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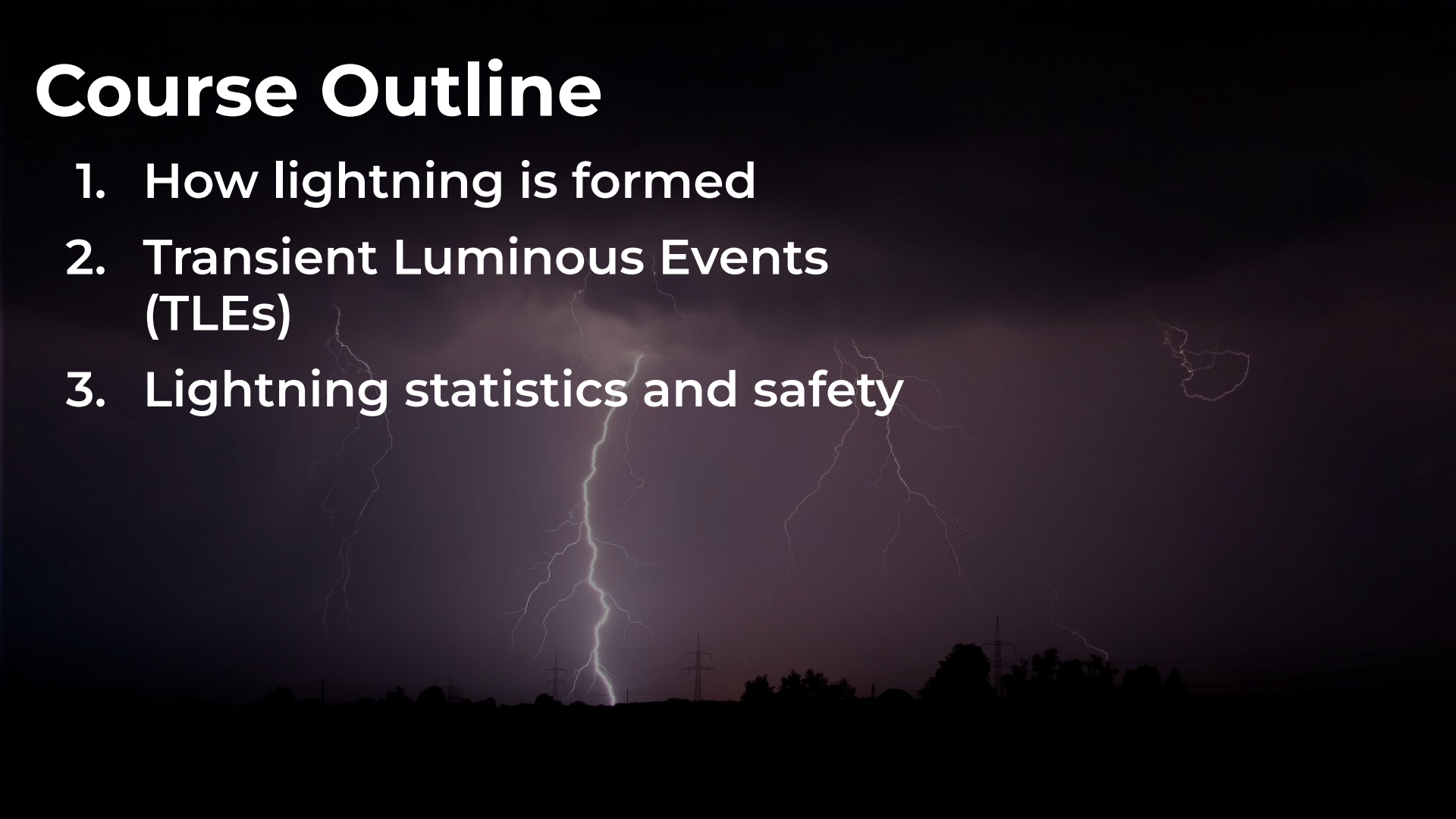
National Weather Service - Fort Worth/Dallas

Course Outline

1. How lightning is formed
2. Transient Luminous Events (TLEs)
3. Lightning statistics and safety

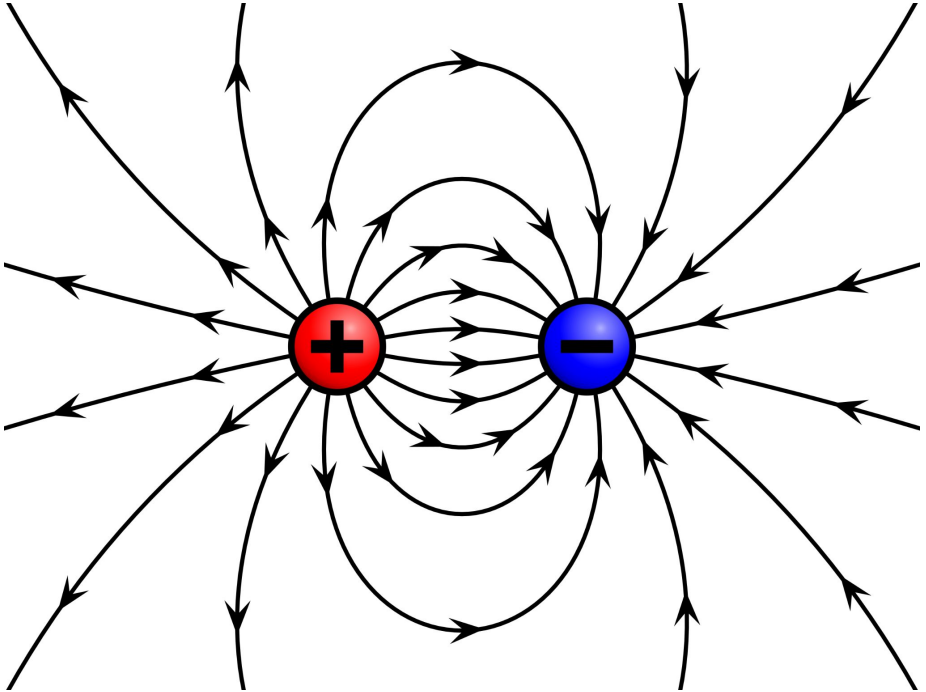


Lightning Formation

- Needs a storm with both liquid water and ice
- Liquid water rises upwards
- Ice (graupel, hail, etc.) fall towards the surface
- When ice particles like graupel and hail collide with liquid water drops, electrons are sheared off the ascending water droplets and collect on the descending hydrometeors

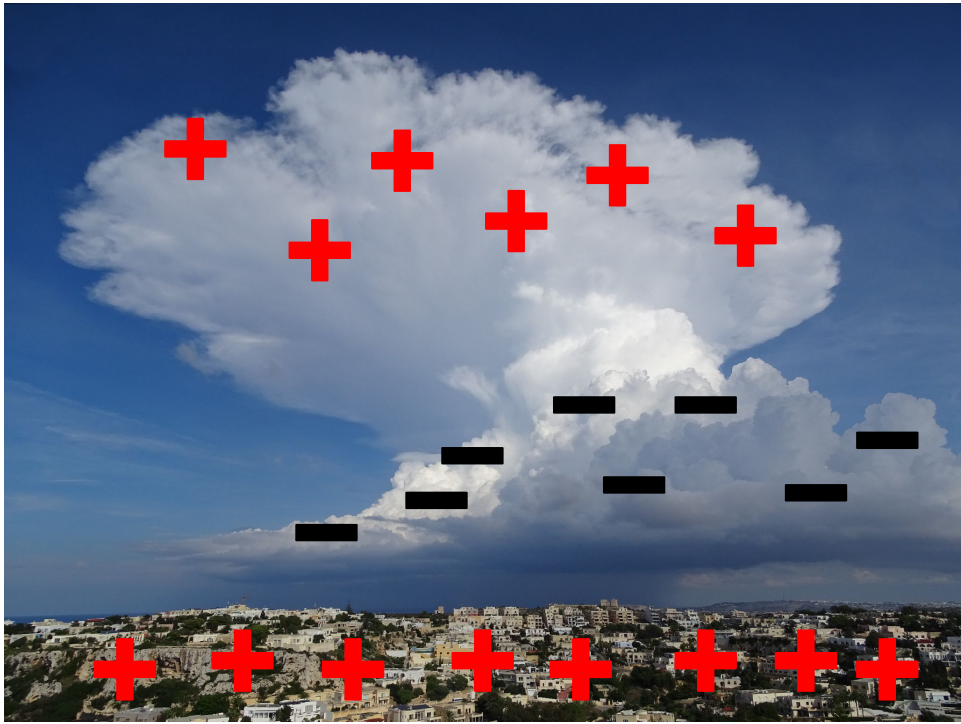
Electric Field Brief Overview

- A physical property describing the force a charged particle feels due to its proximity to other electrical charges
- Visualized using electric field lines.
  - Always points from positive to negative charge
- Electric field strength proportional to the charge difference, and inversely related to the distance between charged particles.
- Stronger electric field -> denser field lines

