

SO YOU
THINK YOU KNOW
LIGHTNING



A COLLECTION OF **ELECTRIFYING** FAST FACTS!

PUBLISHED BY

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As a meteorological consultant and a university general science course instructor for many years, the authors have collected questions regarding lightning that are frequently asked by customers, students and friends. This booklet answers these questions and provides additional knowledge to help the readers understand basic lightning physics and lightning safety, as well as lightning detection.

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Chapter *ONE*

Phenomenon



Physics



Distribution



What is lightning?



Lightning is a common atmospheric electricity phenomenon. The American Meteorological Society defines lightning as “the series of electrical processes taking place continuously by which charge is transferred along discharge channels between electric charge centers of opposite sign.”

SPELLING TIP:



Further reading: Lang, T.J. et al., 2017: WMO world record lightning extremes: Longest reported flash distance and longest reported flash duration. *Bulletin of the American Meteorological Society*, 98, 1153-1168.



2 types of Flashes

A flash that only consists of cloud pulses is called a **cloud flash**.

A flash that has at least one cloud-to-ground stroke is called a **cloud-to-ground flash**, which is more dangerous to lives and property.

What are the differences between a pulse, stroke, and flash?

A **pulse** (or a **cloud pulse**) is a lightning discharge that connects regions with opposite polarity (+/-) within one cloud or between multiple clouds.

A **stroke** (or a **cloud-to-ground stroke**) is a lightning discharge that connects a charge region in a cloud to the ground.

A lightning **flash** consists of one or more cloud **pulses** and/or cloud-to-ground **strokes** that typically occurs within 1 second.

Further reading: *Uman, M.A., 1986: All about lightning. Dover Press, 167 pp.*

Does lightning travel up or down?



Typically, a cloud-to-ground flash starts with a downward channel, but it is normally not visible because of its very short duration. When it comes close to the ground, it will induce an upward channel from the ground. This upward channel will connect to the first downward channel, and form a bright channel (as we normally see) that travels back up to the cloud through the same path.

In contrast, a cloud lightning flash which consists of only cloud pulses travels mainly horizontally.

Further reading: Rakov, V.A., 2016: *Fundamentals of lightning*. Cambridge University Press, 257 pp.





What is the polarity of lightning?

Lightning can be both positively and negatively charged. In a typical thunderstorm, there are many more negative cloud-to-ground strokes than positive ones. However, in the Great Plains in the U.S., abnormal thunderstorms with relatively more positive strokes have been found.

Further reading: Rakov, V.A., 2016: *Fundamentals of lightning*. Cambridge University Press, 257 pp.

What is thunder?

FAST FACT



Source credit: Environment and Climate Change Canada

Further reading: Uman, M.A., 1984: *Lightning*. Dover Press, 298 pp.

Heat from lightning causes air to rapidly expand around it. This sudden expansion of air causes a shock wave that we hear as thunder.

TRUE OR FALSE?

“Lightning and thunder occur simultaneously.”

Why do we see lightning first?

The speed of light is much greater than the speed of sound, so the light arrives before the sound.

- ▶ **Speed of light:** 3×10^8 meters per second (m/s) or 2×10^5 miles per second (mi/s).
- ▶ **Speed of sound:** 340 m/s or 0.21 mi/s.

How can I tell how far I am from the lightning?

After you see lightning, count the number of seconds until you hear thunder. See the example on the next page.



Example

If you hear thunder 5 seconds after you see lightning, how far away are you from the lightning?

$$\begin{aligned} \text{Distance} &= \text{Speed} \times \text{Duration} \\ &= 340 \text{ m/s} \times 5 \text{ sec}^* \quad \text{or} \quad = 0.21 \text{ mi/s} \times 5 \text{ sec} \\ &= 1,700 \text{ meters} \qquad \qquad \qquad = 1.05 \text{ miles} \end{aligned}$$

You are 1.7 km or about 1 mile away from the lightning.

It takes **5 seconds** for sound to travel **1 mile.**

*sec = second(s)

TRUE OR FALSE?

“Only thunderstorms produce lightning.”

FALSE

Lightning also occurs in volcanic eruptions. Lightning occurs wherever there are two regions with opposite charges between them, whether it is in a volcanic eruption or a thunderstorm.



Source credit: Sakurajima Volcano, Japan by Dr. Carrado Cimarelli, Ludwig-Maximilians-Universität

Further reading: Behnke, S.A., and E.C. Bruning, 2015: Changes to the turbulent kinematics of a volcanic plume inferred from lightning data. *Geophysical Research Letters*, 42, 4232-4239.

Can you hear thunder more than 10 miles away?



Although thunder may be heard at a distance greater than 10 miles, the hearing distance is usually shorter if there is traffic noise, you are in a building, or you are facing away from the storm.

Is there always thunder when lightning strikes?

YES. Lightning always produces thunder whether you hear it or not.

Further reading: *Uman, M.A., 1986: All about lightning. Dover Press, 167 pp.*



TRUE OR FALSE?

“Soil composition can influence where lightning strikes.”



FALSE

Cloud-to-ground lightning originates at very high altitudes (typically above 5-7 km). The downward lightning channel within a cloud-to-ground lightning flash is NOT influenced by soil composition.

