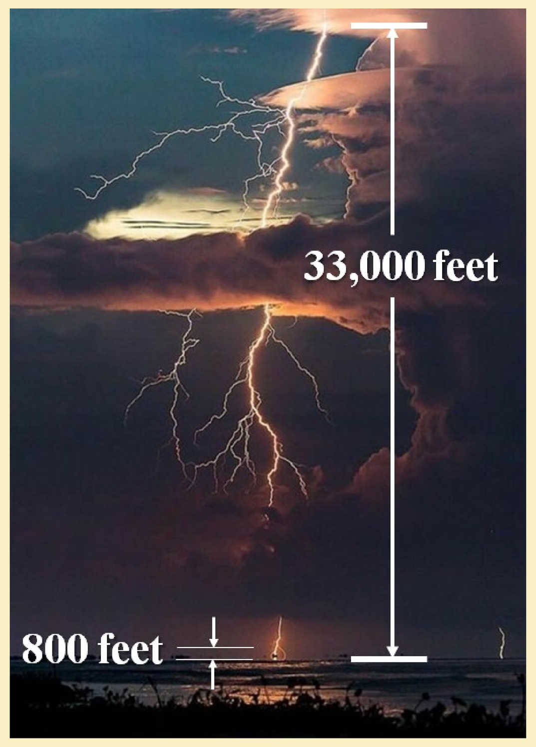
Remote Imaging Geophysical Service Technologies

Discipline	Technique	Source	Receiver	Power	Remote
Potential Fields	Gravity	260 feet (80 m)	Ground, Helicopter, or Satellite	High	Some
Potential Fields	Magnetics	4,000 ft (1200 m)	Airplane or Satellite	High	Yes
Electrical Methods	Tipper (powered by lightning)	Chile-SLC	Ground or Helicopter	Low	Some
Seismic	Earthquake Seismology	Chile-SLC	Remote Seismographs	High	Yes
Satellite	Spatial, Spectral, Temporal, & Geometric Resolution	100-22,000 miles	Low, Medium, Geocentric Orbits	Low	Yes
Satellite	Radiometric Resolution: Thermal, Reflectance, Elevation	160-35,000 kilometers	Low, Medium, Geocentric Orbits	Low	Yes
Lightning	National Lightning Detection Network (NLDN)	Vertically 800-33,000 ft	Horizontally <600 miles (<965 km)	High	Yes
Lightning	Global Lightning Database (GLD-360)	Vertically 0.25-10 km	Horizontally <6,000 miles (<9,650 km)	High	Yes

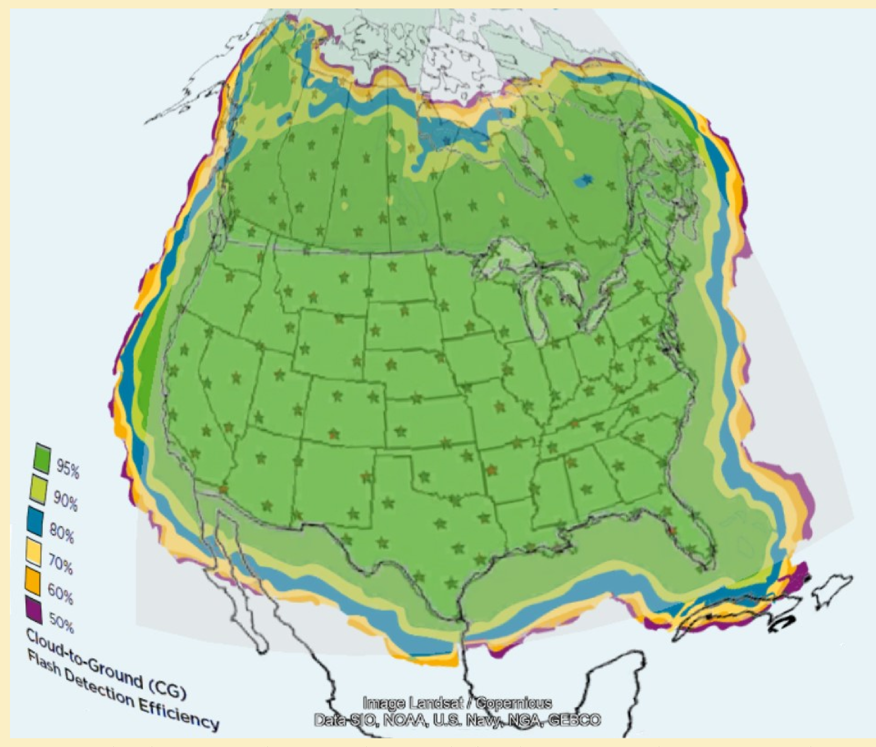


Vaisala: Martin Murphy 2016 Webinar used with permission

Geophysical Passive Source and Permanent Receivers



Long Vertical Energy Source



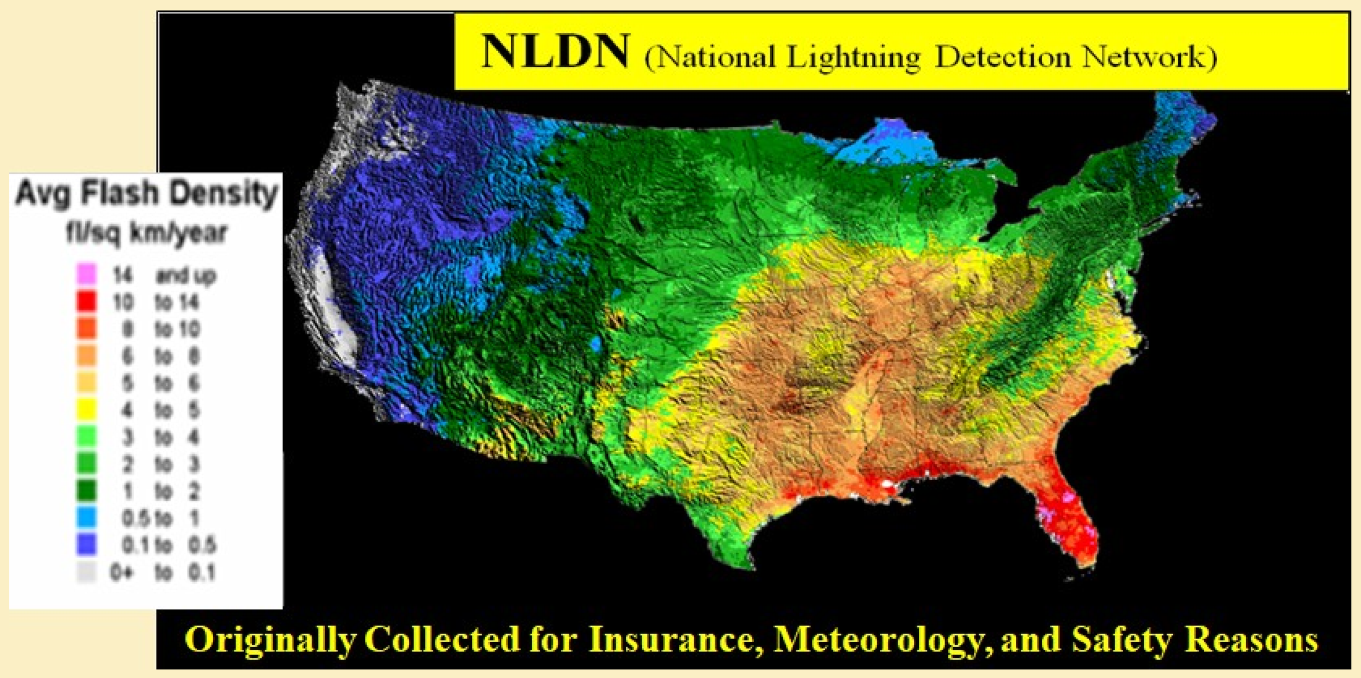
Vaisala's North American Lightning Detection Network

