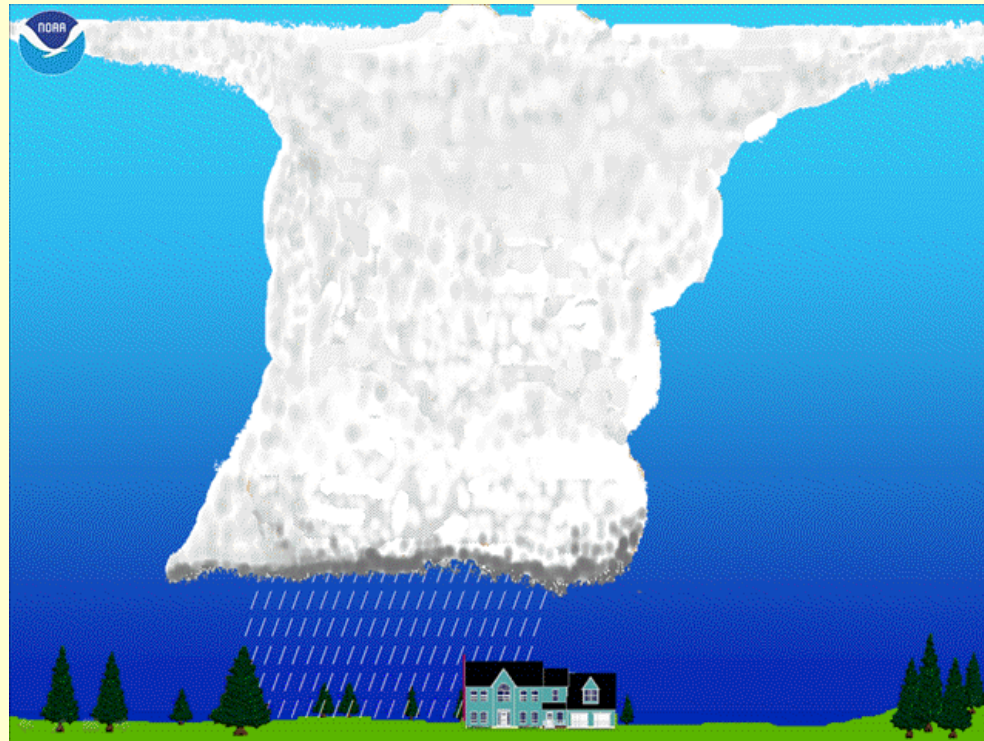




Dr. Lightning's Guide To Lightning and Thunder -- The Science --



**National Weather Service
NOAA**



The Science of Lightning and Thunder



Written, illustrated, and animated
by
John Jensenius
aka: Dr. Lightning





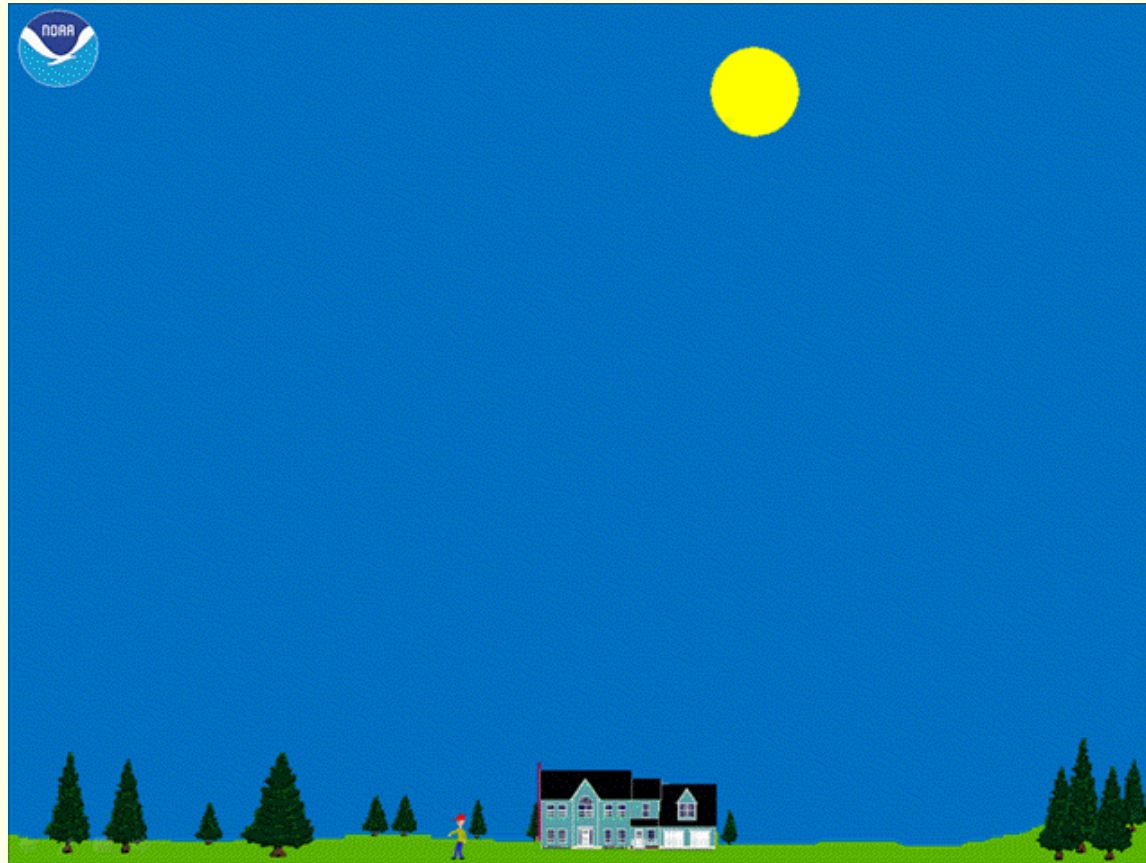
Thunderstorms



By definition, all thunderstorms produce lightning. In this book, we'll see how these storms develop, become electrified, and produce the giant spark we call lightning.