Further reading: Rakov, V.A., 2016: *Fundamentals of lightning*. Cambridge University Press, 257 pp.

What is heat lightning?

**FAST
FACT**



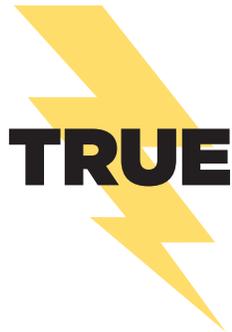
Heat lightning is ordinary lightning - it is just far away.

Source credit: © Ronald L. Holle

Further reading: *Uman, M.A., 1984: Lightning. Dover Press, 298 pp.*

TRUE OR FALSE?

“The temperature of lightning is hotter than the surface of the sun.”



The temperature of lightning is about 30,000 Kelvin (about 53,500 °F). The temperature of the surface of the sun is about 6,000 Kelvin (about 10,300 °F).

Why don't lightning strikes trigger hydrogen-helium nuclear fusion reactions (such as inside the Sun)?

The temperature at the core of the sun is much higher than at its surface. Nuclear fusion requires a temperature more than tens of millions Kelvin, which is only found at the core of the sun rather than at its surface. The temperature of lightning is not high enough to trigger this nuclear fusion.

Further readings: Uman, M.A., 1984: *Lightning*. Dover Press, 298 pp.

Prueitt, M.L., 1963: *The excitation temperature of lightning*. *Journal of Geophysical Research*, 68(3): 803-811.

Is there lightning in tornadoes and hurricanes?



YES. There is lightning in tornadoes.

Tornadoes are formed by thunderstorms containing lightning. However, the frequency of the lightning occurrence varies.

YES. There is lightning in hurricanes.

In a hurricane, lightning is more likely to occur in the outer spiral rainbands than in the hurricane eyewall where the strongest winds and heaviest rain are located.

Further readings: Zheng, D., and D.R. MacGorman, 2016: Characteristics of flash initiations in a supercell cluster with tornadoes. *Atmospheric Research*, 167, 249-264.

Stevenson, S.N., K.L. Corbosiero, and S.F.Abarca, 2016: Lightning in eastern North Pacific tropical cyclones: A comparison to the North Atlantic. *Monthly Weather Review*, 144, 225-239.



TRUE OR FALSE?

“Lightning does not benefit Earth and humankind.”



FALSE

Lightning plays an important role in:

- ▶ the atmospheric nitrogen cycle by producing nitrate nutrients to help fertilize the soil.
- ▶ the Global Electric Circuit, which interplays between the Earth, thunderstorms, and upper atmosphere.
- ▶ a possible mechanism for the origin of life.

Lightning is also visually attractive.

Further readings: Höller, H., U. Finke, H. Huntrieser, M. Hagen and C. Feigl, 1999: *Lightning produced NO_x (LINOX) - Experimental design and case study results.* *Journal of Geophysical Research*, 104, D11, 13911-13922.
Williams, E.R., 2009: *The global electrical circuit: A review.* *Atmospheric Research*, 91(2), 140-152.

What are the duration and distance records for a lightning flash?



Normally, a lightning flash lasts less than a second. However, the longest duration of a lightning flash was recorded at **7.7 seconds**.

Normally, a lightning flash does not travel horizontally more than 20 miles (about 30 km). However, the farthest horizontal distance that a flash traveled was recorded at **200 miles** (321 km).

Further reading: Lang, T.J. et al., 2017: WMO world record lightning extremes: Longest reported flash distance and longest reported flash duration. *Bulletin of the American Meteorological Society*, 98, 1153-1168.



TRUE OR FALSE?

“Lightning flickers because its temperature is very high.”

FALSE

The temperature has nothing to do with the flickering. The flickering is caused by multiple cloud-to-ground strokes with a time interval of less than a tenth of a second.



Source credit: © Ronald L. Holle

How much energy does a lightning flash typically release?



It is hard to estimate the energy released by a lightning flash, but a typical range is about 10^9 to 10^{10} Joules. A common saying is that this amount of energy is equivalent to the energy that lights up a regular light bulb for several months.

Assuming the energy of a lightning flash is 10^9 Joules and a light bulb has a power of 100 watts (Joules/sec), the light-up time can be calculated as:

$$\begin{aligned}\text{Time} &= \text{Energy/Power} = 10^9 \text{ Joules}/100 \text{ watts} \\ &= 10^7 \text{ seconds} \\ &= \text{about 4 months}\end{aligned}$$

Further reading: Rakov, V.A., 2016: *Fundamentals of lightning*. Cambridge University Press, 257 pp.



TRUE OR FALSE?

“Lightning never strikes the same place twice.”



FALSE

In flat open land, it is very unlikely that lightning strikes the same spot more than once over a long period of time. However, natural and man-made features (e.g., trees, buildings, and towers) that stand out from the ground are more likely to be repeatedly struck by lightning.

The Empire State Building is a frequent target for lightning strikes and thus a favorite subject of lightning studies.

