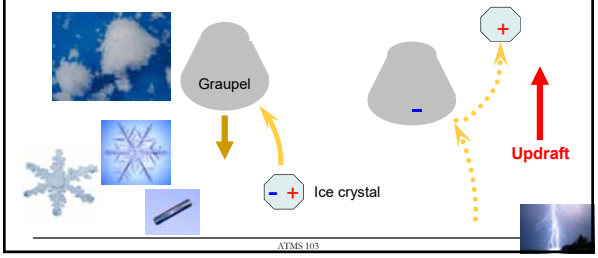
Lightning

Electricity and Charge

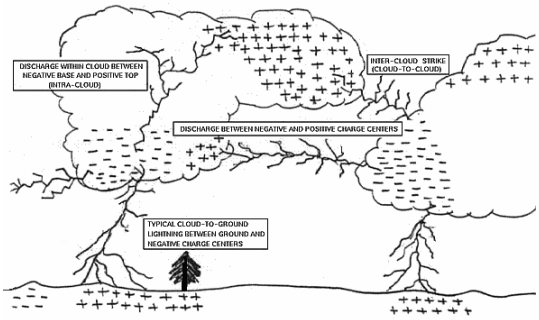
- There exist two types of charged particles:
  - Electron – negative charge e^-
  - Proton – positive charge p^+
- An atom with an unequal number of each is called an ion
- e^-'s are mobile and move from atom to atom
- Current is defined as moving in the direction that the positive charge "moves"
  - Note: the current is *opposite* the direction of electron flow!

How do clouds gain a charge?

Collision between a large graupel particle (traveling downward) and a small ice particle (traveling upward) leaves a net *negative* charge on the graupel and a net *positive* charge on the lighter ice particle.



Three primary types of lightning: IC, CC, CG



Source: NASA

Primary types of lightning

Cloud-to-Ground:

- Most damaging and dangerous
- Best understood
- Most flashes originate near the lower negative charge center and deliver negative charge to Earth—a *negative* lightning strike
- However, an appreciable minority of flashes carry positive charge to Earth—a *positive* lightning strike
  - Often occur during the dissipating stage of a thunderstorm's life
  - More common as a percentage of total ground strikes during the winter months.

Primary types of lightning

Intra-Cloud: *(in-cloud)*

- Most common form
- Occurs between oppositely charged centers within the same cloud
- Usually takes place within the cloud
  - From the outside, it looks like a diffuse brightening that flickers
- The flash may exit the boundary of the cloud such that a bright channel, similar to a cloud-to-ground flash, can be visible for many miles

Primary types of lightning

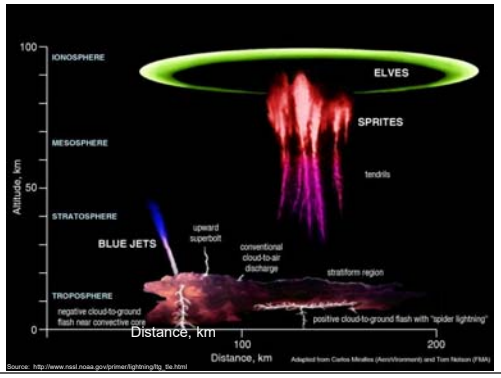
Inter-Cloud: *(cloud-cloud)*

- Occurs between charge centers in two different clouds
- Discharge bridges a gap of clear air between them

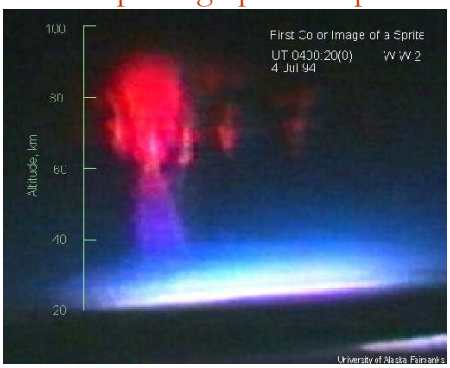
Additional types of electric phenomena above the cloud

- Red sprites, blue jets, elves (flashes above the cloud toward the ionosphere)

Transient Luminous Events



First color photograph of a sprite:



