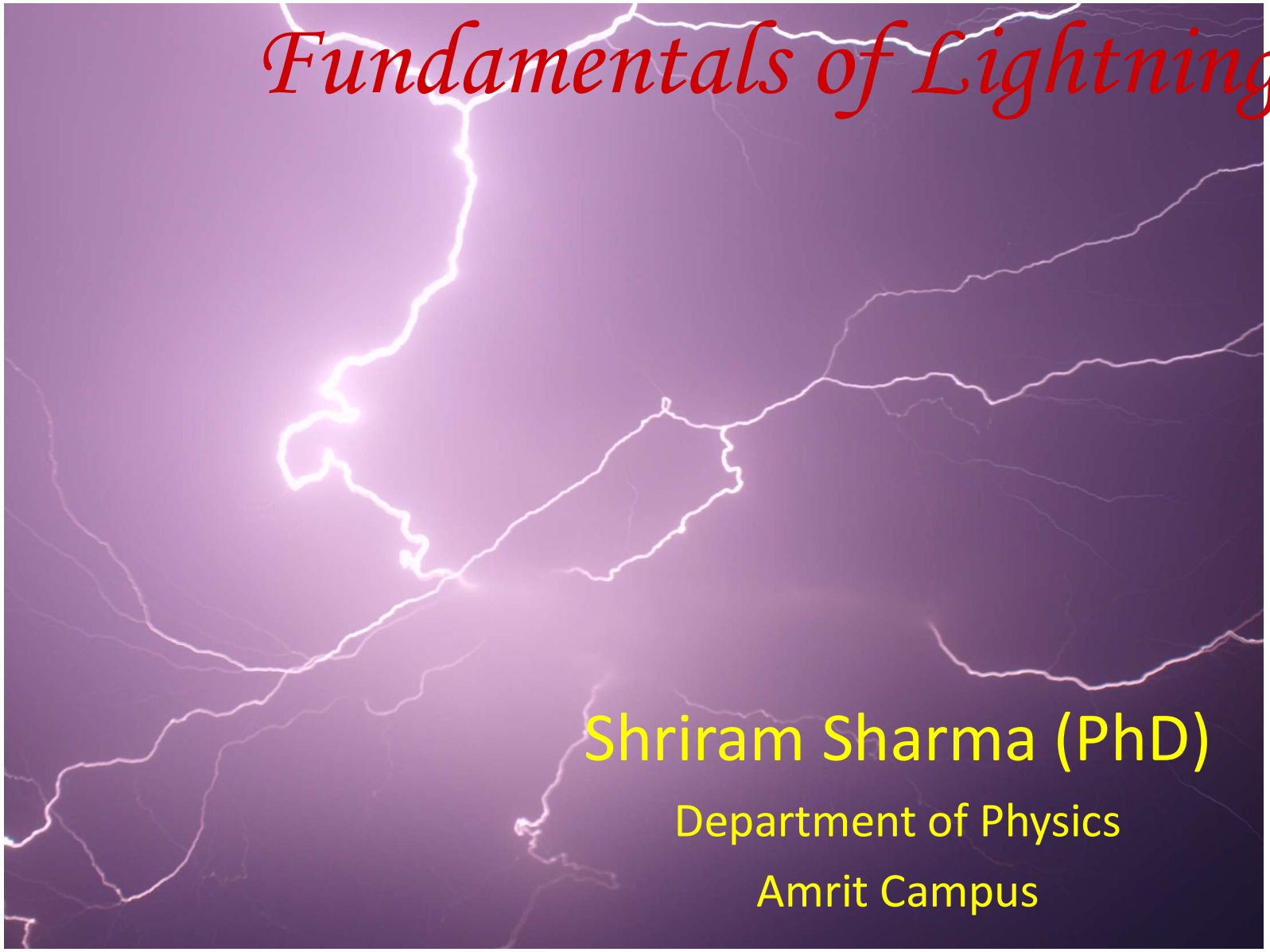

Fundamentals of Lightning

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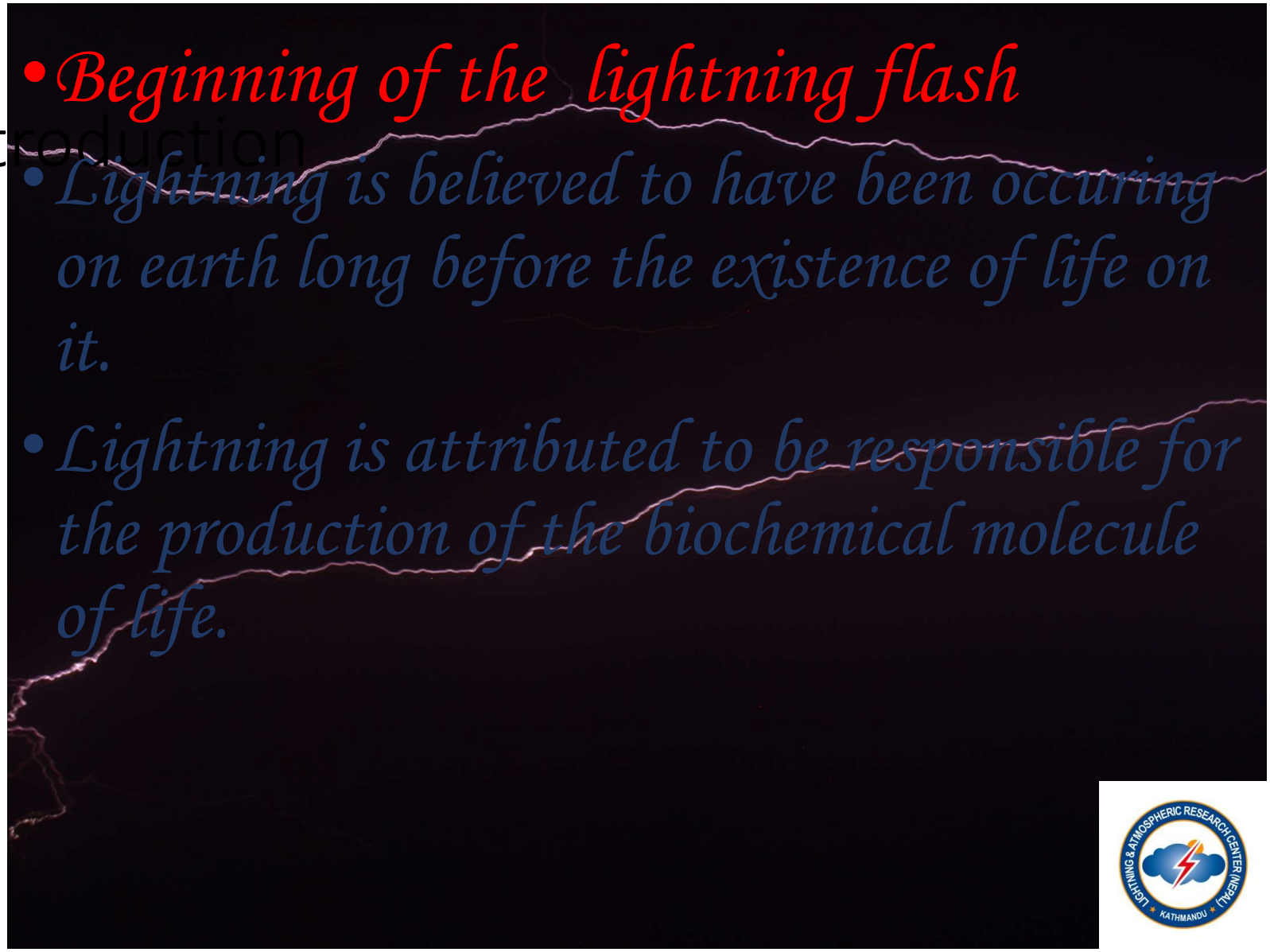
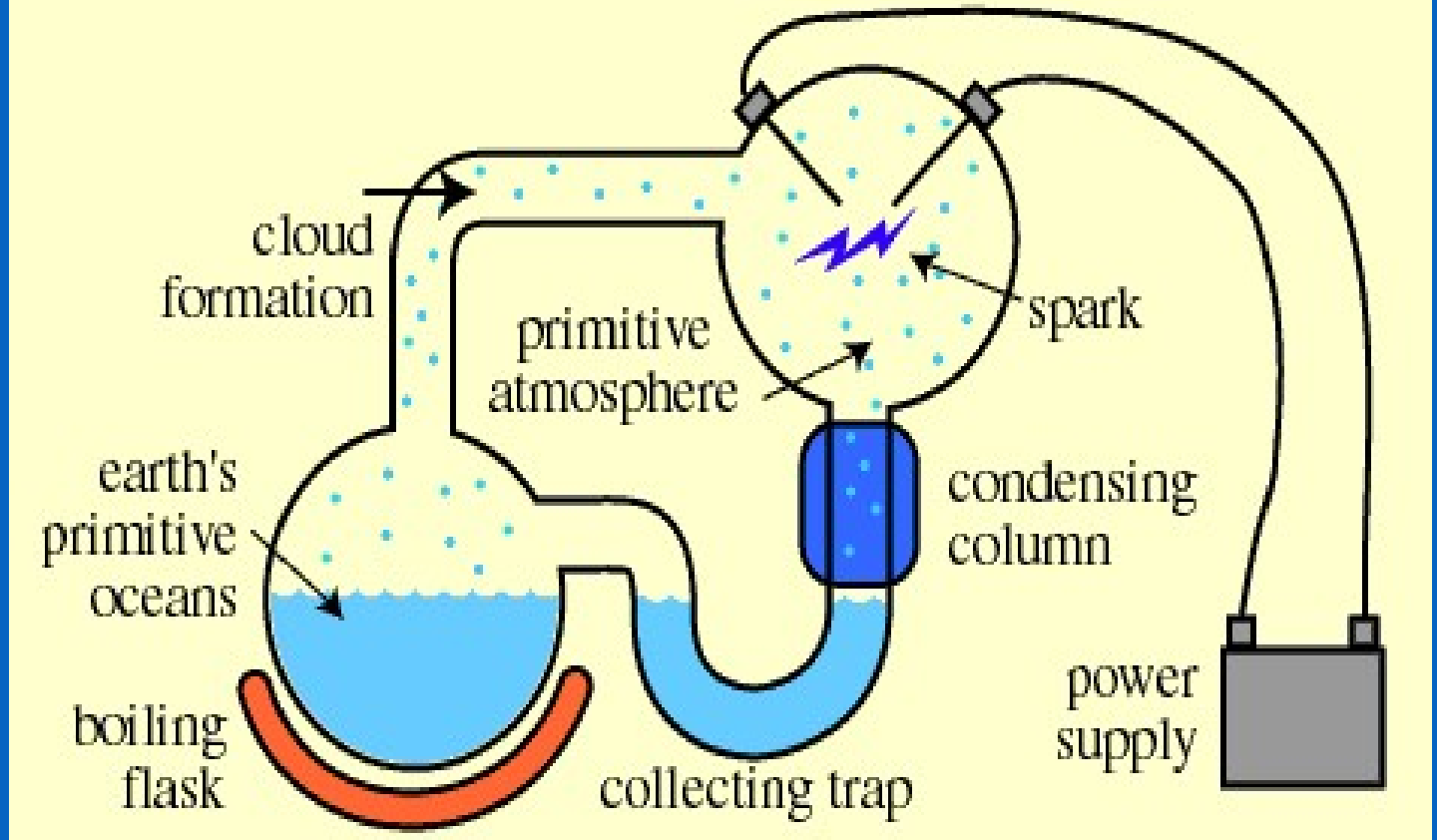
Department of Physics

Amrit Campus

Introduction

- *Beginning of the lightning flash*
- *Lightning is believed to have been occuring on earth long before the existence of life on it.*
- *Lightning is attributed to be responsible for the production of the biochemical molecule of life.*