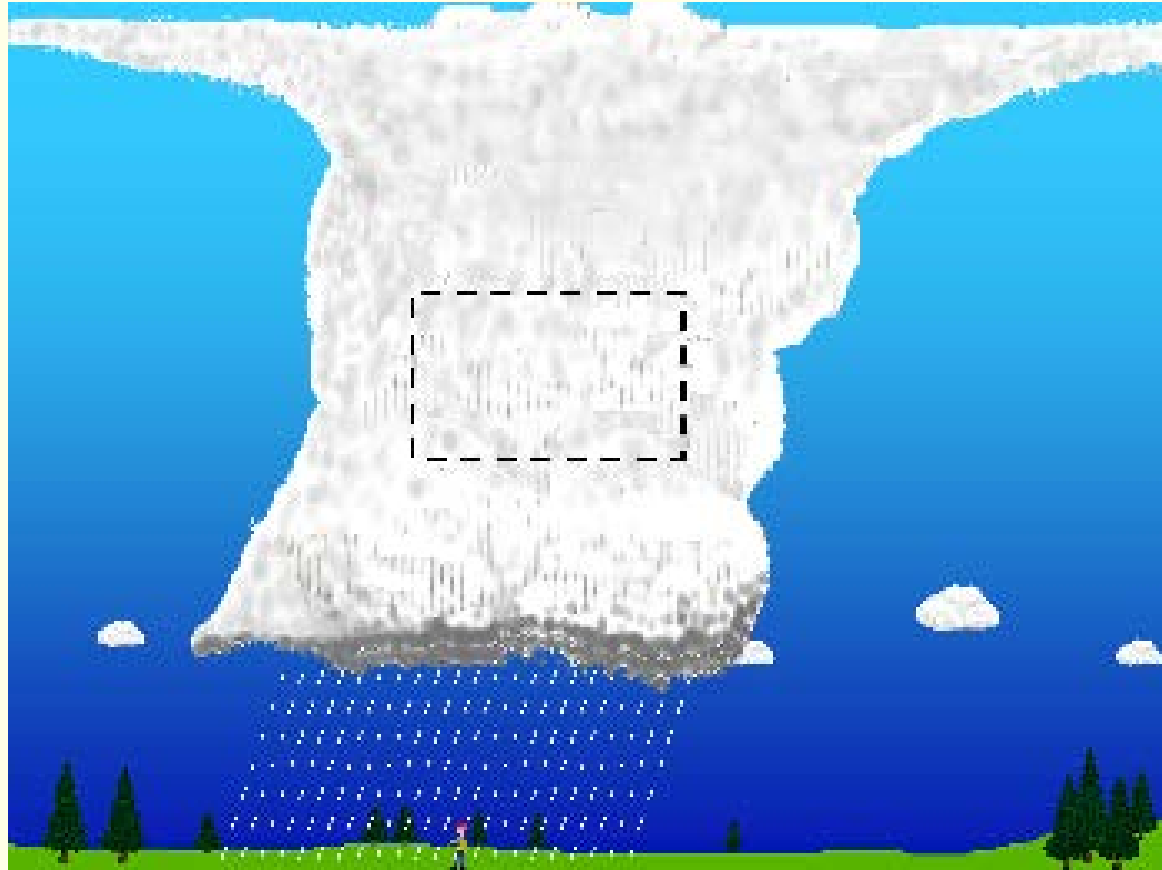
Thunderstorm Development



During the day, the sun heats the air near the ground and causes it to rise. When the rising air reaches a certain level in the atmosphere, cumulus clouds start to form. Under certain atmospheric conditions, these cumulus clouds to grow into an anvil-topped thunderstorm cloud (cumulonimbus).



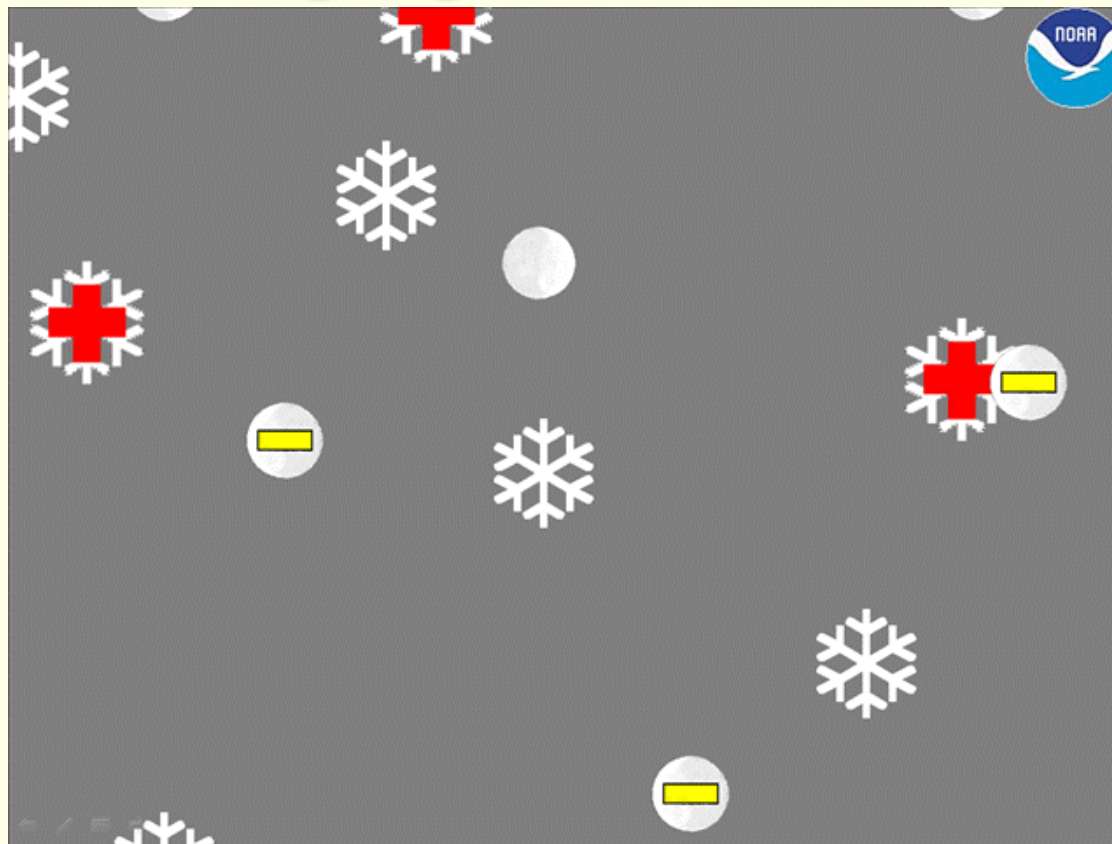
Getting All Charged Up



The main charging area of the thunderstorm cloud is in the central part of the storm where temperatures are between -10 and -25 degrees Celsius.



