Lightning!

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Presented to SFDXA 6 Jan 2016

Lightning and grounding

- Part 1
  - Lightning - the what, when, where and how
  - Lightning effects on a human
- Part 2
  - The challenge – protect your radio equipment

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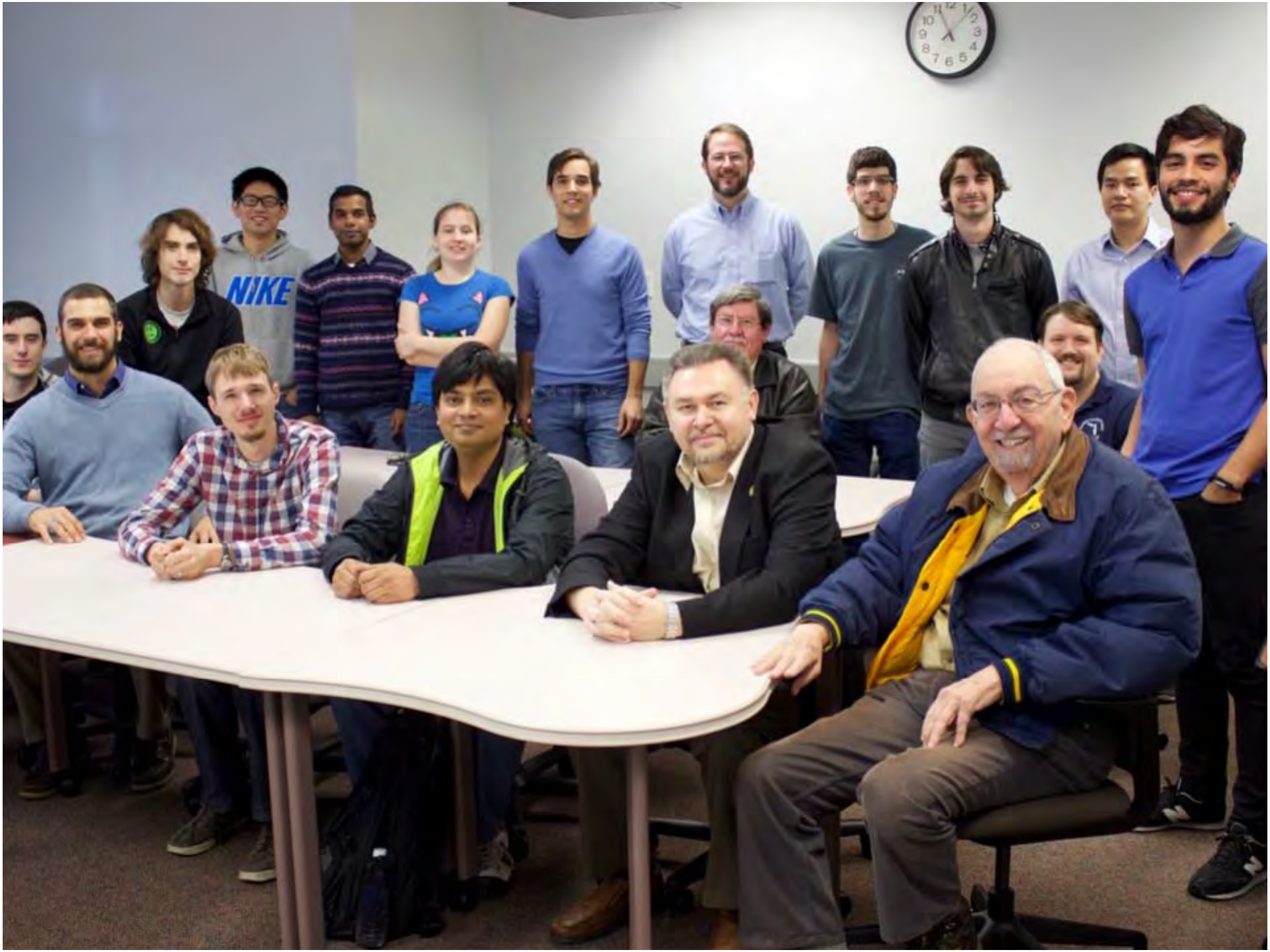
Lightning

What is lightning ?
Lightning Incidence = how much and where ?
How is lightning formed?
What are the types of lightning?
Detecting lightning
Five ways to be zapped
Hail storm interactions
Lightning effects on human
Lightning versus 60 cycle and direct current
“high” voltage on humans
Myths

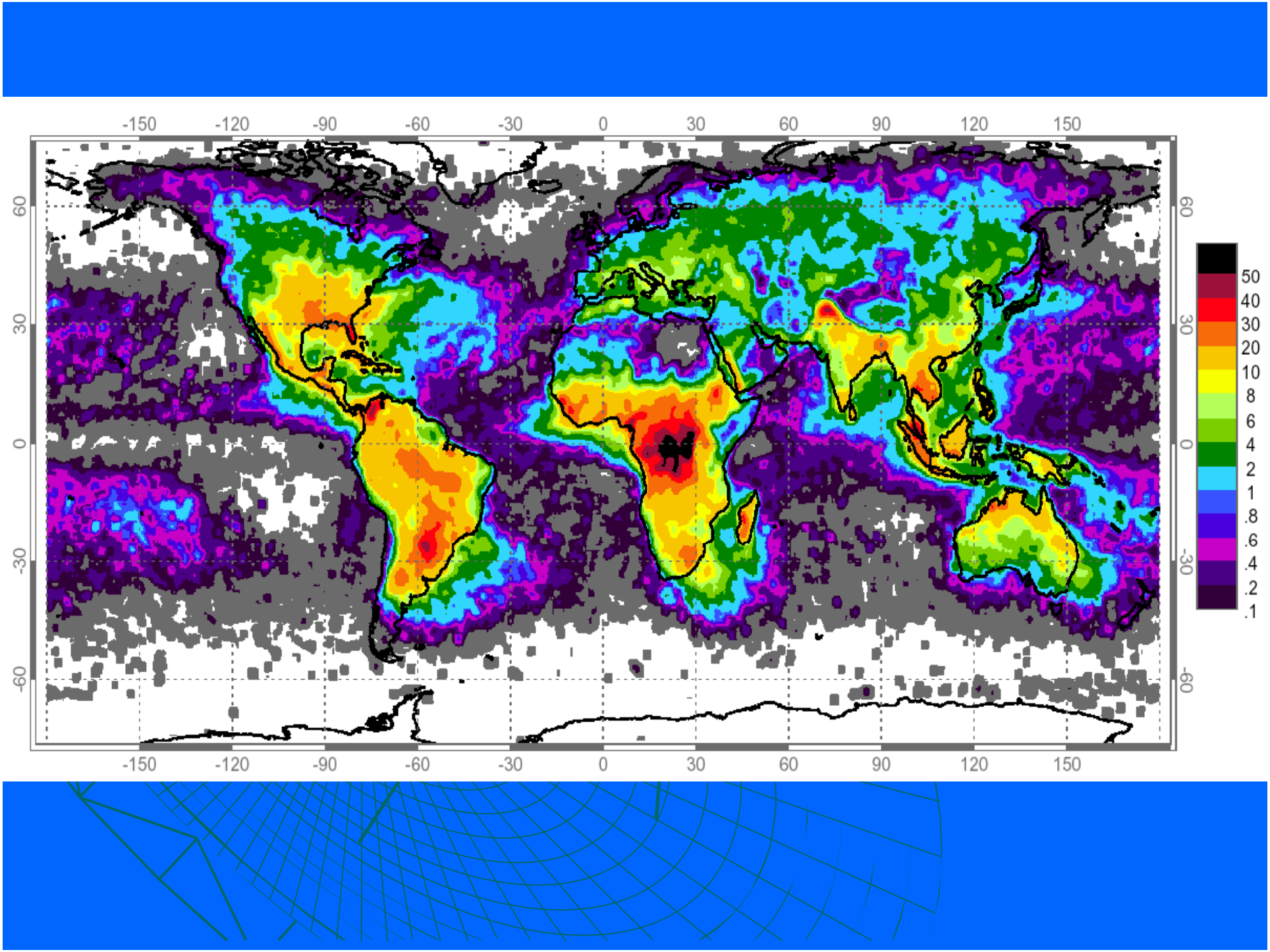
Martin Allen Uman, PhD


NIKE

Lightning

- 2 - 3 cm diameter
- 2 – 10 miles long
- 50,000 to 60,000 degrees Fahrenheit
- 100 million to 1 billion volts
- 10,000 to 250,000 Amps
- Concussive shock wave of up to 20 atm.
- Duration: 1/100th - 1/1000th of a second

Lightning Incidence = how much and where ?


-150
-120
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-30
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Average Number of Thunderstorm Days Per Year

(See key for explanation)

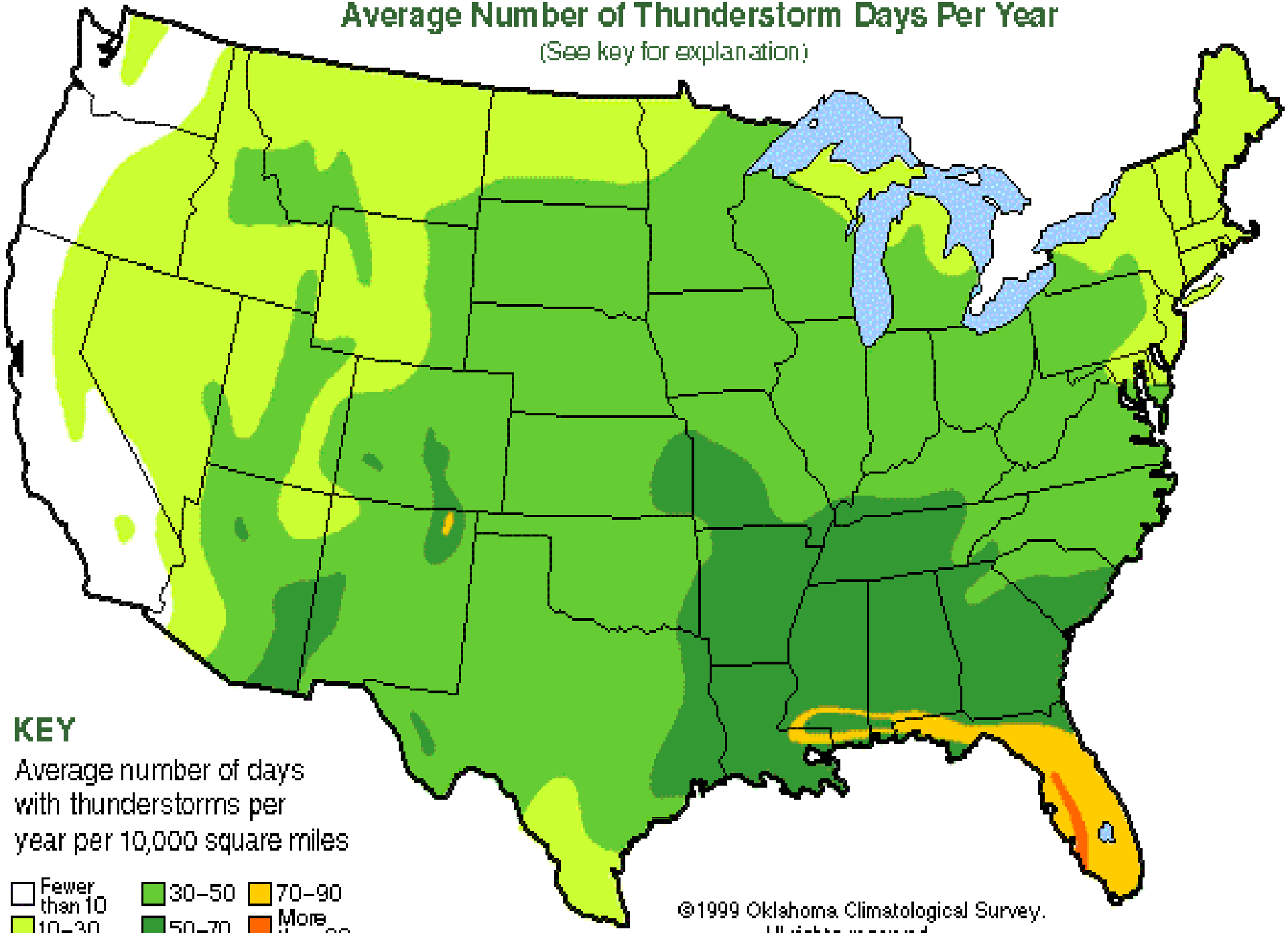


TABLE 3-1. Top 10 Areas of Lightning Density in the World Based on the Optical Transient Detector Satellite

LOCATION	FLASHES (km^2/yr)
1. Kamembe, Rwanda	82.7
2. Boende, Democratic Republic of Congo	66.3
3. Lusambo, Democratic Republic of Congo	52.1
4. Kananga, Democratic Republic of Congo	50.3
5. Kuala Lumpur, Malaysia	48.3
6. Calabar, Nigeria	47.3
7. Franceville, Gabon	47.1
8. Posadas, Argentina	42.7
9. Ocana, Colombia	39.9
10. Concepcion, Paraguay	37.0
. . .	
14. Orlando-Tampa, Florida	35.4

Christian HJ: Global lightning activity. Proceedings, 12th International Confer-

The Good News for most of us…

Our area experiences around 85 Thunderstorm days per year.

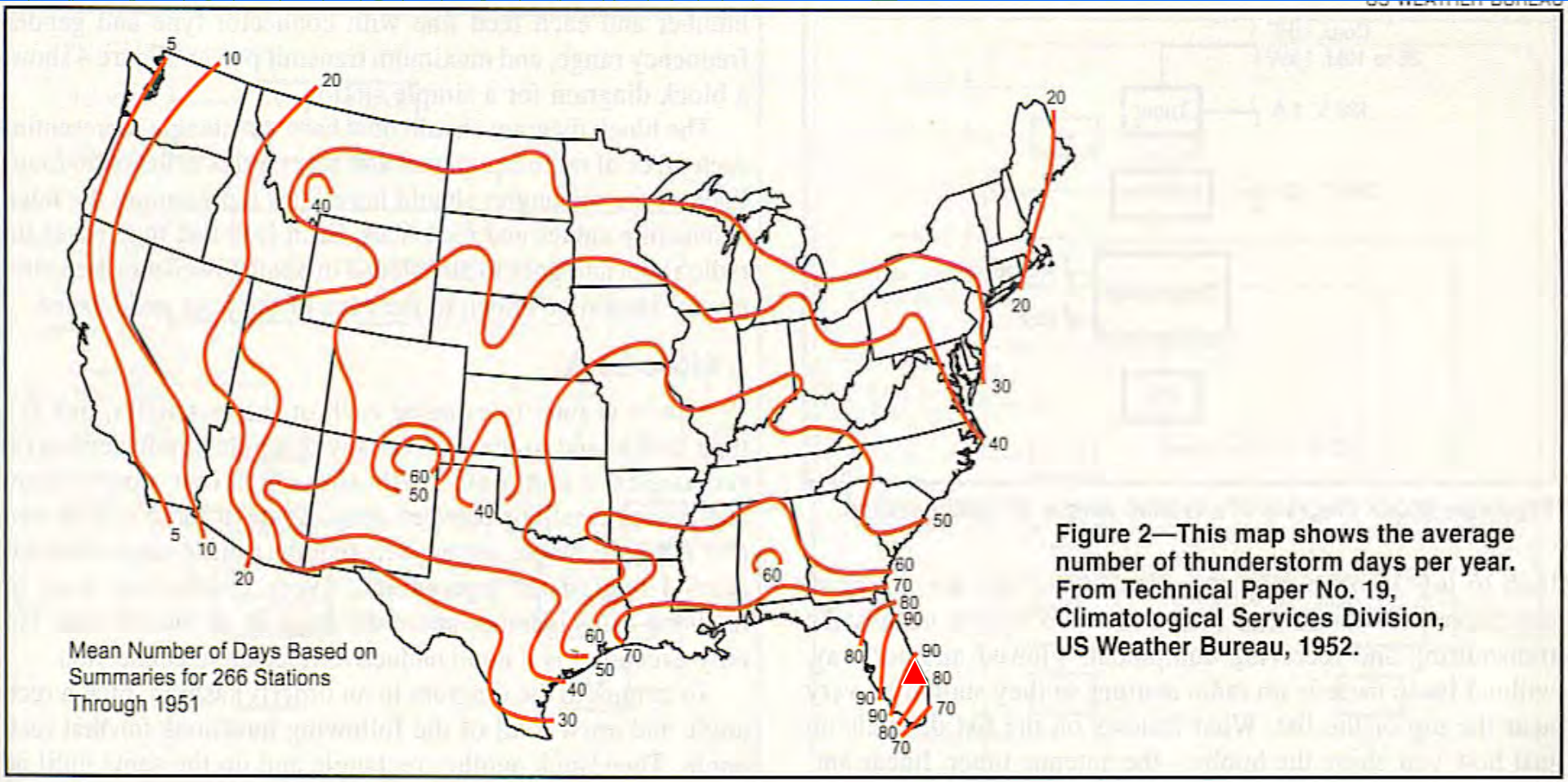


Figure 2—This map shows the average number of thunderstorm days per year. From Technical Paper No. 19, Climatological Services Division, US Weather Bureau, 1952.

Estimated number of lightning Strikes for a given tower height per year. A 80' tower, indicated by the red triangle below would expect to receive 2.9 strikes each year