Lightning may have created the first building block of life on Earth


Beginning of
Lightning
Research

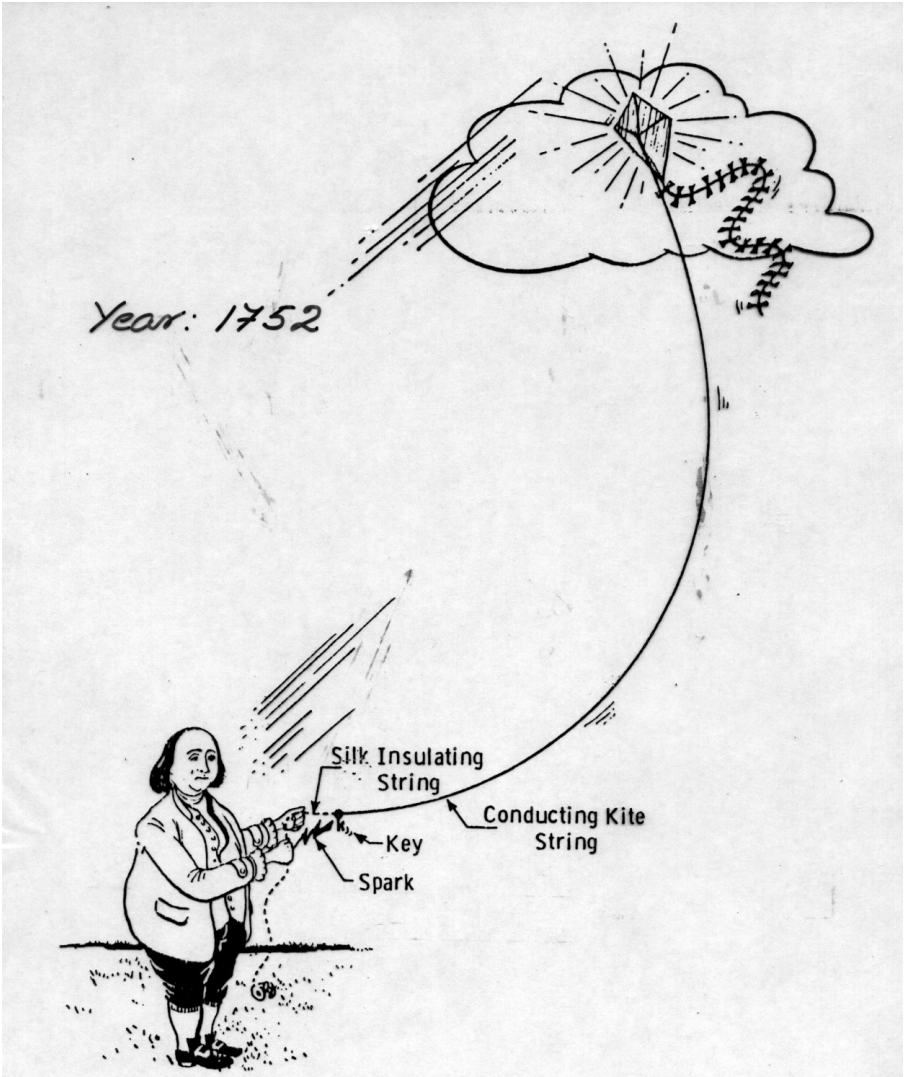
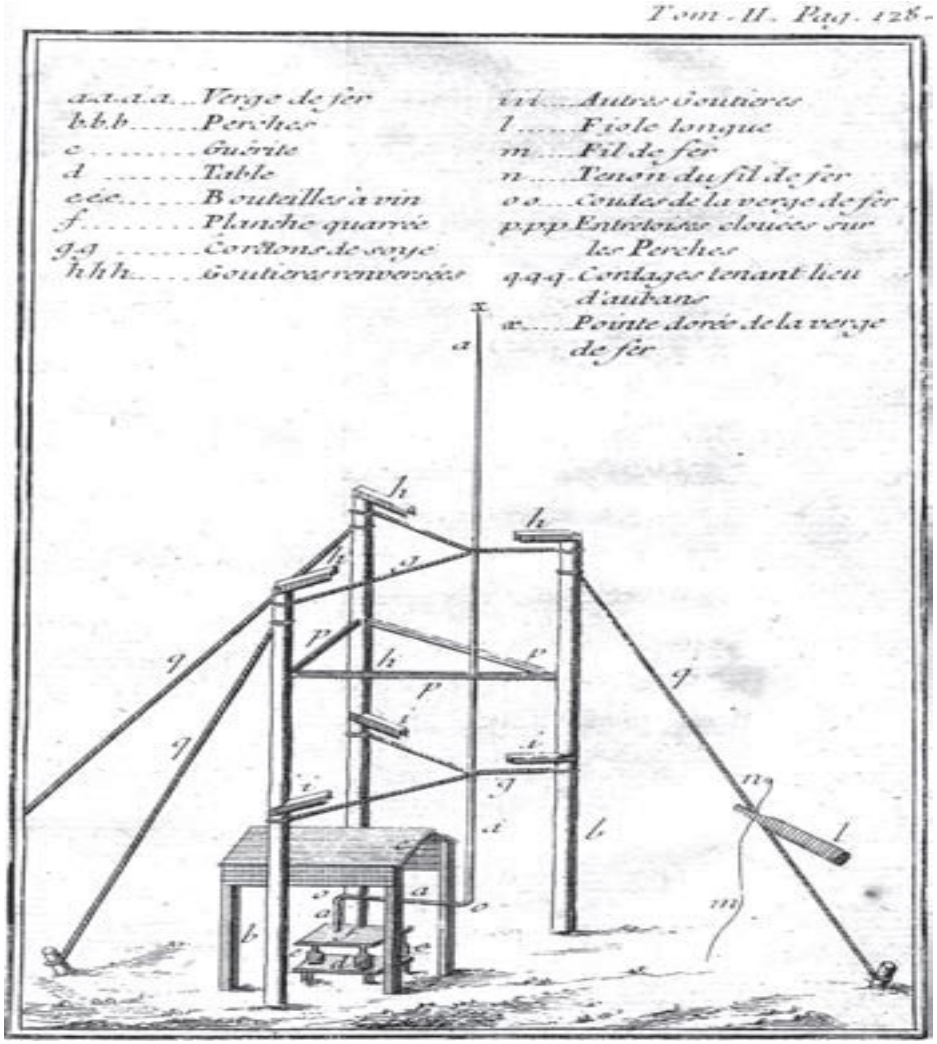


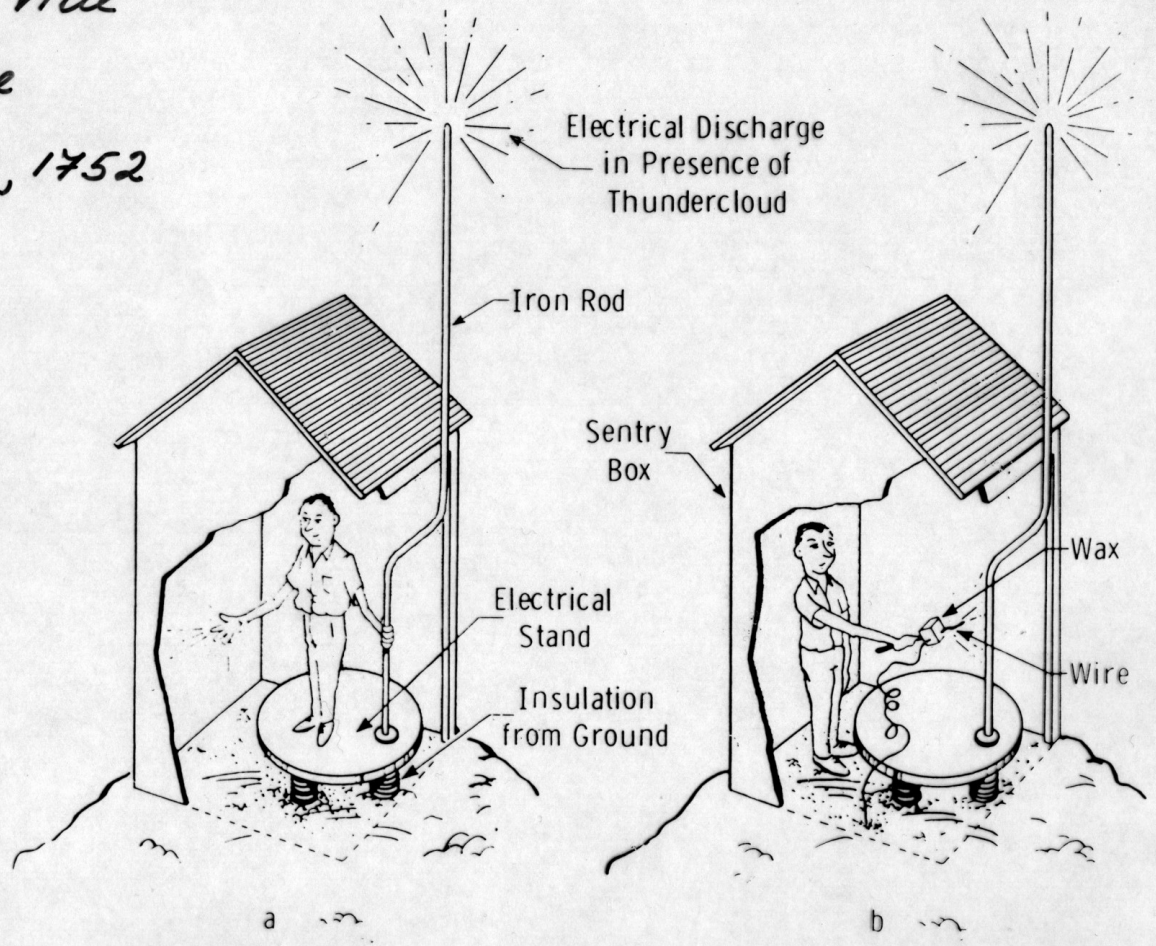
Fig. 1.2. Franklin's electrical kite experiment: Sparks jump from the electrified key at the end of the electrified kite string to Franklin's hand.


100
FEDERAL RESERVE NOTE
KB 46279860 I
B2
THE UNITED STATES OF AMERICA
100
KB 46279860 I
THIS NOTE IS LEGAL TENDER
FOR ALL DEBTS, PUBLIC AND PRIVATE
Anna Escobedo Cabral
Treasurer of the United States.
G 2
SERIES 2006 A
Henry M. Paulson, Jr.
Secretary of the Treasury.
G 205
100
FRANKLIN
ONE HUNDRED DOLLARS

Model Sentry box



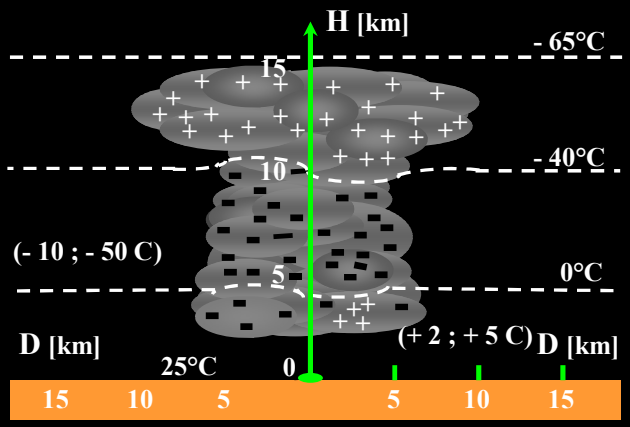
Marly la Ville
France
February, 1752



Benjamin Franklin looking at electrostatic bells he used to
study cloud electricity. Two chimes, separated from each other by a
small gap, are connected to rods that go up through the roof and to
ground. A thundercloud charges the right-hand bell, either by induction
or point discharge; the bell then alternately attracts or repels a small
ball suspended between the chimes on a silk thread. The ball rattles
between the bells, ringing an alarm when a storm approaches. The electroscope hanging from the right-hand bell was used to measure the
cloud's polarity. A grounded rod of Franklin's 1762 design can be
seen through the window on the right

