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Lightning as a Geophysical Data Type

Frequently-Asked Questions

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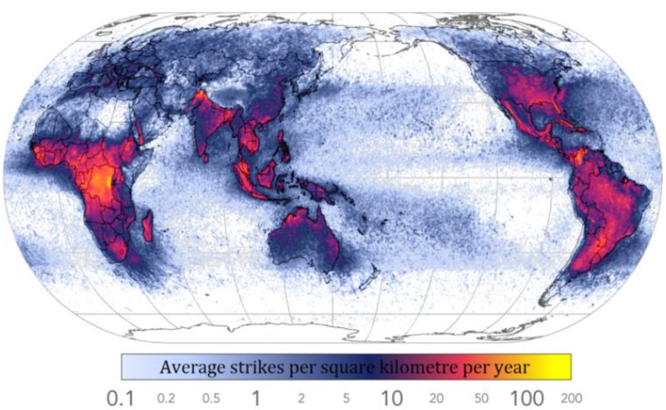
Frequently-Asked Questions

General

What causes lightning?

Lightning is a meteorological event where there is a massive electrostatic discharge between electrically charged regions with clouds or between clouds and the surface of the Earth. Lightning is tied to when warm air mixes with colder air masses, and small particles in the two air masses create a large buildup of electrostatic energy. The map below of global map of lightning strike density shows the meteorological overprint.



Does lightning strike twice in the same location?

Lightning strikes in the same place quite often. While the structure of the thunderstorm always varies, the actual location of a strike depends largely on subsurface resistivity, and to a lesser extent on surface shape, materials, infrastructure, and vegetation.

What role does Vaisala play, in lightning data?

Vaisala is the source of lightning data for Dynamic Measurement, LLC's lightning data analytics offering. Per Vaisala's annual report: Vaisala is a global leader in environmental and industrial measurement. Building on 78 years of experience, Vaisala contributes to a better quality of life by providing a comprehensive range of innovative observation and measurement products and services for chosen weather-related and industrial markets. Headquartered in Finland, Vaisala employs approximately 1,500 professionals worldwide and is listed on the NASDAQ OMX Helsinki stock exchange. www.vaisala.com www.twitter.com/VaisalaGroup

How far will lightning travel cloud-to-cloud before becoming a cloud-to-ground lightning strike?

In 2011, Vaisala published that it is not uncommon for lightning to travel up to 120 miles (about 190 km) cloud to cloud before going to ground (Meteorological Technology International, May 2011, page 48, Nikki Hembury and Ron Holle).

Do lightning strikes have anything to do with natural resources?

Because lightning is affected by subsurface resistivity, it is affected by natural resources which affect resistivity. This includes materials which are resistive, like oil, gas, aquifers, and salt, as well as things which are conductive, like mineralization, brines, kimberlite pipes, and geothermal waters.

Why is data about lightning strikes recorded?

While the recording of lightning strikes was first performed by academics, the current lightning detection networks are largely financed by insurance companies, by meteorological organizations such as television broadcasters, and for safety reasons at airports and golf courses.

What is the primary factor determining where lightning goes to ground?

Geology is the primary determinant. While there is a contribution from topography, infrastructure and vegetation, the primary factors determining where cloud-to-ground lightning strikes hit is are the electrical currents in the geology.

Do lightning patterns change over time?

There is some change over time. However, the patterns are somewhat consistent over time, including lightning density and lightning attributes.