Further reading: *Uman, M.A., 1986: All about lightning. Dover Press, 167 pp.*

Can we collect and utilize the energy from lightning?



NO.

1. Because the location of a lightning strike is unpredictable (see p. 51), it is uncertain where to put a “container.”
2. Much of the energy produced by lightning comes in the form of light, sound, and heat that cannot be practically harvested.
3. No container is able to withstand such a short powerful surge and then store this energy without it being “lost”.
4. Lightning transfers both positive and negative charges. Even if we had a way to collect the energy, the opposite charges would tend to neutralize each other.
5. There is no way to transport the energy to the power grid or to convert the energy to alternating current (AC) or direct current (DC).



TRUE OR FALSE?

“Lightning always strikes the tallest structures.”



FALSE

Lightning tends to strike taller buildings, but it may strike a nearby shorter one under certain conditions. The final striking location is determined at the instant when the lightning channel is about 30-50 meters above the ground or an object. If a tall building is not within that limited range, lightning will hit a shorter building or object instead.

Further reading: Uman, M.A., 1986: *All about lightning*. Dover Press, 167 pp.

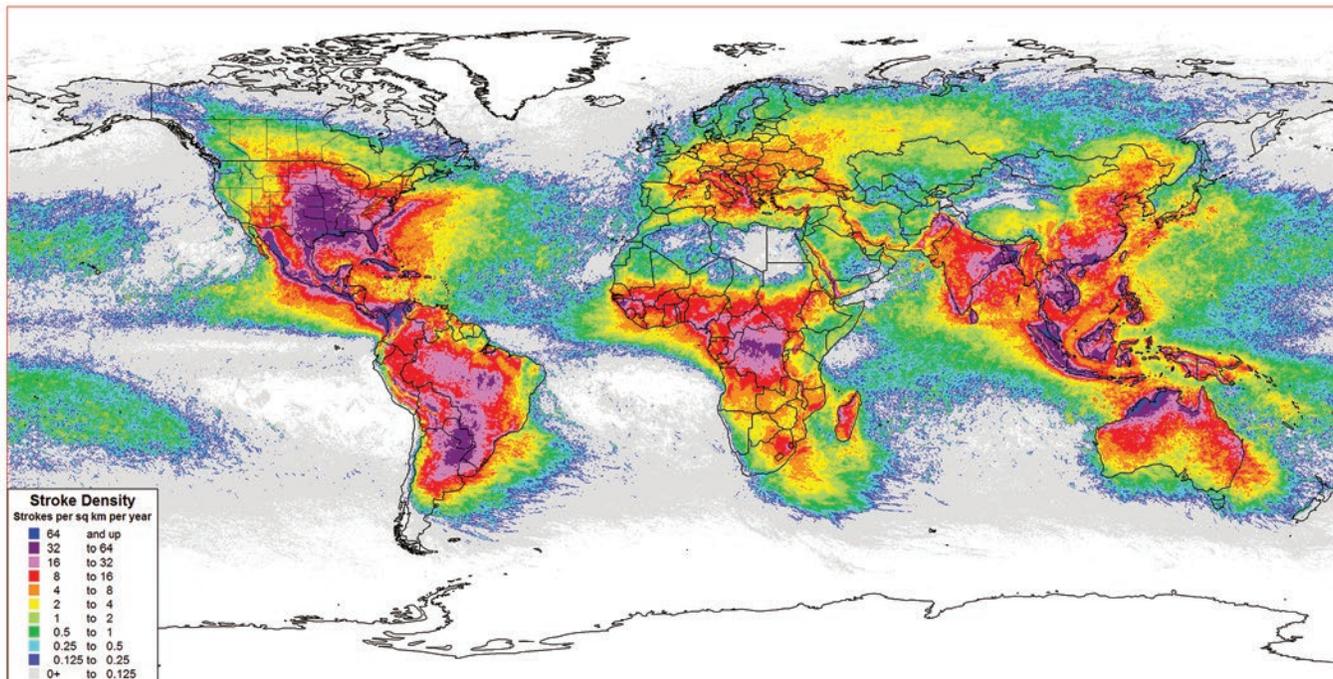
How often does lightning occur around the globe?

Vaisala's Global Lightning Dataset GLD360 network currently detects nearly two billion lightning occurrences every year. These include both cloud-to-ground strokes and cloud pulses.

Do some places have more lightning than others?

Yes. Lightning is not equally distributed around the globe. More lightning occurs over land than over the ocean. Lightning also occurs more in the tropics than elsewhere. See the GLD360 lightning map to the right.

Further reading: Holle, R.L., 2016: A summary of recent national-scale lightning fatality studies. *Weather, Climate, and Society*, 8, 35-42.