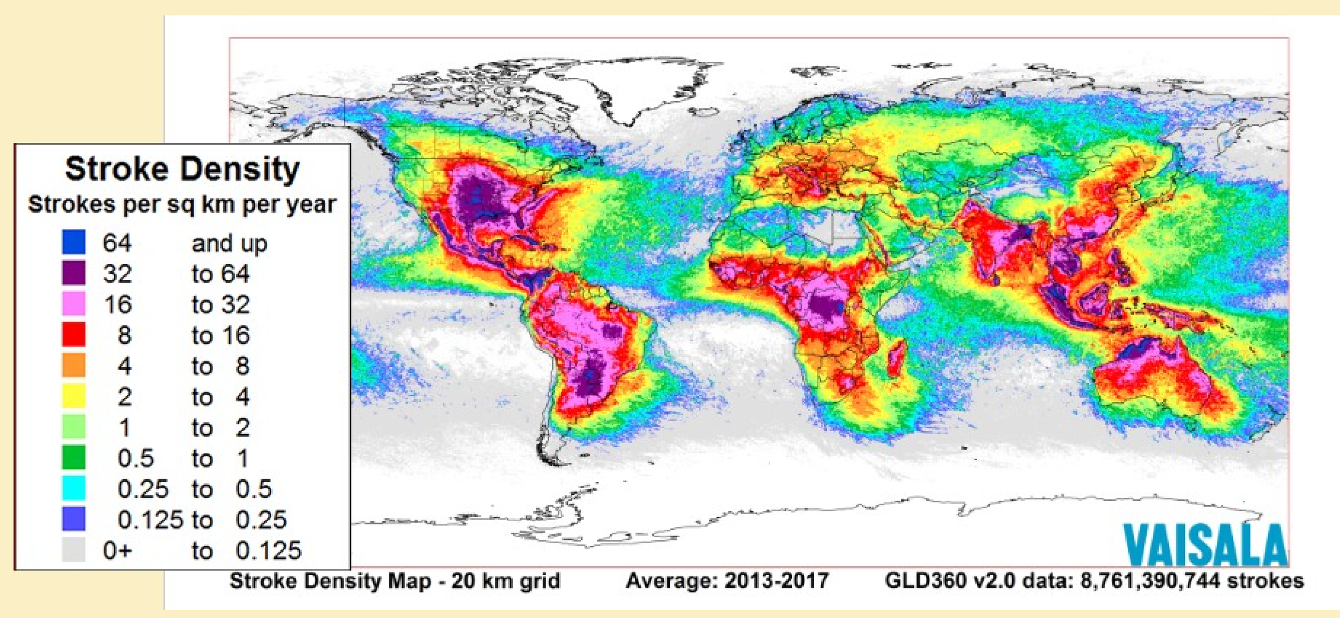
In Texas
12-24 Sensors record each Lightning Strike

Location Accuracy:
150-600 feet

Fault Accuracy:
30-100 feet

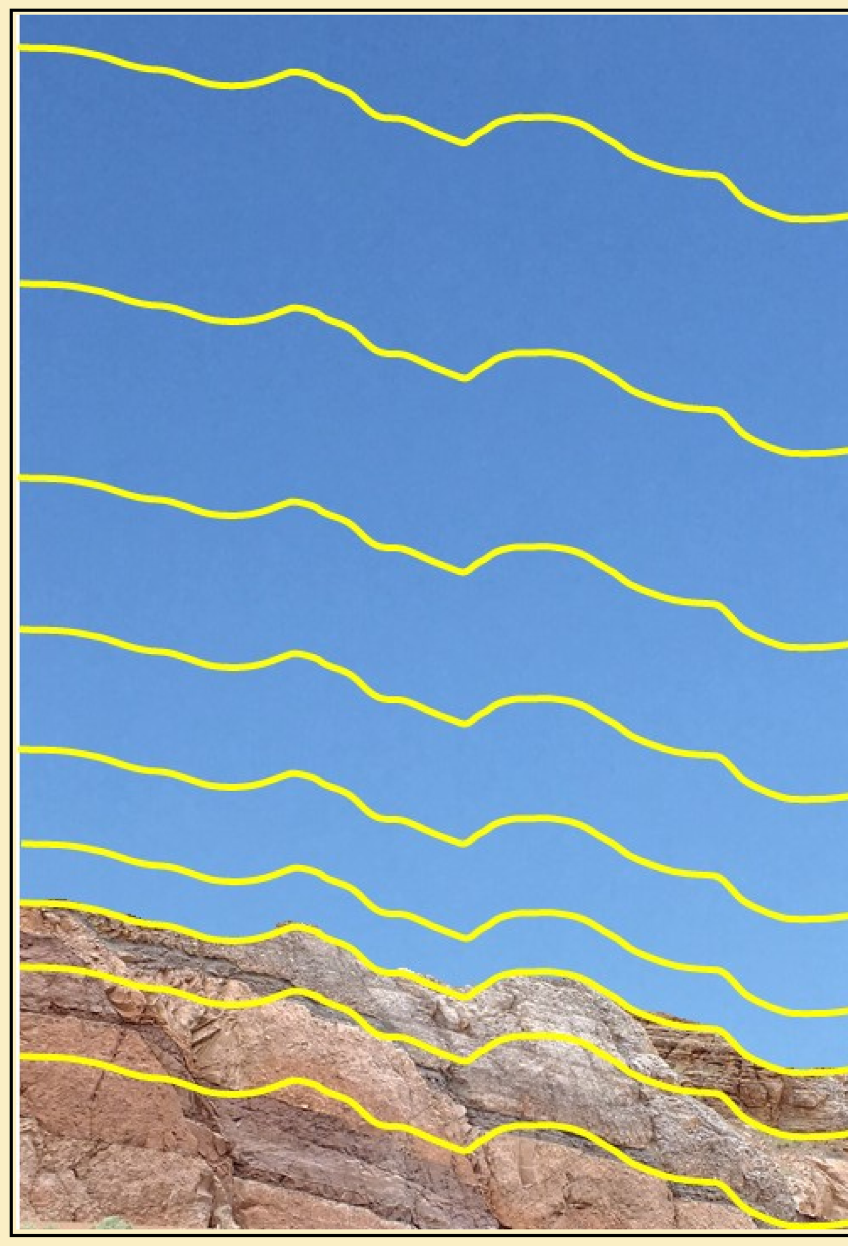
Exclusive License to Vaisala's Lightning Data Bases for Natural Resource Exploration