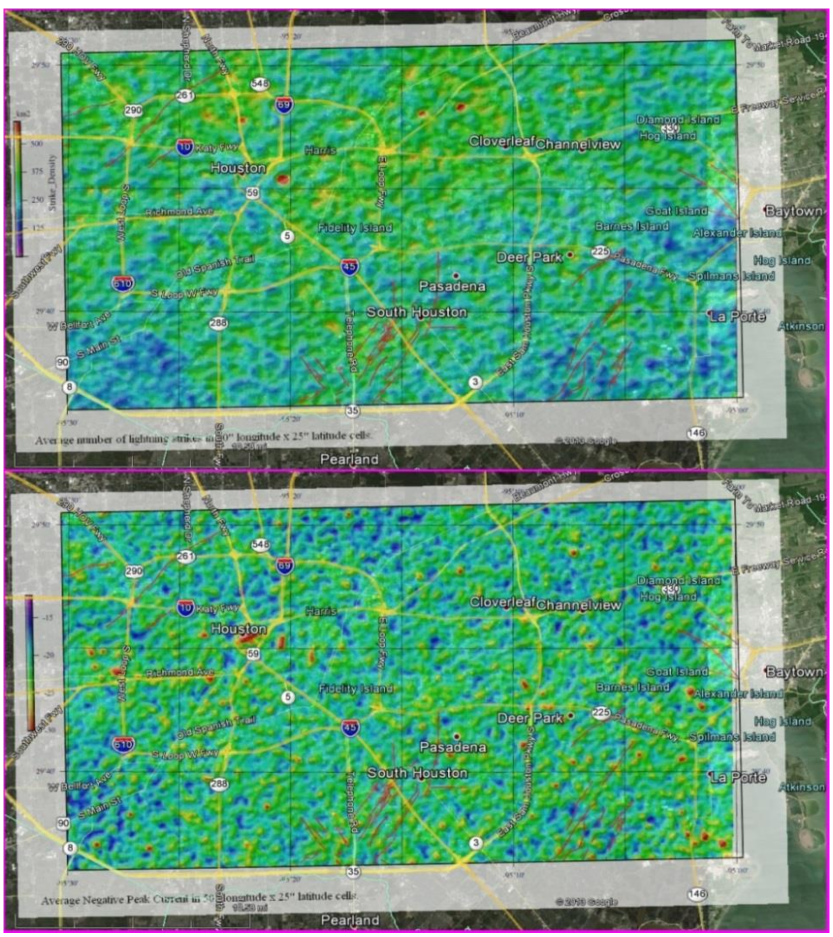
What causes lightning patterns to change?

Meteorological changes. For example, years and locations where there are many large hurricanes will have significant lightning strikes vs. years where there are no hurricanes.

Does lightning always strike the highest thing?

No. Each lightning analysis project shows there are increases in lightning density away from the tallest objects in the analysis area. The top image below shows the strongest density of lightning strikes in the Houston area is just east of downtown where there are 2 story warehouses. The bottom image shows the strongest negative peak current recordings are where the downtown and Transco Tower buildings are located, but these are not where most of the lightning strikes occur.

Infrastructure does have an impact, including impacting the location of the strongest negative peak current recordings. The top image shows lightning does not always strike the tallest building. However, there are anomalies tied to tall buildings for the negative lightning strikes. Knowing these anomalies, we can filter them out and remove or filter out that bias in terms of showing only data impacted by the geology.



What depths does lightning volumetric data likely image?

Most of Dynamic Measurement, LLC's (DML's) maps are a surface projection of subsurface electrical currents, which DML calls terralevis currents. Based on reasonable assumptions, DML has developed an approach to calculate surface resistivity and to create resistivity volumes from electrical measurements in the NLDN lightning database. The depth of these resistivity volumes is a function of the attributes of the lightning database. The assumptions imply the bottom depths of the resistivity volumes are between 10,000 feet and 30,000 feet.

Are all radio towers hit by lightning?

No. Some are, some are not. We don't know why this happens. It could be because of how well some towers are grounded with lightning rods, or more likely the geology on which the radio towers sit.

Do steel encased wells act as giant lightning rods?

They don't appear to have any measurable effect on lightning, perhaps because the amount of steel involved is so tiny relative to the amount of rock surrounding them. The rocks within 1.0 meter of a typical well have a volume about 100 times as large as the volume of the steel casing. Our conclusion is the electrical properties of the rock matrix overwhelm any conductivity and lightning rod attributes tied to the drill pipe.

Lightning Attributes

What attributes are recorded in lightning strike databases?