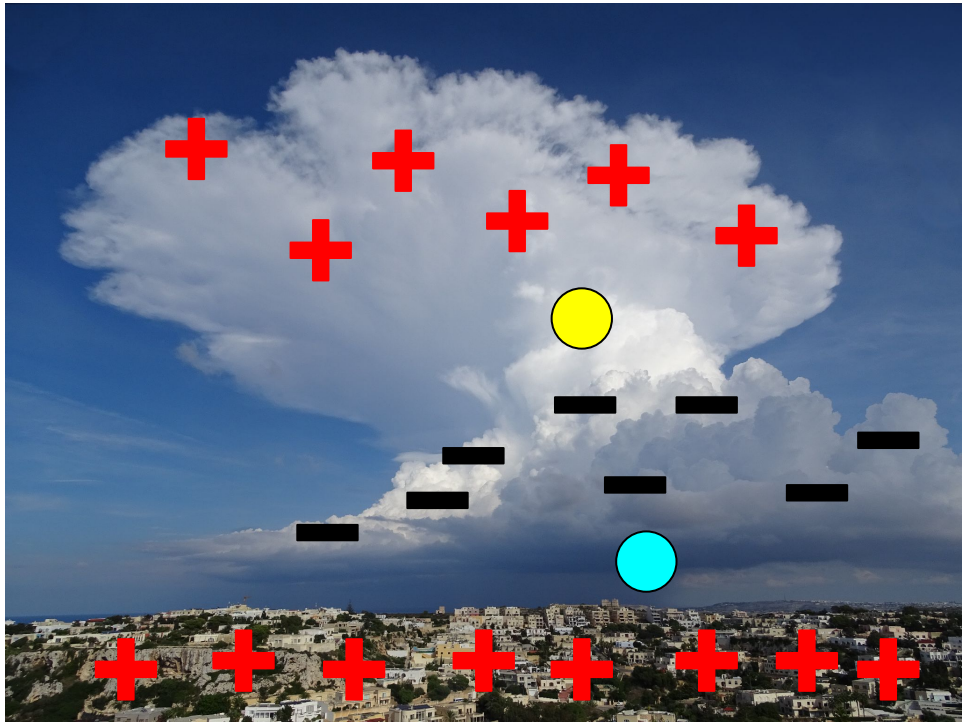


Electric Field in Thunderstorms

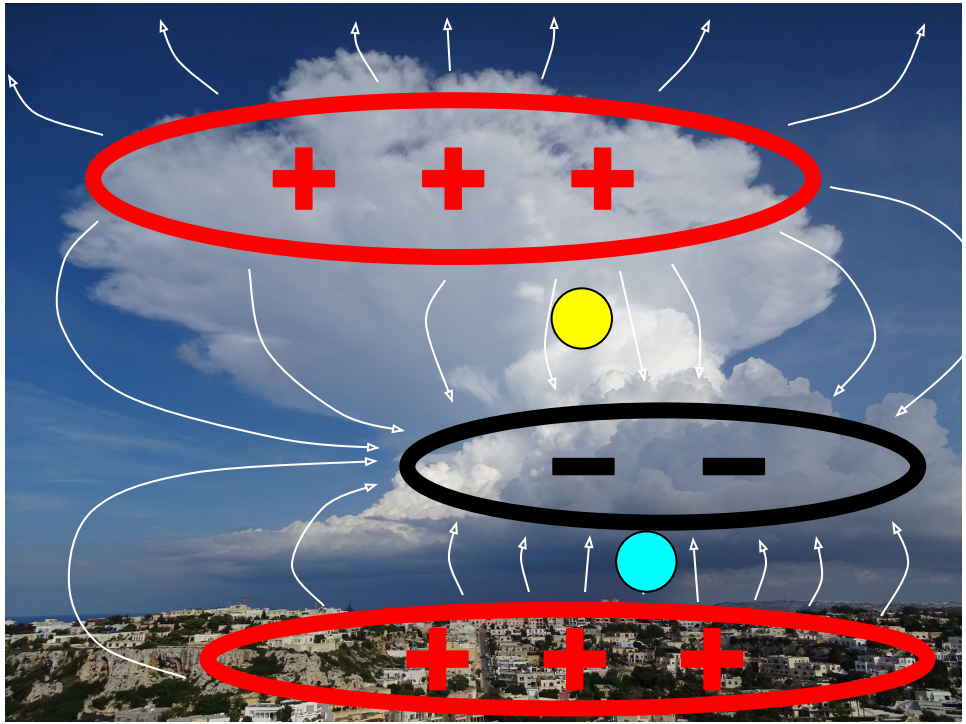
- As a thunderstorm develops, electrons (negative charge) collect in the lower levels of the storm
- In response, a positive charge develops higher up in the storm and on the ground



Electric Field in Thunderstorms

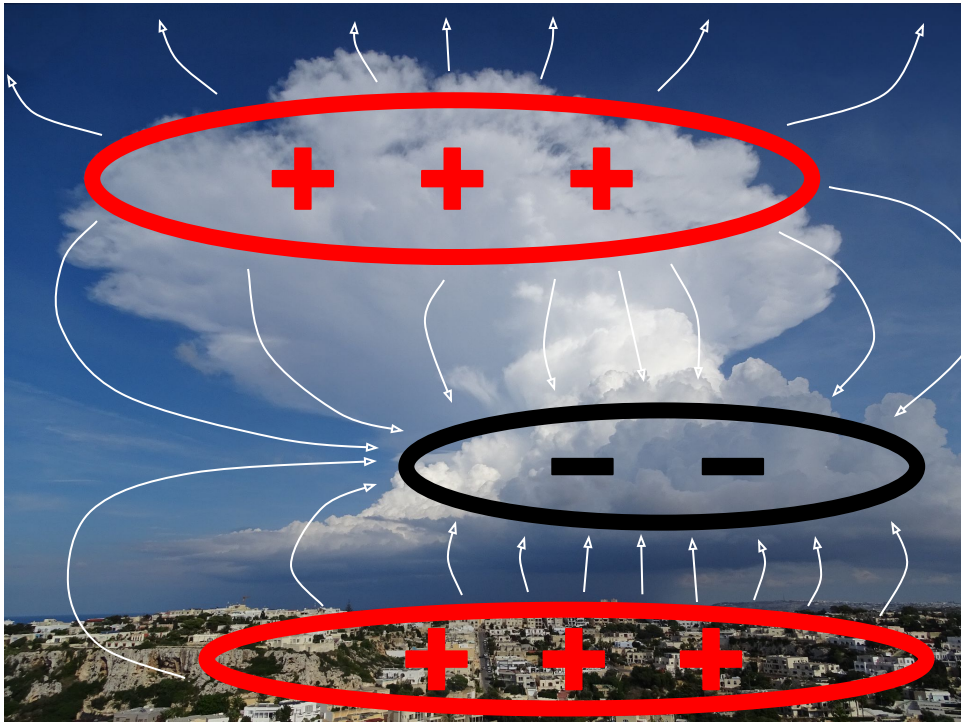


Electric Field in Thunderstorms



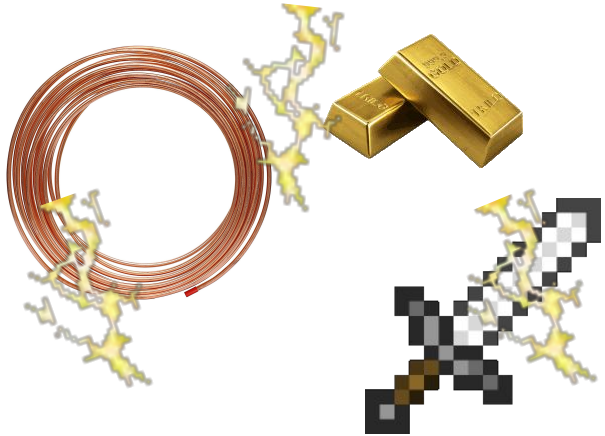
Electric Field in Thunderstorms

- Over time, the magnitude of these charges grows as liquid water and ice continually collide and mix with one another within the storm
- However, there is one obstacle that needs to be overcome for lightning formation...