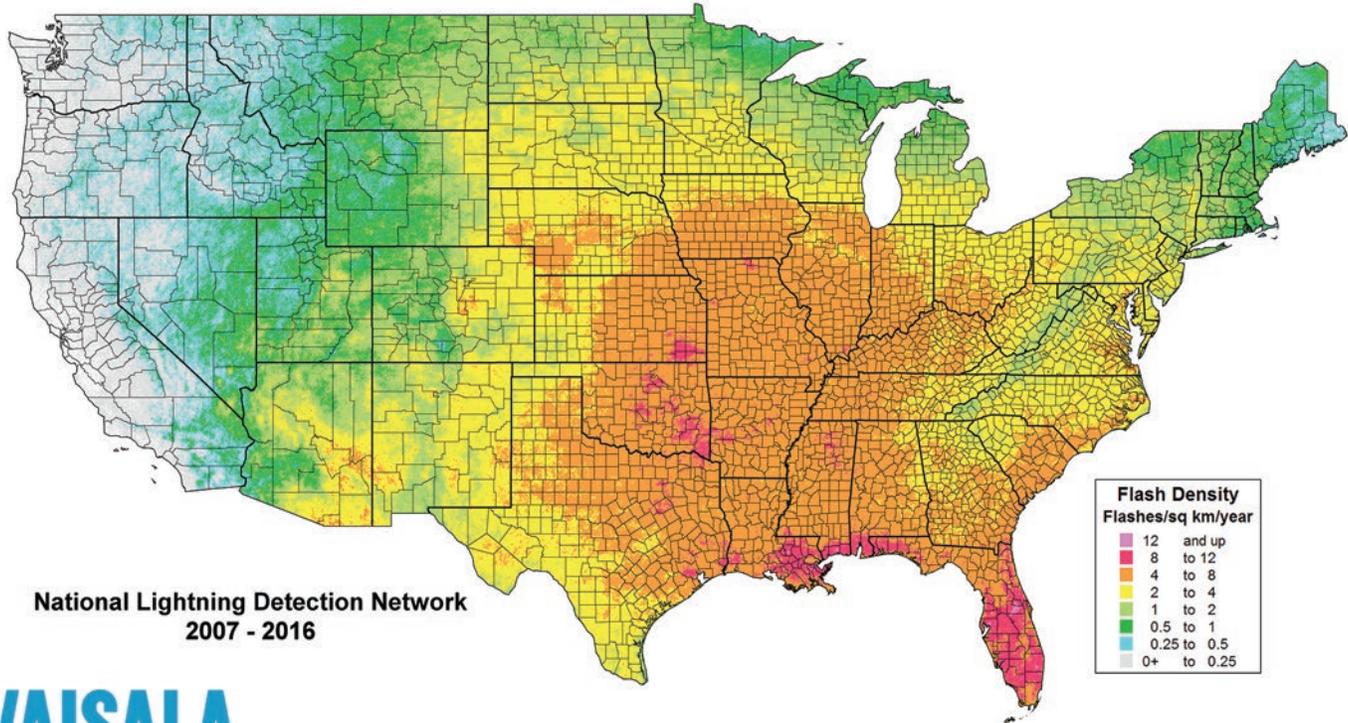


Stroke Density Map - 20 km grid

Average: 2012-2016

GLD360 v2.0 data: 7,828,464,140 strokes

How often do cloud-to-ground flashes strike in the U.S.?



VAISALA

TRUE OR FALSE?

“Florida is the lightning capital of the United States.”

Three locations in Florida have the highest lightning flash densities in the U.S. — near Tampa, West Palm Beach, and Daytona Beach.

How many lightning flashes occur in the United States each year?

Vaisala’s National Lightning Detection Network detects an average of 20 million cloud-to-ground flashes over the contiguous 48 states every year. See the map on the left. In addition, there are about 3-4 times more cloud flashes as there are cloud-to-ground flashes.

Further readings: Holle, R.L., K.L. Cummins, and W.A. Brooks, 2016: Seasonal, monthly, and weekly distributions of NLDN and GLD360 cloud-to-ground lightning. *Monthly Weather Review*, 144, 2855-2870.

Medici, G., K.L. Cummins, D.J. Cecil, W.J. Koshak, and S.D. Rudlosky, 2017: The intra-cloud lightning fraction in the contiguous United States. *Monthly Weather Review*, 145, 4481-4499.



How often does lightning strike the ground?

**FAST
FACT**



Source credit: © Ronald L. Holle

Further reading: RMedici, G., K.L. Cummins, D.J. Cecil, W.J. Koshak, and S.D. Rudlosky, 2017: The intra-cloud lightning fraction in the contiguous United States. *Monthly Weather Review*, 145, 4481-4499.

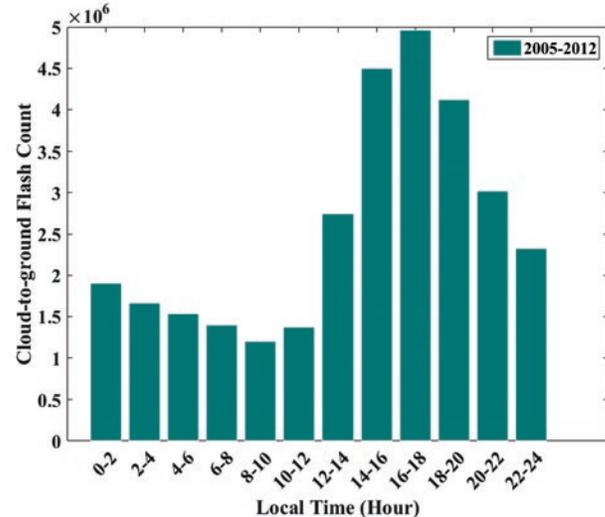
On average, about **1/3** of lightning reaches the ground and the other **2/3** stays in the cloud. However, the actual ratio within each thunderstorm can vary.

