

SHE Conference 2017

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Lightning Awareness

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High Voltage and High Current Institute

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Contents

- Lightning Science
- Lightning Characteristics
- Lightning Effects
- Lightning Protection
- Lightning Myths and Facts
- Conclusion

Lightning Science

How does lightning occur ?

- All thunderstorms go through stages of **growth, development, electrification** and **dissipation**.
- Thunderstorms often begin to develop early in the day when the **sun heats the air** near the ground and **pockets of warmer air start to rise in the atmosphere**.
- When these pockets of air reach a certain level in the atmosphere, **cumulus clouds** start to form.
- **Continued heating** causes these clouds to **grow vertically** into the atmosphere.

Lightning Science

How does lightning occur ?

- These "**towering cumulus**" clouds may be one of the first signs of a developing thunderstorm.
- The final stage of development occurs as the **top of the cloud becomes anvil-shaped**.



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Lightning Science

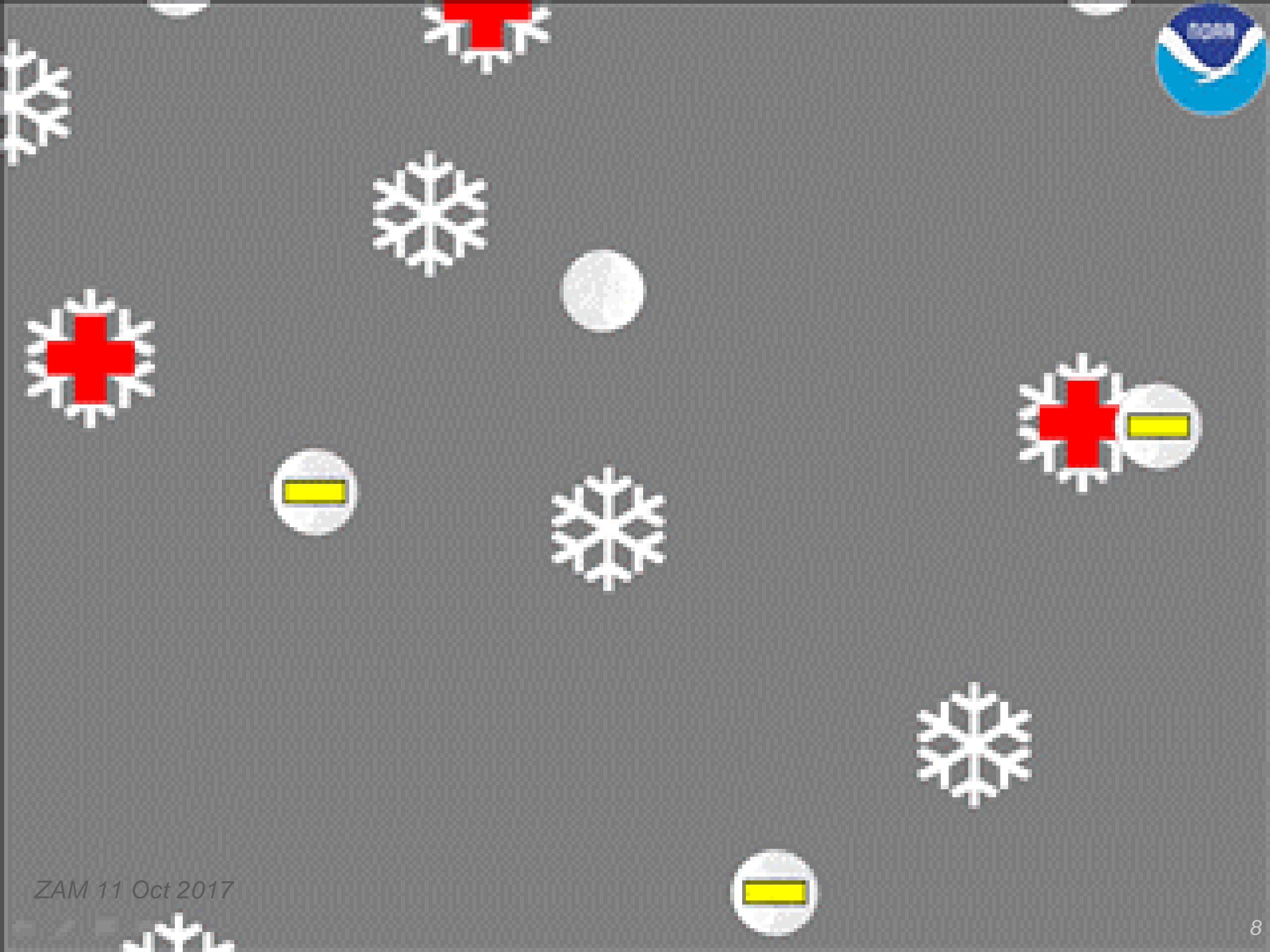
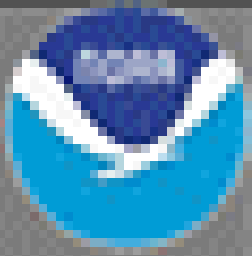
How does lightning occur ?

- As a thunderstorm cloud grows, precipitation forms within the cloud.
- A well-developed thunderstorm cloud contains mostly small ice crystals in the upper levels of the cloud, a mixture of small ice crystals and small hail in the middle levels of the cloud, and a mixture of rain and melting hail in the lower levels of the cloud.
- Air movements and collisions between the various types of precipitation in the middle of the cloud cause the precipitation particles to become charged.
- The lighter ice crystals become positively charged and are carried upward into the upper part of the storm by rising air.

Lightning Science

How does lightning occur ?

- The heavier hail becomes negatively charged and is either suspended by the rising air or falls toward the lower part of the storm.
- These collisions and air movements cause the top of the thunderstorm cloud to become positively charged and the middle and lower part of the storm to become negatively charged.



Lightning Science

How does lightning occur ?

- In addition, a small positive charge develops near the bottom of the thunderstorm cloud.
- The **negative** charge in the **middle** of **thunderstorm cloud** causes **the ground underneath to become positively charged**, and the positively charged anvil causes the ground under the anvil to become negatively charged.



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Lightning Science

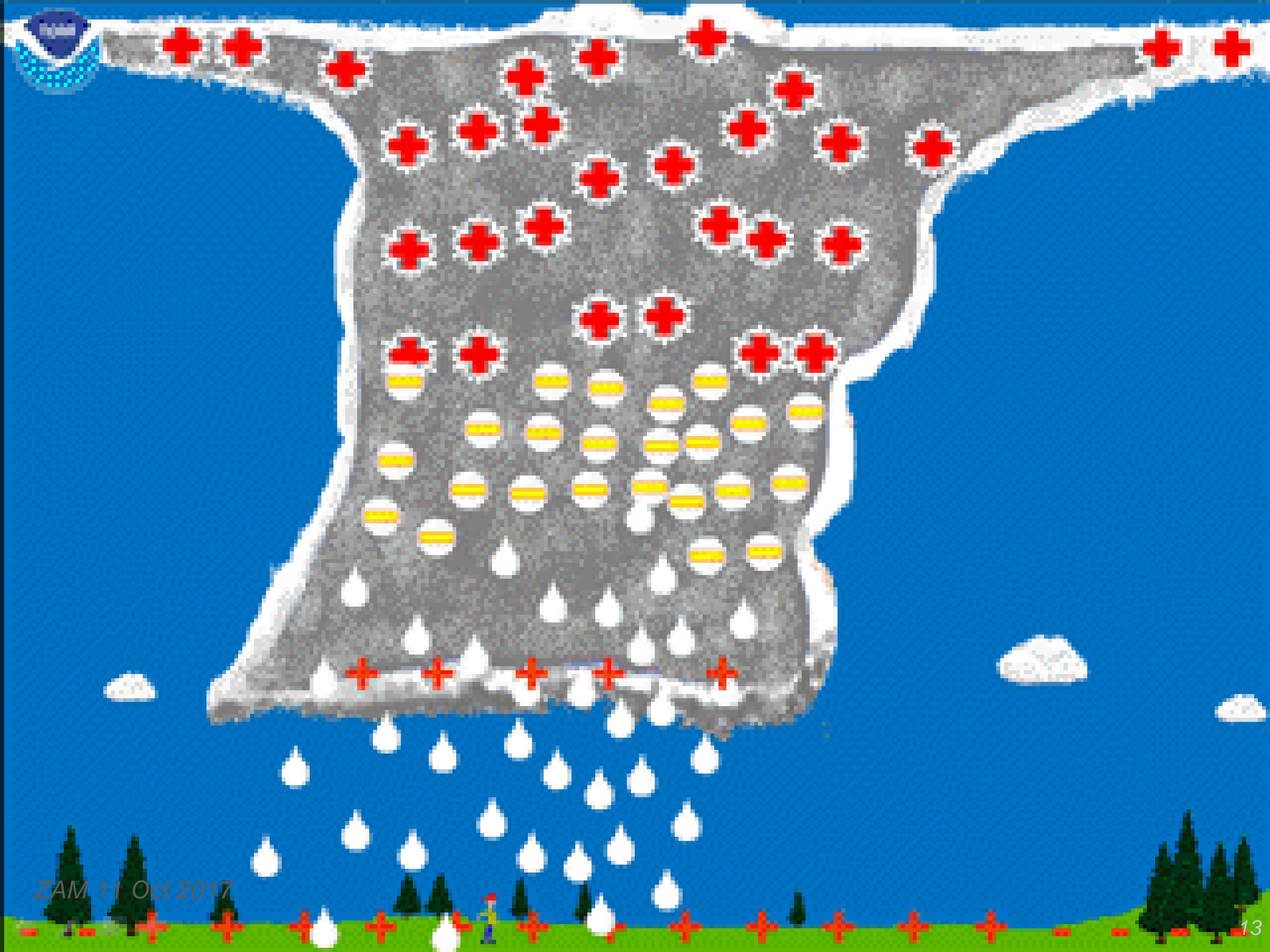
How does lightning occur ?

- Lightning is a **giant spark of electricity** in the **atmosphere** or **between the atmosphere and the ground**.
- In the initial stages of development, **air acts as an insulator between the positive and negative charges in the cloud and between the cloud and the ground**; however, when the **differences in charges becomes too great**, this insulating capacity of the **air breaks down** and there is a **rapid discharge of electricity** that we know as **lightning**.

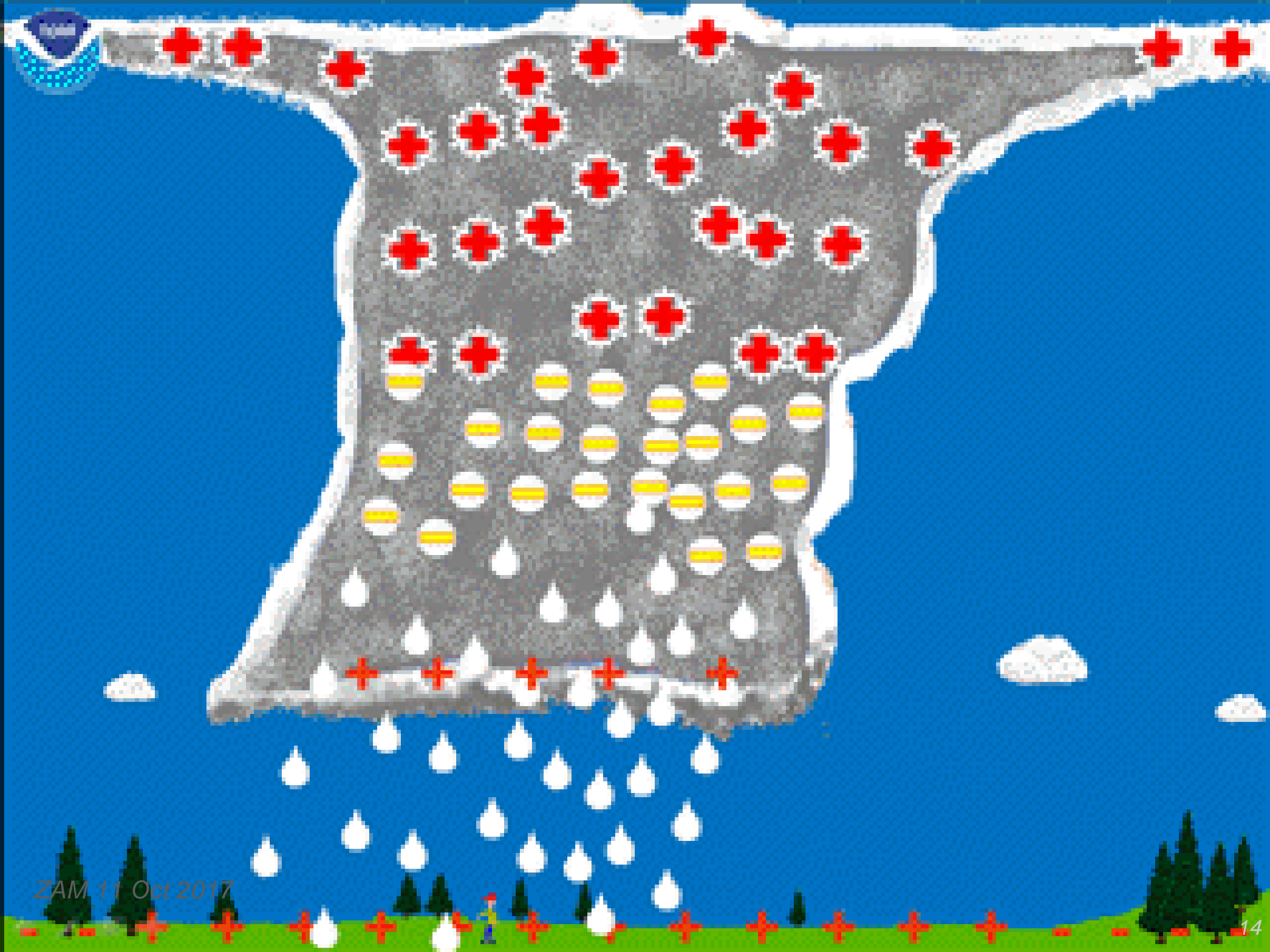
Lightning Science

How does lightning occur ?

- Lightning can occur **between opposite charges within the thunderstorm cloud (Intra Cloud Lightning)** or **between opposite charges in the cloud and on the ground (Cloud-To-Ground Lightning)**.
- Cloud-to-ground lightning is divided into two different types of flashes depending on the **charge** in the cloud where the lightning originates.



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Lightning Science

Thunder

- Thunder is the sound made by a flash of lightning.
- As lightning passes through the air it heats the air quickly.
- This causes the air to expand rapidly and creates the sound wave we hear as thunder.
- Normally, you can hear thunder about 10 miles from a lightning strike.
- Since lightning can strike outward 10 miles from a thunderstorm, if you hear thunder, you are likely within striking distance from the storm.

Lightning Science

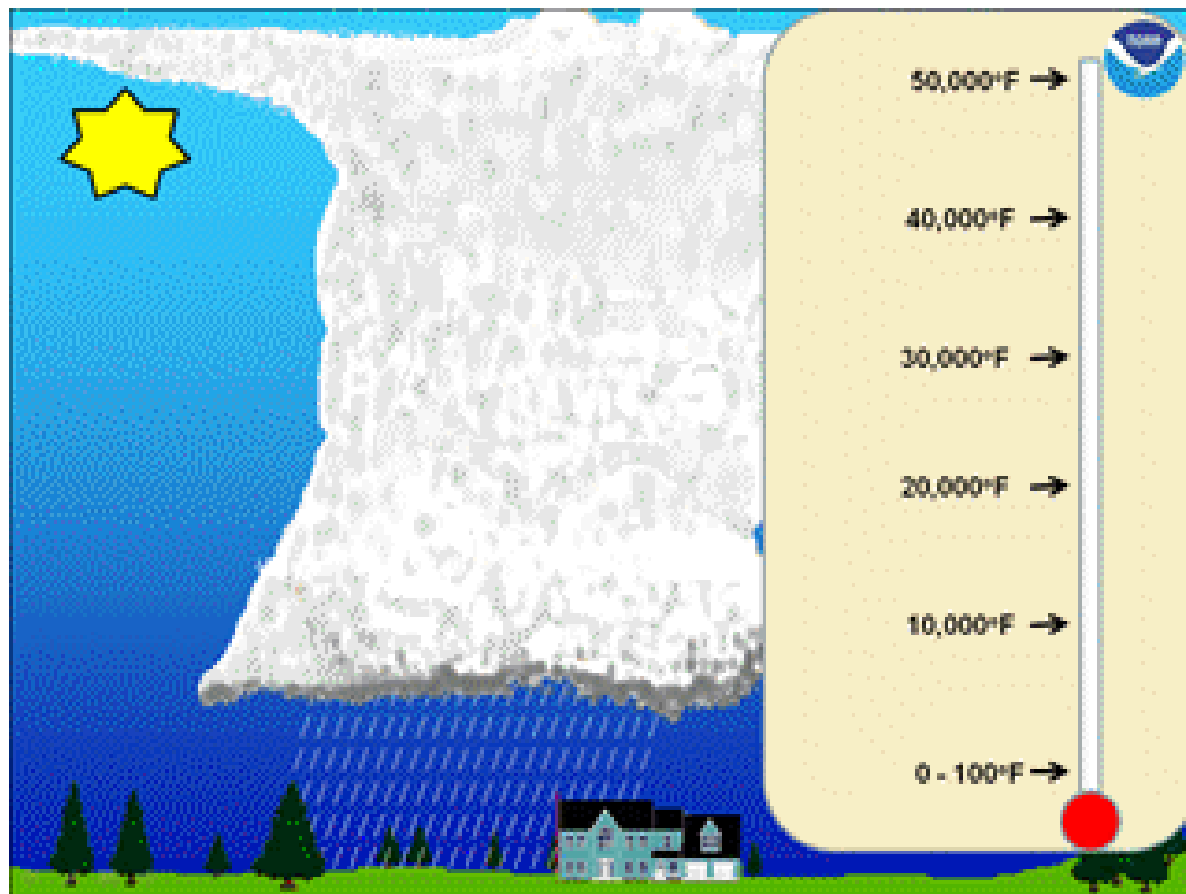
Thunder

How Far Away Was That Lightning?

