

ATM S 103

# Hurricanes and Thunderstorms

Their Science and Impacts



Nichas Anastasios (from <http://www.severe-weather.eu>)

# Announcements

- Homework 2: due 6 PM on Friday (April 19)
- Homework 1: problems and answers available from TA ([kanglt@uw.edu](mailto:kanglt@uw.edu))
- Mid-term: May 1
- A guest lecture: May 3 (Prof. Dargan Frierson)

# Enhanced risk of severe thunderstorms

...THERE IS AN ENHANCED RISK OF SEVERE THUNDERSTORMS OVER PARTS OF THE SOUTHERN GREAT PLAINS...

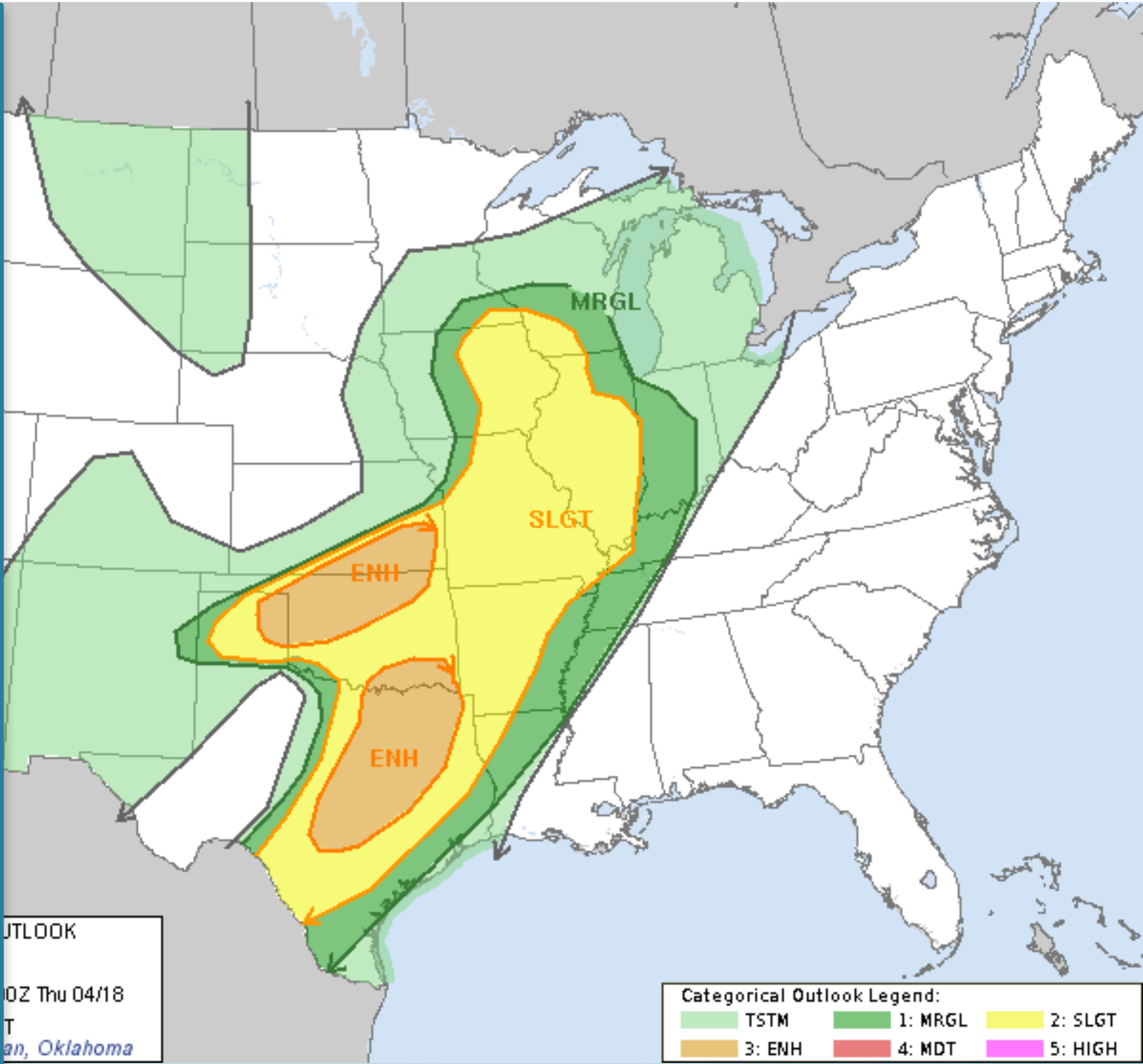
...SUMMARY...

Scattered to numerous severe storms are expected from the Texas Panhandle to the Mid-Mississippi Valley from late afternoon through tonight, and from south-central to northeast Texas, mainly this evening into tonight. **Very large hail, damaging winds, and a few tornadoes are possible.**

...TX Panhandle to the Mid-MS Valley...

Highest confidence signal for severe storm development is across this region. Thunderstorms will form in the vicinity of the surface cyclone over the TX Panhandle by 21Z and then develop northeast along a quasi-stationary front across northwest OK to southeast KS through the early evening. **Very steep mid-level lapse rates of 8-9 C/km will support a warm sector characterized by MLCAPE of 1000-2500 J/kg.** Storms initially will pose a threat for very large hail and a couple tornadoes. However, upscale growth/consolidation is expected rather quickly given the degree of ascent and orientation of the deep-layer wind fields to the front. Latest CAMs are somewhat inconsistent with the degree of development into the higher-quality buoyancy across central OK.

40-50 kt effective shear will support potential for several bowing line segments as the cold front sharpens during the evening. Damaging winds, some embedded hail, and a few tornadoes will be possible as multiple MCSs likely persist east-northeast towards the Mid-MS Valley overnight.



| Area Pop.  | Some Larger Population Centers in Risk Area                                           |
|------------|---------------------------------------------------------------------------------------|
| 13,028,351 | Dallas, TX...Austin, TX...Fort Worth, TX...Tulsa, OK...Arlington, TX...               |
| 20,967,559 | San Antonio, TX...Oklahoma City, OK...St. Louis, MO...Madison, WI...Shreveport, LA... |
| 28,573,760 | Chicago, IL...Houston, TX...Indianapolis, IN...Memphis, TN...Kansas City, MO...       |

## **W** Which of the following is NOT the associated with typical thunderstorm outbreaks?

high CAPE (convective available potential energy)

low CIN (convective inhibition)

low dew point near the surface

forced vertical motion

# Answer: 3

- High CAPE
- Low CIN
- **High** dew point near the surface
- Force vertical motion (trigger)

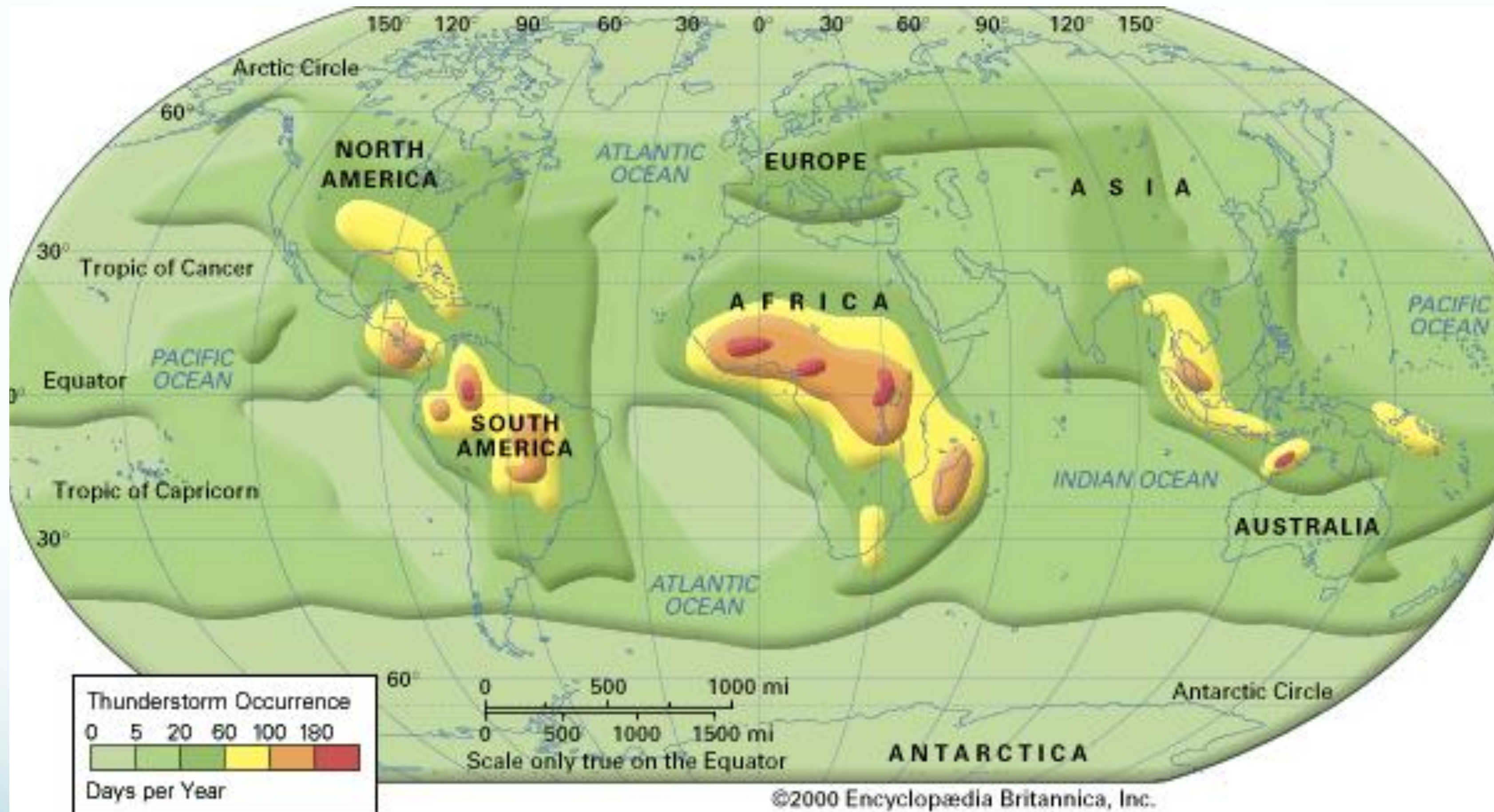
# Thunderstorm Induced Hazards

(Yearly-averaged values)