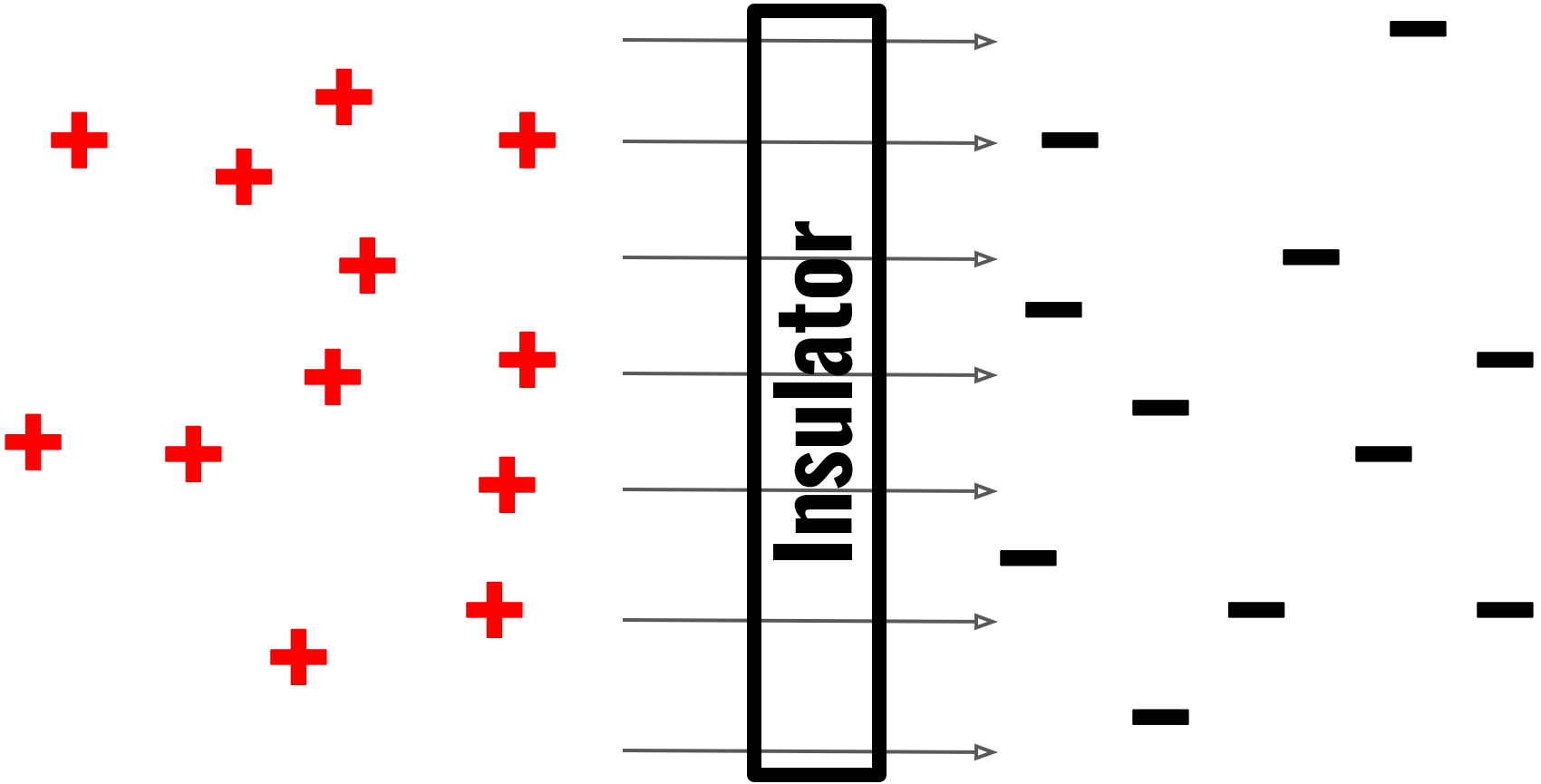


Electricity - Conductors and Insulators

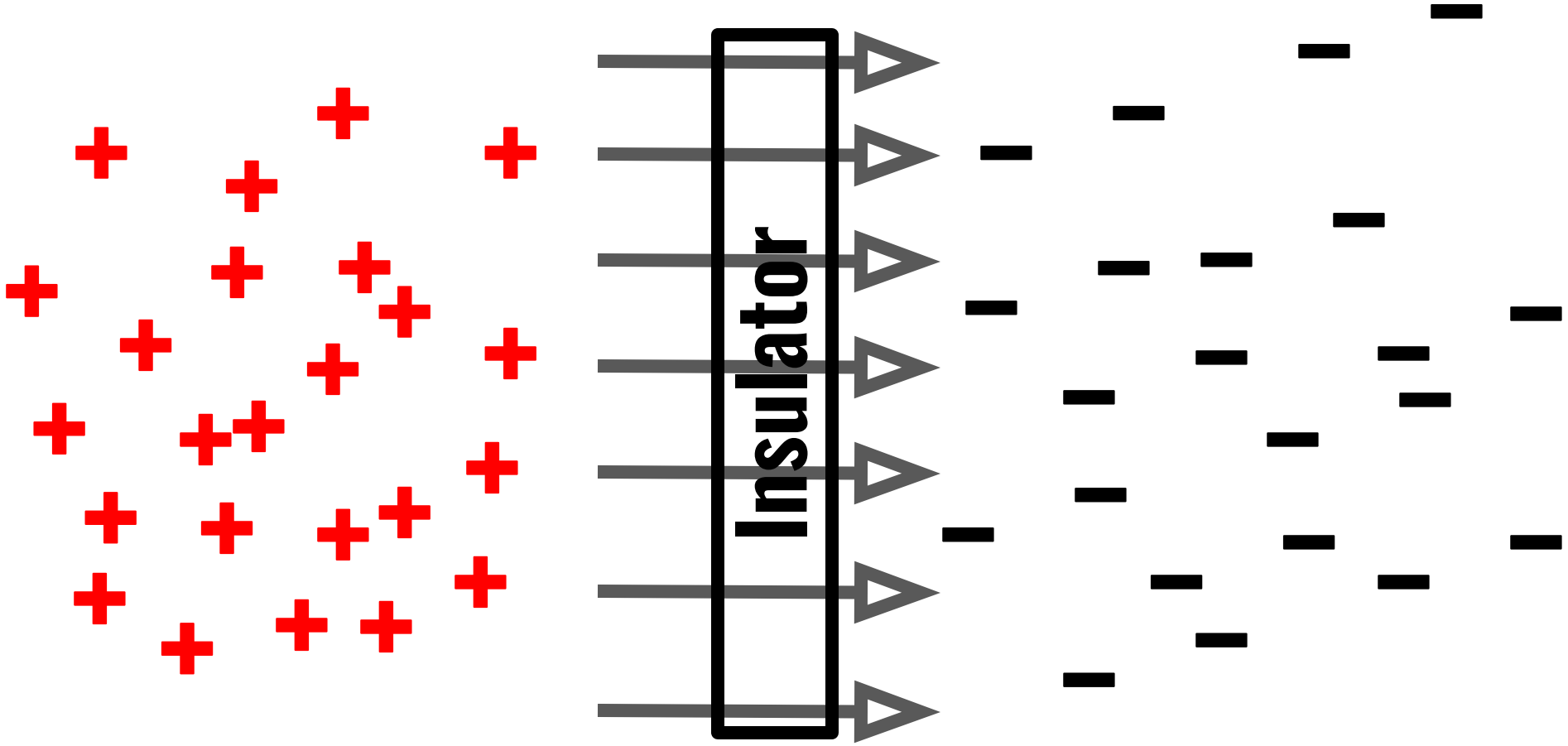
- The composition of any given material will determine how easily electric current can flow through it.
- Materials that allow electricity to move easily through it are called **conductors.**
- Materials that inhibit the flow of electricity are called **insulators.**



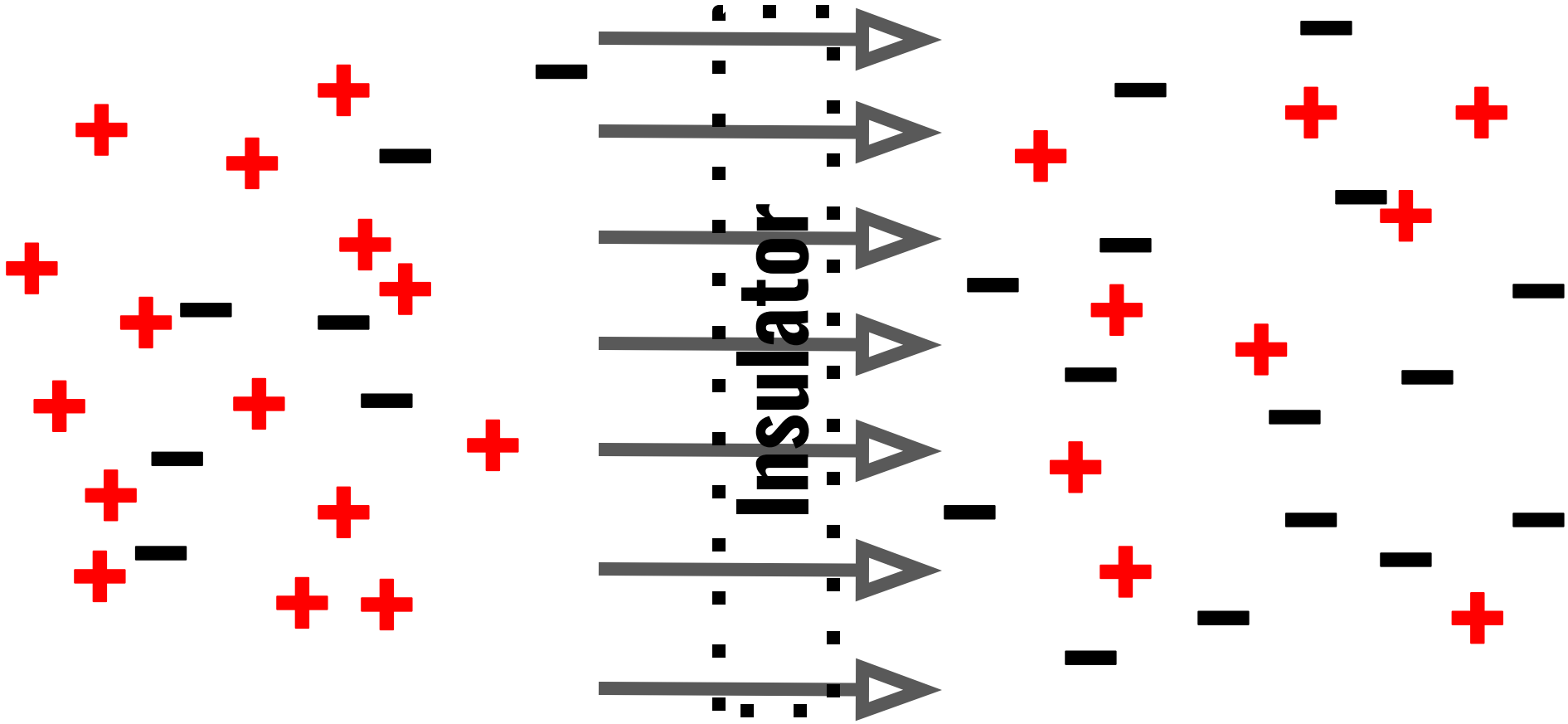
Electricity - Insulators (cont.)