- The sound of thunder travels about a mile every 5 seconds.
- If you count the seconds between the flash of lightning and the crack of thunder and divided by 5, you get the number of miles away from you (10 seconds is 2 miles).

Lightning Science

How hot?



- **Lightning** is the movement of electrical charges and **doesn't have a temperature**; however, resistance to the movement of these **electrical charges causes the materials** that the lightning is **passing through to heat up**.
- If an object is a good conductor of electricity, it won't heat up as much as a **poor conductor**. **Air is a very poor conductor** of electricity and **gets extremely hot** when lightning passes through it.
- Lightning can heat the air it passes through to 50,000 degrees Fahrenheit (**5 times hotter than the surface of the sun**).

Lightning Science

How powerful?



- A typical lightning flash is about **300 million Volts** and about **30,000 Amps**. In comparison, household values are 240 Volts and 15 Amps.
- There is enough energy in a typical flash of lightning to light a **100-watt incandescent** light bulb for about **three months** or the equivalent **compact fluorescent** bulb for about a **year**.
- When lightning strikes a tree, the heat **vaporizes any water** in its path possibly causing the tree to explode or a strip of bark to be blown off.

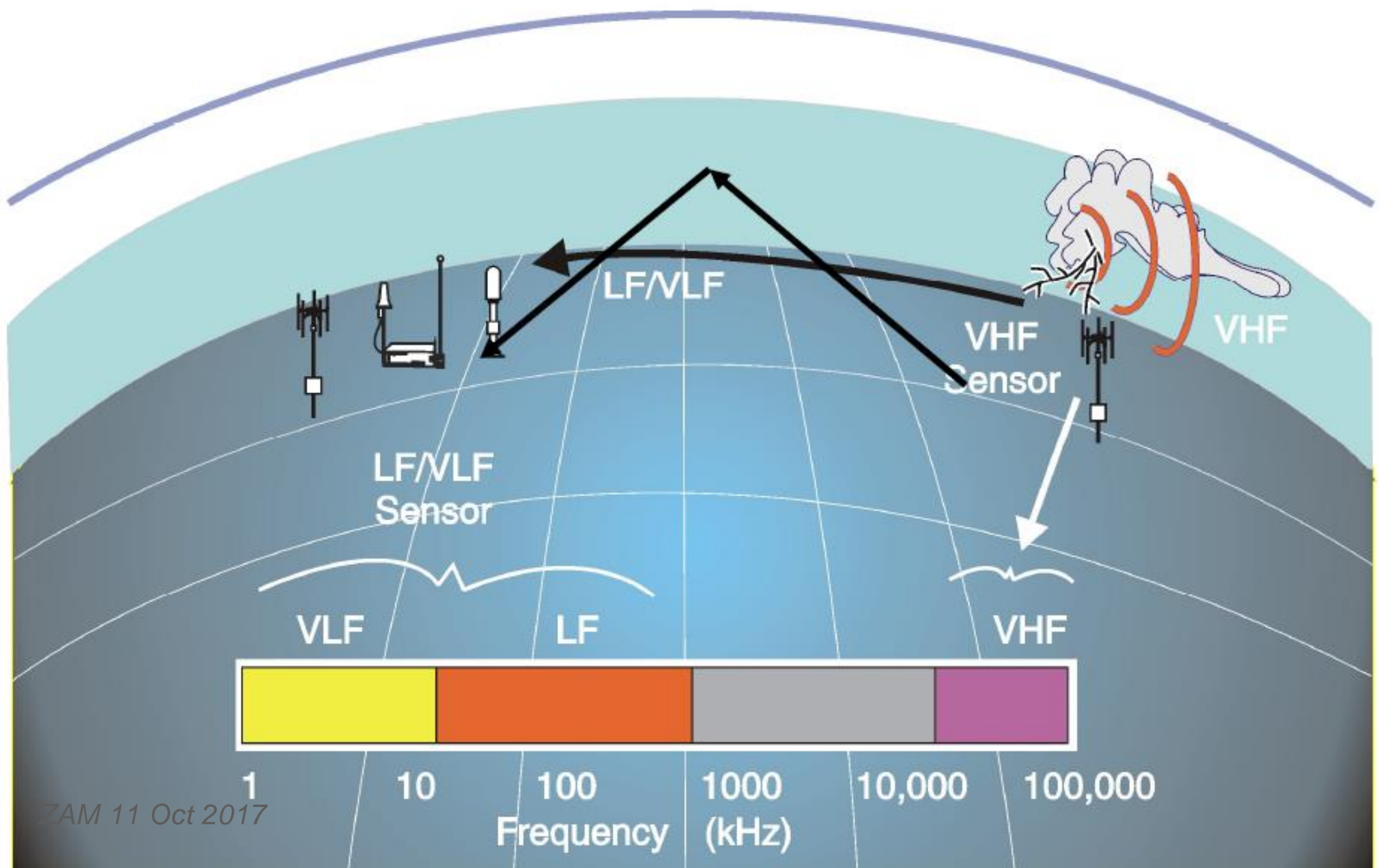
Lightning Science

How does lightning occur ?

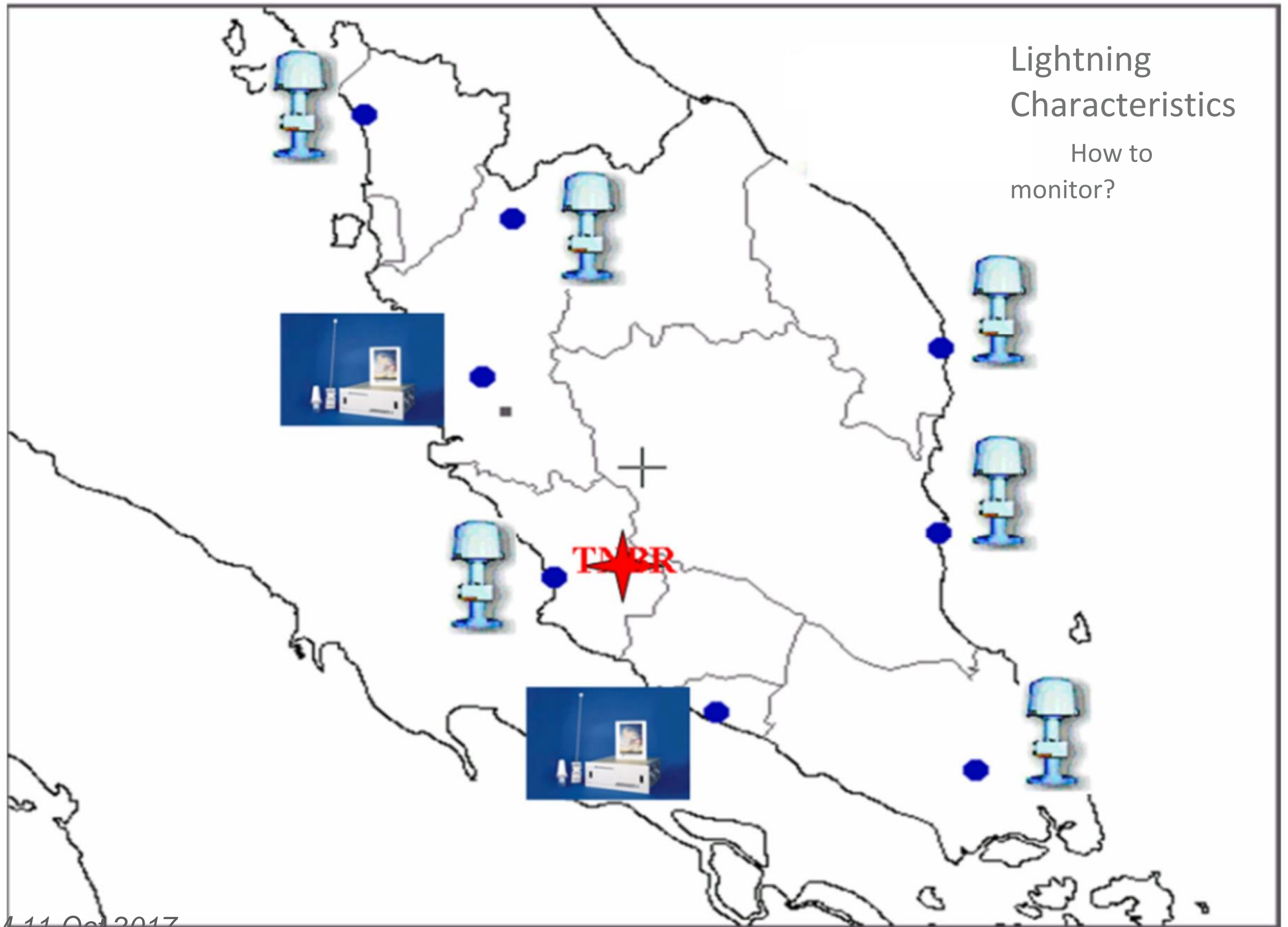
- [Video on Lightning](#)
- Watch out for these things:
 - stepped leaders,**
 - streamers,**
 - downward, upward,**
 - negative, positive,**
 - series of pulses (multiple pulse),**
 - tree-like structures**

Lightning Characteristics

How does lightning EMF propagate ?

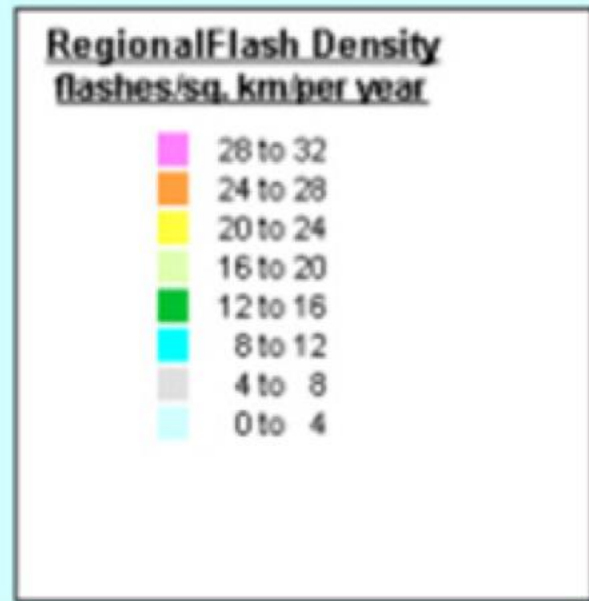
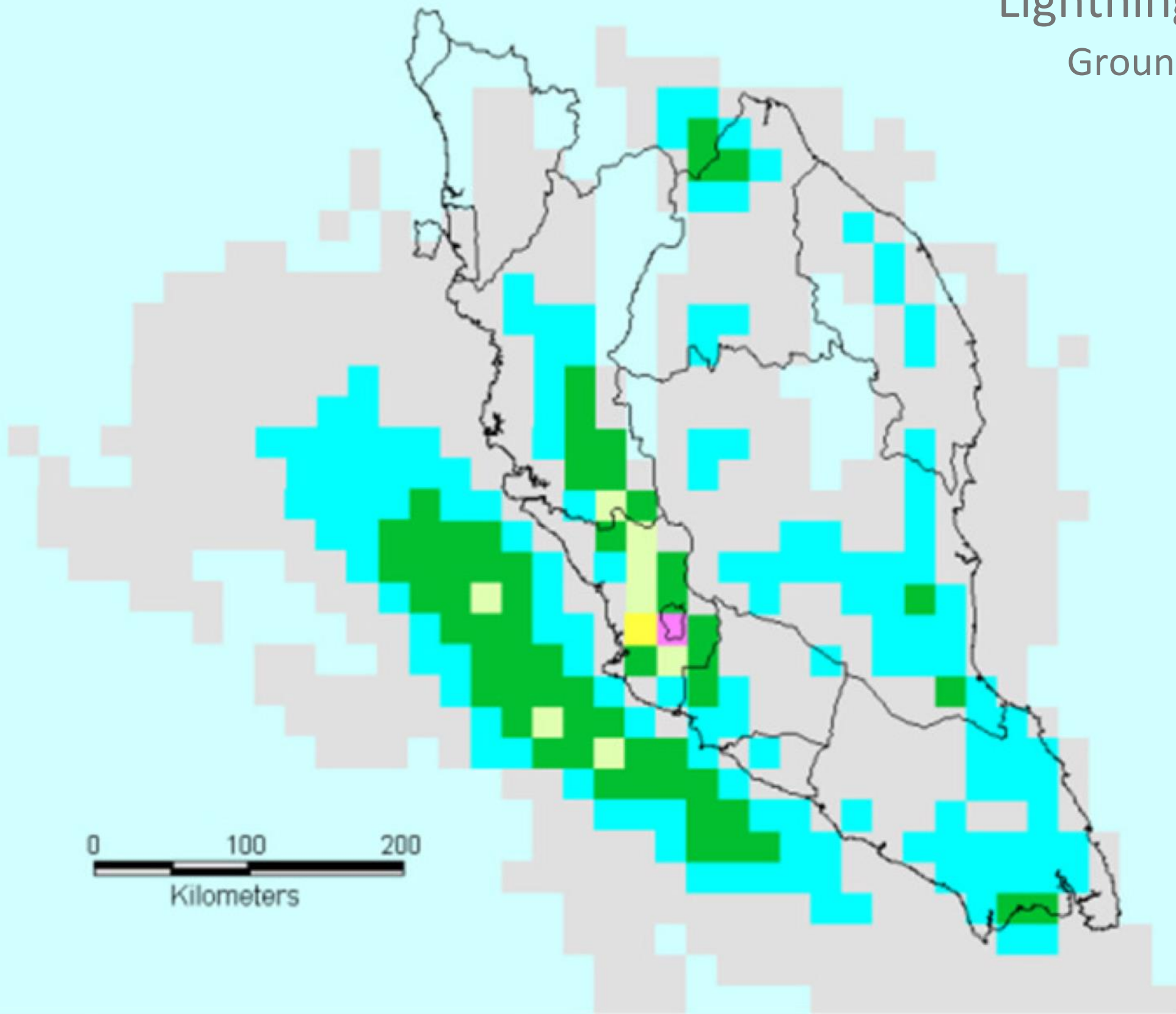