Thunderstorms

Cumulonimbus cloud



diameter : ~ 10 km

height to top (anvil) : ~ 10 to 15 km

height to base : ~ 1 to 2 km

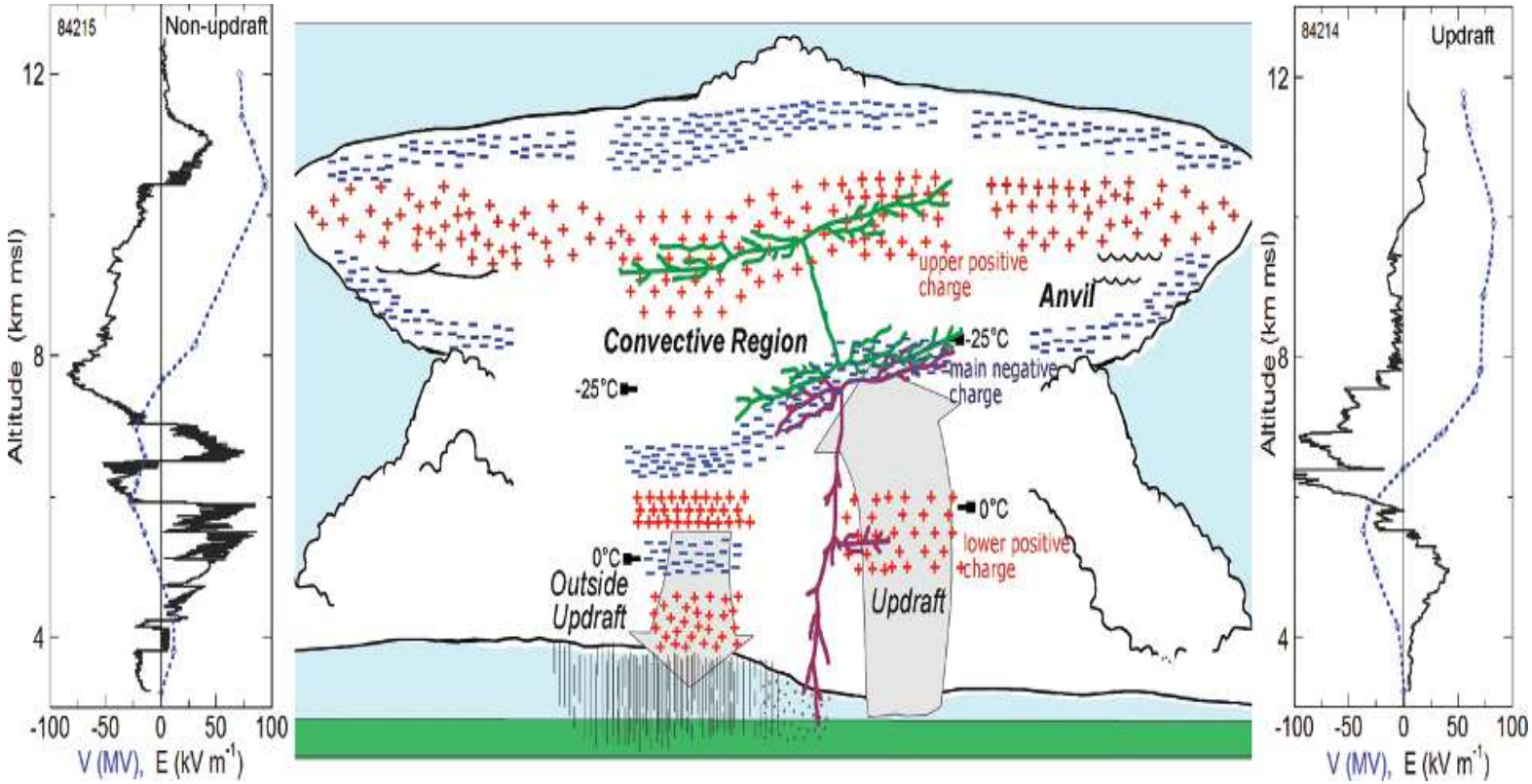
mass of water : ~ 10^8 kg

electric charge : ~ 100 C

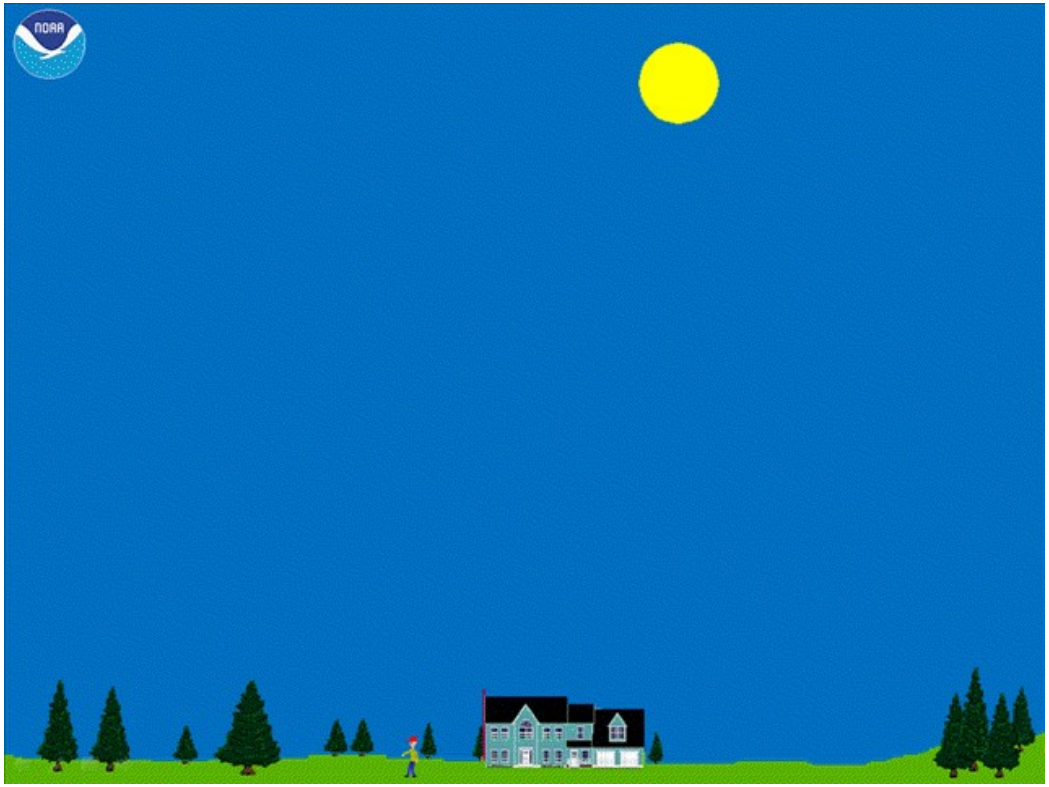
electric potential (CG) : ~ 100 MV

duration : ~ 1 hour

Charge structure of thundercloud

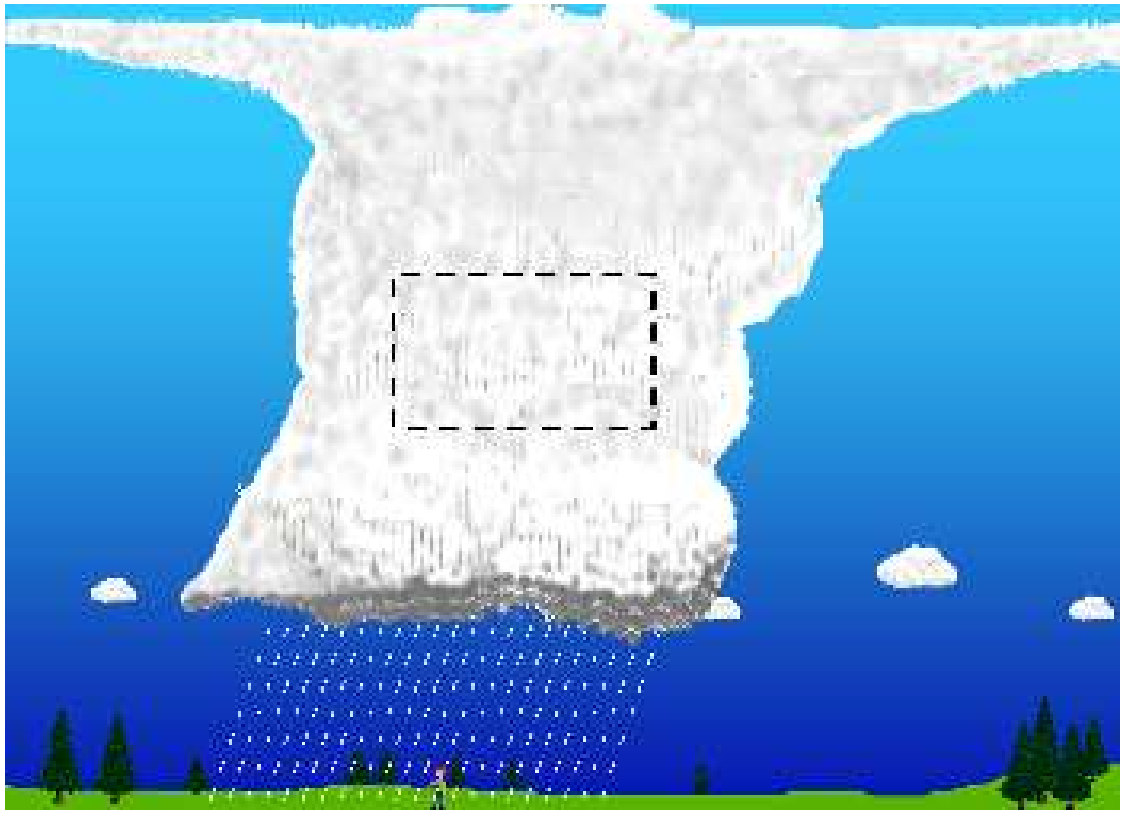


Thunderstorm Development



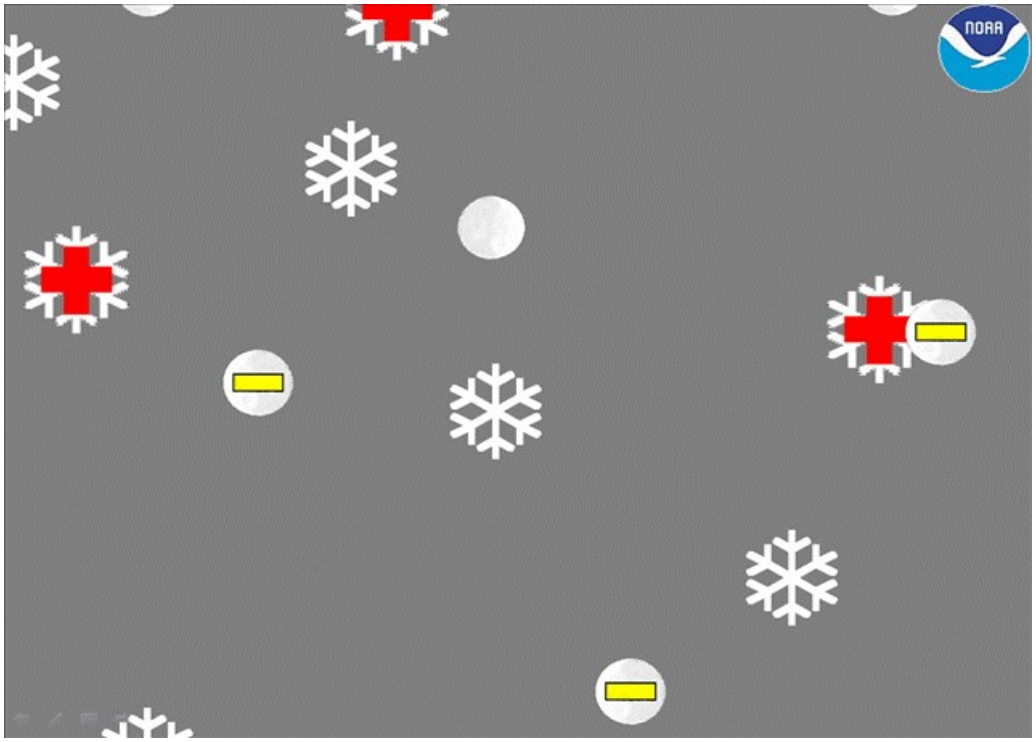
During the day, the sun heats the air near the ground and causes it to rise. When the rising air reaches a certain level in the atmosphere, cumulus clouds start to form. Under certain atmospheric conditions, these cumulus clouds to grow into an anvil-topped thunderstorm cloud (cumulonimbus).

Getting All Charged Up



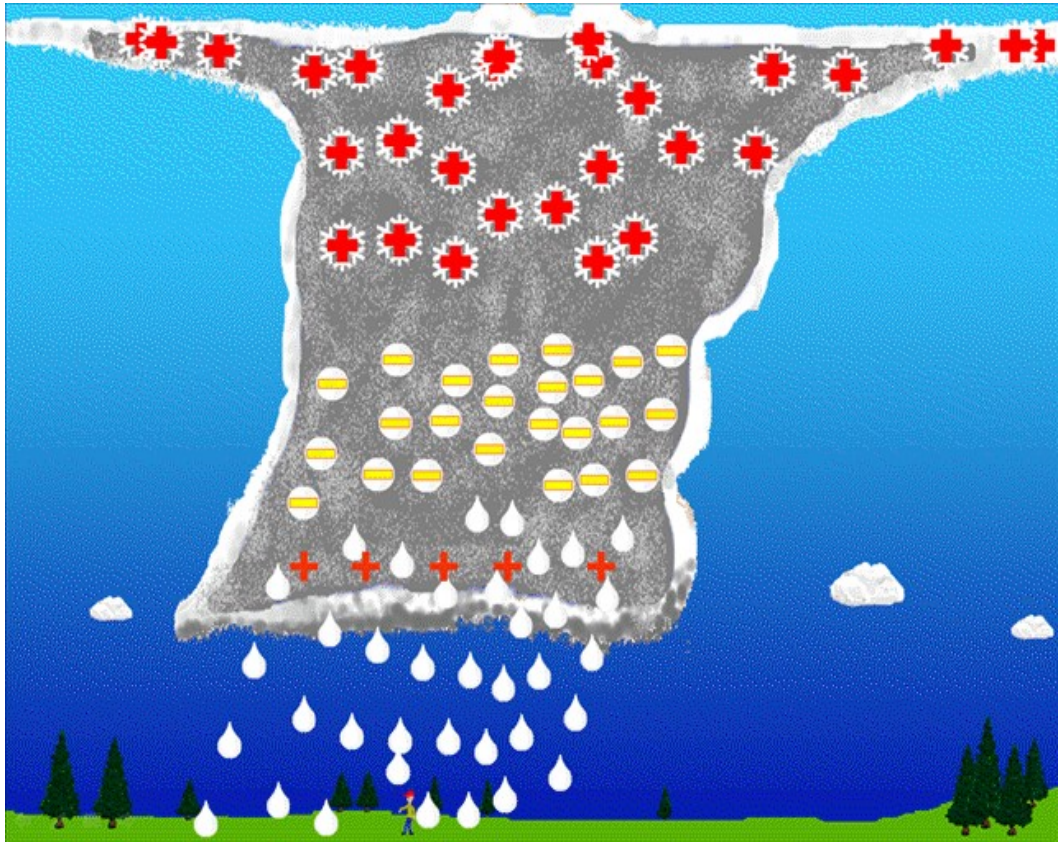
The main charging area of the thunderstorm cloud is in the central part of the storm where temperatures are between -10 and -25 degrees Celsius.

