



Courtesy of NOAA

## Chapter 21 Lightning

**Lightning** – an electrical discharge in the atmosphere

### Lightning Facts

On average a lightning stroke is 5 km long and 2 to 3 cm in diameter

Approximately 100 lightning strokes occur on the Earth every second

The temperature of a lightning stroke is 30,000 deg C (this is 5 times hotter than the surface of the Sun)

20 million cloud-to-ground lightning flashes occur in the US each year

Approximately 50 people are killed and 300 people are injured by lightning each year in the United States

### Types of lightning strokes:

In-cloud lightning

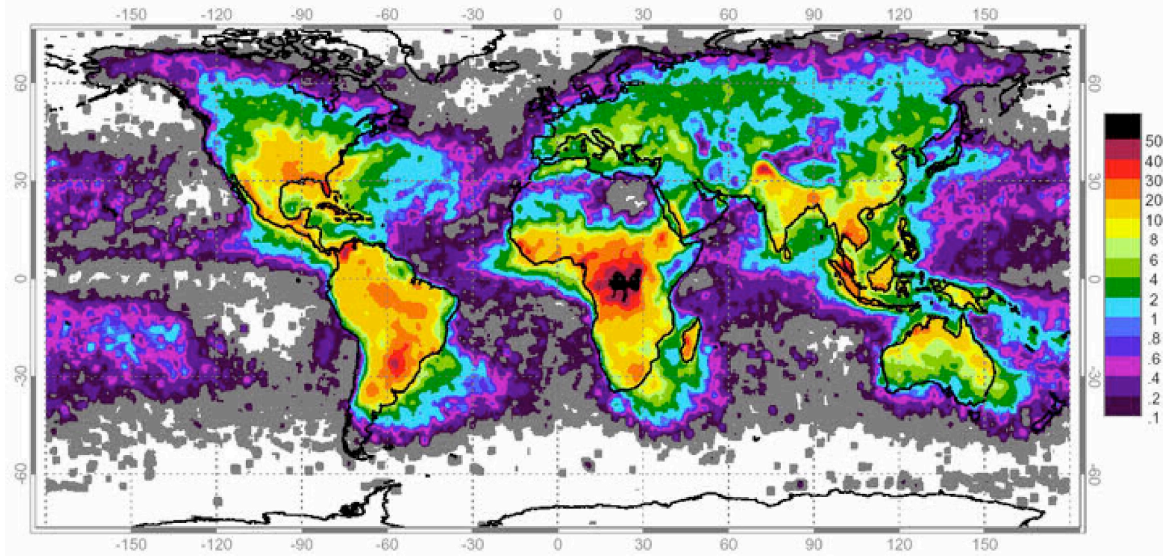
Cloud-to-cloud lightning

Cloud-to-ground lightning

What percent of lightning strokes are either in-cloud or cloud-to-cloud strokes?