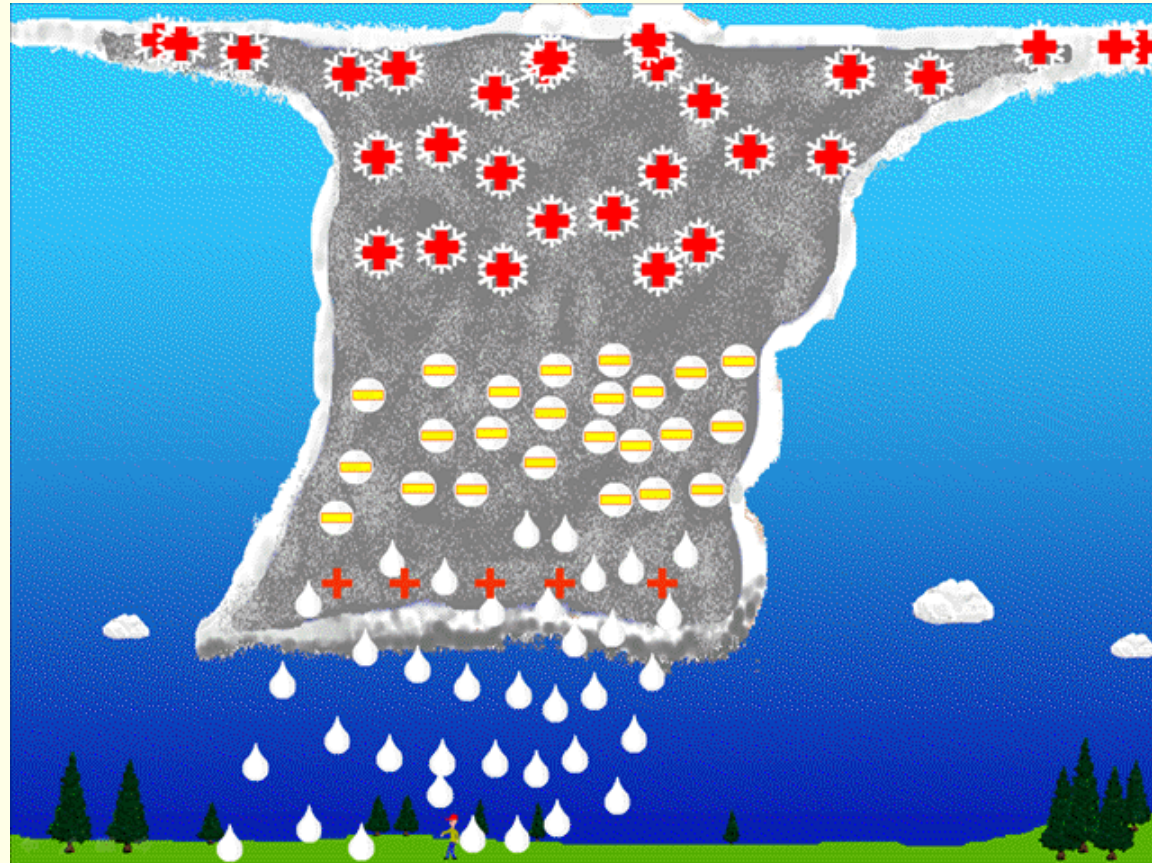
Charging in the Clouds



Here in the central part of the storm, very tiny ice crystals collide with soft pellets of hail in the presence of tiny liquid cloud droplets. After the collisions, where cloud temperatures are between -15°C and -25°C , the ice crystals become positively charged and the soft hail becomes negatively charged. Where cloud temperatures are between -10°C and -15°C (not shown), the ice crystals become negatively charged and the hail becomes positively charged.



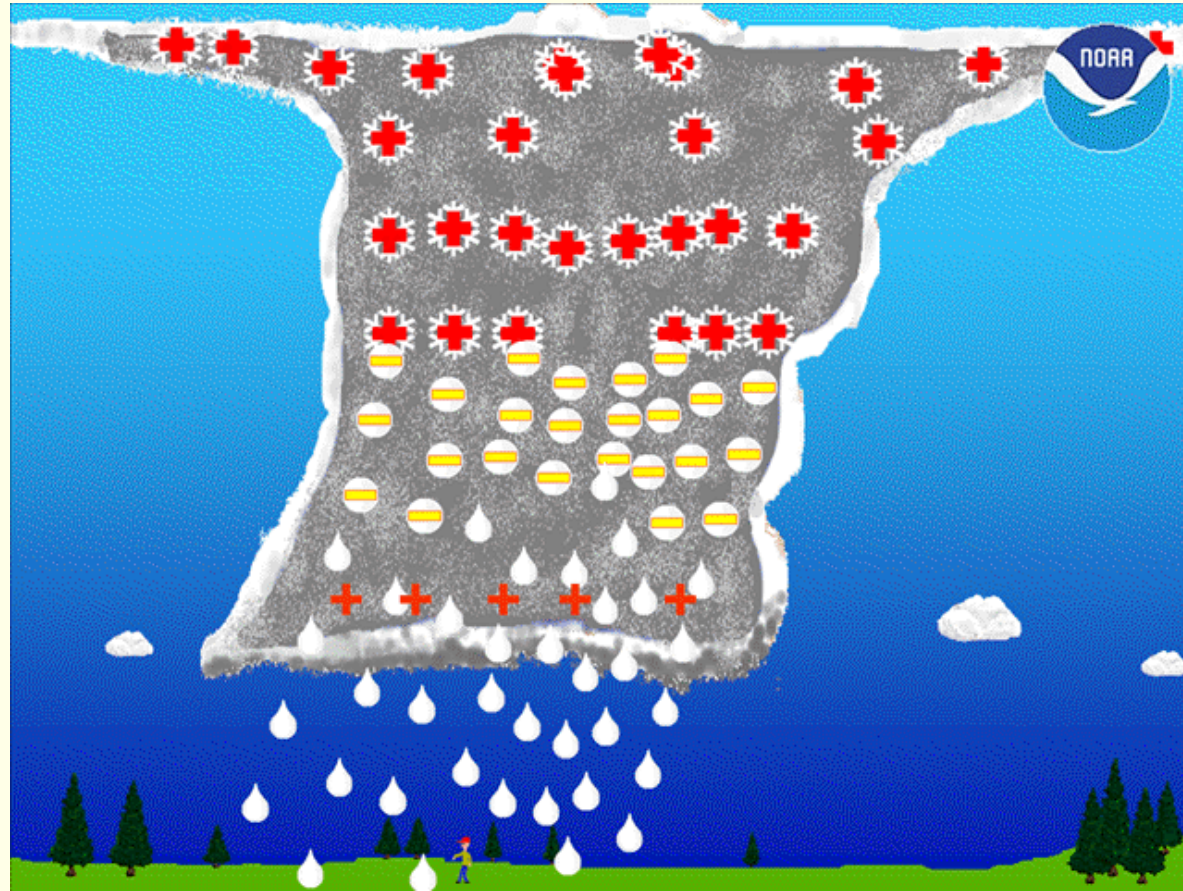
Charge Separation



The very light ice crystals are carried upward by the updraft winds. In comparison, the larger and denser soft hail is suspended or falls. As a result, the top of the storm cloud becomes positively charged while the central to lower part of the storm becomes negatively charged. A small positive charge forms in the lower part of the storm.



Ground Charges



The charges in the cloud affect the charges on the ground. When a thunderstorm is directly overhead, the large and relatively close negative charge in the central part of the storm causes the ground directly beneath the storm to become positively charged.



Don't Get All Charged Up!



The cloud charges also affect objects on the ground. The negative charges in the cloud not only repel the negative charges in the ground, but, if you're outside, also in you. This could cause you to become positively charged.



A Very Dangerous Situation



If you become “charged up,” you could be struck and killed at any moment. Signs that you are becoming “charged” include hair standing on end or a tingling sensation. Don’t wait for these signs to happen as it may be too late to avoid getting struck. Seek shelter as soon as there are any signs of a developing or approaching thunderstorm.



The Lightning Flash

The most common cloud-to-ground lightning flash* consists of:

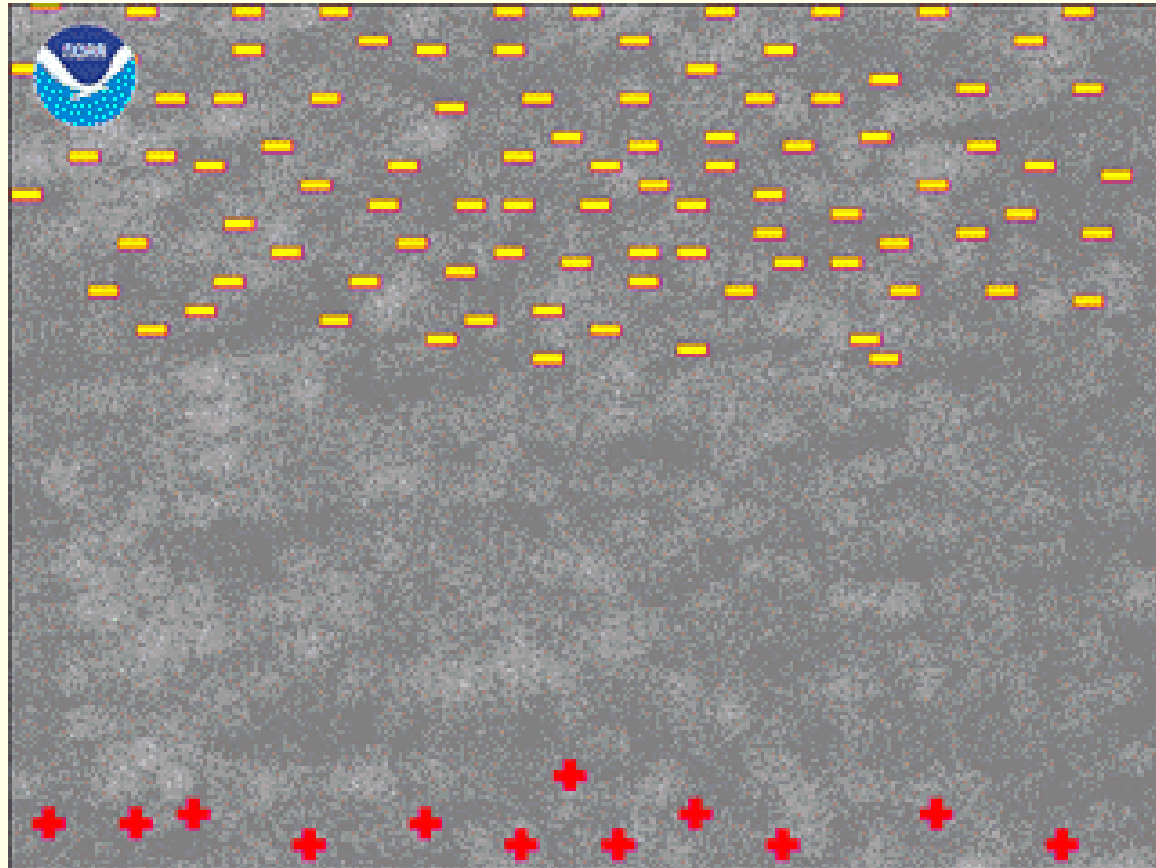
- 1. A stepped leader**
- 2. A return stroke**
- 3. Dart leader(s)**
- 4. Return stroke(s)**

