What Is Lightning?

Lightning is a discharge of electrical energy. Essentially a giant "spark" between regions of positive (+) and negative (-) charge.

May occur:

- Between cells in the same storm (inter-cloud lightning)
- Within a cloud (intra-cloud lightning)
- Cloud to air
- Cloud to ground (CG)

Why Do We Care?

National lightning safety institute (NLSI) reports annual lightning damage at about $4-5 billion!

Formation of Lightning

- Fair weather electric field
- Charge separation
- Initiation of the lightning stroke
- Does lightning strike twice? -- The mechanics of the lightning stroke
- "Kinds" of lightning

Fair Weather Charge

In fair weather there is a natural separation of charge in the atmosphere.

Fair Weather "Circuit"

- Thunderstorms "charge" the fair weather circuit.
- Without thunderstorms, the fair weather charge separation would be neutralized in about 10 minutes.

Lightning

- Air is a very good insulator (but not perfect).
- To have lightning:
  - Need to have the charge centers very close to each other
  - Have very large differences in charge "strength"
  - In order to get lightning in a thunderstorm you need to separate large amounts of charge. How is this done?

Cloud "Charging" Mechanisms

Poorly Understood!

- Two Primary Theories on Cloud Charging
  - Collision Mechanism (Inductive Charging)
  - Graupel Mechanism (Non-Inductive Charging)

Collision Mechanism

- Precipitation particle (rain, snow, ice, etc.) is polarized by the ambient electric field.
- Collision between a falling large drop and a smaller one leaves a net negative charge on the large drop and a positive charge on the small drop.

Graupel Mechanism

During a collision between (unpolarized) heavy graupel particles and lighter ice crystals:
Negative charge is transferred to the graupel
Positive charge is transferred to the ice crystals
Graupel falls to the bottom of the cloud bringing the negative charge with it
Ice crystals are transported to the upper levels of the thunderstorm

Charge Separation

If the electric field, or the difference between the negative and positive charge regions, is large enough, the insulator between the charge regions (the air) "breaks down" and the lightning discharge can occur between the regions of positive and negative charge.

The (CG) Lightning Stroke

The lightning stroke begins when the electric fields exceed breakdown voltage. (We think!!!!)
Initially streams of electrons surge from the cloud base toward the ground in steps of 50 to 100 m.
Start and stop steps as the stepped leader progresses toward ground.

