Thunderstorms, Tornadoes, Derochos and Waterspouts

GEOG/ENST 2331 – Lecture 16

Ahrens: Chapter 13

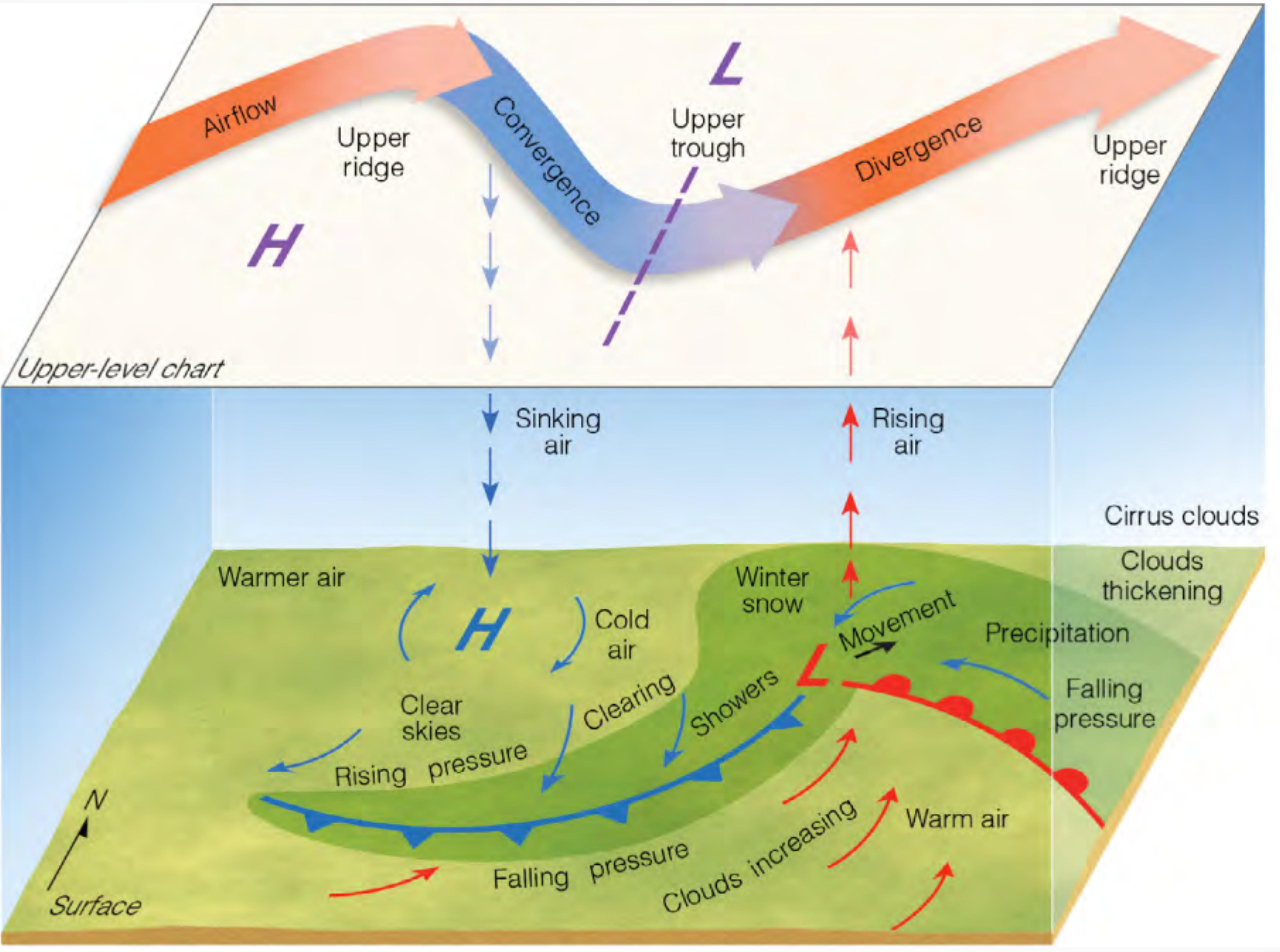
Photo source

Lake Huron NOAA

9 September 1999

Last lecture

- Midlatitude cyclones
  - Polar front theory
  - Vorticity
  - Baroclinic instability
  - Jet streaks


Airflow
Upper ridge
Convergence
L
Upper trough
Divergence
Upper ridge
H
Upper-level chart
Sinking air
Rising air
Cirrus clouds
Clouds thickening
Warmer air
Winter snow
H
Cold air
Movement
Precipitation
L
Clear skies
Clearing
Showers
Falling pressure
Rising pressure
N
Warm air
Falling pressure
Clouds increasing
Surface

Thunderstorms and Tornadoes

- **Thunderstorms**
  - **Ordinary thunderstorms**
  - **Supercell thunderstorms**
  - **Lightning and thunder**
- Tornadoes