Charging in the Clouds



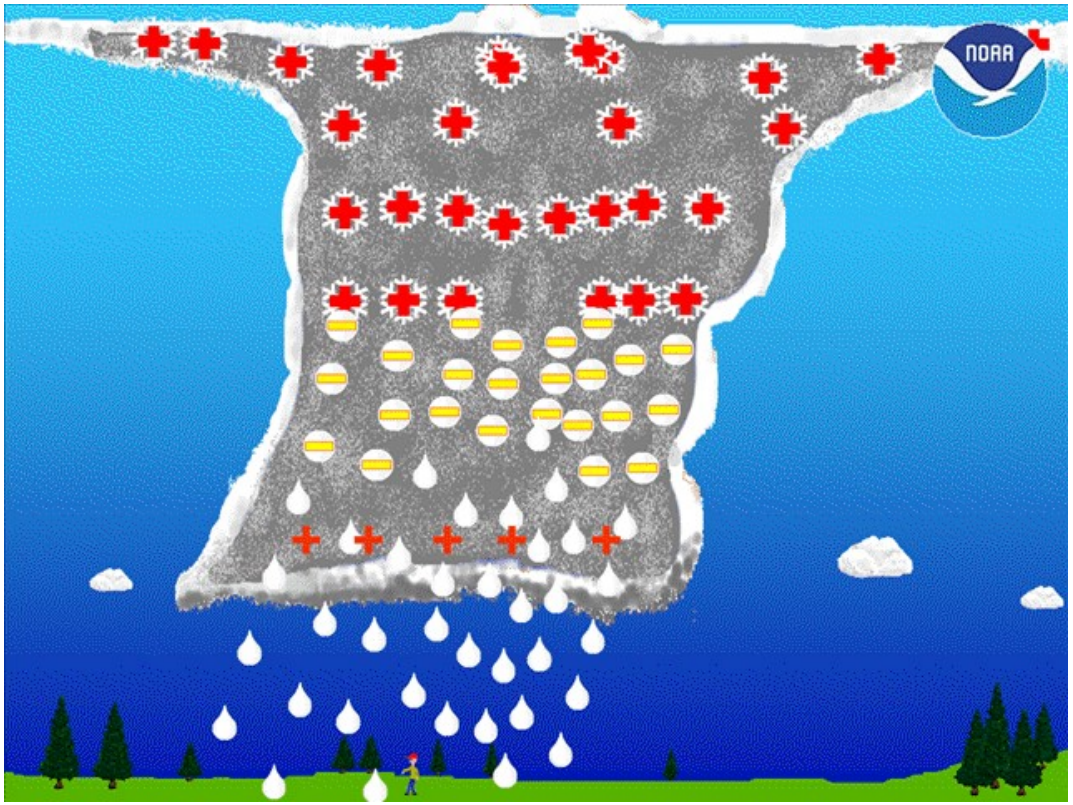
Here in the central part of the storm, very tiny ice crystals collide with soft pellets of hail in the presence of tiny liquid cloud droplets. After the collisions, where cloud temperatures are between -15°C and -25°C, the ice crystals become positively charged and the soft hail becomes negatively charged. 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



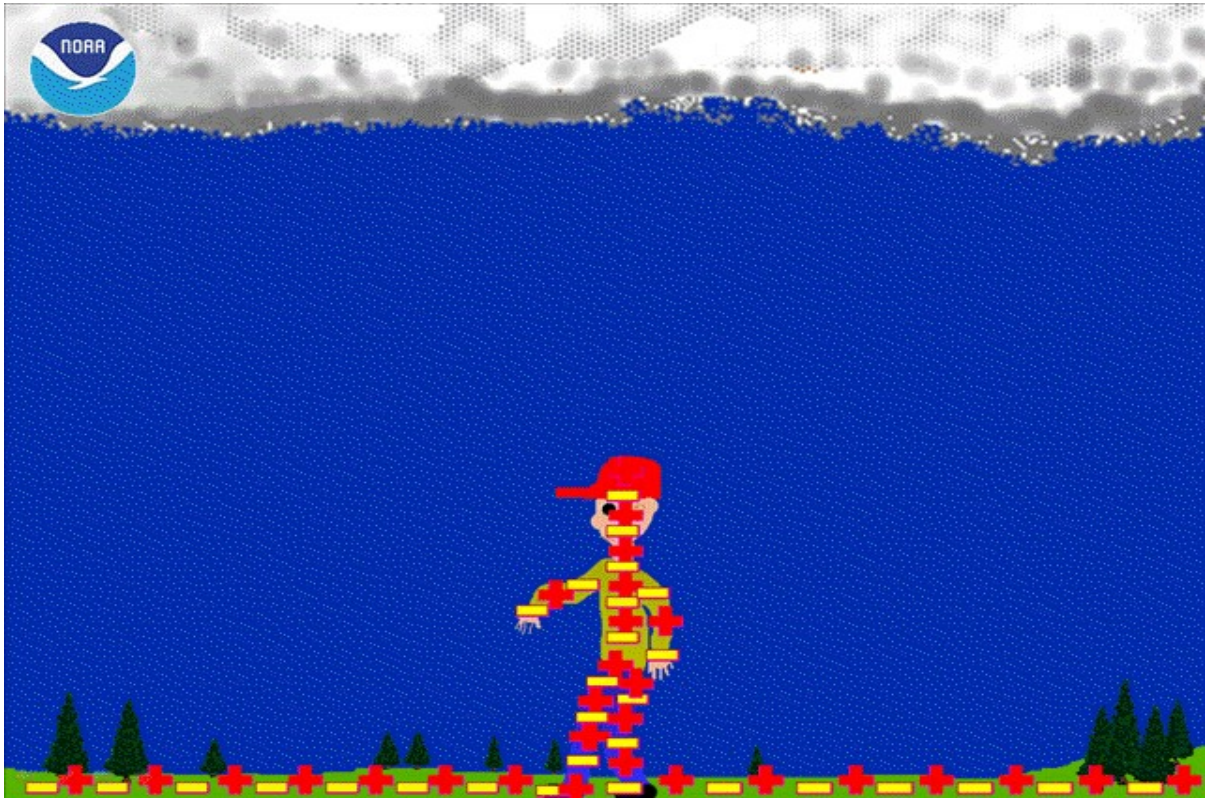
The very light ice crystals are carried upward by the updraft winds. In comparison, the larger and denser soft hail is suspended or falls. As a result, the top of the storm cloud becomes positively charged while the central to lower part of the storm becomes negatively charged. A small positive charge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

Charging on the ground

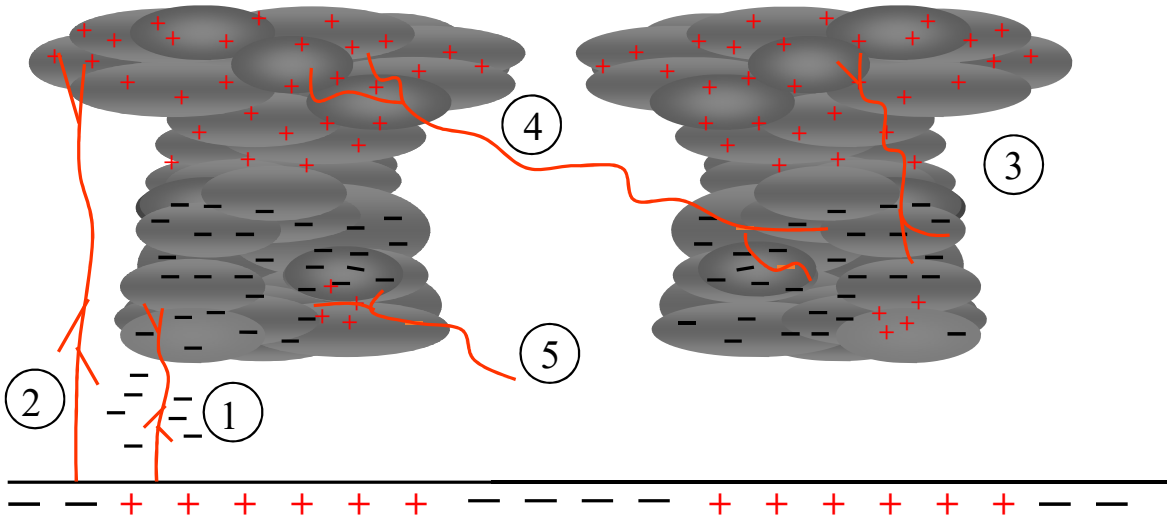


The cloud charges also affect objects on the ground. The negative charges in the cloud not only repel the negative charges in the ground, but, if you're outside, also in you. This could cause you to become positively charged.

Under the charged thunderstorm

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.

Types of lightning discharges



① cloud-to-ground flash (negative)

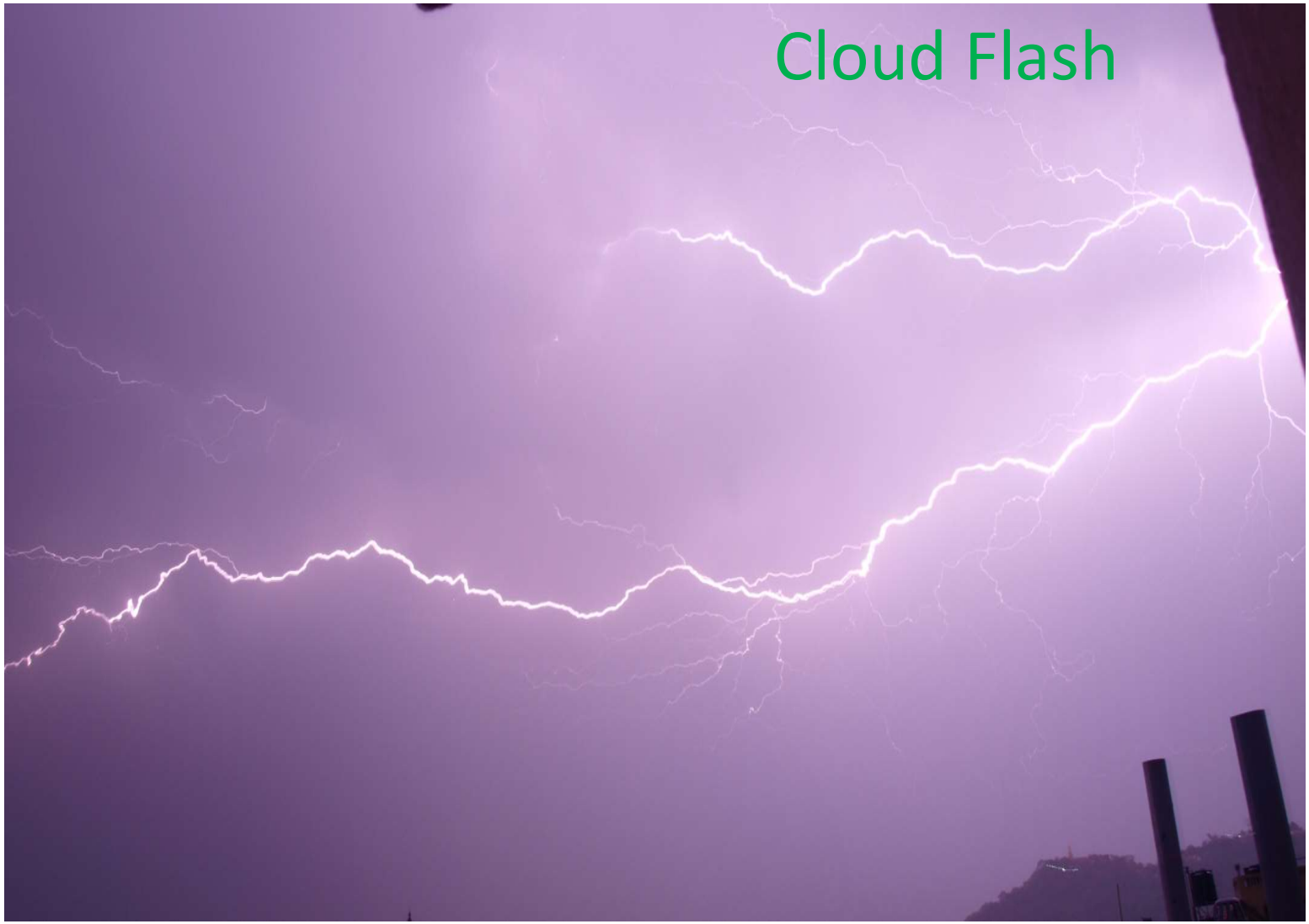
② cloud-to-ground flash (positive)