Fulgurites in The University of Nevada at Reno Museum

Lightning skin-depth is not limited to the length of melted sand

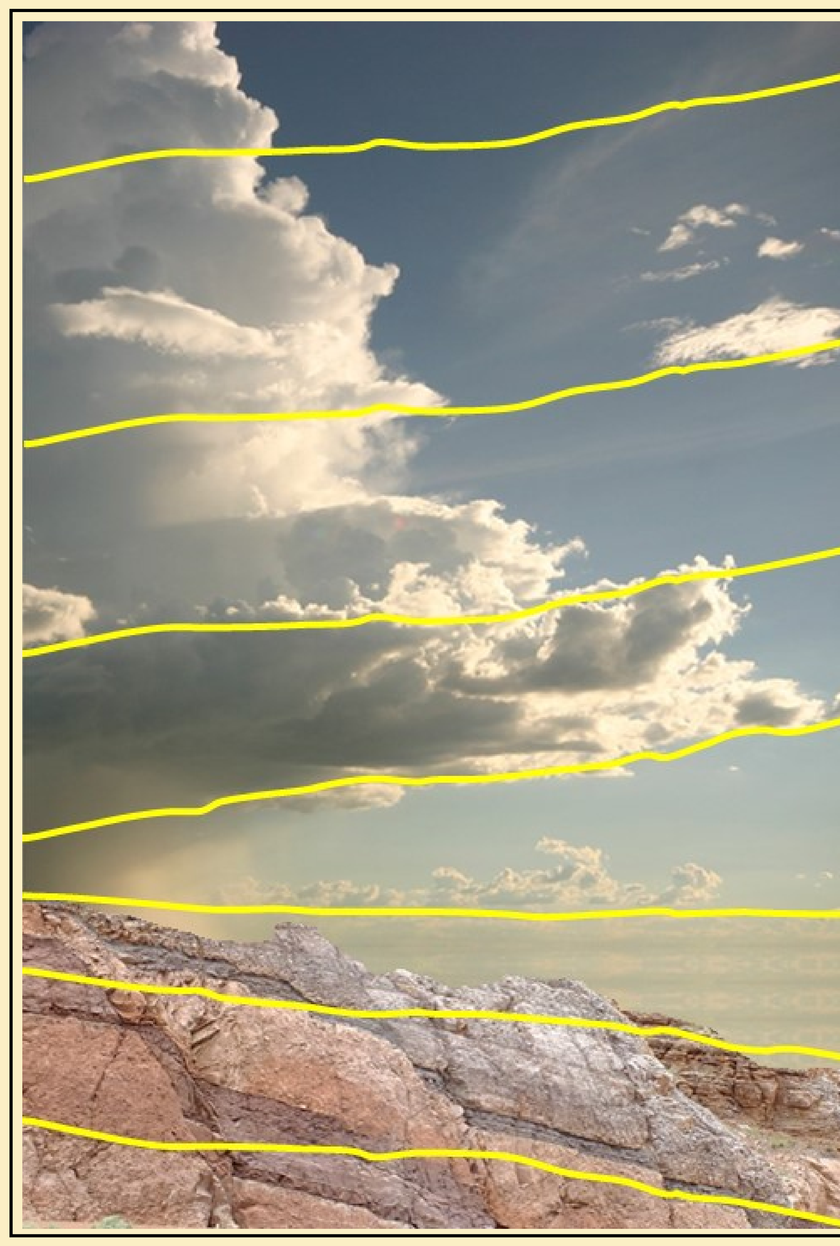


On a Clear Day the Earth's Surface is an Equipotential Surface

Telluric Currents (Earth Currents) do not change quickly, because geology does not change over short periods of time.

Atmospheric Currents constantly change, especially with each new electrical storm.

As Atmospheric Currents change, the change induces changes in Telluric Currents.



Electrical Charge Builds Up in the Atmosphere over Hours, Minutes, and Microseconds