SENSORS LOCATIONS



Lightning Characteristics

Ground Flash Density Map

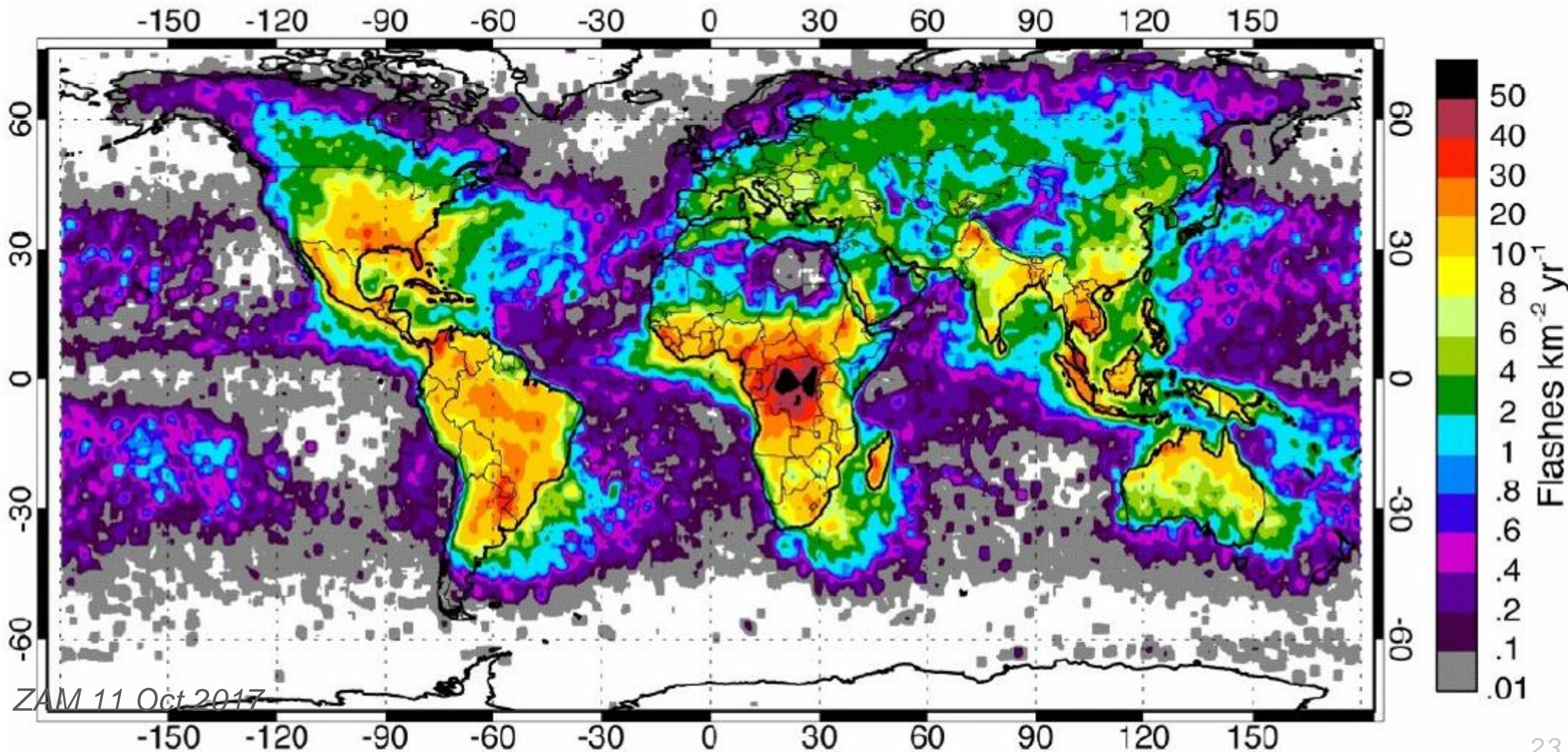


0 100 200
Kilometers

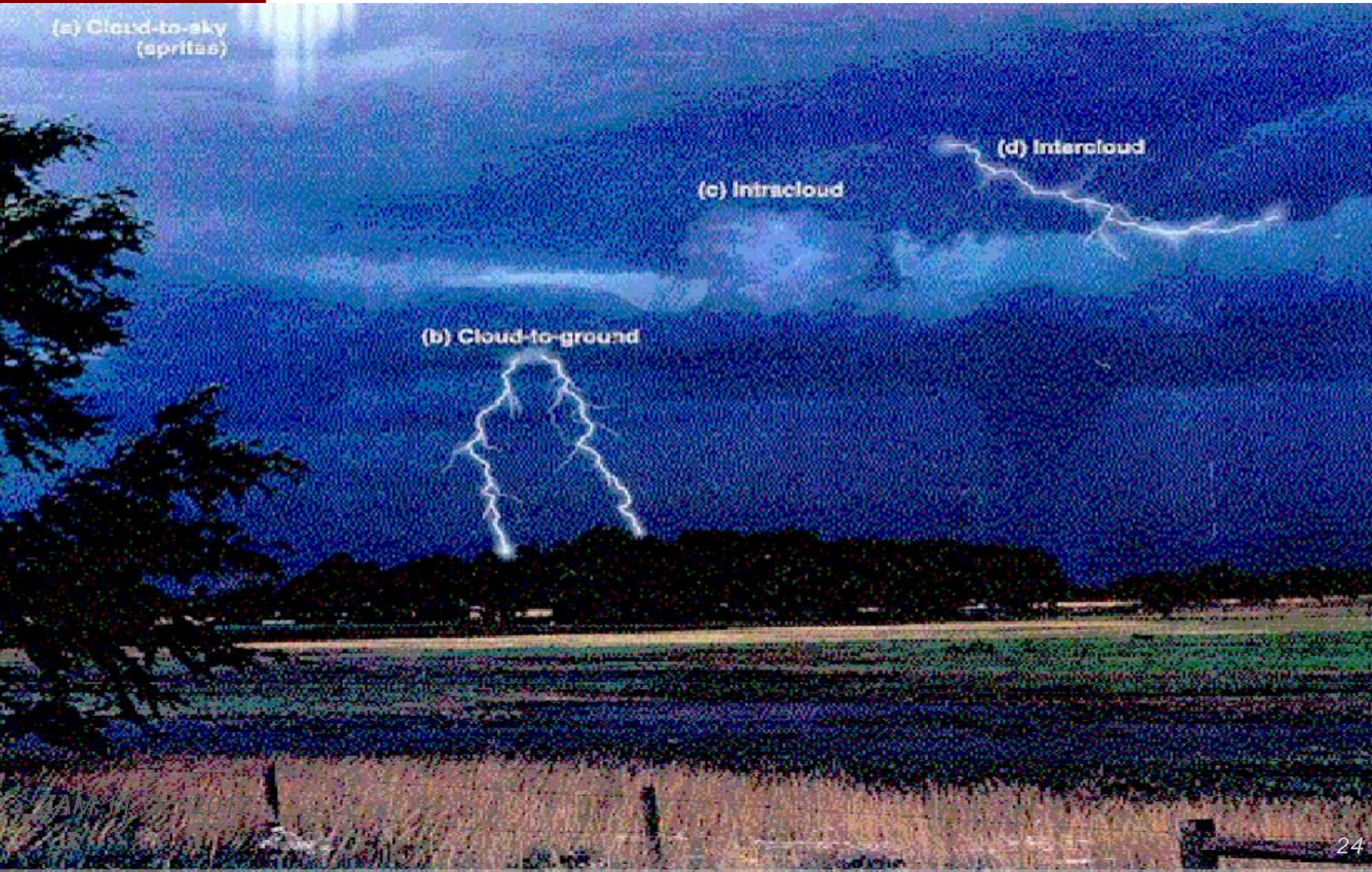
Lightning Characteristics

Ground Flash Density Map

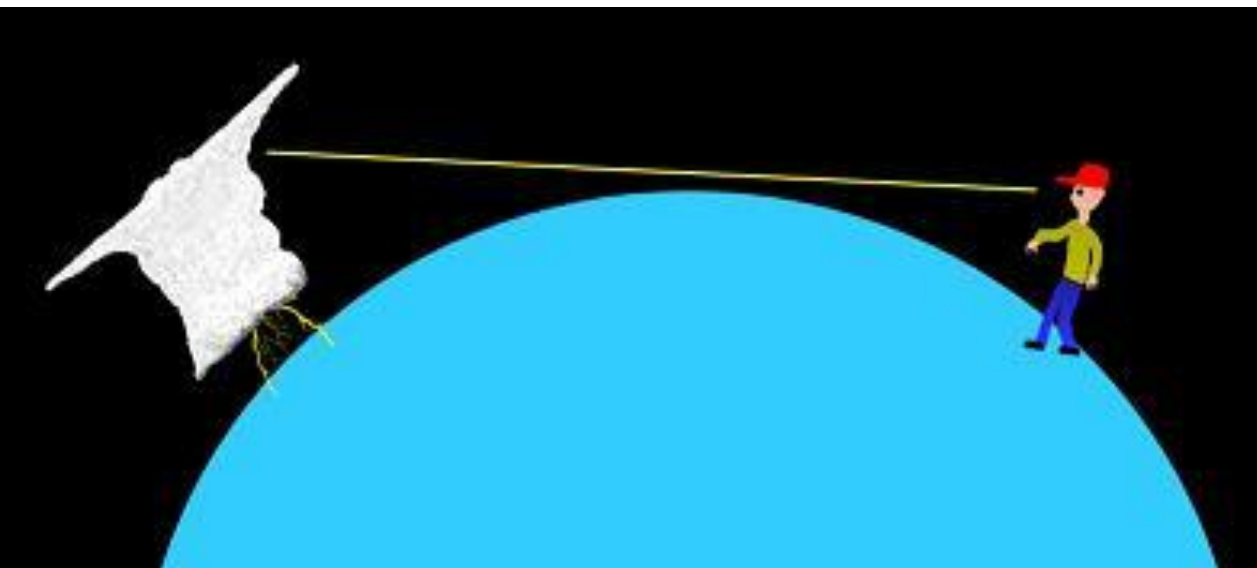
- An estimated 2000 thunderstorms are in progress in the world at any given moment.



Types of lightning



Heat lightning



- Lightning from a distant thunderstorm just too far away to see the actual cloud-to-ground flash or to hear the accompanying thunder.



- Simply the light produced by a distant thunderstorm. The sound of thunder can only be heard for about 10 miles from a flash
- The faint flash seen by the observer is light being reflected off higher-level clouds.

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Generation of potentials in the ground

- [Video illustrating the Step potential](#)

- **Note:**

Similar to the AC or DC voltages, lightning impulse voltage behaves in similar manner, except that lightning impulse voltages are momentous and disappear within split seconds, compared to AC and DC voltages which are continuously energised by the power supply.

In the case of lightning, the power supply is from the charges in the cloud, once discharged, no more current is flowing and hence no more voltage exist after the lightning event itself.

Lightning Characteristics

Soil resistivity

- **Conductivity** of : Human body > soil > air
- Air: worst conductor, but ionises and finally breakdown when stressed. Stress come from the electric field due to the cloud charges
- Soil: not a conductor, its resistivity varies with locations. The higher the resistivity the poorer its conductivity eg hard rock cf garden soil

- When lightning current (30 kA average) flows inside the soil, the resistance of the soil causes voltage drops to be developed between one point to the other. If we are standing on the ground through which lightning current flow (with both feet apart), a voltage drop exist between our two legs.
- The larger the resistivity of the soil, the larger will be the voltage drop, the more is the risk.
- Squat with both feet as close as possible with minimal contact with ground basically reduce the voltage drop between the two feet.
- Grounding plates/mesh used in protection system is to reduced such potential difference between any two point on the ground

Lightning Effect

How does lightning harm you?

- [Video/animation on Lightning effect](#)
(How to survive a lightning strike)

Watch out for these things:

Potential difference that matters

Faraday cage

Step potential

Lightning Effect

How does lightning harm you?

Human safety

Personal Lightning Safety Tips

- *The less known crouch/squat position.*
- *Cover your eyes*
- *Close your eyes*





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How People Are Struck By Lightning

Lightning Effect

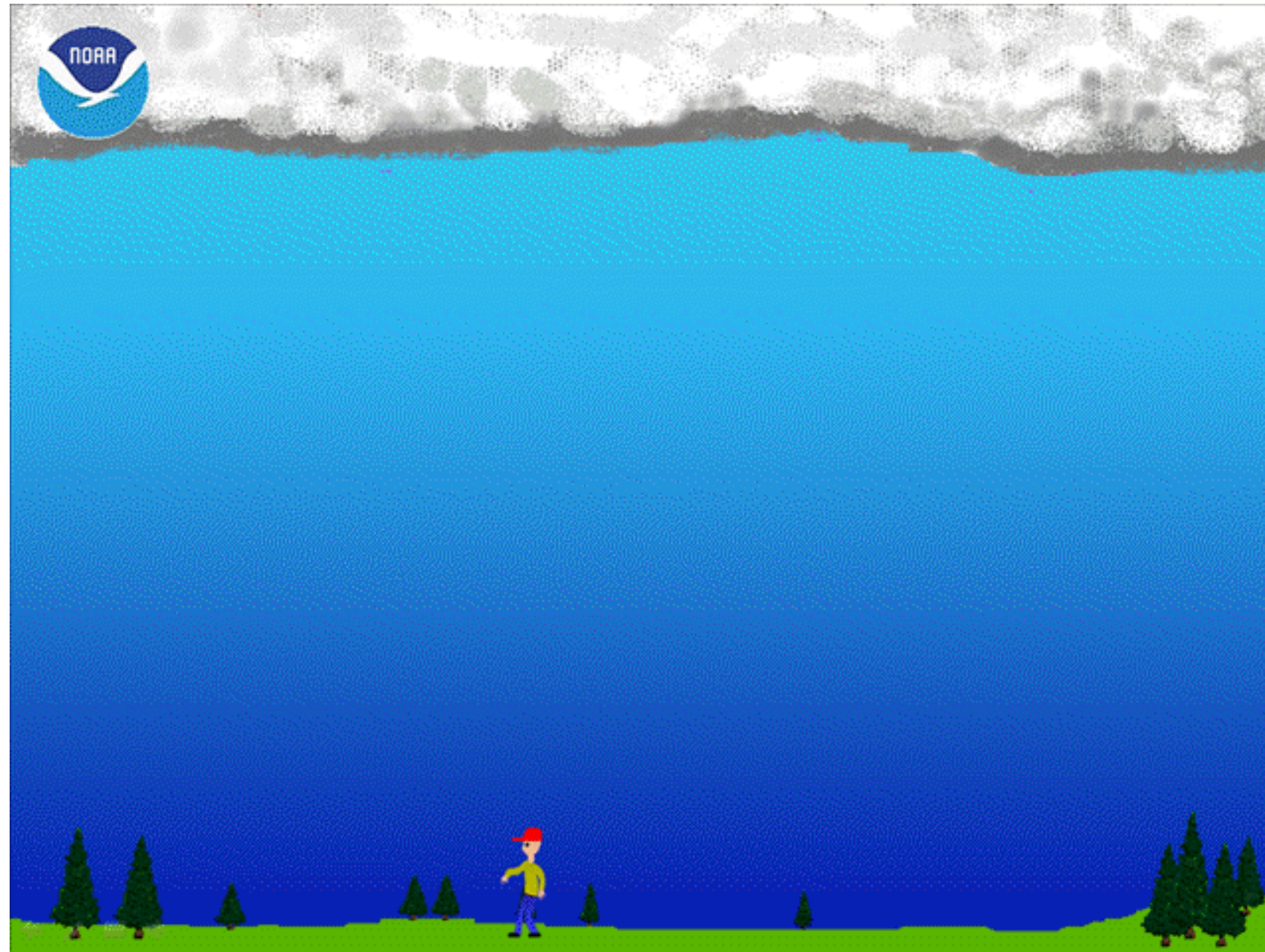
- How does lightning harm you?

- 1. Direct Strike***
- 2. Side Flash***
- 3. Ground Current***
- 4. Conduction***
- 5. Streamer***

Direct Strike

Lightning Effect

- How does lightning harm you?



Victims struck directly by lightning are usually in open areas. Direct strikes are less common than some of the other ways people are struck, but they are potentially the most deadly.

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Lightning Effect

- How does lightning harm you?



Victims struck by a side flash are usually standing next to a taller object -- often a tree. On its way to the ground, the lightning jumps from the taller object to the person.

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Side Flash

Lightning Effect

- How does lightning harm you?



***In 2011, a man took shelter under this tall tree.
When lightning struck the tree, the man was
killed by a side flash.***

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Ground Current

Lightning Effect

- How does lightning harm you?



People struck by ground current are somewhere very near a lightning strike. The lightning might strike a nearby tree or even the ground. Ground current is likely responsible for most lightning fatalities.

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Lightning Effect

- How does lightning harm you?



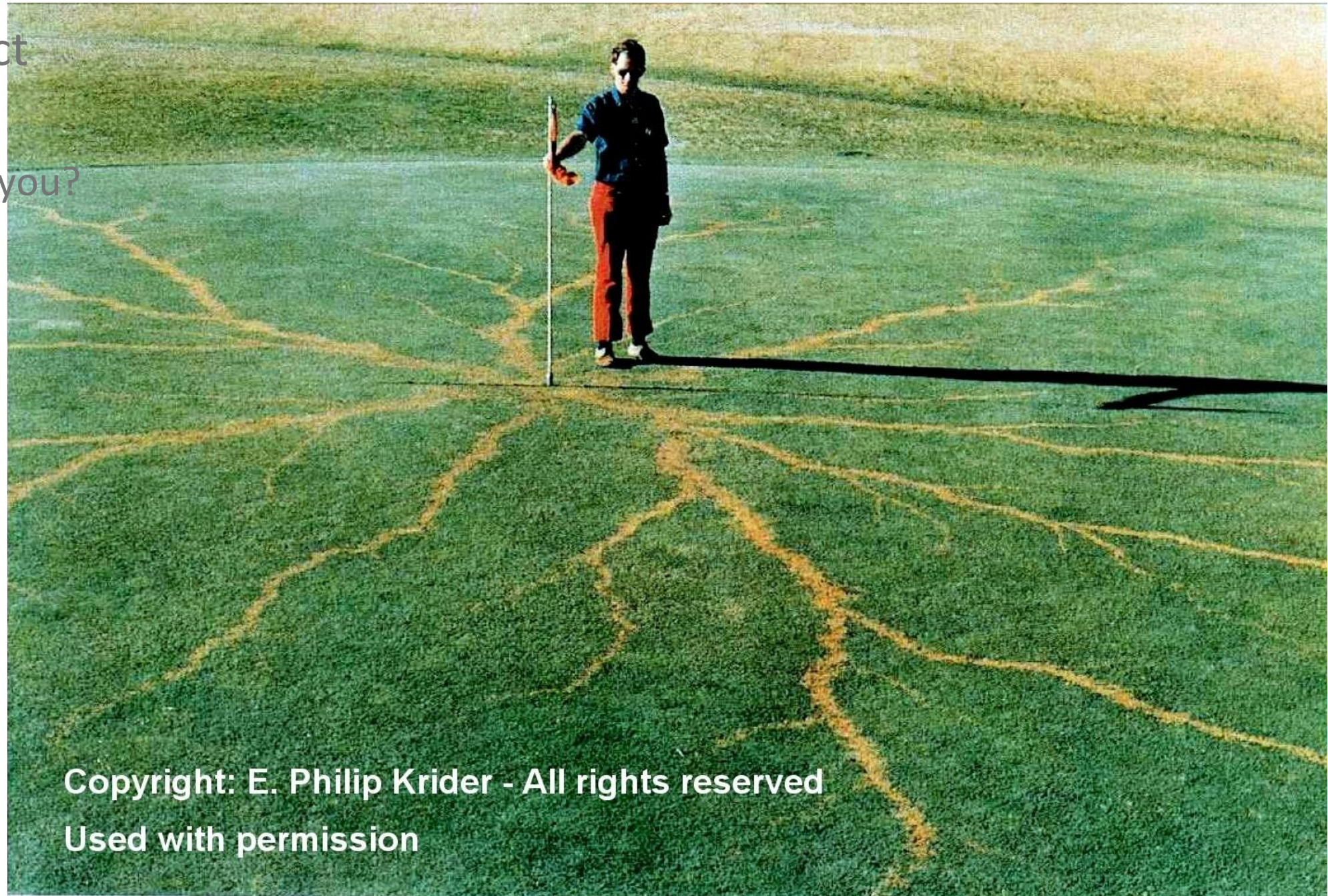
Ground current usually passes in one leg and out the other, passing through the body. It is particularly dangerous to anyone lying down. Ground current kills many farm animals every year.

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Ground Current

Lightning Effect

- How does lightning harm you?



Ground current moves in and along the surface of the ground. In this case, lightning struck the flag and spread out along the ground.

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Ground Current

Lightning Effect

- How does lightning harm you?



