Chap 14: Thunderstorms & Tornadoes

Thunderstorms (p. 368)

- As the name indicates, all thunderstorms produce thunder and hence lightning. They are "convective" storms associated with warm, buoyant rising air.
- Atmosphere is often "conditionally unstable" (p. 145), meaning that air isn't warm enough to rise on its own. Initial rise to condensation level and instability occurs because:
  - Unequal surface heating creates warm bubble and/or
  - Air flows over upward-sloping topography and/or
  - Air is lifted by converging cooler air, perhaps from another thunderstorm, which wedges underneath
- T'storms most common in summer but can occur in cool season when cold air aloft creates very unstable situation. Florida can have winter thunderstorms.

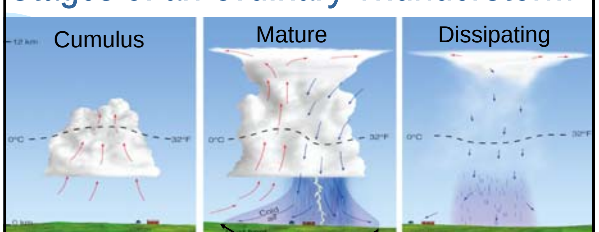
Thunderstorm Structure

- Any thunderstorm contains rising air (updraft) and sinking air (downdraft)
- **Updraft:** warm air rising in cloud. It cools by work of expansion, reaches dew point, & forms cumulus cloud.
- **Downdraft**: air sinking in cloud. Drier air from around the cloud is entrained (mixed) in at the cloud's sides, as evidenced by the swirls on sides of cumulus clouds. The entrained air is cooled as rain evaporates into it, and cooled air sinks. Also, falling rain drags down air.
- **Cell**: updraft and downdraft pair. Thunderstorm may contain one or more cells.
- **Supercell**: thunderstorm with single very strong cell

Ordinary Thunderstorms (pp. 368-371)

- "Ordinary thunderstorm" (or pop-up or air-mass thunderstorm) forms within an air mass having little vertical shear, i.e., change of wind speed and/or direction with increasing height.
- **Cumulus (or growth) stage**: the updraft fills the cloud. (That's why there is a cloud.) As condensation forms, latent heat is released, making the air more buoyant. Updraft strong enough to prevent small droplets from raining out.
- **Mature stage**: cloud becomes tall enough that droplets become large and heavy enough to rain out of the cloud. Downdraft appears. Mature stage may last 15-30 min.
  - Updraft is at peak intensity when rain first starts to fall, because once the downdraft gets going, it impedes & ultimately kills the updraft in an ordinary thunderstorm.
- **Dissipating stage**: updraft weakens, downdraft dominates

Stages of an Ordinary Thunderstorm



Warm air rises & cools by expansion. Vapor condenses, & cumulus forms.

Rain starts, creating downdraft from cooling by evaporation & drag from falling rain. Gust fronts form at surface

Downdraft dominates, so air can't rise & thunder-storm dies|

Fig 14.1, p. 369

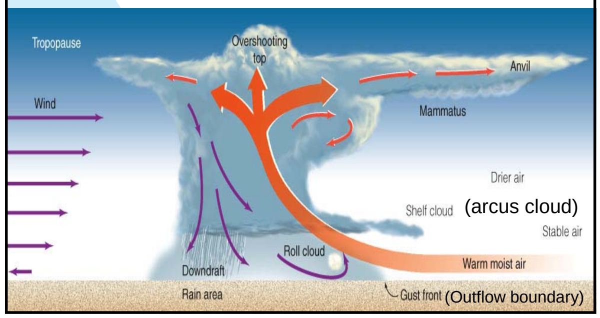
Multicell storm complex (fig. 14.4, p. 371)

Typical ordinary thunderstorm contains multiple "cells," each with updraft & downdraft. Cell lifetime: hour or less. Example:
Cumulus congestus Mature cumulonimbus Cumulus stage

Severe Thunderstorm (pp. 371-373)

- Defn: any thunderstorm that produces ¾" hail and/or surface wind gusts of 50 knots (58 mph) or more and/or a tornado.
- The longer a thunderstorm lives, the stronger it can get.
- Few "ordinary" thunderstorms live long enough to become severe. Long-lived severe thunderstorms usually form in regions with vertical shear (wind speed &/or direction change rapidly with height), which separates updraft & downdraft.