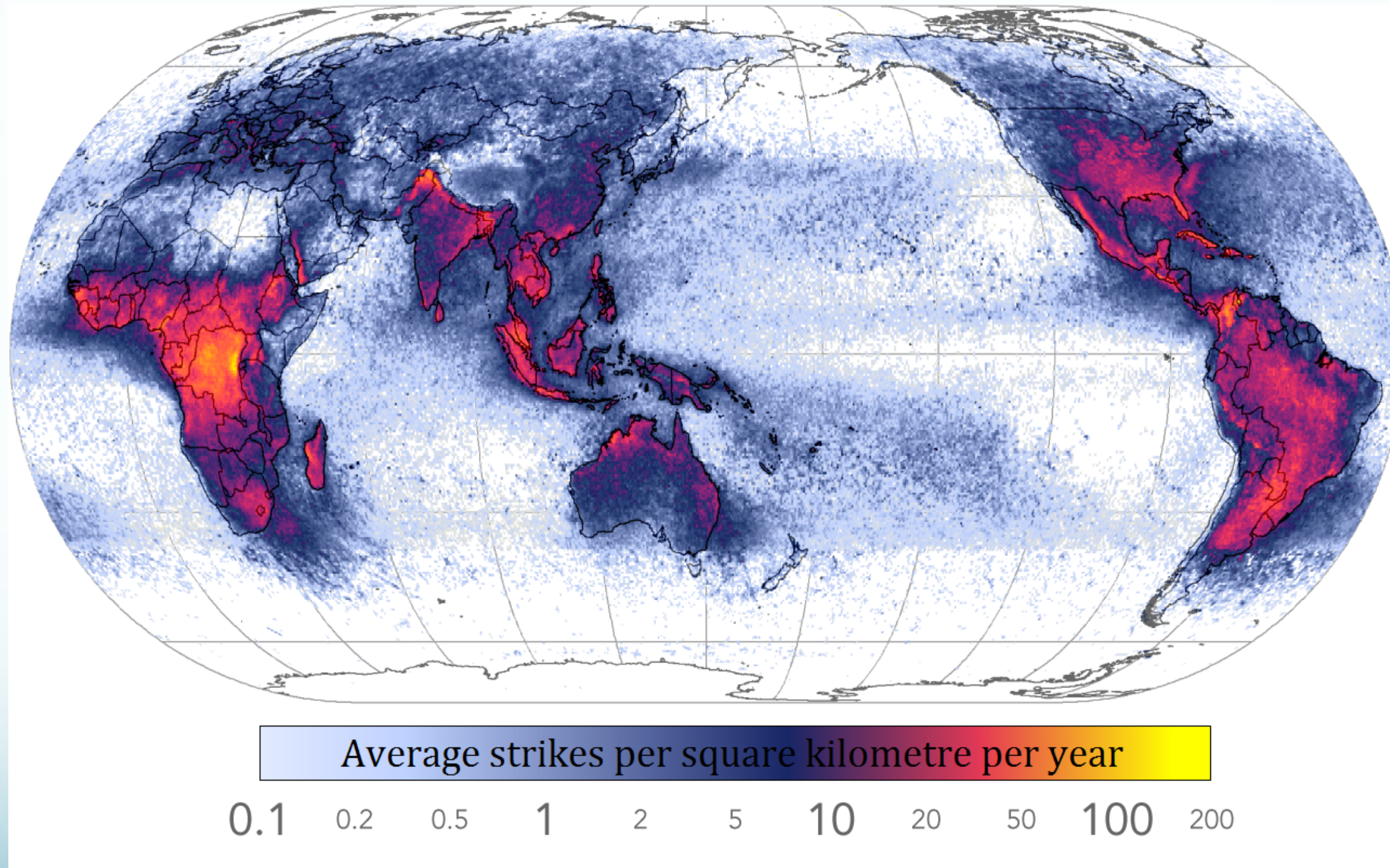
- Tornadoes: 60-65 deaths, 1,500 injuries
- **Lightning: 55-60 deaths, 400 injuries**
- Flash floods: over 90 deaths
- Hail: over \$1 billion in crop damage
- Winds: can exceed 125 mph

(Source: NOAA Thunderstorms, Tornadoes, Lightning Preparedness Guide, NOAA/PA 201051)

# Thunderstorm Frequency



# Global Lightning Frequency



# Observations of Lightning Events

- Video: <https://www.youtube.com/watch?v=nBYZpsbu9ds>

# Lightning

Super slow motion

# Lightning: A Big Spark

- Air will start to conduct if the voltage difference between two points is big enough
  - 3,000,000 volts per meter in dry air
  - 1,000,000 volts per meter in rain filled air
- Lightning involves *high* voltages.
  - Benjamin Franklin didn't completely appreciate this.



# Topics for today

- How do electrical charges develop in thunderstorms?
- What should you do to avoid being struck by lightning?

# W Why do you see lightning before you hear thunder?

Because it takes a while for noise to be produced as air is heated by a lightning bolt.

Because sound travels much slower than light.

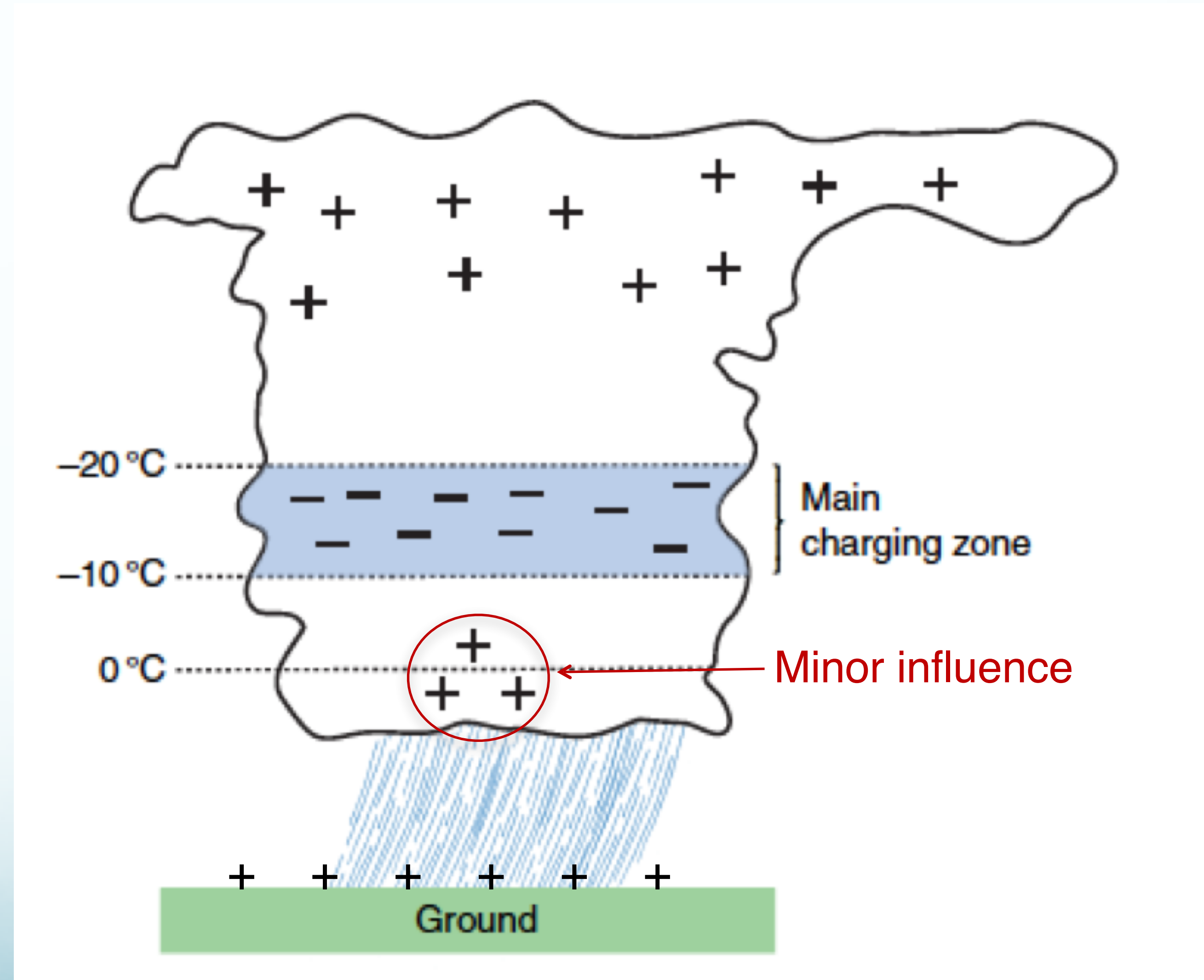
# Answer: Because sound travels much slower than light

- Speeds in air: **sound 340** m/s; **light 3,000,000** m/s.
- Thunder is produced at virtually the same time as the lightning flash.
  - The electrical current in the lightning bolt heats the air almost instantly to 30,000 °C.
  - No time for the air to expand (change its density), so the pressure increases drastically.
  - Response to the region of enormously unbalanced pressure is the same as to a stick of exploding dynamite (boom).

# A Recipe for Lightning

- *Generate separate regions* of positive and negative charge.
- *Trigger* a bolt (an avalanche of electrons) between these regions
  - Maybe relates to cosmic rays
  - Maybe ?

# Basic Charge Distribution



# Observations

- Region of maximum negative charge occur at environmental temperature of  $-15\text{ }^{\circ}\text{C}$ .
- Charges develop after radar shows storm has developed falling graupel and hail ( $> 5\text{mm}$  in diameter).