Now we'll take a look at the science of the lightning flash.

*** The most common cloud-to-ground lightning flash is the "negative" cloud-to-ground flash.**



Charges on the Move



Air is normally a poor conductor of electricity. However, if the charge difference (electrical potential) between the oppositely charged areas within the cloud becomes too large, the air loses its ability to stop charge movement and negative charges start to move toward the ground.



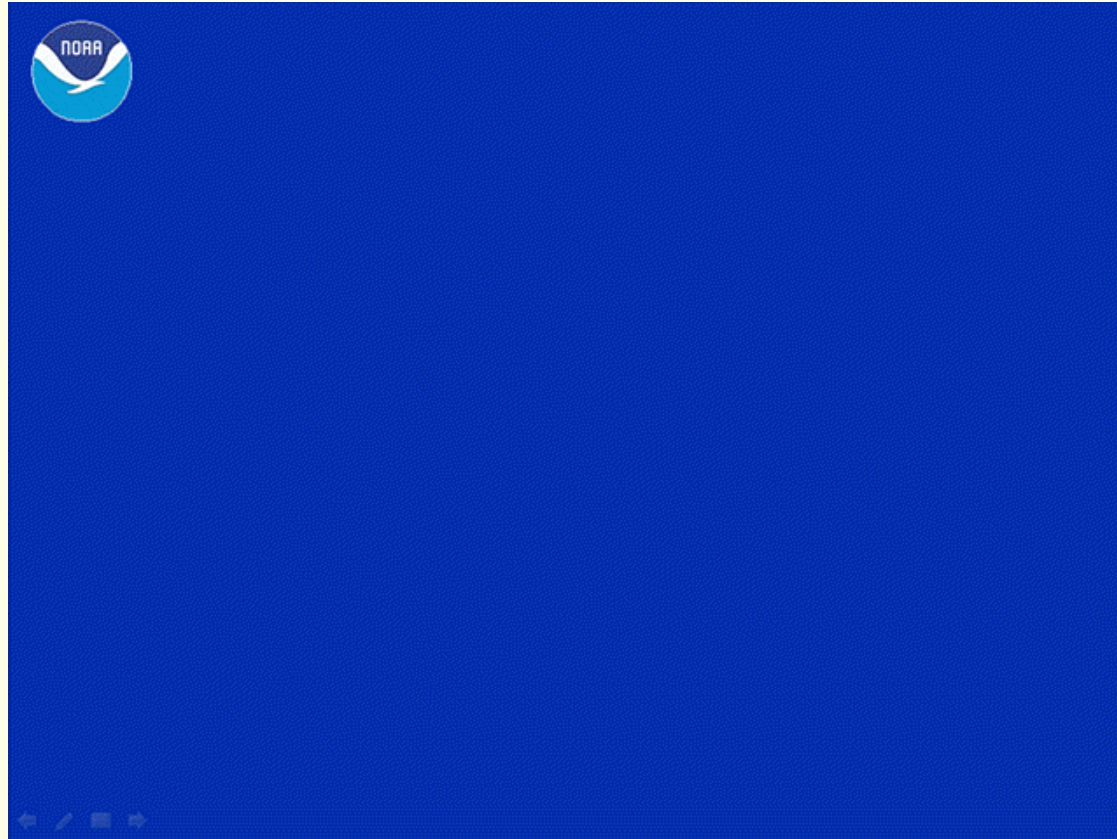
Charges Emerge from the Cloud



The negative charge emerges from the base of the cloud as the “stepped leader.” Although the stepped leader doesn’t initially sense objects on the ground, it moves toward the ground and often branches outward as it attempts to make a connection.



Stepping Its Way to the Ground



The stepped leader jumps in little steps of about 150 feet (50 meters) as it moves toward the ground (which is why it's called a stepped leader). Between each step, it pauses for a very short moment. Each little step creates a very small flash.



Faster Than a Speeding Bullet



Although the stepped leader “steps and pauses” its way to the ground, it’s still very fast. On average, the stepped leader moves about 200,000 miles per hour and travels from the cloud to the ground in a small fraction of a second.