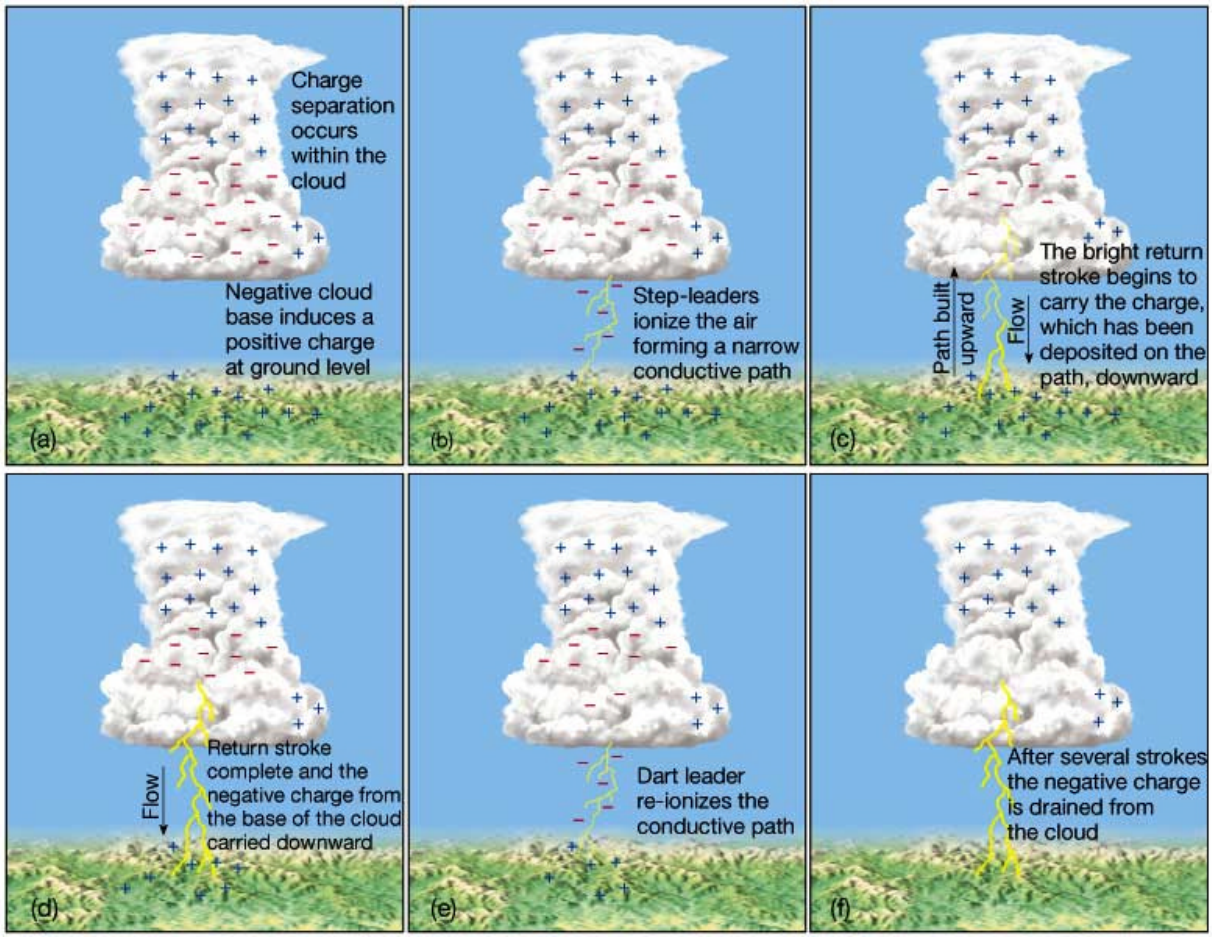
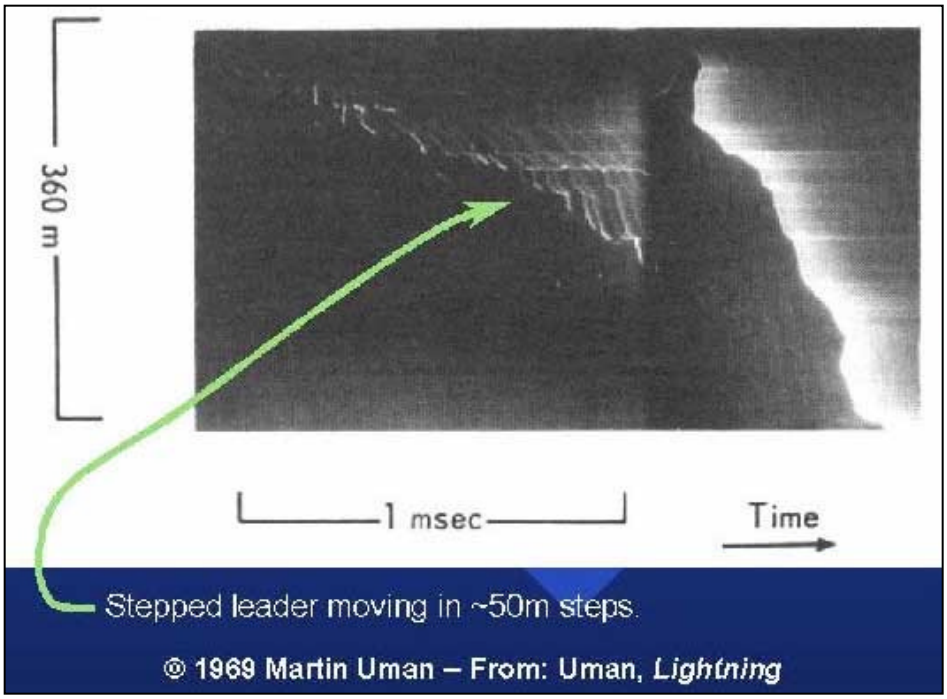


Figure 10.15 from Lutgens and Tarbuck – The Atmosphere, 8th Edition

Stepped Leader

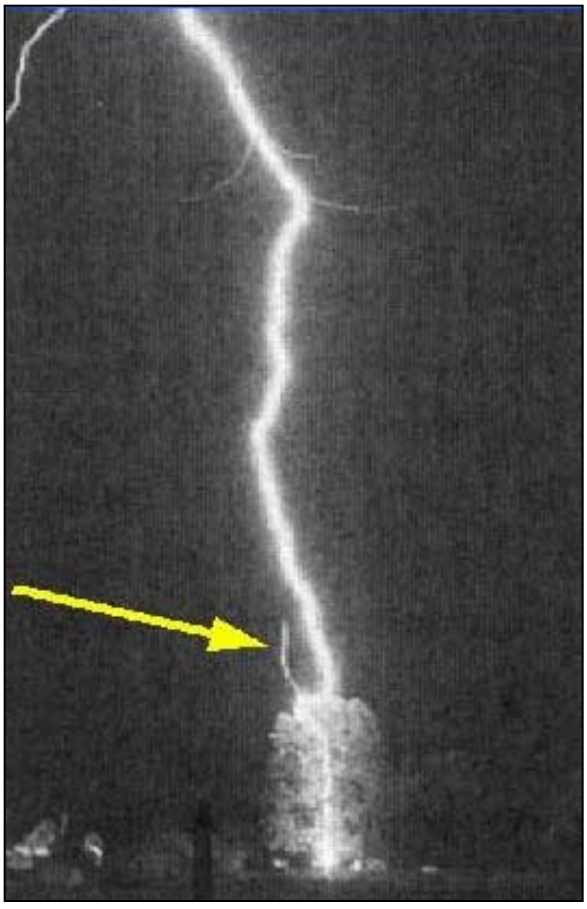
The stepped leader is:

- Very Faint
- Essentially invisible to the human eye
- Produces an ionized channel that will allow for the flow of charge during the remainder of the lightning stroke.