# W Ice plays a key role in thunderstorm electrification.

True

False

Start the presentation to see live content. Still no live content? Install the app or get help at [PolleEv.com/app](https://PolleEv.com/app)

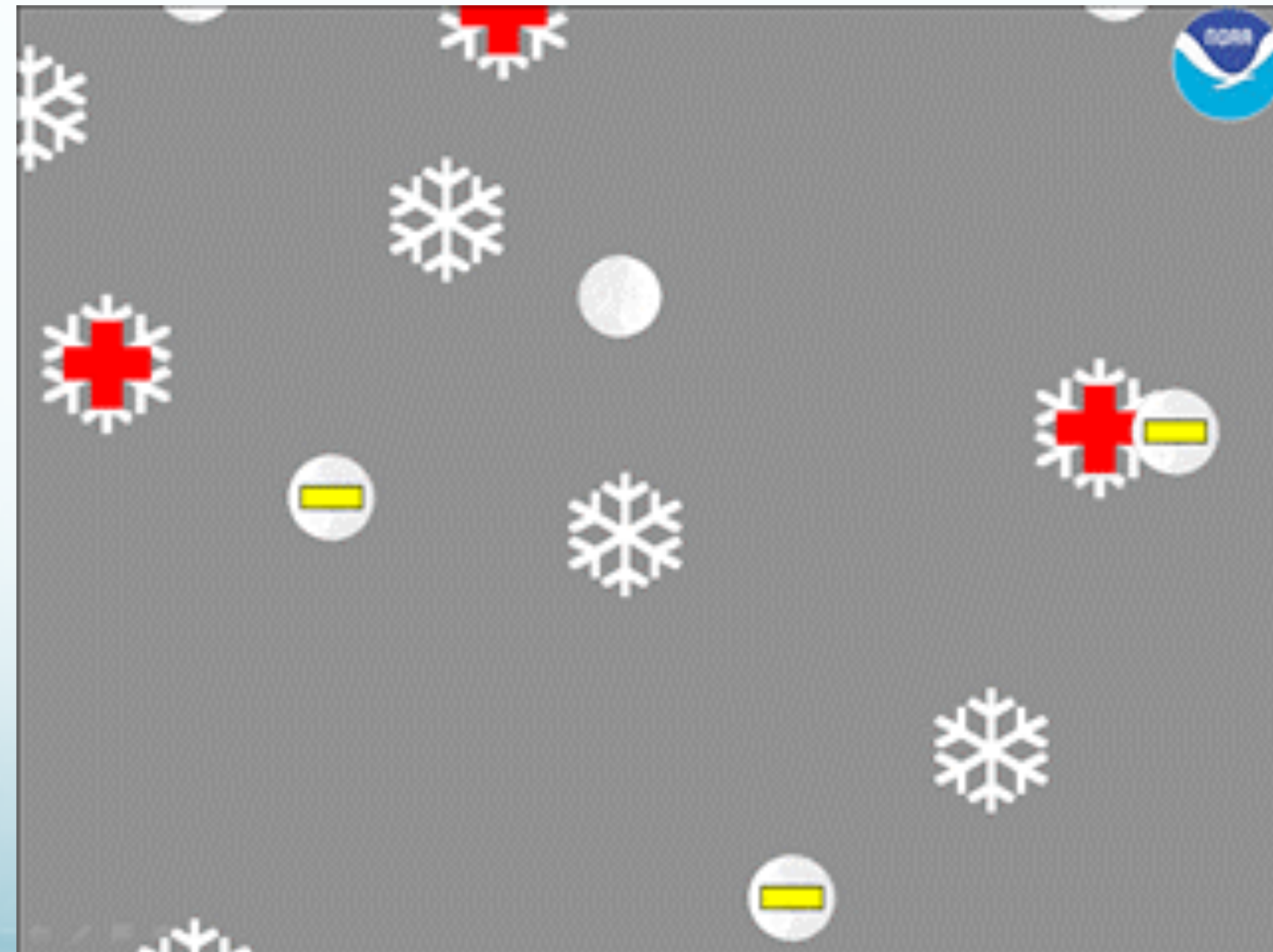
Total Results

Answer: True

Ice plays a key role in electrification.

# Creating Charged Particles

- Falling graupel and hail *collide* with rising ice crystals
  - Graupel and hail become negative
  - Ice crystals become positive



# Separating the Charges

- **Ice crystals** (+ charge) keep rising and accumulate in the top of the cloud.
- **Graupel and hail** (– charge) remain lower in the cloud

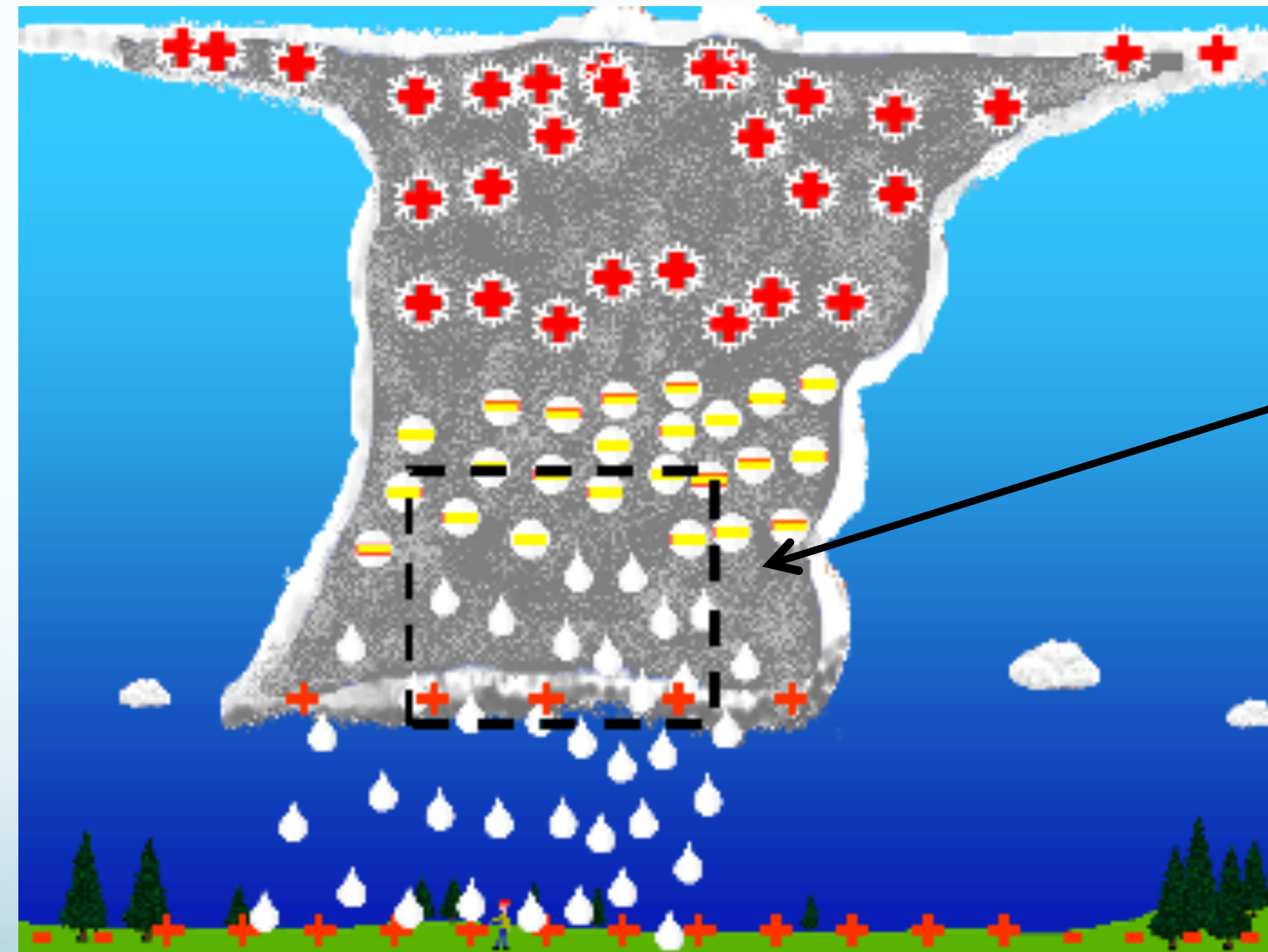


Positive charge is induced at the surface  
by the negative charges aloft



# Stepped Leader Initiation

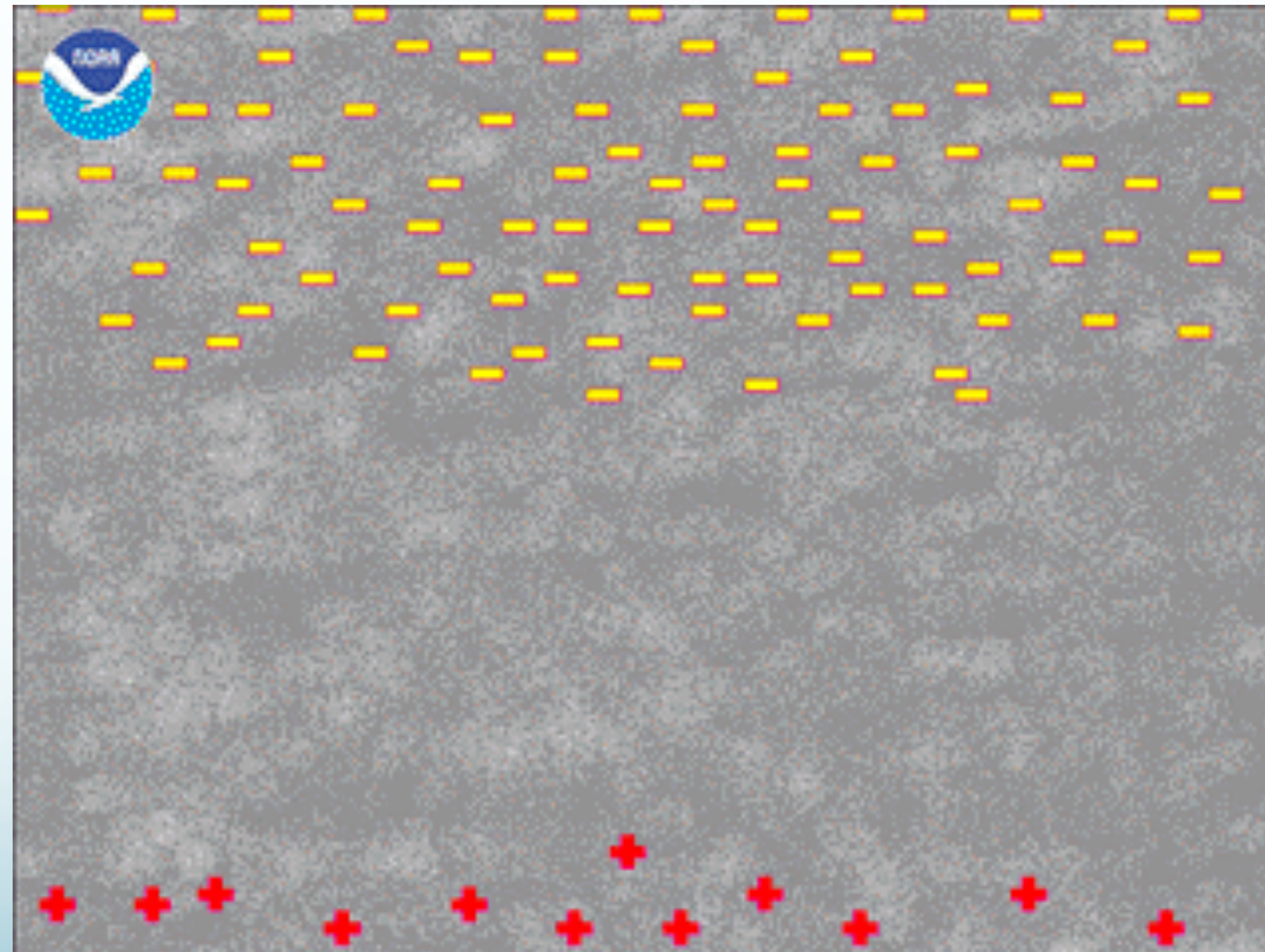
- Starts by transferring negative charge toward the small region of positive charge near the cloud base



