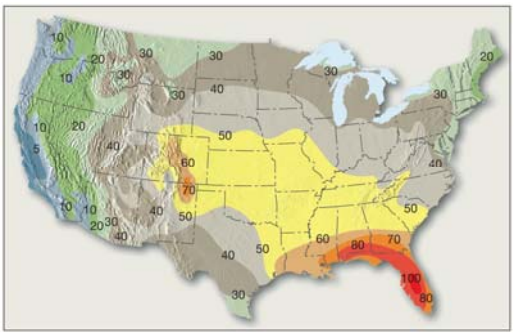
MET3003

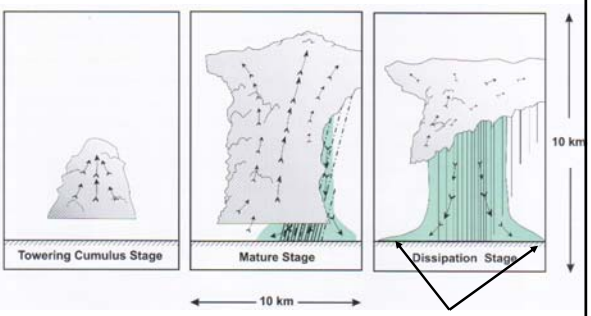
What is severe weather?

- Large, damaging hail (20 mm, or ¾ in)
- Damaging winds (60 mph, 50 kt, or 25 m s^{-1})
- Tornado
- Or all of the above
- Mesoscale with strong updrafts!
- ***Thunderstorm:*** Any storm that produces thunder

Number of Thunderstorm Days a Year

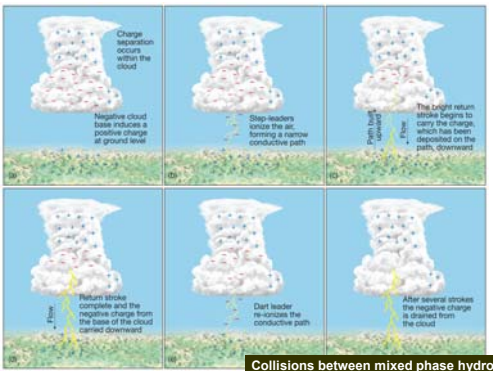


Air-Mass Thunderstorm Life Cycle



Form when moist (i.e. mT) air moves over a land surface and solar heating triggers convection

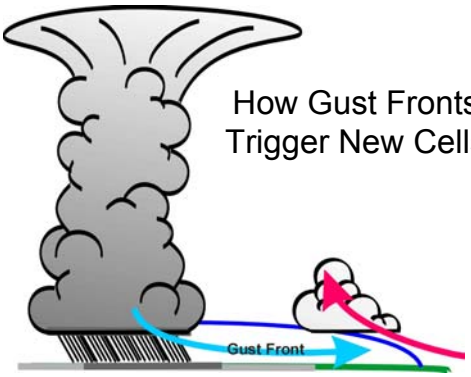
Lightning: Updraft levitates smaller positively charged particles



Collisions between mixed phase hydrometeors separates positive charge onto smaller particles

Lightning Stroke

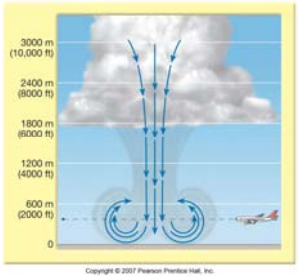
- Initiated by stepped leader
  - Takes 20 ms to reach ground
  - In 50 m steps
- Return stroke lasts 70 μs
  - Conducts 10-20 ka
- Flash is made up of multiple strokes
- After 30-40
  - Dart leader
  - Second stroke
- Single strokes, 3-6, and more than 20 can happen.
- Total charge is a few Coulombs



How Gust Fronts Trigger New Cells

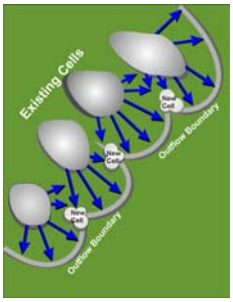
Microbursts

- Strong convective downdraft
- Spreads out along ground.
- Airplane on final approach
  - Encounters head wind
  - Reduces airspeed
  - Then encounters downdraft as the head wind becomes a tail wind



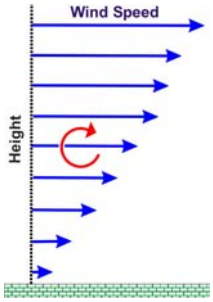
Outflow Boundaries

- Downdraft air spreads at the surface
  - Gust front
  - Outflow boundary
  - Arc cloud
  - Bow echo…
- Important to forming new convection
- Maintain identity for hours after convection
- Deep convection triggered when outflow boundaries intersect
- With weak forcing, boundary interactions control thunderstorm formation

