Thunderstorms, Supercells, Tornadoes

- How do thunderstorms form?
- How do supercells and tornadoes form?

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Thunderstorms: Definition

- Really just a storm that produces thunder (and lightning)
  - Some are capable of producing strong surface winds, heavy rain, hail, tornadoes
  - Single cumulonimbus cloud, cluster of storms, line of storms extending several kilometers
- Thunderstorms are convective storms: birth of a thunderstorm begins when warm, humid air rises in a conditionally unstable environment (→lectures on stability)
  - Unequal surface heating
  - Terrain induced
  - Lifting of air along shallow boundaries of converging surface winds

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Thunderstorms: Types

- Ordinary Thunderstorms
  - Single cell
  - Multicell
- Severe Thunderstorms
  - Supercell
  - Mesoscale Convective Systems (MCSs)
    - Squall lines
    - Mesoscale convective complexes (MCCs)
  - Dryline thunderstorms

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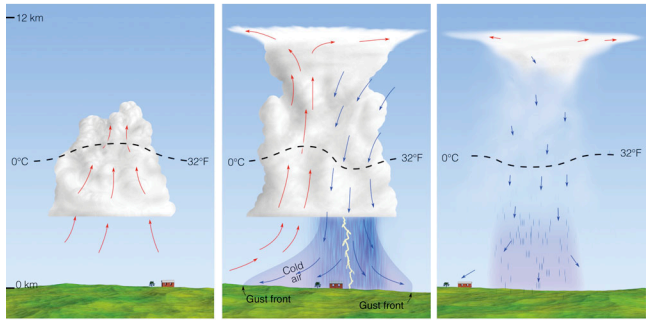
Ordinary Thunderstorms



- Duration: 1 hour or less. Environment: weak vertical wind shear, shallow zone of surface wind convergence
- Three stages: cumulus, mature, dissipating

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Ordinary Thunderstorms

- Cumulus Stage (growth stage)
  - Warm, moist air parcel rises, cools, and condenses into a single cumulus cloud or cloud cluster
  - Extensive vertical development (fed from below) to become towering cumulus (cumulus congestus)
  - Large, heavier particles higher in cloud begin to fall
- Mature Stage
  - Entrainment and downdraft
  - Most intense stage (precipitation, lightning, thunder, overshooting, anvil)
  - Gust front
- Dissipating Stage
  - Updrafts weakened / cut off by downdrafts
  - Left with only weak downdrafts

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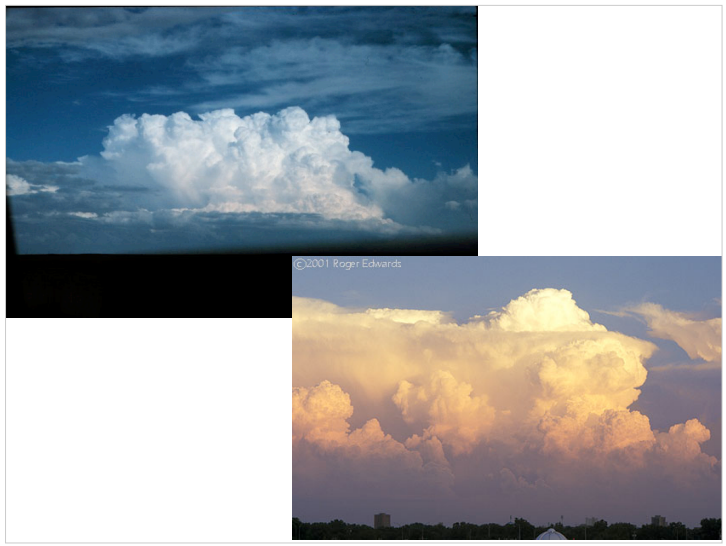
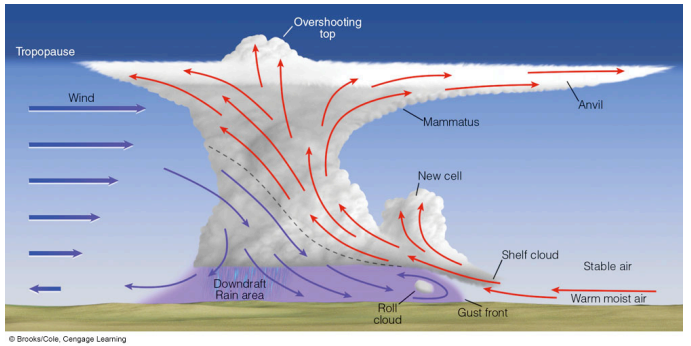