Photo credit: Kelli Easterling | Richmond County Daily Journal
Used with permission

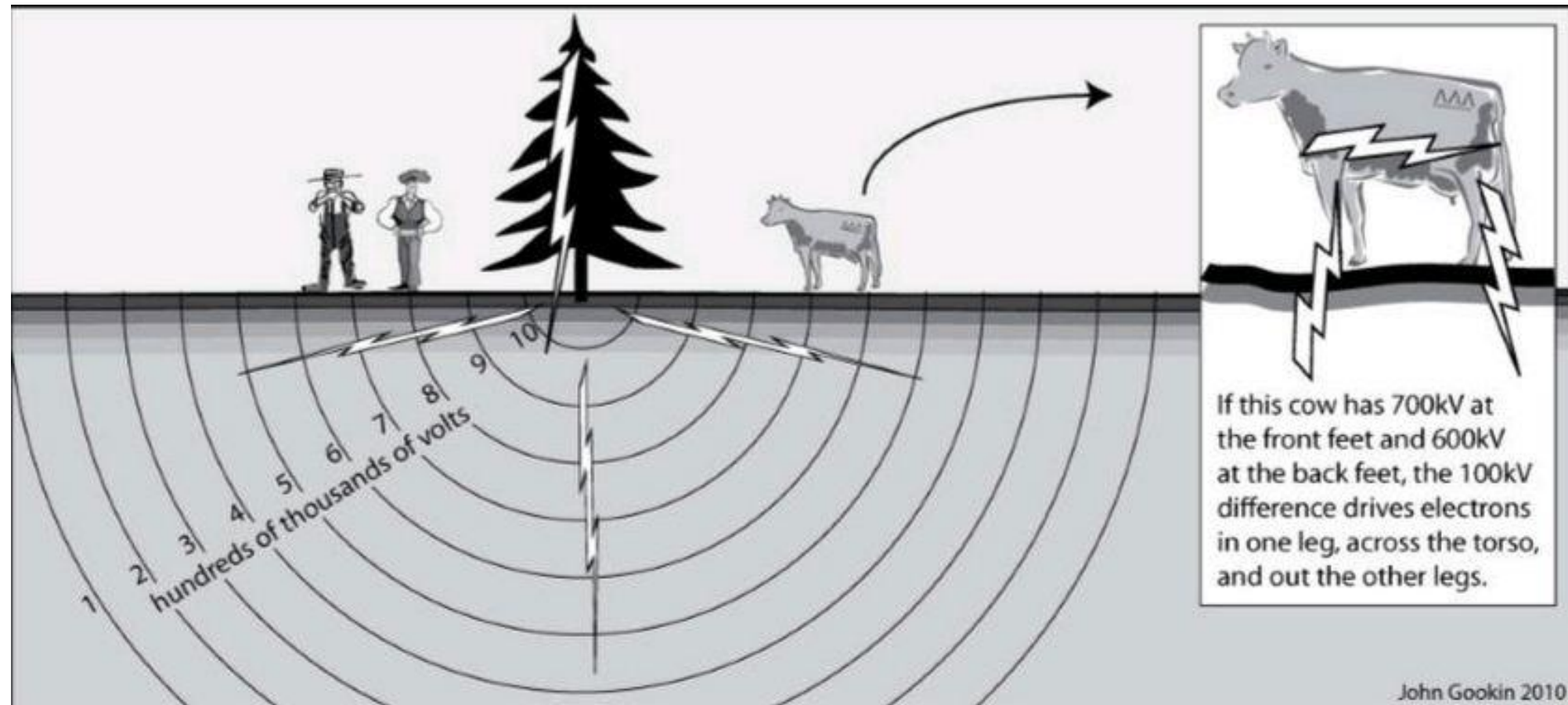
Farm animals are often killed by ground current. In this case, lightning struck the tree and spread out along the ground, killing these cattle.

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Ground Current

Lightning Effect

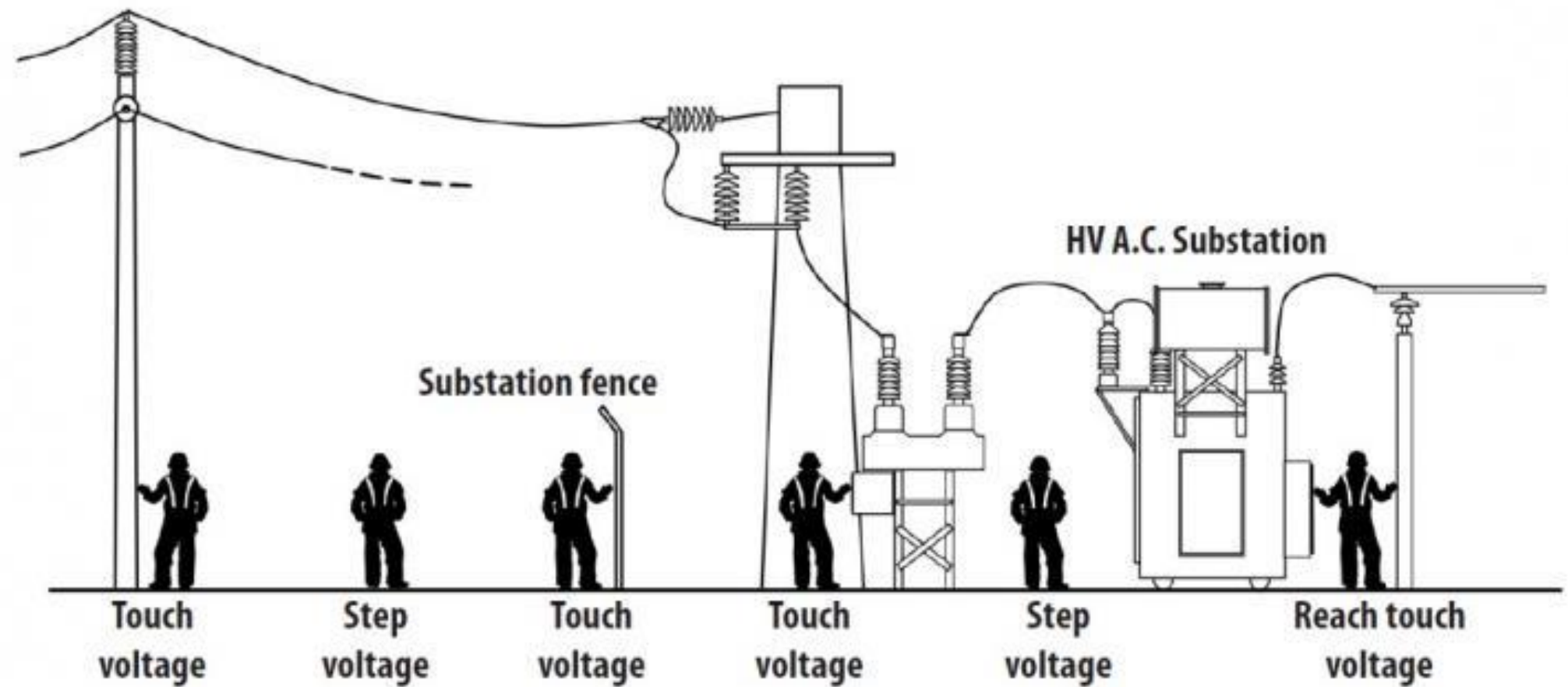
- How does lightning harm you?



Ground Current

Lightning Effect

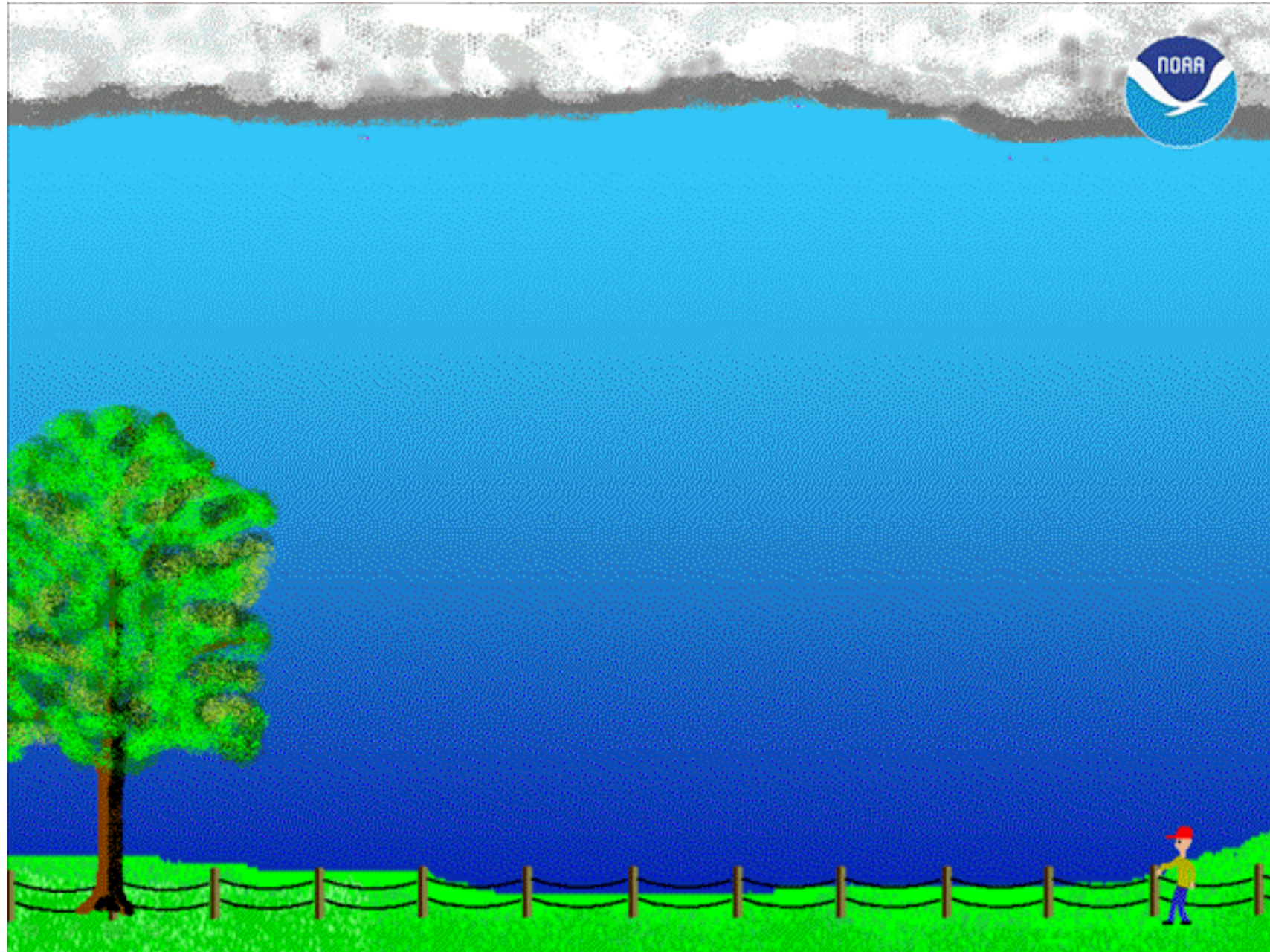
- How does lightning harm you?



Conduction

Lightning Effect

- How does lightning harm you?



Lightning can travel long distances through wires or metal. Metal does not attract lightning, but it does provide a path for lightning to follow.

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Lightning Effect

- How does lightning harm you?



Lightning struck somewhere along this wire fence. The charge traveled along the fence and killed all these cows.

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Conduction

Lightning Effect

- How does lightning harm you?



Conduction is responsible for most indoor lightning casualties. Lightning can enter a home through wires or pipes. Anyone that touches plumbing or anything plugged into an electrical outlet is at risk of being struck.

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Streamer

Lightning Effect

- How does lightning harm you?



Although not as common as other types of fatal incidents, victims caught in “streamers” are at risk of being killed or injured. Streamers discharge when lightning strikes nearby.

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Streamer

Lightning Effect

- How does lightning harm you?



This photo shows a nearby flash of lightning. The photographer was lucky that he wasn't killed or seriously injured. In addition to the main flash, there are also "streamers" nearby (see next page).

Streamer

Lightning Effect

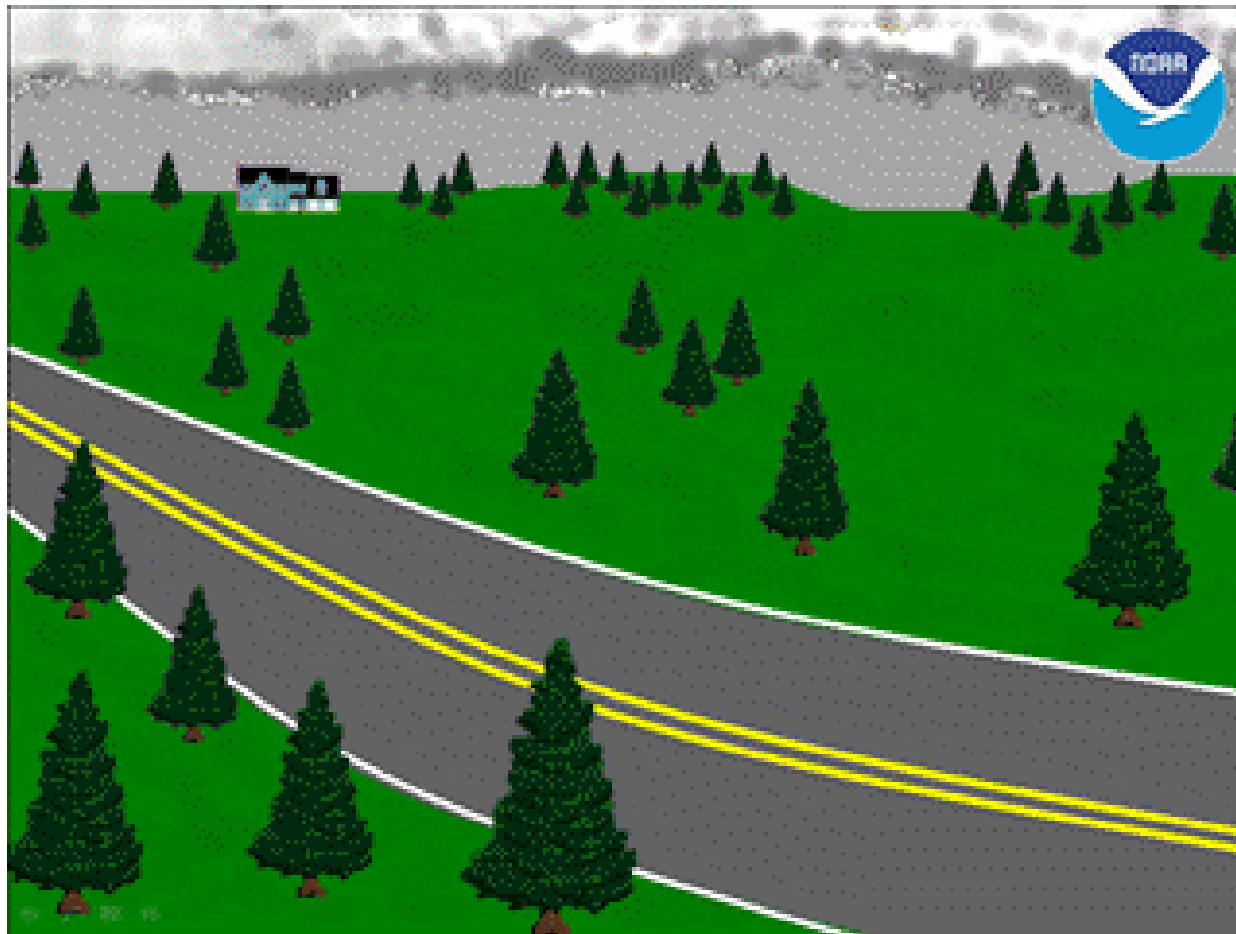
- How does lightning harm you?



When we zoom in on the picture, you can see two streamers coming from trees in the background.