③ intracloud discharge

④ intercloud discharge

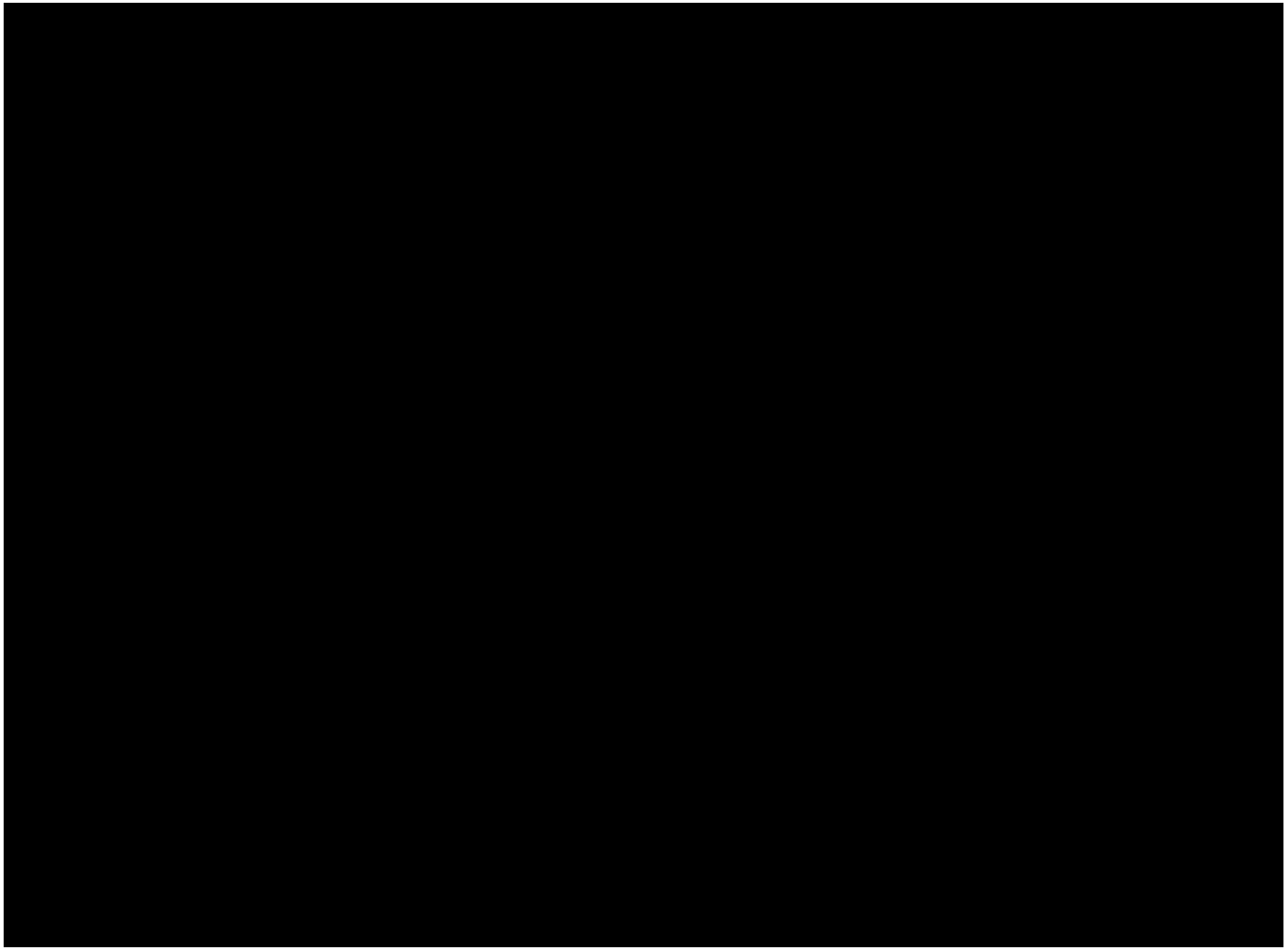
⑤ cloud-to-air discharge

Cloud to ground flash


Cloud Flash

Cloud to the air upward

Lightning phenomenology



The Lightning Ground Flash

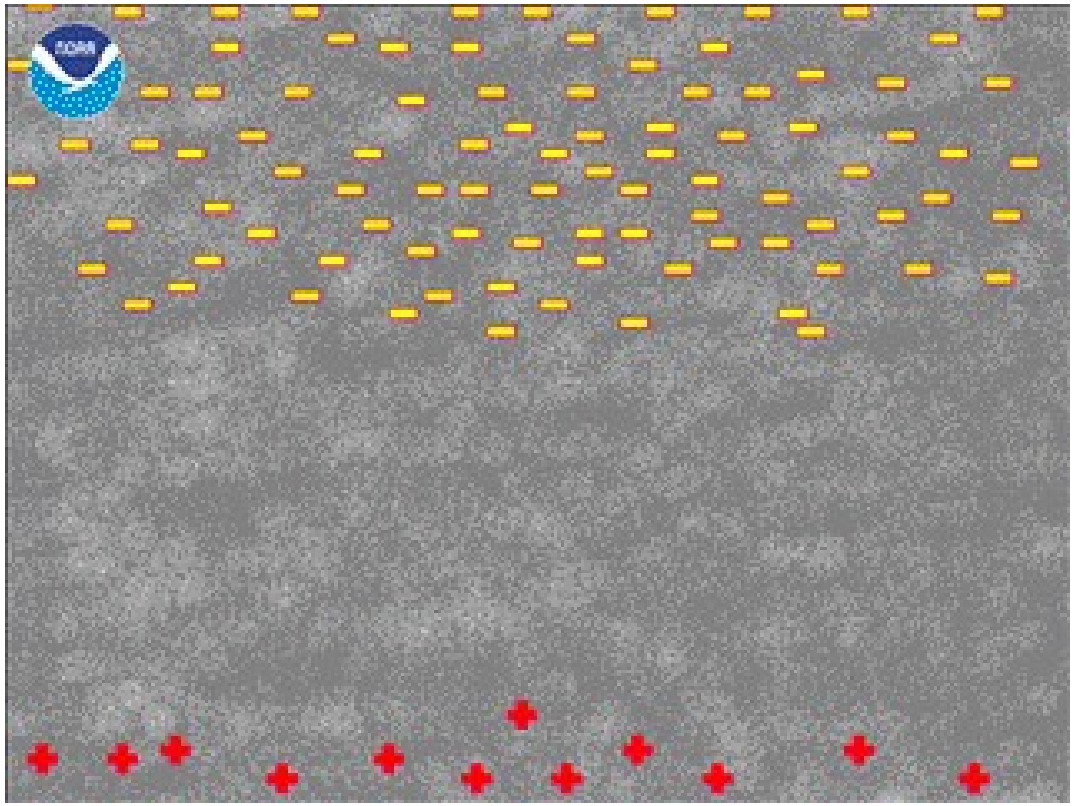
The most common cloud-to-ground lightning flash consists of:

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

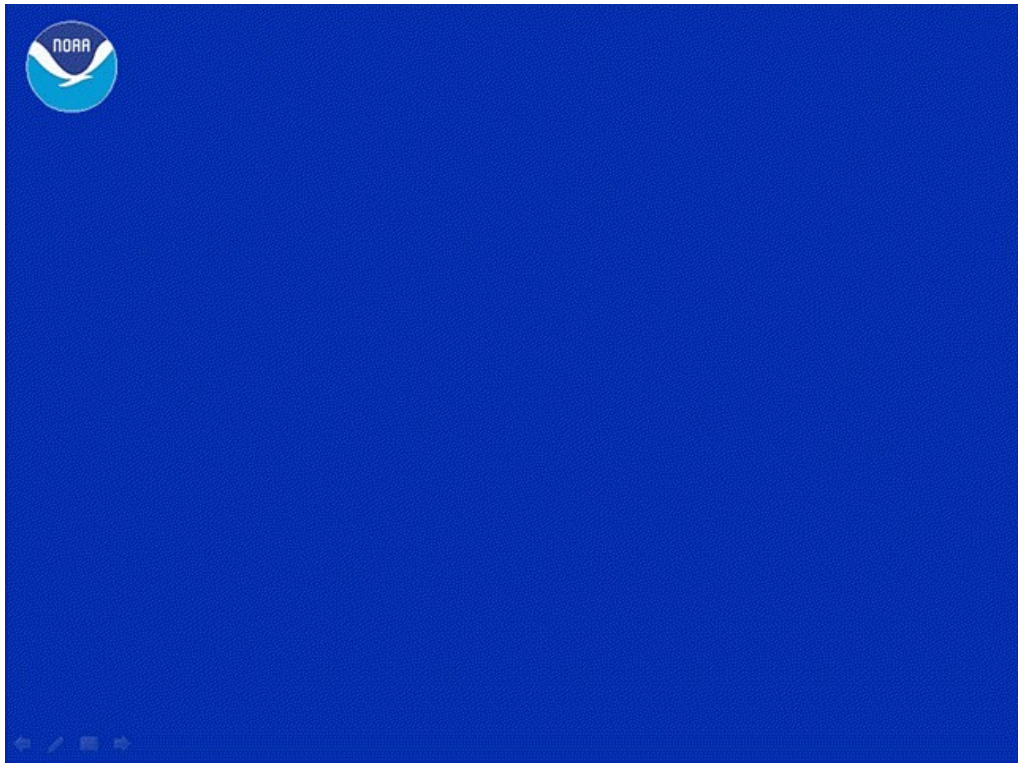


Air is normally a poor conductor of electricity. However, if the charge difference (electrical potential) between the oppositely charged areas within the cloud becomes too large, the air loses its ability to stop charge movement and negative charges start to move toward the ground.

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.

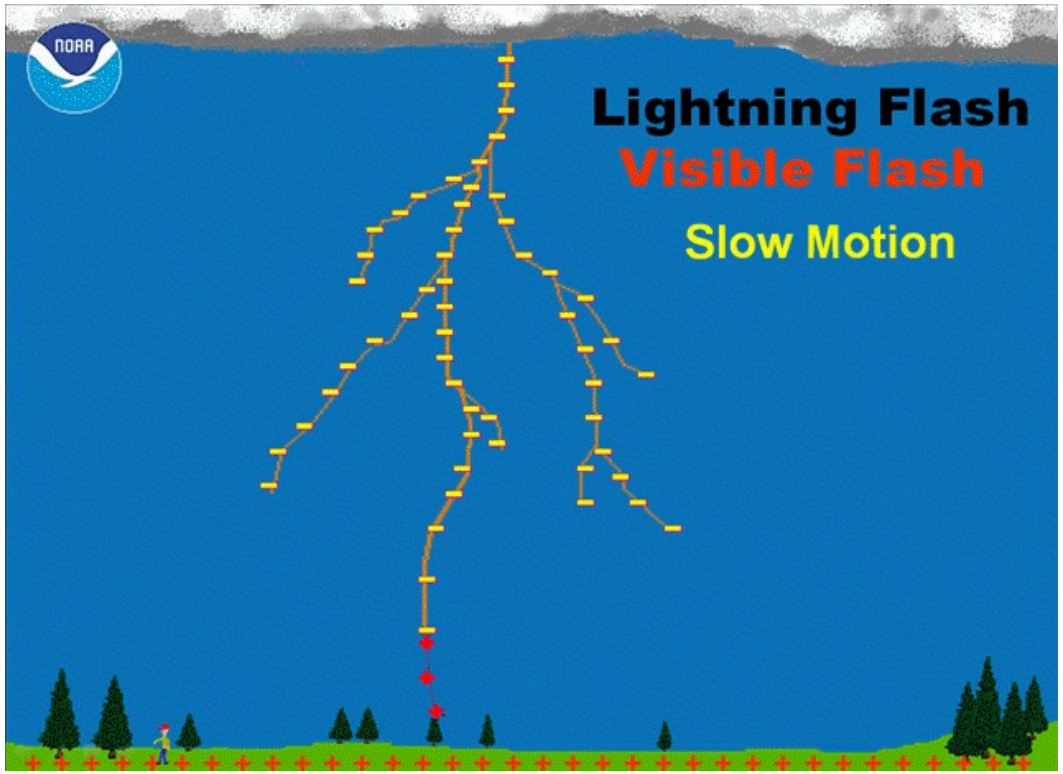
Faster Than a Speeding Bullet

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

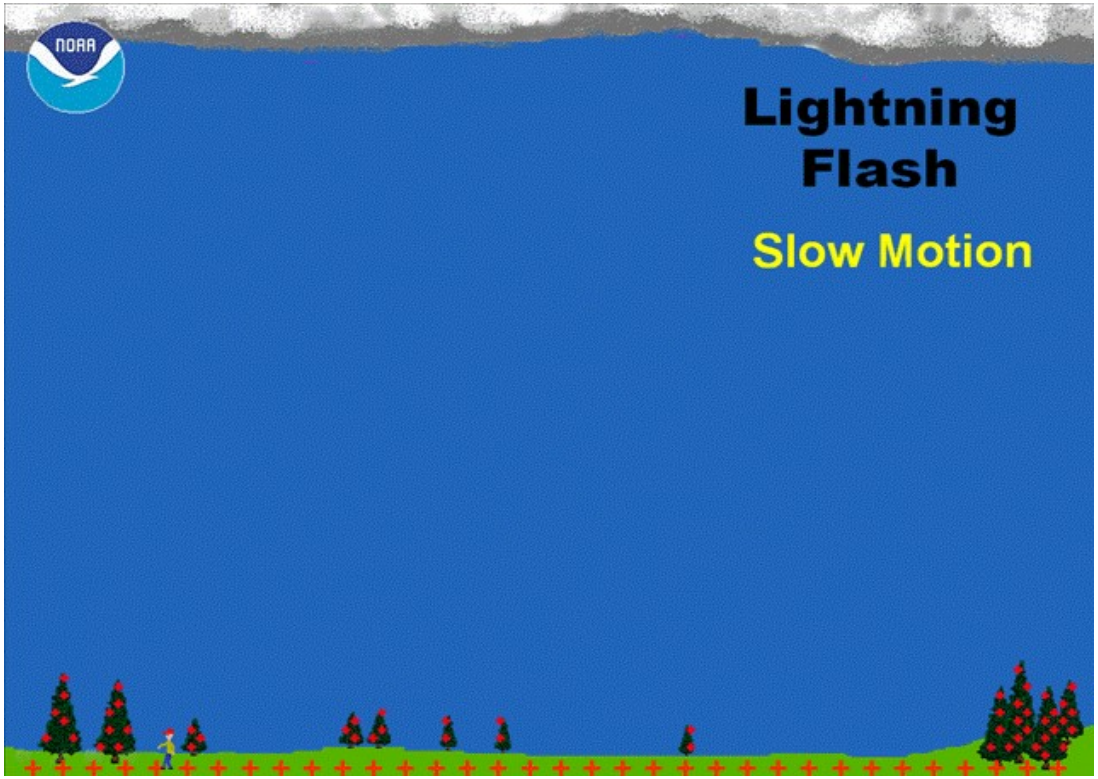


Once the stepped leader connects with an upward streamer, the channel starts discharging rapidly to the ground. The actual discharge begins near the ground and works its way through the entire channel. As it does, the discharge creates a very bright flash of light called the "return stroke" which moves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