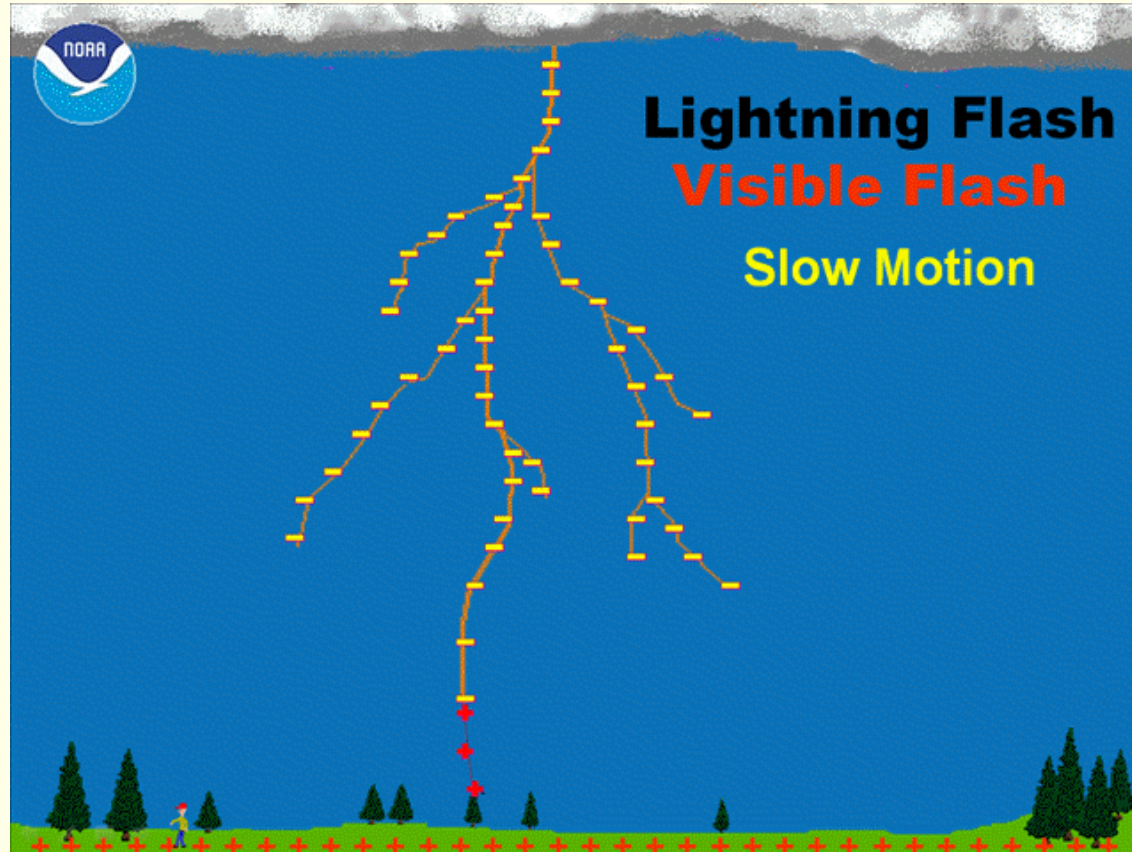
Making a Connection



When the stepped leader approaches the ground, the air above taller objects starts to ionize and negative charges start moving toward the ground. This allows one or more positively-charged “streamers” to develop upward toward the stepped leader. Eventually, the stepped leader makes a connection with a streamer.



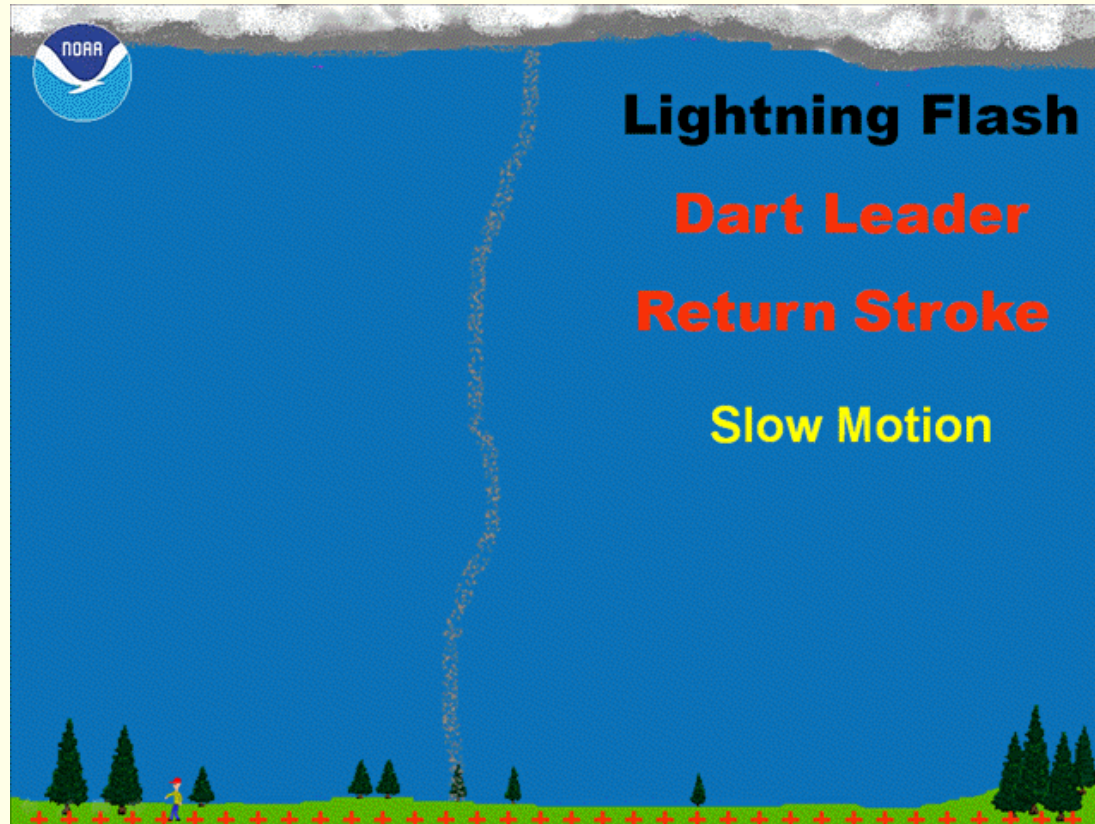
The Visible Flash



Once the stepped leader connects with an upward streamer, the channel starts discharging rapidly to the ground. The actual discharge begins near the ground and works its way through the entire channel. As it does, the discharge creates a very bright flash of light called the “return stroke” which moves upward through the channel at about 200 million miles per hour.



Dart Leaders and Return Strokes



The initial flash momentarily leaves an ionized channel in the atmosphere. If additional charges in the cloud are immediately available to the channel, another negatively charged leader will start moving toward the ground. We call this a “dart leader.” Once it reaches the ground, it will discharge via another return stroke.



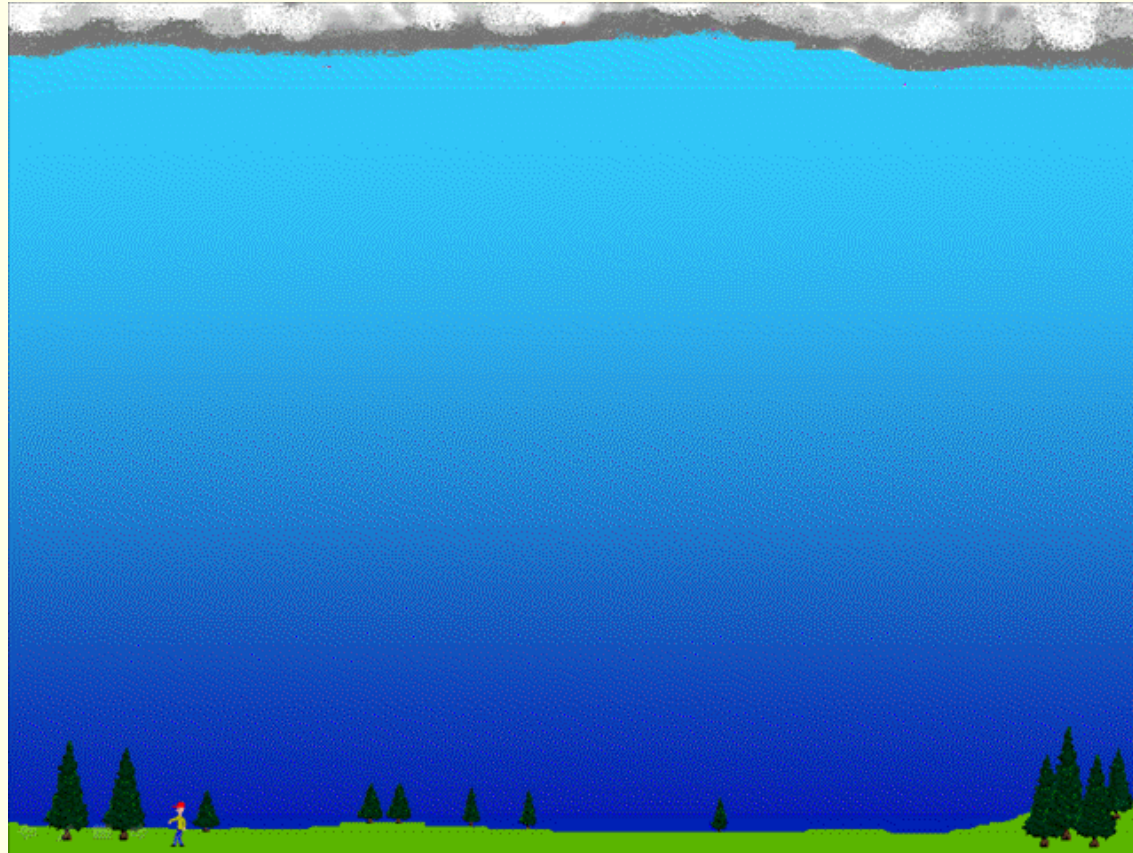
The Lightning Flash in Slow Motion



Here's a look at the entire lightning flash in slow motion. Notice the stepped leader, upward streamers, and return stroke followed by three dart leaders/return strokes. After the initial return stroke, lightning flashes typically have several dart leaders/return strokes. This causes the lightning to flicker.