Ingredients

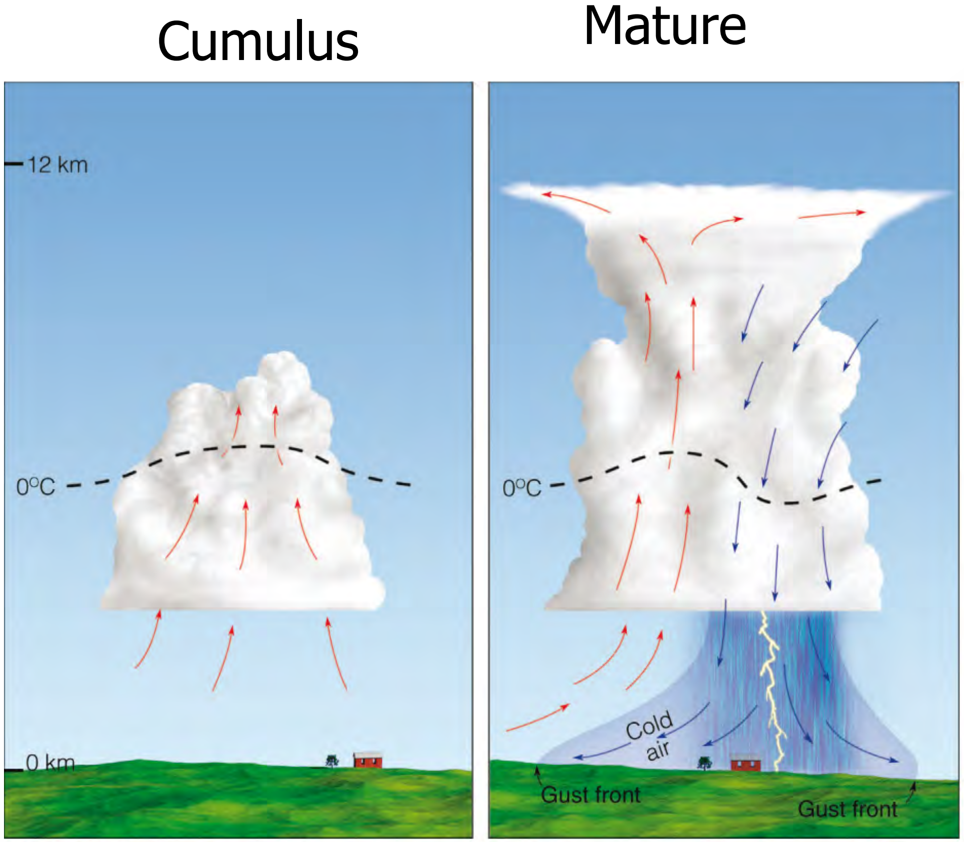
- Warm, humid air
- Conditional or absolutely unstable ELR
- Once air starts moving upward, it keeps going until it hits a stable layer – possibly right to the stratosphere

Ahrens: Fig. 13.1

Thunderstorms

- As the air rises, moisture condenses and clouds form
- Too fast for precipitation
- Kept aloft by updraft.

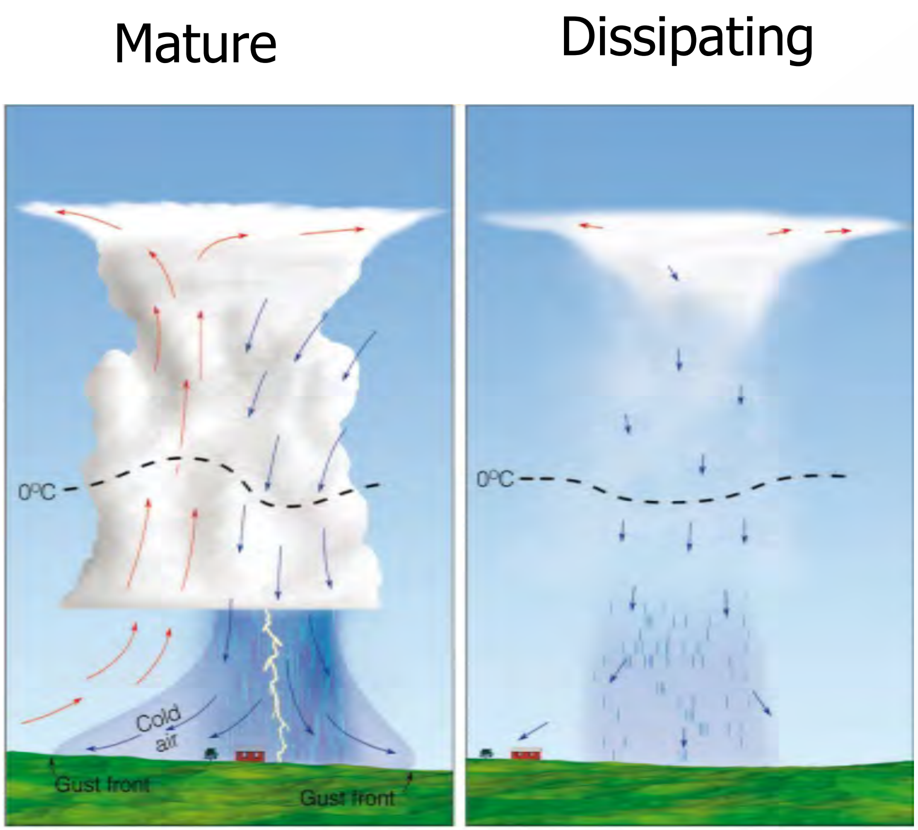
- *Entrainment*
- Heavy drops begin to fall
- Cold air and precipitation cause a downdraft.