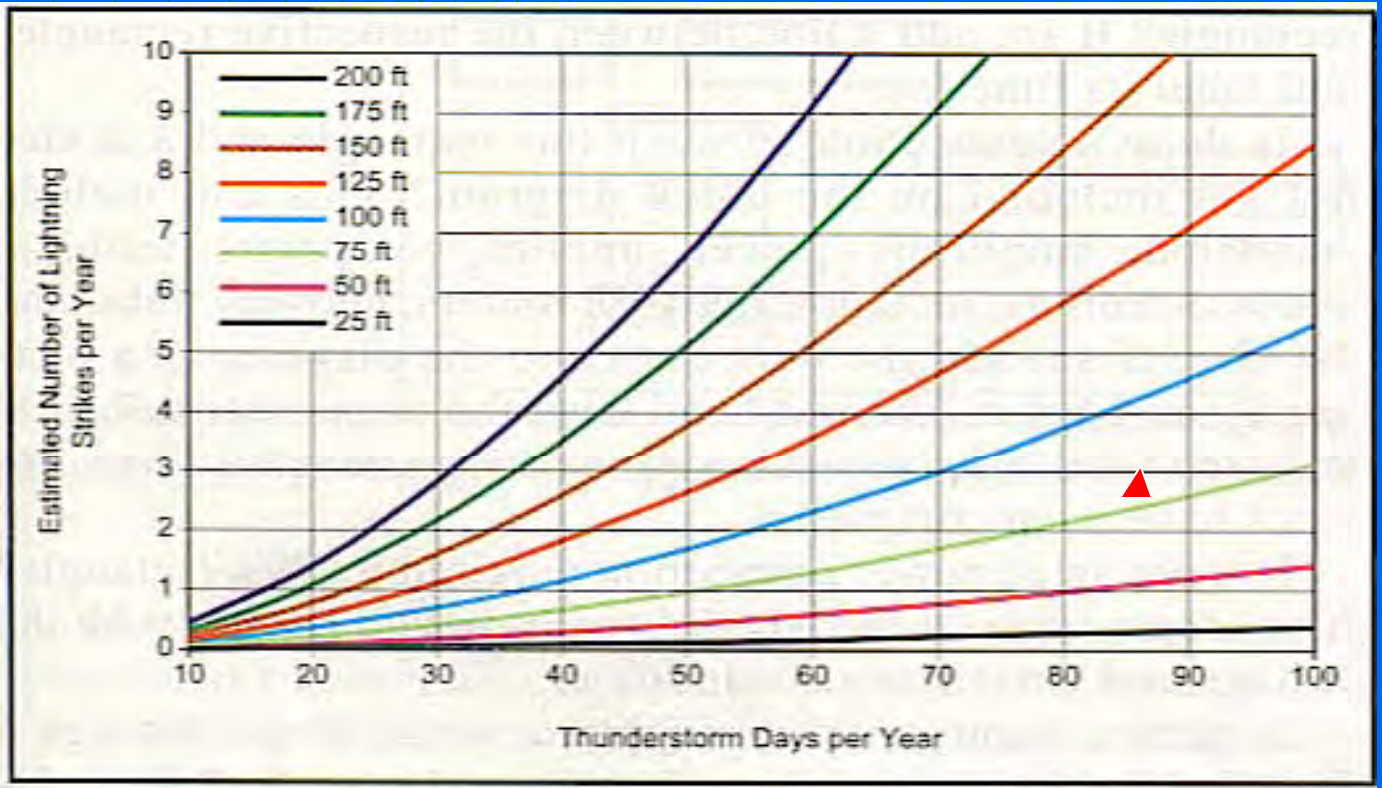
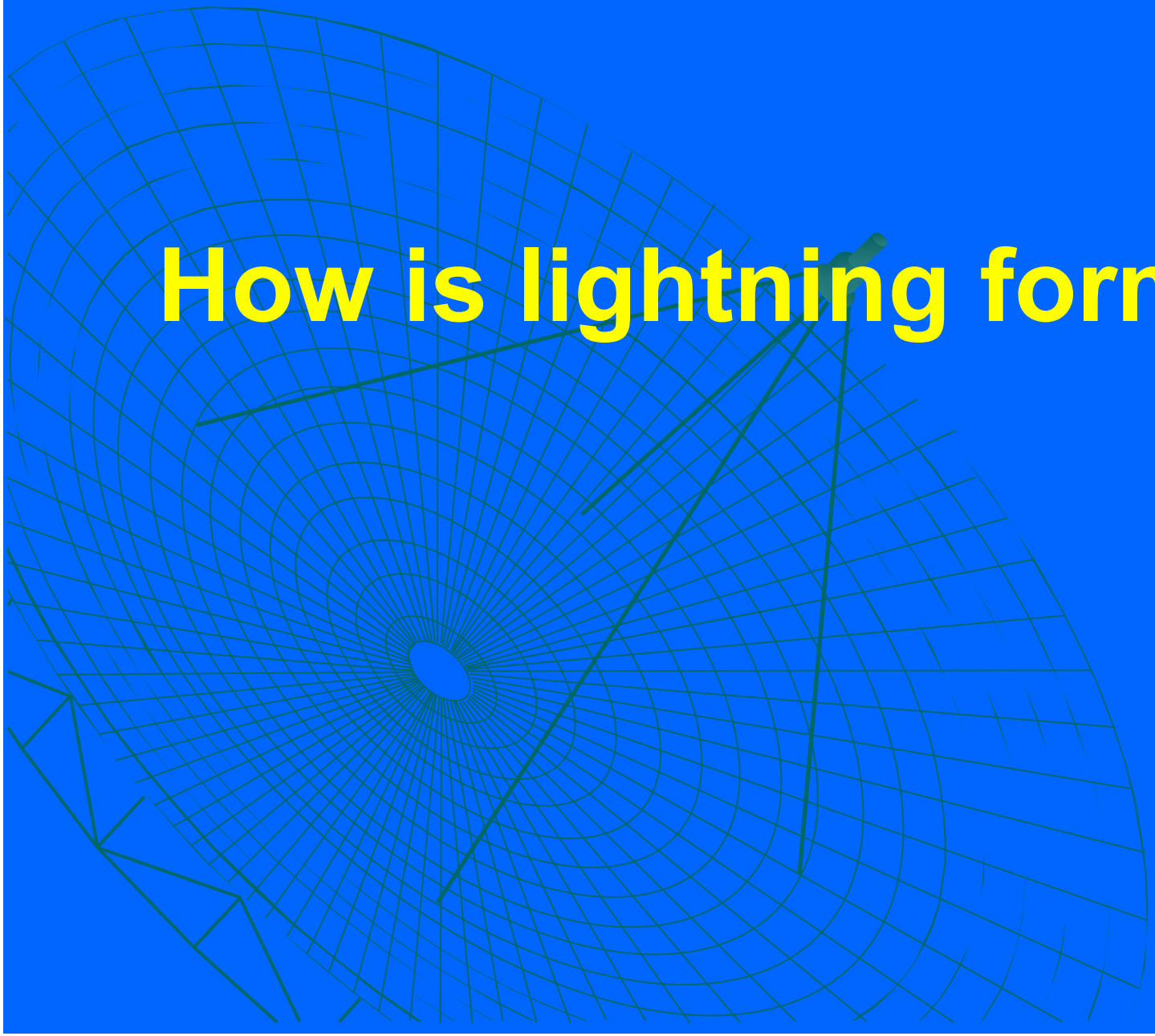
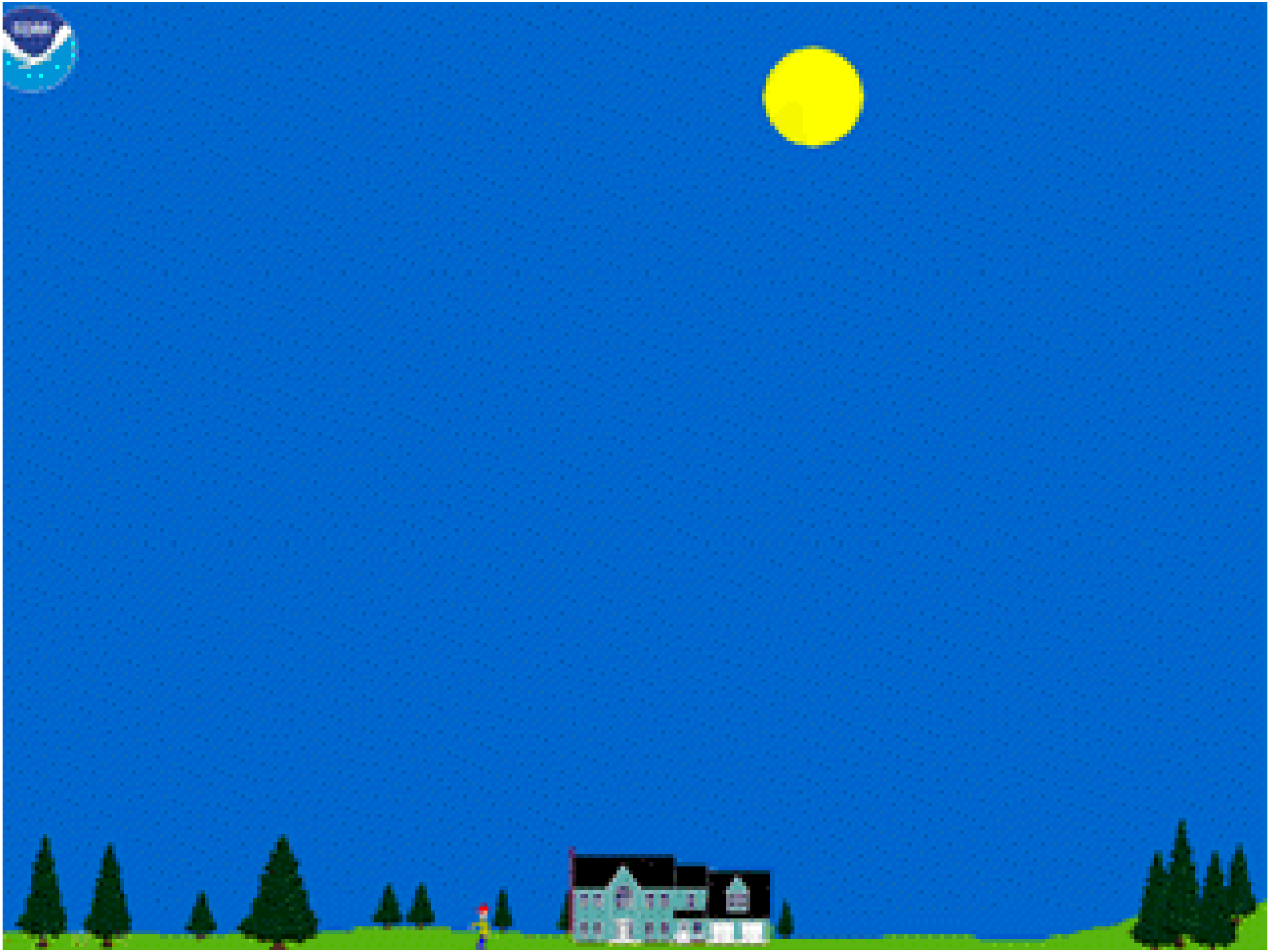
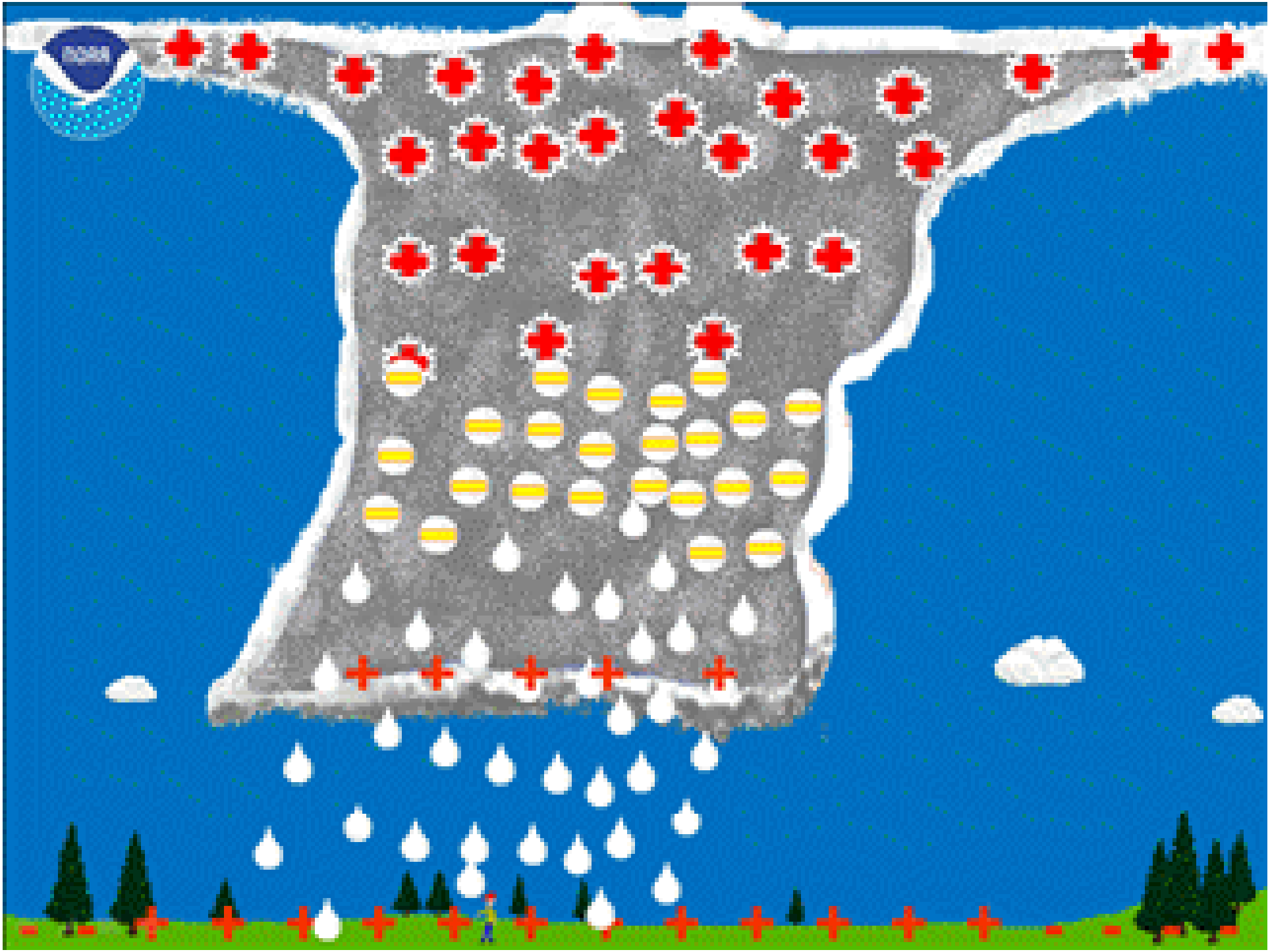


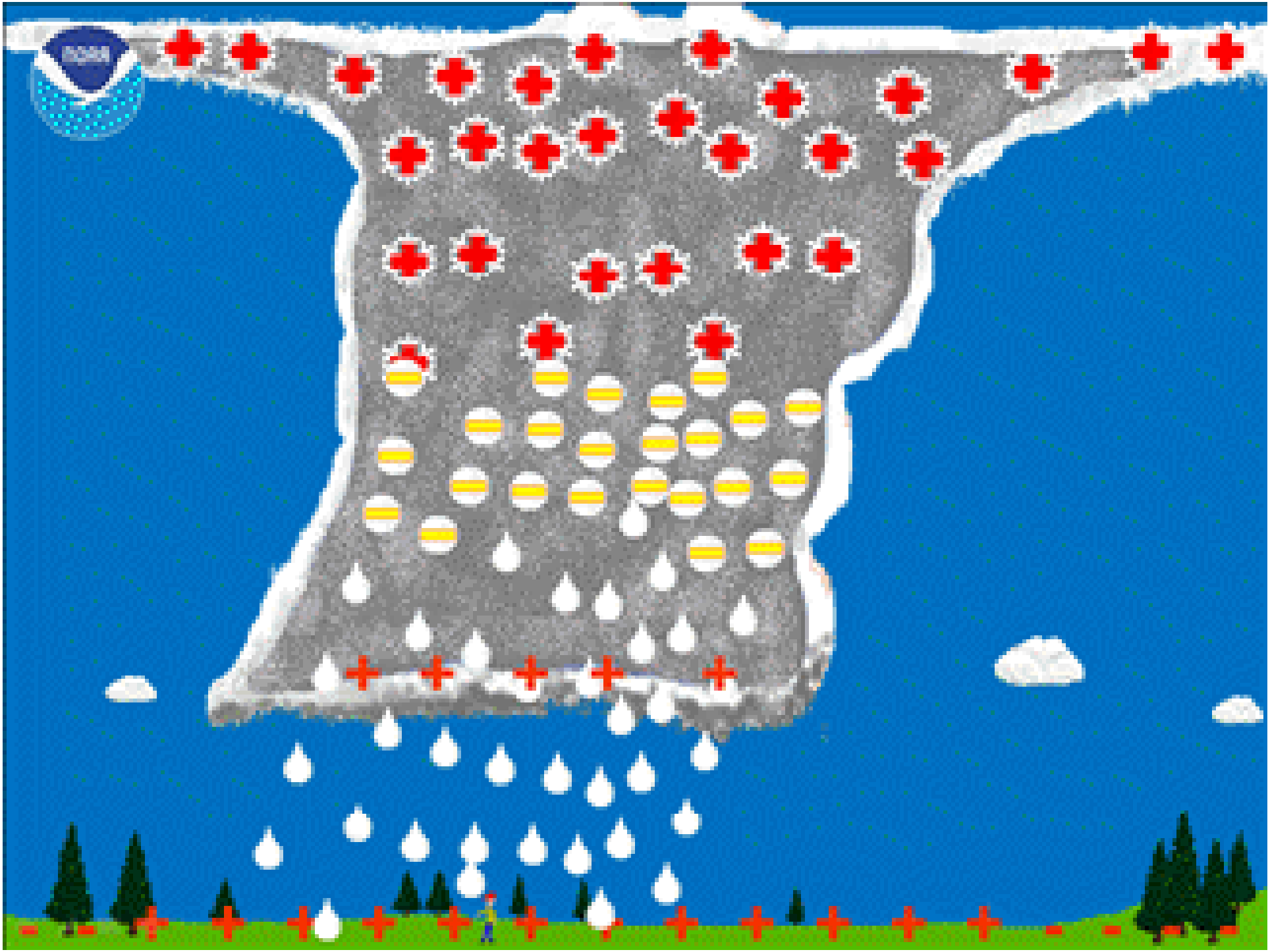
Figure 3—Estimated number of lightning strikes per year based on the number of thunderstorm days in your area and the height of your antenna. Based on information from *Living with Lightning*, Seminar Notes #ECP-826B Version F, GE Mobile Radio Technical Training, © GE 1985.

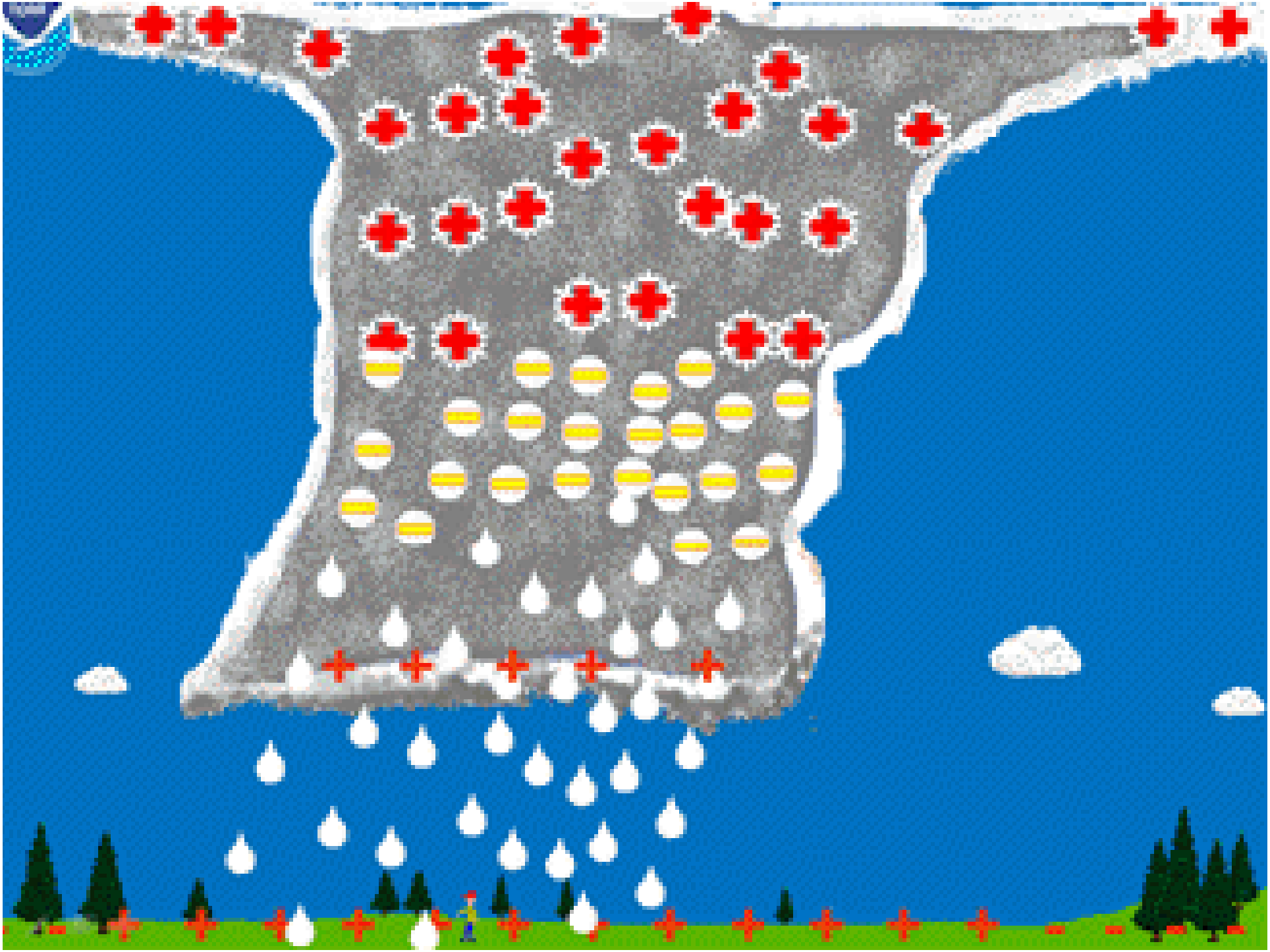
How is lightning formed?