When the stepped leader gets near the ground (~100 m or so):

- Positive charge moves from the ground up toward the stepped leader -- these are called **streamers**.
- The streamers may come from almost any pointed object on the ground:
  - Trees Antennas Grass
  - Flagpoles Telephone Poles People
  - Really Tall Towers Etc.



The photograph to the right shows a streamer emerging from the tree – notice how it didn't connect to the stepped leader to complete the circuit.

Return Stroke

- One of the streamers will meet the stepped leader -- not necessarily the one from the tallest object!
- When they meet a pulse of energy flows up toward the cloud (along the ionized path) and toward the ground.
- This luminous pulse of electrical energy is called the return stroke.
- Occurs very fast -- we see it as a flash!

Dart Leader

Often a second series of stepped flow of electrons moves from the cloud toward the ground.

Since the ionized channel already exists, the stepped flow is much faster.

This stepped flow is called the dart leader.

Return Stroke

When the dart leader connects with a streamer from the ground (usually along the same path) another return stroke moves toward the cloud and ground.

May get several sets of dart leader/return stroke pairs.

Appears as if the lightning "flashes."

Lightning Channel is not Always Straight!

Thunder

Lightning is very hot (~30,000°C).

Violently expanding air causes an audible shock wave.

Nearby Lightning - Thunder sounds like a "crack" or a loud bang.

Distant Lightning - Thunder sounds like a rumble. We are hearing the sound from different parts of the lightning channel.

How far is that lightning????

Light travels much faster than sound.

Count the time between when you saw the flash and heard the thunder.

5 seconds per mile

3 seconds per km

Therefore – if the time between the flash and the thunder is 12 seconds, the lightning is 2.4 miles away, or 4 kilometers.

No thunder?

Could be too far away

Sound could be "bent" by the atmosphere away from you.

Lightning Safety

No place is absolutely safe from the lightning threat, however, some places are safer than others.

Substantially constructed buildings

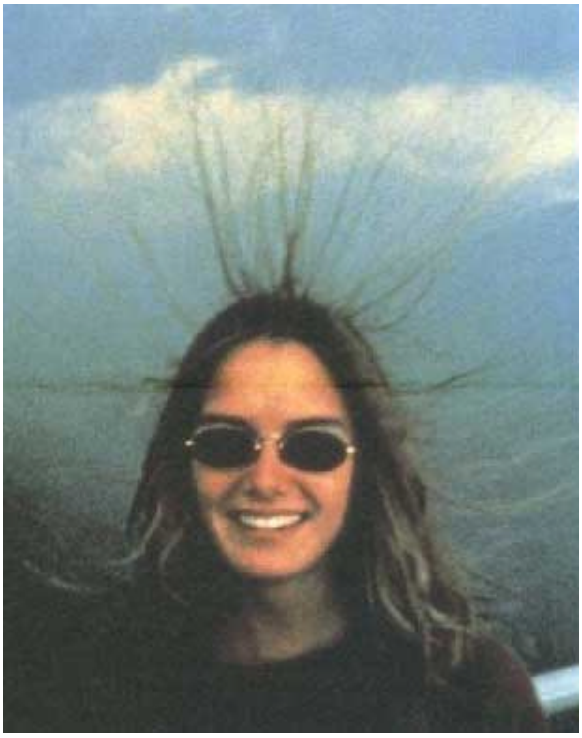
Fully enclosed metal vehicles

AVOID

Telephone, taking a shower, washing your hands, doing dishes, or any contact with conductive surfaces with exposure to the outside such as metal door or window frames, electrical wiring, telephone wiring, cable TV wiring, plumbing, etc.

When outside AVOID:

- High places and open fields
- Isolated trees
- Unprotected places such as gazebos, rain or picnic shelters, baseball dugouts, communications towers, flagpoles, light poles, bleachers (metal or wood), metal fences, convertibles, golf carts, water (ocean, lakes, swimming pools, rivers, etc.).
- Make yourself as small of a "target" as possible with minimal ground contact



These two photographs show apparent happy campers who don't realize that they may be about to get hit by lightning. Notice where they are located – the couple on the left are located high in the Great Smoky Mountains, above other peaks, whereas the woman on the right is standing in a boat on the open water in the Florida Keys. I guess these three haven't taken my Weather and Climate class.

Lightning Protection

- Lightning rods act as locations where streamers can be launched toward descending stepped leaders.
- It is better for the lightning rods to be struck, where the electrical energy can be safely transferred to ground, than the house.
- The "cone of safety" is about 45° under the lightning rod.

Lightning protection and safety devices
- Lightning Protection System (Rods, cables, etc.)
- Surge suppressors
- Well grounded equipment
- Routine Testing and Maintenance
- Warning Devices
- NOAA Weather Radio
- Lightning detection devices
- Resuscitation Equipment

Lightning During the Day
- Lightning is more common during the day.
  - This is primarily due to the fact that more convection occurs during the day and at dusk.
- Lightning also occurs at night over the oceans. Puzzling!
  - The land cools much more than the oceans. Air over the warm oceans destabilizes resulting in nocturnal convection.