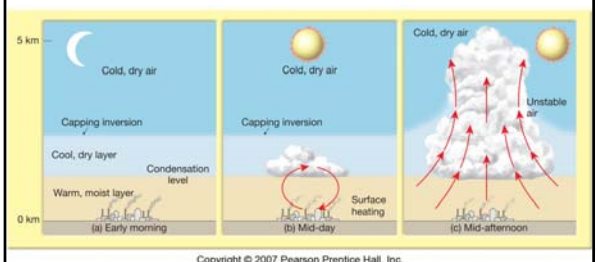


Vertical Shear

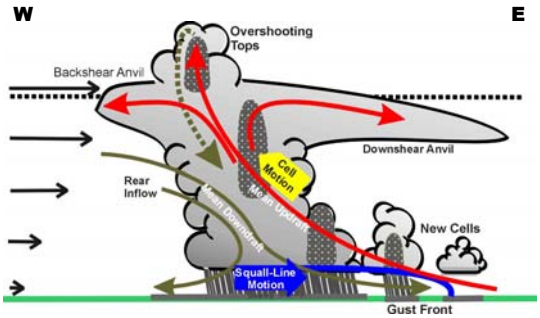
- Defined as upper-level wind minus lower-level
- Due to thermal wind effects
- Can arise from changes in direction or speed
- Is equivalent to rotation around a horizontal axis perpendicular to the wind (vorticity)
- Plays an essential role in setting the environment for severe weather



How a Capping Inversion Makes Convection Stronger

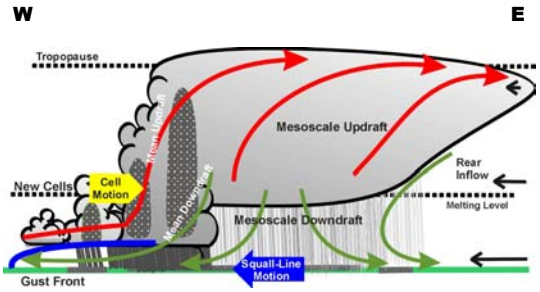


Mid-Latitude Squall Line



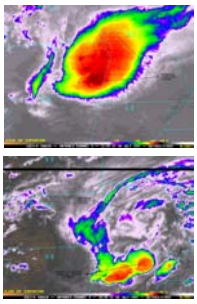
Backshear anvil can be much more extensive

Tropical Squall Line



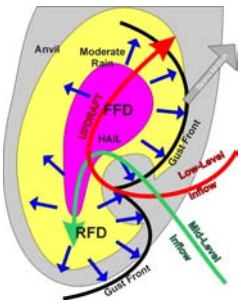
Mesoscale Convective Complexes

- Form in late afternoon or evening
- Several thunderstorms combine
- Many convective cells
- Outflow boundaries trigger new convection
- Characteristics:
  - 100,000 km^2 with cloud top temperature < -32^{o}C
  - Must stay that large for 6 h
  - Elliptical, (minor axis)/(major axis) > 0.7
- Cause nighttime rainfall max in Great Plains
- Some severe weather, but mostly beneficial rain



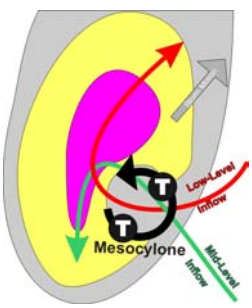
Supercell Thunderstorms

- Require shear and powerful instability
- Shear causes sloping updrafts
- Hydrometeors fall from updrafts
- So precipitation loading is less of a factor
- Crossing mid-level and surface inflows form front- and rear flank downdrafts (FFD & RFD)
- Which generate permanent merging outflow bondaries
- That maintain a long-lasting (hours) updraft