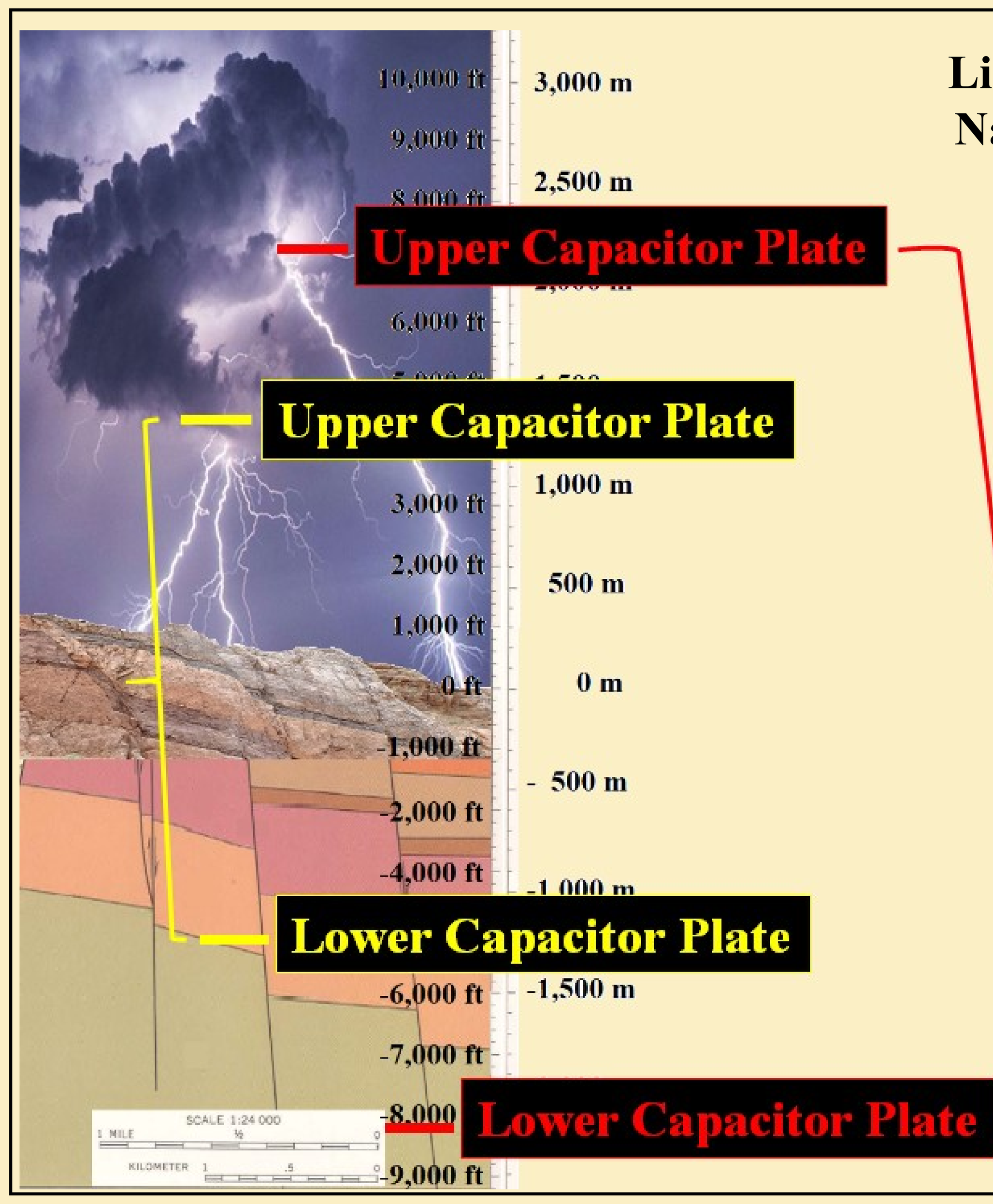
The earth's electromagnetic half-space mirrors the atmospheric electromagnetic half-space as wind currents modify thundercloud distribution.

Signals with a period of 24 hz can have skin depths of 375-500 mi (600-800 km).

Lightning Strokes last microseconds, and build up over tens of milliseconds, which provides skin depths reaching the Mohorovičić Discontinuity.

Lightning is a key charge of telluric currents.

Lighting is a Large Natural Capacitor



Key Assumptions:

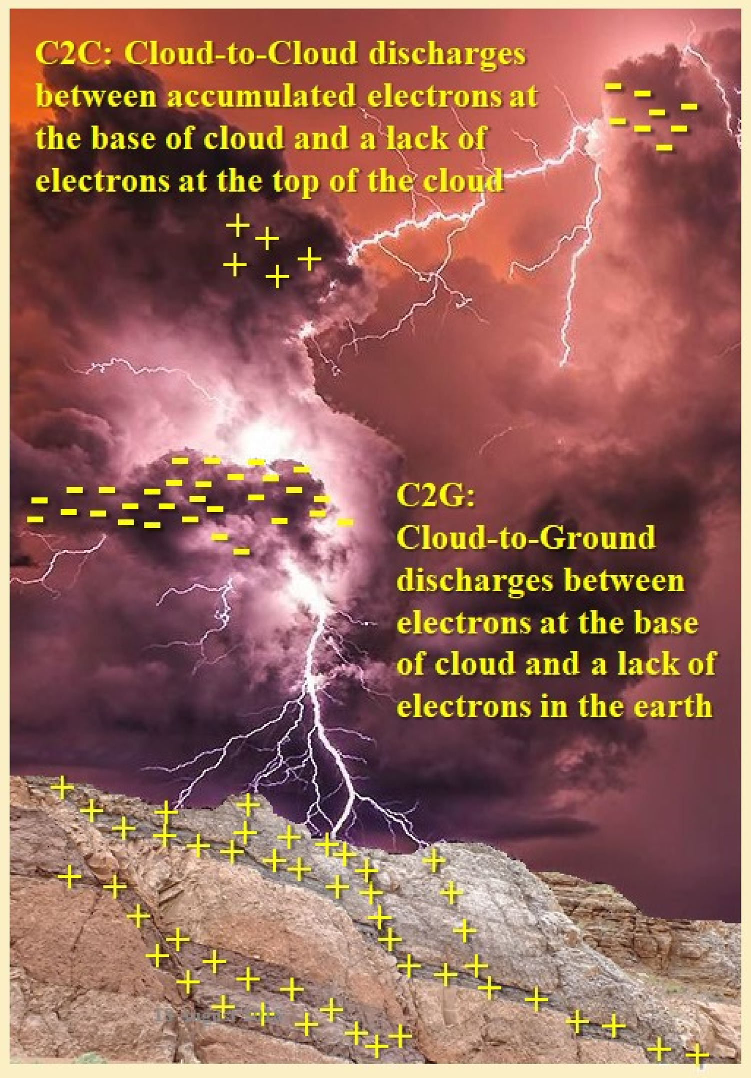
1. Lightning occurs when there is sufficient charge to bridge the atmospheric capacitor.
2. Lightning is affected by geology to a depth proportional to cloud height, as derived from Peak Current.