Zoom into  
this area

# Stepped Leader Initiation

- Starts by transferring negative charge toward the small region of positive charge near the cloud base



# Stepped Leader Descends Below Cloud Base (showing charges)

- Tries to find the path of least resistance toward the ground

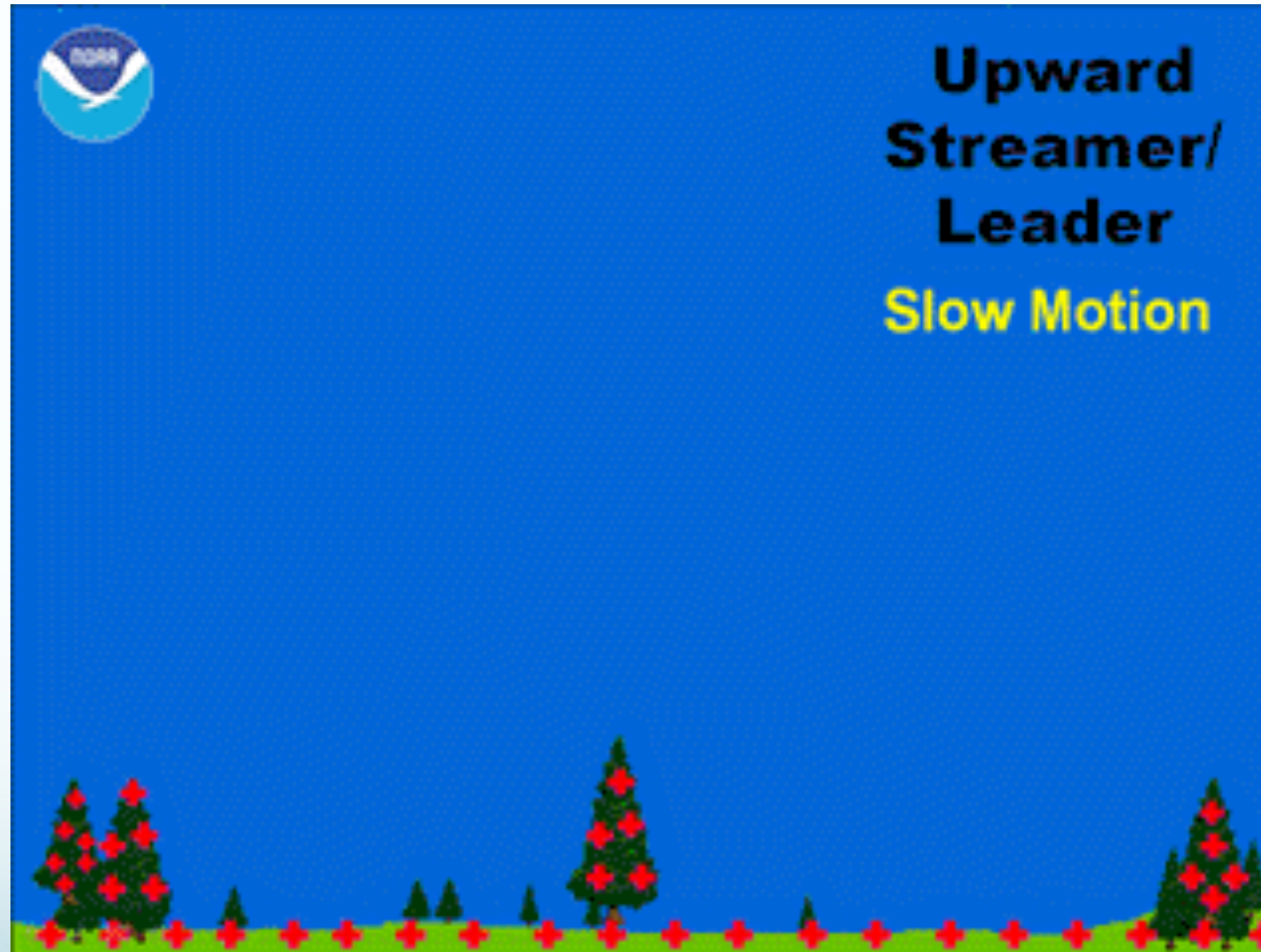


# Stepped Leader Descends Below Cloud Base (showing steps)

- Tries to find the path of least resistance toward the ground

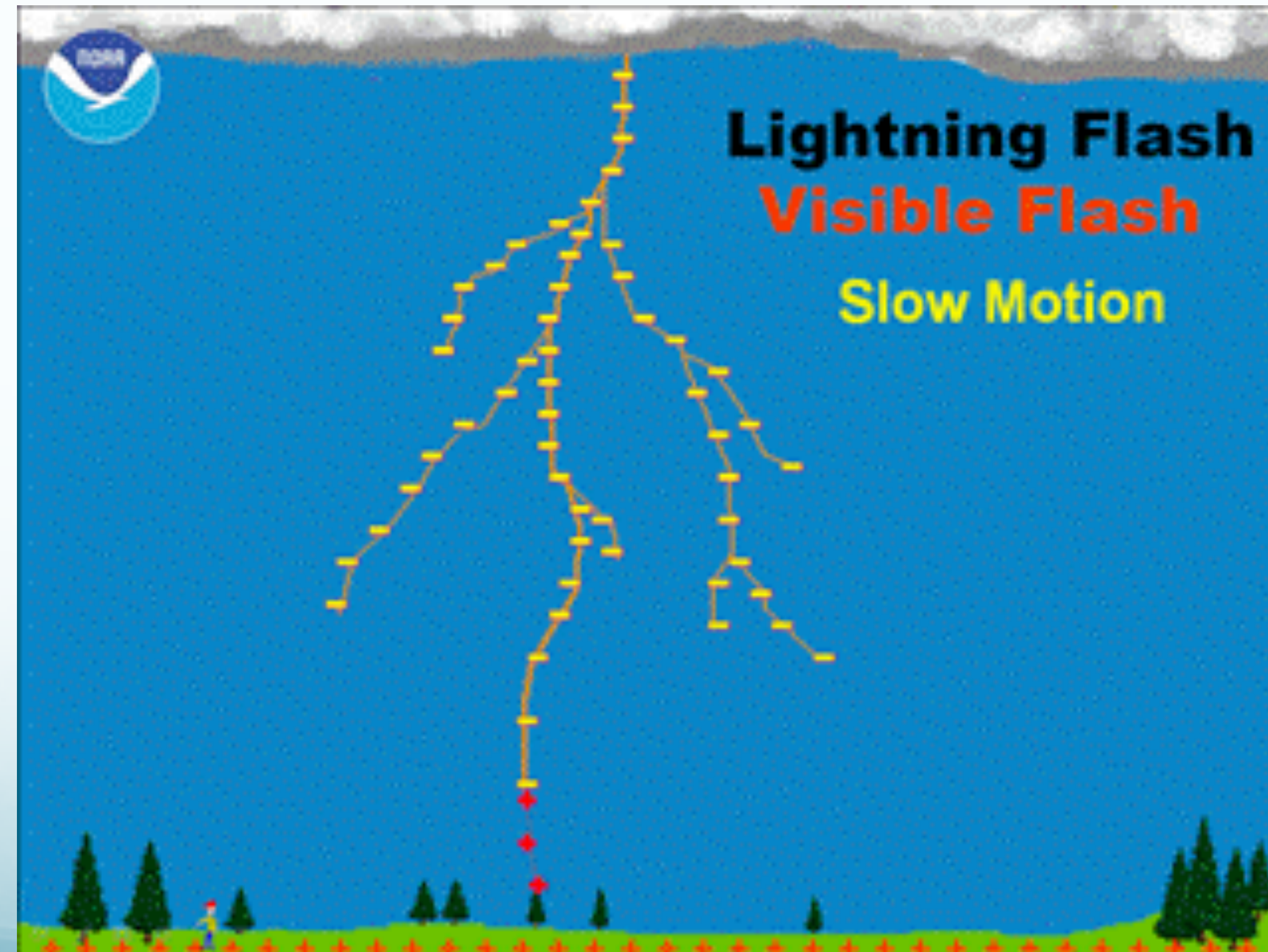


Streamers extend upward from high points on the surface.