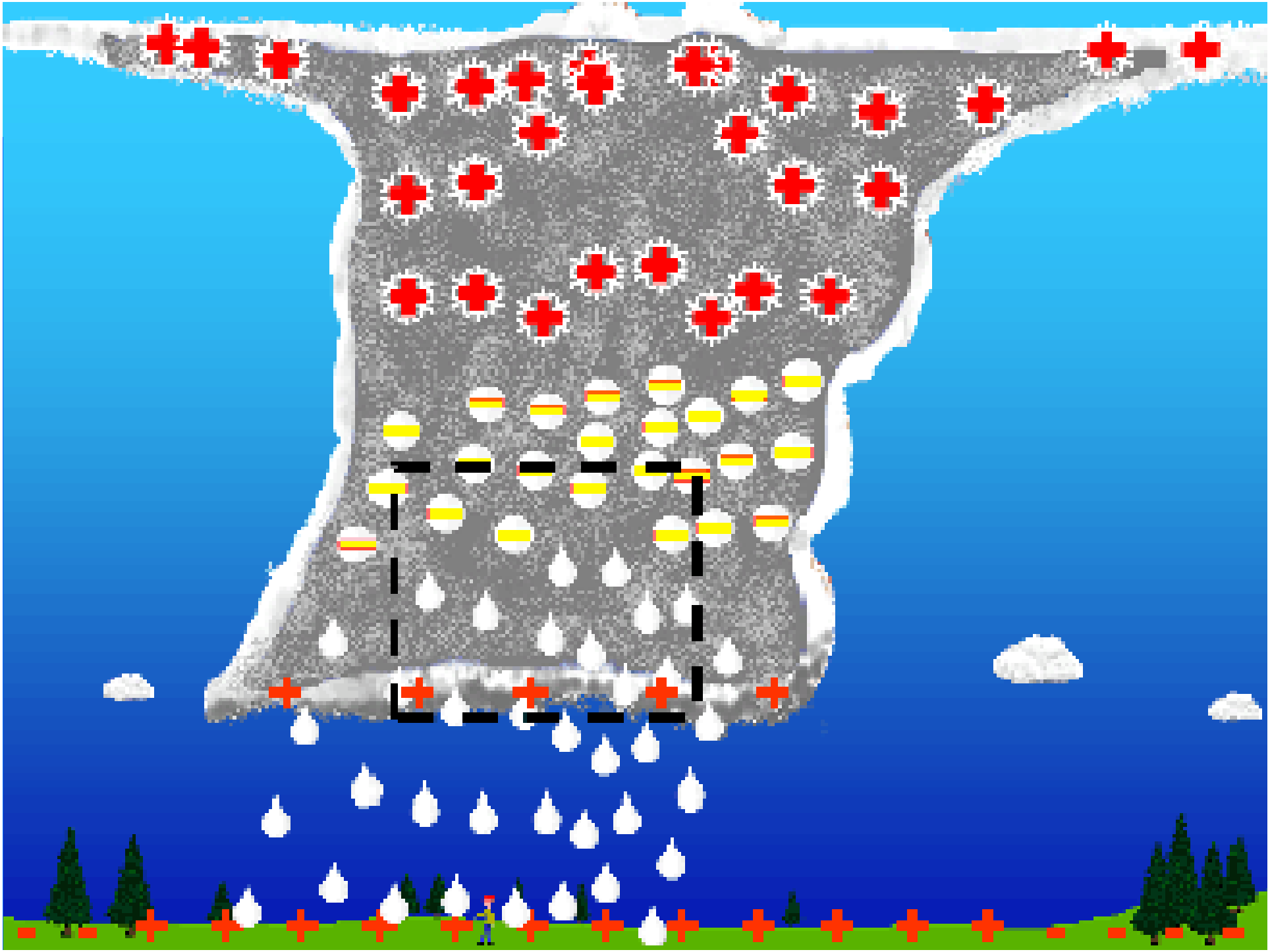


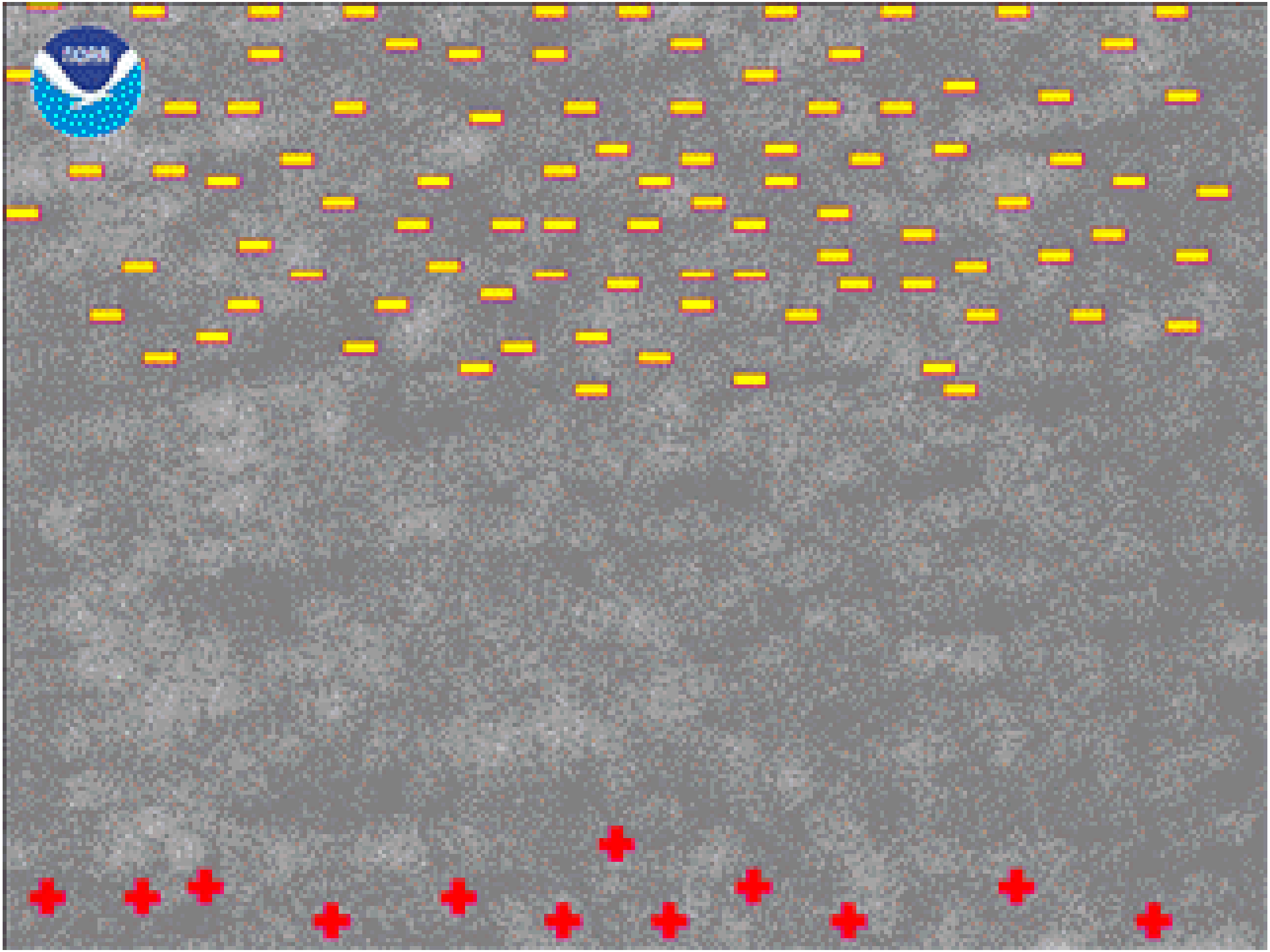






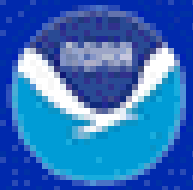




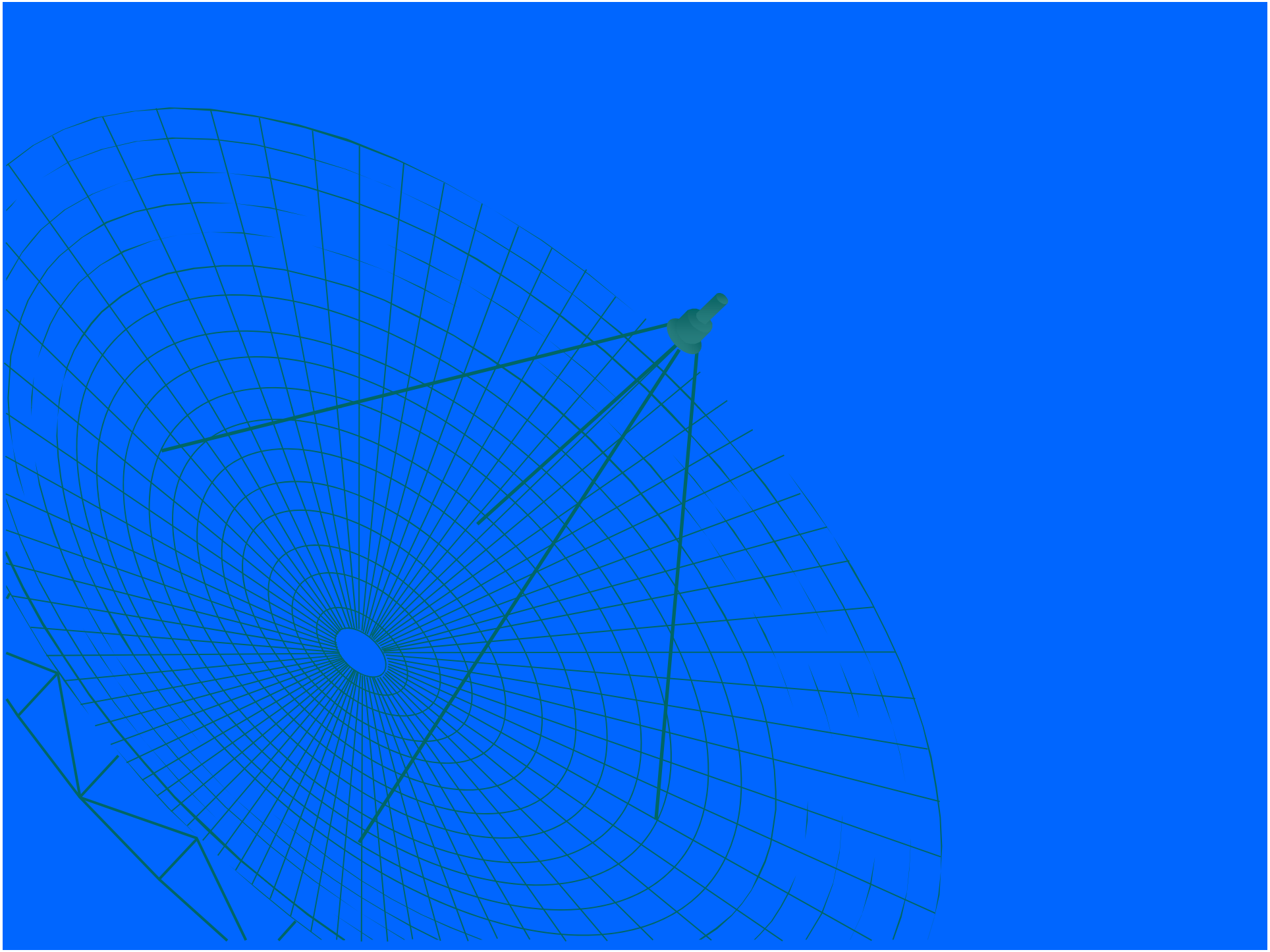


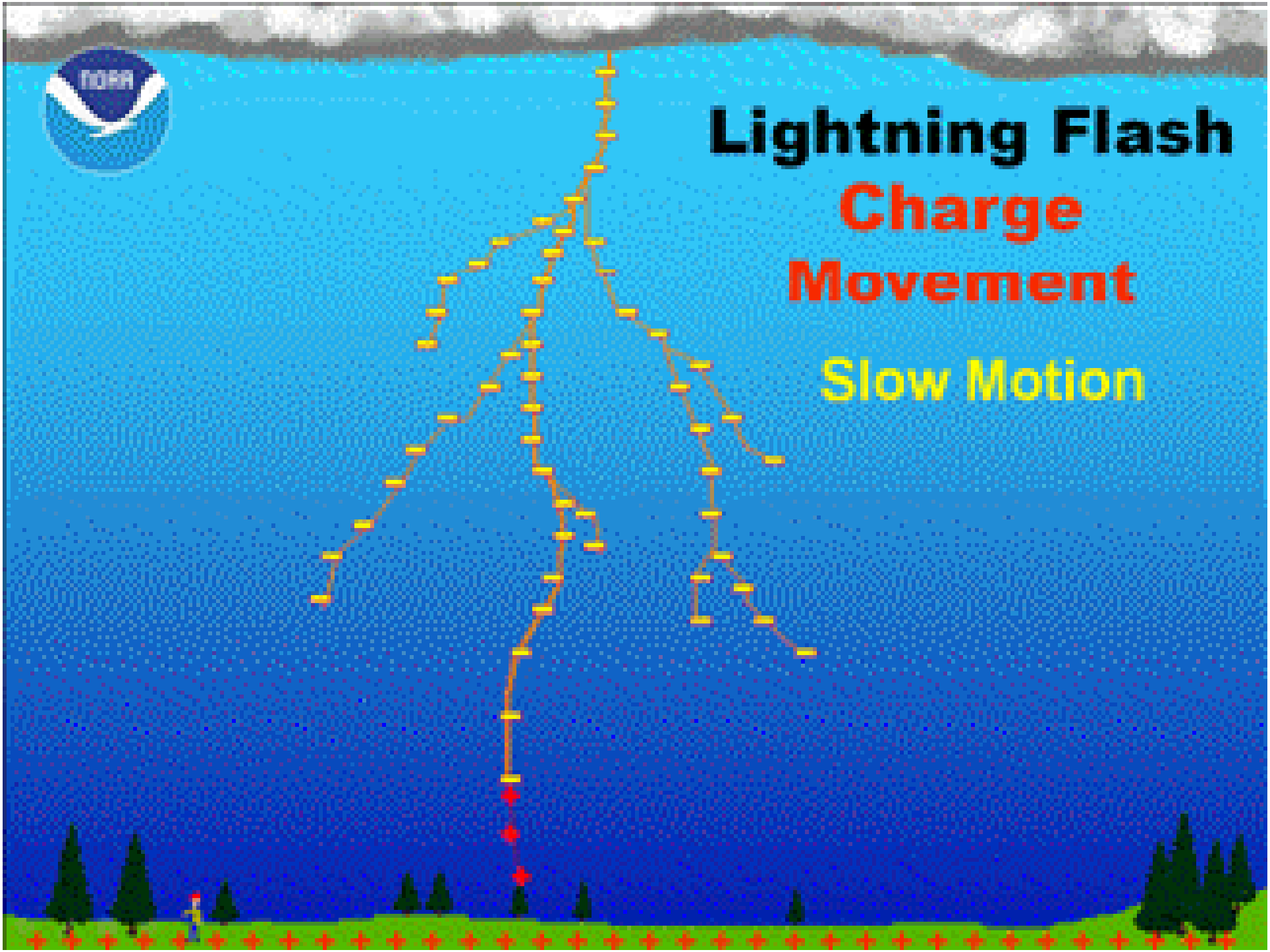

Stepped
Leader
Slow Motion

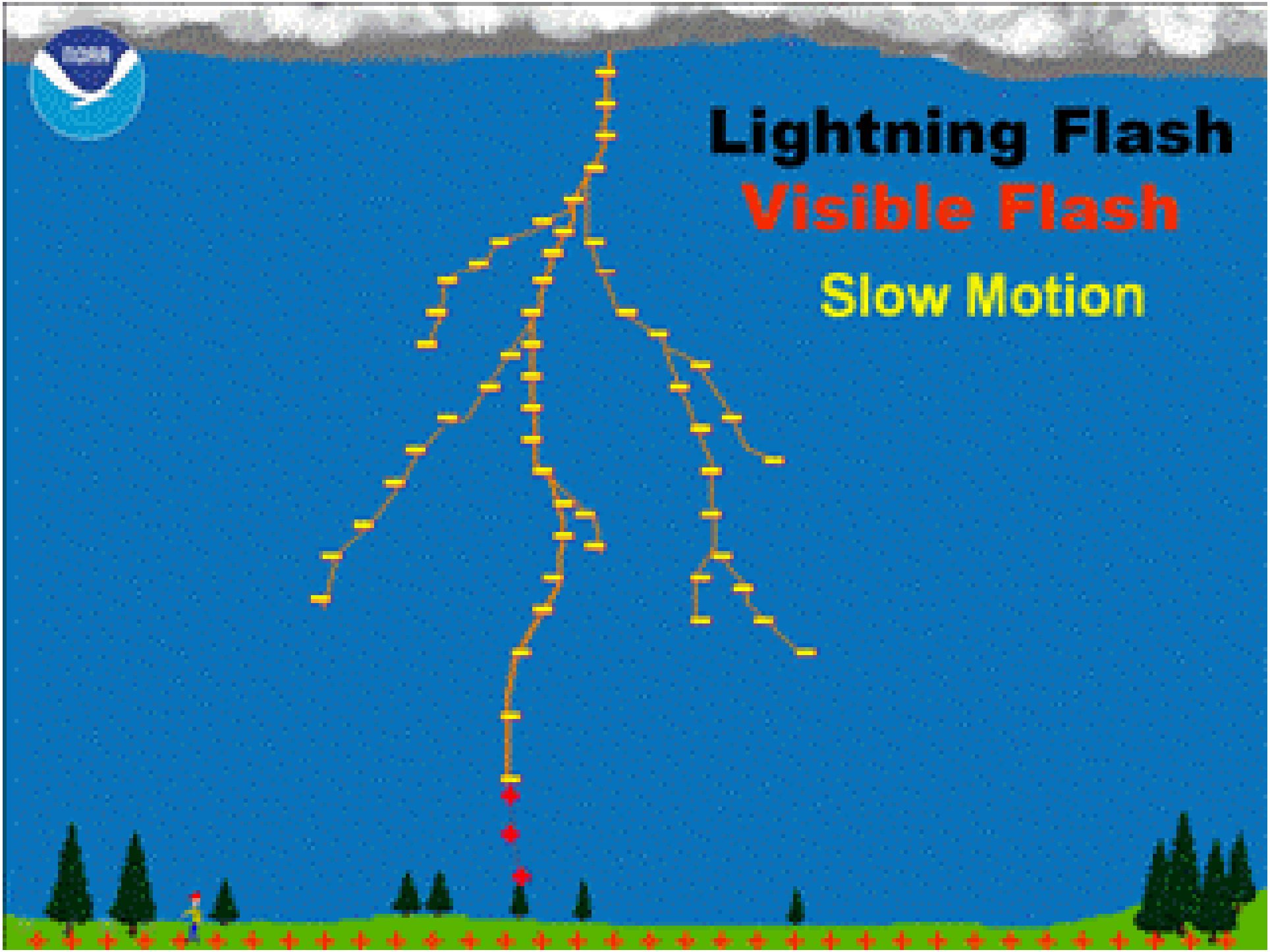

Stepped
Leader
Slow Motion



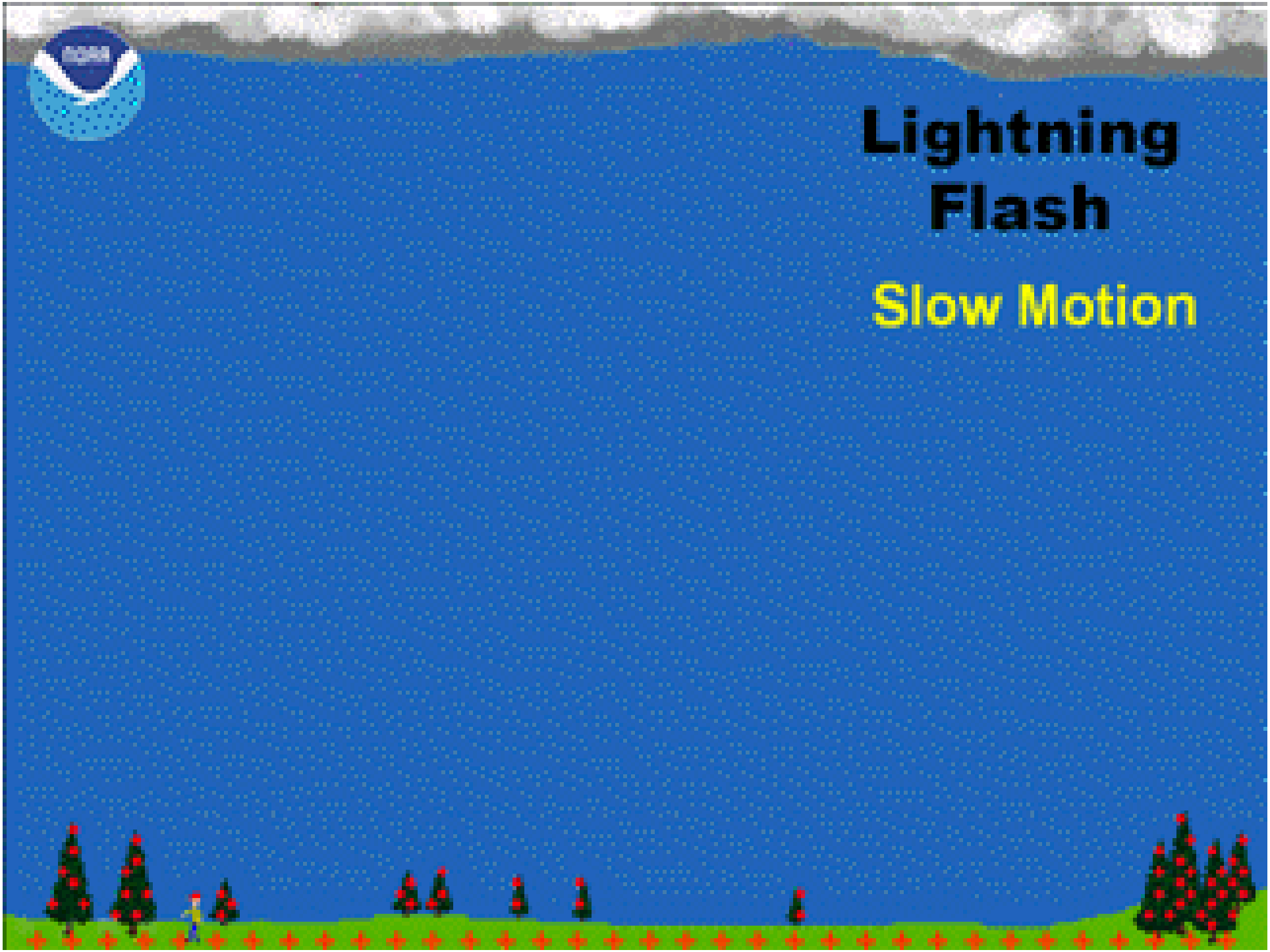

Upward
Streamer/
Leader
Slow Motion



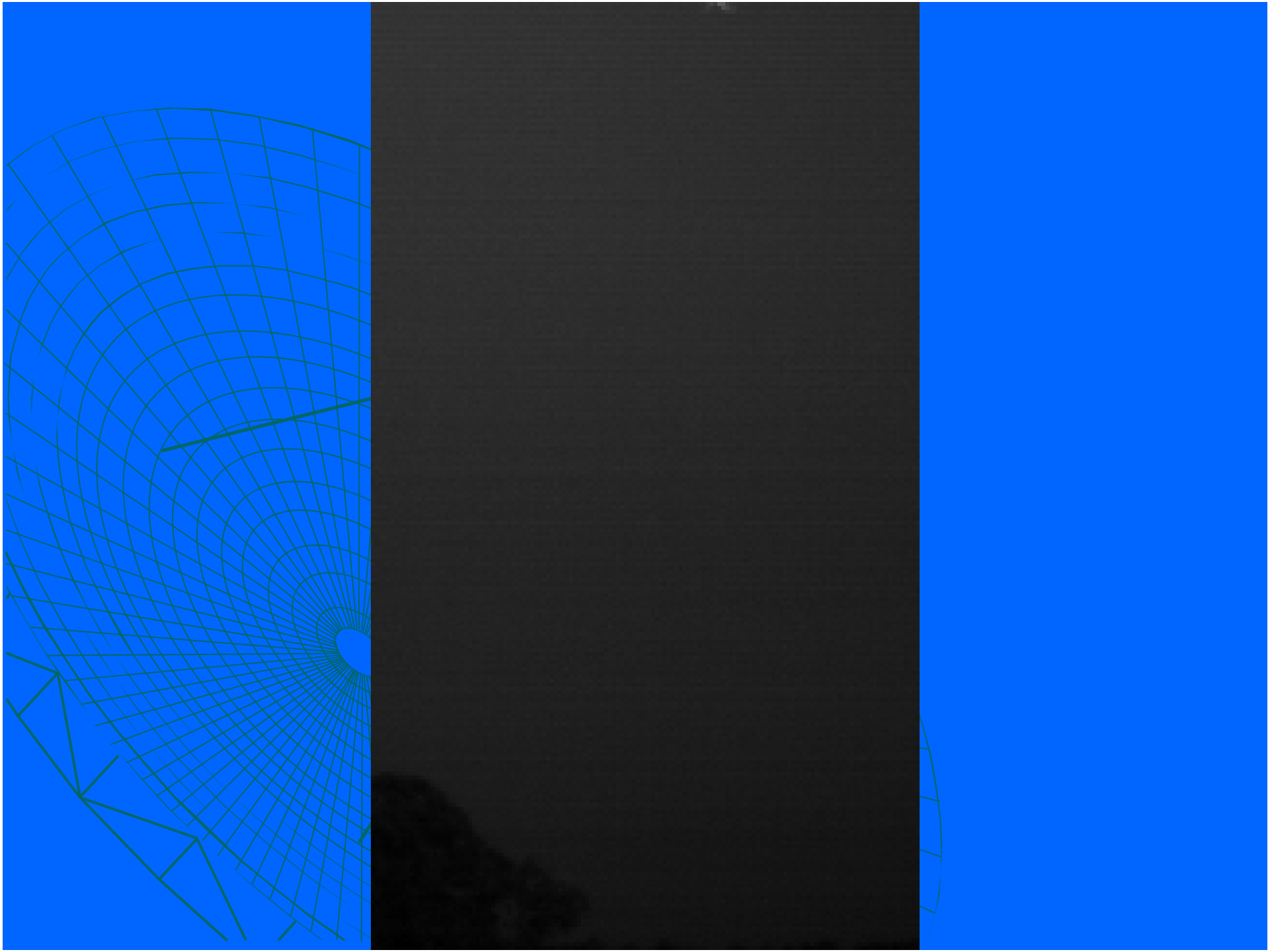

Lightning Flash
Charge
Movement
Slow Motion