The key attributes from the NLDN and CLDN databases include:

- Time (microseconds)
- Location (100-400 foot or 30-150 meter horizontal resolution)
- Polarity (negative, most common, or positive, at the end of a lightning from the top of clouds)
- Rise-Time (microseconds to go from background electrical noise to Peak Current)
- Peak Current (thousands of amperes)
- Peak-to-Zero (microseconds to go from Peak Current to the background electrical noise)
- Number of Sensors recording each lighting strike
- Chi-Squared (quality measurement of how well various sensor measurements match)
- Major Axis (major ellipse axis of how well lightning strike locations from various sensors match)
- Minor Axis (minor ellipse axis of how well lightning strike locations from various sensors match)

What attributes can be calculated from the lightning strike databases?

After 6 years DML is just starting to understand the ramifications of the database. Key attributes calculated to date include:

- Total Wavelet Time (Rise-Time + Peak-to-Zero Time)
- Wavelet Symmetry (Rise-Time / Peak-to-Zero Time or Peak-to-Zero Time / Rise-Time)
- EM1 (major axis of the principal component combination of Rise-Time, Peak Current, & Peak-to-Zero time)
- EM2 (minor axis of the principal component combination of Rise-Time, Peak Current, & Peak-to-Zero time)
- Lightning Strikes can be sorted by time and these sorts can be combined, including:
  - Hour of the Day
  - Day of the Month
    - Earth Tide Cycle

        - Combined Earth and Sun Tidal Cycle
        - Maximum Flood and Maximum Ebb of Earth Tides
    - Season
    - Year (Electromagnetic time-lapse studies)
- Surface Resistivity
- Resistivity Volumes

What is the most useful electrical information in lightning strike databases?

Based on reasonable assumptions, Dynamic Measurement has determined how to use the Rise-Time, Peak Current, and Peak-to-Zero time to measure surface resistivity and to calculate resistivity volumes anyplace within the NLDN and CLDN lightning coverage.

DML has developed and has patent pending to calculate resistivity volumes from the electrical measurements in lightning databases.

Large companies have been built on the ability to measure resistivity downhole. While these resistivity logging techniques have excellent vertical resolution, horizontal resolution is limited to the logged well spacing. Since lightning occurs everywhere, DML's resistivity volumes have a 100-300 foot horizontal resolution. Vertical resolution is currently limited to about 10 samples over about 20,000 feet. Since hydrocarbons always migrate upward, this resolution turns out to be sufficient to show migration pathways, gas chimneys, and lateral changes due to faulting. The technology is evolving very fast. Resistivity volume calculation requires measurements from ground based sensor networks, and so DML can calculate resistivity volumes anywhere in the continental U.S. and Canada out to 300 feet of water depth, interpolate them to the same line and trace spacing as any 3-D seismic survey in these areas, and export them as standard SEG-Y volumes to be overlaid on the 3-D seismic survey like a velocity volume. This is a very exciting technical development with many potential uses in both exploration and reservoir characterization.

Stratigraphic geology consists of layers of rock, which have much more variation vertically than laterally. However, as has been learned with 3-D seismic surveys, the slower changing lateral variations of properties like resistivity determine the extent of source, reservoir, seal, migration pathways, and traps. We anticipate the ability to calculate resistivity volumes at any horizontal scale, matched to the bin location of 3-D seismic surveys, will prove to be very valuable to natural resource exploration industries.

What is the lower limit of data that can yield statistically valid results?

We have found by experience 3 or 4 lightning strikes per square kilometer is sufficient to evaluate an area.

Vaisala and Lightning Data

What is the GLD-360?

The GLD-360 is Vaisala's privately owned Global Lightning Database, which has 4 years of data recorded in the archives.

What are the NLDN and the CLDN?

The NLDN is the National Lightning Detection Network, and is Vaisala's privately owned lightning sensor network and database managed out of Tucson, Arizona. The CLDN database is the publically owned Canadian Lightning Detection Network, and is also managed out of Tucson, Arizona by Vaisala and data is distributed out of Calgary, Canada. Each of these databases has 15+ years of lightning data stored in their archives.

Geography

Is there more lightning on the tops of mountains?

Not in most cases. There are lightning strikes at the top of mountains, as anyone who has hiked in the mountains has learned. There are also lightning strikes in the valleys and on the sides of the mountains. Where a cloud-to-ground lightning strike occurs is primarily a function of the resistivity/conductivity of the earth.