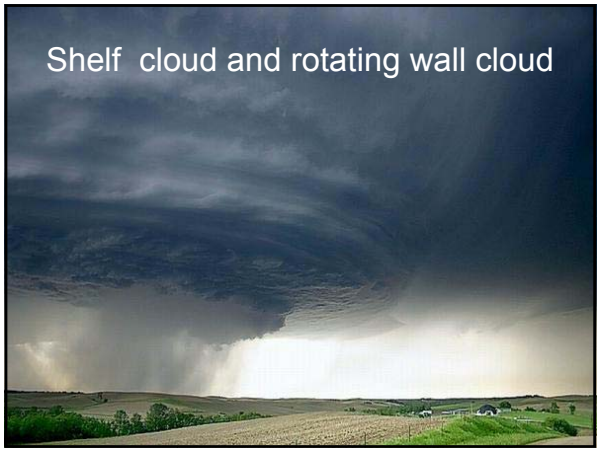
Supercells and Tornadoes

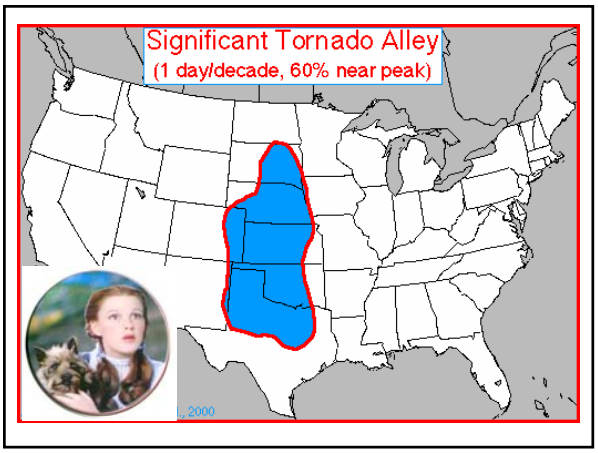
- Most F2-F5 tornadoes form in supercells
- Rotating updraft forms a mesocylone
- Tips horizontal rotation (low-level shear) into the vertical
- Causing cyclonic and anticyclonic rotation on the flanks of the updraft



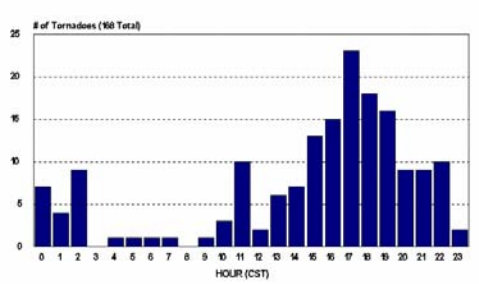
Tornado Characteristics

- Must have a funnel cloud extending from cloud base to the surface
- Maximum winds can be as strong as 100 m/s, or 200 mph
- Size ranges a few meters to nearly a kilometer, 100m typical
- Typically about 1000 per year (20-50 of which a "violent")
- ***Type I*** Tornadoes
  - Form within the ***Mesocyclone*** of a supecell thunderstorm
  - Strongest tornadoes are Type I
- **Type II** Tornadoes
  - Form along stationary or slowly moving wind-shift lines
  - Much weaker
- **Operational Enhanced Fujita Scale**
  (Feb 2007, uses 3 s gust))
  - Weak F0, 65-85
    F1, 85-110 mph
  - Strong F2,111-135 mph
    F3, 135-165 mph
  - Violent F4, 166-200 mph
    F5, > 200 mph

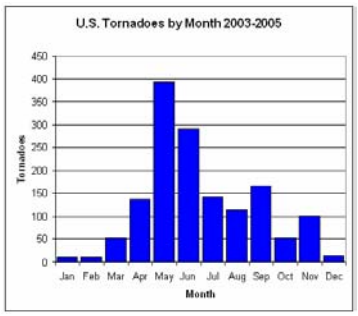


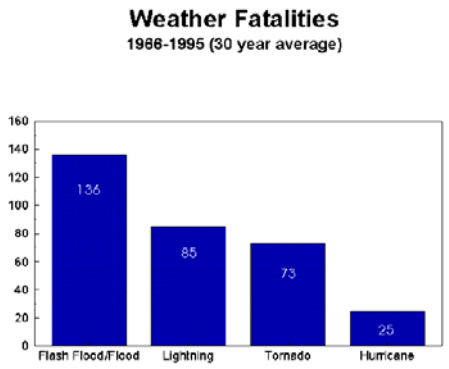


When do Tornadoes Occur During the Day?



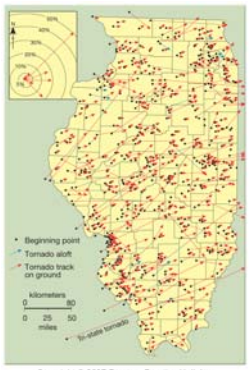
When Do Tornadoes Occur During the Year

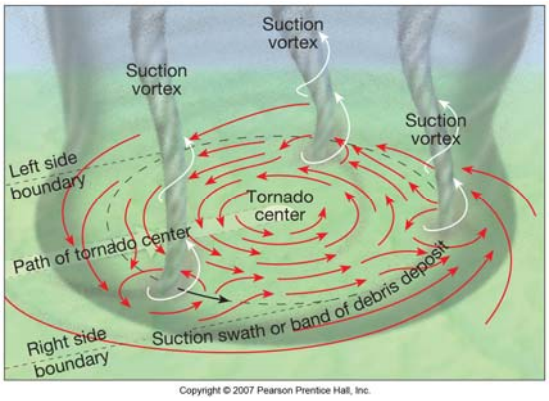




Tornado Motion

- Form in warm sector or in warm air above the cold frontal surface
- Flow is from the SW so that Tornadoes generallymove SW-NE
- Often with a looping or cycloidal motion



