# Lightning data – the new EM "seismic" data

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## Abstract

Lightning data base volume sizes, processing, and interpretation processes are a previously unrecognized new type of electromagnetic (EM) "seismic" data. There are databases with the location of billions of lightning strikes, along with the basic data defining the waveform of lightning strikes. These data are available to data mine and to integrate with other exploration data. Lightning data has been collected for decades for insurance, meteorological, and safety reasons (Orville, 2008). Geophysicists have indirectly used lightning data as an electrical source for magnetotellurics (MT) since the 1950's (Cagniard, 1953).

Learning about the NLDN (National Lightning Detection Network) and equivalent worldwide lightning data bases, we recognized these large lightning databases as a new geophysical data type. The data is similar to gravity and magnetic and electromagnetic data, in that it derives from natural potential field activity. As with the other potential field data, it has differences and similarities in acquisition, processing, interpretation, and integration compared to seismic data.

### Acquisition

Lightning data comes from measuring lightning strike locations and attributes, much as seismic data comes from measuring seismic events and attributes. Microseismic (Duncan and Eisner, 2010) and earthquake seismology monitor and passively measure random seismic events. Lightning sensors monitor and passively measure natural electromagnetic events. The location of lightning strikes is controlled by deep telluric currents, despite the shallow skin penetration of the high frequency component of lightning strikes. Reflection and refraction seismic use artificial seismic sources. We see possible futures where artificial lightning strikes will be an EM source for exploration surveys.

### Processing

Both passive seismic and lightning data are processed by deriving source locations and data attributes. Large databases are generated as instruments monitor and measure passive events. Like reflection and refraction seismic data, lightning databases have redundancy, which can be "stacked" to improve the signal-to-noise of measured attributes. Data mining lightning data bases has similarities to curvature and wavelet seismic attribute processing and studies.

### Interpretation

Interpretation of passive seismic and lighting data starts with three-dimensional displays of source locations, and searching for patterns which relate to subsurface geology. The primary patterns in both data types appear to be related to faulting and fracture orientations. Interpretation of reflection seismic data includes seismic attribute maps, which have a direct analog with lightning attribute maps.

### Integration

A dozen preliminary studies over the last five years confirm lightning strike locations are not random. These studies included integration with potential field, seismic, topography, vegetation, infrastructure, and earth tide data bases. We mapped faults, showed relationship to sediment thickness, possibly predicting seeps, and mapped anisotropy, which has the potential to differentiate between ductile and brittle shales in resource plays. We demonstrated lightning strike location are not dominantly tied to infrastructure (wells and pipelines), nor are locations primarily controlled by either topography or vegetation.

### Analog "New" EM Data Type

Controlled source electromagnetics (CSEM) has been used as an electrical exploration approach since the 1960's, both offshore (Chessman, et.al., 1987) and onshore (Keller and Frischknecht, 1967; Nabighian, 1991; Wilt, et.al., 1989). Since then CSEM has been tied to deep water exploration. Lightning data is a noise train to be removed from a CSEM study. The use of lightning data as a new geophysical data type is usually called audio magnetotellurics (AMT or AFMAG, Sheriff 2002) sourced electromagnetics.

### Future Use of Lightning Data

Based on a dozen preliminary case histories, we anticipate broad use of lighting data to explore for hydrocarbons, minerals, kimberlite pipes, geothermal energy, water, and other natural resources. Knowing the control telluric currents have on where lightning strikes occur will influence civil engineering projects, like the location of golf courses and subdivisions.

## Theory and method

Lightning is a meteorological phenomenon. However, lightning strike location and lightning strike attributes are at some level controlled by geology. Figure 1 summarizes our working theory: telluric currents, which are modified by faults, mineralization, and fluids, control lightning strike locations, shown with an example of Kimberlite pipes. Similar modifications of telluric currents occur at faults, or where there are fluids or anisotropy. This fits the fact Cloud-to Cloud lightning has been shown to travel 50 to 120 miles before determining where to become a CG strike.

Lightning data collection and processing procedures are described in meteorological literature (Murphy, et. al., 2008). Figure 2 shows typical lightning waveform. Key attributes of the waveform are the rise time (RT in microseconds), Peak Current (PC in kiloampres), and Peak-to-Zero (P2Z in microseconds). Because of the large volume of data the full waveform is typically not recorded except for scientific studies.