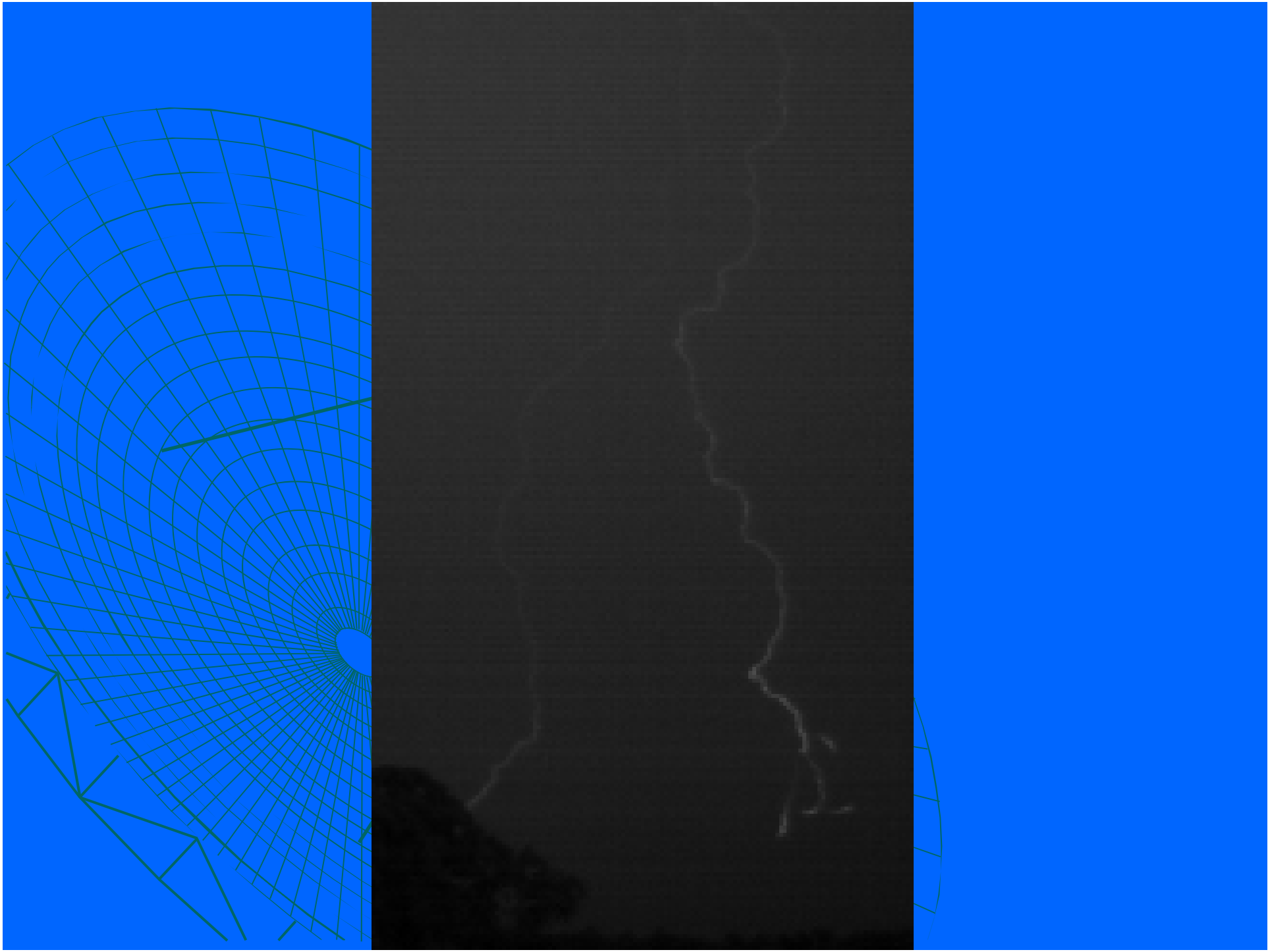

Lightning Flash
Visible Flash
Slow Motion

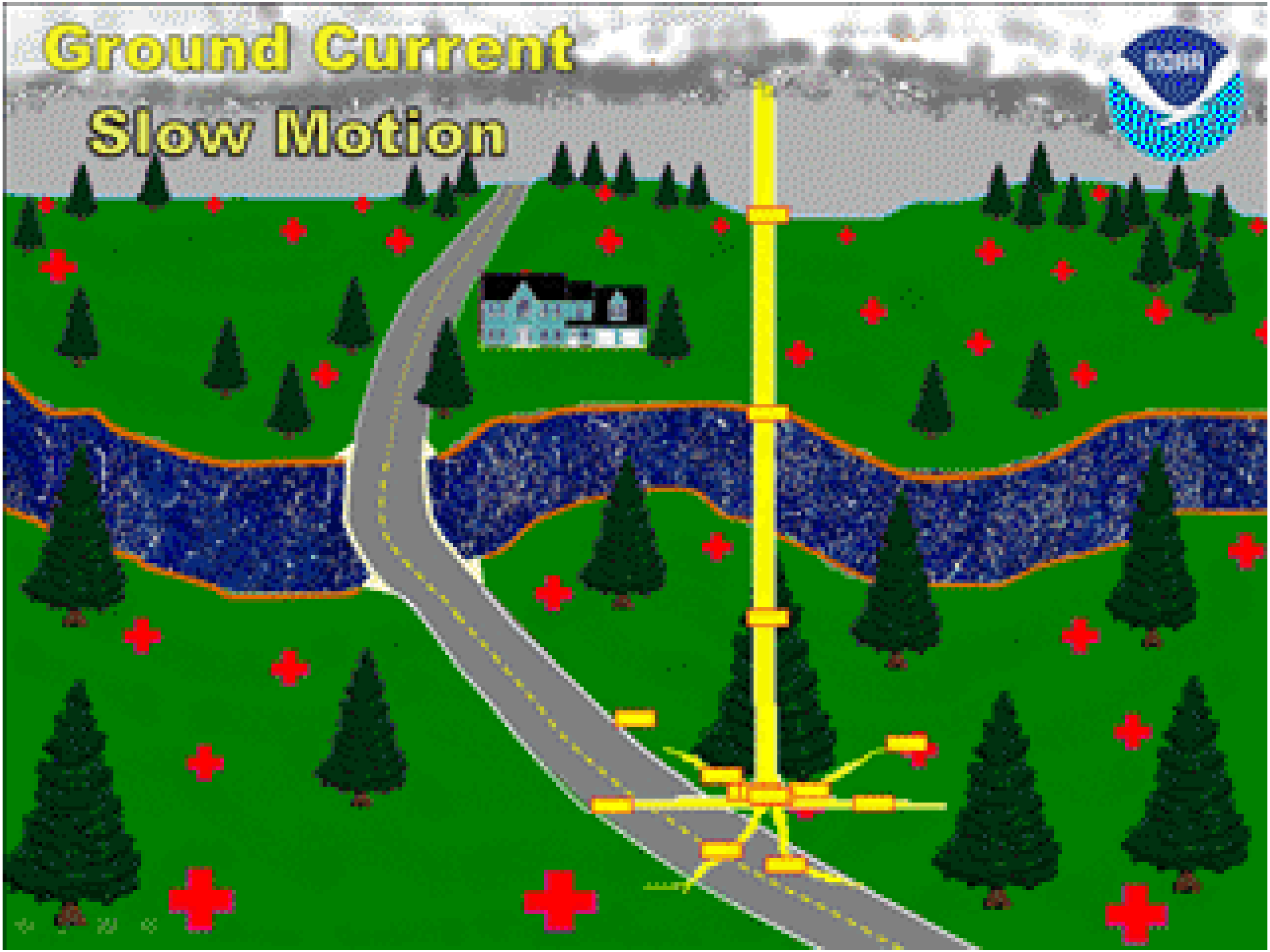

Lightning Flash
Dart Leader
Return Stroke
Slow Motion


Lightning
Flash
Slow Motion


Lightning Flash
Normal Speed






Ground Current
Slow Motion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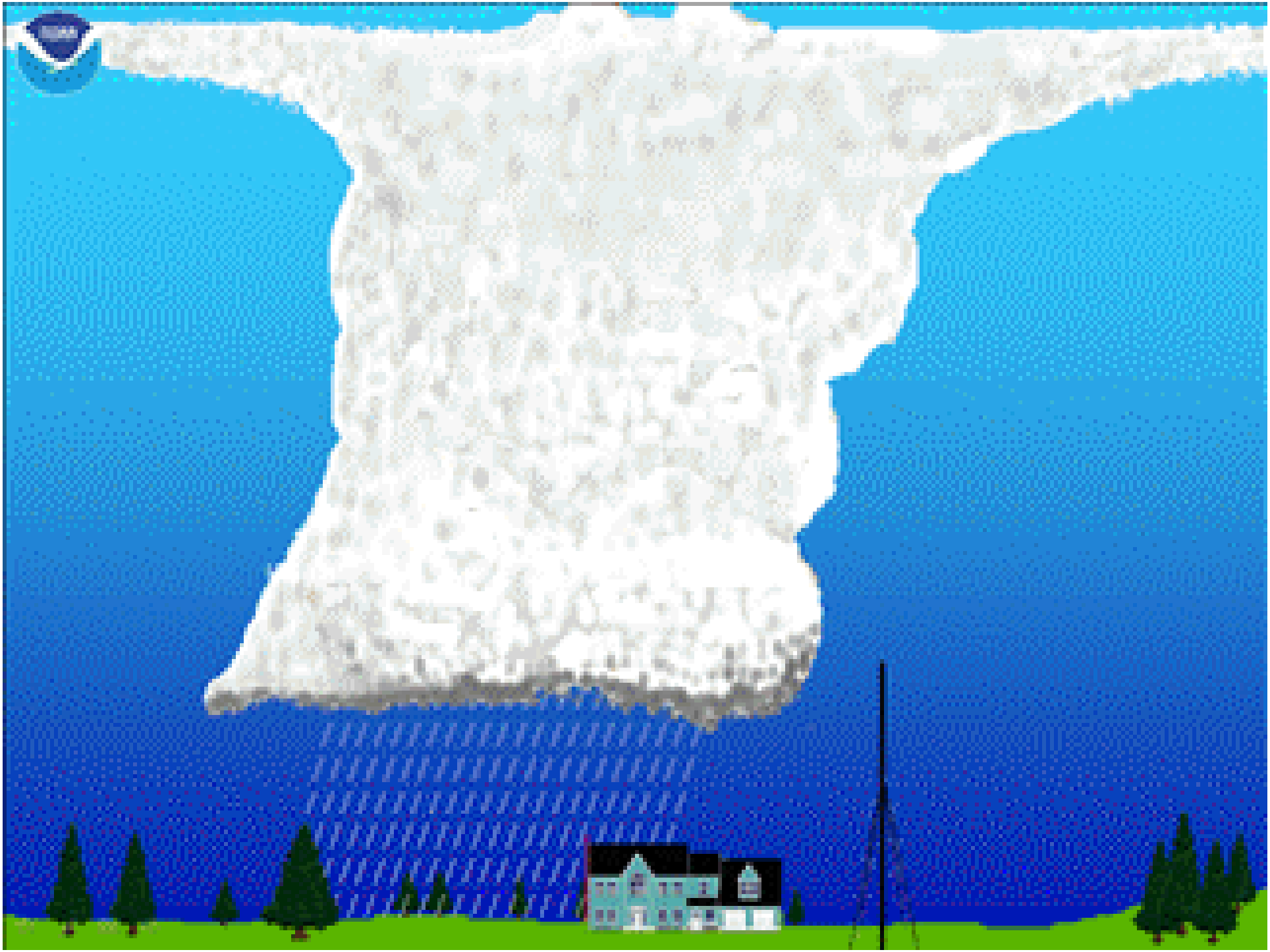
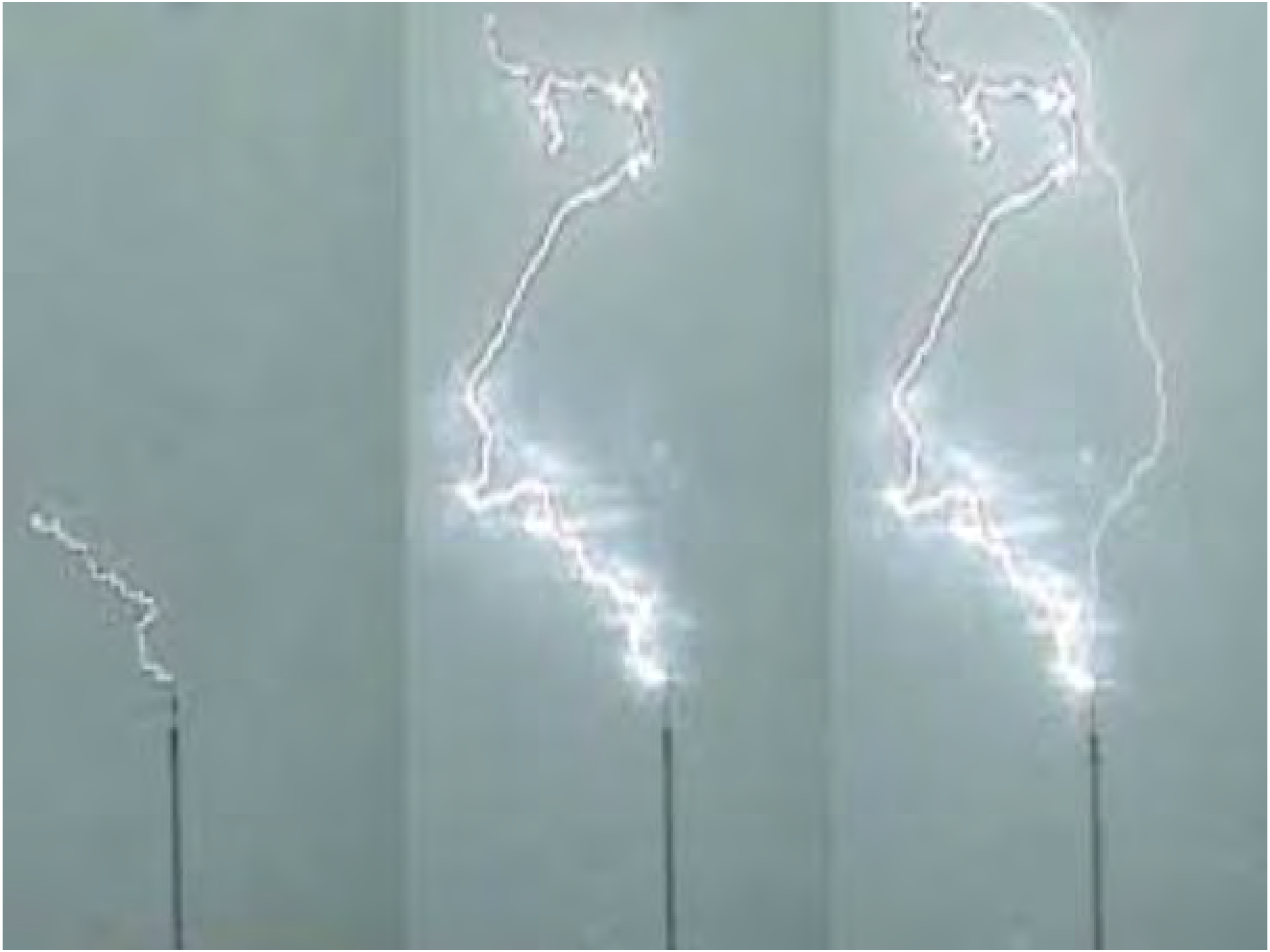
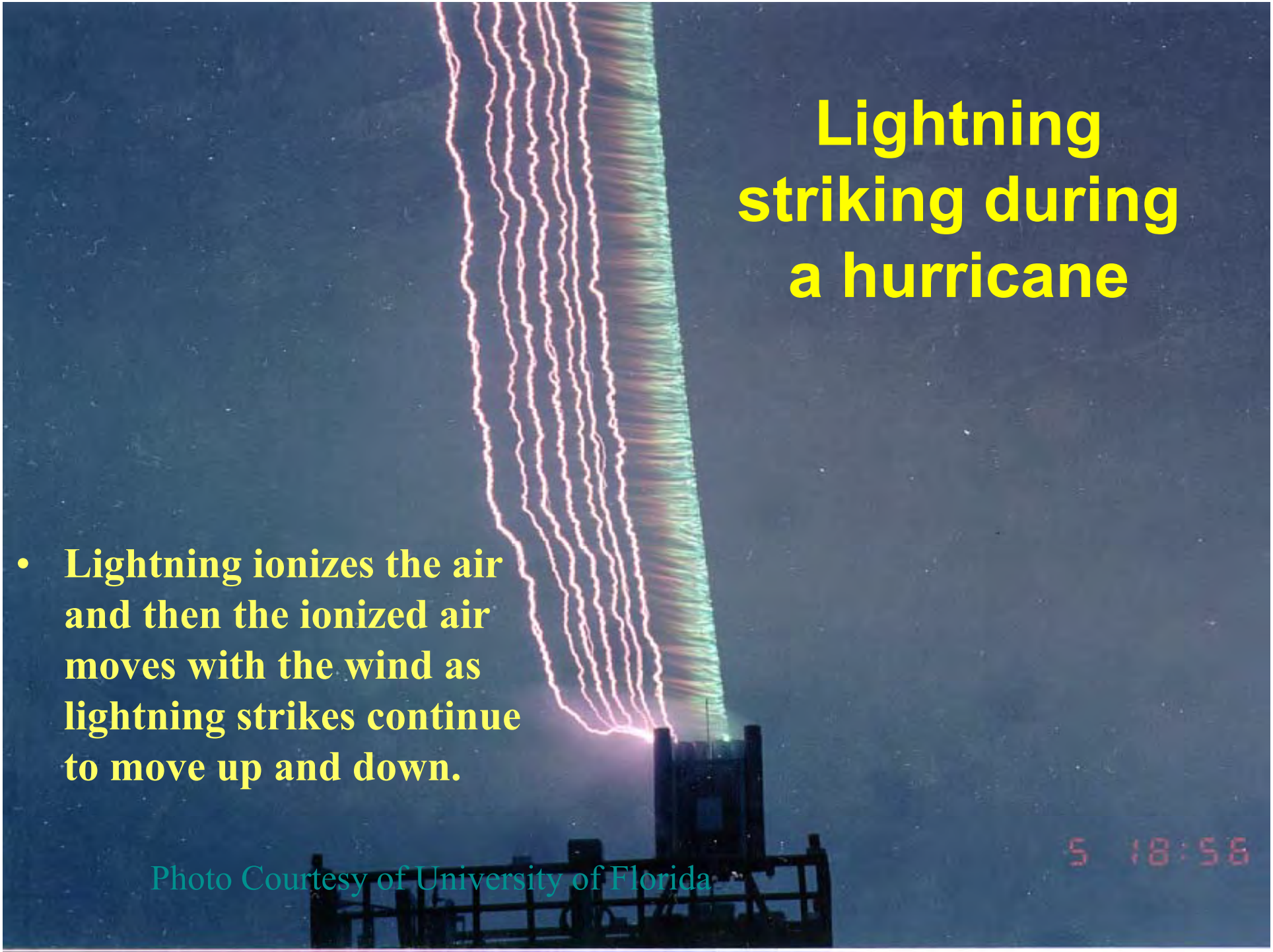
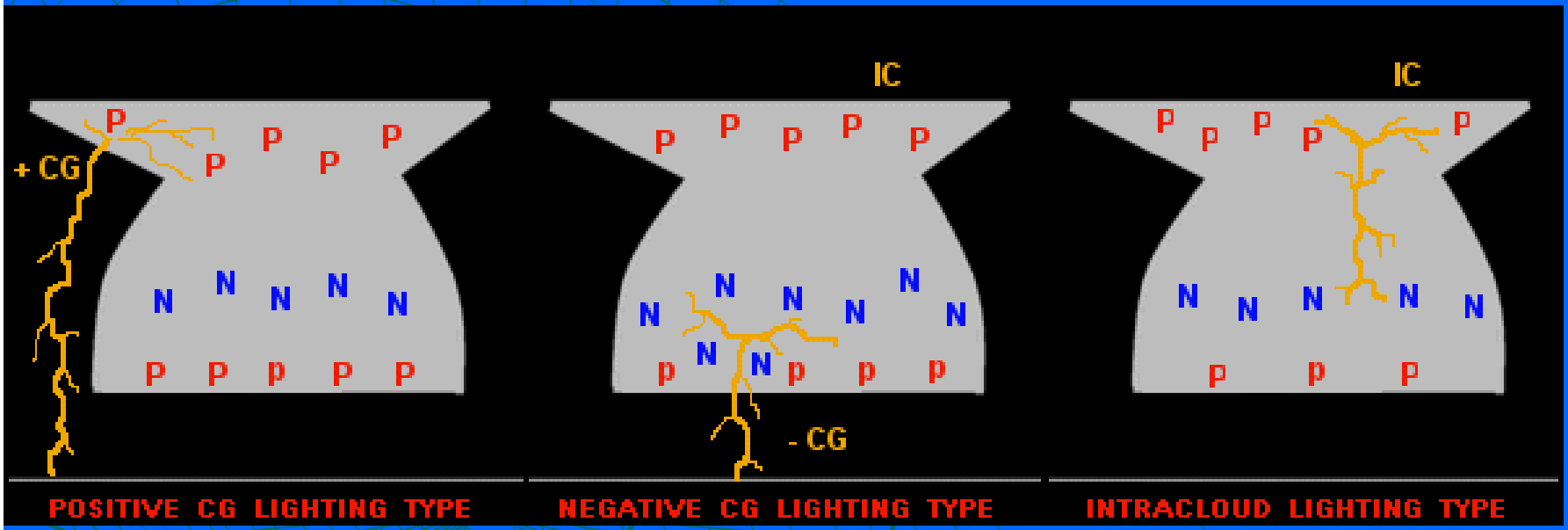