The Lightning Flash at Normal Speed



Here's a look at the lightning flash at near normal speed. The stepped leader and dart leaders happen so quickly that we can't see them. All we see are the bright return strokes.



Lightning Flash Video #1



Courtesy of Dr. Marcelo Saba
National Institute For Space Research,
Brazil

High speed cameras can be used to capture video of lightning strikes. When played back in slow motion, we can see the stepped leader and return stroke. In this video, the elapsed time between when you see the stepped leader and when you see the return stroke is 1/133rd of a second.

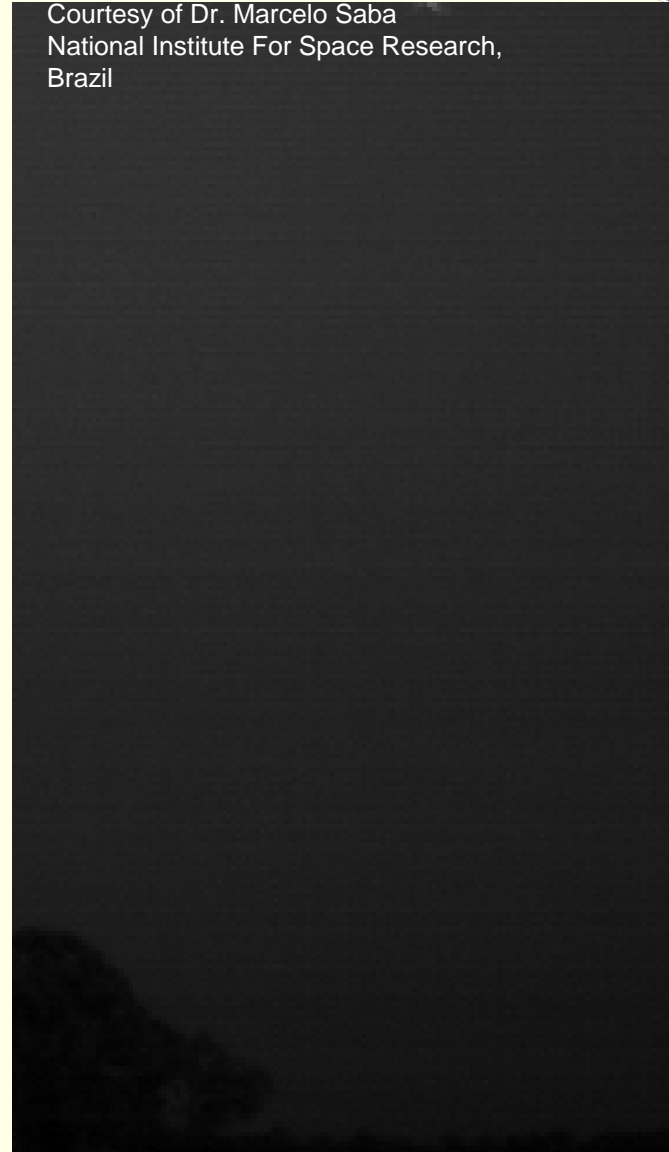


Lightning Flash Video #2



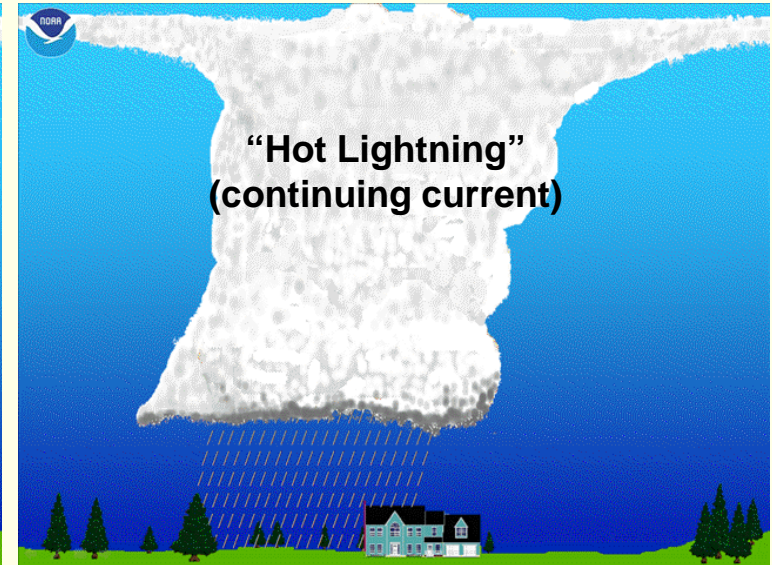
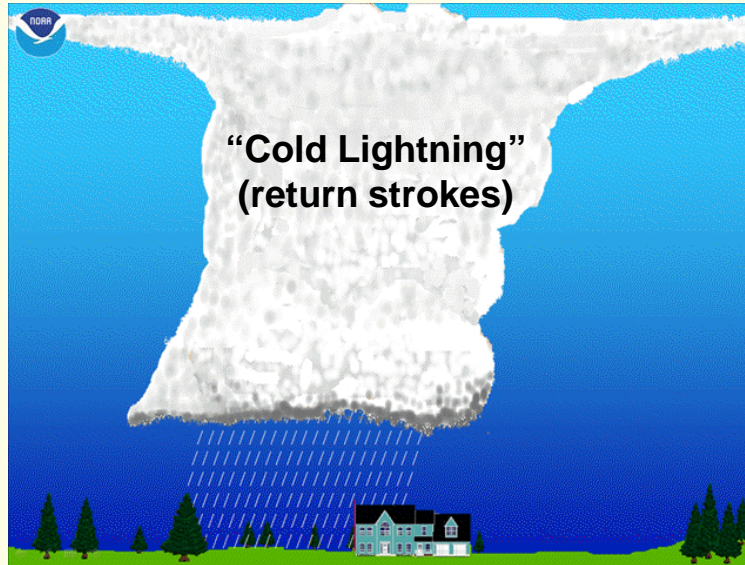
Here's another video of a lightning flash. In this case, two branches of a stepped leader race to the ground looking for a connection. The first branch to reach the ground, discharges the entire channel. In this video, the elapsed time from when you first see the stepped leader to when you see the return stroke is 1/50th of a second. Note that this stepped leader appears much fainter than the previous. In this case, rather than dart leaders and return strokes, there is a more continuous flow of electricity. We call this continuing current.