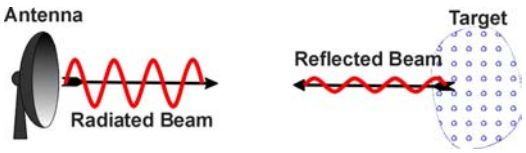


Tornado Forecasting

- Starts with forecasting instability based upon large scale flow.
  - Jet stream
  - Air masses
- Set up **Watch Boxes** within which Tornado formation is likely
- Based upon radar and visual observation the Watch becomes a ***Warning***
- Meaning tornado in the ground.
- Radar cannot detect tornadoes, but it can tell where to look

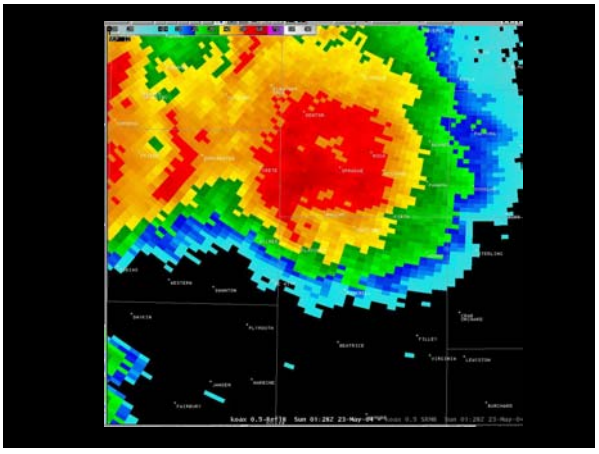
How Does Radar Work?

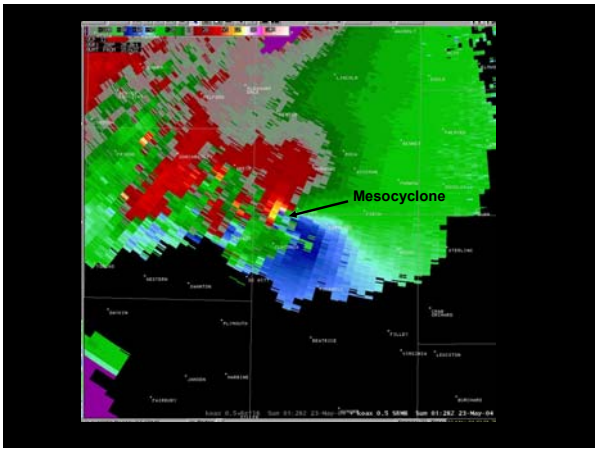
- Radar emits a pulse
- Travels until it reaches a target
- Reflected back to antenna
- Time of travel tells distance
- Brightness of echo tells size and/or number of scatterers



Doppler Radar

- Pulse reflected from an approaching target gets compressed to shorter wavelength (higher freq)
- Pulse reflected from a receding target gets expanded to longer wavelength (lower freq)
- Measures only radial wind toward or away from radar





Summary

- Know the definition of ***Severe Weather***
- Be able to draw and explain the life cycle of an Air Mass Thunderstorm
- Be able to draw and explain the evolution of a Lightning Stroke, illustrating the ***Stepped Leader, Return Stroke, Dart Leader*** and subsequent Return Strokes.
- Understand how gust fronts trigger new convection
- Know what a ***Microburst*** is and how it poses a hazard to low-flying aircraft
- Know why ***Wind Shear*** and ***Capping Inversions*** are important
- Be able to recognize, ***Middle-Latitude Squall Lines***, ***Tropical Squall Lines***, ***Mesoscale Convective Complexes*** and ***Supercell Thunderstorms*** and know their significance
- Know the general characteristics of tornadoes and their climatology including, maximum winds, size, number per year in the US, most dangerous month of the year or time of day, and motion
- Know generally what the ***Extended Fujita Scale*** is and what EF0-EF5 mean
- Understand how tornado forecasting works, including the definitions of ***Watch*** and ***Warning*** in this context.
- For next time: **Read Chapter 11**