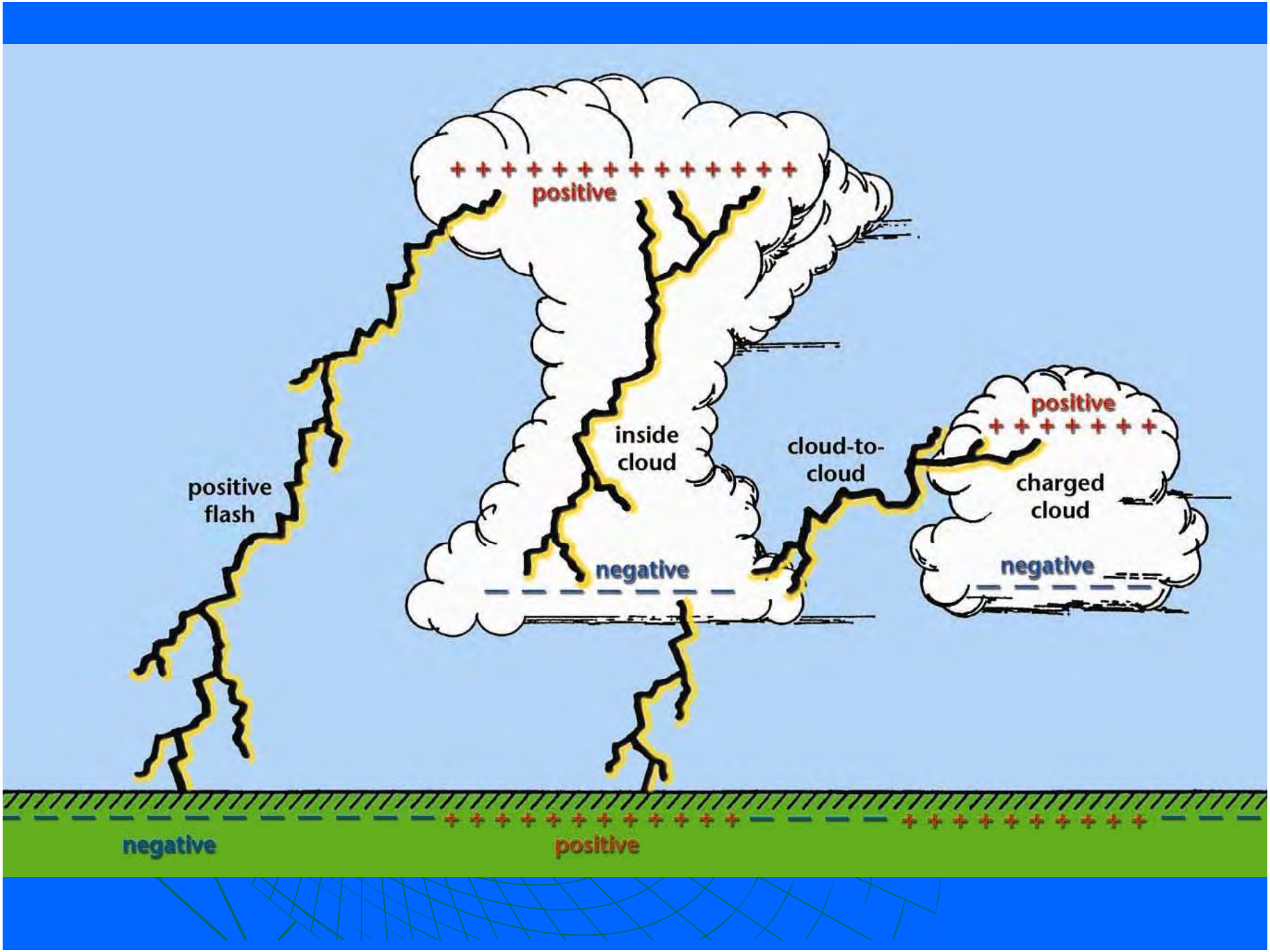

Lightning striking during a hurricane
• Lightning ionizes the air and then the ionized air moves with the wind as lightning strikes continue to move up and down.
Photo Courtesy of University of Florida
5 18:56

Lightning – Where does it go?

Lightning paths

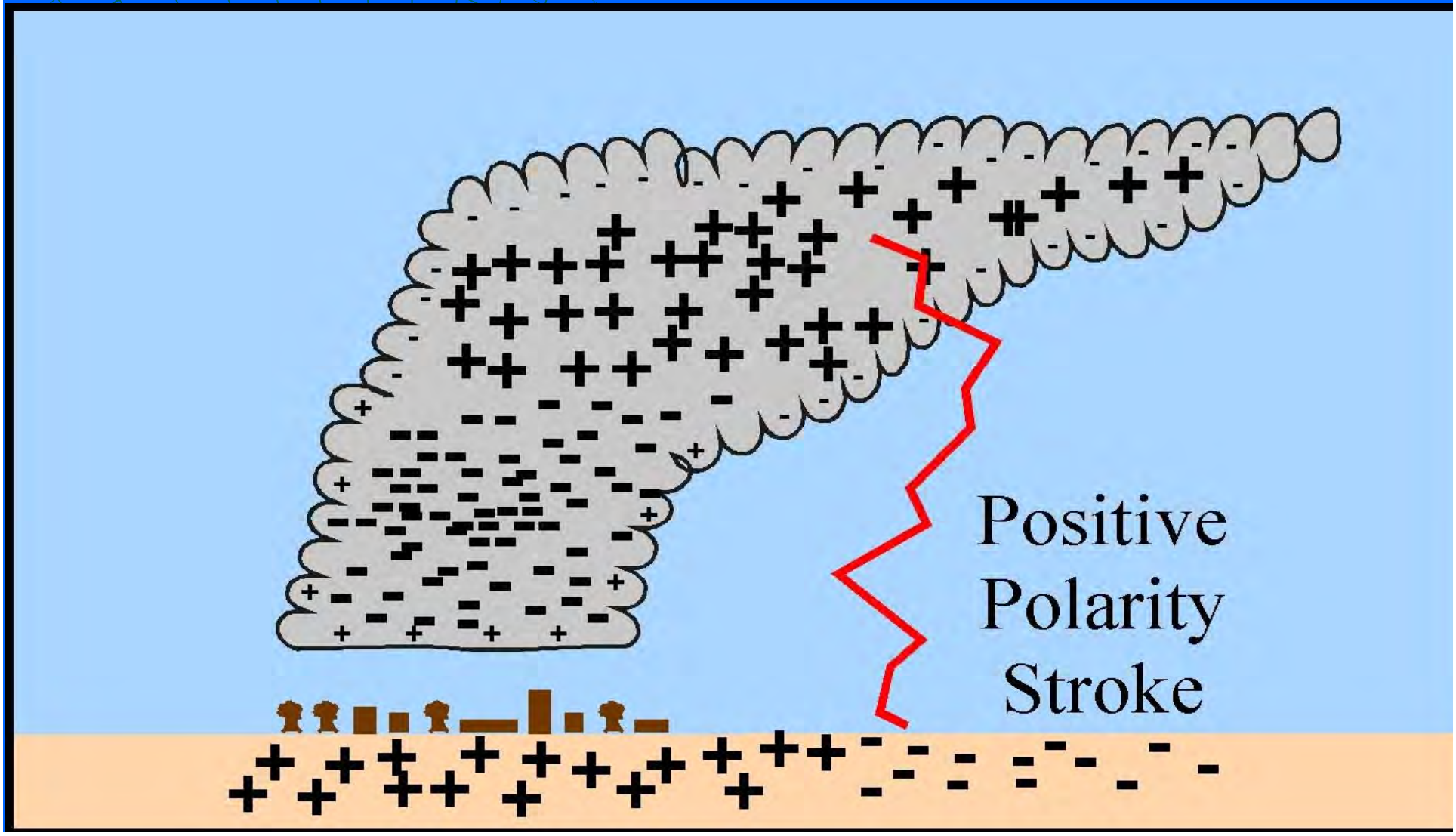


- When voltage between two oppositely charged fields exceeds atmospheric resistance, discharge occurs.

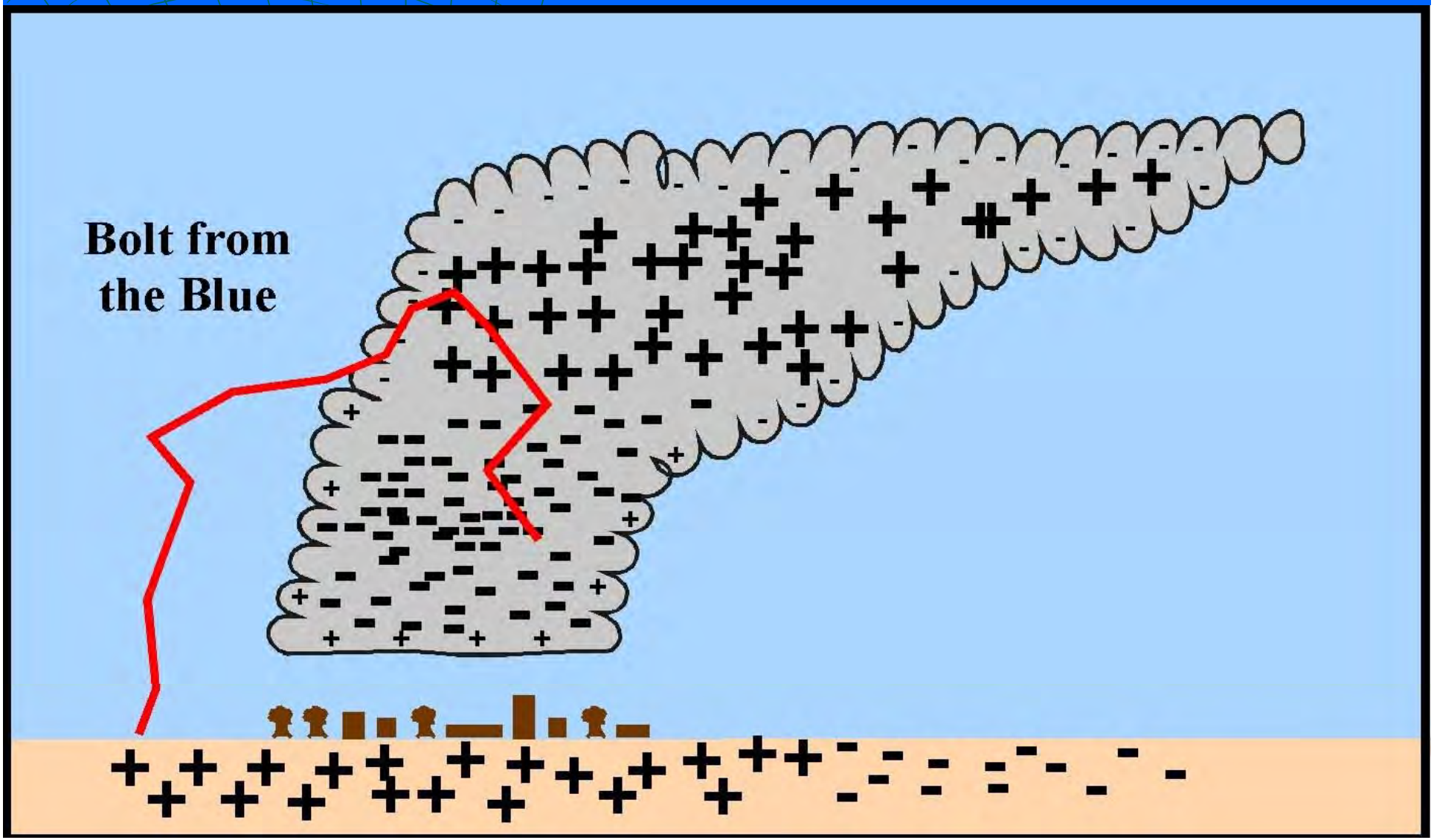

positive
inside cloud
positive flash
cloud-to-cloud
positive
charged cloud
negative
negative
negative
positive

