

**ESCI 107 – The Atmosphere
Lesson 15 – Lightning**

Reading: *Meteorology Today*, Chapter 14

ELECTRICITY BASICS

- **There are two kinds of charge; positive and negative**
- **Opposite charges attract; like charges repel each other**
- **Electricity is the flow of charge from one region to another.**
- **If a substance readily allows electricity to flow through it, it is a *conductor*.**
- **If a substance is highly resistant to the flow of electricity, it is an *insulator*.**
- **The electrical potential between two charged regions is measured in *Volts*.**
- **If there is a great enough potential across an insulator it will eventually break down, and electricity will flow across it.**

ELECTRICAL PROPERTIES OF THE FAIR WEATHER ATMOSPHERE

- **The earth normally has a negative charge, and the upper atmosphere normally has a positive charge.**
- **There is a constant “leakage current” through the atmosphere that could neutralize the earth-atmosphere charge imbalance in about 10 minutes.**
- **There must be some mechanism to continually put positive charges into the upper atmosphere. Thunderstorms provide this mechanism.**

ELECTRICAL PROPERTIES OF A THUNDERSTORM

- **The top of a thunderstorm (cumulonimbus) cloud becomes positively charged.**
- **The bottom of the cloud becomes negatively charged.**
- **The reason for this charge separation is not well understood, though it does have something to do with frozen vs. liquid hydrometeors. The frozen hydrometeors are positively charged, and are found at the top of the cloud. The liquid hydrometeors are negatively charged, and are found at the bottom of the cloud.**
- **The negative charge at the bottom of the cloud *induces* a positive charge at the ground.**

- **Lightning is a discharge of electricity between the oppositely charged centers, either from the cloud to the ground, or within the cloud.**
- ***There are roughly 50 lightning flashes around the globe every second!***

BENJAMIN FRANKLIN'S FAMOUS KITE EXPERIMENT

- **Benjamin Franklin designed an experiment to prove that lightning is electricity.**
- **Franklin's experiment used a kite with a conducting wire between the kite and a metal key. The kite was flown in the vicinity of a thunderstorm.**
- ***HIS EXPERIMENT WAS NOT DESIGNED SO THAT THE KITE WOULD BE DIRECTLY STRUCK BY LIGHTNING, NOR WAS HIS KITE EVER DIRECTLY STRUCK BY LIGHTNING!*** Instead, his experiment was designed only to observe a small spark from the key to his hand.

CLOUD-TO-GROUND (CG) LIGHTNING

- ***Cloud-to-ground (CG) lightning is a lightning discharge from the cloud to the ground.***
- **CG lightning proceeds in a distinct sequence**
 - ***Stepped leader*** – The stepped leader is an ionized path that forms from the cloud to the ground. It has many short segments, and is highly branched. Usually it is not even visible.
 - ***Return stroke*** – Once the stepped leader reaches to within 50 meters or so above the ground, a positive charge flow is initiated from the ground back toward the cloud. This is the return stroke, and it is the brightest and most energetic part of the lightning flash.
 - ***Dart leader*** – After the return stroke subsides, another leader progresses back down the lightning channel. This leader is similar to the stepped leader, but is not branched.
 - ***Return stroke*** – As the dart leader approaches the ground another return stroke is initiated from the ground back to the cloud.
- **The dart leader-return stroke sequence continues until enough charge is neutralized that the atmosphere is able to once again act as an insulator.**

- On average there are 3 or 4 return strokes per CG flash, though there may be more.
- The entire sequence of a CG flash lasts for only a few-tenths of a second.
- *Note that the return stroke travels from the ground upward to the cloud.*
- The peak electrical current in a CG flash is typically 30 to 40 KAmps.
- The lightning channel is only a few centimeters in diameter.
- The air in the lightning channel is heated to temperatures as high as 60,000°F.
- *CG lightning normally lowers negative charge to the ground.*
- A very small percent of CG lightning lowers positive charge to the ground. These positive discharges are usually much more energetic than the normal, negative discharges.

INTRA-CLOUD (IC) LIGHTNING

- *Intra-cloud (IC) lightning is a lightning discharge between charge centers within the cloud, or between clouds, and doesn't reach the ground.*
- *The vast majority (60 to 80 percent) of lightning is IC lightning.*
- Less is known about IC lightning than CG lightning, because it is much harder to observe and measure.

OTHER FORMS OF LIGHTNING

- *Heat lightning* – Heat lightning is just lightning seen at night from a very distant thunderstorm. It is so far away that the thunder is not heard. It is called heat lightning because it usually occurs on hot summer nights.
- *Sheet lightning* – Sheet lightning is just IC lightning that illuminates a large section of the sky seemingly all at once.
- *Ribbon Lightning* – Ribbon Lightning is caused by the wind blowing the air so that each return stroke occurs in a different location, giving the effect of a ribbon.
- *Ball lightning* – *Ball lightning* is a rarely reported phenomenon of a ball of light or electricity that occurs during a thunderstorm. It may move through buildings or even airplanes.

- The balls are reported to be about the size of a grapefruit, and last for only a few second.
- Not much is known about ball lightning other than anecdotal accounts from persons encountering it.
- Many occurrences have been associated with CG lightning strikes.

THUNDER

- Thunder is the sound caused by the rapid expansion of the heated air in the lightning channel.
- The sound travels at around 750 mph, or about 1/5 of a mile per second.
- Light travels at about 186,000 miles per second.
- The difference between the speed of light and the speed of sound can be used to estimate how far a way a lightning flash was.
 - Each second of time between when you see the flash and when you hear the thunder is 1/5 (0.2) miles. Therefore, every five seconds equals one mile.
 - So, if there is 14 seconds between the flash and the thunder, the lightning was $14 \times .2 = 2.8$ miles away.
- Sound rays usually bend upward in the atmosphere. Therefore, if lightning is more than about 15 miles away the sound passes over your head and you do not hear it.
- Thunder rumbles because the sound generated by different parts of the lightning channel reaches you at different times. The closer you are to the lightning, the sharper and shorter the thunder will sound.

LIGHTNING RODS

- A lightning rod is a long, metal rod designed to attract the lightning bolt and direct its current harmlessly through a wire to the ground. ***LIGHTNING RODS DO NOT SLOWLY DISCHARGE THE ELECTRICITY FROM THE CLOUD!***
- A rod of height H will protect a cone around it having a base of $2H$.
- The lightning rod must be well grounded. Otherwise the lightning may jump from the rod to building it is designed to protect.

LIGHTNING WITHOUT THUNDERSTORMS

- **Lightning can occur without thunderstorms present.**
- **Lightning has been observed with**
 - Nuclear explosions
 - Volcanoes
 - Underwater explosions

LIGHTNING SAFETY

- **About 500 people are struck each year by lightning in the u.s., and about 20% of these are killed.**
- ***The key to lightning safety is to not let yourself be a lightning rod!***
- **During a thunderstorm you should**
 - **Get inside an enclosed building or vehicle (not a convertible).**
 - **Note: it is not the rubber tires on the car that offer protection from lightning. It is the fact that if lightning does strike the car it will travel through and along the metal, and not through the people inside.**
 - **Stay away from windows and doors.**
 - **Stay away from metal or other conducting surfaces.**
 - **Do not use the telephone or plumbing (lighting can travel through the phone wiring, electric wiring, cable TV wiring, or plumbing pipes).**
 - **If outdoors, do not stand in exposed fields, or under tall objects such as isolated trees**