Courtesy of Dr. Marcelo Saba
National Institute For Space Research,
Brazil





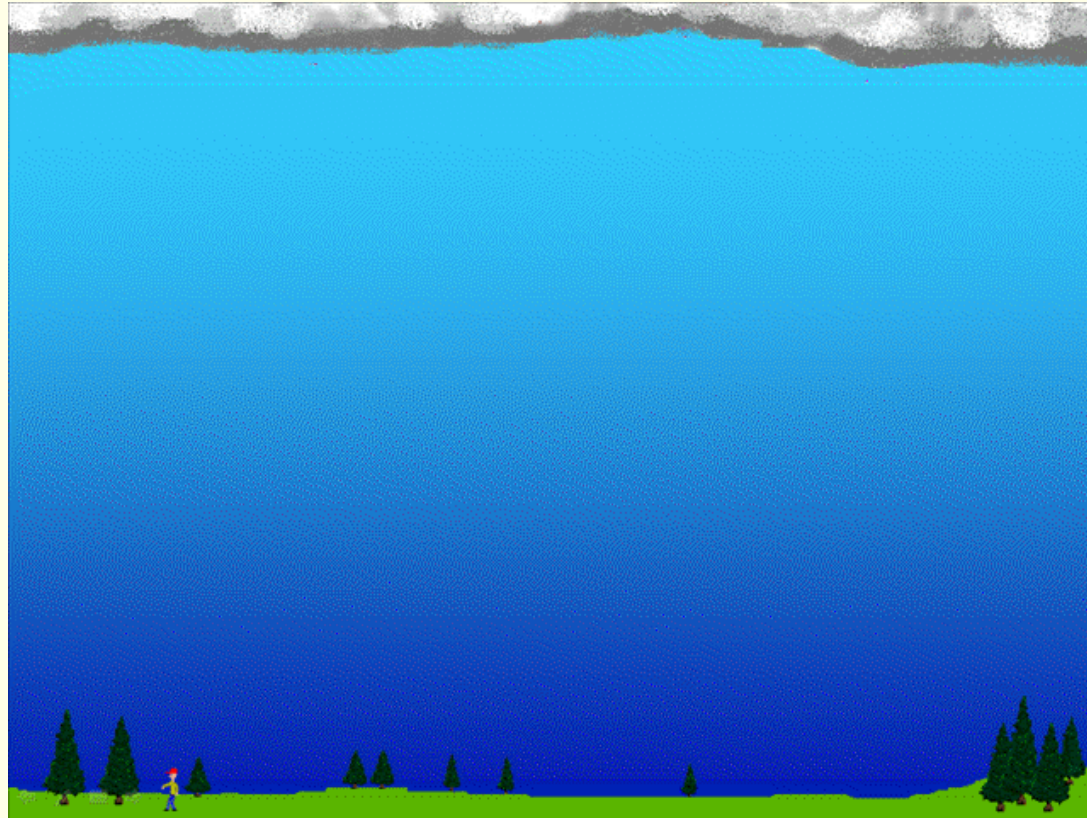
Continuing Current and Fires



As shown on the previous page, some lightning flashes contain a continuous flow of electricity rather than (or in addition to) return strokes. Because this “continuing current” flows for a much longer period of time, it can heat an object to its ignition point and cause a fire. Lightning with continuing current is sometimes referred to as “Hot Lightning” while lightning with just return strokes is referred to as “Cold Lightning.” Note, however, that both “hot” and “cold” lightning are still very hot.



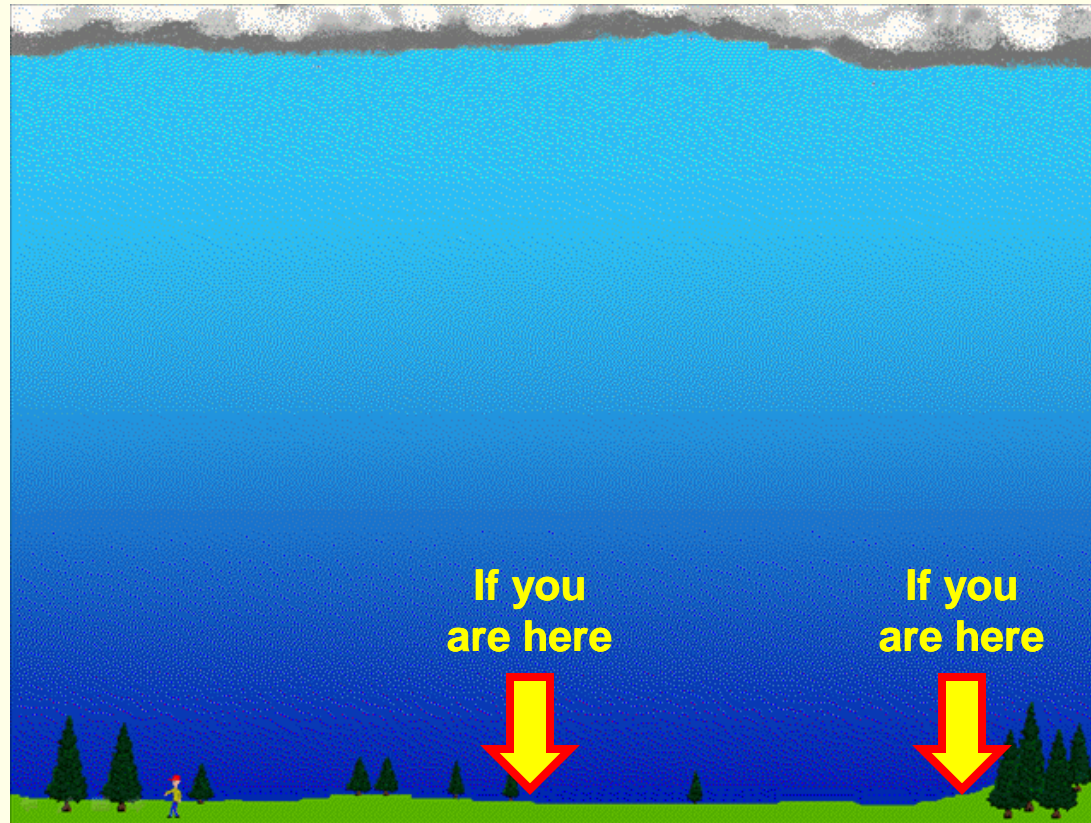
Thunder



When lightning passes through the air, it heats the air very rapidly and causes it to expand. Immediately after the flash, the air cools and contracts quickly. This rapid expansion and contraction creates a sound wave that we call thunder.



Thunder



While you see lightning immediately, the sound of thunder travels outward from the lightning flash at about 1100 feet per second which is about a mile every five seconds. The farther you are from the lightning flash, the longer it will take for the sound of thunder to reach you.



Listening to Thunder



By listening to the sound of thunder, you can learn some things about the lightning.

As sound travels through air, the higher pitched sounds are absorbed. A sharp click, crack, or clap indicates that the lightning channel passed nearby.

If the thunder sounds more like a rumble, the lightning discharge was at least several miles away.

The loud clap or boom is caused by the main lightning channel as it hits the ground.