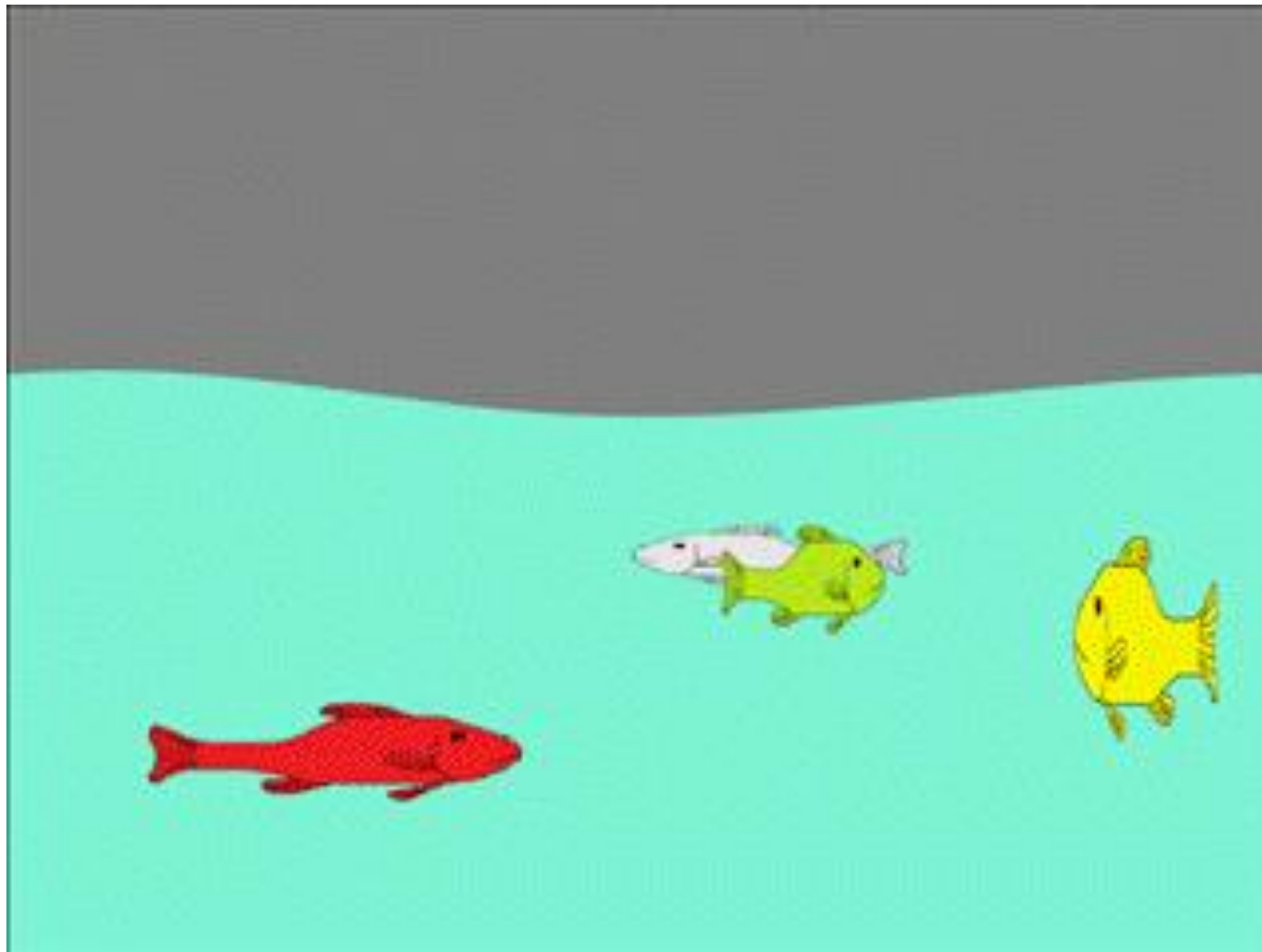
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Lightning Effect on a car



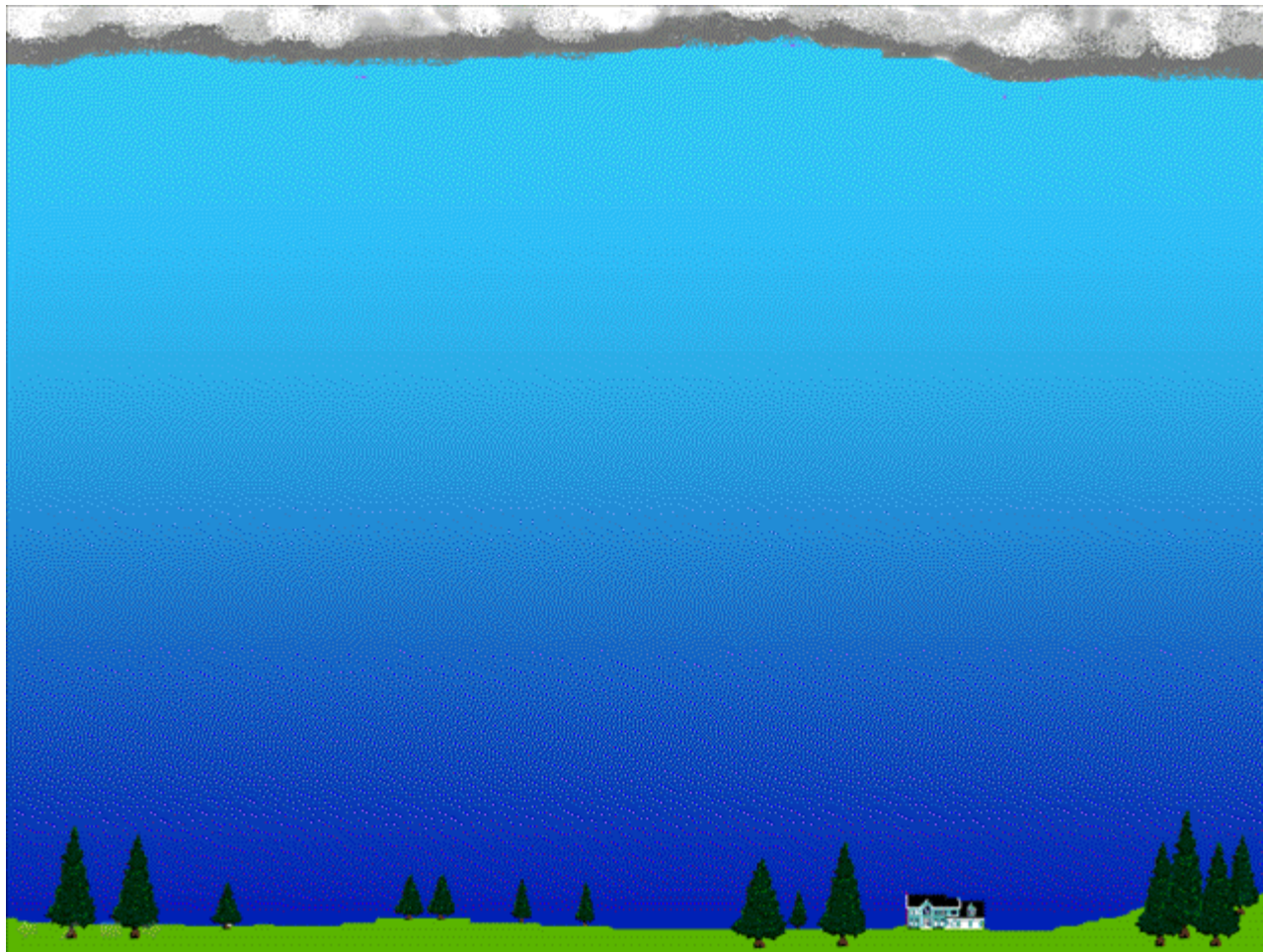
- The outer metal shell of hard-topped metal vehicles does provide protection to those inside a vehicle with the windows closed.
- A typical cloud-to-vehicle lightning strike will either strike the antenna of the vehicle or along the roofline. The lightning will then pass through the vehicle's outer metal shell, then through the tires to the ground.
- Damage to the antenna, electrical system, rear windshield, and tires is common.

Lightning Effect on fish



- Bodies of water are frequently struck by lightning. So why don't all the fish die?
- Before a lightning strike, a charge builds up along the water's surface. When lightning strikes, most of electrical discharge occurs near the water's surface.
- Most fish swim below the surface and are unaffected. Although scientists don't know exactly just how deep the lightning discharge reaches in water, it's very dangerous to be swimming or boating during a thunderstorm.

Lightning Effect on a plane



- Commercial transport passenger planes are hit by lightning an average of one or two times a year.
- They are designed and built to have conducting paths through the plane to take the lightning strike and conduct the currents.
- Aircraft often initiate the strike because their presence enhances the ambient electric fields typical for thunderstorms and facilitates electrical breakdown through air.
- When it is suspected that a plane was hit by lightning, there is a mandatory inspection for damage, which can delay flights and be quite expensive. For that reason, as well as for turbulence, they avoid thunderstorms as much as possible.

What We Learn By Tracking Lightning Fatalities

Lightning
Effect

- Statistics

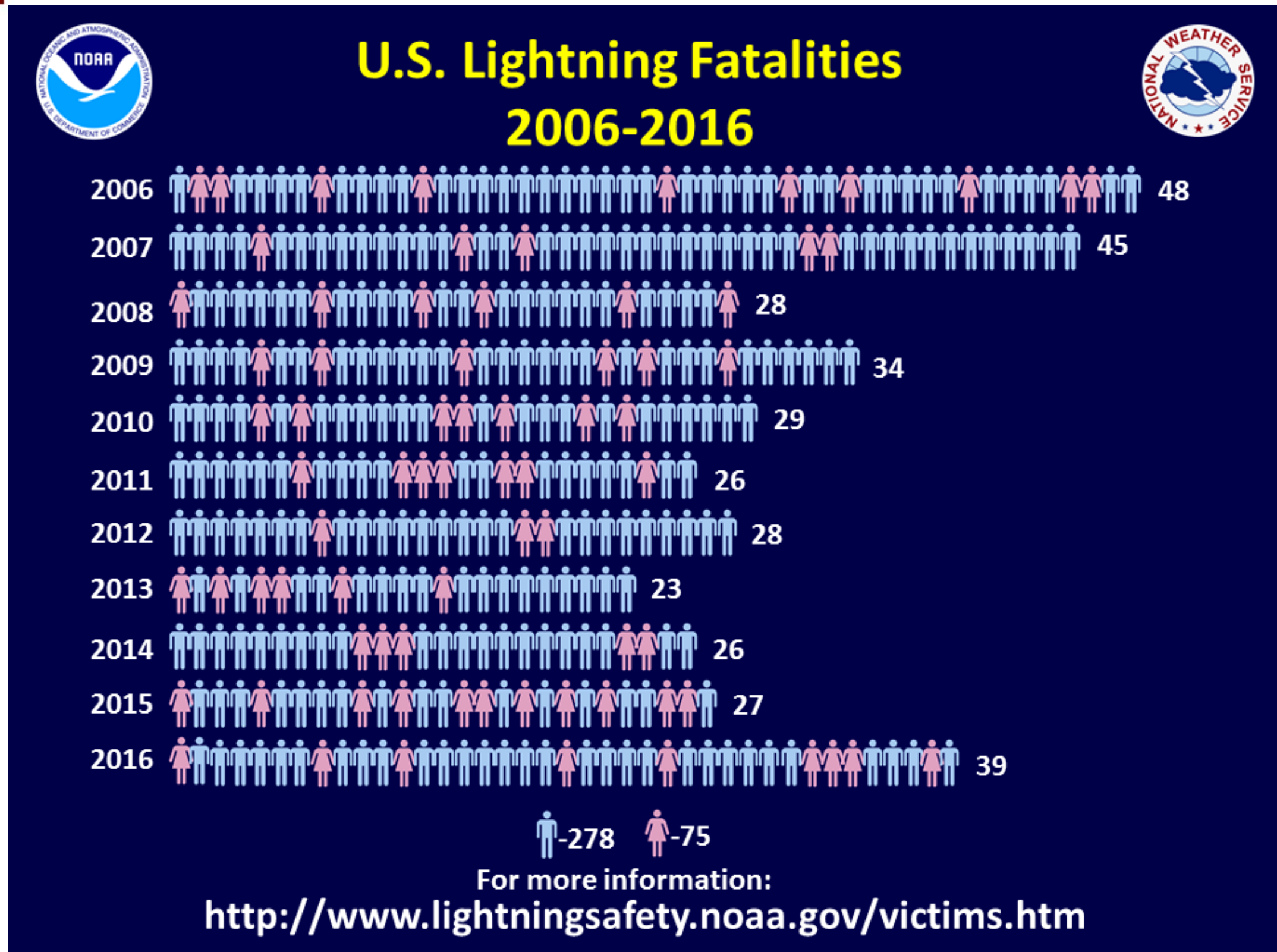
A list of lightning fatalities help understand what can be done to prevent these untimely deaths and injuries.

By tracking statistics like age, gender, location, activity, and day of the week for each fatal incident, we get a better understanding of who is being struck and what they were doing at the time.

Our primary goal is to reduce the number of deaths and injuries. By collecting and analyzing these data, we are able to focus our efforts on behaviors and activities that contribute most to lightning deaths and injuries in a given country.

Lightning Effect

- Statistics



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Lightning
Effect

- Statistics

Looking At The Statistics

Findings show the factors that contribute most to lightning fatalities.

Lightning
Effect
- Statistics

Lightning Fatality Pie Male versus Female

Men and boys account for more than 80% of the lightning fatalities in the United States.

In general, men are less likely to seek shelter immediately when they first see lightning or hear thunder.

Lightning
Effect

- Statistics

Lightning Fatality Pie **Inside versus Outside**

Almost all lightning fatalities occur outside.

People often wait too long to seek shelter when a thunderstorm is approaching or developing.

Remember, there is no safe place outside when a thunderstorm is in the area.

Lightning
Effect

- Statistics

Lightning Fatality Pie **Fatal Activities**

Most lightning victims are outside enjoying leisure activities.

These activities include fishing, boating, hiking, camping, sports, or a trip to a beach or lake.

Others are killed during their normal daily activities or at work.

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Lightning
Effect

- Statistics

Lightning Fatality Pie **Water-Related Fatalities**

**Almost half of all water-related fatalities are people fishing.
It's especially important for people out on the water to plan
ahead so that there's adequate time to get to a safe place
before a thunderstorm threatens.**

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Lightning
Effect

- Statistics

Lightning Fatality Pie **Sports-Related Fatalities**

For sports-related lightning fatalities, soccer tops the list.

Golf and running also contribute significantly to the deaths.

Both participants and spectators need a plan to get to safety, if necessary.

Lightning
Effect

- Statistics

Lightning Fatality Graph Month

Lightning fatalities can occur at any time of the year but are more frequent during the warmer months.

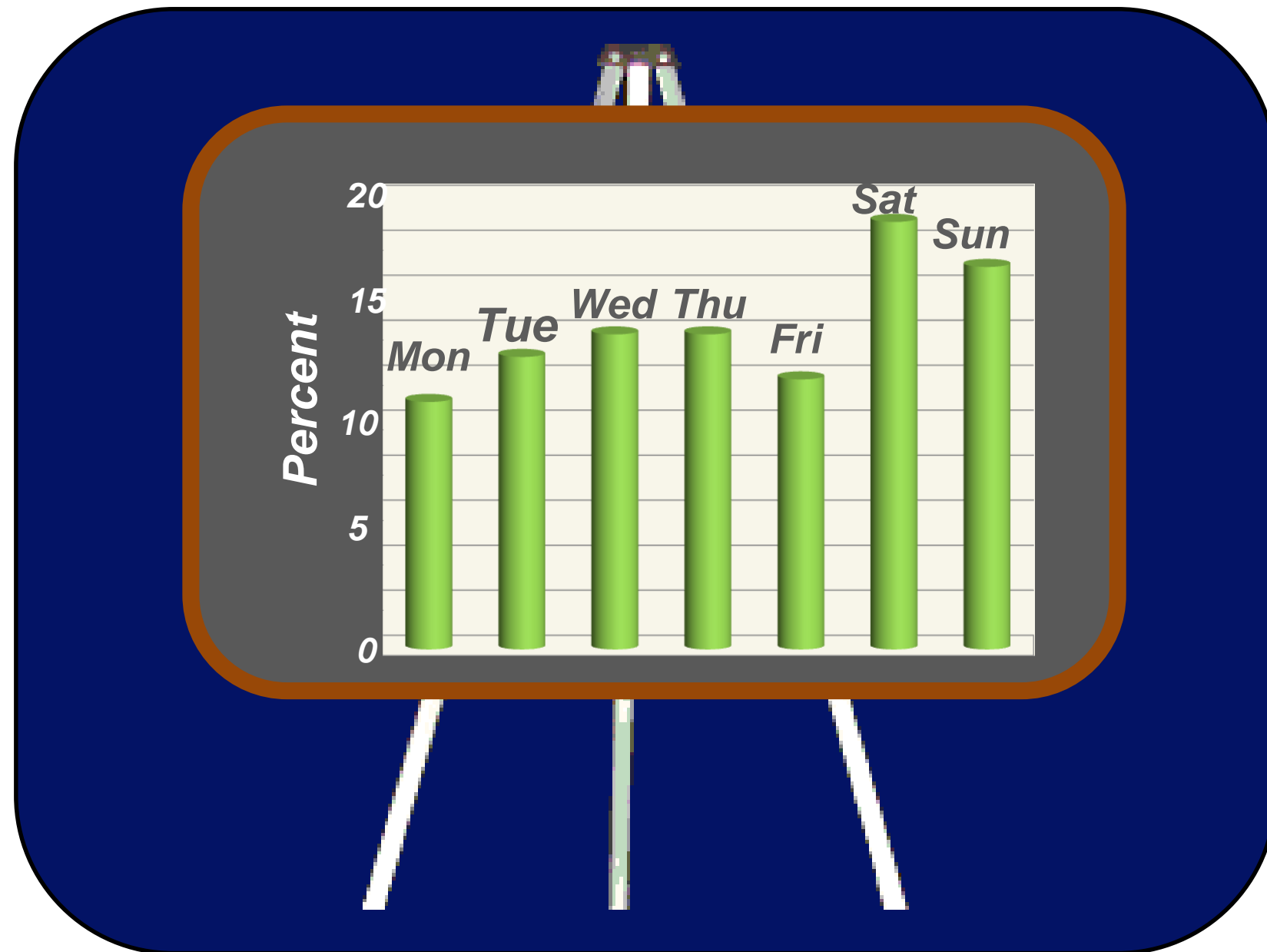
During summer, people spend more time outdoors and there are more thunderstorms.