TRUE OR FALSE?

“Lightning is most common in the afternoons.”

TRUE

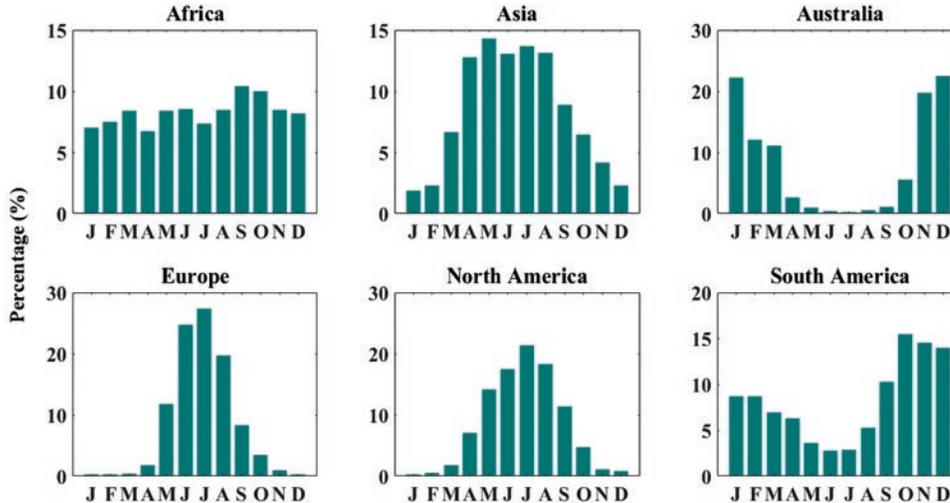
Around 2/3 of all lightning over land occurs between noon and the late afternoon hours of 16-18 local time.



Further reading: Holle, R.L., 2014: Diurnal variations of NLDN-reported cloud-to-ground lightning in the United States. *Monthly Weather Review*, 142, 1037-1052.

Is the seasonal distribution of lightning different around the world?

**FAST
FACT**



Further reading: Holle, R., R. Said, and M. Scott, 2017: Lightning variations: A large data set comprising five years of lightning detection data is helping to draw global comparisons. *Meteorological Technology International*, September, 139-140.

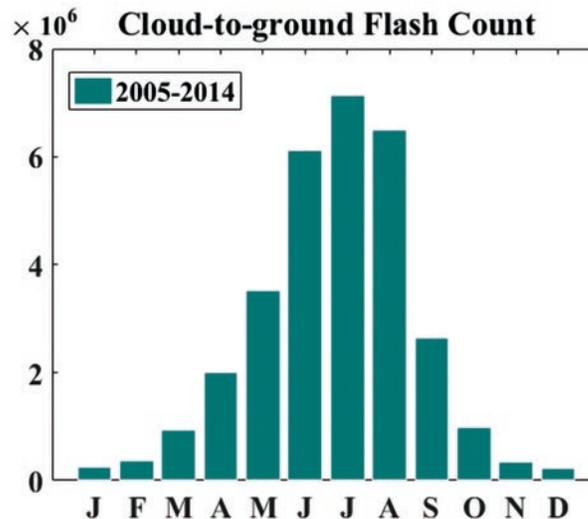
YES.
See the seasonal variations of lightning occurrence in different continents.

TRUE OR FALSE?

“In the U.S., lightning is most common in summertime.”



About 2/3 of lightning over land occurs during the three summer months in the U.S.



Further reading: Holle, R.L., K.L. Cummins, and W.A. Brooks, 2016: Seasonal, monthly, and weekly distributions of NLDN and GLD360 cloud-to-ground lightning. *Monthly Weather Review*, 144, 2855-2870.

Chapter *TWO*



Human



Property



TRUE OR FALSE?

“When thunder roars, go indoors.”

In the United States and most developed countries, as well-constructed buildings are available and accessible most of the time. People are safe in these buildings, so going indoors is a good recommendation.

****However, in some developing countries or areas, as buildings are poorly built, such as those with thatched roofs and mud walls. These buildings are not lightning-safe, and therefore, going indoors may not be safe.***

Further reading: www.lightningsafety.noaa.gov; www.ACLENet.org

Roeder, W.P., R.L. Holle, M.A. Cooper, and S. Hodanish, 2011: Communicating lightning safety effectively. Preprints, 5th Conference on the Meteorological Applications of Lightning Data, January 23-27, Seattle, Washington, American Meteorological Society, 18 pp.



Is it safe to use a mobile phone during a thunderstorm?



YES. Only use a mobile phone inside a safe vehicle or building. It is safe to use a mobile phone as long as you are inside a safe building or vehicle. However, it is not safe to use a mobile phone outdoors during a thunderstorm, and this is only because it is just not safe to be outside. The lack of safety has nothing to do with the mobile phone itself because cellphones do NOT attract lightning.