Dart Leaders and Return Strokes

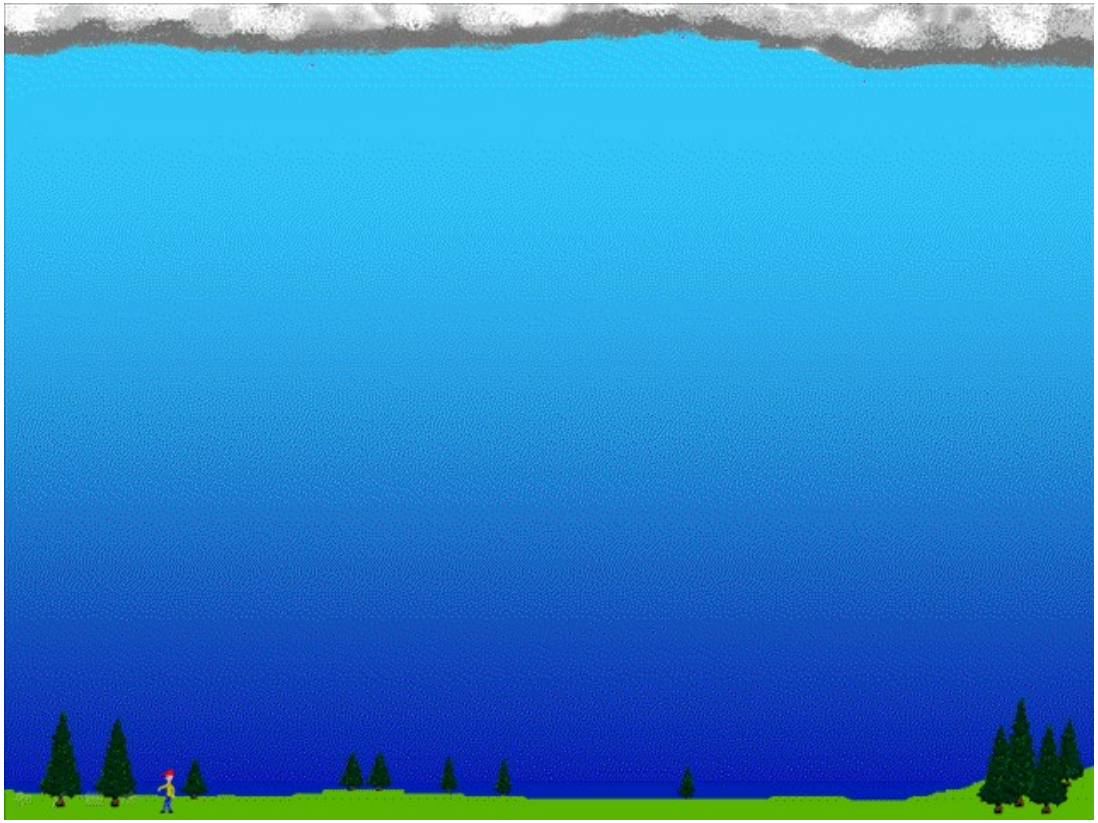
The initial flash momentarily leaves an ionized channel in the atmosphere. If additional charges in the cloud are immediately available to the channel, another negatively charged leader will start moving toward the ground. We call this a "dart leader." Once it reaches the ground, it will discharge via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

The Lightning Flash - 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

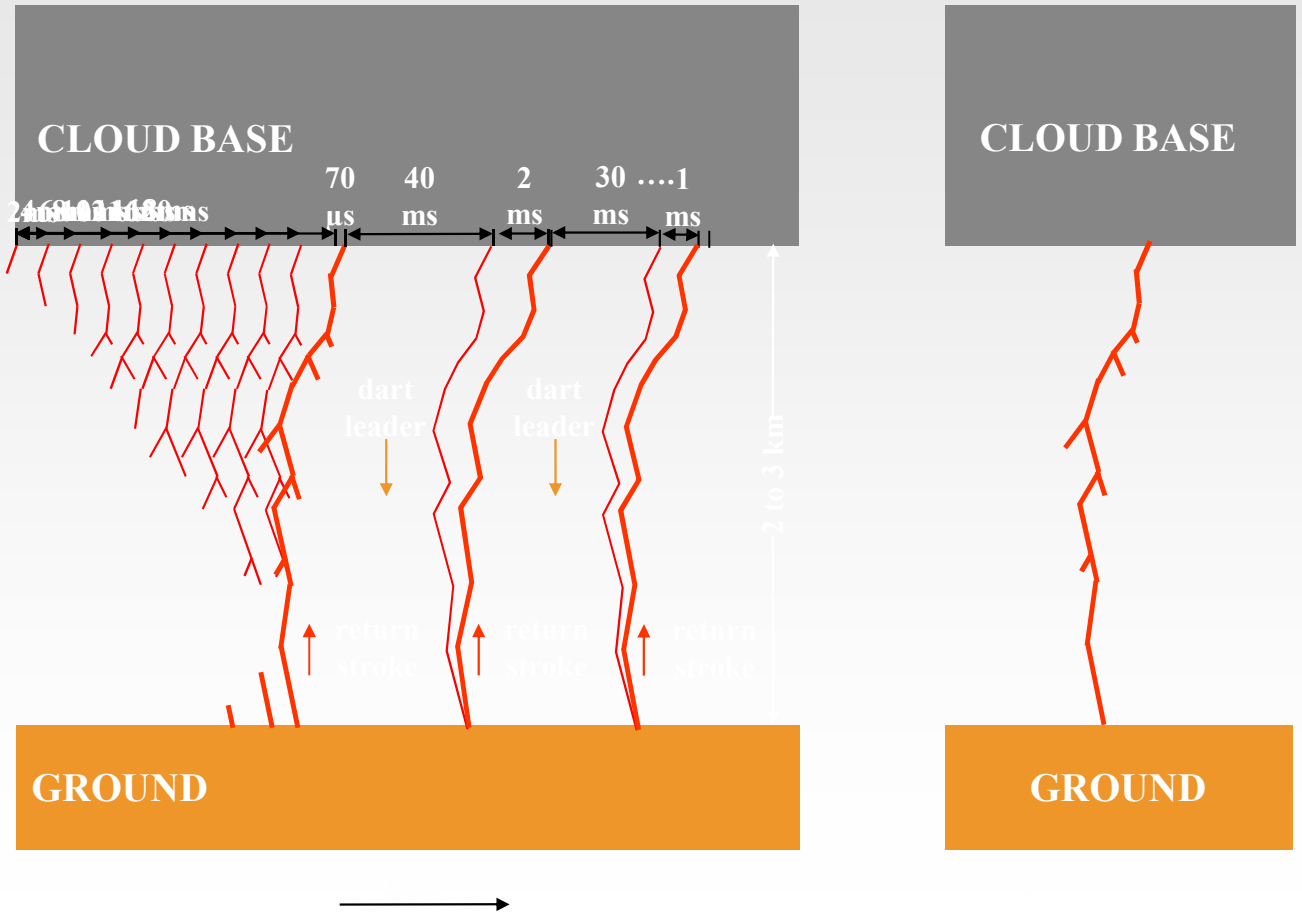
High speed cameras can be used to capture video of lightning strikes. When played back in slow motion, we can see the stepped leader and return stroke. In this video, the elapsed time between when you see the stepped leader and when you see the return stroke is 1/133rd of a second.

Lightning Flash Video

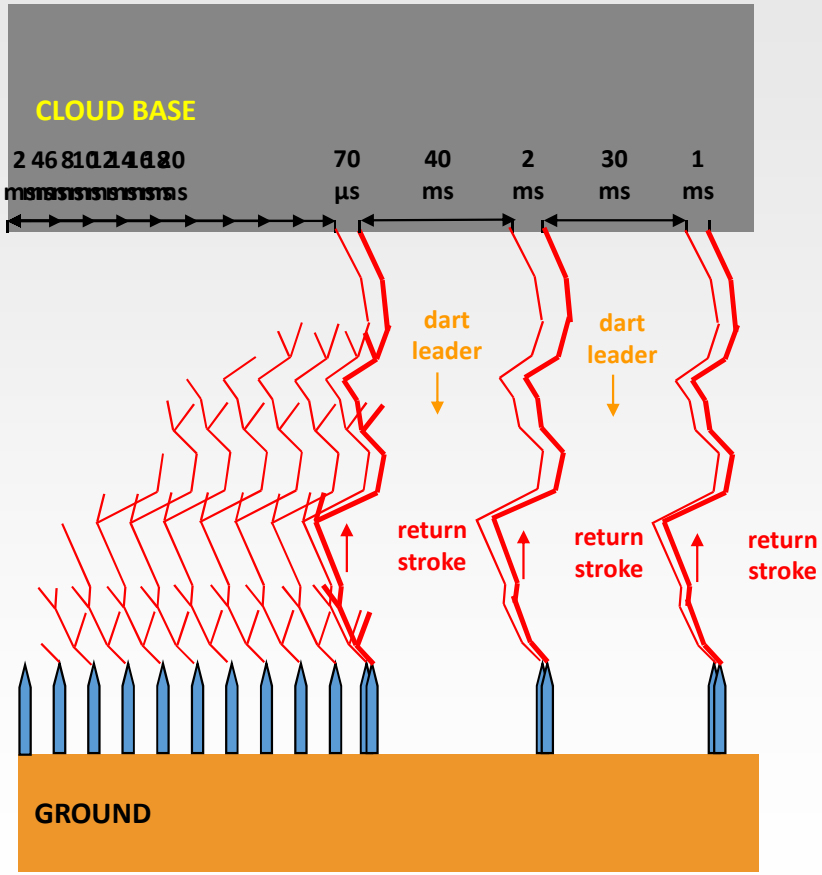
Here's another video of a lightning flash. In this case, two branches of a stepped leader race to the ground looking for a connection. The first branch to reach the ground, discharges the entire channel. In this video, the elapsed time from when you first see the stepped leader to when you see the return 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.