Cloud to ground

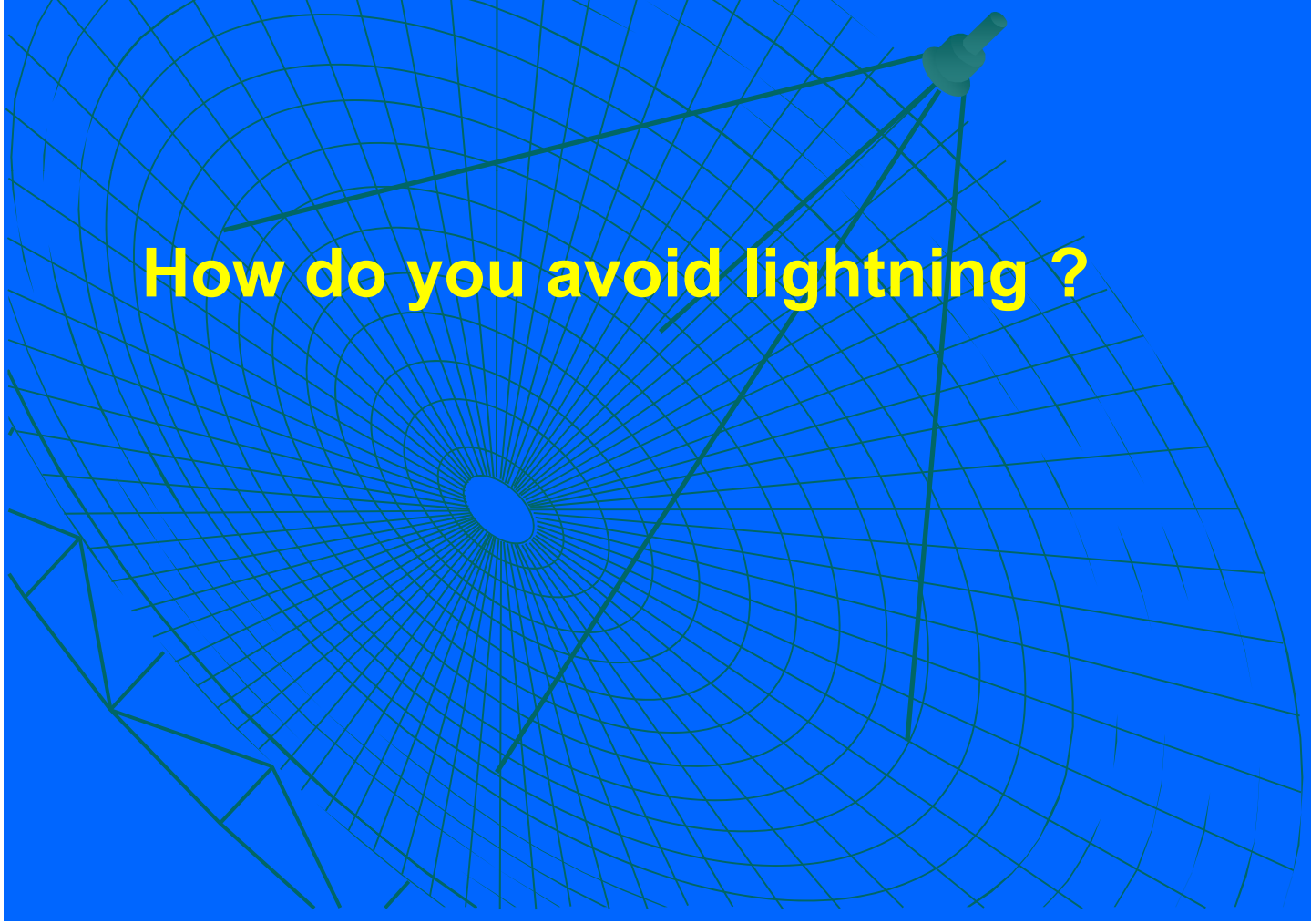
Anvil



Bolt from the blue



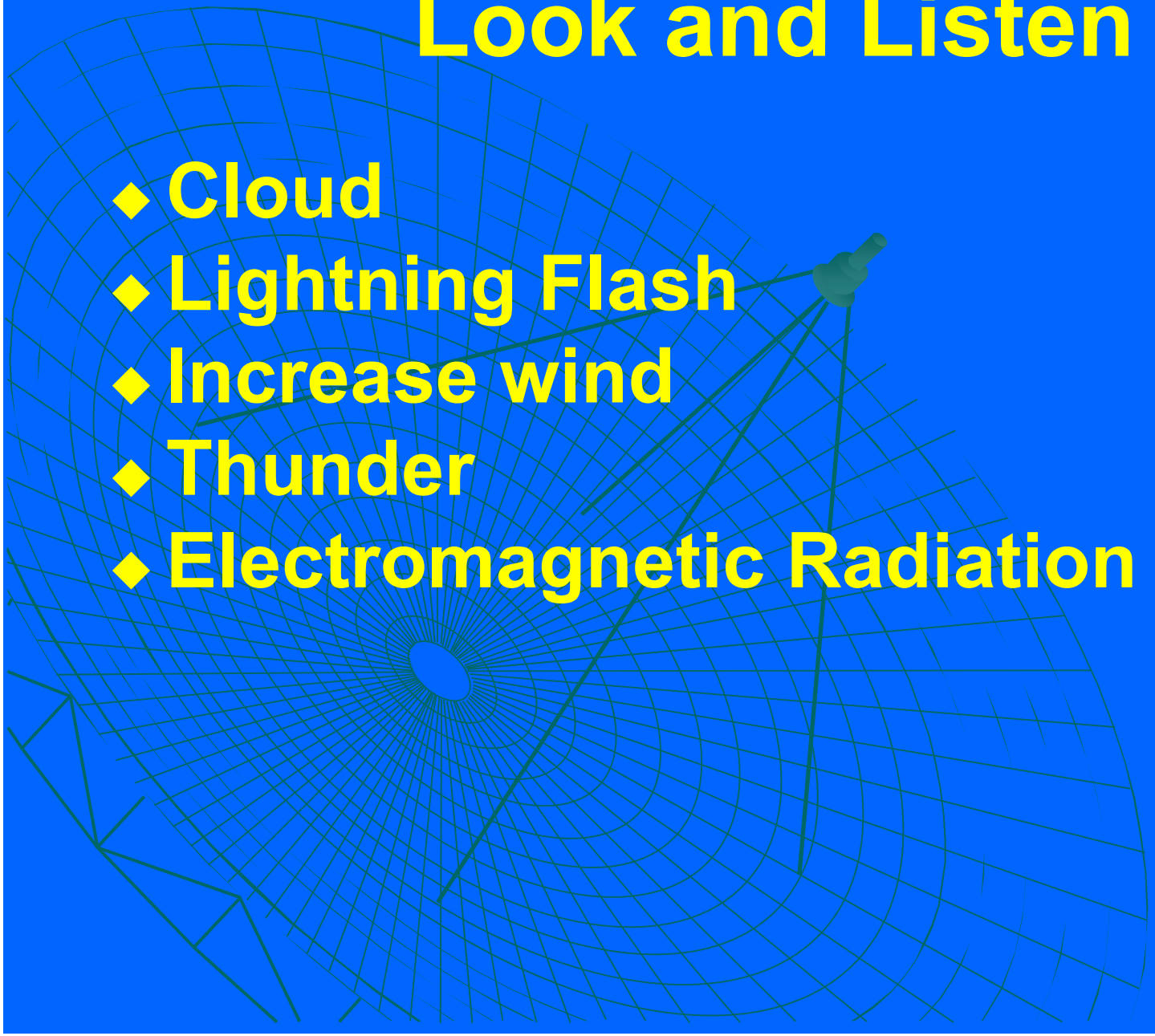
Unless you like people pounding on your chest and blowing air into your lungs, it's better to avoid needing CPR



How do you avoid lightning ?

Look and Listen

- Cloud
- Lightning Flash
- Increase wind
- Thunder
- Electromagnetic Radiation



Cloud Formation

Thunder

- Air surround a lightning strike becomes hotter than the sun's surface
  - Heat causes the flash that we see
  -
- The air expands so quickly that it explodes. This causes a shockwave which is a sound wave
-

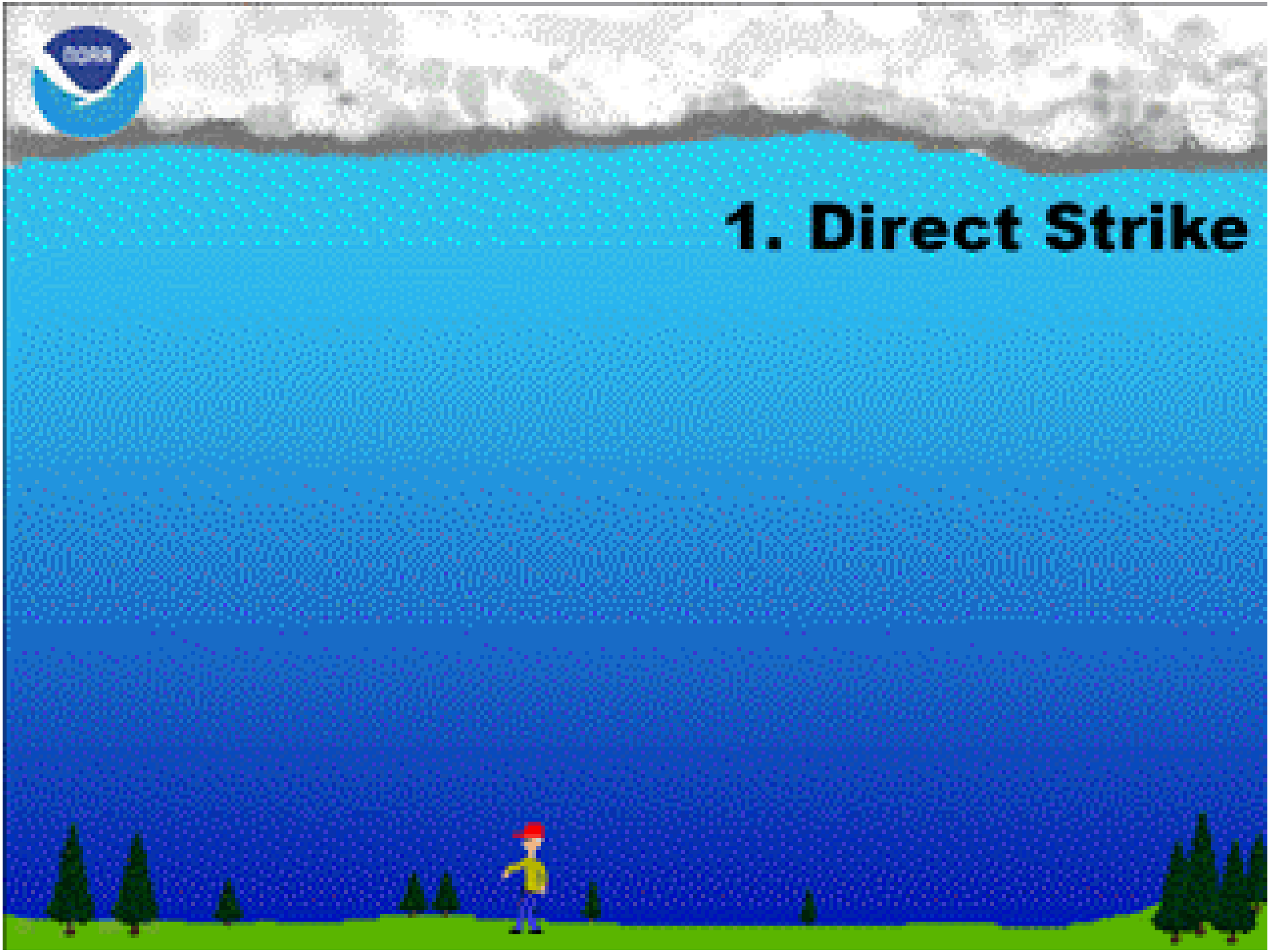
Thunder

- Thunder = sound wave
- Long tube of air, 6 km x 1.5 cm diameter heated almost instantaneously to 12-30,000 K expands air violently.
- Shock wave = thunder (both audible and inaudible).
- Speed of light = 300,000,000 m / sec
- Speed of sound ~ 0.33 km / sec
- 3 second delay = 3 km; 5 second delay = 1 mile

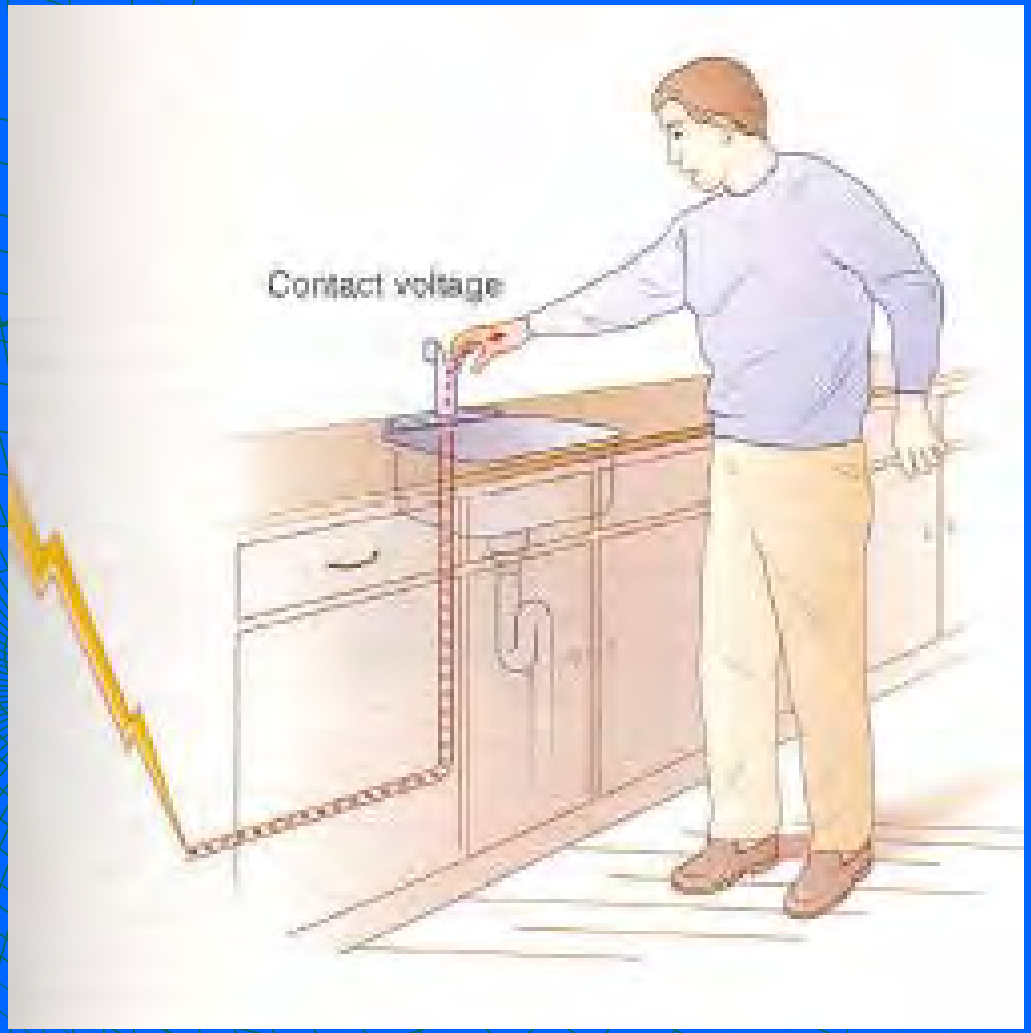
Electromagnetic Radiation

Five ways to be zapped

- Direct strike
- Side splash or branch channel
- Ground current effect as the energy spreads out across the surface of the earth
- Direct contact
- Electromagnetic induction - Being part of an upward lightning streamer that does not connect with the main channel