Electricity - Insulators (cont.)

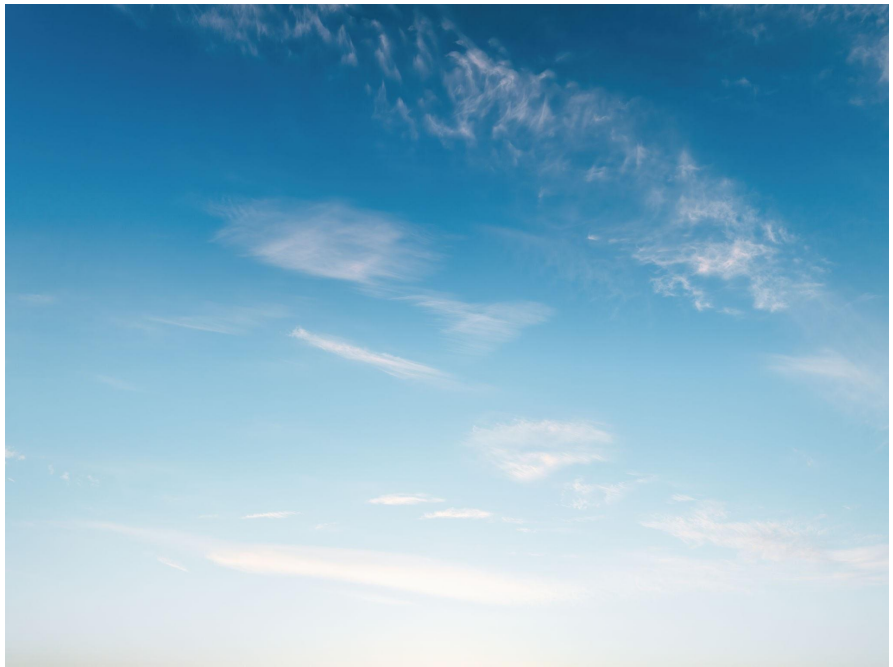


Electricity - Insulators (cont.)



Electricity - Insulators (cont.)

- Another example of a very good insulator would be air, or the atmosphere!

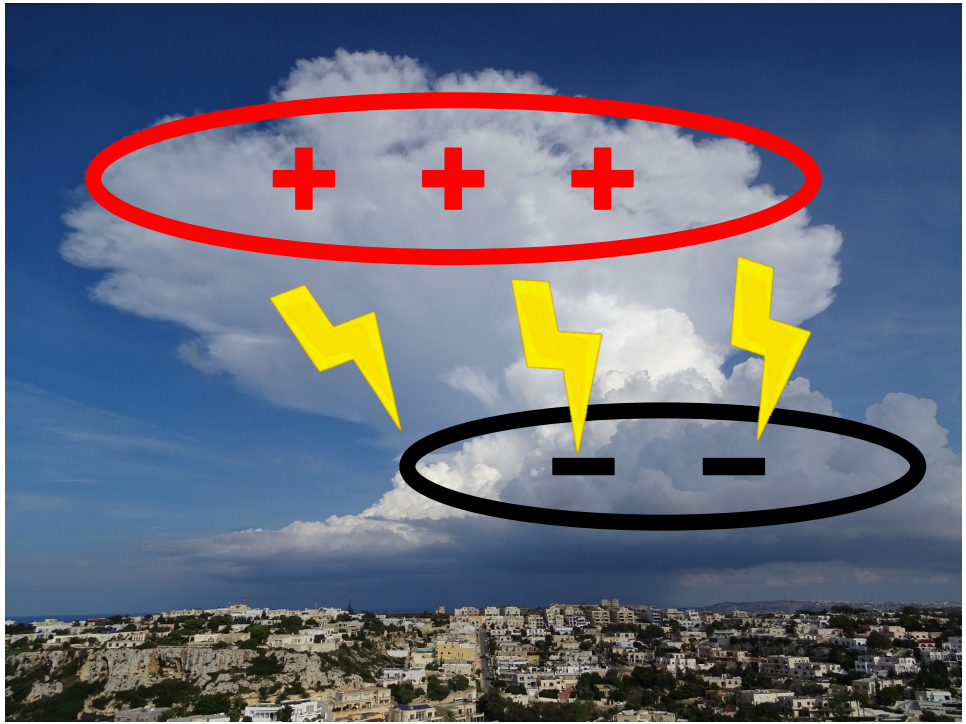


Electric Field in Thunderstorms (cont.)

- The atmosphere acts as a barrier to lightning development since it's an insulator
- Need to build enough charge before this barrier can be overcome
- Resistance is strongest in dry air outside the storm
- Weaker resistance in the storm cloud
- Once this threshold is reached, lightning is able to occur!

Cloud to Cloud Lightning

- Most common type of lightning occurs within the storm itself
- This is due to water and ice in the storm reducing the insulating properties of the atmosphere

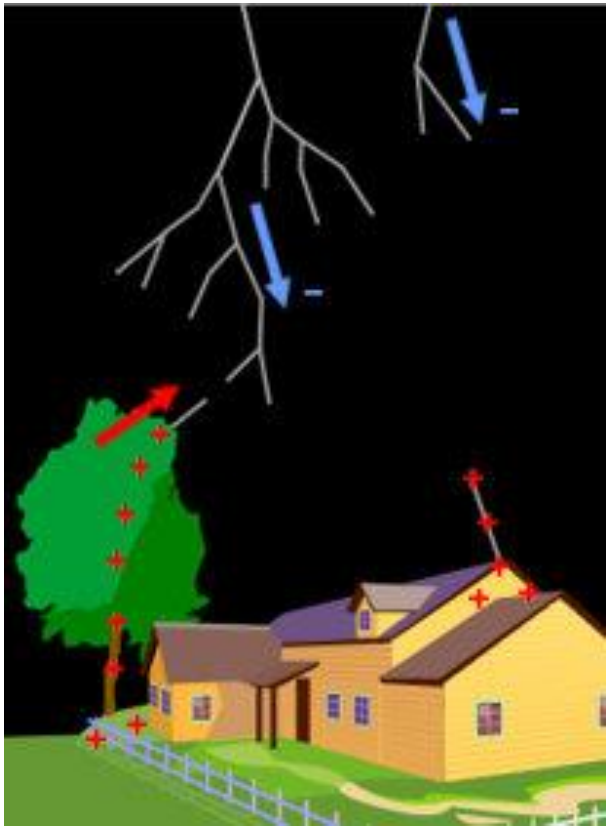


Cloud to Ground Lightning - Stepped Leader

- A CG lightning strike is initiated when a “stepped leader” begins to extend from the base of the thunderstorm towards the ground
- The stepped leader makes small jumps towards the ground about every 50 microseconds (0.00005 seconds)
- After each step, it “looks” for the path of least resistance through the air to make its next step towards the ground

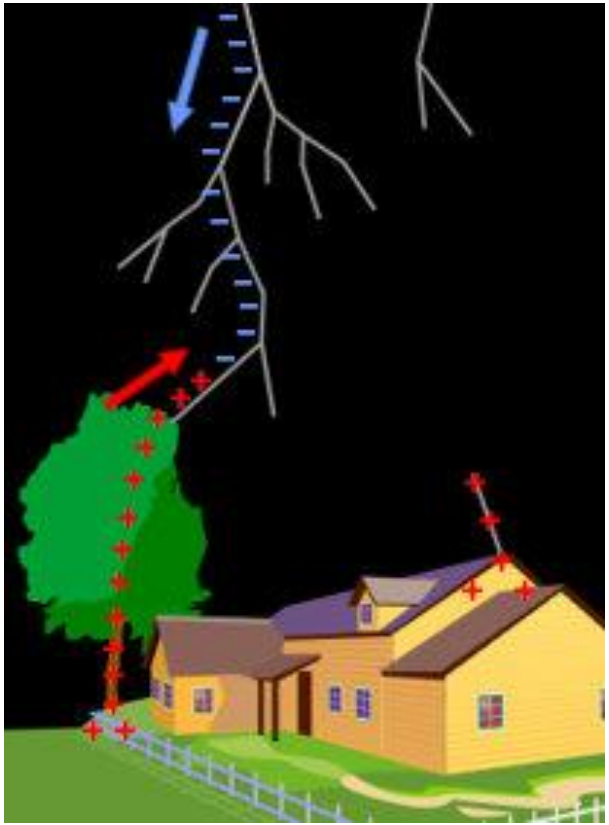
Cloud to Ground Lightning - Streamers

- As the stepped leader approaches the ground, its strong negative charge repels electrons at the surface
- The strong positive charge at the surface is attracted to the negative charge of the approaching stepped leader
- This induces a reactionary channel of positive charge from the surface up towards the stepped leader called a streamer