In general, being outside during a thunderstorm is always dangerous! Beware that using a corded phone during a thunderstorm can also be dangerous!

Further reading: Cooper, M.A., 2008: *Is it dangerous to use a cell phone in a thunderstorm? Lightning fact and fiction. Bottom Line Personal, 29, June 1, 13-14.*



TRUE OR FALSE?

“A person can survive being struck by lightning.”



Lightning usually has a very short duration (normally less than 1/5 of a second) and most of the energy tends to travel over the body rather than go through it. That is why some people can survive. However, sometimes, it causes severe injuries (mainly neurological) that can be devastating and lead to life-long debilitating effects.

Further readings: www.lightning-strike.org

Cherington, M., J. Walker, J. Boyson, R. Glancy, H. Hedegaard, and S. Clark, 1999: Closing the gap on the actual numbers of lightning casualties and deaths. Preprints, 11th Conference on Applied Climatology, Dallas, TX, American Meteorological Society, 379-380.

Can rubber tires save you from a direct strike to your car?



NO. It is the metal shell of a car, rather than the rubber tires, that provides protection.

When lightning strikes a car, the current travels through the exterior metal shell of the car and then to the ground via the axles and tires. Consequently, a person fully inside the car will be protected from the lightning current.

Further reading: Holle, R.L., 2008: *Lightning-caused deaths and injuries in the vicinity of vehicles. Preprints, 3rd Conference on Meteorological Applications of Lightning Data, January 20-24, New Orleans, Louisiana, American Meteorological Society, 10 pp.*

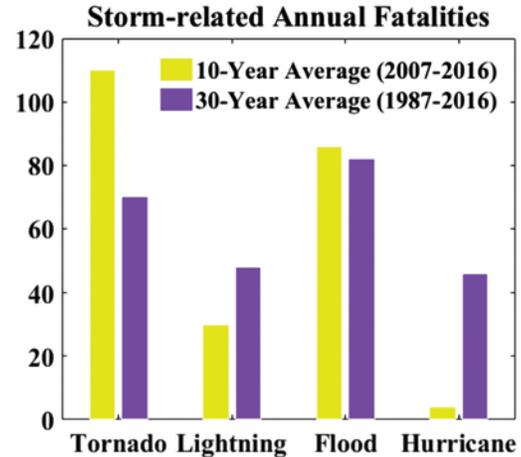


TRUE OR FALSE?

“Lightning is the deadliest storm hazard in the U.S.”

FALSE

Both tornadoes and floods have killed more people than lightning in the last 30 years in the U.S. The U.S. death rate caused by lightning is about 30 people per year during the last ten years.



Further readings: Lopez, R.D., and R.L. Holle, 1998: Changes in the number of lightning deaths in the United States during the twentieth century. *Journal of Climate*, 11, 2070-2077.

Roeder, W.P., 2012: Lightning has fallen to third leading source of U.S. storm deaths. Preprints, National Weather Association Annual Meeting, Madison, Wisconsin, 9 pp.

Are tents and small shelters safe during a thunderstorm?



NO. Tents have no metal exterior frame that is strong enough to carry the lightning current to ground to protect a person inside. You should leave a tent and seek a safe building or a vehicle during a thunderstorm.

Small shelters, such as sun shelters, beach shelters, bus shelters, rain shelters, picnic shelters, agricultural shelters, and small road-side shops are unsafe. They are rarely built with lightning protection.

Further reading: Holle, R.L., 2010: *Lightning-caused casualties in and near dwellings and other buildings.* Preprints, International Lightning Meteorology Conference, Vaisala, April 21-22, Orlando, Florida, 19 pp.

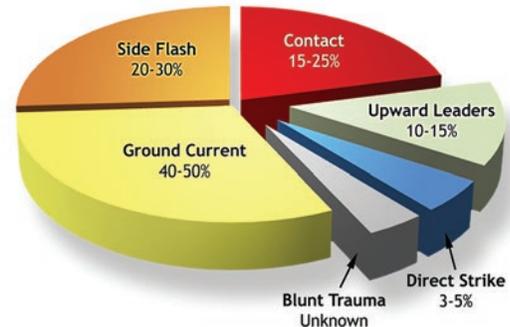


TRUE OR FALSE?

“A direct strike is the only way a person can be injured by lightning.”

FALSE

Most lightning safety advice only focuses on the direct strike. However, as shown in this diagram, direct strike is the least common way to be killed or injured by lightning. Instead, ground current which will cause step voltage is the most likely cause of lightning deaths and injuries.



Source credit: Environment and Climate Change Canada (ECCC)

Further reading: Cooper, M.A. and R.L. Holle, 2010: Mechanisms of lightning injury should affect lightning safety messages. Preprints, International Lightning Meteorology Conference, Vaisala, April 21-22, Orlando, Florida, 5 pp.

Is it safe to stand under a tree during a thunderstorm?



NO. Around 10% of all lightning fatalities and injuries in the world are related to trees. When a tree is struck by lightning, a side flash can “jump” horizontally from the tree trunk to a person next to the tree. In addition, the lightning current will flow outward from the trunk across the ground to people or animals standing beneath the tree. Moreover, pieces of bark and branches can explode horizontally.