Thunderstorm with separated updraft & downdraft (Fig. 14.13, p. 376)



Shelf & Roll Clouds: Photos by Bill Boutwell http://www.crh.noaa.gov/dlh/album2.htm

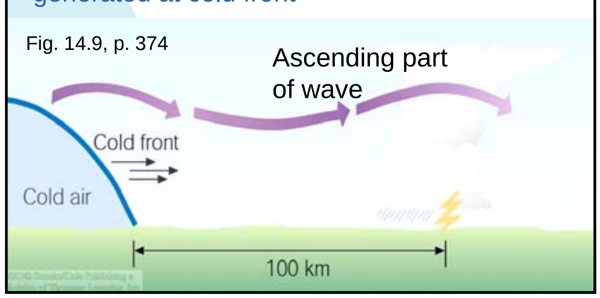
Shelf and Roll Clouds

Mesoscale Convective Systems (MCS, pp. 373-375)

- MCS: Ensemble of convective thunderstorms producing precipitation over a wide area
- Two types of MCS's have names
  - Squall lines
    - Line (or arc or bow) of thunderstorms along or ahead of cold front
    - Longest and most intense squall lines usually form ahead of fronts (50 – 200 miles ahead): pre-frontal
  - Mesoscale convective complex
    - Very large, round collection of thunderstorms
- Collection of thunderstorms that is not a squall line or mesoscale convective complex is given the generic term "mesoscale convective system"
- More details on following slides

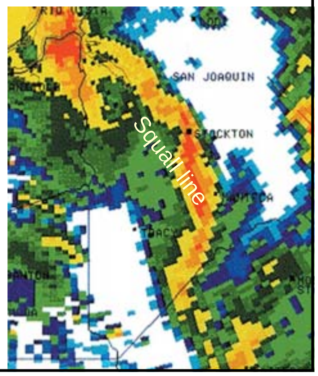
Triggering a Pre-Frontal Squall Line

- Pre-fontal squall lines can be triggered by ascending part of upper-level waves generated at cold front



Squall line on radar

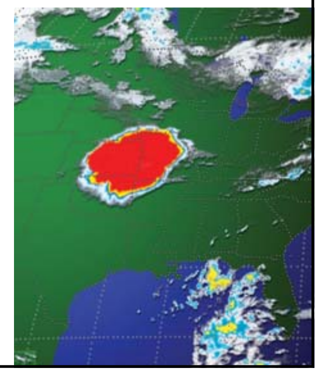
- Yellow and red in this radar image indicate intense rainfall associated with a squall line
- This squall line is an arc, and its appearance on radar is called a “bow echo”
- The thunderstorms responsible for a bow echo occur at the leading edge of intense low-level winds, which push the gust front ahead rapidly, thereby lifting the air in front of it.
- A long-lived large bow echo is called a derecho (pronounced duh-RAY-sho)



Mesoscale Convective Complex (MCC, pp. 374-375)

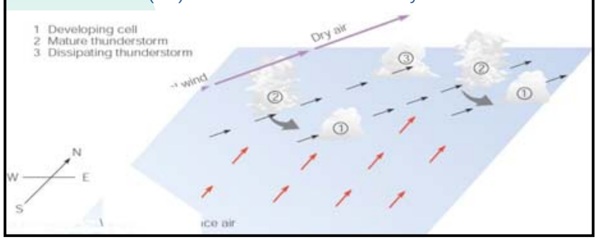
- Very large area of organized thunderstorms in summer
- Can be 1000 times bigger than a single thunderstorm
- Identified in satellite pictures by huge circle of cirrus clouds from thunderstorms
- Often exist overnight for 12 hours or more
- Provide significant amount of rain for Midwest
- Term “MCC” not as popular now because it is only based on the satellite view, which does not tell you what is going on underneath the cirrus deck.