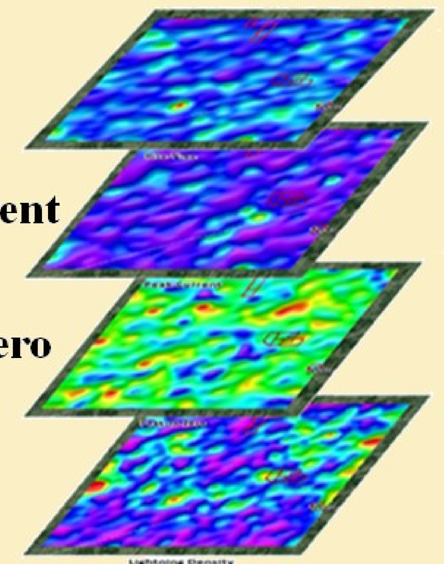
Remote Imaging and Lightning analysis

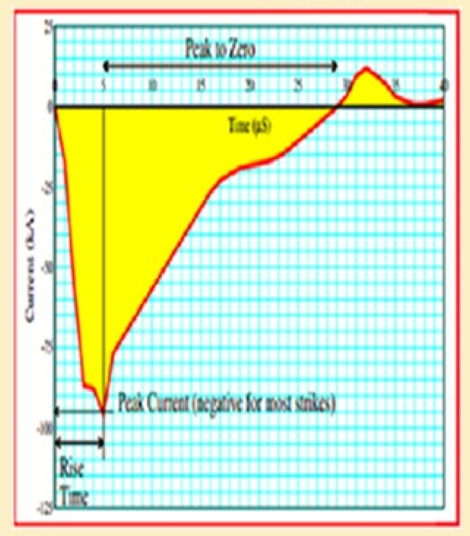
EM technologies provide linkages between electrical and magnetic earth currents, and atmospheric currents

Conductivity surveys record near surface conditions. Induction well logging tools image near boreholes. Some combination approaches image Direct Hydrocarbon Indicators (DHIs) by blending electrical signals and acoustic seismic wave responses. Some EM methods map shallow features with currents and magnetics (flow paths of water). Lightning attributes are a hybrid approach, induction at the source and fixed receivers, providing information on apparent resistivity and structure at the surface and at depth.

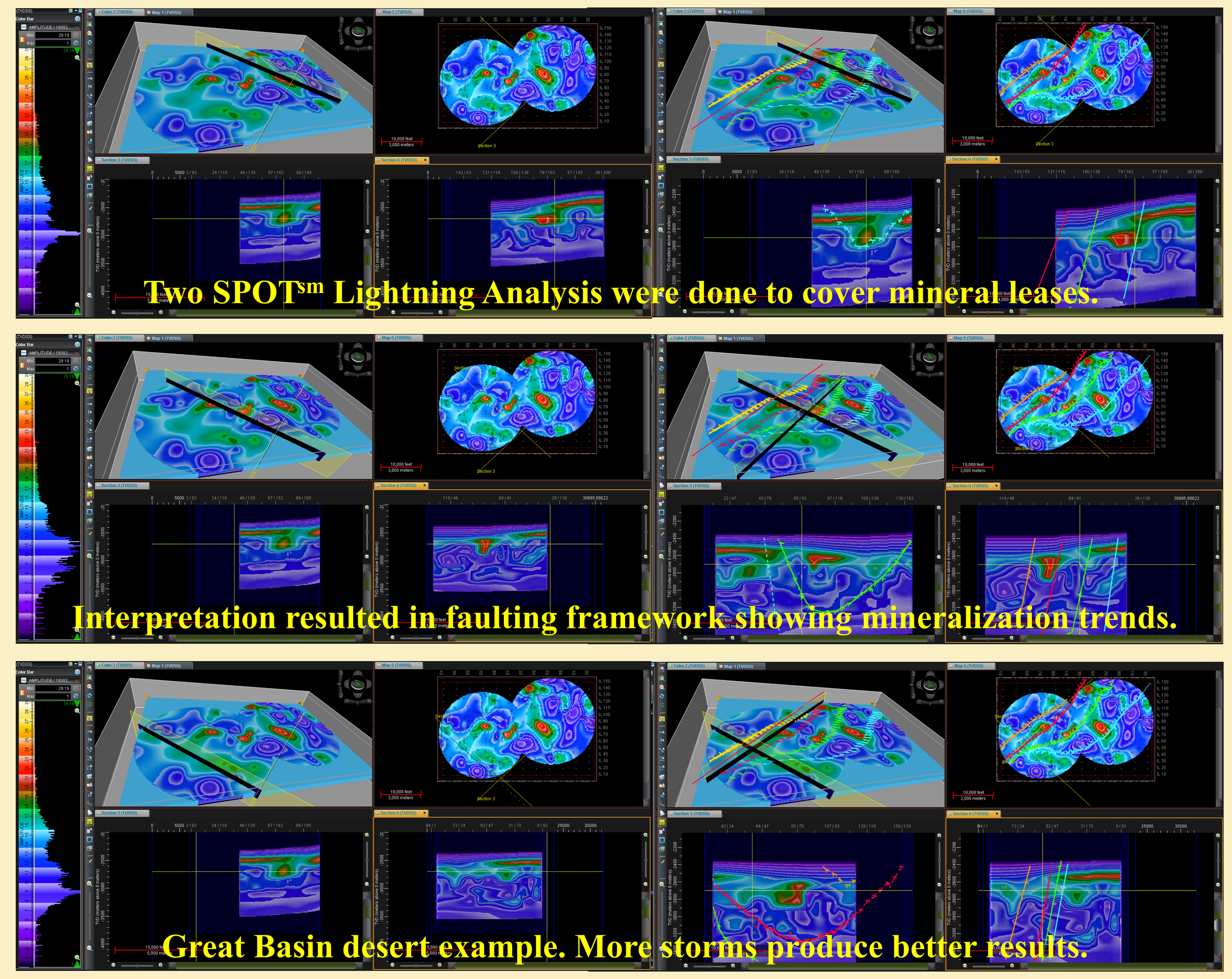
C2C & C2G Strokes Transfer Electrical Energy







North Nevada



Skin Effect

We've all seen fulgurites – melted silica from lightning strikes that can extend a few tens of meters into the ground. However, there is more to this earth/atmosphere relationship.