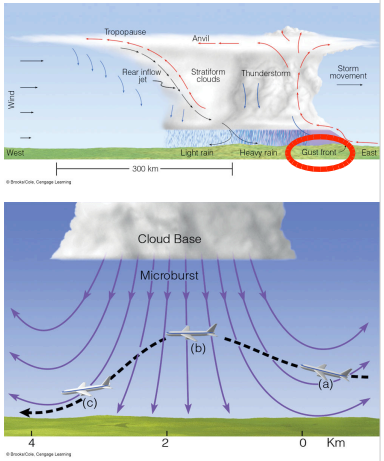
Severe Thunderstorms

- Requirements: produces hail with at least .75" diameter AND/OR produces surface wind gusts ≥ 50 kt AND/OR produces a tornado
- Environment: strong vertical wind shear → updrafts sustained, can produce large hail



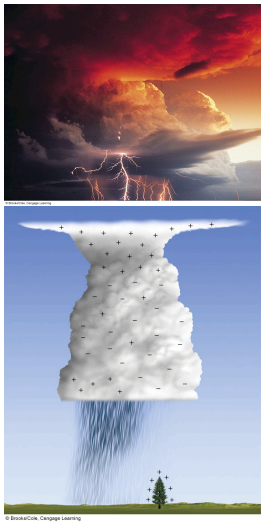
Gust Front and Microburst

- Gust Front: leading edge of cold air originating in storm
  - wind changes direction and speed, temperature decreases (like a cold front)
  - Local increase in surface pressure (mesohigh)
- Downburst: intense, localized downdraft hits ground and spreads out horizontally
  - Microburst: a downburst with winds extending only 4 km or less
    - Can produce a gust front
    - Responsible for airplane crashes



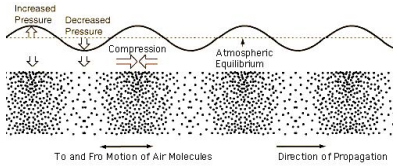
Lightning

- Discharge of electricity, between regions of opposite charge
- Air insulates, but not completely → can bridge gap for high enough charge difference
- Not fully understood how charged regions within clouds come about
  - collisions of rimed particles (incl. graupel & hail) with ice crystals play big role
- Typical charge distribution: positive toward the top / negative toward the bottom / positive at the surface



Thunder

- Lightning discharge causes instantaneous & localized heating by 30,000°C (54,000°F) – 5 times the temperature of the sun!
- Extreme heating causes air to expand explosively → shock compression/sound wave = thunder
- Speed of sound ~ 1 km per 3 sec (1 mi per 5 sec) → can be used to estimate distance to thunderstorm



Compression (sound) wave illustration

Floods

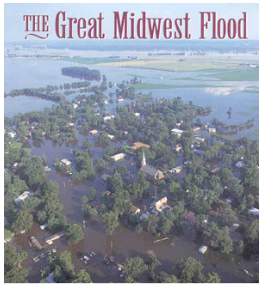
- When thunderstorms stall or move very slowly
  - heavy rainfall over a relatively small area
  - can cause rivers and creeks to overflow
- Flash Floods: floods that rise rapidly with little or no advance warning
  - Leading cause of weather related deaths in the U.S. – approximately 200 deaths per year

Tuesday AM, Explain: Thunderstorms & Tornadoes

- Big Thompson Canyon: 31 July 1976
- The Great Flood of 1993: June-July 1993
- Fort Collins: 27-28 July 1997