Further reading: Holle, R.L., 2012: *Lightning-caused deaths and injuries in the vicinity of trees. Preprints, International Conference on Lightning Protection, September 2-7, Vienna, Austria, 8 pp.*



TRUE OR FALSE?

“Rubber-soled shoes will save you from lightning.”

A thin layer of rubber at the bottom of your shoes is impossible to save you from the power of a direct lightning strike.

However, if you are far enough away from the lightning strike location, then you may be safe because the step voltage decreases with distance. Therefore, it is the distance, rather than the rubber-soled shoes that may save you from a lightning strike.



Further reading: Roeder, W.P., R.L. Holle, M.A. Cooper, and S. Hodanish, 2011: *Communicating lightning safety effectively. Preprints, 5th Conference on the Meteorological Applications of Lightning Data, January 23-27, Seattle, Washington, American Meteorological Society, 18 pp.*

How do lightning rods work?

**FAST
FACT**

Lightning rods do not keep lightning from striking a building, but provide a safe path for the current to reach the ground. There are three components to the protection provided by lightning rods:

1. A rod extending above the roof (air terminal)
2. A thick cable from the rod to the ground (down conductor)
3. A heavy rod pounded into the ground (ground terminal)

When lightning strikes a lightning rod on a building, the current travels through the cable to the ground without going inside the building. Lightning protection systems must be installed by a properly-trained technician.

Lightning rods are very common on sensitive installations such as hospitals and utilities.

Further reading: *Uman, M.A., 2008: The art and science of lightning protection. Cambridge University Press, 240 pp.*



How do surge protectors work?

Most often, lightning current surges through the electric wires into a house after it strikes a power pole. Surge protectors are designed to protect your electronic devices from being damaged or destroyed by diverting the overflow.

Further reading: *Uman, M.A., 2008: The art and science of lightning protection. Cambridge University Press, 240 pp.*

Are passengers safe if lightning strikes a plane?



YES. Passengers inside a commercial plane are safe from a lightning strike. Instead of going inside the plane, the lightning current travels around the conducting metal exterior and dissipates into the air. There is also special lightning protection for the fuel tanks and electronic devices.

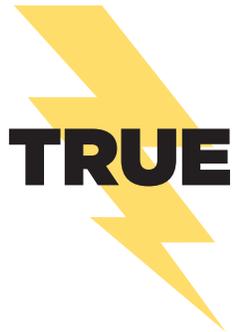
Nevertheless, an airplane needs to be inspected before and after each flight to make sure that there is no major damage from a suspected lightning strike.

Further reading: Mulvey, G.J., J.F. Miller, and J.P. Moriarty, 2017: Atmospheric electrical phenomena: A pilot's view. *Weatherwise*, 70, 32-39



TRUE OR FALSE?

“Lightning is a major cause of wildfires in the U.S.”



Due to the extremely high temperature of cloud-to-ground lightning, trees and other organic materials can be set afire. In the western United States, about one half of all forest fires are initiated by lightning, mostly in summer when “dry lightning” is frequent. “Dry lightning” refers to a phenomenon when rain from a thunderstorm evaporates before reaching the ground, and therefore the fire cannot be extinguished.

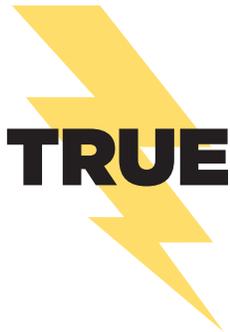
Further readings: www.nifc.gov/fireInfo/fireInfo_stats_lightng.html
www.ec.gc.ca/foudre-lightning/default.asp?lang=En&n=48337EAE-1

Chapter *THREE*



TRUE OR FALSE?

“We can detect where lightning has struck.”



Lightning emits unique electromagnetic signals at a wide range of frequencies (about 1 Hz to 3×10^9 Hz). When two or more ground-based lightning sensors detect a lightning signal, the data are sent to a central processor where the lightning occurrence times and the corresponding angles between the lightning to the sensors are processed. The location of the lightning is then determined by statistical and geometrical computations.

Further readings: Cummins, K.L., and M.J. Murphy, 2009: An overview of lightning locating systems: History, techniques, and data uses, with an in-depth look at the U.S. NLDN. *IEEE Transaction on Electromagnetic Compatibility*, 51, 499-518.

Nag, A., M.J. Murphy, W. Schulz, and K.L. Cummins, 2015: Lightning locating systems: Insights on characteristics and validation techniques. *Earth and Space Science*, 2.

Can satellites detect lightning from space?



YES. As of 2017, three U.S. satellite-based instruments have been, or are currently being used for lightning observations. They observe lightning from above the thunderstorms in contrast to ground-based lightning detection networks. To improve the detection accuracy, they use a very narrow range of electromagnetic signals in the near-infrared band.

Further readings: Goodman, S.J., R.J. Blakeslee, W.J. Koshak et al., 2013: *The GOES-R Geostationary Lightning Mapper (GLM)*. *Atmospheric Research*, 125:34-49.

