Chapters 20-22: Hailstorms, Lightning, Downbursts

Courtesy NOAA/NSSL photo library

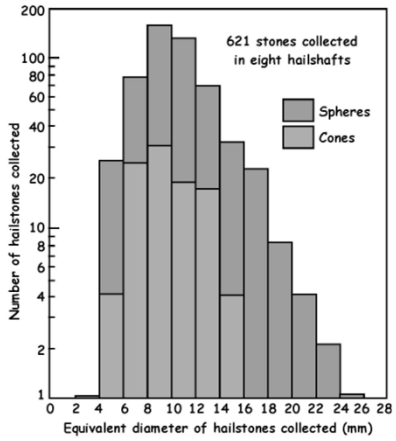
- Hailstone Formation and Growth
- Lightning Stroke
- Downburst Formation, Structure, and Type

Hail

Courtesy of Bruce Lee

- Hail is one of the most spectacular phenomena associated with strong thunderstorms.
- Unlink lightning, which is present in every thunderstorm, hail reaches the ground in only small fraction of thunderstorms.

Hailstone Size



Courtesy of the American Meteorological Society

- The potential for damage from a falling hailstone increases with a stone's size and its corresponding fall speed.
- Most of the collected hailstones had sizes of about 1 cm.

The Largest Hailstone ever Collected in the US

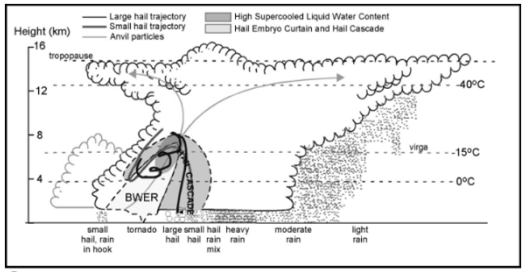
Courtesy of NOAA

It measured 17.8cm (7 inches) in diameter, and fell in Aurora, Nebraska.

Hailstone

- Hail growth can be thought of as occurring in two steps: (1) the formation of a ***hail embryo*** and (2) the formation of the ***hailstone***.
- ***Hail Embryos***: are the ice particles that occupy the center of hailstones and serve as cores for their initial growth.
- ***Hailstones***: are the final large stones composed of hard or spongy ice.
- Each step, hail embryo formation and hailstone formation, requires one up-down cycle through the storm clouds.

Hail Growth



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- As air rises in a developing thunderstorm updraft, supercooled cloud droplets are found between altitudes where the temperature ranges from 0°C to -15°C.
- The ice particles that form at higher altitudes can fall back to this supercooled cloud water region and collect the water to form graupel particles, which are soft ice particle with diameters of one to a few millimeters.
- These graupel particles centering around the updrafts form an embryo curtain (the blue region) will eventually grow into hailstones.

Hail Curtain (aka Hail Cascade)

Courtesy of Glen Romine

- Hail curtain appears to the right of the rain-free base.

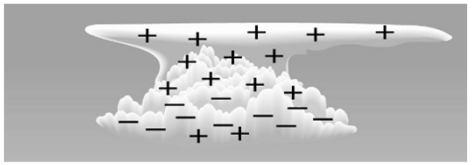
Chapter 21 : Lightning

Courtesy of NOAA

Major Sequence for Lightning

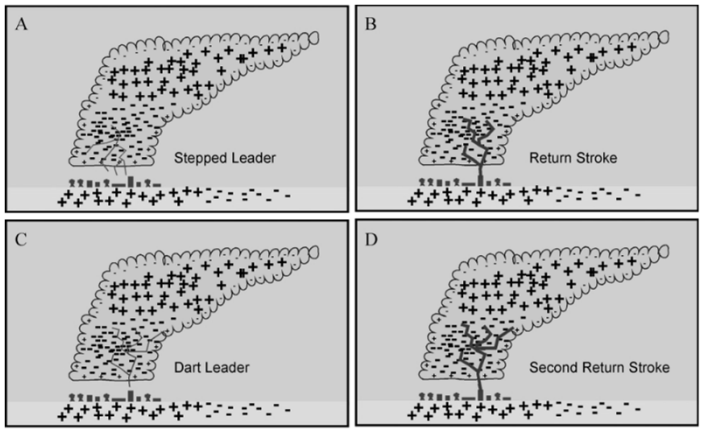
- Electrification of a cloud: Charge Separation
- Development of a path through which the electrons can flow
- Discharge: Lightning