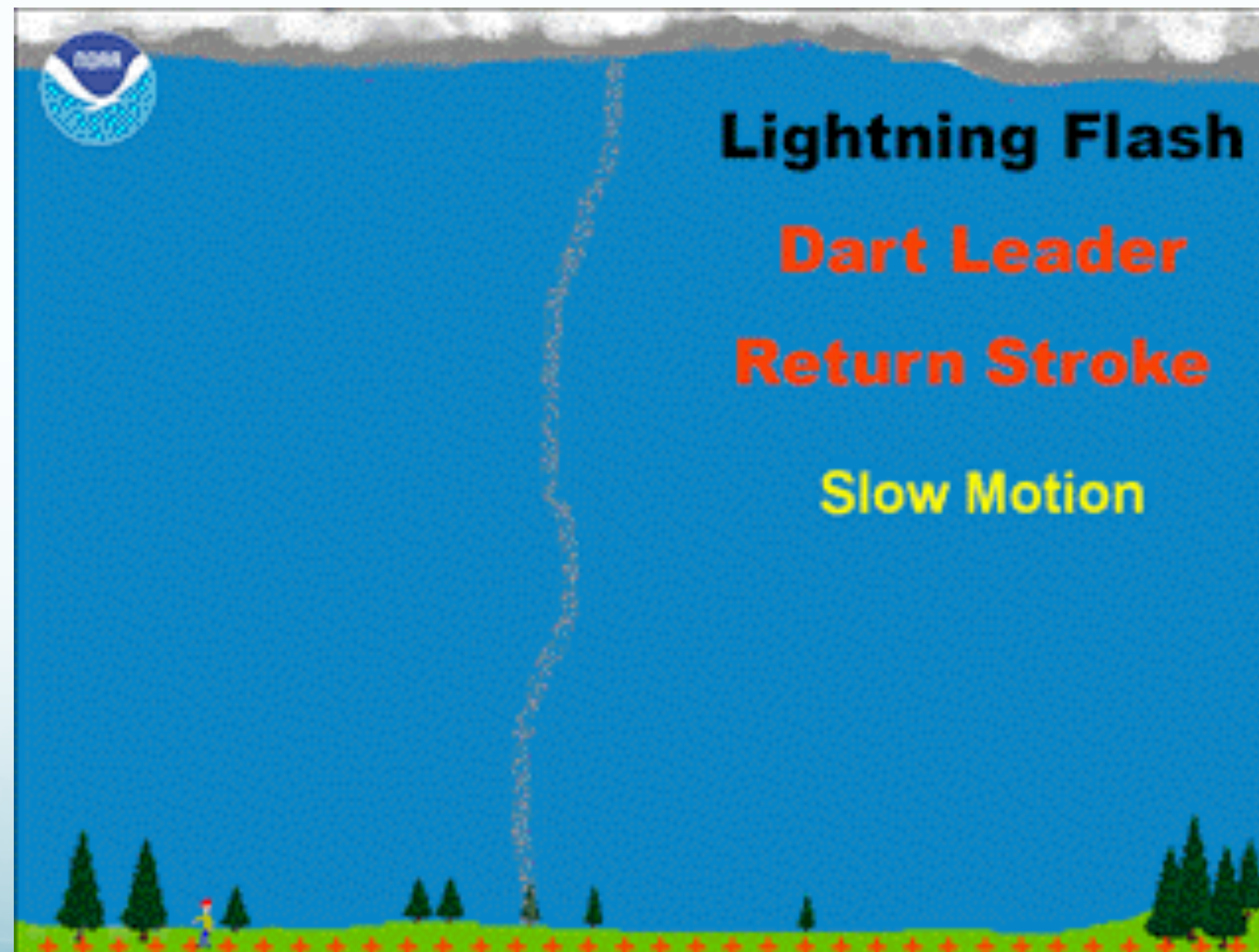
# Return stroke carries the main discharge.

- Stroke moves upward from the surface, but electrons (negatives) flow downward from cloud.

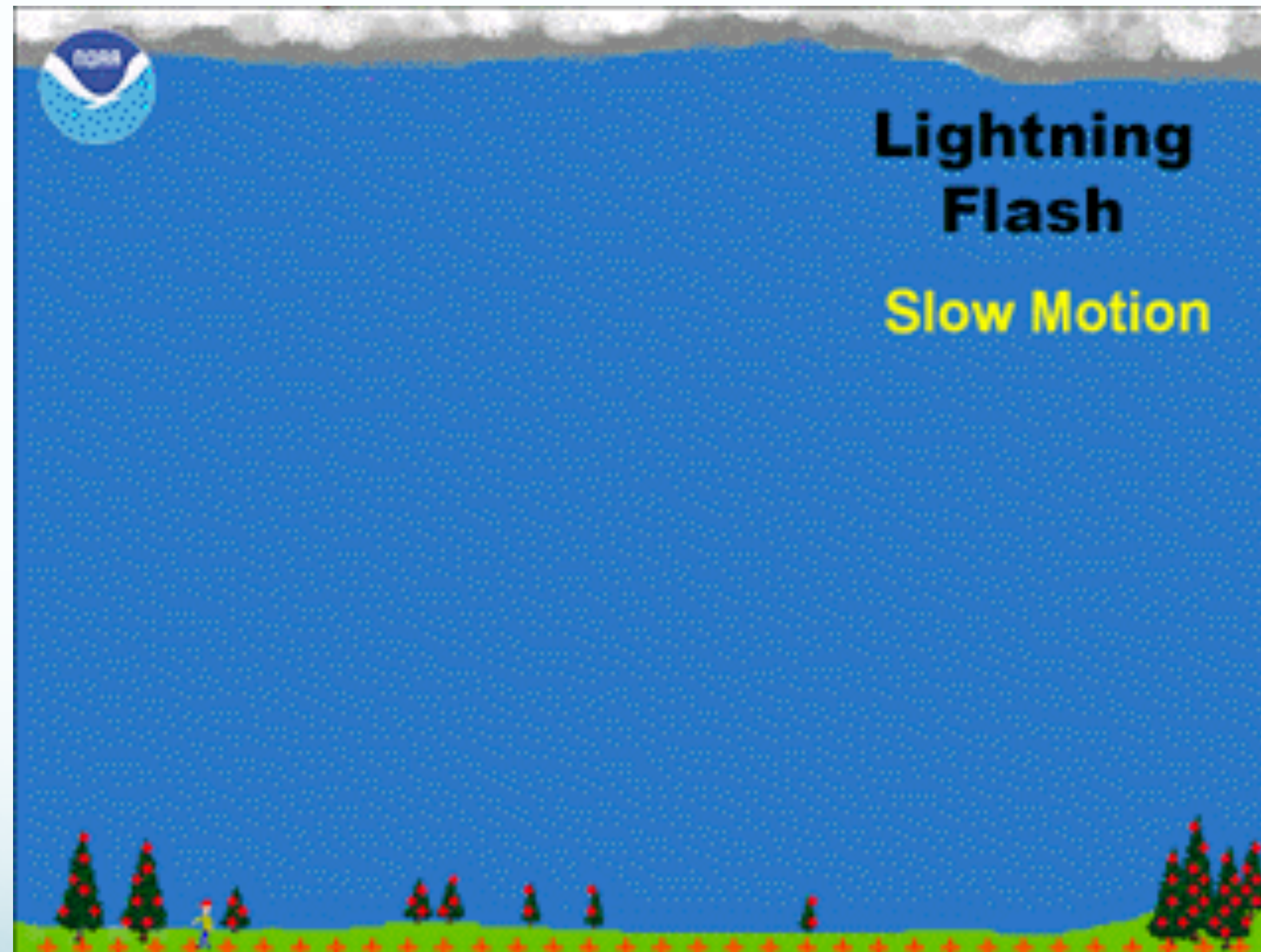


# Dart Leader

- Flows down from above along the path of the previous discharge.
- Triggers subsequent return strokes (3-4 total flashes is common)



# Complete Lightning Event – Slow Motion



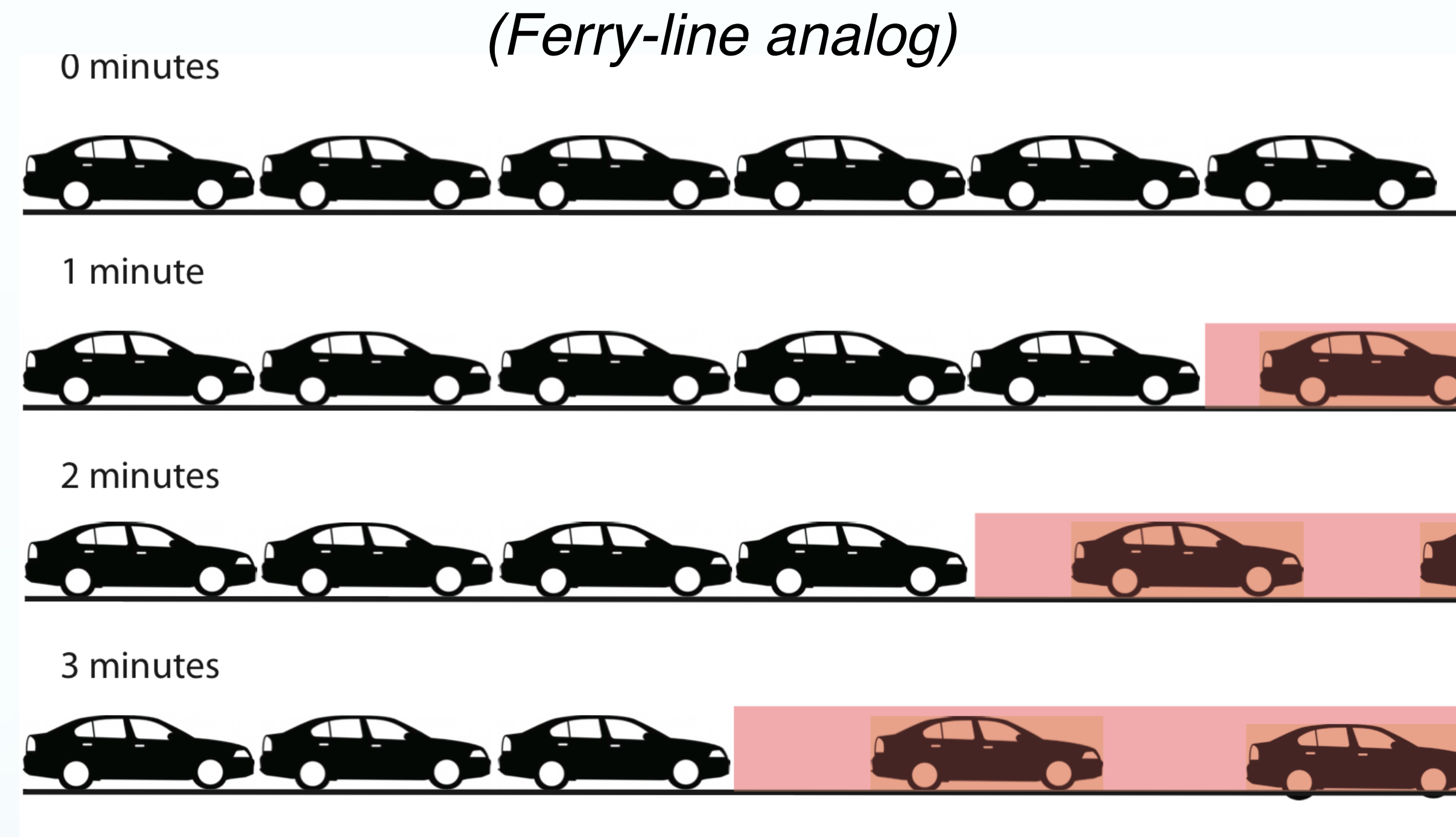
# Complete Lightning Event – Normal Speed