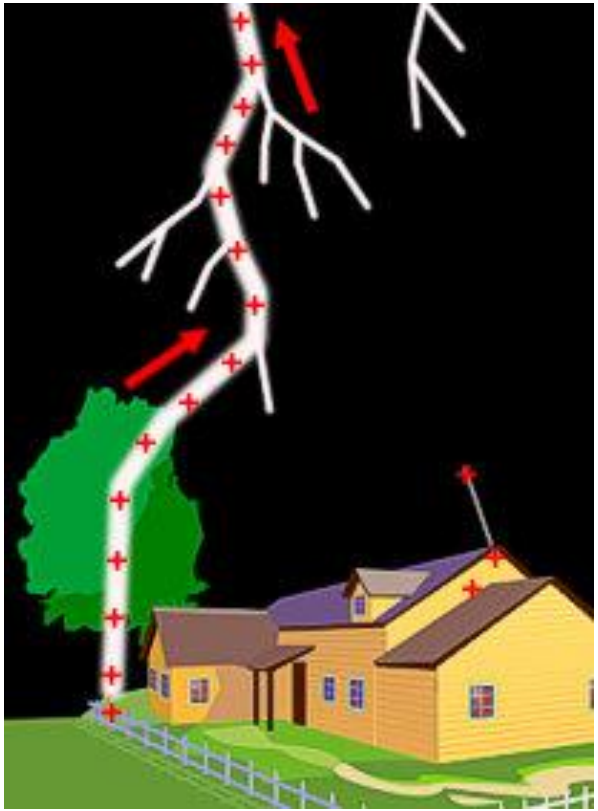
Cloud to Ground Lightning - The Channel

- Whichever branch of the stepped leader first connects with a streamer, a channel is formed
- This channel connects the negatively charged base of the storm with the positively charged surface



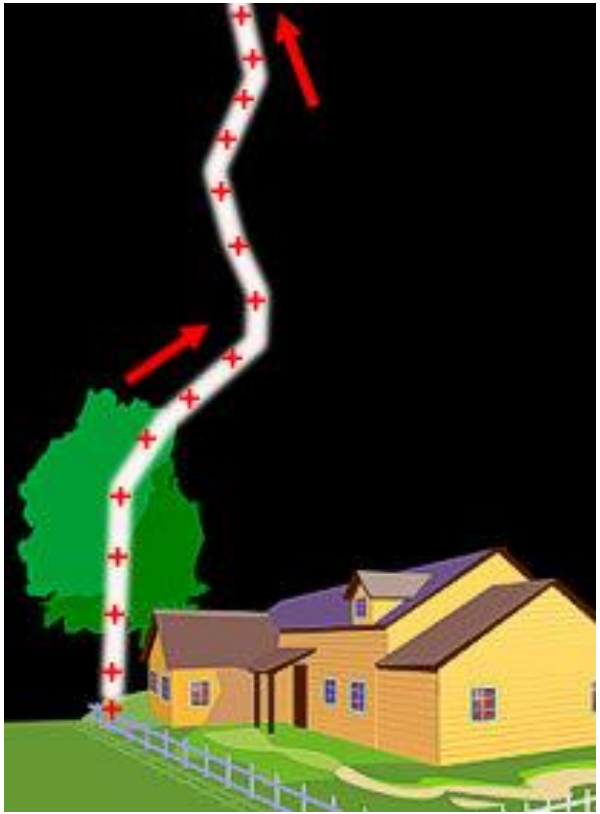
Cloud to Ground Lightning - Return Stroke

- The channel acts as a perfect conductor, meaning there are no insulating properties
- This allows an immensely strong surge of electrical charge to be exchanged between the ground and the storm
- This surge of electricity is called the return stroke
- Air in the channel is “ionized” by the extreme energy passed through it causing the bright flash of light we can see with our eyes



Cloud to Ground Lightning - Dart Leader

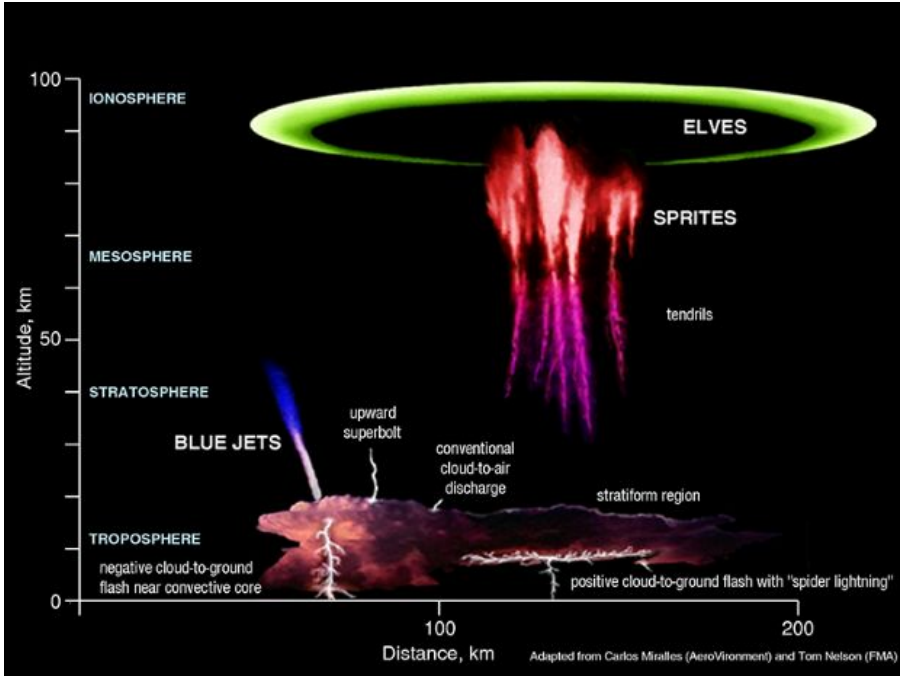
- After the initial strike, there may still be enough energy for additional strokes of lightning
- These subsequent strokes are called dart leaders
- Dart leaders use the same channel that was opened by the stepped leader and the streamer
- Once the electric field is weakened enough by the lightning, the channel closes and the process restarts from the beginning




Lightning Basics Review!

Transient Luminous Events (TLEs)

- Strong thunderstorms can produce other types of lightning called TLEs
- These phenomena occur above the active storm, sometimes 50-60 miles above the surface
- Still a very new area of research and poorly understood



TLEs - Sprites

- Most common TLE
- Extend as much as 60 miles above the surface
- Thought to be tied to strong electric discharge from CG strikes within a thunderstorm.
- Sprites themselves are large, but relatively weak compared to other forms of lightning
- Last only a few milliseconds (~0.001 seconds)

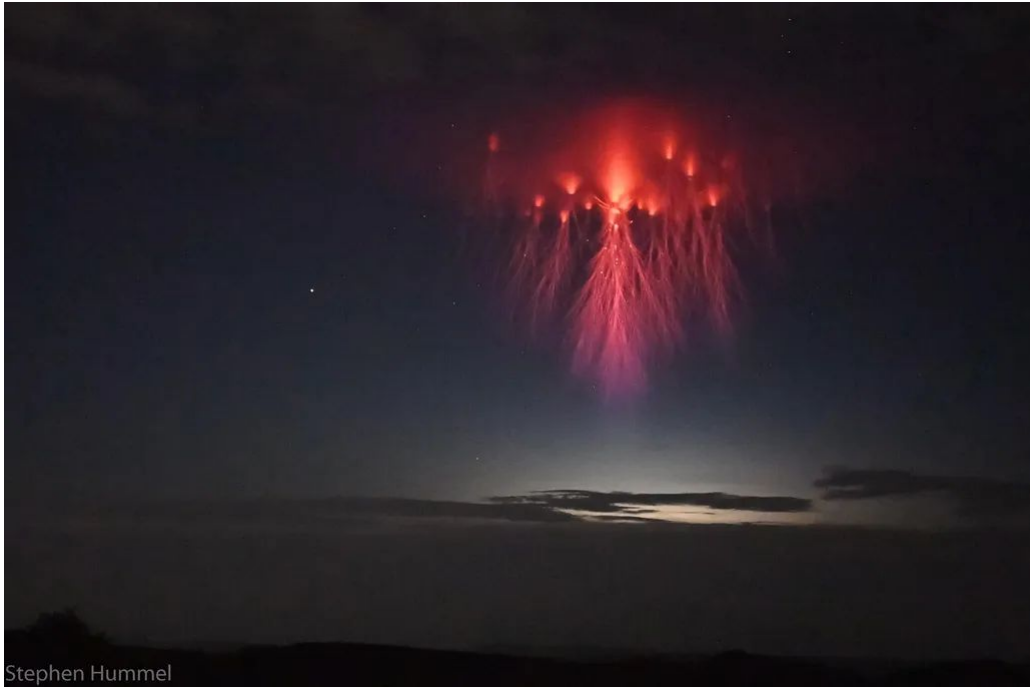


Photo taken by Stephen Hummel of the Univeristy of Texas @ Austin

TLEs - Blue Jets

- Extend upwards from the tops of thunderstorms, fanning out in a blue cone
- Occur in the stratosphere
- Lasts generally 0.1-0.3 seconds
- Extend up to 30 miles above the ground
- Some research points to blue jets being tied to thunderstorms with large amounts of hail