Charge Separation in Clouds

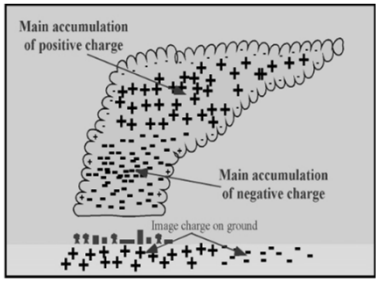


- Positive charges in the upper portions of the cloud; Negatively charges in lower portions; Small packet of positive charges in the cloud base.
- lightning occurs only in clouds that extend above the freezing level ➔ charge separation is related to ice crystals.
- Lighter crystals collide with heavy hailstones in the cloud.
- The lighter crystals are positively charged and move to upper portions of the cloud.
- The heavy hail stones are negatively charged and move to the lower portion of the cloud.

Creation of a Lightning Stroke



Charge Distribution

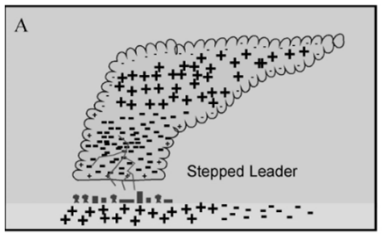


- ❑ Lightning is an electric discharge in the atmosphere.
- ❑ The upper part of a typical thunderstorm, including the anvil, has an excess of positive ions and is positively charged.
- ❑ The lower part of the storm has an excess of negative ions, and is negatively charged.
- ❑ The ground beneath the main part of the storm is positive charged.
- ❑ The ground beneath the anvil is negatively charged.

Lightning

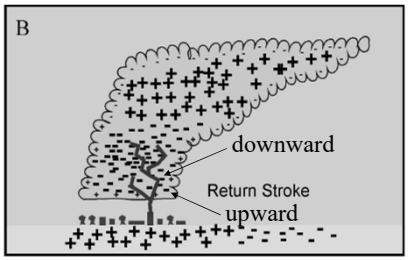
- **Cloud-to-Cloud Lightning**
  - ✓ **80% of all lightning**
  - ✓ **Electricity discharge happens within clouds**
  - ✓ **Causes the sky to light up uniformly (sheet lightning)**
- **Cloud-to-Ground Lightning**
  - ✓ **20% of all lightning**
  - ✓ **Electricity discharge happens between cloud base and ground**

Step Leaders



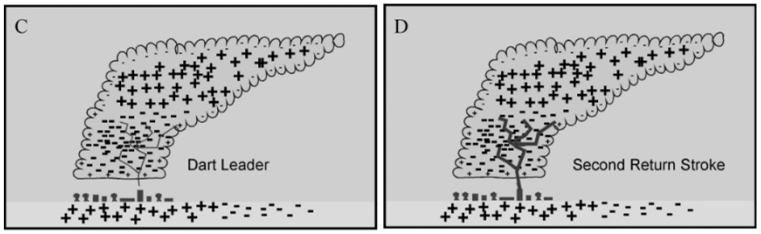
- The dry air is a good electrical insulator, so a flow of current can not occur.
- For cloud-to-ground lightning to occur, a ***stepped-leader*** must emanate from the cloud base.
- The leader is essentially an ionized particle chamber about 10 cm (4 in) in diameter which forks repeatedly from a main channel.
- Each section travels about 50-100 m in a microsecond (a millionth of a sec).
- The sections continue until contact is made with an unlike charged area (the ground).

Return Strokes



- Upon connection, electrons flow resulting in an illuminated ***return stroke.***
- Although the electrical current is from the cloud to the ground (moves downward), the return stroke is in the opposite direction (move upward).
- It is the return stroke that produces the visible flash, but it all happens so fast
- The upward return stroke happens so fast, our eyes can not resolve its upward direction.