# Oops

- Weather Book, p. 131 suggests the lightning stroke consists of “an intense wave of positive charge traveling upward.”
- The current is carried by (negatively charged) electrons traveling downward,
  - But as we have seen the current flow propagates upwards.
- Confusing?

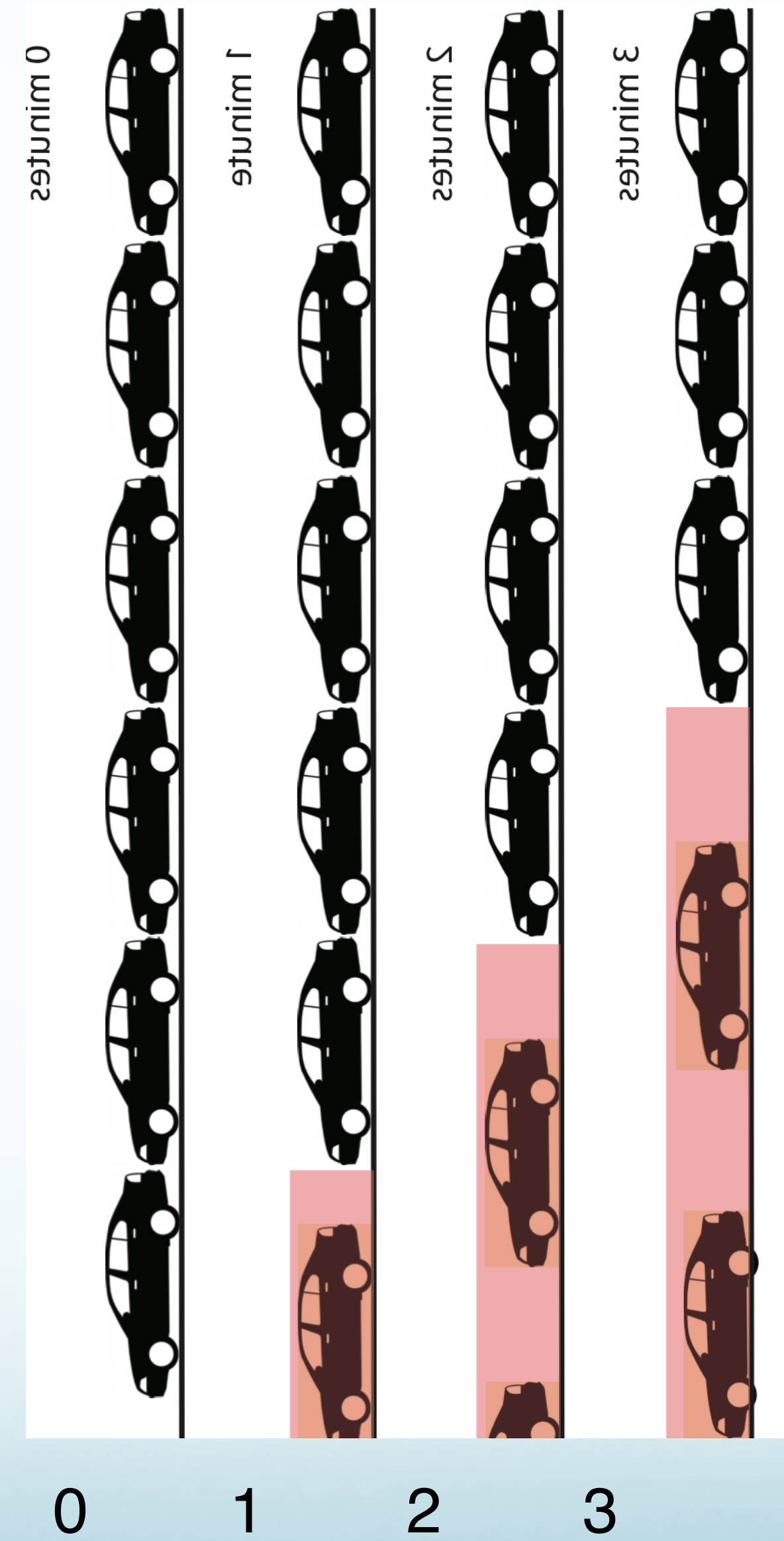
# How do the electrons flow downward, while the lightning propagates upward?



- Electrons=cars
- Flowing electrons (red highlight) = lightning discharge
- Ground at right, cloud base at left

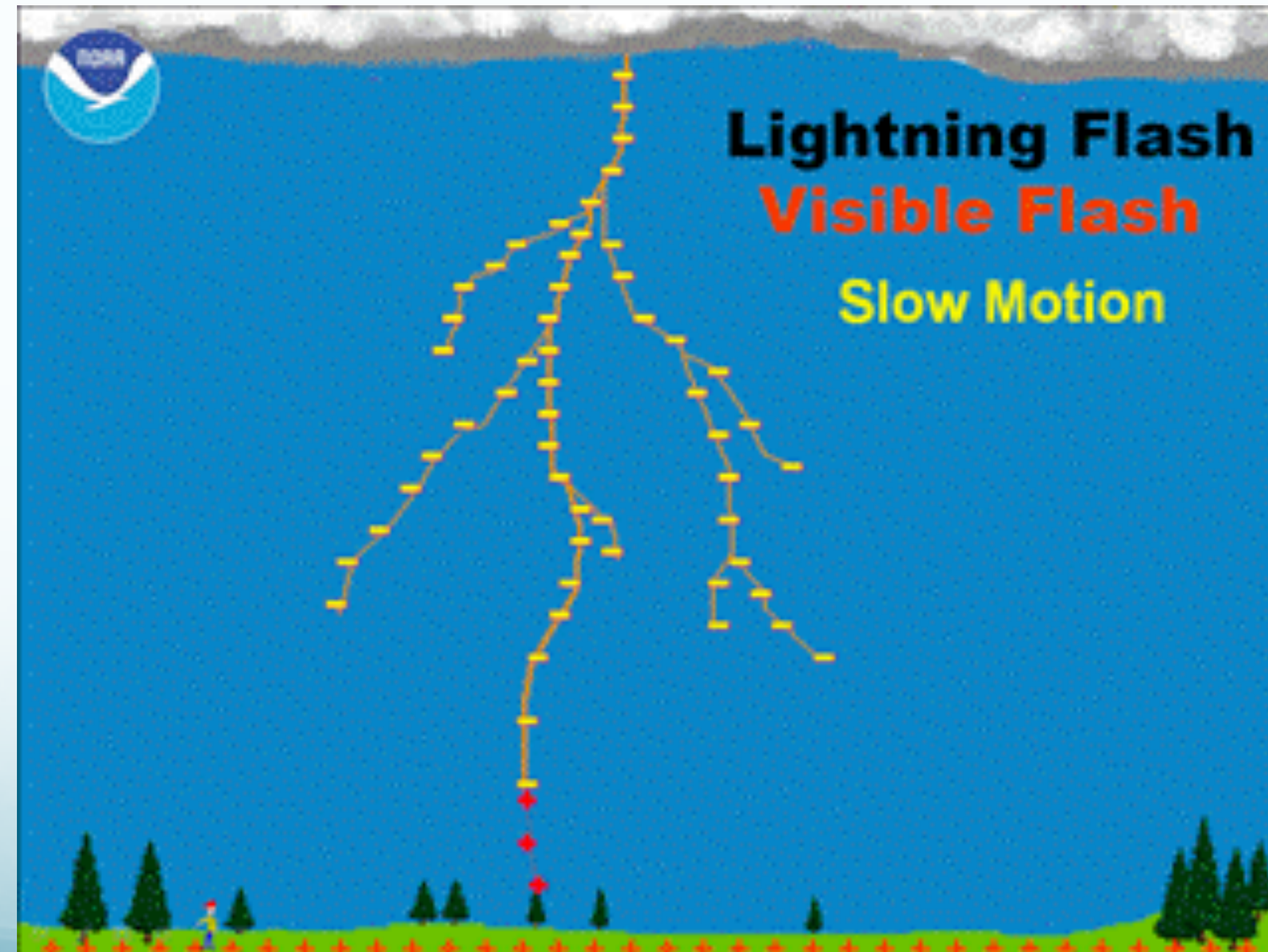
# Ferry line rotated into the vertical

Time



# Return stroke carries the main discharge.

- Stroke moves upward from the surface, but electrons (negatives) flow downward from cloud.