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Lightning Fatality Graph

Day of Week

Lightning
Effect
- Statistics

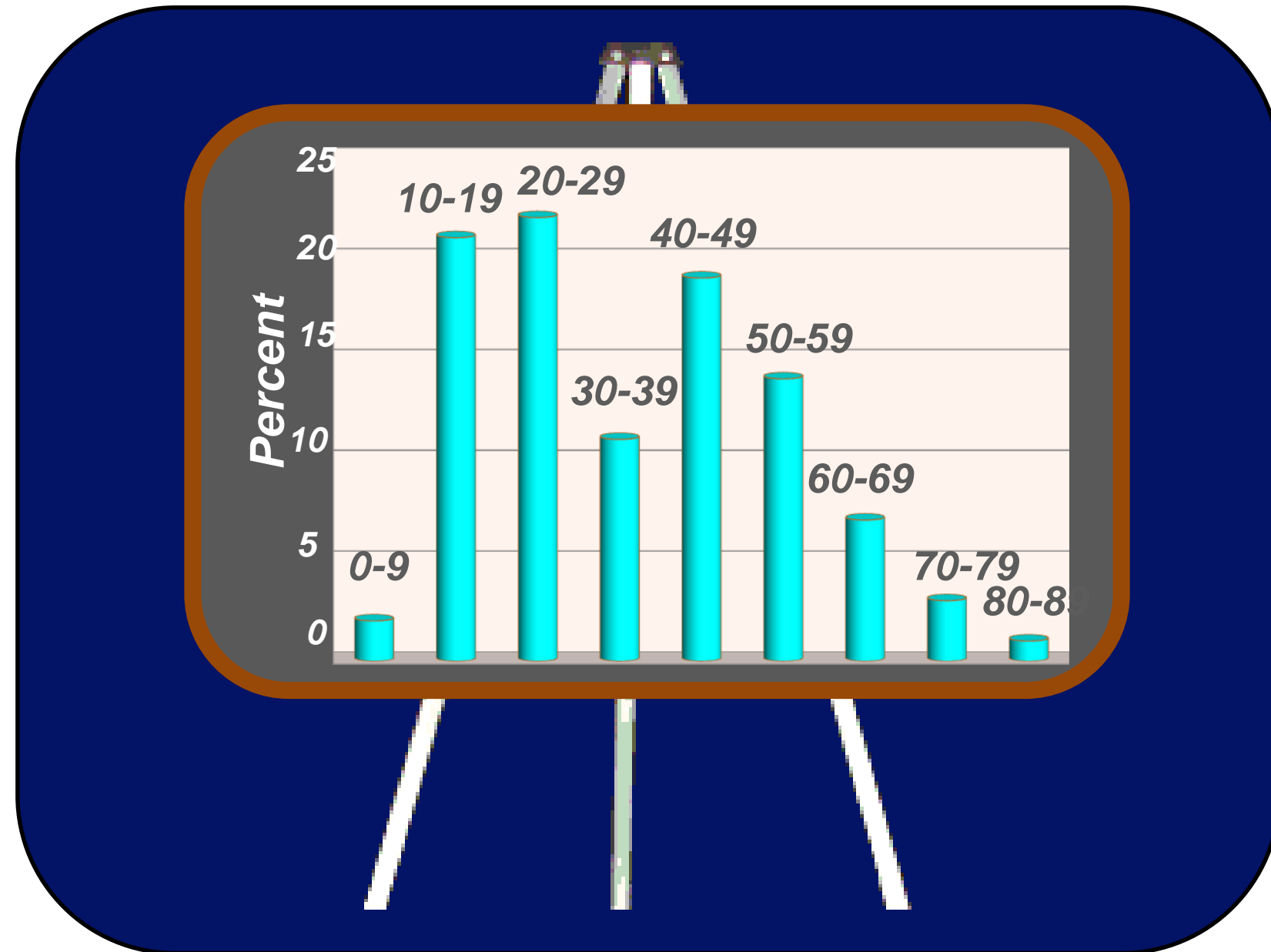


Lightning fatalities occur all days of the week but are more common during the weekend when people enjoy many outdoor leisure activities.

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Lightning Fatality Graph

Age



Lightning kills people of all ages. However, most of the people killed by lightning are between the ages of 10 and 60.

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Basics

Basic protection for living beings

- Minimisation of potential difference eg step potential, touch potential etc.

Basic protection for non living things

- Reduce fire and damages by external air terminals, down conductors, grounding, internal protection, and bonding.

Living beings

- Protected shades and structures or open space from direct strikes
- Minimisation of potential differences by equipotential bonding, grounding mesh, grounding plates, grounding grids
- Warning systems (for unprotected areas)

Lightning Protection

Man made systems

Basics

- Protection Poles/Rods

Protection cones

- Protection Wires

Protection areas

Lightning Victims

Lightning Protection

- Human

Every year, hundreds of people across the world fall victim to one of nature's most powerful weather threats... **LIGHTNING!**

While most people survive a lightning strike, some survivors are left with permanent, painful neurological disabilities.

Most, if not all, of these tragedies could be prevented with a few simple precautions. Plan ahead so that you can get to a safe place if a thunderstorm threatens, and go there immediately if you see signs of a developing or approaching thunderstorm. A little inconvenience can save your life.

If Someone is Struck

Lightning
Protection

- Human



Lightning victims do not carry an electrical charge, are safe to touch and may need urgent medical attention.

If someone is struck, call 911 for help. If necessary, begin CPR and use an Automatic External Defibrillator (AED) if one is available. Cardiac arrest is the immediate cause of death for those who die.

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Lightning Survivors

Lightning
Protection

- Human



After being struck, people are often confused and don't know what happened. Although a survivor may suffer burns, a greater concern is the effect of the lightning on the heart and nervous system.

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Lightning Survivors

Effects of a Lightning Strike

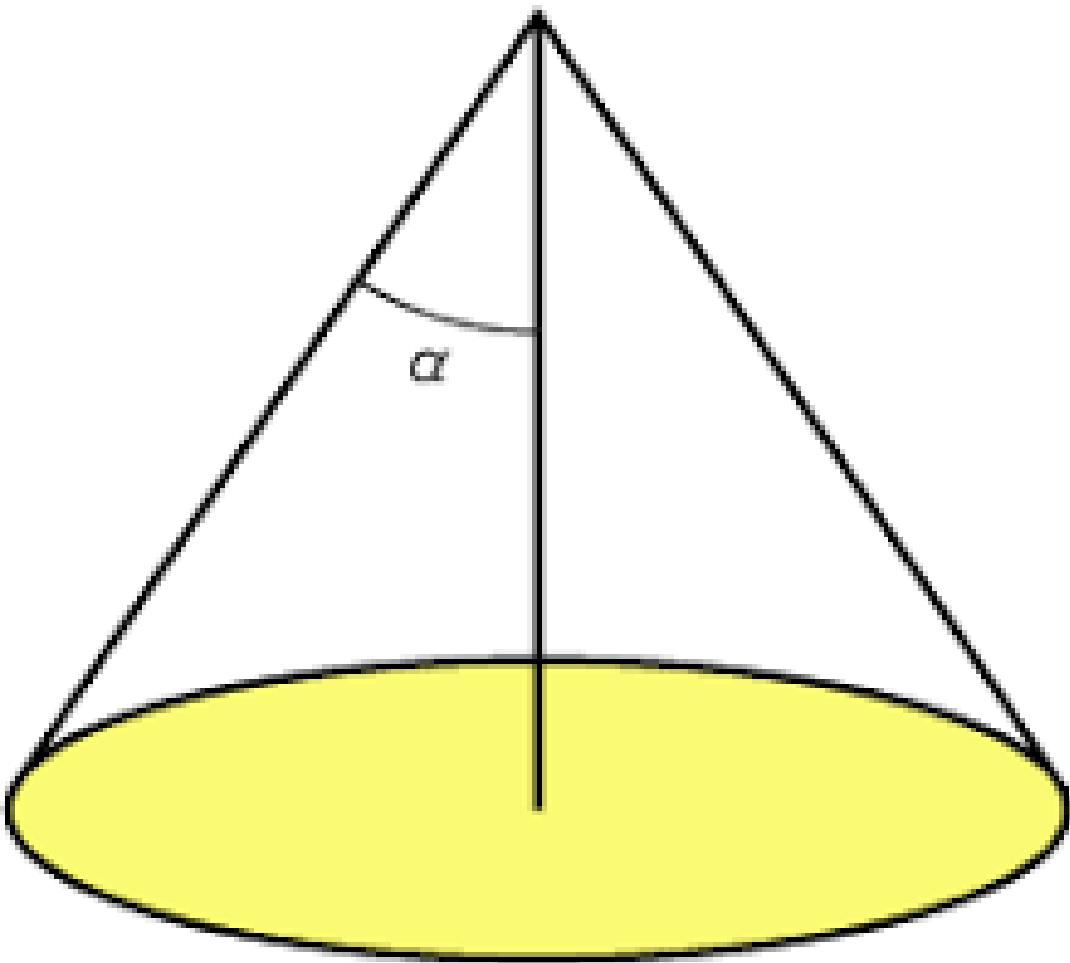
Lightning
Protection
- Human

- Mental –**
 - Difficulty with mental processes
 - Problems multitasking
 - Short-term memory loss
 - Forgetfulness
 - Easily distracted
 - Personality changes
 - Irritability
 - Depression
- Physical –**
 - Intense headaches
 - Body pain
 - Easily fatigued
 - Difficulty sleeping

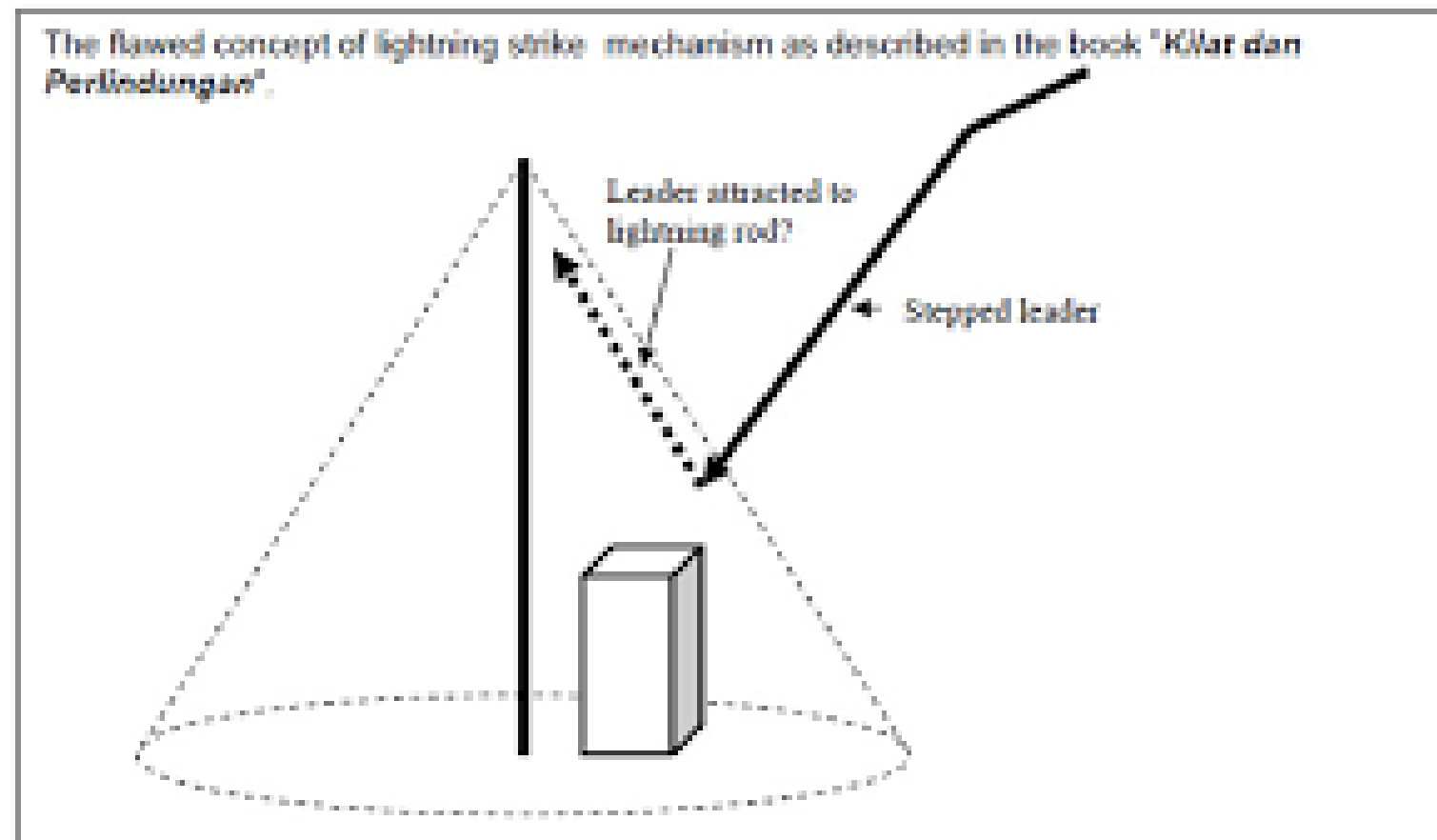
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Man made systems

Buildings



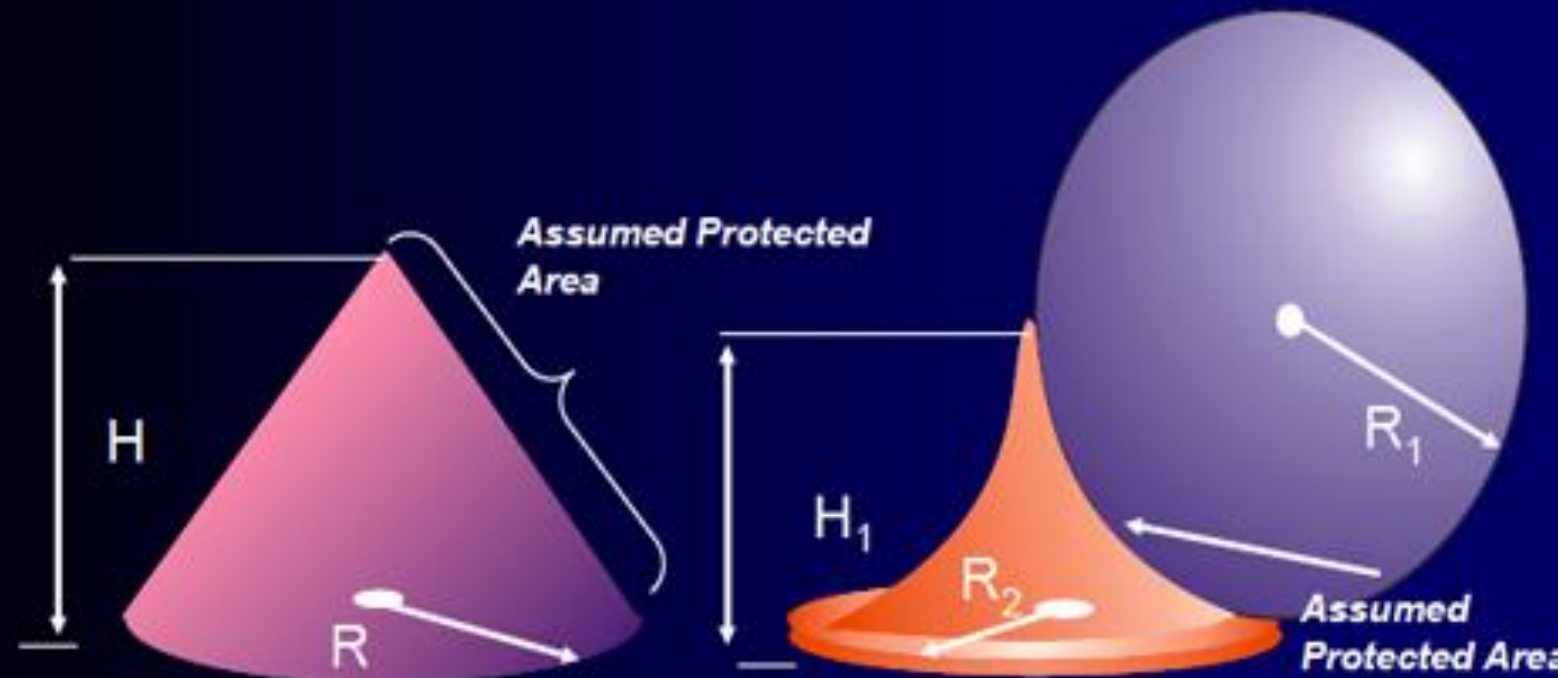
Range of protection
 α : Angle of protection



Man made systems

Buildings

Air Terminal Concepts (not technology)