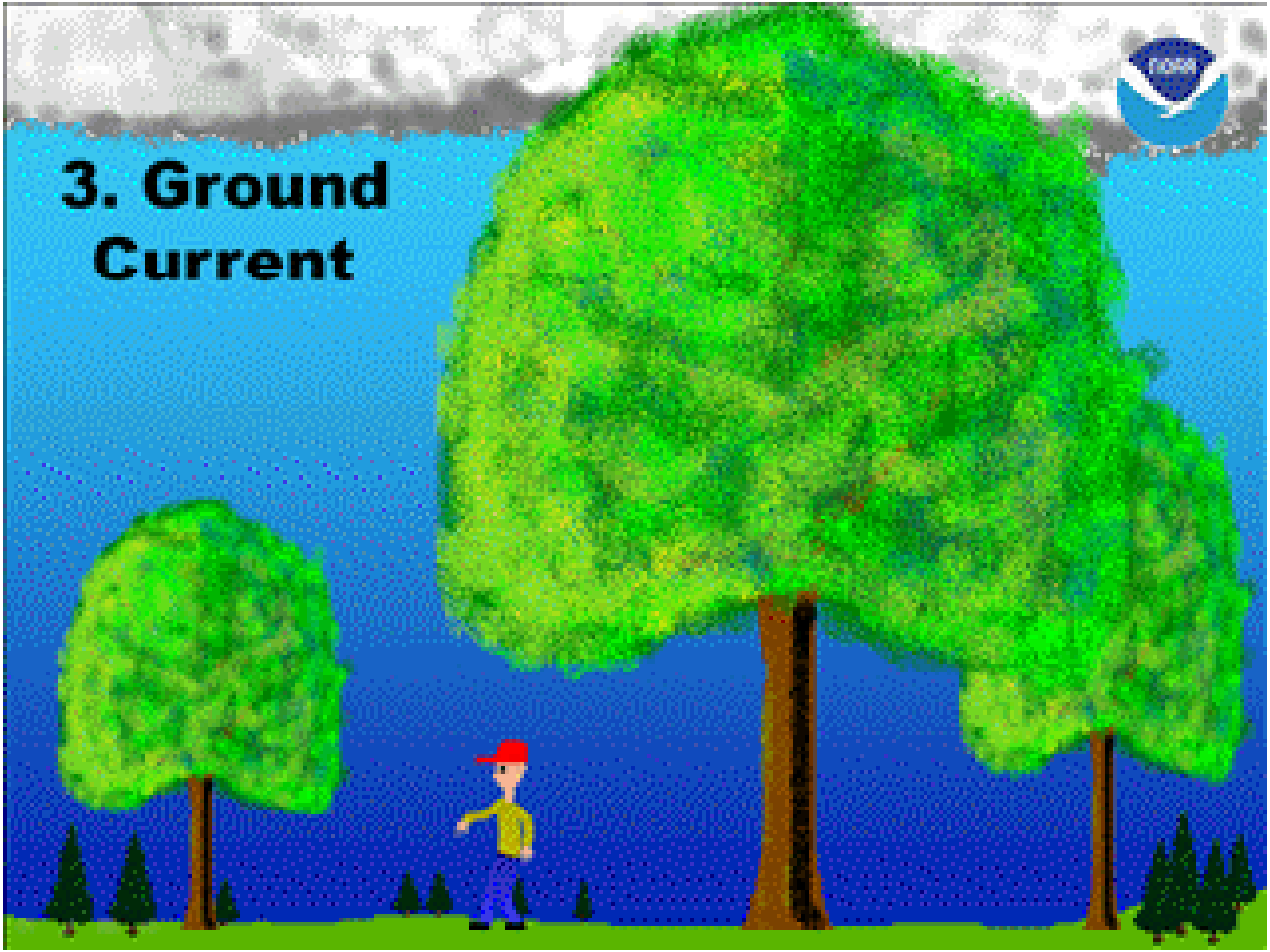

1. Direct Strike

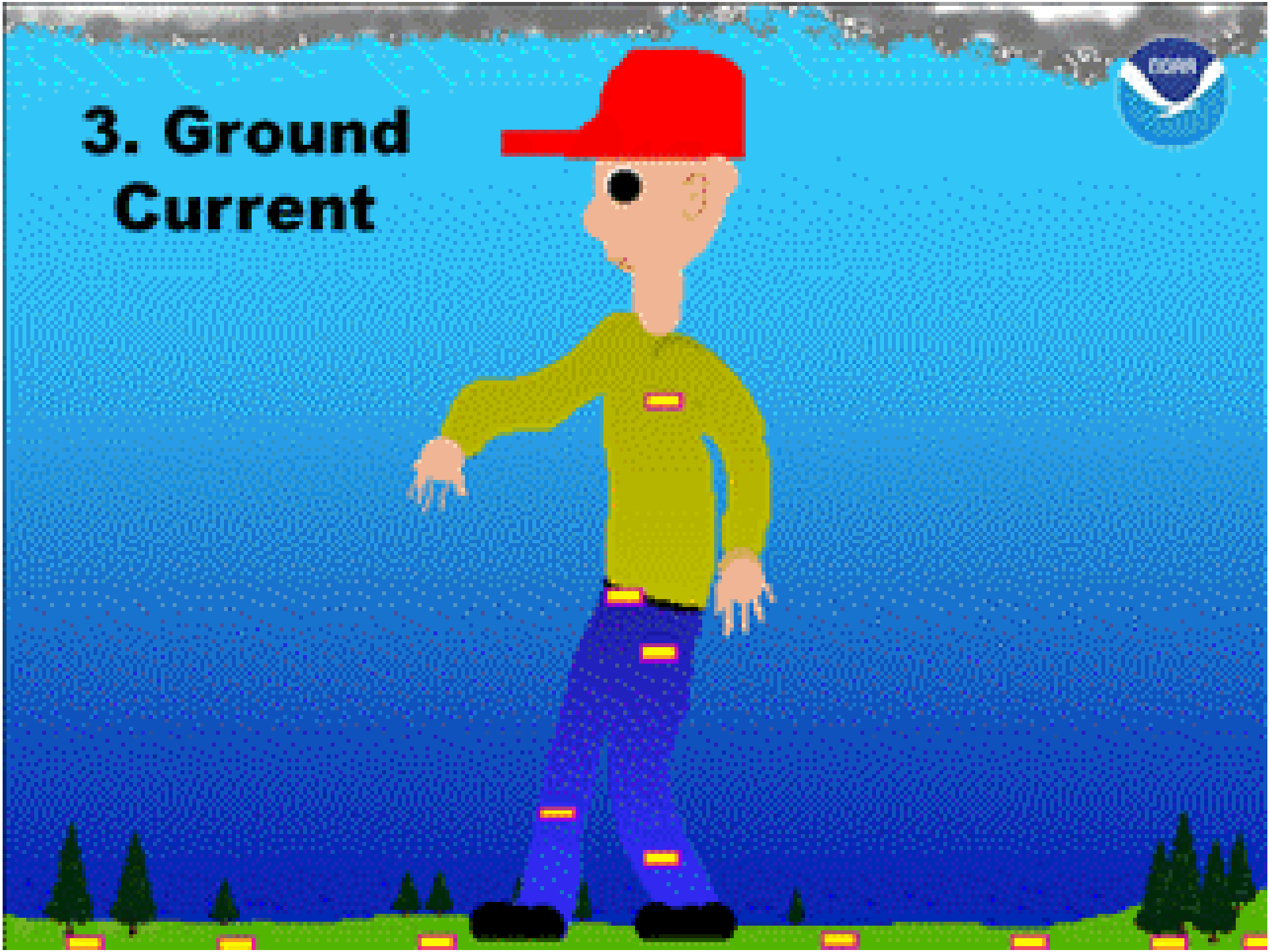
Direct contact



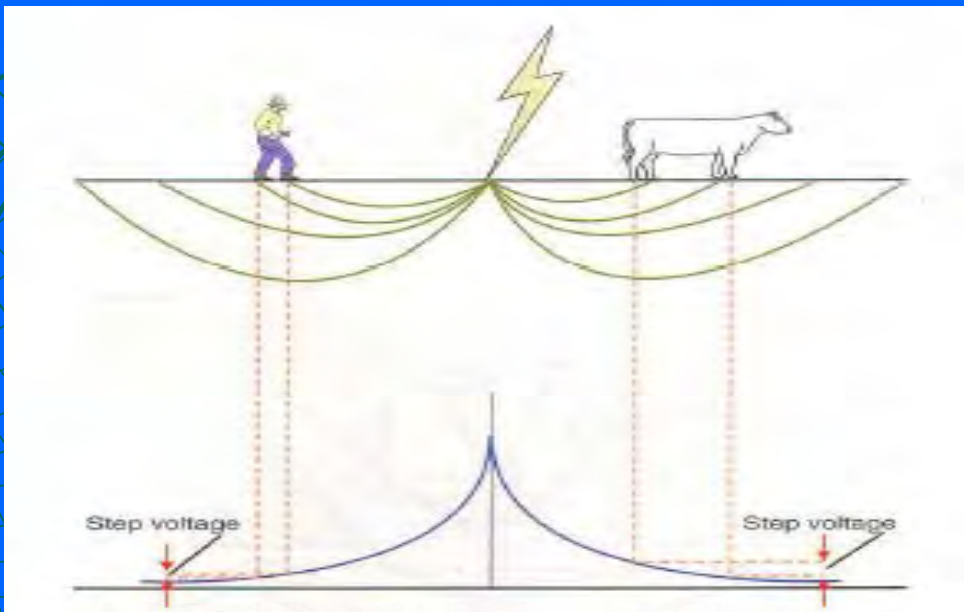

2. Side Flash
Side Splash

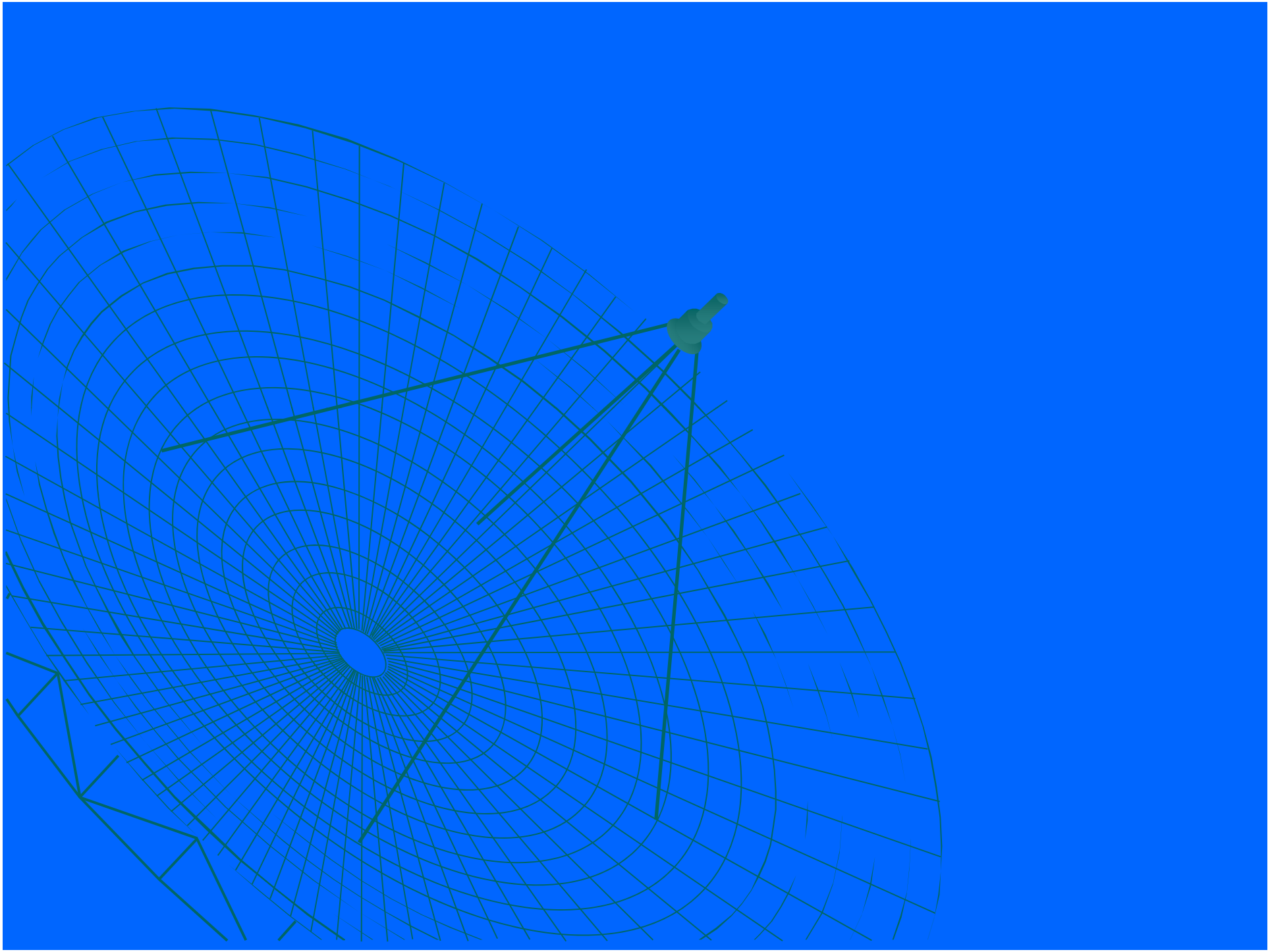
Side flash or branch channel

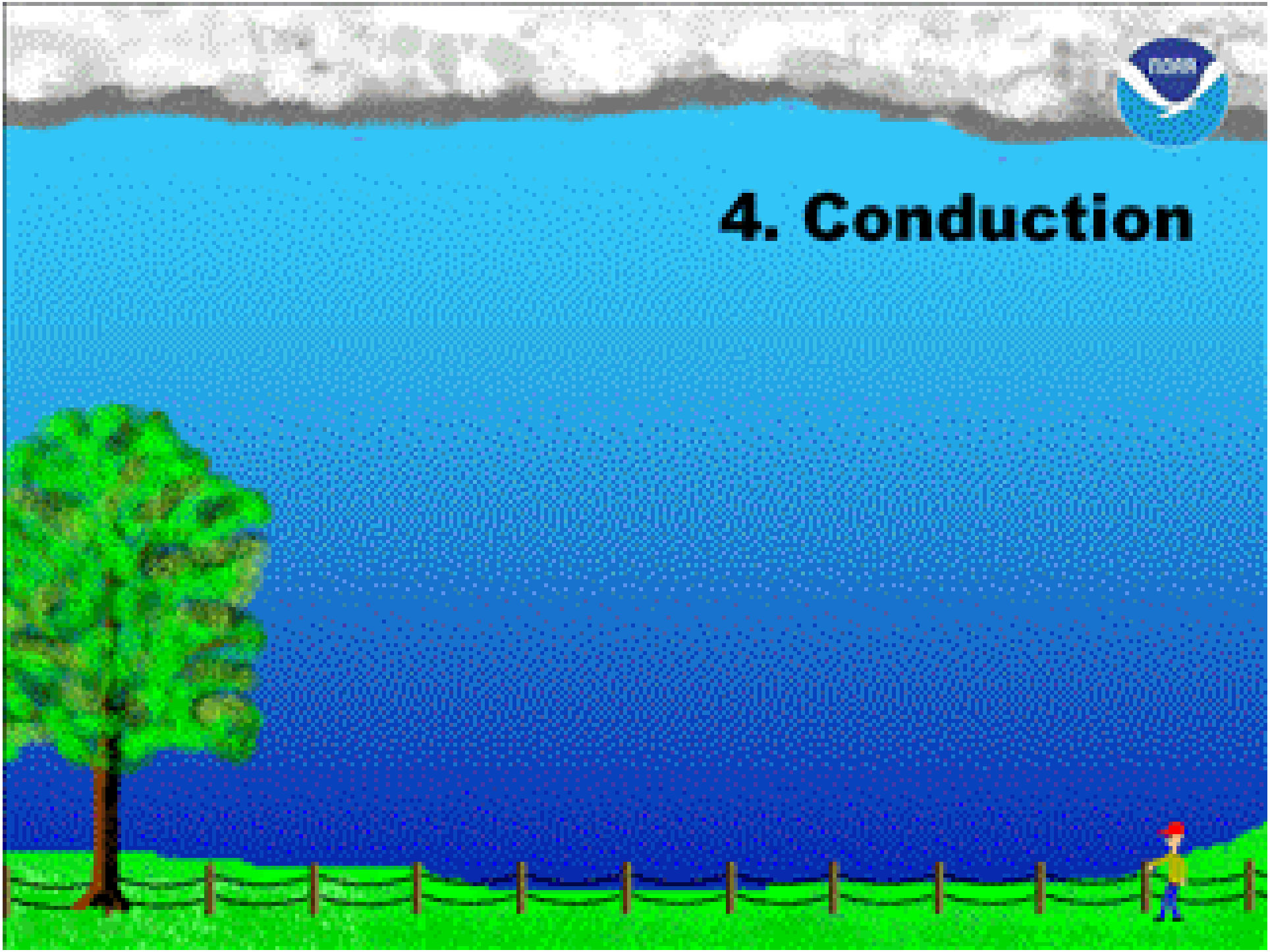

3. Ground
Current


3. Ground
Current

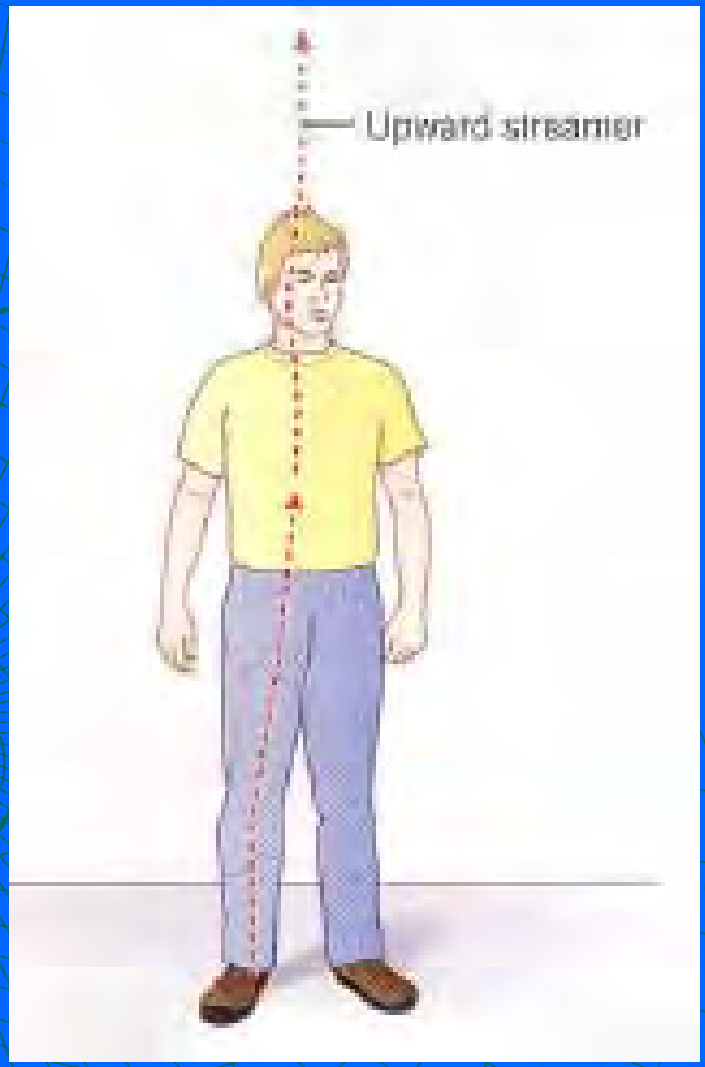
Ground current





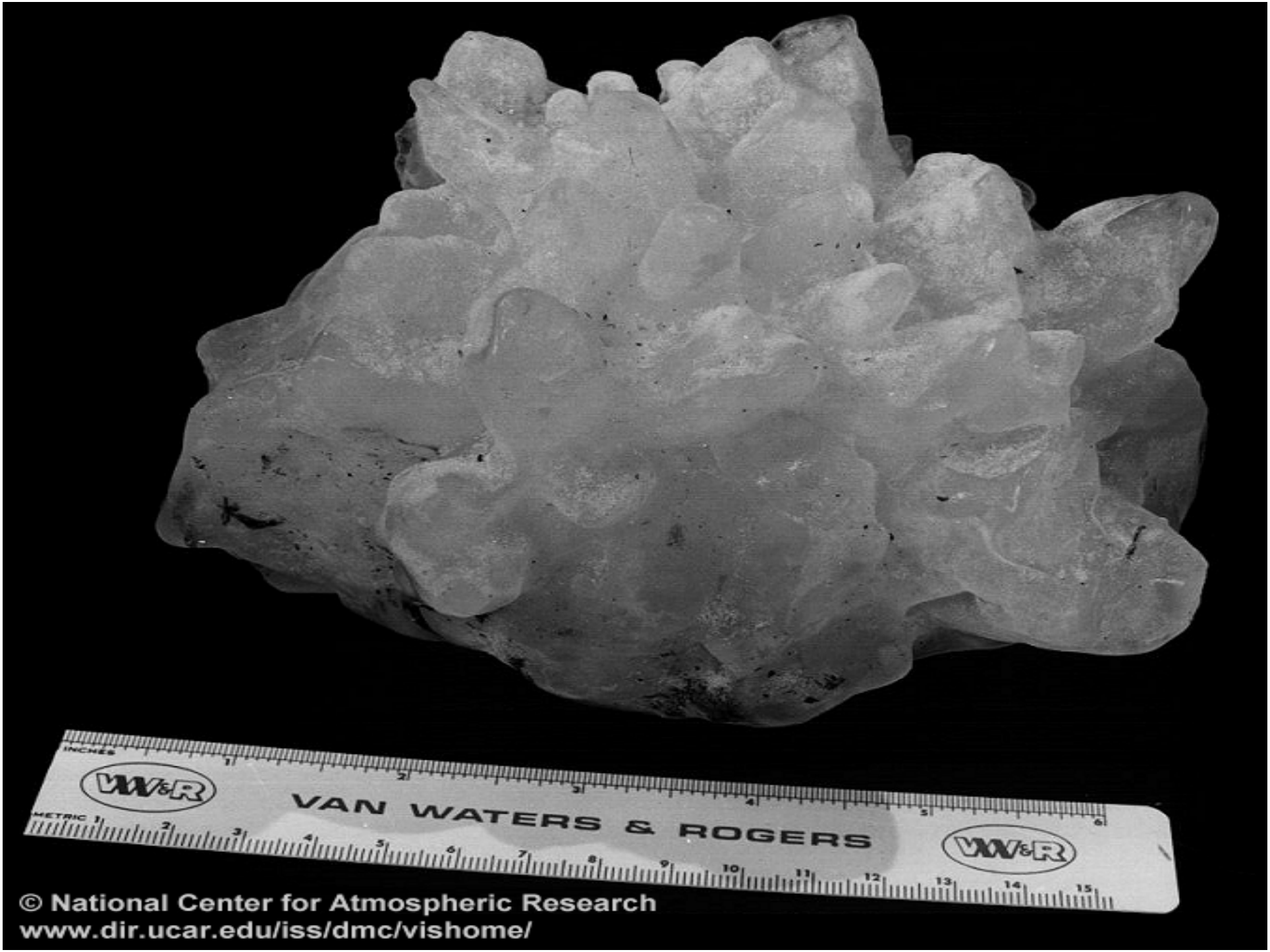

4. Conduction

Electromagnetic induction




5. Streamer

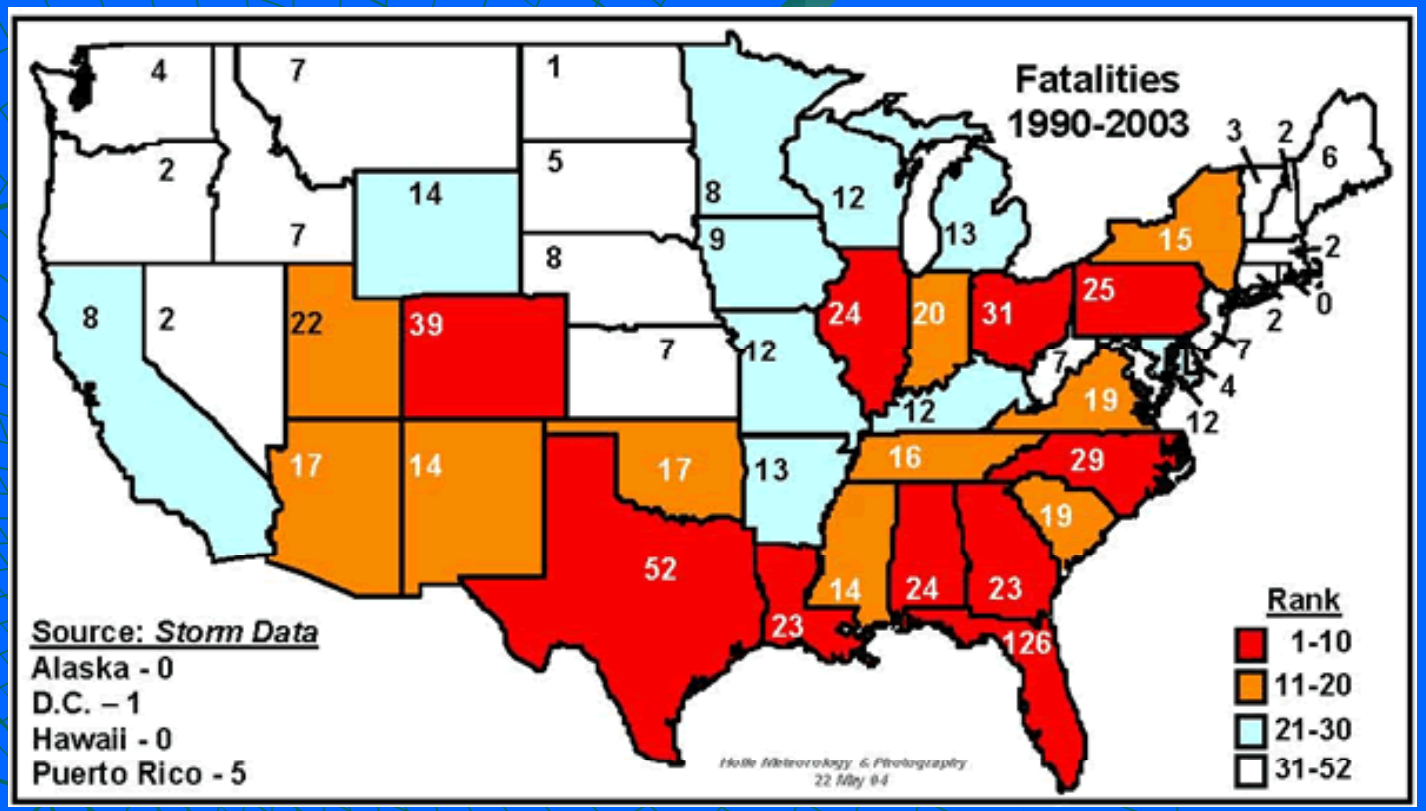
Hail Damage



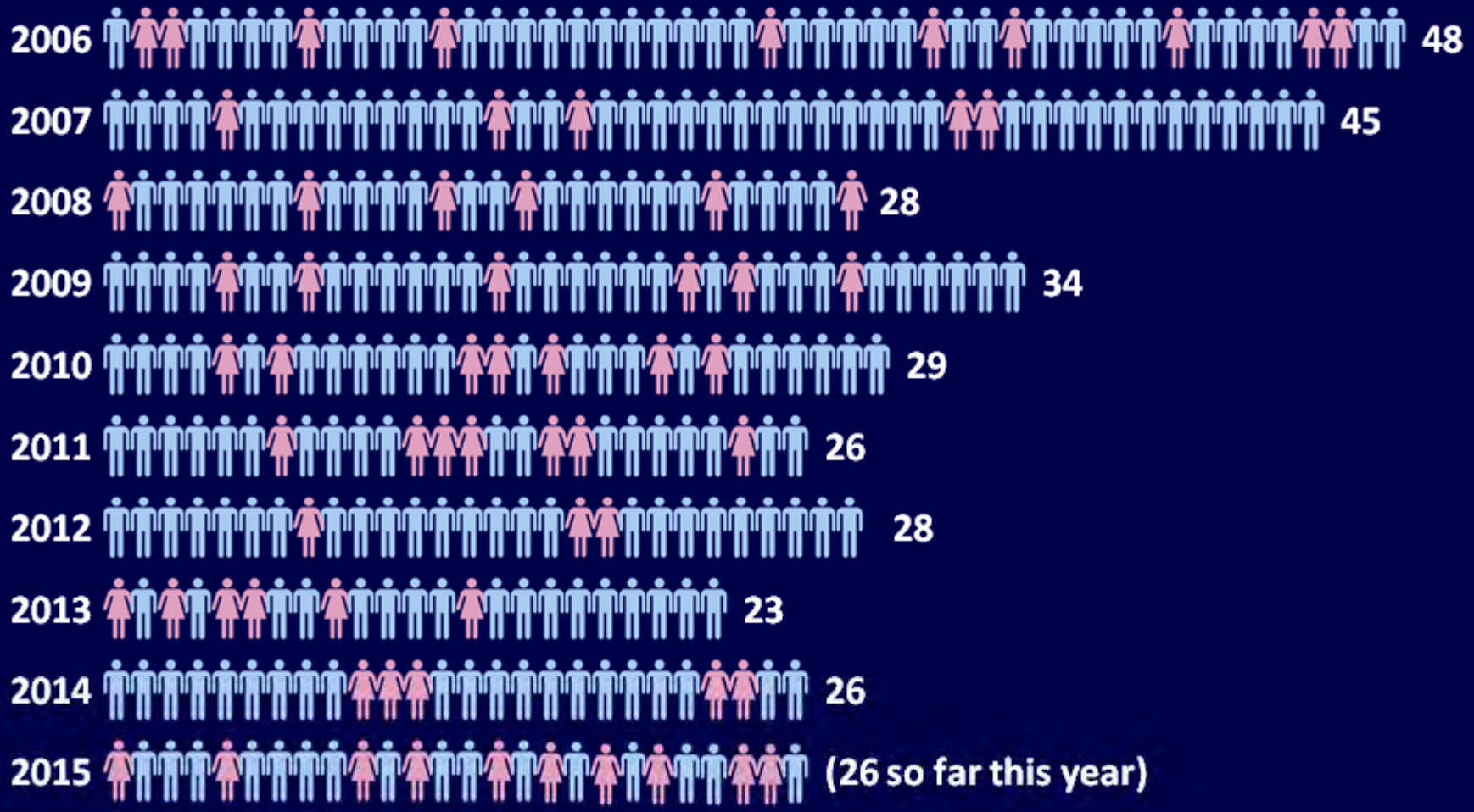
Mary Ann Cooper, MD

Lightning fatalities

About 60 fatalities per year in the US, 360 severe injuries



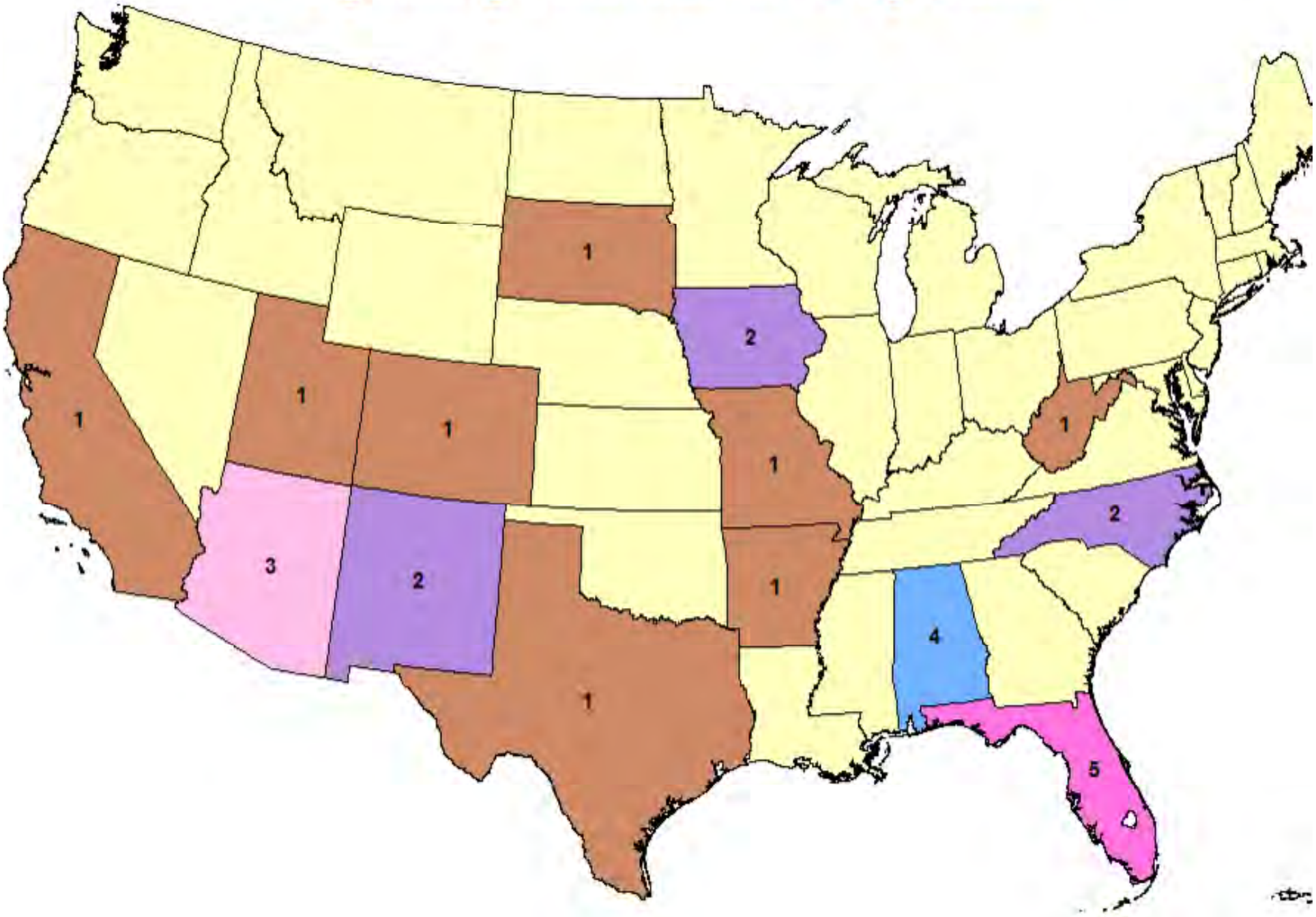
U.S. Lightning Fatalities
2006-2015



For more information:

http://www.lightningsafety.noaa.gov/victims.htm

Lightning Fatalities 2015 by State



U.S. Lightning Deaths in 2015: 26

No.	Date	Day	ST	City	Age	Sex	Location	Activity	Victim
1	4/9	Thu	NC	Anderson Creek	56	F	Under tree, near home	Walking dogs	Frankie Roberts
2	4/9	Thu	NC	Cary	28	M	Parking Lot	Waiting for friend	Steven Bryan
3	5/4	Mon	IA	Moscow	35	M	On horse	Rounding up cattle	William Clevenger
4	5/13	Wed	FL	Bonita Springs	36	M	Roof	Roofing	Rigoberto Diaz-Segura
5	5/15	Fri	NM	Carrizozo	40	F	Road	Riding on Motorcycle	Kalina Jinzo
6	5/21	Thu	TX	Port Lavaca	56	M	Outside store		Jesus Herrera Alvarez
7	6/1	Mon	WV	Fayette County	17	M	Near tree	Fishing	Jacob Neff
8	6/13	Sat	AR	Benton County	22	M	Boat on lake	Fishing	Connor Clayman
9	6/19	Fri	FL	Largo	81	M	Near home	Walking	Jay Freres
10	6/20	Sat	IA	Palo	42	F	Campground	Camping	Rebecca McCarthy
11	6/23	Tue	AL	Opp	42	M	Outside home near tree	Covering chickens	Miguel Belnar
12	6/23	Tue	AL	Opp	45	F	Outside home near tree	Covering chickens	Sharon G. Fletcher
13	6/26	Fri	FL	Port Orange	26	M	Rooftop of home	Working on roof	Steven Lee Gang
14	6/26	Fri	MO	Seymour	30	M	In field	Cultivating field	
15	6/27	Sat	AZ	Forest Lakes	24	F	Under tree	Hiking	Christine Garcia
16	6/30	Tue	AZ	Benson	32	M		Walking	Alvaro Montoya
17	7/5	Sun	AL	Fort Morgan	12	F	Beach	Volleyball	Megan Nickell
18	7/12	Sun	SD	Spearfish	21	M	Disc golf course	Disc golf	Gage McSpadden
19	7/17	Fri	CO	Mt. Yale	31	F	Mountains	Hiking	Kathleen Bartlett
20	7/18	Sat	CA	Bakersfield	62	M	Under tree near house	Checking on home	Stephen Ermigarat
21	7/23	Thu	AL	Autauga County	73	F	Under tree near home	Picking blueberries	
22	8/1	Sat	NM	Rio Arriba County	37	M	Highway	Riding motorcycle	Juan Trujillo
23	8/8	Sat	FL	Miami-Dade	54	M	Near park	Walking to vehicle	Jean Golbert Jean-Pierre
24	8/20	Thu	FL	Jacksonville	56	F	In car	In car driving, hit by tree	Barbara M. Pearson
25	8/30	Sun	UT	Lehi	50	F	Near tree	Family picnic	Carla Grow
26	0/13	Sun	AZ	Grand Canyon	21	M	Trail	Hiking	Jonathan Crowden

Lightning medical effects symptoms and signs

- Injury = severe, moderate or mild
- Complications
  - Cardiac, pulmonic, neurologic, ophthalmic, otologic, and dermatologic

Severe injury

- Cardiac arrest or fibrillation
- Respiratory arrest
- Central nervous system damage from blast effect
- Temporomandibular disruption with hemotypmanum and otorrhea common
- Blunt trauma
- More severe burns

Moderate Injury

- More severe altered medical status or coma
- Often motor paralysis
- Mottled skin and absent pulses – vasomotor spasm
- Anticipate ruptured temperomandibular
- hemotympanum suggests skull fracture
- 1st or 2nd degree burns
- Usually survive and recover but long term neuropsychiatric sequela common (personality change, pain, weakness, and sleep disorders)

Mild injury

- Usually awake and c/o dysesthesia in affected extremity and feeling of being hit on head or in an explosion
- Often confused / amnestic
- Temporomandibular rupture common

Lightning

- Electrical energy follows the path of least resistance
- Decreasing tissue resistance : bone, fat, tendon, skin, muscle, blood vessel, and nerve