# Slo-mo video

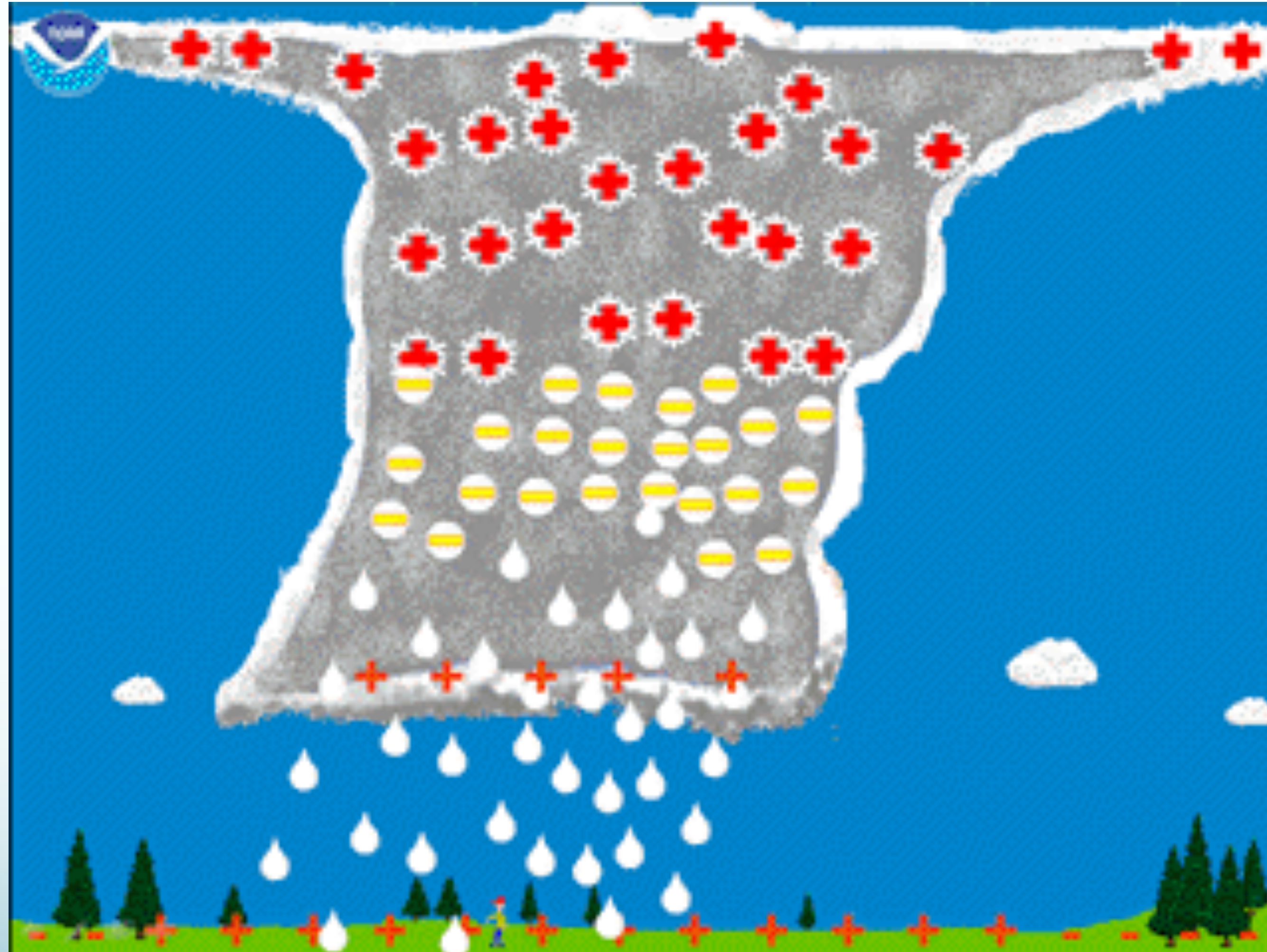
- Can see stepped leader and return strokes



# Another Slo-Mo

- Note the more persistent strike
- This continuous current is more likely to ignite fires

# Flashes: Intra-Cloud, Cloud-to-Ground Negative and Positive



# A cloud-to-cloud lightning stroke



Helena Bragonfly (from <http://www.severe-weather.eu>)

# A positive lightning stroke



Entoni Novosel (from <http://www.severe-weather.eu>)

# Lightning Safety



WINSTON KEMP AND JUDIE STANFORD

W

Cars provide safety from lightning because they are insulated from the ground by their tires.

True

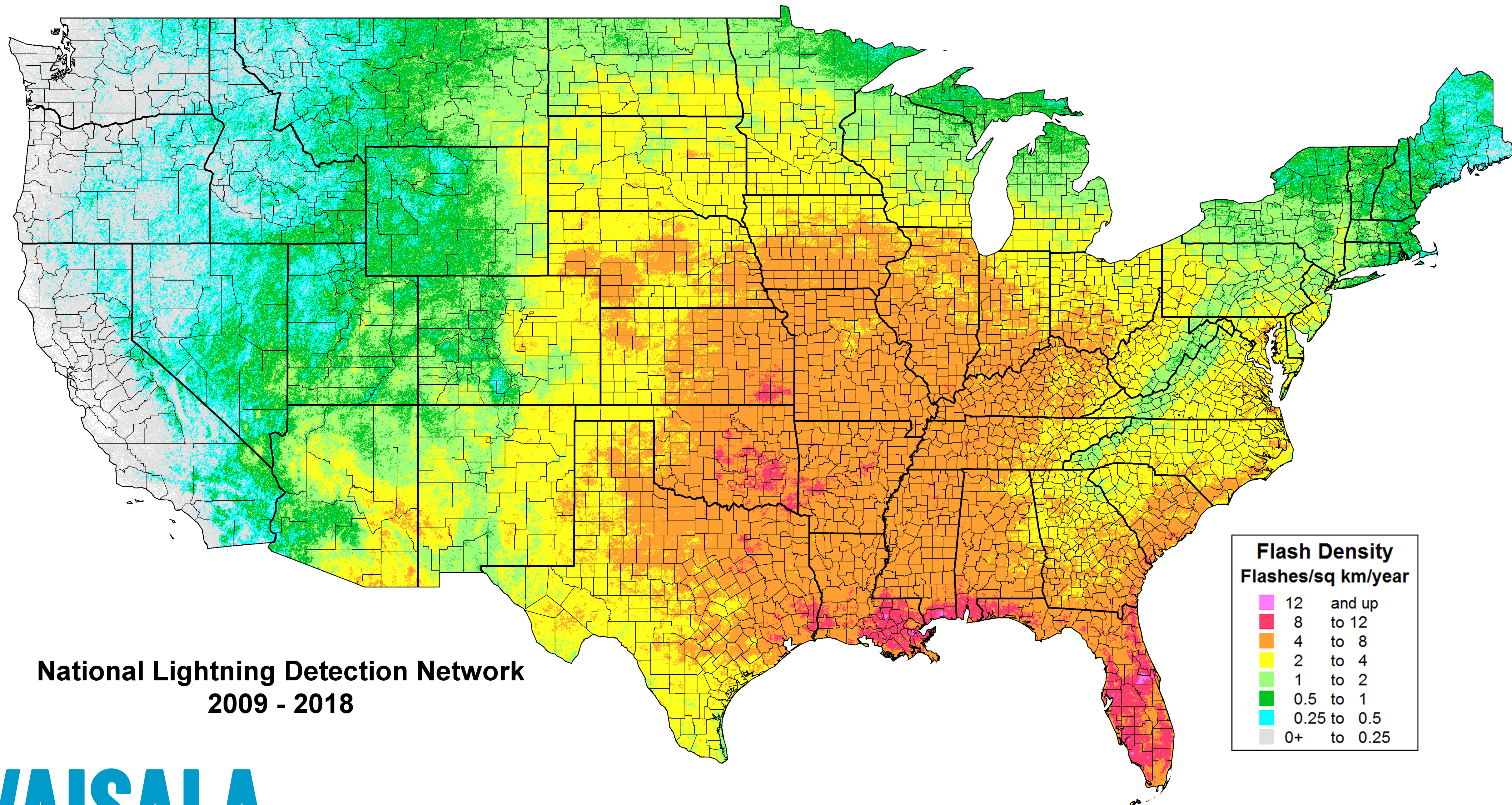
False

Start the presentation to see live content. Still no live content? Install the app or get help at [PolleEv.com/app](https://PolleEv.com/app)

Total Results

False: lightning can easily jump across 6" of tire to the ground.