Fig. 14.11, p. 375



Multicell thunderstorms move to right of wind direction

- Individual thunderstorm cells move roughly at speed and direction of wind at 10,000 ft (3 km) above surface
- Southerly winds from Gulf of Mexico feed warm, moist air to the south (right) side of a multicell thunderstorm
- New cells grow on the south (right) side.
- Cells on north (left) side of are shut of from buoyant air and die



Dryline Thunderstorms (pp. 375-376)

- Dryline (pp. 302-303): boundary between maritime tropical (mT) and continental tropical (cT) air.
- Most commonly occur in western Texas, Oklahoma, & Kansas in spring and early summer when seen 40% of time.
- Severe thunderstorms may form on or just east of a dryline

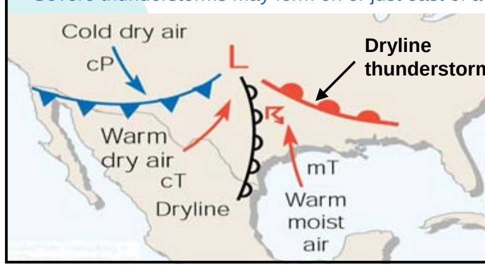
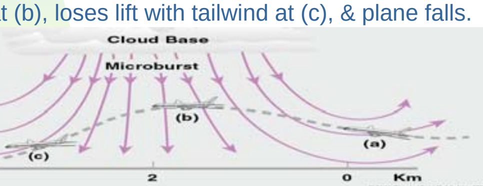


Fig. 14.12, p. 375

Microburst (pp. 376 & fig. 14.18)

- Microburst: intense downdraft from cloud base concentrated into a small area
- Can knock over structures (homes, trees, etc.). Public confuses this damage with that of a tornado, but microburst knocks everything in one direction.
- Very dangerous to aviation. Plane trying to land gains lift with headwind in figure below at (a). Pilot throttles back at (b), loses lift with tailwind at (c), & plane falls.

Fig. 14.18, p. 378



Why do thunderstorms appear so bright or so dark?

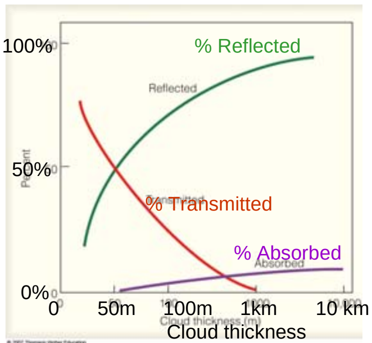
- The multicell photo (fig. 14.1, p. 371) shows that a thunderstorm can appear quite bright.
- The shelf and roll cloud pictures show that a thunderstorm can appear quite dark.
- How can a thunderstorm appear both bright and dark?
- Answer: It depends on which side of the cloud you are. If you are on the same side as the sun is, the cloud appears quite bright because almost all the light that enters the cloud is scattered back in the general direction of the sun. Very little light is transmitted through the cloud, so the back side of the cloud is quite dark.

What happens to sunlight in a cloud?

If a cloud is thicker than 1 km, which is certainly true for a thunderstorm:

- 1% or less of light is transmitted through the cloud
- About 5% of light is absorbed in the cloud
- About 95% of light is reflected (scattered) back out of the cloud

Fig. 19.3, p. 519



Days per year with t'storms & hail (pp. 381-383, figs. 14.22 & 14.23)

- Florida gets the most thunder-storms in continental US: >75 days/yr for whole state, >90 days for central FL
- Thunderstorm domain extends from FL NW to central Midwest, also max in Colorado
- Very few thunderstorms along Pacific coast
- Maximum number of hail days occurs in Colorado just NE of where a regional thunderstorm max is