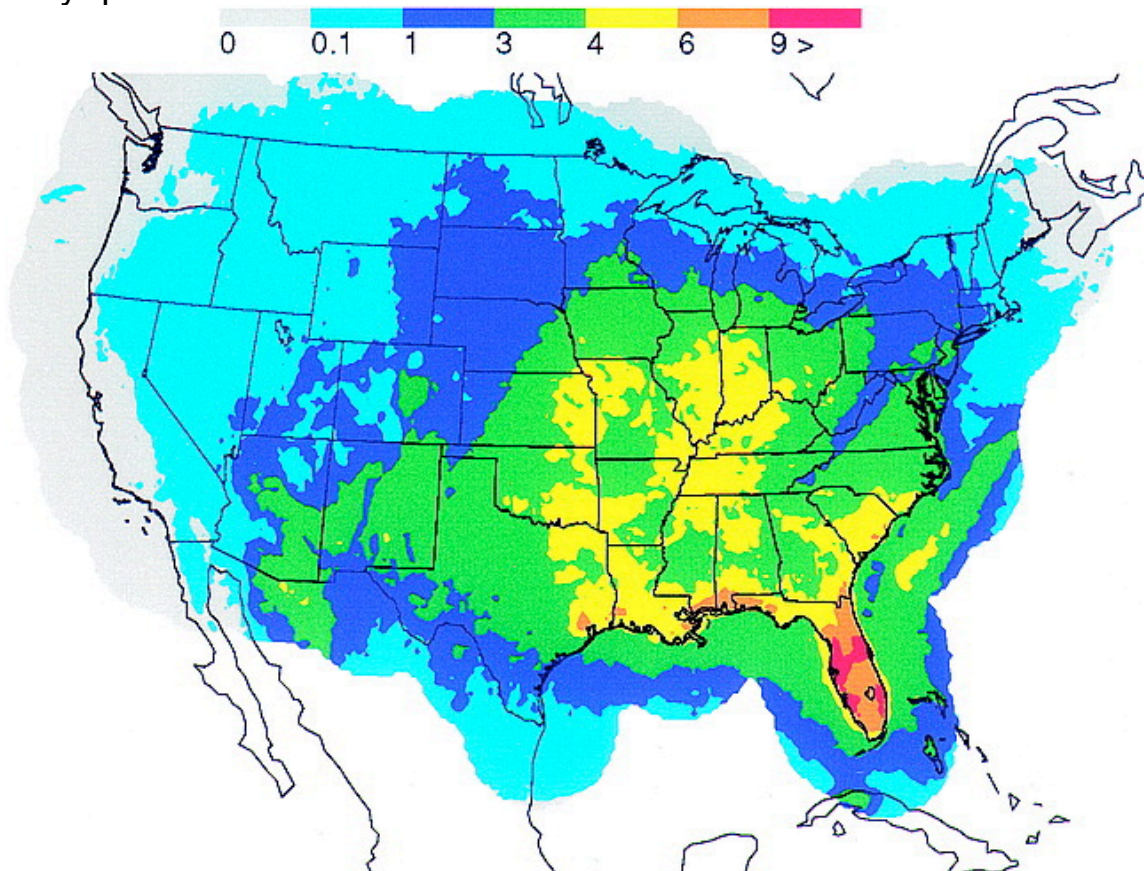
## Where does lightning occur?

Average annual number of (total) lightning flashes per sq km worldwide



Courtesy of NASA

Number of cloud-to-ground lightning strikes per square km per year in the 10-yr period 1989-1998 in the U.S.



## Electricity and Charge

**Proton** – positively charged particle

**Electron** – negatively charged particle

**Ion** – an atom with an unequal number of protons and electrons

**Electrical current** – movement of an electrical charge (typically due to the movement of electrons)

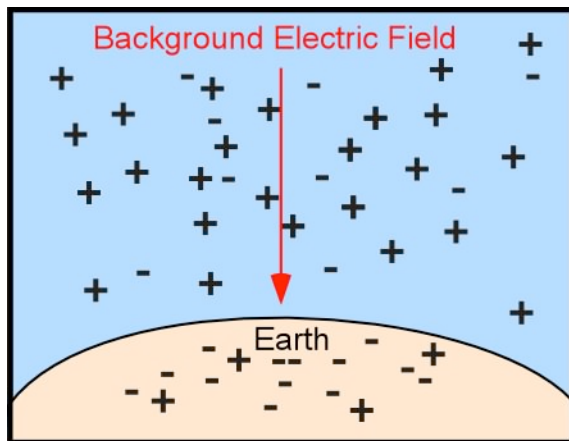
An **electric field** is present in any region where positive and negative charges exist.

A charge will experience attractive and repulsive forces in the presence of an electric field.

**Like charges repel and opposite charges attract.**

The magnitude of this force is measured in volts (V).

The strength of the electric field is measured in volts / meter (V/m).



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### Fair Weather Electric Field

This is the background electric field that exists in the lower atmosphere

In general the atmosphere is positively charged and the surface of the earth is negatively charged.

The strength of this fair weather electric field is 100 V/m

Current will move easily through conductors (such as metal or water) and will move poorly (or not at all) through insulators (such as air or plastic).