Photo taken by photographer Matthew Griffiths in Marfa, TX

TLEs - Gigantic Jets

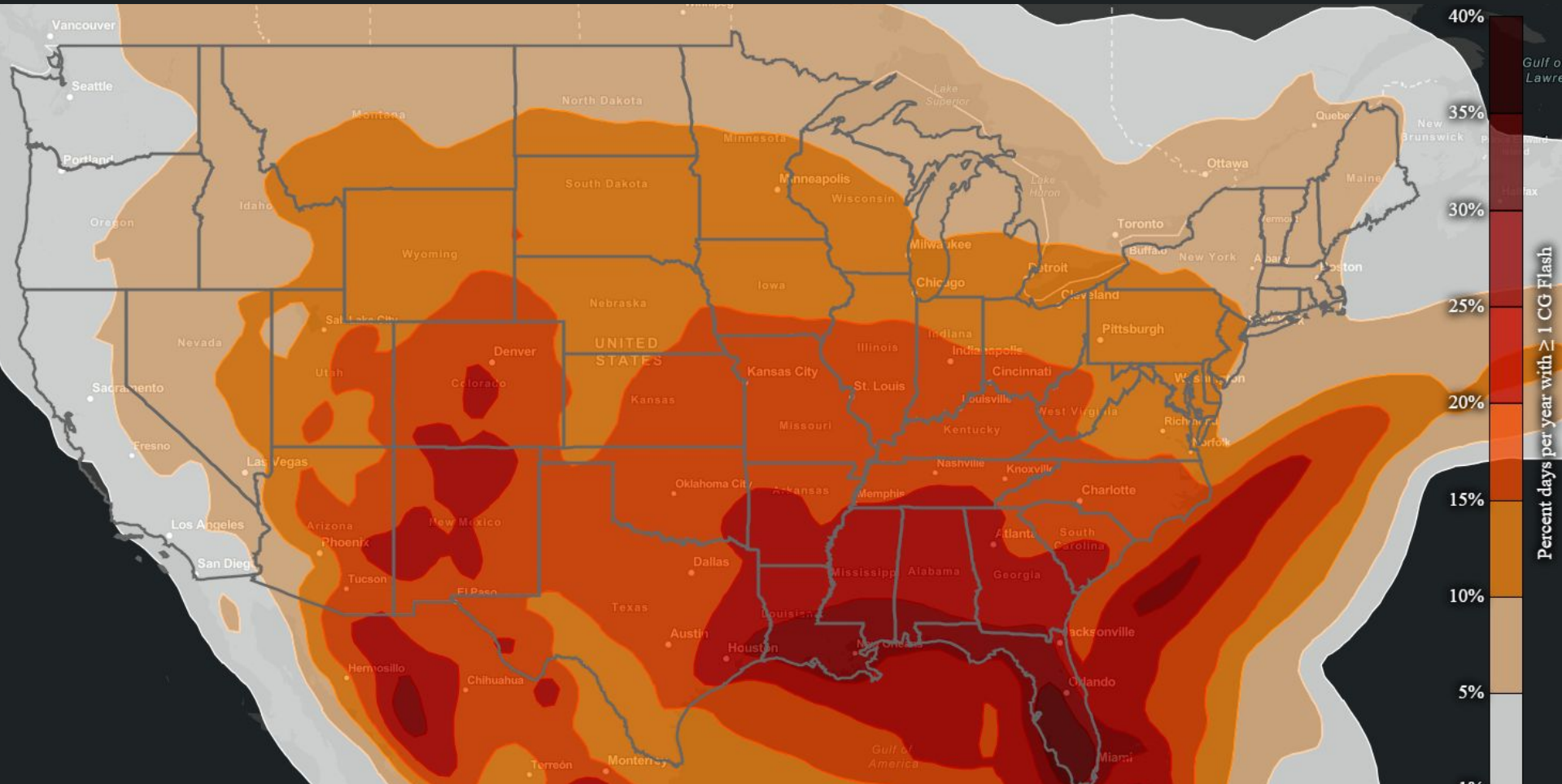
- Extend from thunderstorm tops into the ionosphere (over 50 miles above the ground)
- Occur during peak intensity of thunderstorm life cycle
- Some research suggests a correlation between GJs and overshooting tops

TLEs - ELVES

- Emissions of Light and Very low frequency perturbations due to Electromagnetic pulse Sources
- Rapidly expanding glowing disk that emanates from other TLEs
- Can reach 300 miles across
- Associated with terrestrial gamma ray flashes (TGFs)