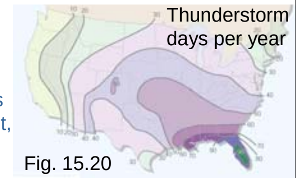


Fig. 15.20

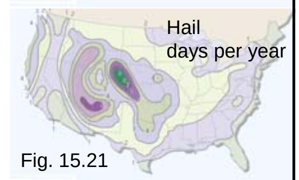


Fig. 15.21

Lightning & Thunder (pp. 383-388)

- Light travels at 186,000 miles/second, so we see lightning almost instantaneously.
- Sound travels at 1000 feet/second, so count seconds from flash of lightning until first sound of thunder. The no. of seconds is the number of 1000 feet the storm is away.
- Research is ongoing to understand how positive and negative charges are separated in a cloud to make lightning possible. Details would take too long to explain for this course. Most suggested processes involve ice, which correlates with cumulonimbus clouds (which have ice tops) being thunderstorm clouds

Lightning: Down & up several times

- Lightning strike begins with downward **stepped leaders**
- When a stepped leader nears the surface, a **return stroke** comes up from ground. The main flow of current goes up to the cloud and is the bright part of a lightning flash.
- Typically, leader and return strokes are repeated 3-4 times in less than a second along the same path through the air

Fig. 14.26, p. 386

Lightning does strike twice

- Lightning is much more likely to hit tall objects, so repeat hits to tall objects are likely. Therefore, do not take shelter under trees!
- Ben Franklin invented the lightning rod in 1752. He refused to patent it because he did not want to make money on something so important for public safety.
- In the last half of the 1700's, some churches (which had the tallest buildings) opposed lightning rods, despite the damage and deaths they suffered because of lightning. See http://www.evolvefish.com/freewrite/franklgt.htm for details.

Fig. 3, p. 389

Fulgurites

- When lightning hits sand, it can fuse the sand together, making what is a called a fulgurite.
- Watch for these at the beach.
- A fulgurite as large as the one below (fig. 14.29, p. 387) can cost hundreds of dollars at a "rock shop."

Lightning flows in the metal body of a car or airplane

- You are safer inside a car than outside not because of the rubber tires. If lightning can travel miles through the air to reach the car, the 6 inches between the bottom of the car and the ground are nothing.
- You are safer because, if lightning hits, it will flow through the metal car body around you rather than through you.
- Same thing for airplanes. It is not uncommon for an airplane to be hit by lightning.
- Governor Jeb Bush's plane was hit by lightning in February 2003.

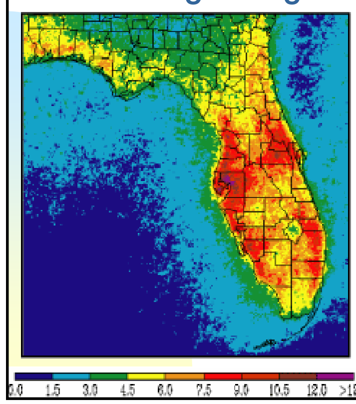
Lightning safety

- Lightning kills average of 70-90/year in US. Floods kill about the same number: www.nws.noaa.gov/oh/hic/flood_stats/recent_individual_deaths.html
- Florida has far more lightning deaths and injuries than any other state. During 1959-2001, 404 killed & 1979 injured by lightning in Florida, most in the peninsula, which has more lightning and more people than the Gulf coast.
- If you can hear thunder, you can be hit by lightning.

Lightning safety

- Most lighting deaths occur where it is not raining. (People are indoors when it is raining.) Golfers, farmers, and construction workers are particularly vulnerable because they are outside.
- Go inside if you here thunder. If you are caught outside and feel your hair stand up or your skin tingle, squat low on the balls of your feet. Don't lie on the ground because current from a nearby strike could flow through your body.
- 30-30 rule: If you hear thunder less than 30 seconds away (30,000 feet), stay inside for 30 minutes after the last thunder.
- See www.floridadisaster.org for more information.