# Charging Mechanisms in Thunderstorms

The electric field right before a lightning stroke is typically 3,000,000 V/m

How does a thunderstorm become charged so that lightning can occur?

- Interface charging (also called non-inductive charging)
- Induction charging
- Other methods may also be important for creating the electric field in a thunderstorm

Both interface and induction charging typically cause ice crystals in a thunderstorm to become positively charged and hail to become negatively charged.

How do particles acquire charge?

Interface charging (also called non-inductive charging)

Graupel (like small hail) and hail stones grow by supercooled liquid water freezing on them

What is this freezing process called?

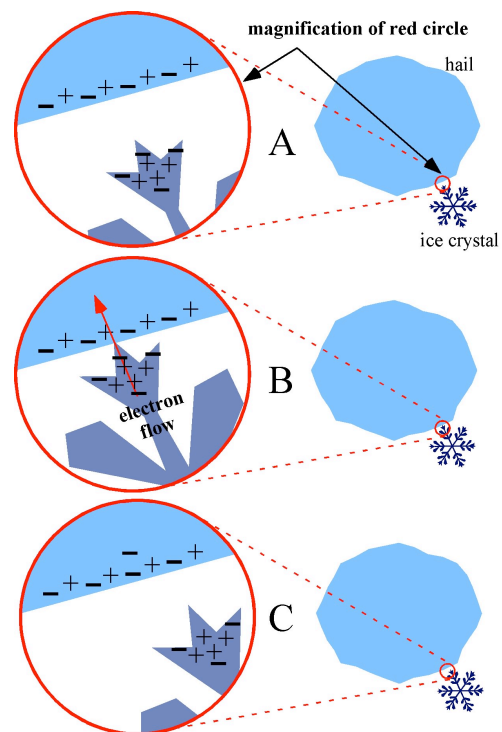
How do ice crystals grow?

Due to the different formation, the electrons on the surface of each particle are distributed differently

When an ice crystal collides with a rimed ice particle, charge can be transferred between the two particles

What charge is acquired by ice crystals?

What charge is acquired by rimed particles?





## Induction charging

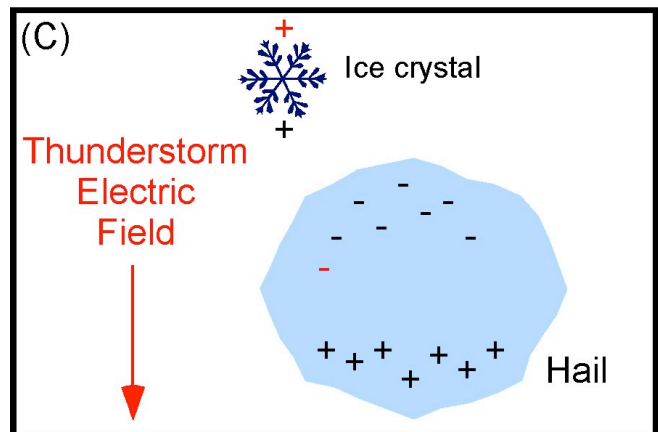
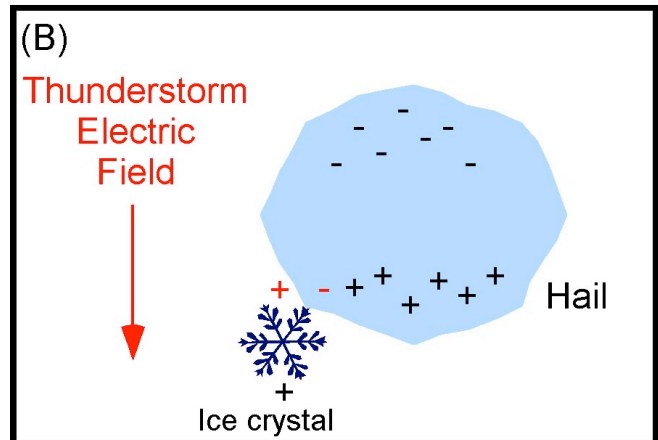
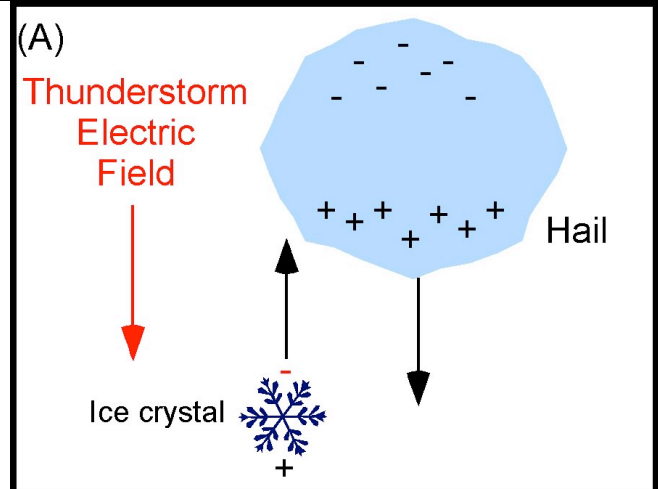
This process is based on collisions again, but now the distribution of charge in each particle is determined by the local electric field