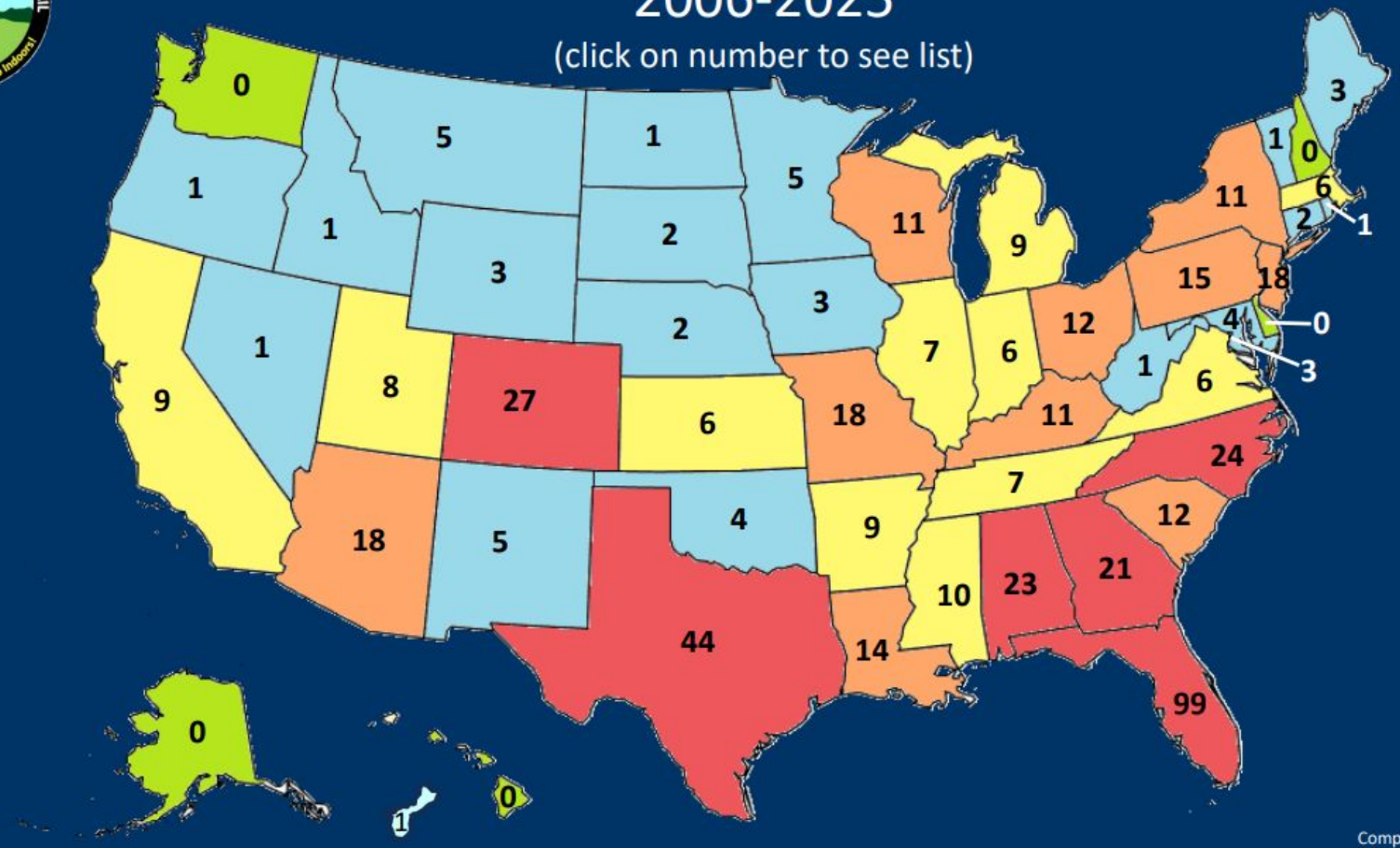
Photograph taken from Possagno, Italy

Lightning Climatology



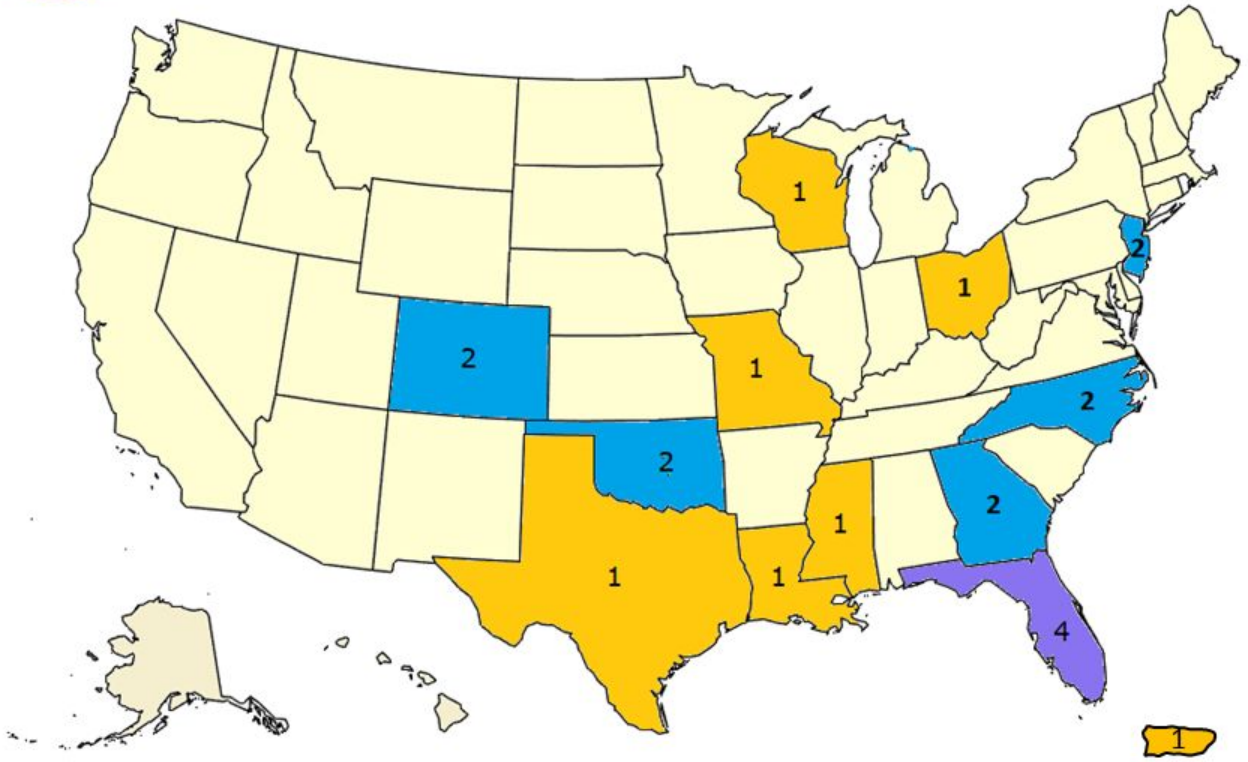
State Lightning Fatalities
2006-2025

(click on number to see list)



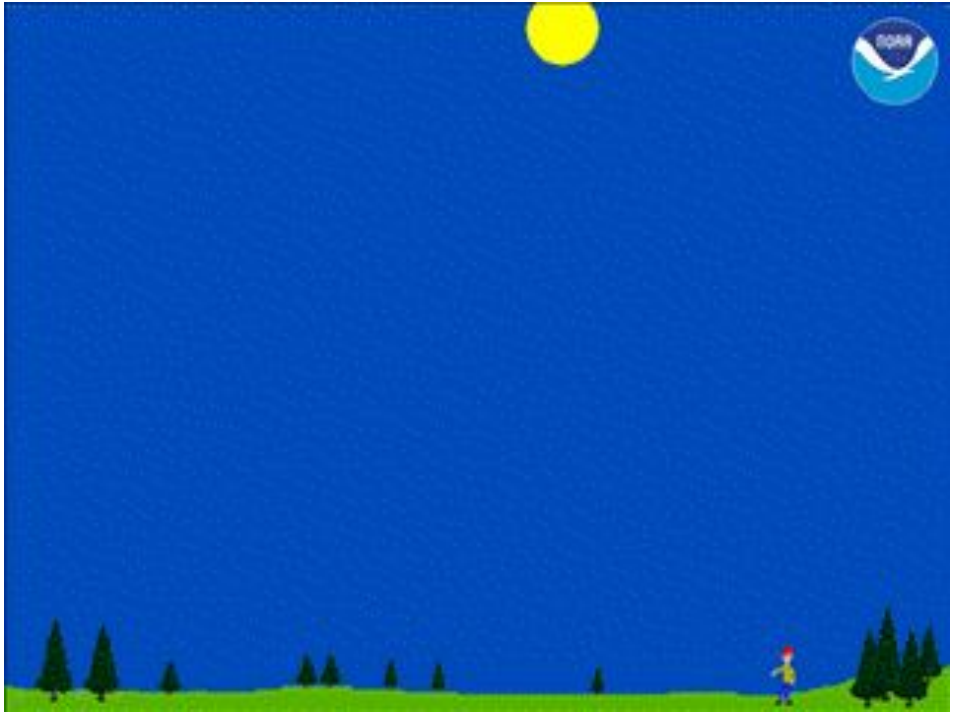
Compiled by John Jensenius
National Lightning Safety Council