For example, at the recent AAPG (American Association of Petroleum Geologists) conference in Houston, a geologist described his summer house on a Budah Limestone cliff overlooking a valley in West Texas, where they would watch lightning strikes in the valley which never hit the resistive limestone cliffs, and how before hearing Dynamic Measurement's insights he had not been able to explain why this happens.

Do lightning strikes occur in northern latitudes?

Yes, but not often. The further north you go the longer the ground is covered by snow, which is resistive pure water, and increases the cloud-to-ground dielectric. Also, when the ground is cold, there are no thermals generated, which create the updrafts necessary to create thunderstorms.

Why are oak and elm trees hit more often than other trees?

We don't know, and we suspect it is because the soil they like is low resistivity. It could be the ball roots of oak trees act as an inverted Van der Graff Generator, and static electricity goes to the tree as electrical storms pass overhead. This is one of many questions which have come out of work with lightning data which would be appropriate for graduate level research studies.

What is the role of soil moisture on lightning strike locations?

It probably does not have much role at all. Vaisala has been able to develop ways to predict soil moisture from lightning strike data, which is useful to the agricultural community.

Do lightning strikes occur in deserts?

Yes. There are both dry lightning, and normal cloud-to-ground lightning strikes.

What causes lightning in the deserts of the world?

There is dry lightning from static electricity built up in dust storms. There are also storms, even if they do not occur as often as in the tropics.

Offshore

Are there lightning strike patterns offshore?

Yes. Lightning strikes occur worldwide. However, there are very few lightning strikes in deep water. There is too much energy dispersion and a poorer connection with earth currents. We have found patterns in the lightning data out to 300 feet (~100 meters) water depths.

How often are ships hit by lightning?

Not very often. There are a couple of examples which can be found searching on the Internet, and they are very few compared to the number of ships and number of years ships have been sailing in the seas. Much more common is St. Elmo's fire, which is a luminous plasma discharged from sharp or pointed objects, like sailing masts, in a strong electric field in the atmosphere tied to thunderstorms or volcanic eruptions.

Do lightning strikes occur in the deep water oceans?

Yes, but less frequently than over land or shallow water. Lightning is much less common in deep water, and few lightning detection networks have much deep water coverage, so the patterns in deep water are not as well known. The introduction of the GLD-360 global lightning database about 4 years ago has provided data to study deep water lightning density and currents.

Earth/Atmospheric

How do you generalize the earth's electrical system?

The earth's electrical system can be thought of as a large capacitor, where the ionosphere is collecting charged particles from the Sun and the bottom of the capacitor are telluric currents at the top of the mantle or near the Mohorovičić discontinuity. Lightning strikes help balance this capacitor.

What is the relationship with the Aurora Borealis and lightning strikes?

The Aurora Borealis (northern lights) and the Aurora Australis (southern lights) are a visible normalization of the earth's capacitor as excess ions travel to the earth following magnetic field lines.

What is the relationship between upper atmosphere lightning events, like Blue Sprites and Red Dwarfs, and cloud-to-ground lightning strikes?

They are related (they happen at the same instant of time, and in the same geographic location) but the exact relationship is not clear yet in the literature. We anticipate the energy necessary to send these events into the upper atmosphere is tied to the build-up of electrical currents in local geology. Again, this is something we believe is a good research project for graduate studies.

How long have we known about upper atmosphere lightning events?

The first visual observations are less than 20 years old. In the 1920's, the Scottish physicist C.T.R. Wilson predicted that electrical breakdown should occur in the atmosphere high above large thunderstorms (C. T. R. Wilson (1924) "The electric field of a thundercloud and some of its effects," *Proceedings of the Physical Society of London*, 37 (1): 32D-37D). The basic types of transient luminous events (TLEs) are; Elves (a dim, flattened, expanding glow around 400 km (250 mi.) up), Sprites (occurring in clusters 50-90 km (30-55 mi.) above the Earth's surface), Gigantic Jets (reaching 70 km (45 mi.) into the atmosphere), Blue Jets (narrow cones 40-50 km (25-30 mi.) above the Earth's surface), and Blue Starters (shorter and brighter than Blue Jets and only reaching up to 20 km (12 mi.) above the Earth's surface).