Summer Lightning in Florida

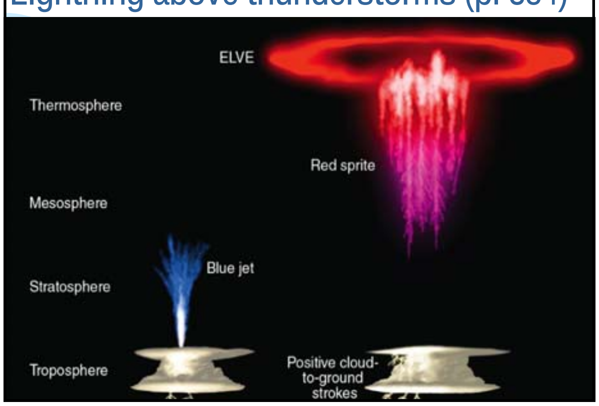


Lightning strikes per sq. kilometer per year. Multiply by 2.6 to convert to strikes per sq. mile per year. (http://fuelberg.met.fsu.edu/research/fpl_lightning.html)

Many strikes at Tampa

Fewer strikes over water, including Lake Okeechobee

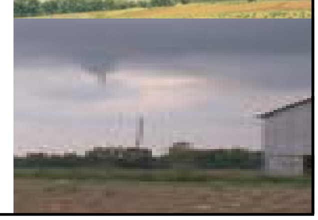
Lightning above thunderstorms (p. 384)



Tornadoes (pp. 389 & on)

- Tornado: column of air rotating rapidly around low pressure with circulation that reaches the ground (fig. 14.32, p. 390).

- Funnel cloud: like a tornado, but the circulation does not reach the ground. Photo from http://www.srh.noaa.gov/bna/surveys/ss090101.htm



Tornadoes

- Typical diameter: 100 - 600 yards, but can be as large as 1 mile across
- Wind speeds characterized by Fujita scale
  - Weak: F0 (40 - 70 mph), F1 (70 - 110 mph
  - Strong: F2 (110 - 160 mph), F3 (160 - 200 mph)
  - Violent: F4 (200 - 260 mph), F5 (260 - 320 mph)
- Most tornadoes are F0 or F1
- Only a few percent are F4 or stronger
- Forward speed: 20-40 mph but can exceed 70 mph
- Most move with upper-level winds from SW to NE.
- Take shelter in sturdy building away from glass and cover your head, e.g., bike or football helmet.

Tornadoes occur in all 50 states

Upper #: Tornadoes in 25 years

Lower #: Tornadoes per year per 10,000 sq miles

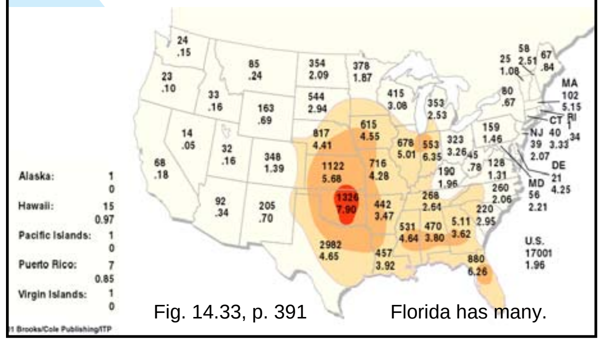


Fig. 14.33, p. 391

Florida has many.