Time resolved picture of a lightning flash

FLASH DEVELOPEMENT
from a flat ground

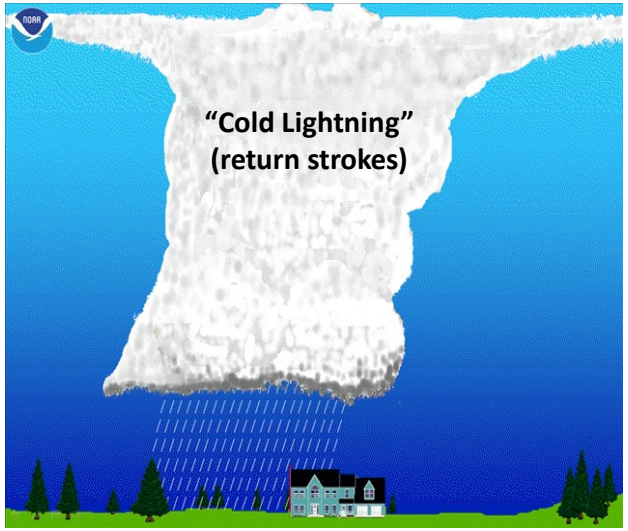


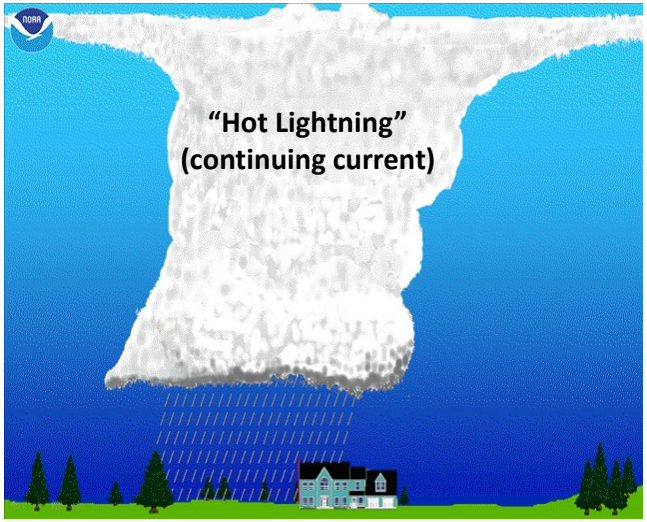
FLASH DEVELOPMENT
from a tall structure



Static picture

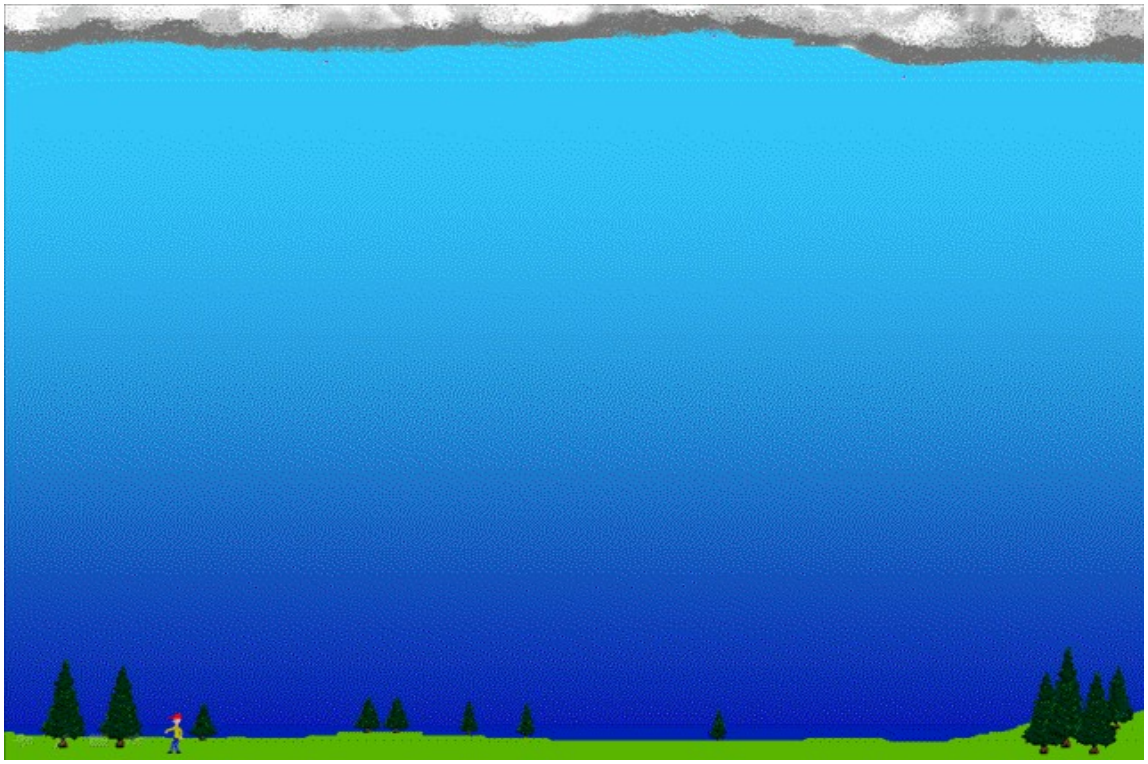
Continuing Current and Fires





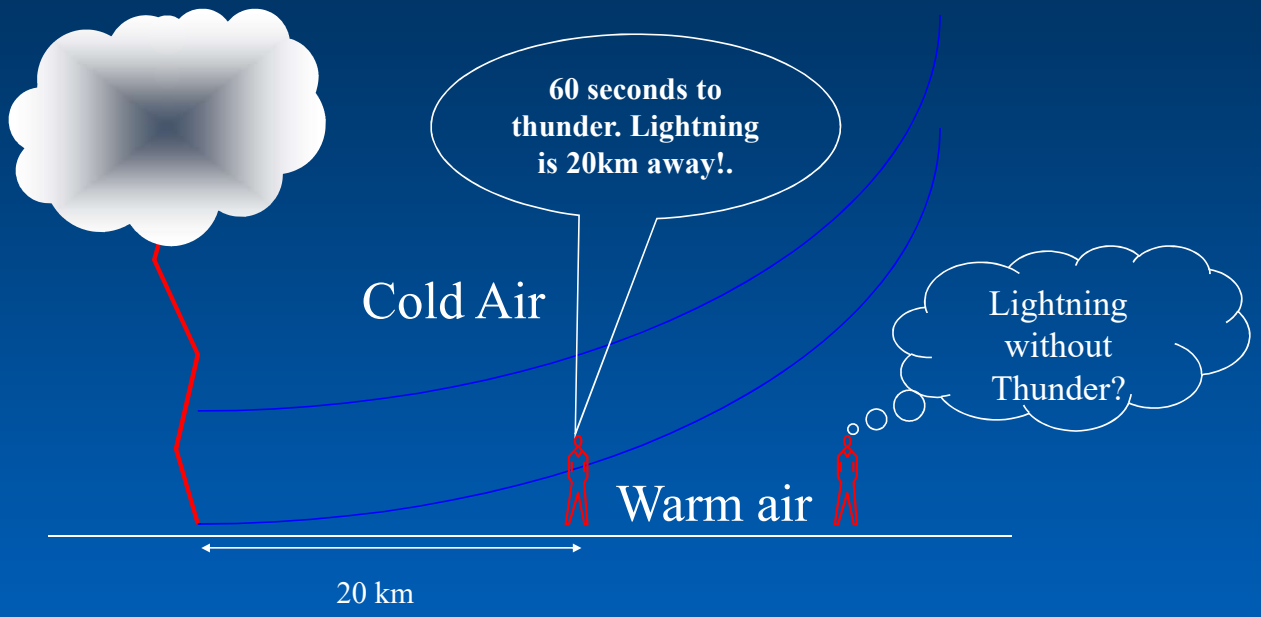
As shown on the previous page, some lightning flashes contain a continuous flow of electricity rather than (or in addition to) return strokes. Because this "continuing current" flows for a much longer period of time, it can heat an object to its ignition point and cause a fire. Lightning with continuing 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



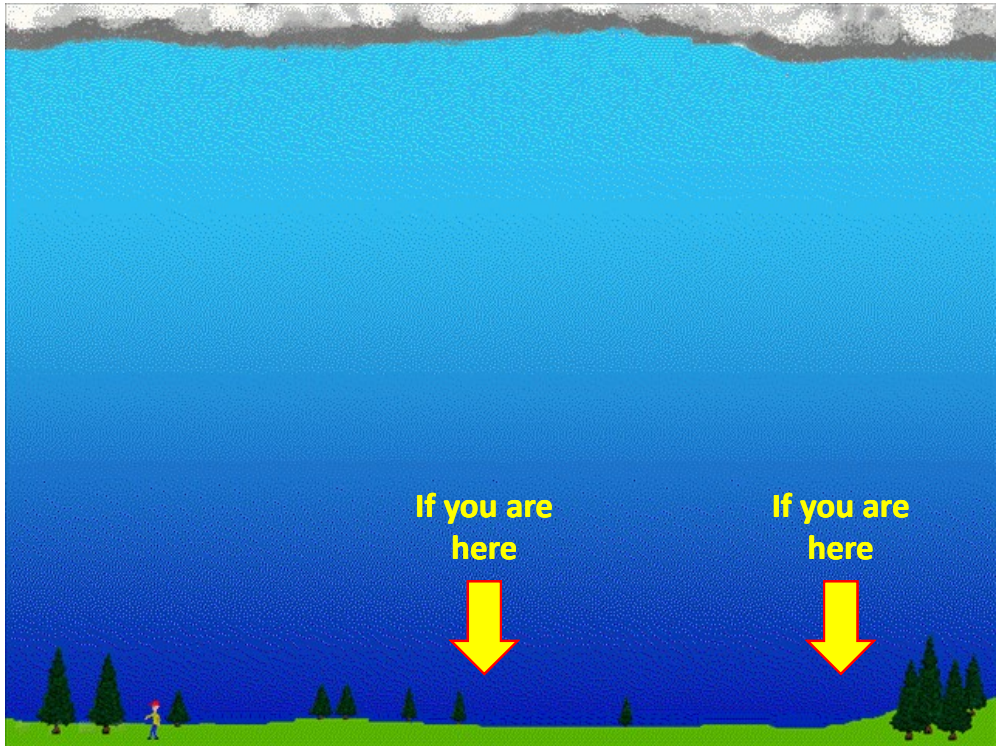
When lightning passes through the air, it heats the air very rapidly and causes it to expand. Immediately after the flash, the air cools and contracts quickly. This rapid expansion and contraction creates a sound wave that we call thunder.

Thunder?

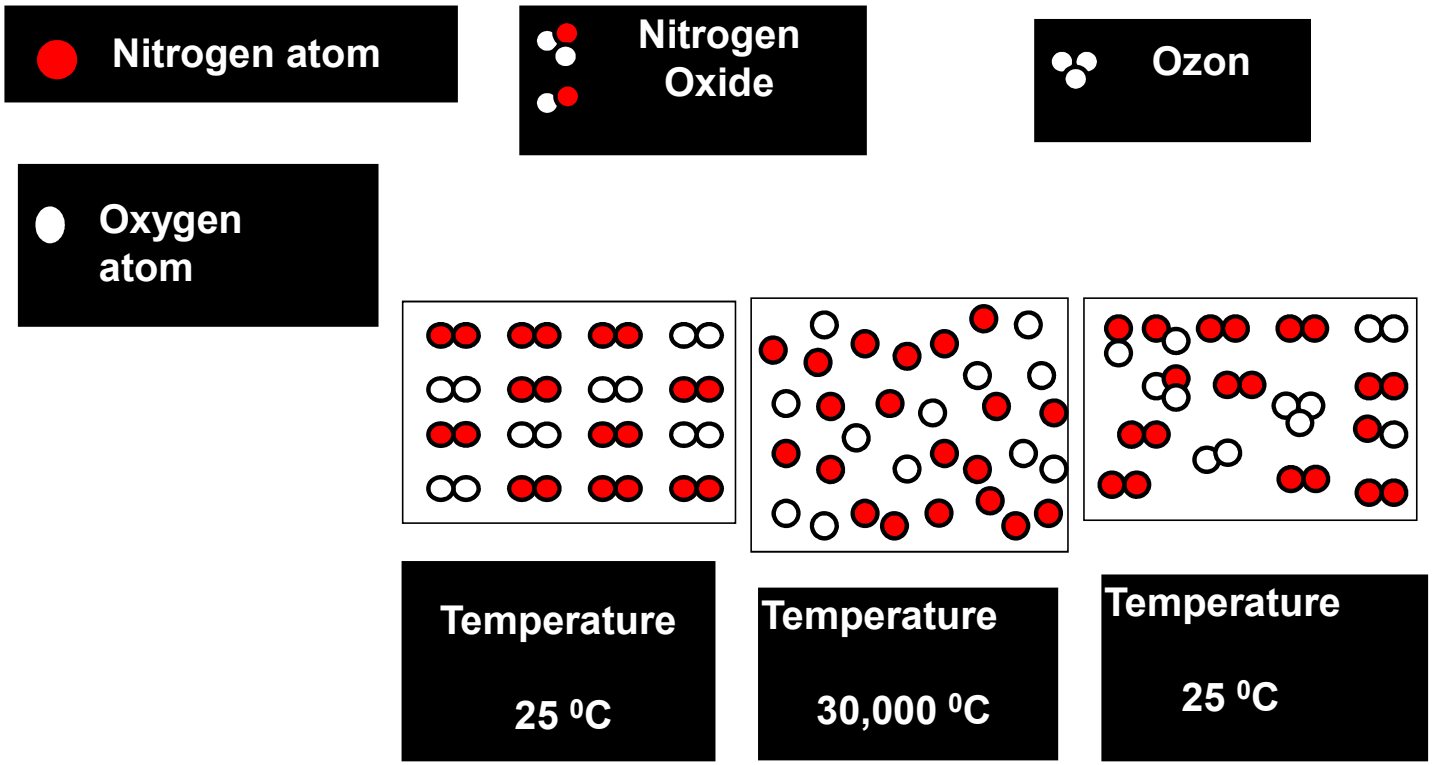


In a lightning flash air is heated to about 30000 K.

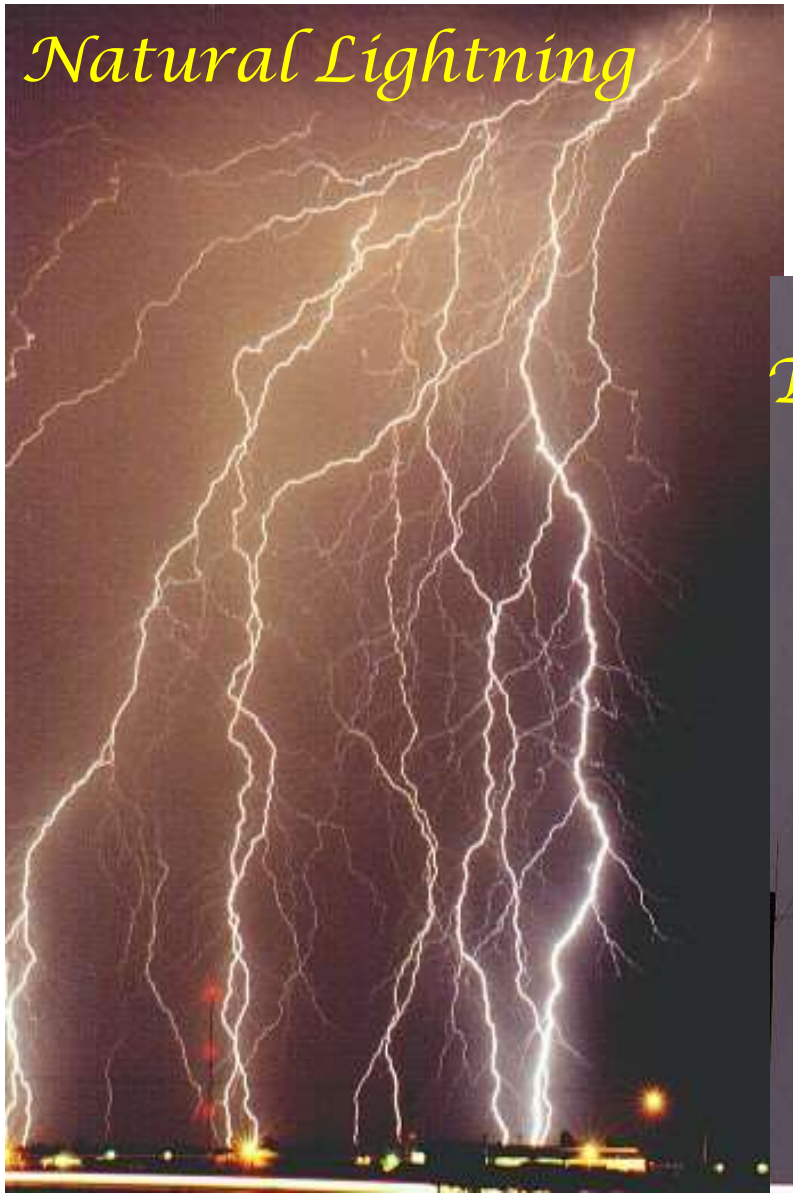
Thunder



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.