Since lightning is not common along the west coast and in northern latitudes, is there enough data to statistically evaluate lightning data?

Yes. It is true there is only about 1 lightning strike per square kilometer every other year in the Mojave Desert, other parts of the west coast, and northern latitudes. However, DML has an exclusive license for 15+ years of lightning data in the continental U.S. for natural resource exploration. Since geology does not change over 15 years, and since the lightning strike location and attributes are largely controlled by the geology, this means there is the equivalent of 7.5 lightning strikes per square kilometer every year in these places. Adding, or stacking the lightning strike data together, improves signal and reduces noise.

Do cyclic weather patterns like El Nino affect lightning frequency?

Absolutely. So do solar flares, volcanic ash, and other natural events. Lightning frequency is a meteorological phenomenon. Where lightning strikes the ground and the attributes of these lightning strikes is largely controlled by geology. These facts are DML's unique insight.

How does lightning compare to gravity and magnetics as an exploratory evaluation tool?

The maps DML generates look very much like gravity and magnetic maps. The trends are similar because the same geology is being mapped. However, the measurements are not density nor magnetism, but rather are related to terralevis currents, and so there will be differences. These differences are expected to become the real value of lightning analysis. Lightning analysis is less expensive than either gravity or magnetic data. More important, the data is already collected, and so there is no new field data collection required. Analysis is simply a function of ordering the data, cleaning the data, and mapping the lightning data.

Land Permission

Do you have to have landowner permission to collect and map lightning strike data?

A nice aspect of lightning analysis is the fact that there are already 15 years of data in the NLDN and CLDN covering the Continental United States and Canada and there are 4 years of data worldwide in the GLD-360 database. These databases are evergreen, in that they are continually recording new information. There is no ownership of the data by landowners, and so there is no need to obtain permission to collect or to distribute the data. Dynamic Measurement has a worldwide exclusive license to use this lightning data for natural resource exploration.

Additional

Can you detect hydrocarbon seeps with lightning data?

DML believes so. The south end of Lake Maracaibo in Venezuela is surrounded by the Andes. Westerly winds from the Caribbean are lifted by the mountains and there are lightning strikes every afternoon. These lightning strikes have unique green and blue colors, which a National Geographic article (see attachment) states are due to hydrocarbon seeps. It appears the seeps disrupt the atmosphere, and provide a pathway for lightning leaders. This article was the first clue lightning strikes are seeing seeps.

In a lightning analysis project in the U.S. Gulf Coast, DML found additional support regarding seeing seeps with lightning strikes. In this part of the world there are shallow carbonate layers with very high porosity. In fact, porosity is so high the water level goes up and down in water wells with lunar tides. Looking at lightning strike density at different stages of the lunar tide, we discovered there are 25-40% more lightning strikes at high lunar tide than low lunar tide. What was particularly interesting was the fact over 15 years there were no cloud-to-ground lightning strikes at the maximum ebb and flow of earth tides. DML's current interpretation is the earth tides move the ground water and washes both biogenic and thermogenic gas out of the area, and there is no gas left to disrupt the atmosphere and create pathways for lightning leaders.

Is lightning strike location a function of volatility of the hydrocarbons associated with a seep?

DML has not conducted enough projects to be able to answer this question.

Is there any anomaly associated with the La Brea Tar Pits?

It is expected that is so, but DML has not done an analysis over this area yet.

Is the change a function of fluid migration - saline vs. fresh, hydrocarbons vs. saline, or gas vs. fresh water?

DML has not done time-lapse analysis yet. With 15 years of data, we are looking for opportunities to do a lightning analysis over fields which have been produced over the last 15 years to see if there is a relationship between lightning strike data and fluid migration.

Can lightning data be used to evaluate water movements or salinity wedges in aquifers over time?

DML hopes so, and we are looking for analysis projects to study this.

Are buried pipelines safe from lightning strikes?

No. If a pipeline goes through an area where there are a lot of lightning strikes, it means there are a lot more terralevis currents in the ground, and these currents will greatly speed up corrosion of the pipeline. DML lightning density maps can be of great value in planning pipeline routes, to avoid these electromagnetic hotspots, and to plan where extra corrosion protection is required.