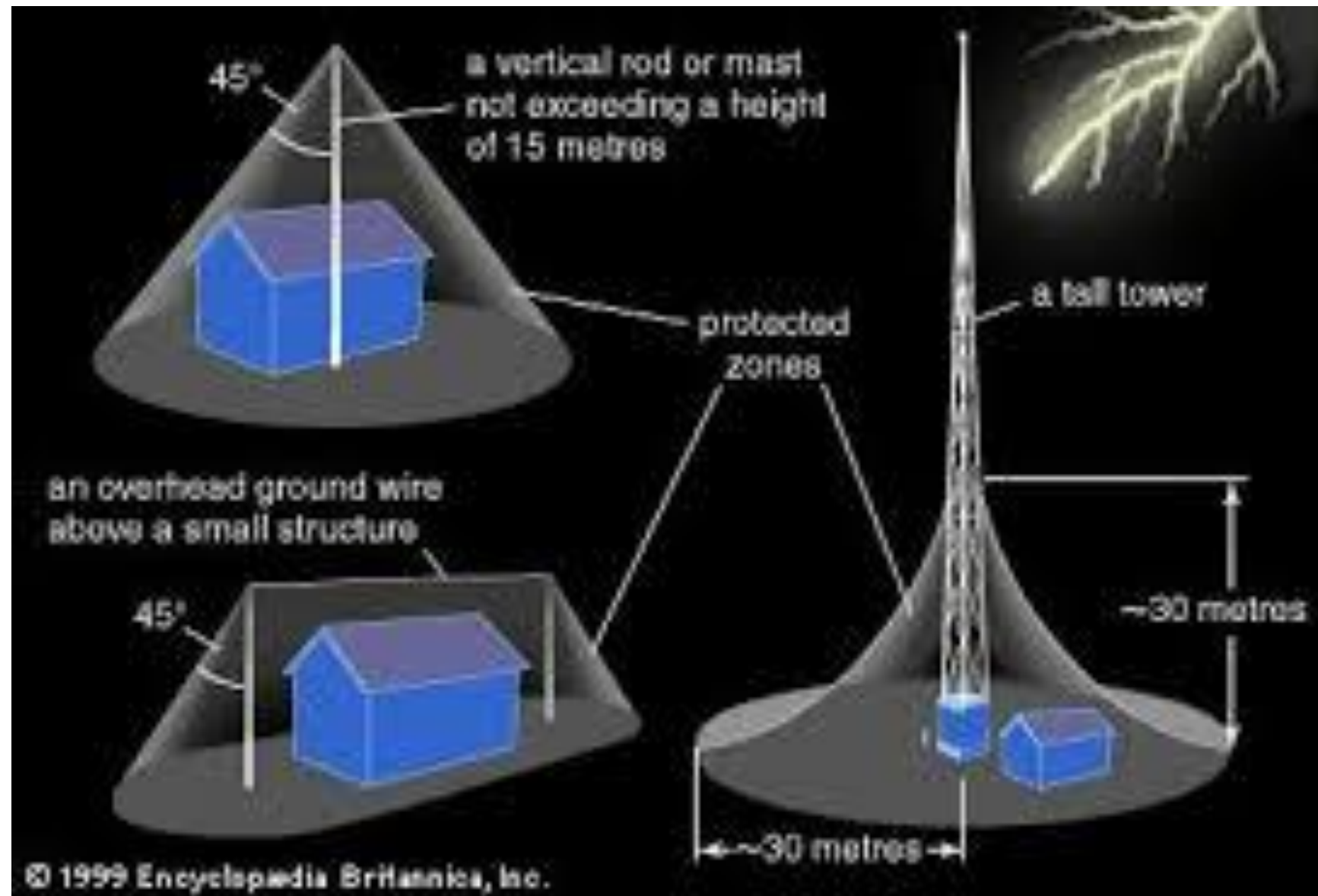


No supporting foundation in physics*

*According to NFPA-780 9/99 study

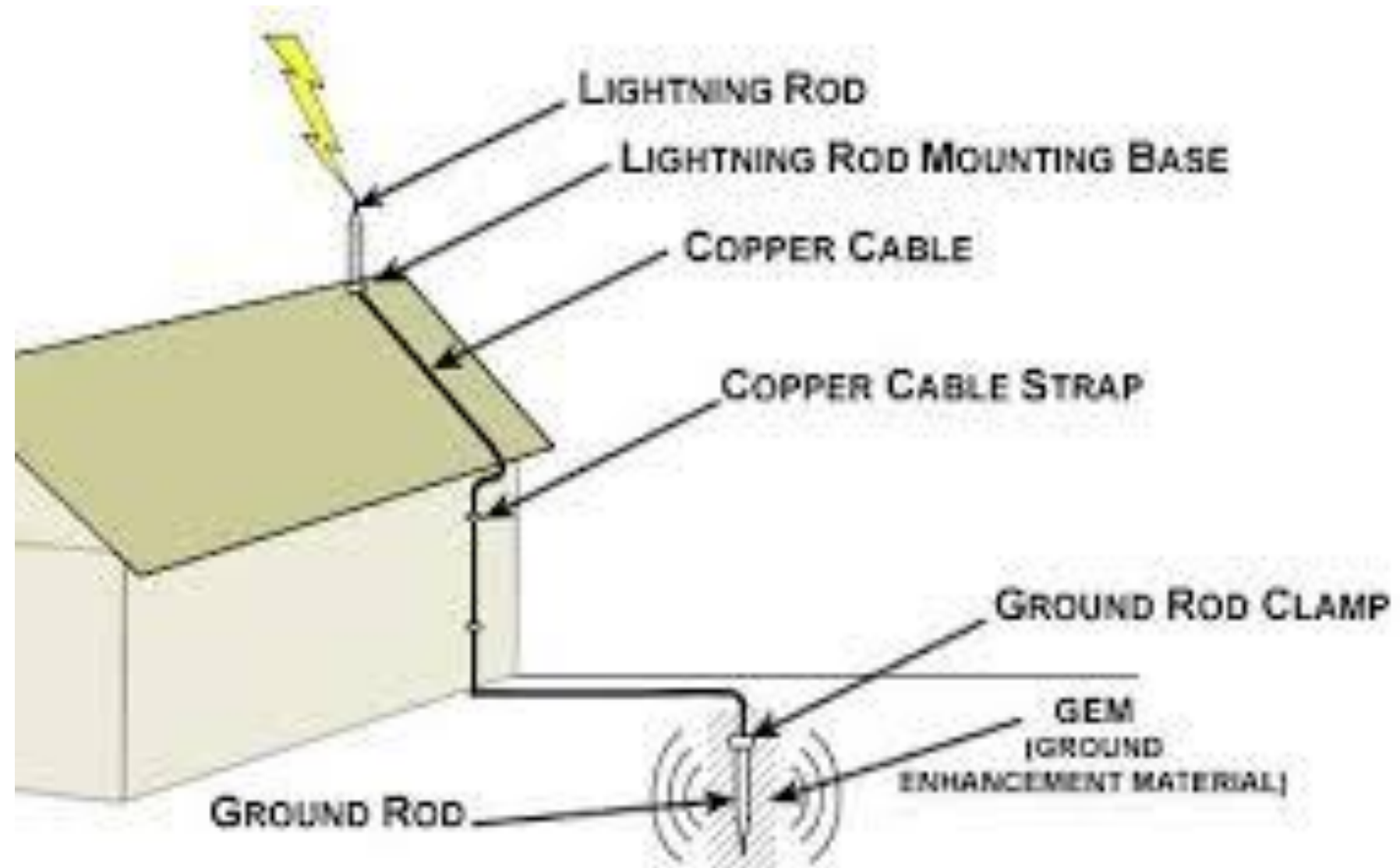
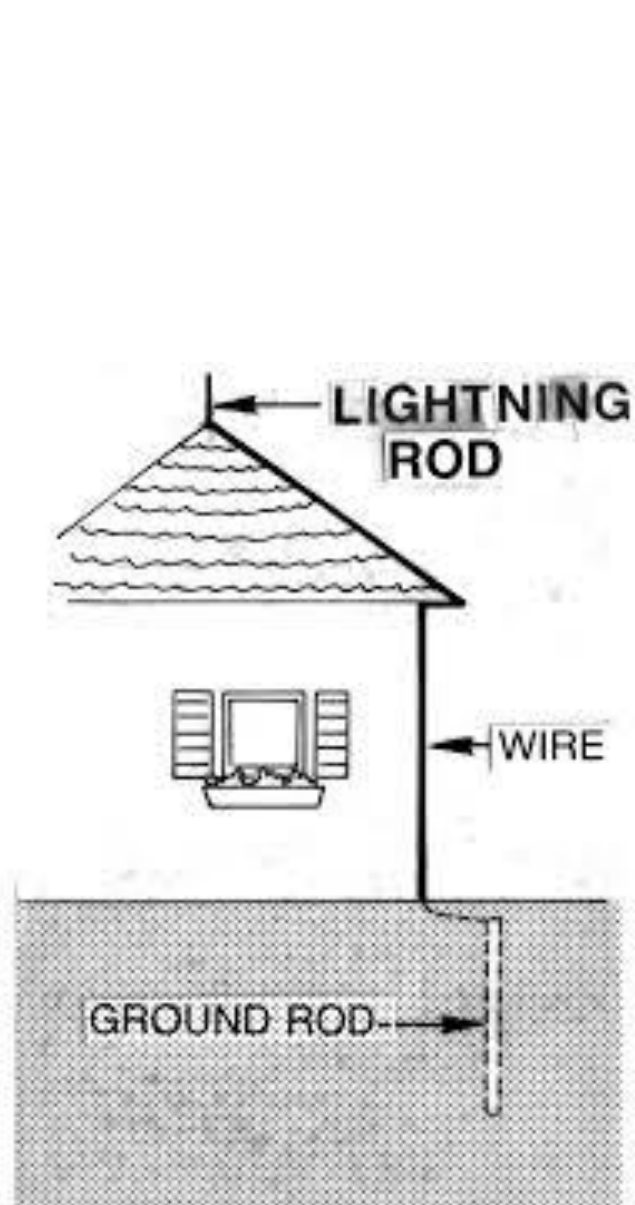
Man made systems

Buildings



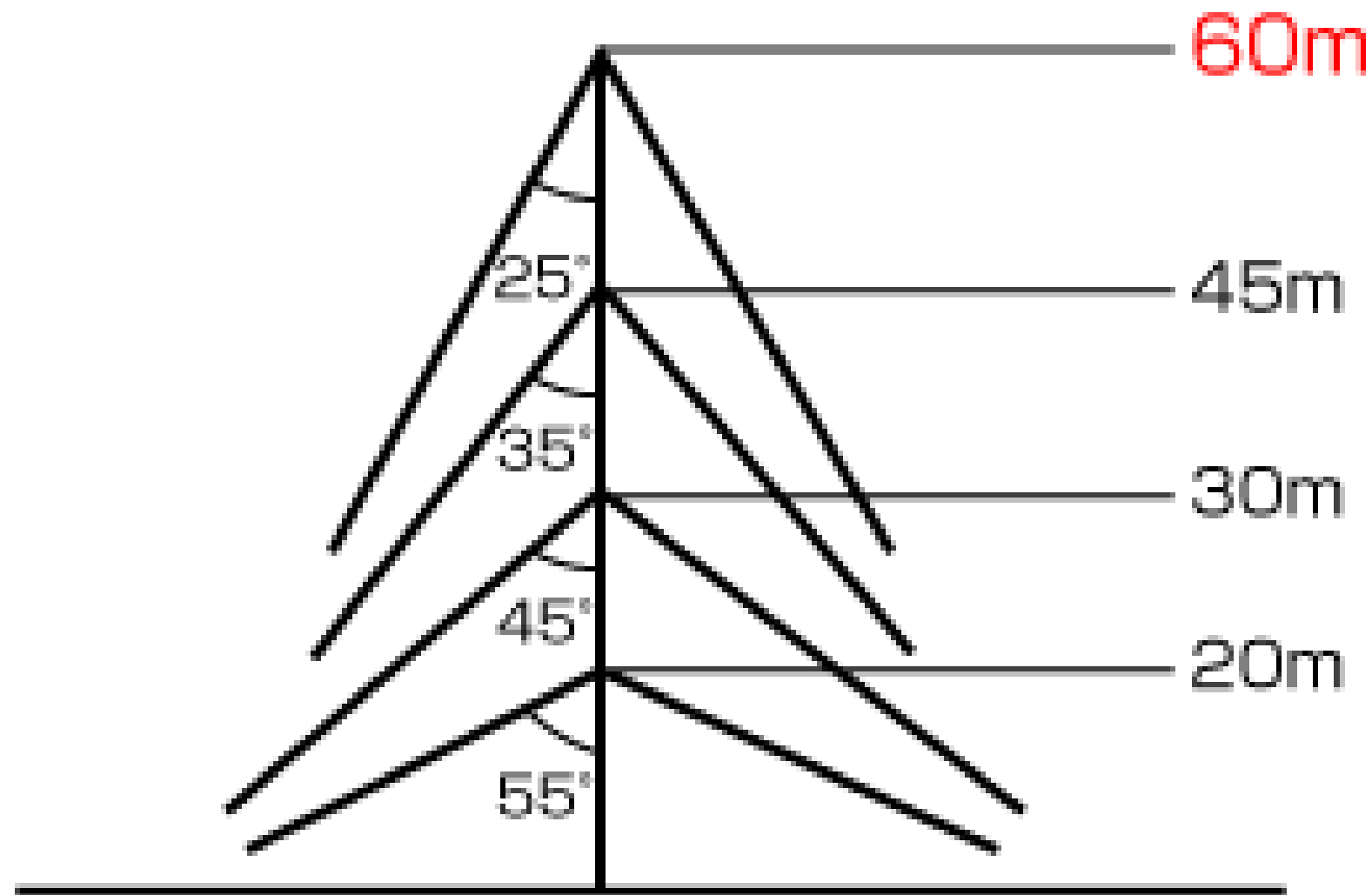
Man made systems

Buildings



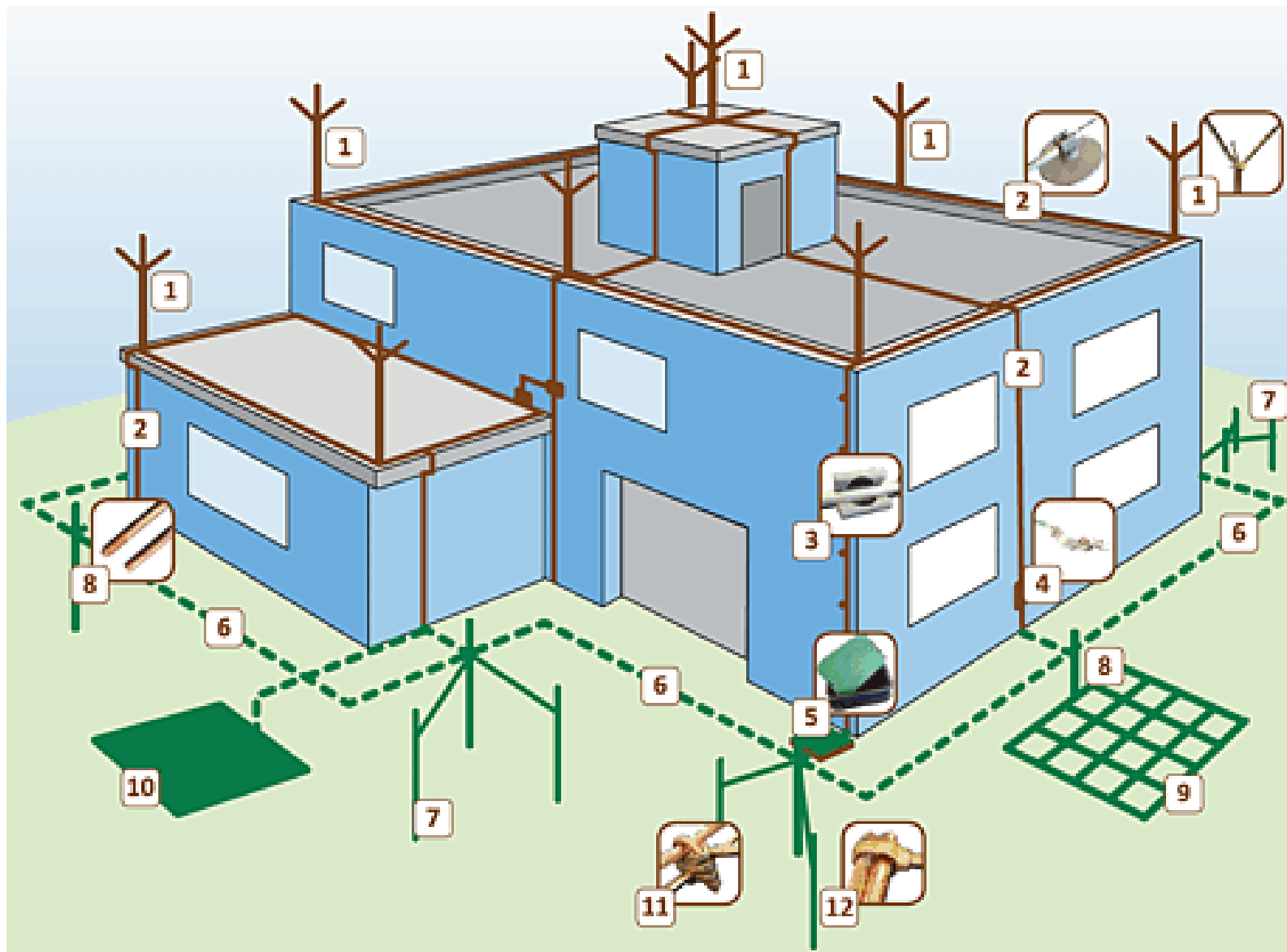
Man made systems

Buildings



Man made systems

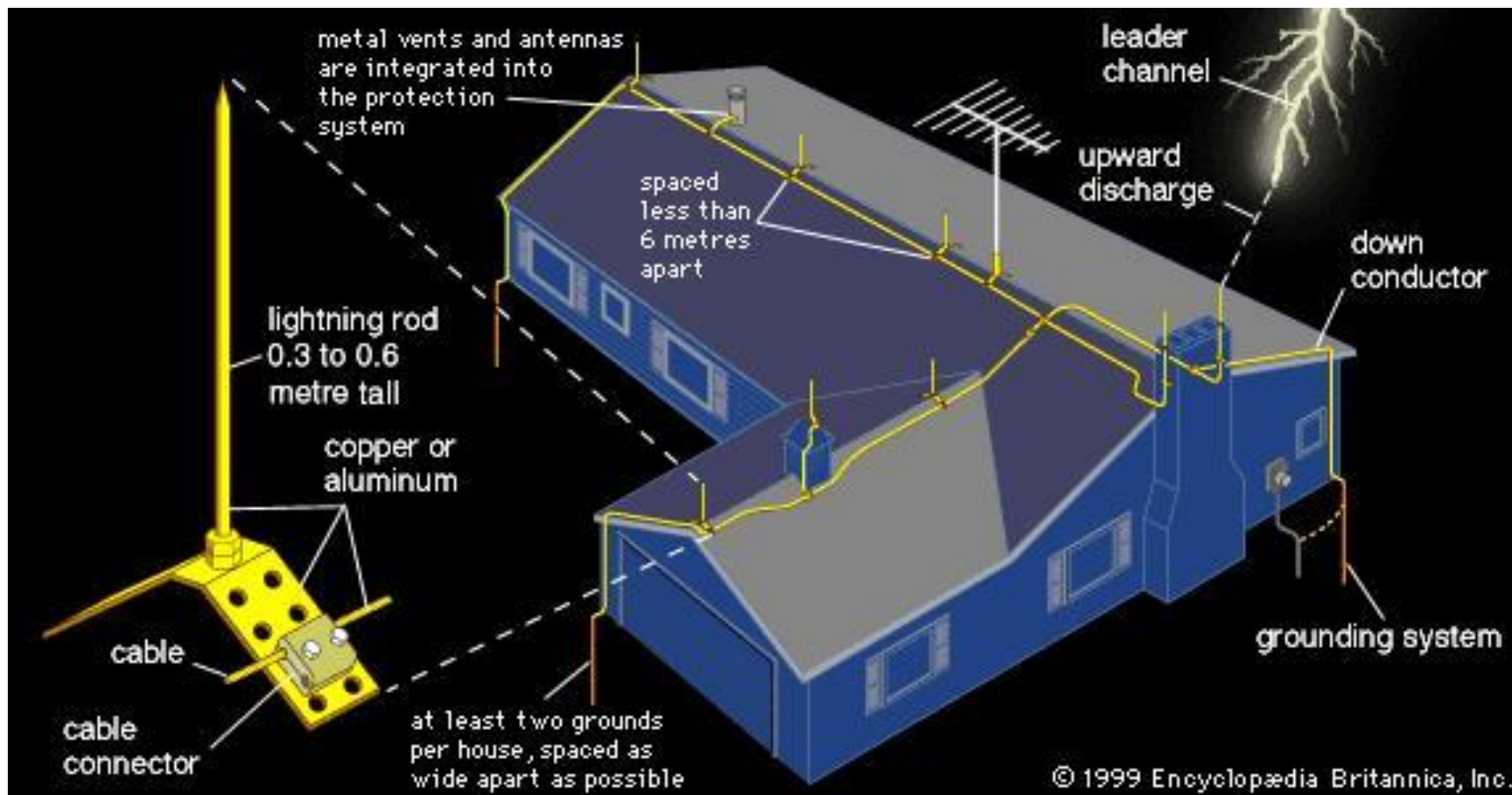
Buildings



key	description
1	3 pointed brass finial mounted on rod & flat parapit mounting bracket
2	Aluminium conductor
3	Push in clips for mounting 8mm aluminium conductor
4	Test clamp
5	Inspection box
6	Buried earth conductor
7	Crows foot earth installation consisting of 3 earth rods
8	Earth rods
9	Lattice copper earth mat
10	Solid earth plate
11	Universal clamp used for multiple earth connections
12	Brass earth rod clamp