The charge will align itself in each particle based on the ambient electric field

In other words, the charge distribution within the particle will be induced by the ambient electric field

What charge is acquired by ice crystals?

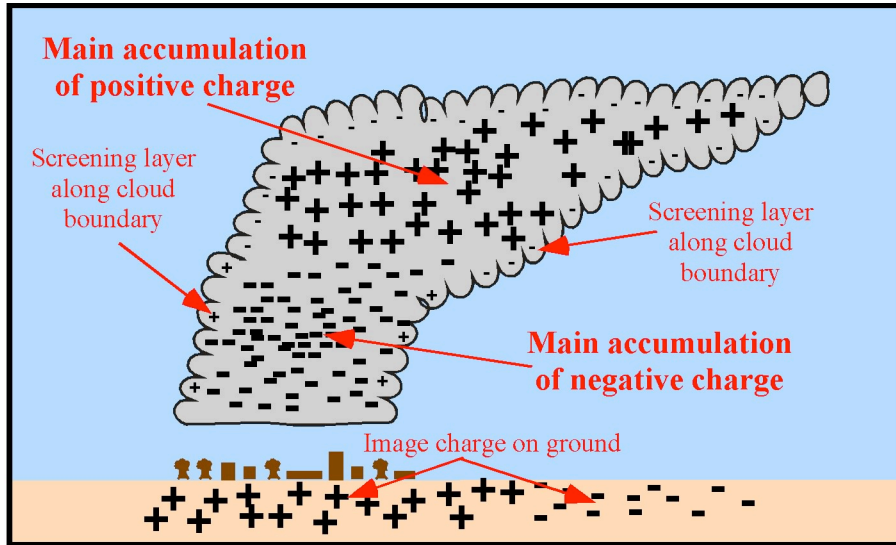
What charge is acquired by rimed particles?



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Are there differences in how hail and ice crystals move through a thunderstorm?

What is the charge distribution in and around a thunderstorm?