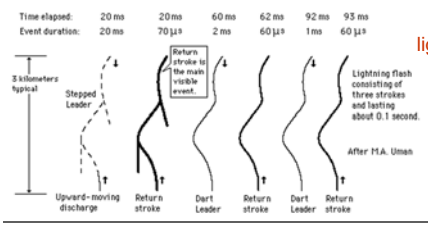
Other Lightning Terms

- **Heat lightning** – lightning is visible, but thunder is inaudible because the storm is too far away
- **Bead lightning** – flash looks like a strand of beads
- **Sheet lightning** – widespread glow of an intra-cloud flash
- **St. Elmo's fire** – point discharges that occur when the environmental electric field is high, typically at the tips of sharp conductors that enhance the electric field
  - Often seen on the tall masts of sailing ships

Steps to a Lightning Discharge

1) Stepped Leader – electrons move toward ground, met by 'streamer' coming up from the ground
2) Return Stroke – electrons flow to ground; therefore current travels upward; this is the flash
3) Dart Leader – moves through ionized channel from previous return stroke
4) Multiple return strokes until cloud discharges

The multiple strokes of lightning make it appear to 'flicker'



Thunder

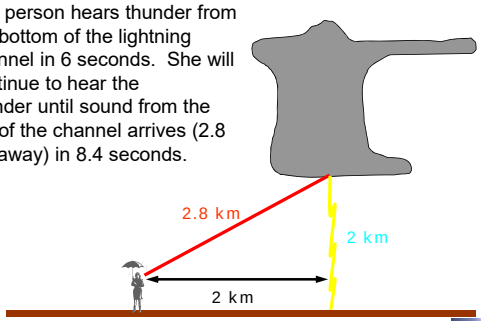
- Lightning is very hot (~30,000ºC).
- Violently expanding air causes an audible shock wave
- Close lightning
  - Thunder sounds like a "crack" or a loud explosion
- Distant lightning
  - Thunder sounds like a low rumble--we're hearing the sound from different parts of the lightning channel
  - Why? Higher frequency sounds bend upward more easily (are refracted); lower frequencies travel farther near ground

Thunder

- How far away is that lightning?
  - Light travels much faster than sound
  - Count the time between when you saw the flash and heard the thunder, and divide by:
    - 5 seconds per mile
    - 3 seconds per km
- Lightning with no thunder?
  - Could be too far away
  - Sound could be bent (refracted) by the atmosphere away from you

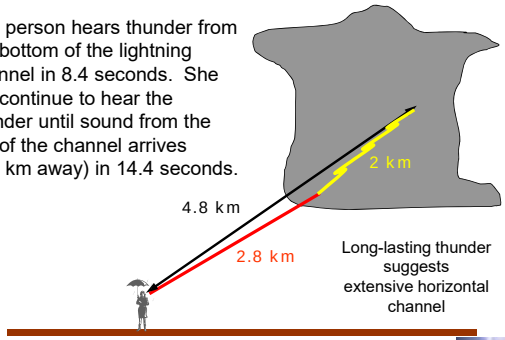
Thunder

The person hears thunder from the bottom of the lightning channel in 6 seconds. She will continue to hear the thunder until sound from the top of the channel arrives (2.8 km away) in 8.4 seconds.



Thunder

The person hears thunder from the bottom of the lightning channel in 8.4 seconds. She will continue to hear the thunder until sound from the top of the channel arrives (4.8 km away) in 14.4 seconds.

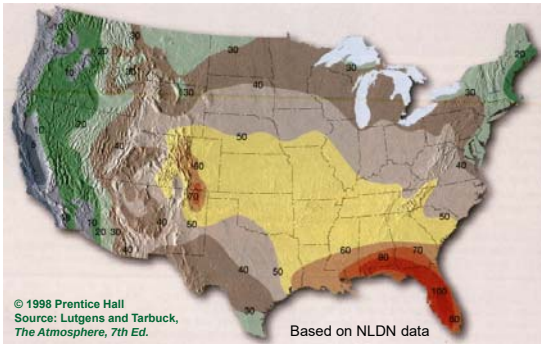


Long-lasting thunder suggests extensive horizontal channel

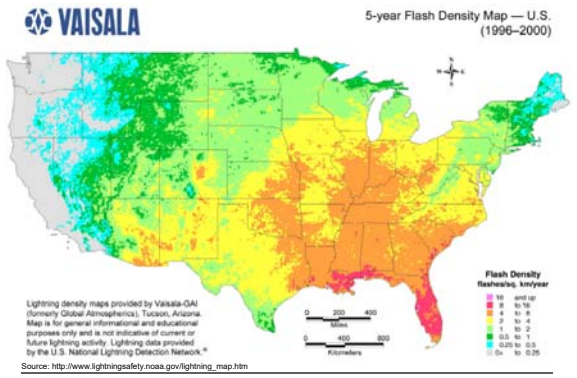
Some Facts About Lightning

- Lightning is an electrical discharge
- Lightning typically extends ~5 km high and is 2 to 3 cm in diameter
  - Note: it appears thicker than it really is
- Temperature in lightning channel can reach up to ~50,000°C (most ~30,000°C)
  - Five times hotter than the surface of the sun!
- Kills an average of ~70 people per year in U.S.
- Odds of you getting struck in your lifetime (assuming you live to be 80 years old) ≈ 1/5000