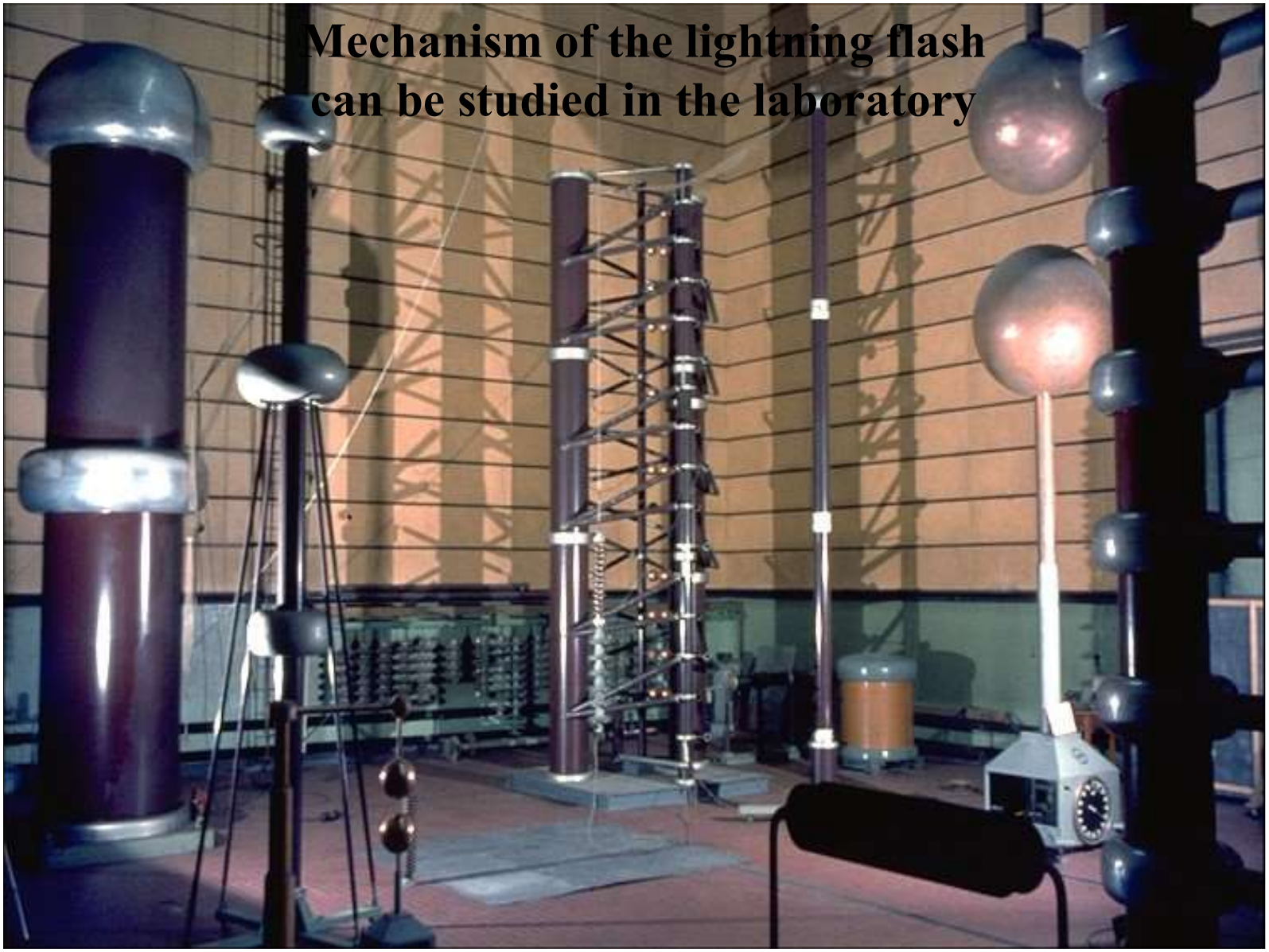


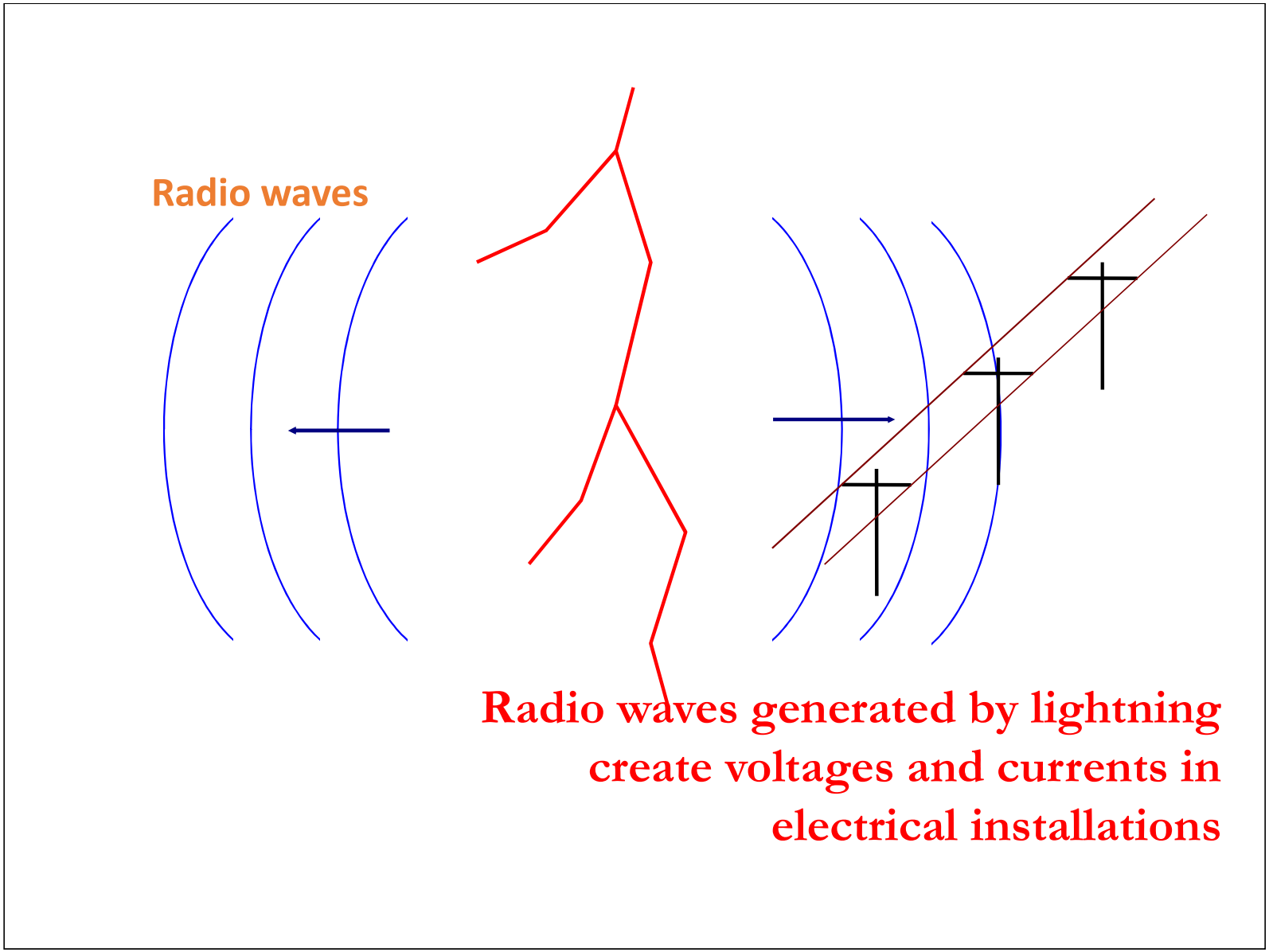
Lightning can create Nitrogen Oxides in air



Natural and triggered lightning

Triggered Lightning


Mechanism of the lightning flash
can be studied in the laboratory


Radio waves
Radio waves generated by lightning
create voltages and currents in
electrical installations

Electric field measurement

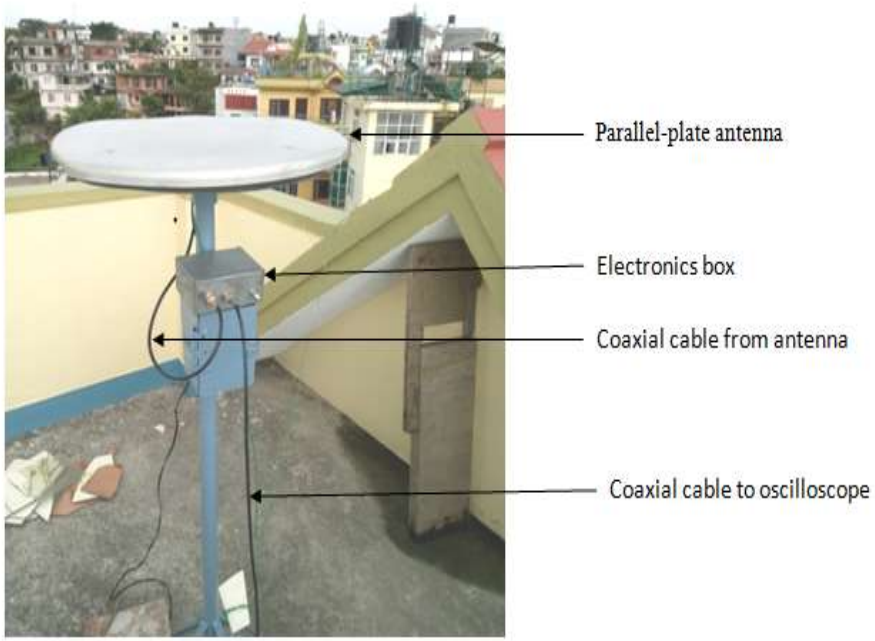
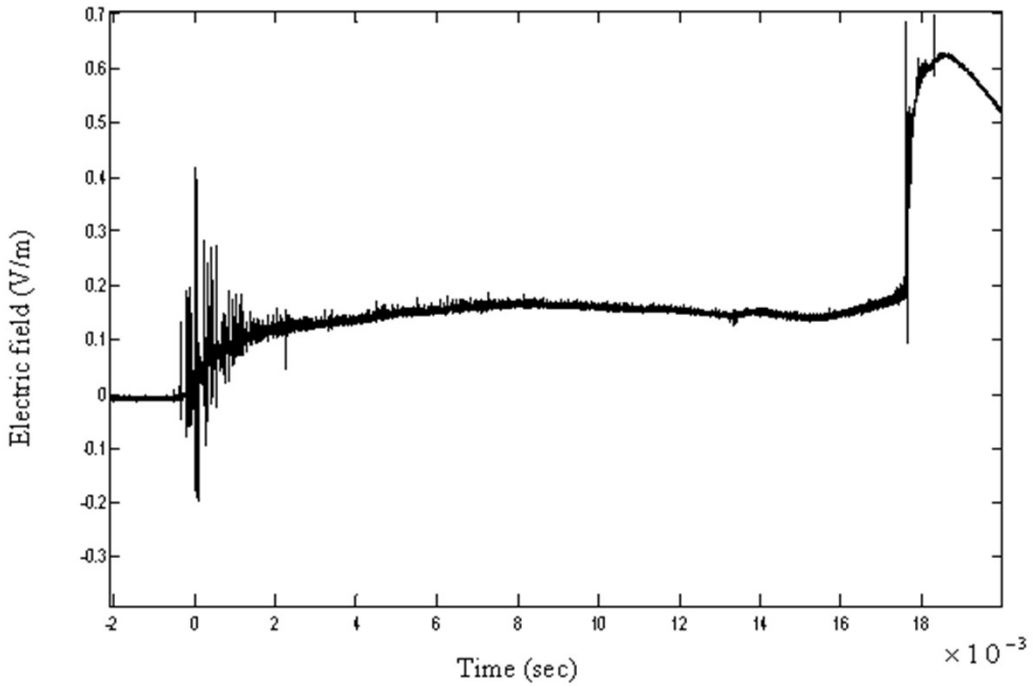


Figure: The elevated parallel-plate antenna installed in Kathmandu in this study

Negative stroke



Stroke Antenna and GPS system

Blue jets and sprites