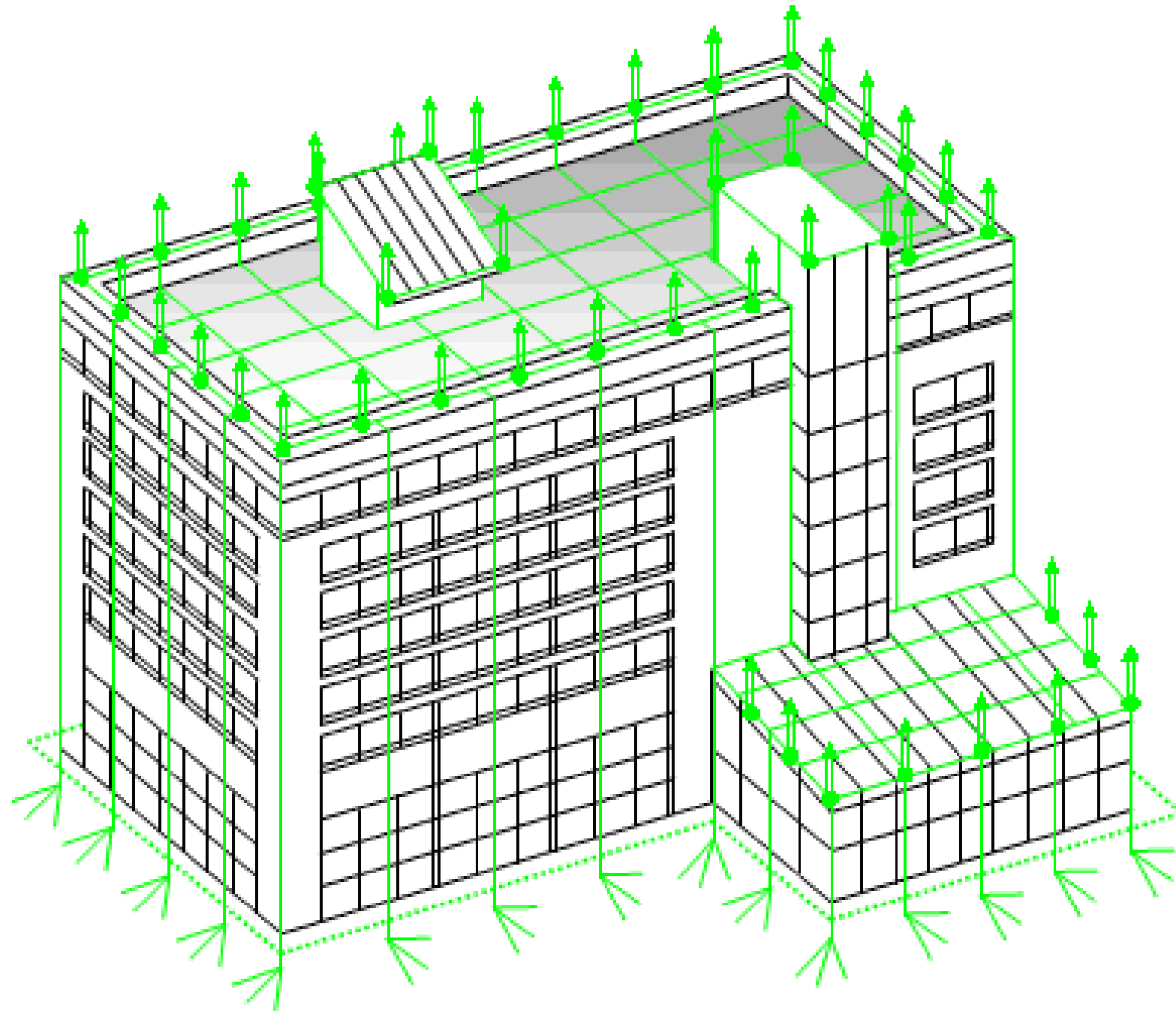
Man made systems

Buildings



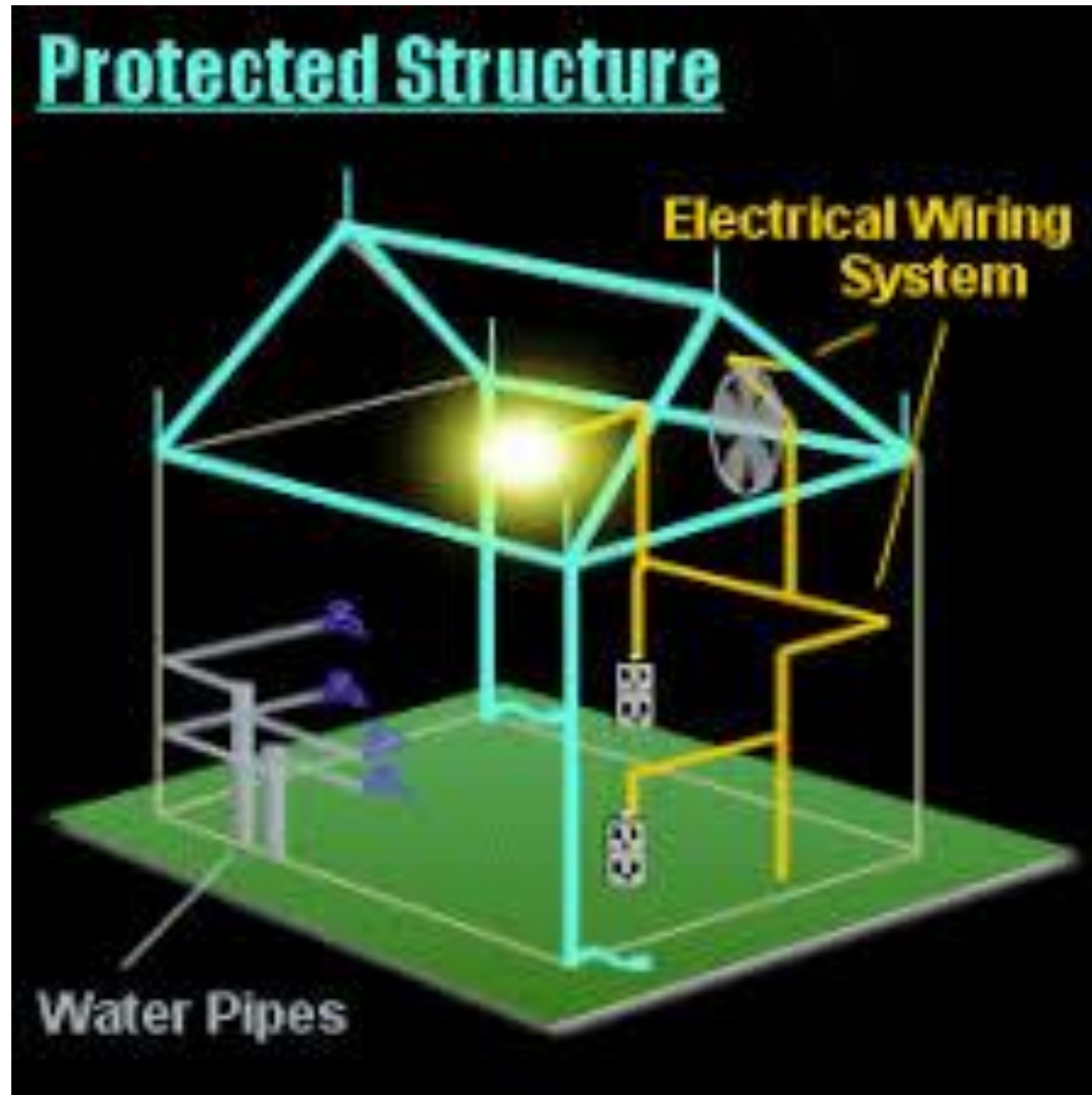
Man made systems

Buildings

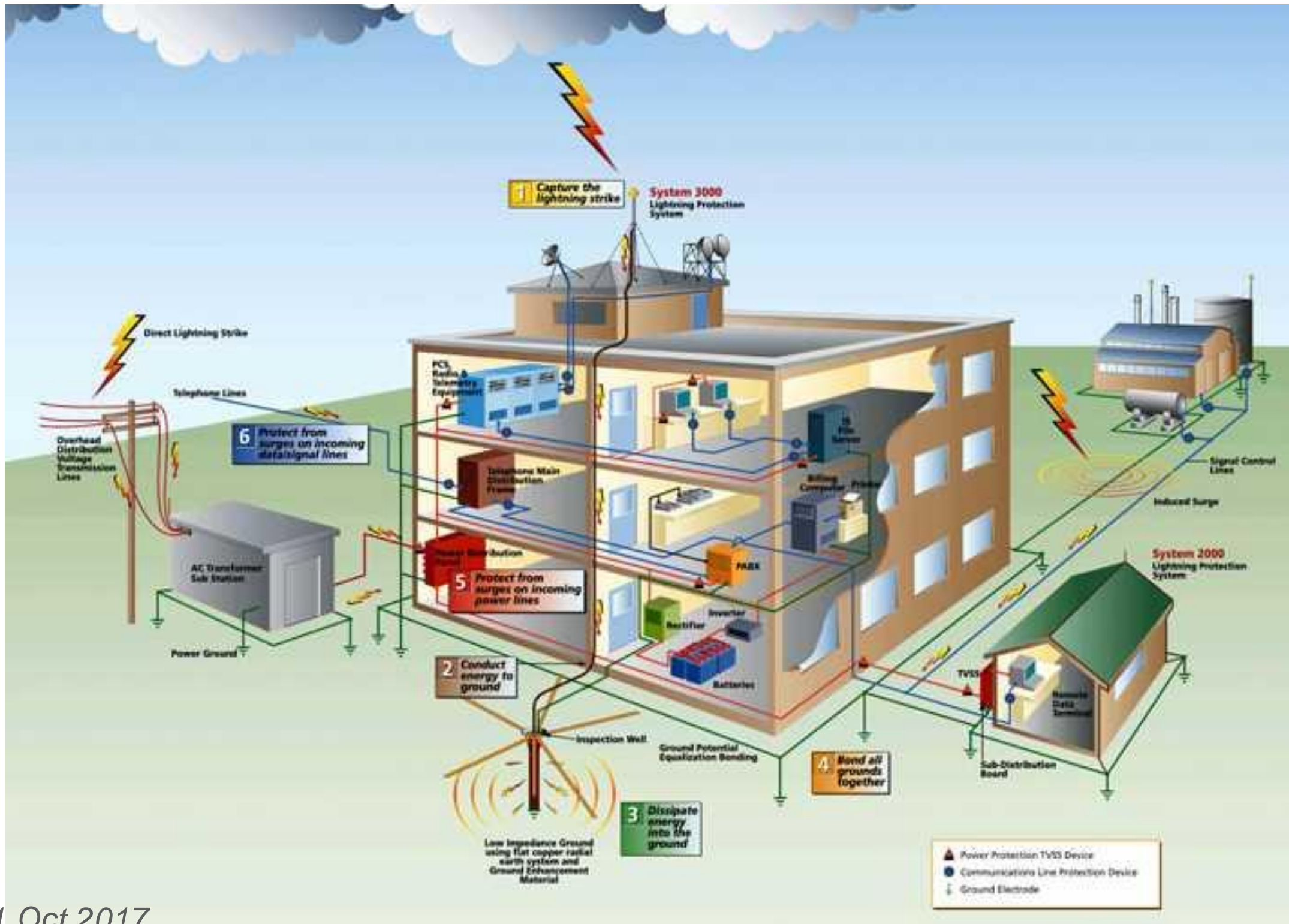


Man made systems

Buildings



Man made systems



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Man made systems

Boats/ships



Man made systems

Open space



Myth and facts

- Myth: Lightning never strikes the same place twice.
- Fact: Lightning often strikes the same place repeatedly, especially if it's a tall, pointy, isolated object. The Empire State Building is hit an average of 23 times a year

Myth and facts

- Myth: If it's not raining or there aren't clouds overhead, you're safe from lightning.
- Fact: Lightning often strikes more than three miles from the center of the thunderstorm, far outside the rain or thunderstorm cloud. "Bolts from the blue" can strike 10-15 miles from the thunderstorm.

Myth and facts

- Myth: Rubber tires on a car protect you from lightning by insulating you from the ground.
- Fact: Most cars are safe from lightning, but it is the metal roof and metal sides that protect you, NOT the rubber tires. Remember, convertibles, motorcycles, bicycles, open-shelled outdoor recreational vehicles and cars with fiberglass shells offer no protection from lightning. When lightning strikes a vehicle, it goes through the metal frame into the ground. Don't lean on doors during a thunderstorm.

Myth and facts

- Myth: A lightning victim is electrified. If you touch them, you'll be electrocuted.
- Fact: The human body does not store electricity. It is perfectly safe to touch a lightning victim to give them first aid. This is the most chilling of lightning Myths. Imagine if someone died because people were afraid to give CPR!

Myth and facts

- Myth: If outside in a thunderstorm, you should seek shelter under a tree to stay dry.
- Fact: Being underneath a tree is the second leading cause of lightning casualties. Better to get wet than fried!

Myth and facts

- Myth: If you are in a house, you are 100% safe from lightning.
- Fact: A house is a safe place to be during a thunderstorm as long as you avoid anything that conducts electricity. This means staying off corded phones, electrical appliances, wires, TV cables, computers, plumbing, metal doors and windows. Windows are hazardous for two reasons: wind generated during a thunderstorm can blow objects into the window, breaking it and causing glass to shatter and second, in older homes, in rare instances, lightning can come in cracks in the sides of windows.

Myth and facts

- Myth: If thunderstorms threaten while you are outside playing a game, it is okay to finish it before seeking shelter.
- Fact: Many lightning casualties occur because people do not seek shelter soon enough. No game is worth death or life-long injuries. Seek proper shelter immediately if you hear thunder. Adults are responsible for the safety of children.

Myth and facts

- Myth: Structures with metal, or metal on the body (jewelry, cell phones, Mp3 players, watches, etc), attract lightning.
- Fact: Height, pointy shape, and isolation are the dominant factors controlling where a lightning bolt will strike. The presence of metal makes absolutely no difference on where lightning strikes. Mountains are made of stone but get struck by lightning many times a year. When lightning threatens, take proper protective action immediately by seeking a safe shelter - don't waste time removing metal. While metal does not attract lightning, it does conduct it so stay away from metal fences, railing, bleachers, etc.

Myth and facts

- Myth: If trapped outside and lightning is about to strike, I should lie flat on the ground.
- Fact: Lying flat increases your chance of being affected by potentially deadly ground current. If you are caught outside in a thunderstorm, you keep moving toward a safe shelter.

Myth and facts

- Myth: lightning flashes are 3-4 km apart
- Fact: Old data said successive flashes were on the order of 3-4 km apart. New data shows half the flashes are about 9 km apart. The National Severe Storms Laboratory report concludes: "It appears the safety rules need to be modified to increase the distance from a previous flash which can be considered to be relatively safe, to at least 10 to 13 km (6 to 8 miles). In the past, 3 to 5 km (2-3 miles) was as used in lightning safety education."

Myth and facts

- Myth: A High Percentage of Lightning Flashes Are Forked.
- Fact: Many cloud-to-ground lightning flashes have forked or multiple attachment points to earth. Tests carried out in the US and Japan verify this finding in at least half of negative flashes and more than 70% of positive flashes. Many lightning detectors cannot acquire accurate information about these multiple ground lightning attachments.

Myth and facts

- Myth: Lightning Can Spread out Some 60 Feet After Striking Earth.
- Fact: Radial horizontal arcing has been measured at least 20 m. from the point where lightning hits ground. Depending on soils characteristics, safe conditions for people and equipment near lightning termination points (ground rods) may need to be re-evaluated.

Trivia

- How far can you see lightning?

According to Cape Canaveral/Kennedy Space Center, up to 100-km flashes.

- Lightning Causes Forest Fires. Can Forest Fires Cause Lightning?

Yes, smoke and carbon micro-particles, when introduced into the upper atmosphere, can become the initiators of static. Sufficient atmospheric static can spark discharge as lightning.

Conclusions

- ✓ Understanding some fundamentals of lightning helps to better protect oneself from the dangers of lightning
- ✓ Lightning has many characteristics, some of which are useful for better lightning protection design
- ✓ Lightning can produce many dangerous effects not only to living beings but also to man-made systems
- ✓ Suitable lightning protection systems or lightning warning systems can help us to avoid losses

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