Dart Leader and Flash

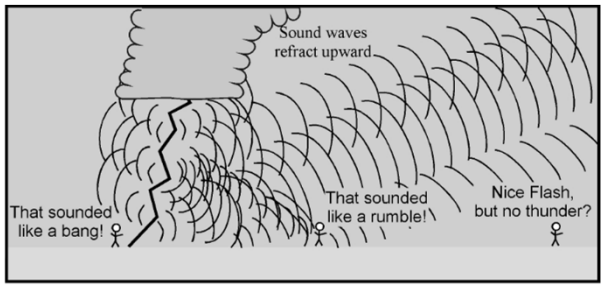


- Usually more than one stroke is needed to neutralize all negative ions.
- Another leader, or ***dart leader***, is initiated and a return stroke follows.
- Dart leader moves downward faster than step leader.
- The process is repeated about 2-3 times on average.
- Individual strokes are almost impossible to detect.
- We call a combination of all strokes a ***lightning flash.***

Lightning (high-speed video)

- https://www.youtube.com/watch?v=XWuZqw3LopE

Thunder



- The lightning stroke can heat the air through which it travels to 30,000ºC (54,000ºF), which is 5 times hotter than the surface of sun.
- This extreme heating causes the air to expand explosively, thus initiating a shock wave that become a booming sound wave (thunder) to travel outward.
- It takes 3 seconds for thunder to travel 1 km (5 seconds to travel 1 mile).

Chapter 22: Downbursts

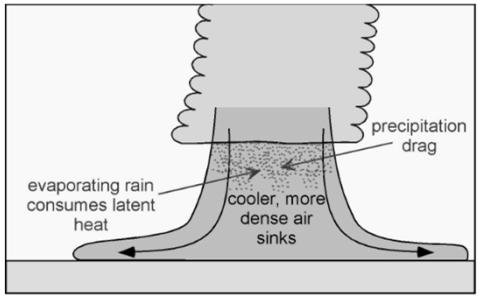
Courtesy of NOAA/NSSL Photo Library

Downburst

virga is an observable streak or shaft of precipitation that falls from a cloud but evaporates before reaching the ground.

- ❑ Downburst is a strong downdraft that originates within the lower part of a cumulus cloud or thunderstorm and descends to the ground.
- ❑ When a downburst reaches the ground, it creates strong straight-line winds and can cause damage equivalent to weak tornadoes.

Downburst Formation



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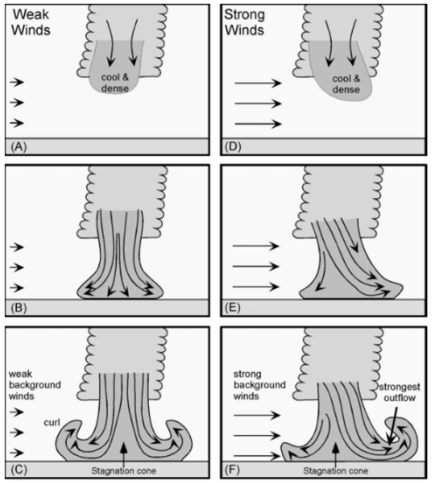
- Downward acceleration of air occurs when evaporating raindrops consume latent heat, cooling the air.
- The cool air is denser, so it begins to sink.
- In addition, falling precipitation drags the air downward, enhancing the downward acceleration.

Structure of Downburst



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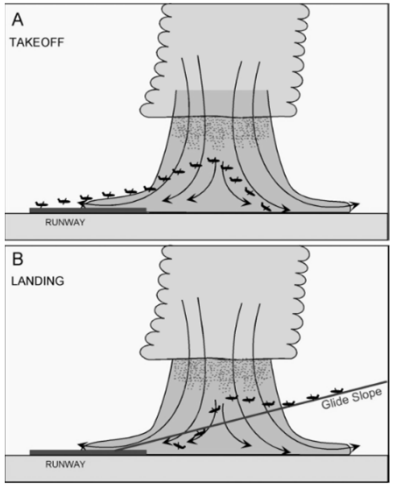
Downburst's Threat to Aircraft



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