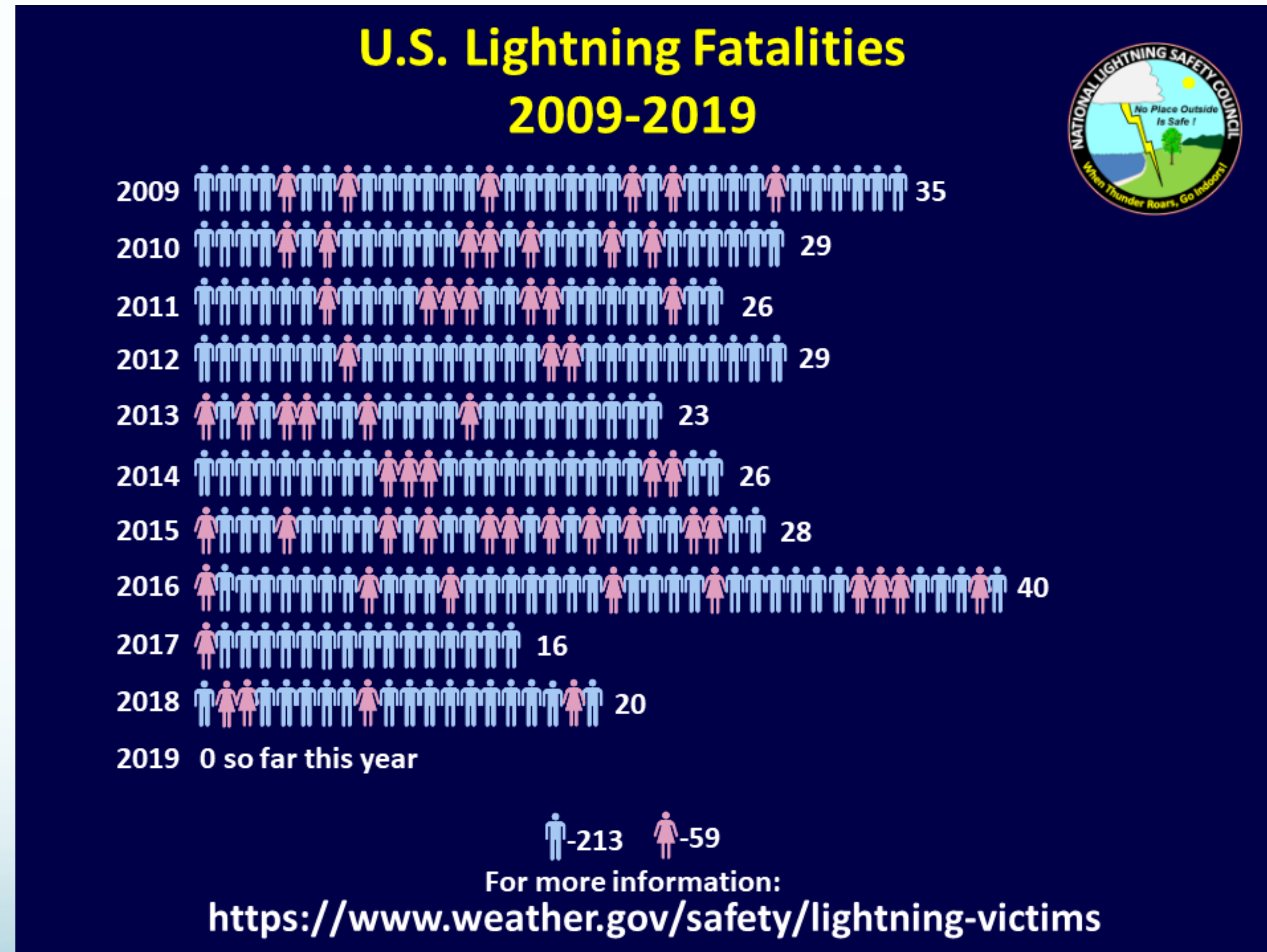




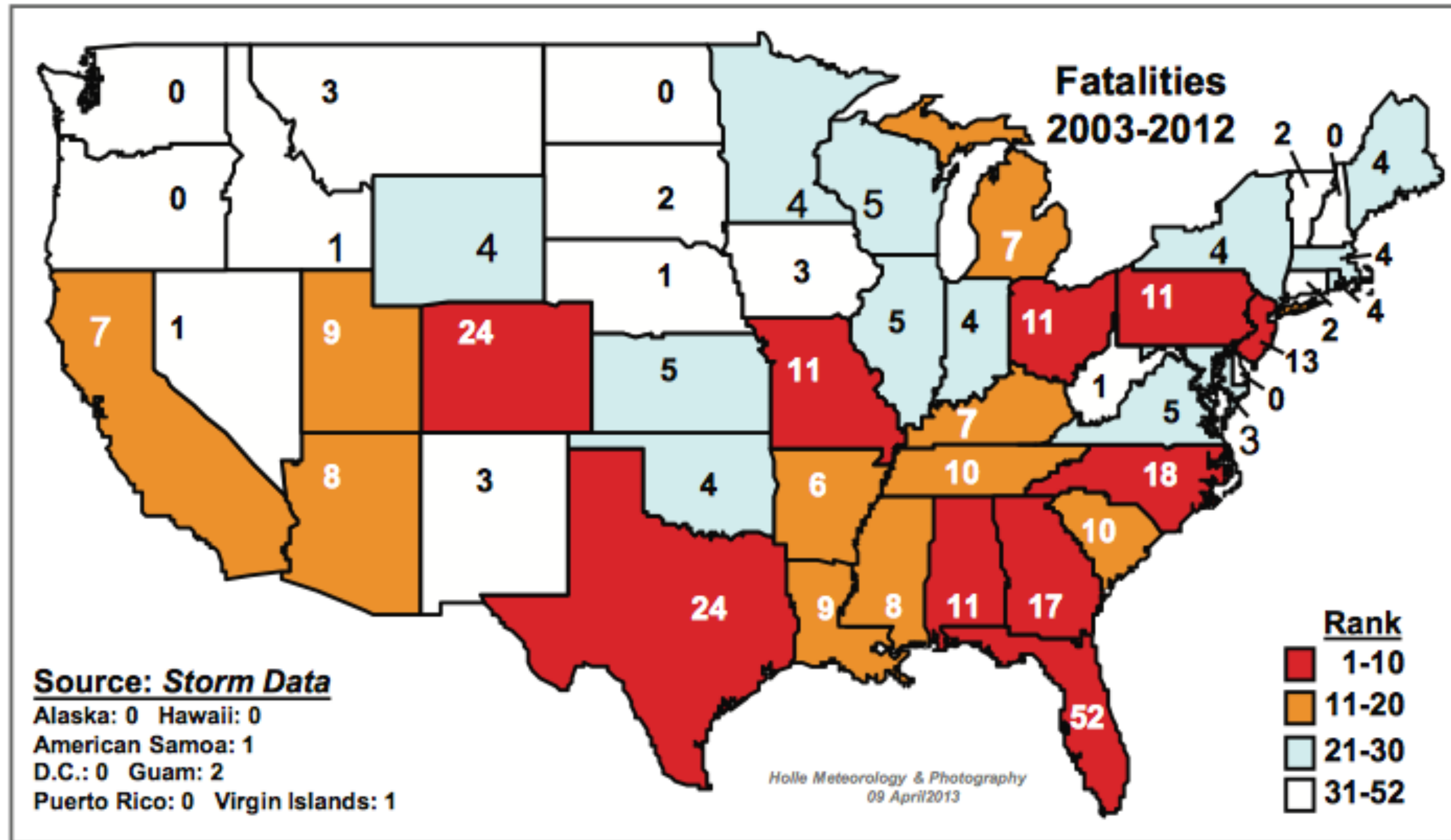
**National Lightning Detection Network**  
**2009 - 2018**

**VAISALA**

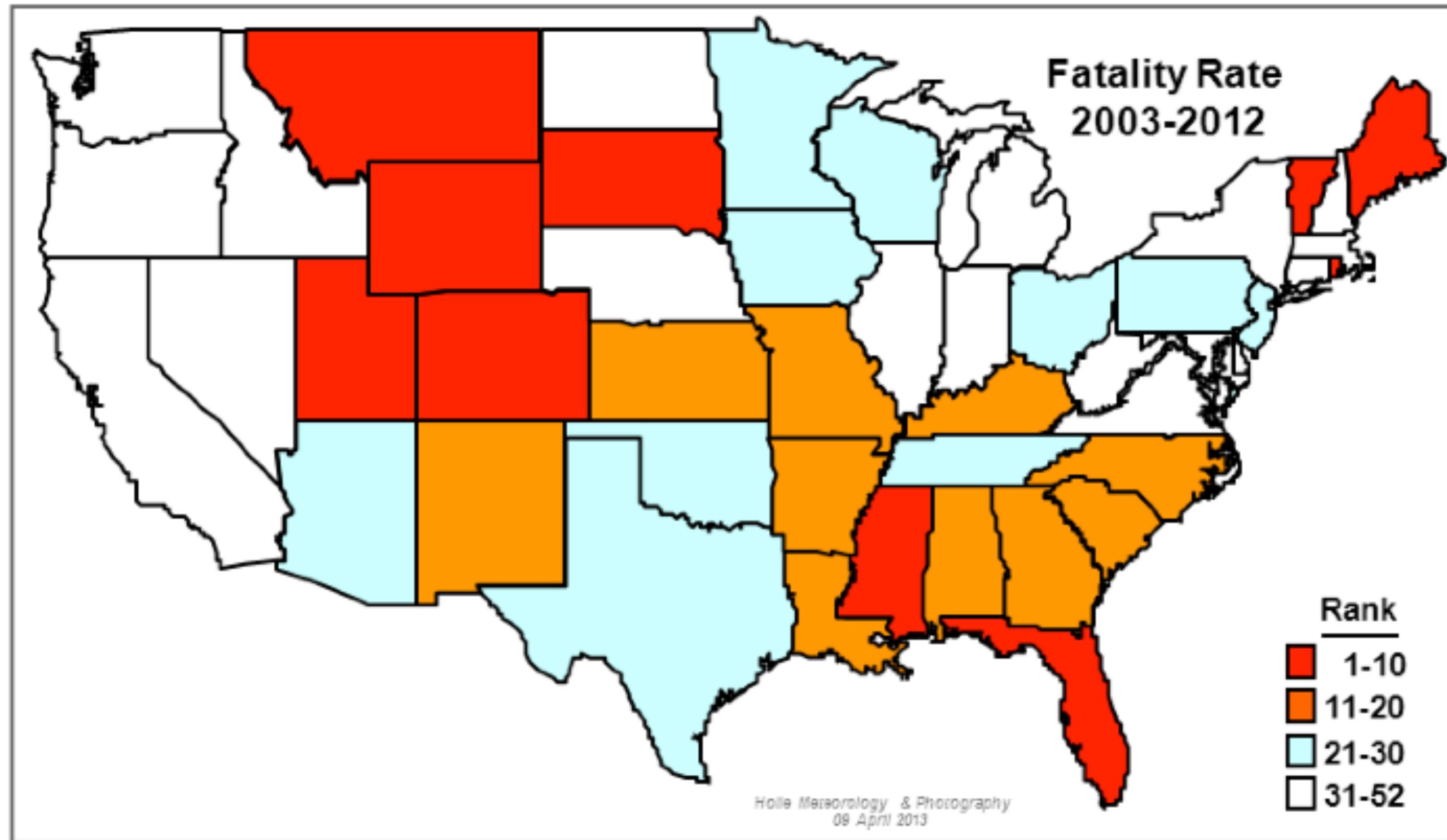
# US Lightning Fatalities 2009-2019



# Lightning Fatalities by State, 2003-2012



## Lightning Fatalities Weighted by Population by State, 2003-2012



**W** In the US, men are killed by lightning \_\_\_\_\_ as often as women.

about

twice

four  
times

Men are killed about four times as often.

# NOAA Safety Guidance

- NO PLACE outside is safe when thunderstorms are in the area!!
- If you hear thunder, lightning is close enough to strike you.
- When you hear thunder, immediately move to safe shelter: a substantial building with electricity or plumbing or an enclosed, metal-topped vehicle with windows up.
- Stay in safe shelter at least 30 minutes after you hear the last sound of thunder.

# Perilous situation

- Hair standing on end means you're charged up, strike is imminent