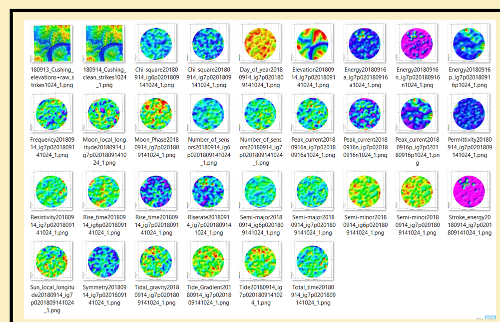
Meteorologists:
- See lightning as an atmospheric event with little interaction with geology.

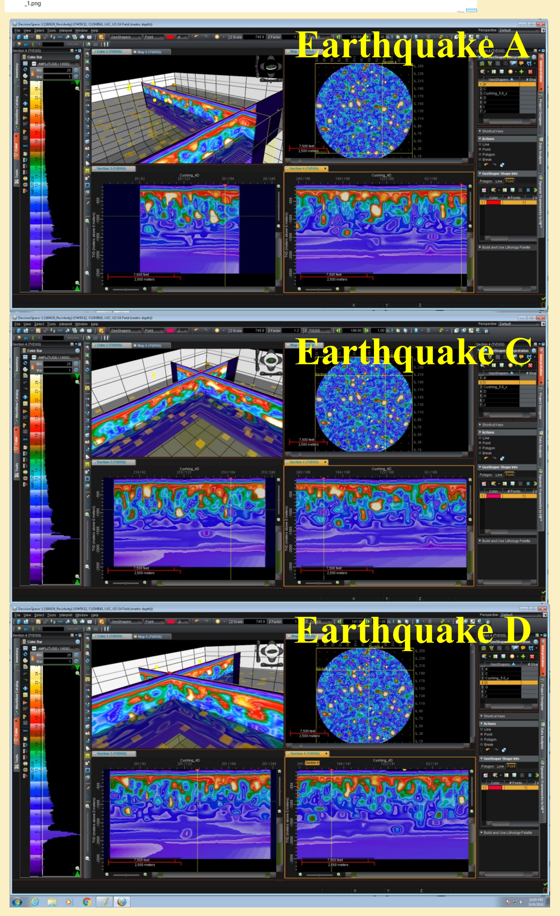
Geophysicists:
- See lightning as a primary charging source of telluric (earth) currents.
- Skin Effect is the depth the current is reduced to 1/e (~0.37 of surface current).

$$\delta = 503\sqrt{\frac{\rho}{\mu_r f}}$$

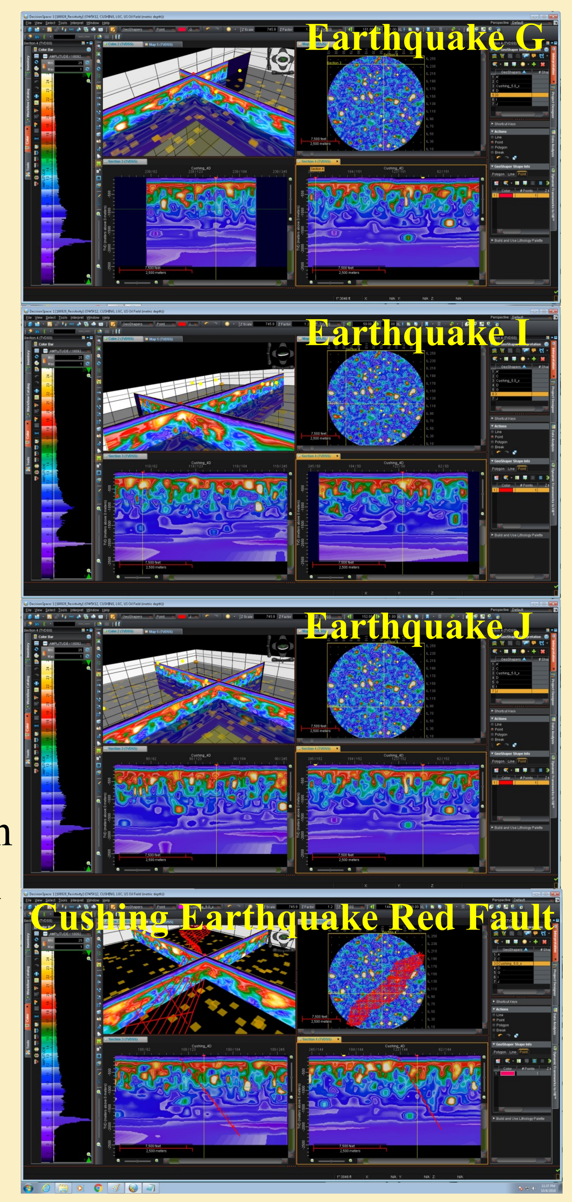
- Given δ is skin depth in meters, μ_r is relative magnetic permeability of the medium, ρ is the resistivity of the medium in ohm-meters, and f is the frequency of the current in kilo-hertz. 503 is the product of constants.
- At 2,000 meters current density is still about 2% of near-surface value.
- A 20 kA Peak Current strike effects an area of 0.01 m^2, with a current density of 2,000 kA/m^2. At 2% of the initial value, it will still be 40,000 A/m^2. Lightning, like current along a wire, induces a magnetic field, which could interact with telluric currents to as much as 12,000 m/40,000 foot depths.
- Telluric currents likely play a significant role in where lightning strikes.