Listening to Thunder

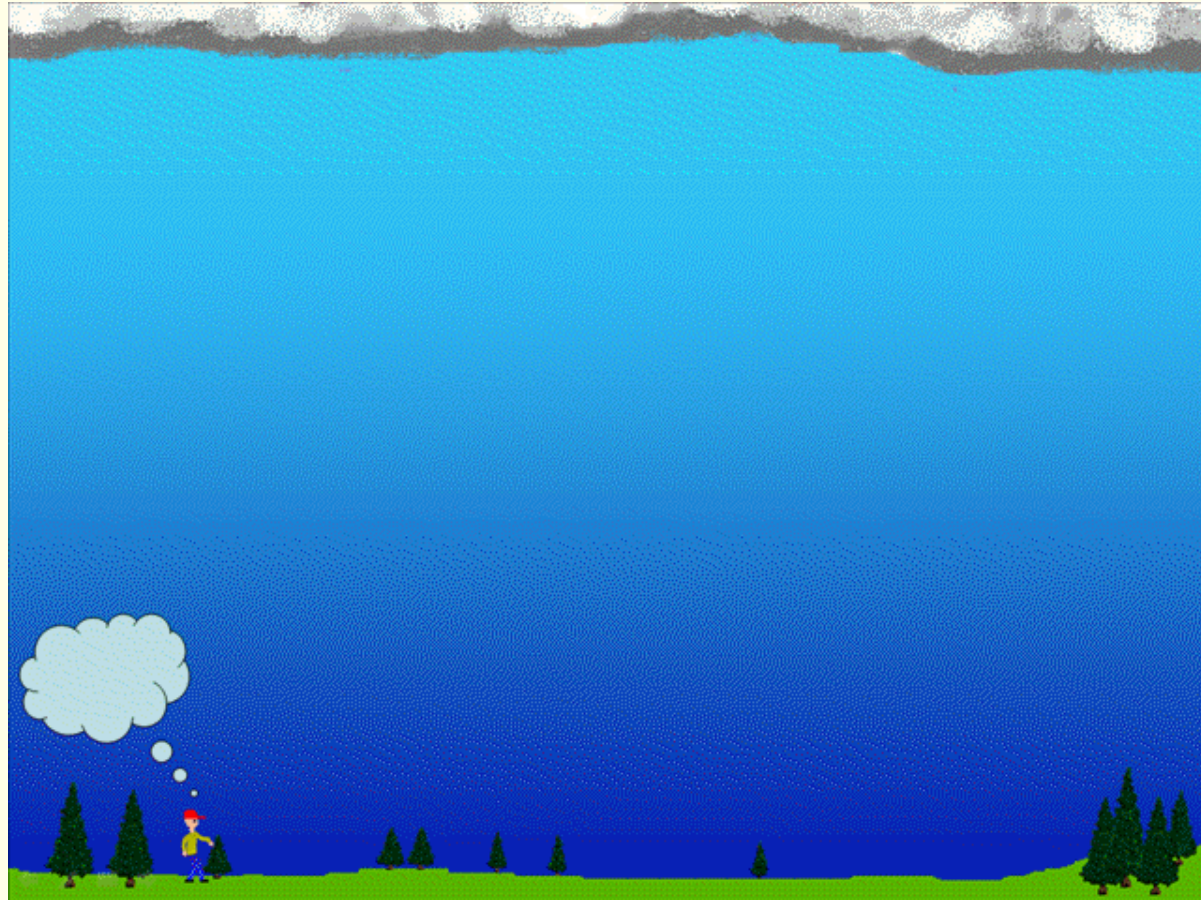


Although a flash of lightning usually strikes just one spot on the ground, it travels many miles through the atmosphere. When you listen to thunder, you'll first hear the sound created by that portion of the lightning channel nearest you. As you continue to listen, you'll hear the sound that was caused from portions of the channel farther and farther away.

The following page shows how a particular lightning strike might sound. Note that the animation shows the sounds from only several portions of the channel. In reality, sound waves are generated by the entire channel and move in all directions.



Thunder



In this example, the person in the red cap first hears a click from the nearby streamer discharge, then a crack from the channel aloft, then a loud clap or boom from the main channel. The person then hears crackling and rumbling as the sounds from more distant portions of the channel reach him.



How Do I Tell How Far Away Lightning Is?



If you count the number of seconds between the flash of lightning and the sound of thunder, and then divide by 5, you'll get the distance in miles to the lightning.

30 seconds = 6 miles

15 seconds = 3 miles

5 seconds = 1 mile

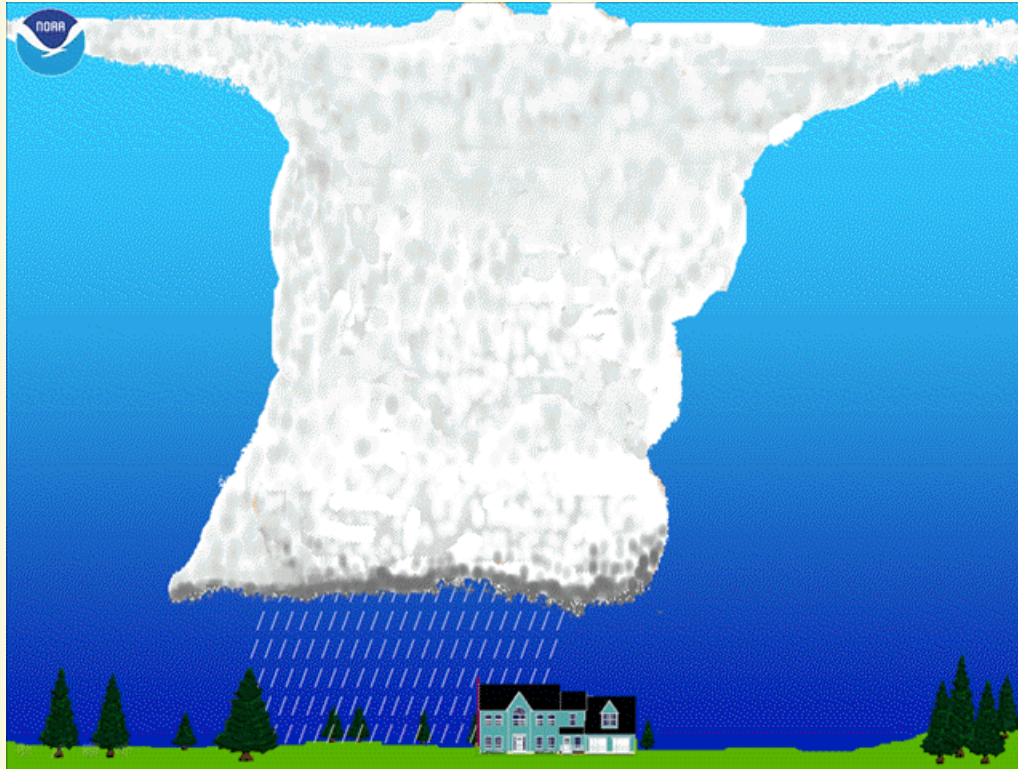
0 seconds = very close

Keep in mind that you should be in a safe place while counting. If you can hear thunder, chances are that you're within striking distance of the storm.

On the next page, you can test your knowledge. Watch for the flash of lightning, then begin counting. See if you can calculate the distance before it appears on the screen.



How Far Away is the Lightning ?



$$10 / 5 = 2 \text{ miles}$$



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Lightning Safety: *When Thunder Roars, Go Indoors!*

What's New?

- NWS Lightning Safety Awareness Message
- Lightning Deaths in 2013
- The Dr Lightning Show: Intro, Victims, Science
- Latest Lightning Safety Blog
- Beyond Thunder Dumb: When Lightning Strikes

Summer is the peak season for one of the nation's deadliest weather phenomena—lightning. Though lightning strike peak in summer, people are struck year round. In the United States, an average of 54 people are killed each year by lightning, and hundreds more are severely injured.



Safety: Learn what you need to do to stay safe when thunderstorms threaten.



Victims: Learn what happens to people who are struck by lightning and look at fatality statistics for the U.S.



Science: Learn how thunderstorms develop and what happens during a lightning discharge.



Myths and Facts: Get answers to many of the questions you have always wondered about



Teachers: find curriculum guides, presentations games, activities, and more.
Kids: Download games, videos, coloring pages and other fun stuff.



More Resources: Download toolkits, posters, pamphlets, and other information to help communities, organizations, and families stay safe from the dangers of lightning

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NOAA Wants You to Have a Safe and Enjoyable Summer



**If you have any comments or suggestions, please email:
Dr.Lightning@noaa.gov**