- Most important resistor to the flow of current is skin:
  - Skin resistance varies from 1,000 ohms on a sweaty palm to 1 million ohms on a dry, calloused hand
  - Flashover: Current travels on the surface of wet skin preventing penetration to deeper tissues

Cardiorespiratory arrest

- "cosmic direct current" like cardioversion
- Usually asystole the norm
- Respiratory arrest lasts longer and can lead to secondary cardiac arrest
- Torsades de pointes also may occur – may be related to survival after prolonged resuscitation

Cardiac Complications

- Transient hypertension
- Electrocardiographic changes
- Myocardial injury - ischemia
- Congestive heart failure
- Dysrhythmias
- Frequent premature ventricular contractions

Pulmonic Complications

- Apnea – paralysis of medullary respiratory center
- Hypoxemia

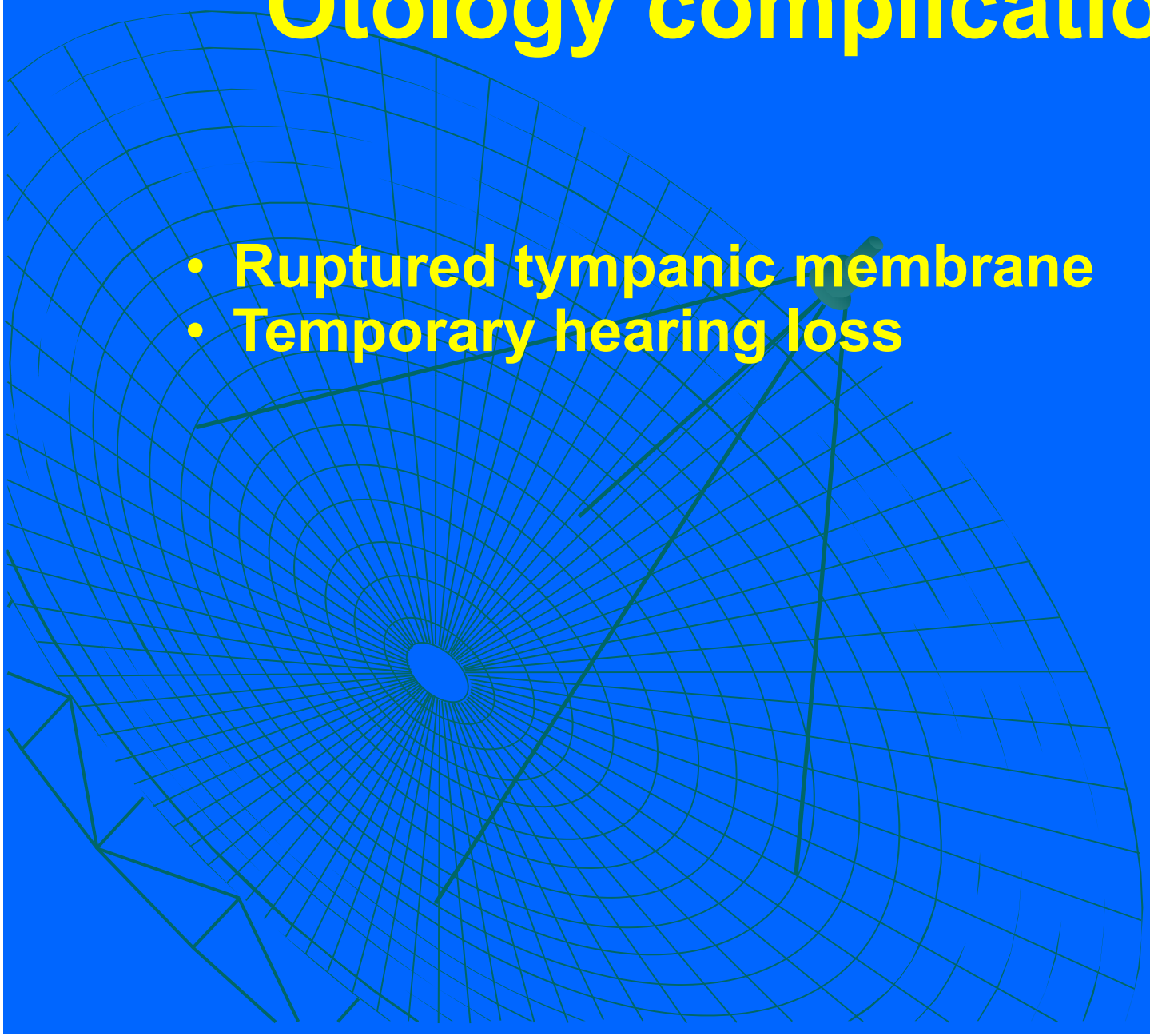
Neurologic complications

- Loss of consciousness
- Confusion
- Paraplegia, quadriplegia
- Retrograde amnesia
- Hemiplegia, aphasia
- Coma
- Seizures
- Intraventricular hemorrh
- Hematomas
- Keraunoparalysis – lower extremity paralysis demarcating at waist or pelvis

Ophthalmic complications

- Cataracts – usually in days to 2 weeks
  - Corneal lesions
  - Hyphema
  - Iritis
  - Vitreous hemorrhage
  - Retinal detachment
  - Optic nerve injury

Otology complications



- Ruptured tympanic membrane
- Temporary hearing loss

Dermatologic Effects

- Deep burns (uncommon) – treat like high voltage injury – suspect myoglobinuria
- Superficial burns:
  - Linear (often secondary to vaporized sweat or rainwater)
  - Pathognomonic fernlike patterns – inflammatory – not true burns
  - Secondary to metal heating, such as necklaces, coins in the pocket, or cleats on the bottom of athletic shoes (iPod)

Punctate lightning burn

Ferning lightning burn

Ferning

- Aka Lichtenberg figure
- Spreads from a central spot
- Transient; manifests within an hour
- Fractal pattern of positive electrical discharge

- **Vascular complications**
  - Vasomotor instability
  - Arterial spasm
  - Vasoconstriction, vasodilatation
- **Compartment syndrome**
- **Blunt trauma – concussive or from being thrown**

Lightning Treatment

- BLS / PALS – survival after prolonged asystole from lightning injury is a myth, but cardiac rhythm may resolve before respiratory arrest
- Triage: apneic, asystolic patients get first priority
- Remove jewelry
- Monitor ECG
- Treat burns and traumatic injuries
- Other investigations guided by careful exam
- Consider referral for neuropsychological evaluation

How does lightning kill ?

- A. Severe burns
- B. Blast trauma (head injuries)
- C. External bleeding from wounds
- D. Internal bleeding from ruptured blood vessels
- E. Cardiac arrest (heart attack)

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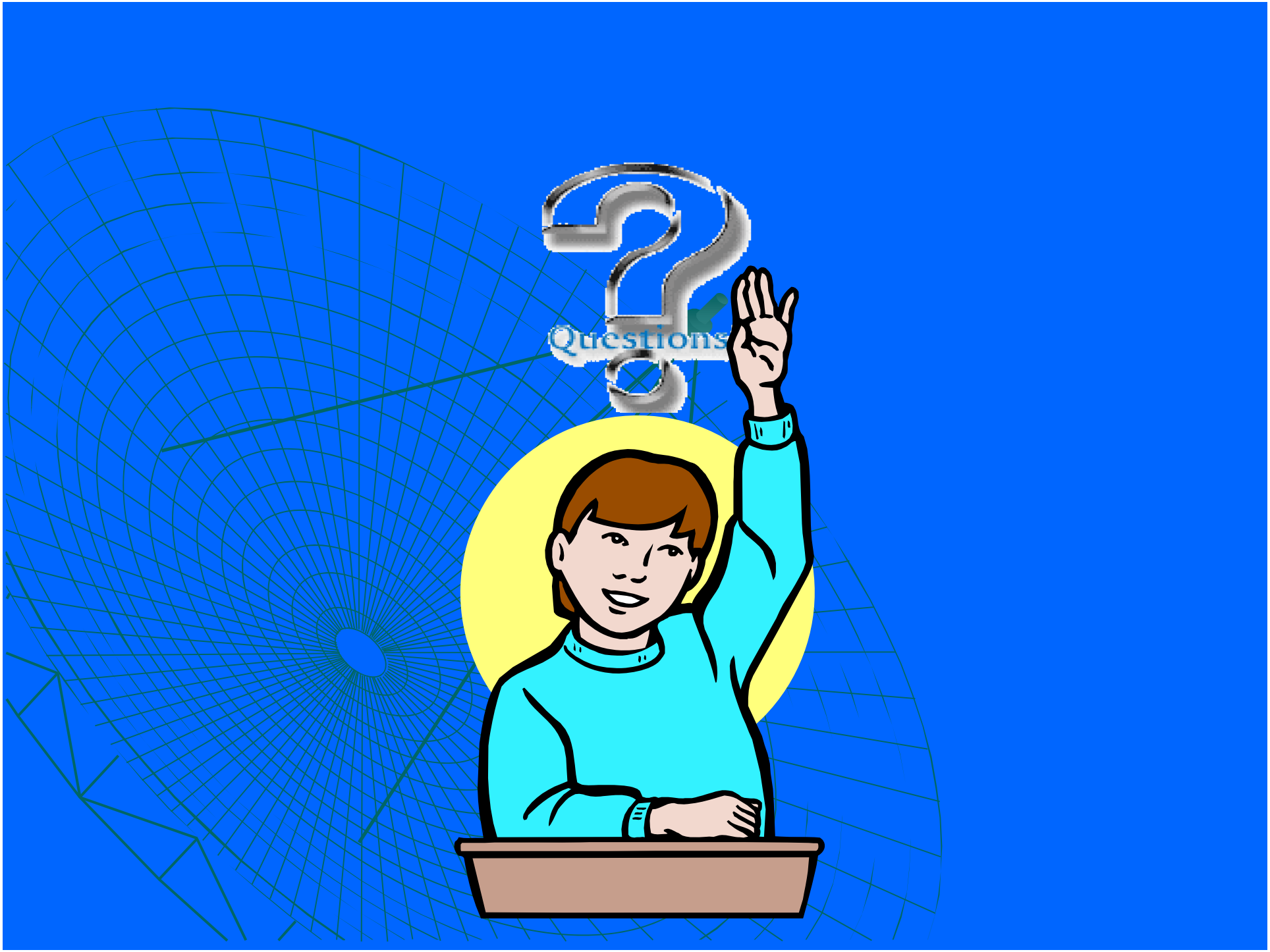
Interesting Lightning Facts

- ~90 % of lightning victims survive
  - Most people struck between 12:00 noon and 4:00 PM
  - Lightning can strike if it is sunny and no apparent storm is around (up to 10 miles away)
  -
- Complications may be life long and debilitating
- North & South Poles almost never have lightning

- Incidence is highest in < 16 year old age group
- males 4.6 times more likely to be killed
- males 5.3 times more likely to be injured than females

Lightning vs "High"-voltage Injury

Factor	Lightning	High-Voltage
Voltage Level	**100 million volts**	**Much lower**
Time of exposure	**Instantaneous**	**Prolonged**
Pathway	**Flashover, orifices**	**Deep, internal**
Burns	**Superficial, minor**	**Deep, major injury**
Cardiac	**Asystole, Primary and secondary arrest**	**Fibrillation**
Renal	**Rare pigmenturia**	**Myoglobinuic renal failure common**
Fasciotomy	**Rarely needed**	**Common, early, extensive**
Blunt Trauma	**Explosive thunder effect**	**Falls, being thrown**


Questions