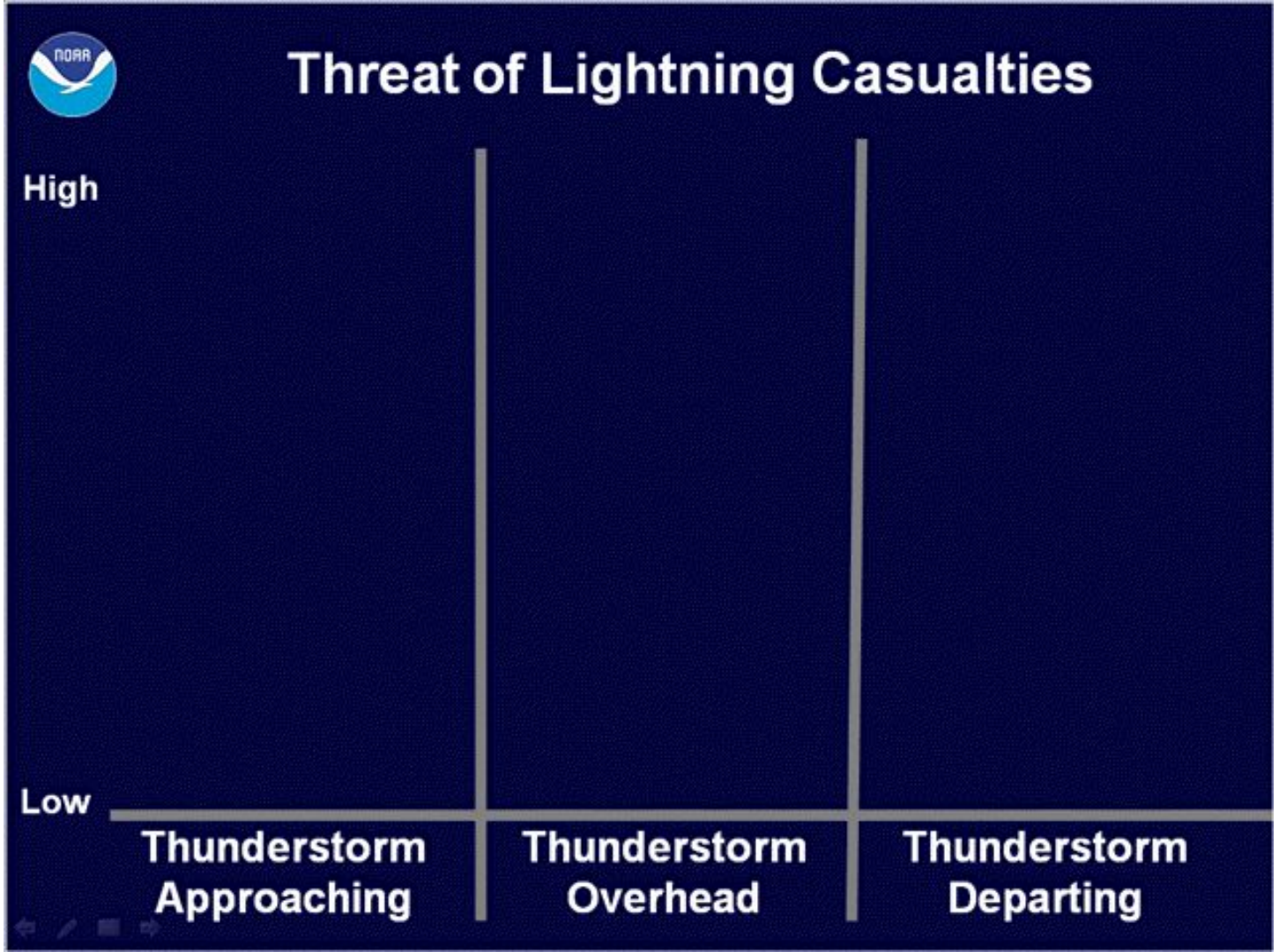
2025 Lightning Fatalities by State

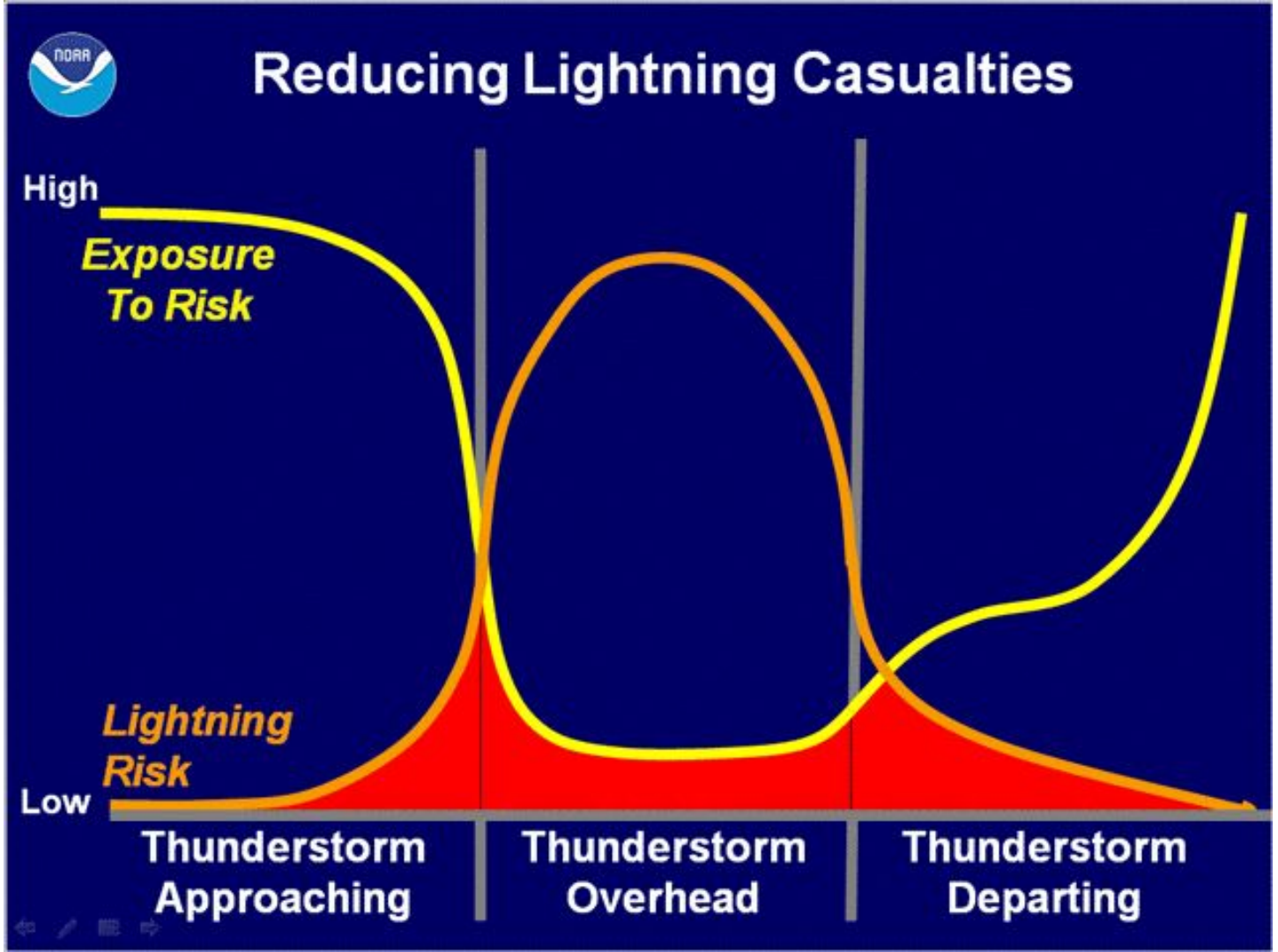


Lightning Safety

- There is no safe place outside when you hear thunder
- This is why we say “when thunder roars go indoors”
- The best way to protect yourself from lightning is to avoid the threat
    - Cancel outdoor plans if there’s a high chance for thunderstorms
    - Don’t delay seeking shelter once you hear thunder




Threat of Lightning Casualties
High
Low
Thunderstorm Approaching
Thunderstorm Overhead
Thunderstorm Departing

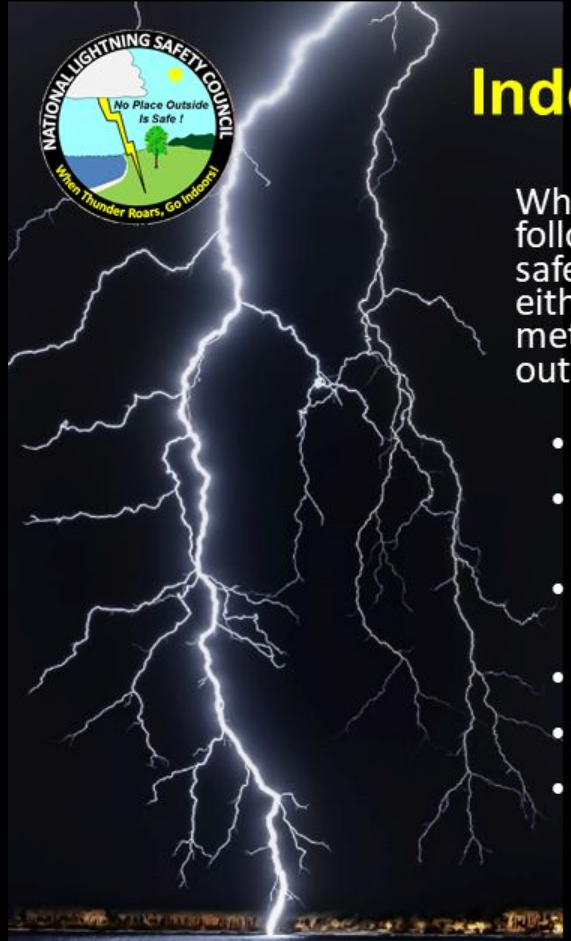

Reducing Lightning Casualties
High
Exposure To Risk
Lightning Risk
Low
Thunderstorm Approaching
Thunderstorm Overhead
Thunderstorm Departing

Lightning Safety Tips for Outdoor Activities

Summer is a great time to enjoy the outdoors. But it's also important to avoid the dangers associated with nature's fireworks.

- Listen to the forecast and plan activities to avoid the lightning threat.
- If thunderstorms are predicted, consider cancelling or postponing outdoor activities, especially if you wouldn't be able to get to a safe place quickly.
- While outdoors, monitor weather conditions.
- If the sky looks threatening or you hear thunder, go to a safe place immediately. Don't ignore any signs of a developing or approaching storm.
- Remain inside the safe place for 30 minutes after the last thunder.

LightningSafetyCouncil.org



Indoor Lightning Safety Tips

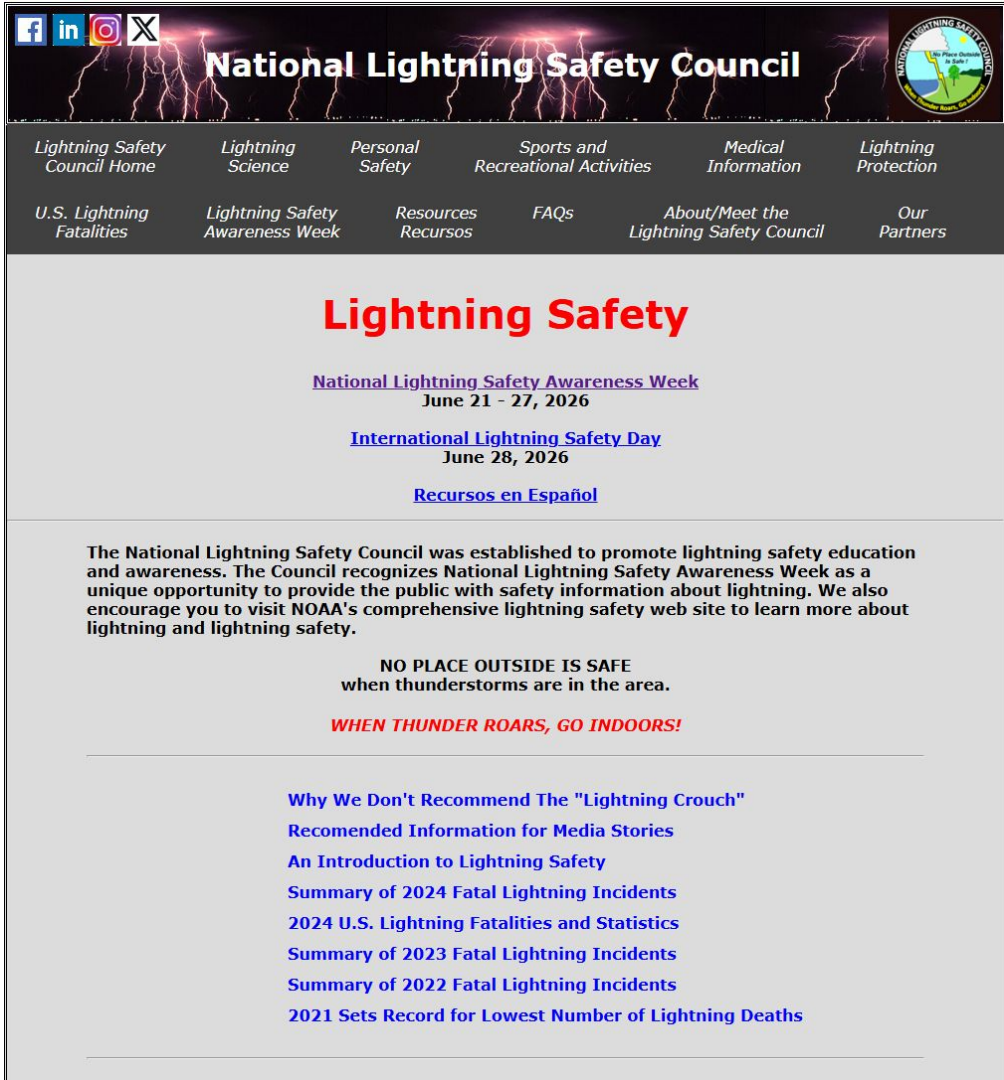
When lightning strikes a home or building, it often follows wiring or plumbing to ground. In order to be safe, you don't want to be connected in any way to either wiring or plumbing. You also want to avoid any metal that could provide lightning with a path from outside your home to inside, such as a doorknob.

- Get inside immediately if you hear thunder.
- Avoid contact with anything that is plugged into an electrical outlet
- Avoid contact with water or plumbing. For example, don't wash dishes or take a shower.
- Stay off corded phones
- Stay away from outside doors and windows.
- Wait at least 30 minutes after the last thunder before returning outside.

LightningSafetyCouncil.org

Lightning Safety

- Additional lightning safety info (and so much more) can be found at the National Lightning Safety Council's website!
  - **lightningsafetycouncil.org**




Lightning Safety Review!


Thanks For Coming!
Slides Link: https://www.weather.gov/ohx/weather101presentations