Average number of thunderstorm days per year

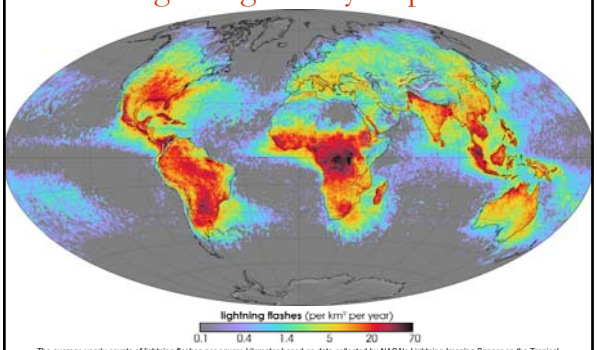


Average number of lightning flashes per year per km^2



Source: http://www.lightningsafety.noaa.gov/lightning_map.htm

Global lightning density map

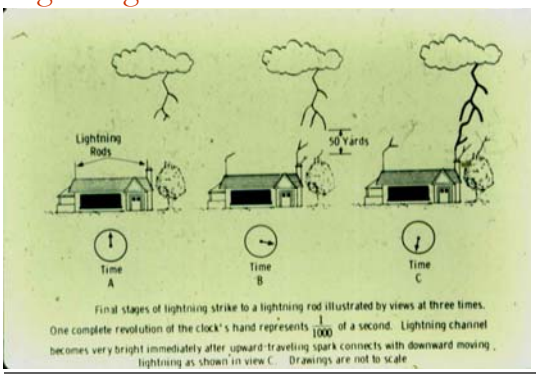


The average yearly counts of lightning flashes per square kilometer based on data collected by NASA's Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission satellite between 1995 and 2002. Source: http://geology.com/articles/lightning-map.shtml

Lightning Protection

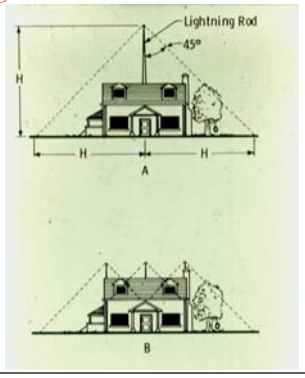
- Lightning rods act as locations where streamers can be launched upward toward descending stepped leaders
- It's better for a lightning rod to be struck, where the electrical energy can be safely transferred to ground, rather than a structure
- The "cone of protection" is ~45° under the lightning rod
  - Is it really "safe"?
  - NO! Lightning can still strike anywhere

Lightning Protection

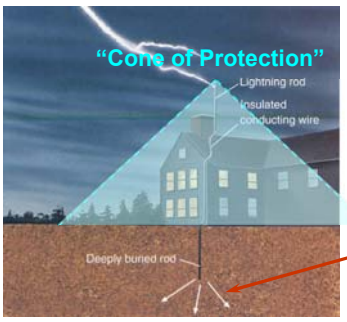


Final stages of lightning strike to a lightning rod illustrated by views at three times. One complete revolution of the clock's hand represents $\frac{1}{1000}$ of a second. Lightning channel becomes very bright immediately after upward-traveling spark connects with downward moving lightning as shown in view C. Drawings are not to scale.

Lightning Protection: Cone of Protection

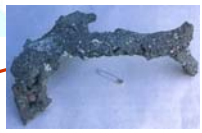


Lightning Protection



Remember: While tall, pointy isolated objects are statistically more likely to be struck by lightning, it's not nearly reliable enough to rely on for safety.

Fulgurite



Lightning striking away from storm

Lightning Striking a Lake

Great websites to check out:

- http://www.lightningsafety.noaa.gov/overview.htm
- http://www.nssl.noaa.gov/primer/lightning/ltg_basics.html
- Sprites and Jets: http://elf.gi.alaska.edu/
- Strike victims: http://www.lightning-strike.org/