Tornado Formation

- Associated with strong multi-cell thunderstorms, often with mesocyclones embedded in supercells
- ¾ of tornadoes form in March to July
- Most common between 4:00 and 6:00 pm but can occur at any hour, so NOAA weather radio with an alarm is a good idea

F3 tornado and associated mesocyclone

Photo from http://www.photolib.noaa.gov/nssl/nssl0208.htm

Supercell (pp. 394-398)

- Enormous thunderstorm 5-10 miles in diameter
- Updrafts as strong as 90 kts (100 mph)
- Can travel 300 miles
- Can produce hail as big as grapefruit
- Can spawn large, strong tornadoes
- Can form isolated or at the southern end of a squall line, where it's fed by moist air.
- Less than 15% of supercells produce tornadoes
- If a supercell contains a rotating thunderstorm a few miles across called a mesocyclone, tornado formation is much more likely

Formation of Mesocyclone (p. 395)

- Step 1: Vertical shear creates rotation around horizontal axis
- Step 2: Thunderstorm updraft tilts this rotation upright.
- CCW-rotating area in southern sector is the mesocyclone. It is more likely to produce a tornado than the CW spinning area, but 5-10% of tornadoes spin CW.

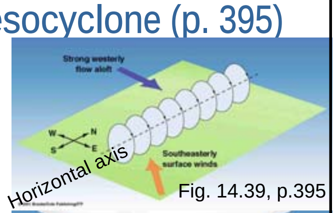


Fig. 14.39, p.395

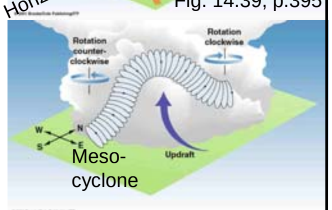
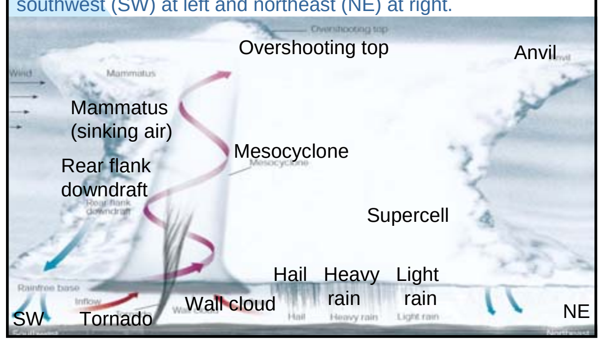


Fig. 15.40, p.395

Tornado inside Mesocylone inside Supercell (Fig 14.41, p. 396)

View from southeast looking northwest with southwest (SW) at left and northeast (NE) at right.



Tornado resources on Web

- Web search will uncover lots of information and photographs of wall clouds and tornadoes
- Small selection of good sites includes:
- National Geographic: http://www.nationalgeographic.com/forcesofnature/interactive/index.html?section=t (Has interactive activities.)
- Storm Prediction Center: http://www.spc.noaa.gov
- http://www.harkphoto.com (One of many sites with storm chase pictures. This chaser is a medical doctor.)

Waterspout (pp. 400-401)

- Rotating column of air over water, typically smaller and weaker than tornadoes.
- Can be tornado that starts over land and moves over water, but most waterspouts start over water.
- Florida Keys: ~100 waterspouts/month in summer

Photo of waterspout from http://www.moc.noaa.gov/gu/visitor/las4/photos2.htm

Doppler Radar (pp. 399-400)

- All US National Weather Service radars have Doppler capability.
- Like regular radars, Doppler radars send out pulses of radio waves and time how long it takes for echoes to return. From this, the distance to the reflecting object can be determined.
- This is the only thing you are shown on TV most of the time.

Doppler Radar (pp. 399-400)

- Doppler radars do more by comparing the frequency of the received radio pulse to that of the transmitted pulses.
  - A higher received frequency means the reflector is approaching; a lower received frequency means receding.
  - Doppler radars can determine and display the speed at which the reflector (such as precipitation) is approaching or receding from the radar but not the part of the velocity (speed) of the reflector that is at right angles to the line of sight to the radar.

Doppler Radar View of Mesocyclone

- A Doppler radar cannot see a tornado because it is too small, but it can see a rotating mesocyclone inside supercell.
- The rotation in a mesocyclone is identified by winds approaching the radar (green & blue) next to winds going away from the radar (yellow & red).

Fig. 14.47, p. 399