Oregon, 1903

Big Thompson River Canyon, 1976

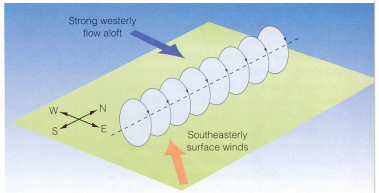


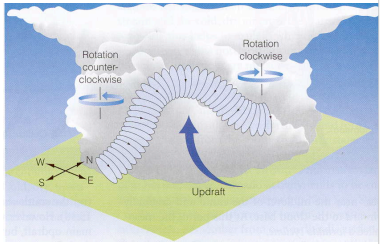
Des Moines, IA 1993

Ft. Collins, 1997

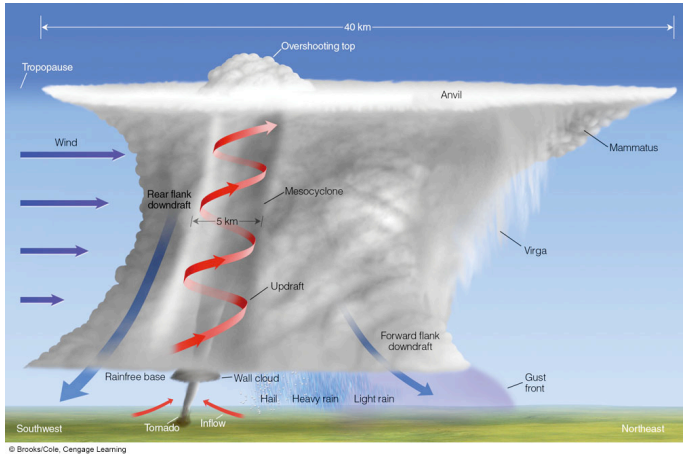
The Supercell

- Requirements
  - Very strong vertical wind shear
  - Cold downdraft never undercuts the updraft
  - Shear creates horizontal spin that can be tilted into the updraft → rotation
- Characteristics
  - Violent rotating updrafts
  - Single, self-sustaining cell (lasts for hours)
  - Updrafts exceed 90 kt
  - Grape fruit sized hail
  - Damaging surface winds
  - Long-lasting tornadoes
- Precipitation: high or low





Tornado-Breeding Supercell



Thomas Birner, ATS, CSU

Tornadoes

- Rapidly rotating column of air around low pressure (that reaches the ground)
- Most tornadoes are a few 100 meters wide, have wind speeds < 100 kt, and last only for a few minutes
- Can rotate clockwise or counterclockwise – why?
- U.S. experiences most tornadoes (> 1000 annually)
- Tornado Alley: central plains between Texas and Nebraska
- Most in March – July (max in May)

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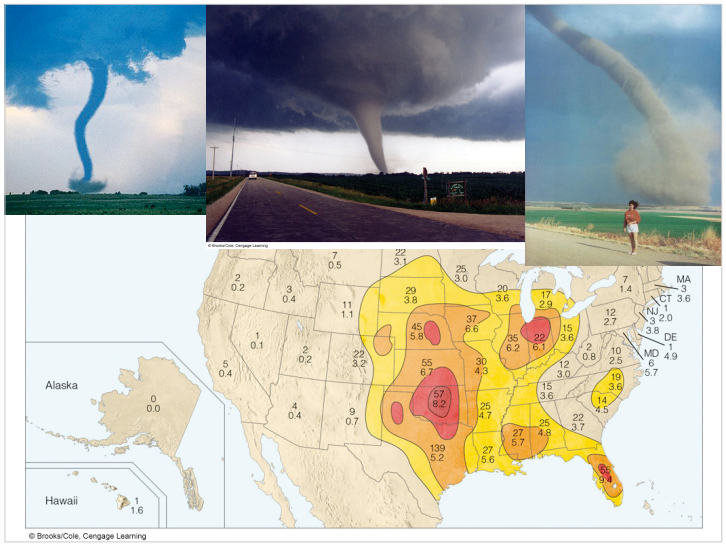
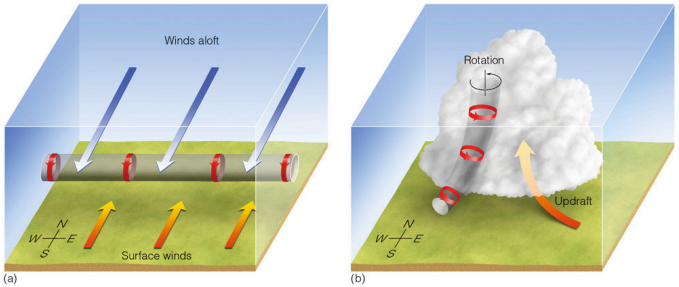