Mach, D.M., H.J. Christian, R.J. Blakeslee et al., 2007: *Performance assessment of the Optical Transient Detector and Lightning Imaging Sensor*. *Journal of Geophysical Research - Atmospheres*, 112, D09210.



TRUE OR FALSE?

“We can predict exactly where lightning is going to strike.”



FALSE

There is no accepted method to predict exactly when and where lightning is going to strike, although the location of a thunderstorm and its movement can be tracked by radar and other instruments with a scanning period of 10 to 30 minutes. Currently, it is impossible to determine the precise location of each lightning strike in advance.

Chapter **FOUR**



Science



Triggers



Photography





What are fulgurites?

Fulgurites are naturally-produced glassy material that are formed from lightning striking and melting sand, soil, or other sediments. They are usually elongated and hollow, and can be bought at mineral shops.



Source credit: © Ronald L. Holle

Further reading: Wright, FW.Jr., 2010: Florida's fantastic fulgurite find. *Weatherwise*, 51, 27-31

What is ball lightning?



There have been reports from around the world of an electrical phenomenon that appears in the shape of a ball and only lasts a few seconds. This ball lightning typically occurs inside an enclosed space. There are no commonly-agreed-upon hypotheses on how ball lightning forms at this time.

Further reading: *Uman, M.A., 1986: All about lightning. Dover Press, 167 pp.*



TRUE OR FALSE?

“All lightning occurs within the troposphere.”



FALSE

Although lightning we normally see during a thunderstorm occurs entirely within the troposphere, a larger thunderstorm can produce electrical phenomena that shoot upward above the storm from the troposphere into the stratosphere, and even higher up into the mesosphere and ionosphere. These phenomena are called sprites and jets.

Further reading: Lyons, W., 2017: *Photographing weather in the dark*. *Weatherwise*, 70:4, 20-27, <http://dx.doi.org/10.1080>

Can we artificially trigger lightning from the ground?



YES. Small rockets have been successfully used to trigger lightning at various locations around the world. These triggered flashes are used to study lightning physics and to test the performance of lightning detection networks and other materials such as utility lines.



Source credit: *State Key Laboratory on Severe Weather, Chinese Academy of Meteorological Sciences. Provided by Dong Zheng*

Further readings: *Rakov, V.A., 2016: Fundamentals of Lightning. Cambridge University Press, 257 pp.*

Yijun, Z, W.Lu, and S. Chen, 2016: A review of advances in lightning observations during the past decade in Guangdong. Journal of Meteorological Research, 30(5), 800-819.



TRUE OR FALSE?

“Tall objects can initiate lightning.”

TRUE

Tall objects such as TV antennas, wind turbines, and tall buildings can initiate lightning, although this happens infrequently. These events are easily identified in photos by their upward channels from the objects.



Source credit: Sao Paulo, Brazil. Provided by Dr. Marcelo Saba, National Institute for Space Research, Brazil

Further reading: Saba, M.M.F., A.R. Paiva, C. Schuman et al. 2017: Lightning attachment process to common buildings. *Geophysical Research Letters*, 44, doi:10.1002/2017/GLO72796.

How can you photograph lightning?



One way is to take a long exposure that will include several lightning channels in the same photo. Another way is to take a video and pull out the frames when there was lightning. A final way is to point a camera toward an active thunderstorm and continuously take photos, but expect a large number of images with no lightning.

Source credit: *A long exposure (several minutes) photo of lightning in Tucson, AZ. © Ralph H. Wetmore II.*

Further reading: *Wetmore, R.A., 2010: Thirty years of lightning photography in southern Arizona. ISBN10:0982566212, 112 pp.*



TRUE OR FALSE?

“Lightning has various colors.”



TRUE

All lightning channels start as bright white. Depending on the type of particles in the air between the camera and the lightning channel, lightning can appear to be blue, purple, red, or yellow when its light reaches you.

Further reading: *Salanave, L. E., 1980: Lightning and its spectrum: An atlas of photographs, University of Arizona Press, 136 pp.*

Why is southern Arizona one of the best places in the U.S. to photograph lightning?



Although southern Arizona is not the lightning capital, it is the lightning photography capital of the U.S. Thunderstorms form during the monsoon season (July to early September), and the cloud bases are high (typically about 3,000 meters, or 10,000 feet). Therefore, the lightning channels can be seen from far away. Plus, southern Arizona is adorned with cacti, surrounded by mountains, and has colorful sunsets (See the lightning photos from Tucson, Arizona on the next 2 pages).

Further reading: *Wetmore, R.A., 2010: Thirty years of lightning photography in southern Arizona. ISBN10:0982566212, 112 pp.*





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- ▶ **U.S. National Weather Service Lightning Safety**
lightningsafety.noaa.gov
- ▶ **Vaisala Inc.**
vaisala.com/lightning
- ▶ **Department of Hydrology & Atmospheric Sciences, University of Arizona**
has.arizona.edu



Did you know?

- Thunder is always produced by lightning, whether you hear it or not.
- The longest lightning flash has been measured as 200 miles (321 kilometers) long.
- The temperature of lightning is hotter than the surface of the sun.
- Volcanoes can produce lightning.

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