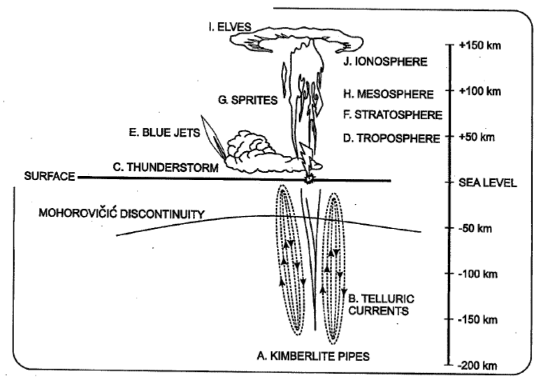


*Figure 1:* Relationships between lightning and telluric currents (Nelson, et. al., 2011)

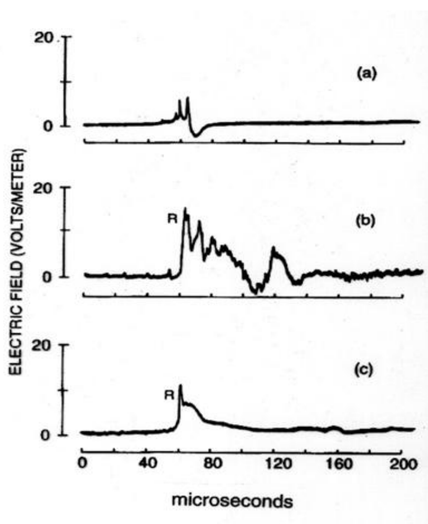


*Figure 2:* Lightning waveform: (a) cloud discharge; (b) cloud-to-ground first return stroke; (c) cloud-to-ground subsequent stroke (Krider, 1986)

## Example

An example showing spatial variation lightning density comes from Mountrail County, North Dakota. Lightning data were retrieved from the NLDN database and mapped using Landmark Graphic's SeisWork software package. Figure 3 shows a map of the Peak Current for each lightning strike occurring from 2008 through 2010 within this area. Similar spatial density variations occur for the count of the number of strikes over various time intervals, the RT, positive PC, negative PC, absolute PC, P2Z, and other mapped attributes.

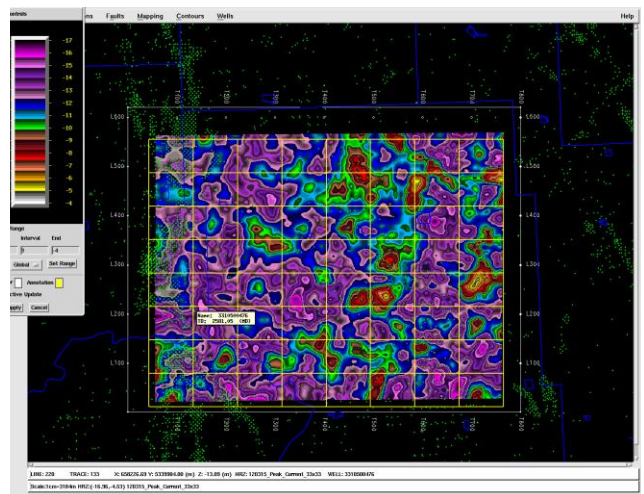

*Figure 3:* Peak Current Mountrail County, ND

One of the surprises of these initial studies was the impact of lunar tides on lightning strike density. We found 25% more lightning strikes during high lunar tide than during low lunar tides. This variation is possibly related to hydrocarbon seepage (hydrocarbons are resistive in reservoirs and highly electrostatically charged as a gas). Figure 4 shows PC spatial variations for lightning strikes occurring during high lunar tides in Mountrail County, ND.

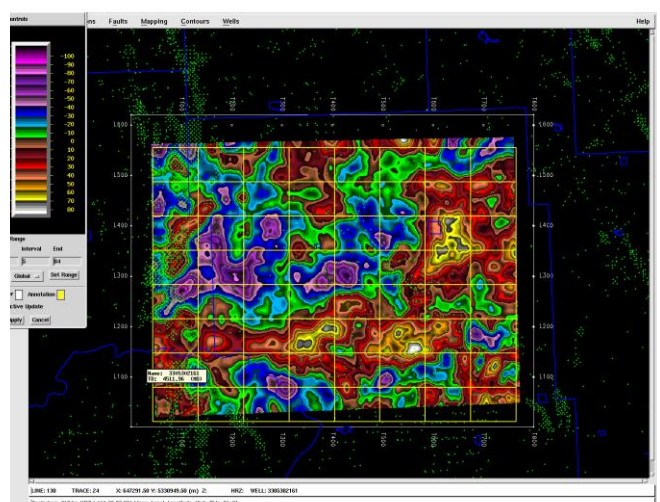

*Figure 4:* Peak current from lightning strikes occurring during high earth tide, Mountrail County, ND

## Conclusions

Lightning strike density varies spatially, and these variations are somewhat consistent over time. Data mining databases of lightning strikes provides a new geophysical data type, which can be integrated with other potential field data types and seismic data to explore for natural resources. Initial studies show correlation with geologic features like fault zones, fracture systems, sediment thickness, etc. all based on the fact lightning strikes seek conductive zones. There are many similarities between lightning and seismic data acquisition, processing, and interpretation processes.

## Acknowledgements

Data was provided by Vaisala under a license agreement with Dynamic Measurement LLC. Robert Ehrlich and Kristin Campbell did data mining tests for North Dakota, which identified and removed bias.

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