Oklahoma

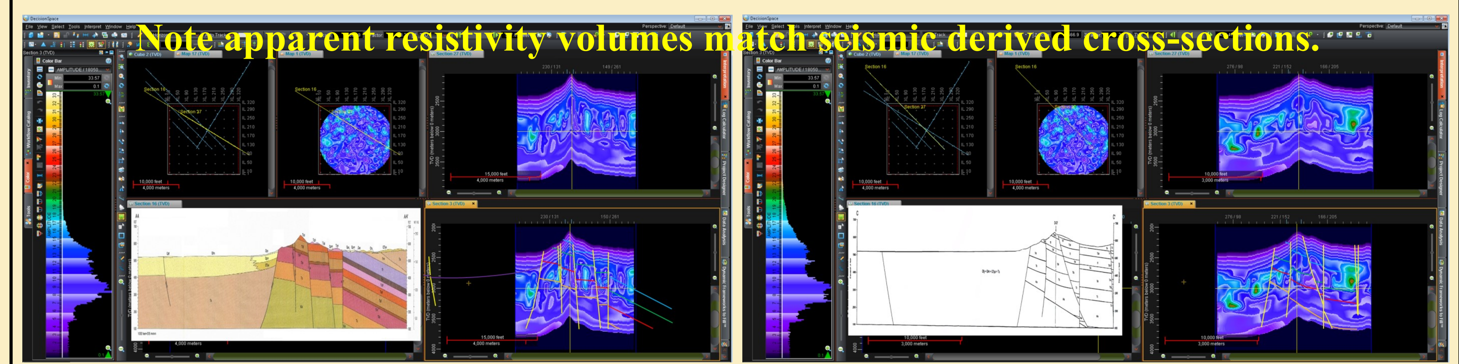




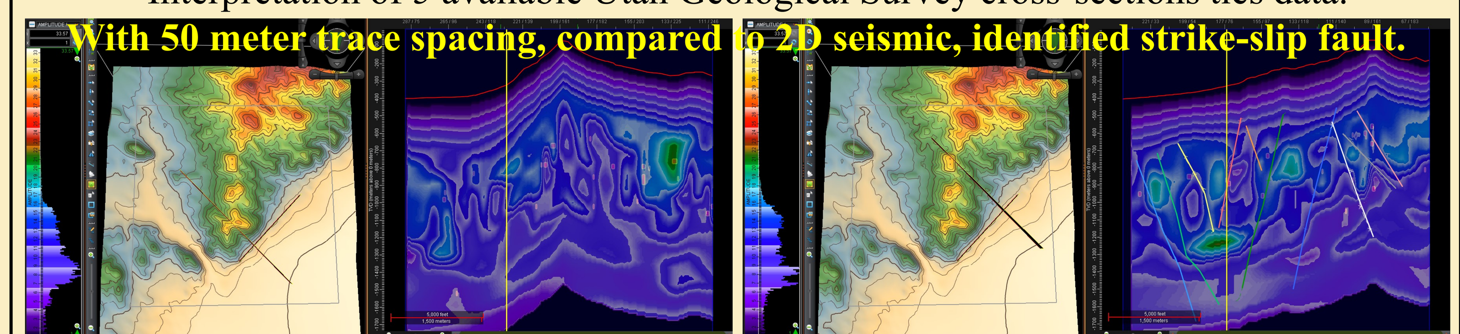
Dynamic just started this joint project with the Oklahoma Geological Survey to study time-lapse apparent resistivity and other lightning attributes to see if there is a relationship with natural and with waste water injection induced earthquakes.



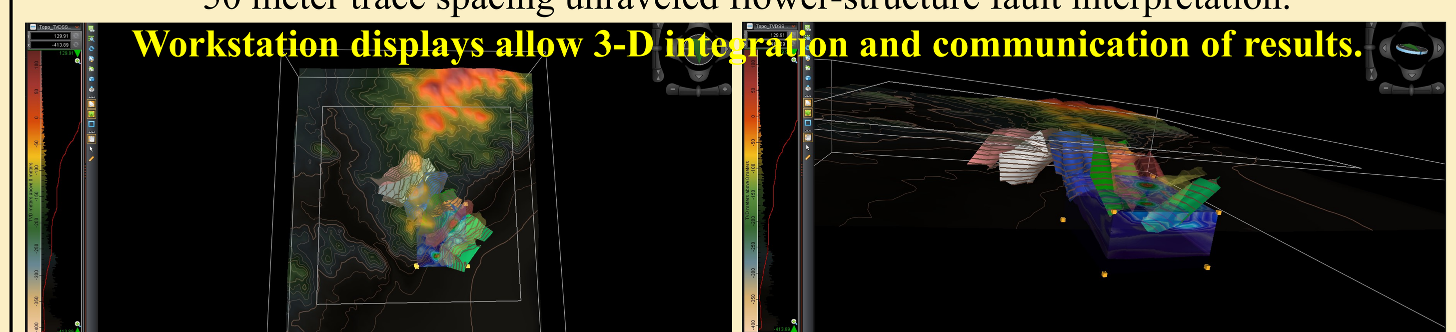
South Utah



Interpretation of 5 available Utah Geological Survey cross-sections ties data.