Tornado Formation



- Strong wind shear near the surface + unstable conditions
- Wind shear generates “vortex tube” that is tilted upward, e.g. into a supercell thunderstorm
- Updraft stretches the tube which increases rotation (angular momentum conservation ~ ice skater effect)

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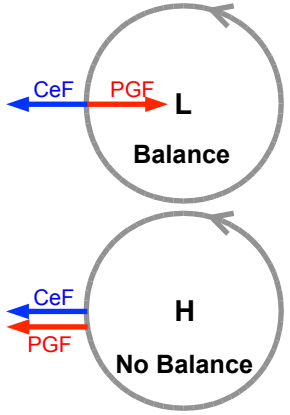
Why is there never high pressure at the center of tornadoes?

- Tornadoes are small-scale phenomena → no Coriolis force
- Strong rotation → Centrifugal force (CeF) is important
- Pressure gradient force (PGF) needs to balance centrifugal force!



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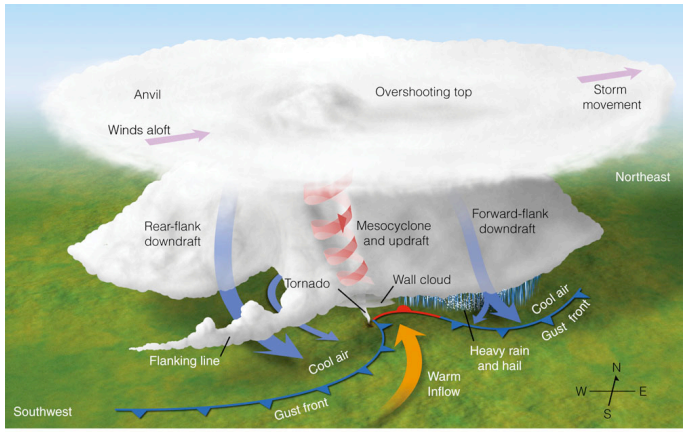
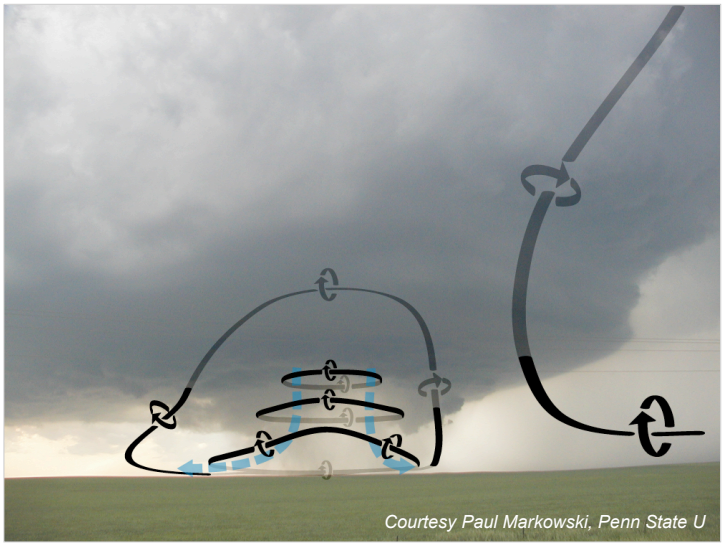
Tornadic Supercell





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