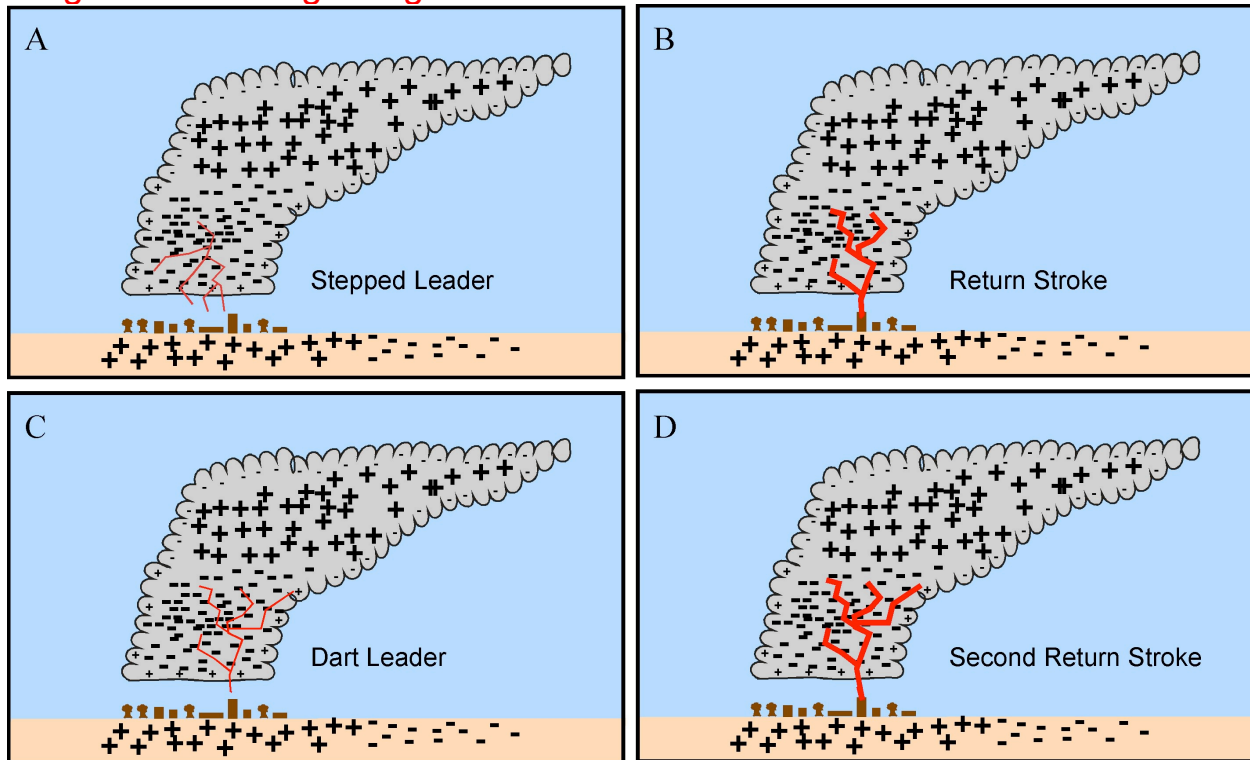
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What types of particles are responsible for the positive charge at the top of a thunderstorm?

What types of particles are responsible for the negative charge near the bottom of a thunderstorm?

# The Lightning Stroke

## Stages of a CG Lightning Stroke



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What magnitude electric field is required before lightning can occur?

**Stepped leader** – electrons moving towards the ground in a series of steps

**Return stroke** – occurs when downward moving electrons meet upward moving positively charged atoms

This process can be repeated multiple times over the same path.

**Dart leader** – leader that occurs after the initial lightning flash

## Thunder

What causes thunder?

How long does it take for the sound of thunder to travel 1 mile?

How can you estimate the distance to a lightning stroke?

## Other phenomena associated with electrical discharges in the atmosphere

**Heat lightning** – Lightning seen on a clear night that originates from a thunderstorm so far off in the distance it cannot be seen or heard (the night sky will just flash)

**Sheet lightning** – When lightning occur within or behind a cloud, illuminating the exterior of the cloud uniformly. Appears like a sheet of light.

**St. Elmo's fire** – When charge is accumulated on tips of objects extending above the earth's surface (antennas, ship masts). Produces small sparks and sometimes a bluish green halo. Often a sign of an impending lightning strike.

**Sprites** – One type of optical phenomena that occur between the tops of thunderstorms and the mesosphere.



## Lightning Safety

### What should you do if a thunderstorm is approaching?

Go inside if possible

Stay away from electrical appliances and corded telephones

Avoid taking a shower or coming in contact with indoor water supplies

### What should you do if you can't go inside?

Crouch as close to the ground as possible and minimize the amount of your body that is in contact with the ground by staying on your toes or heels.

Do not go under trees (unless you are in a forest)

Do not lie on the ground

Remove metal objects if possible

A car with a metal frame is a very safe place in a thunderstorm.