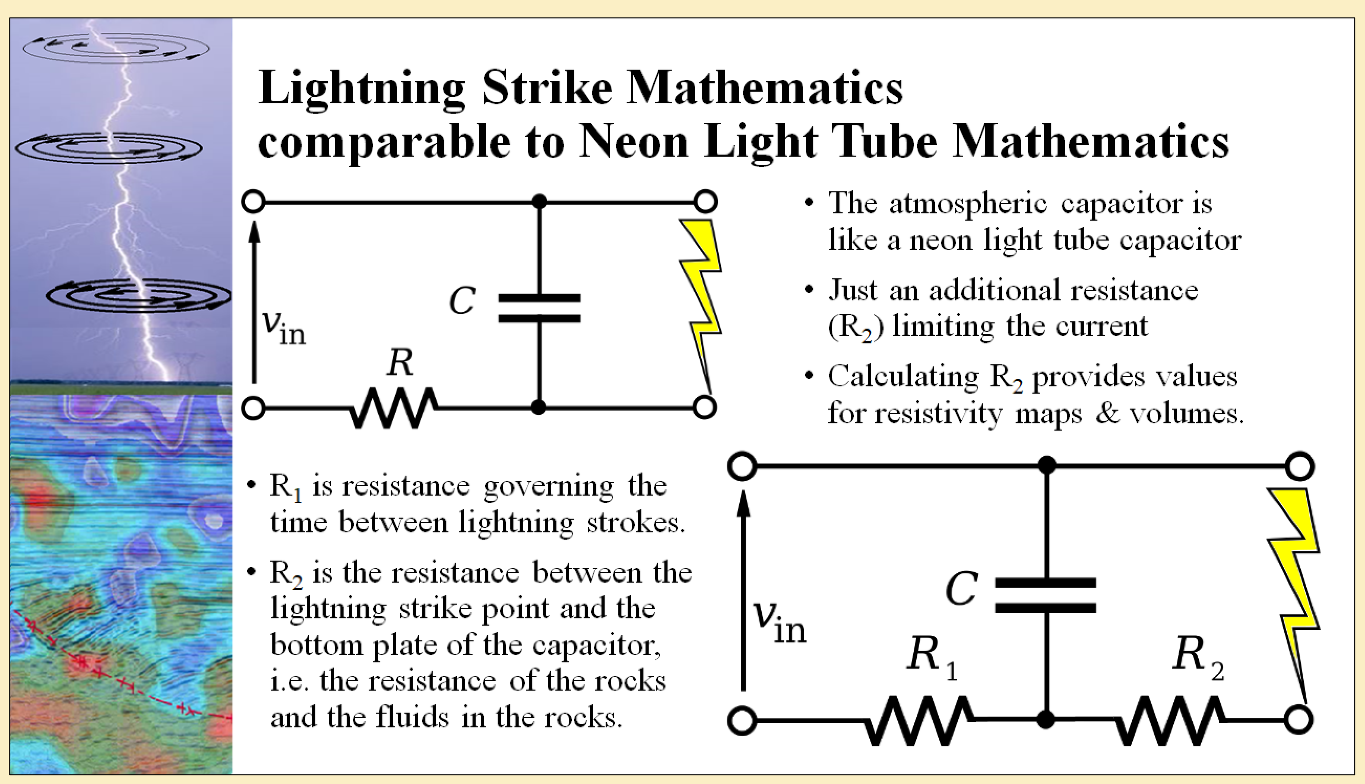


50 meter trace spacing unraveled flower-structure fault interpretation.



Derived Fault Framework easily evaluated with 3-D displays.

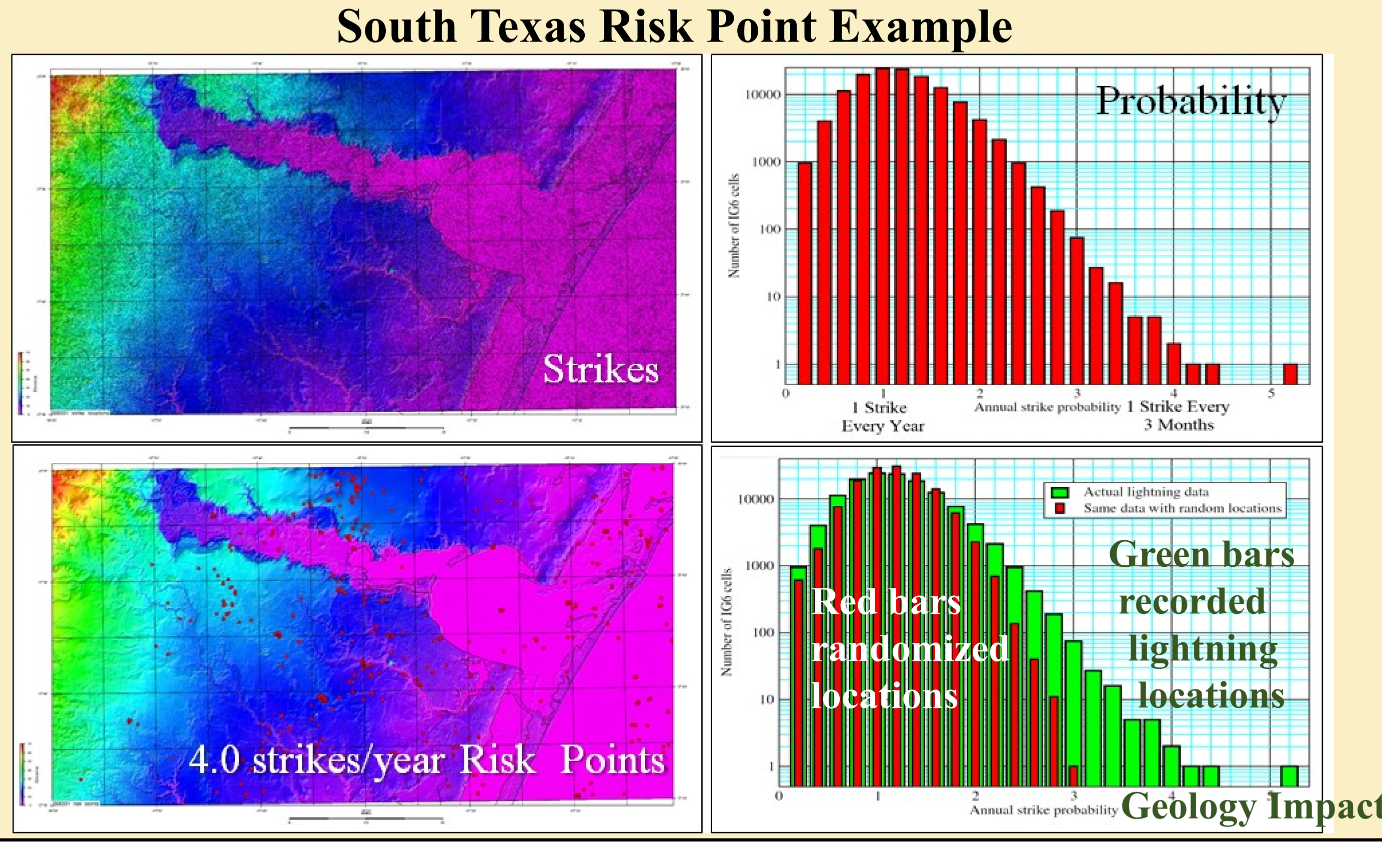
Lightning Strike Math Compares to Neon Light Tube Mathematics



R_2 is apparent resistivity in the subsurface. Dynamic calculates this resistance at the surface, for apparent resistivity maps, and at depth, based on the Peak Current of the lightning strike. Hundreds to millions of these values are then interpolated to create apparent resistivity volumes, which have been shown to tie resistivity logs in a South Texas project.

1 Pending and 2 Issued U.S. Patents and 4 Prepared Submissions

South Texas Risk Point Example



Quicker, safer, & less expensive than other geophysical data types. No boots on the ground to do a lightning analysis.

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Conclusions

- Lighting strike locations are impacted by geology.
- Lightning strikes clusters are predictable from historical data.
- Algorithms are available to predict the probability of lightning strikes – Risk Points – within specified cells, anywhere.
- Randomizing lightning strike cell locations create a completely different distribution than raw data. Difference in these distributions is due to geologic influences on locations.
- Skin depth of lightning electrical energy is tied to the build-up of storms and charges telluric currents at exploration depths.
- Rock properties, apparent resistivity and apparent permittivity, can be calculated from lightning strike databases.
- Distribution of rock properties and lightning attributes can be displayed as maps and as volumes, interpolated to match existing or planned geophysical surveys, filling-the-gaps.
- These maps and volumes allow the creation of geotechnical frameworks – faulting & resistivity anomalies & sweetspots.