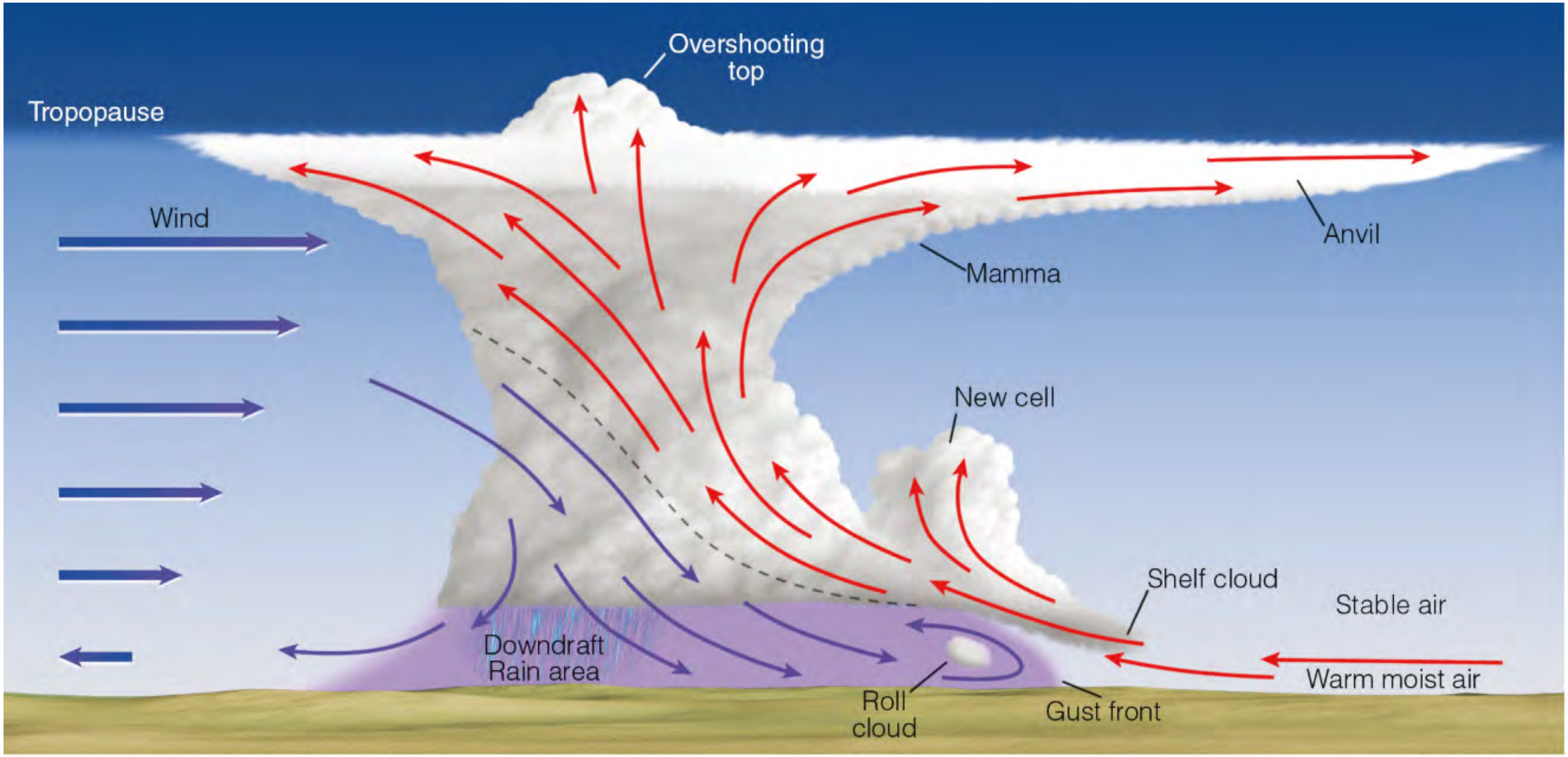
Ahrens: Active Fig. 13.2

Thunderstorms

- *Gust front* forces more air up into the updraft.
- Updraft and downdraft form a *convective cell*.
- When the gust front moves past the updraft, the updraft weakens.
- Rain starts to fall into the updraft, cutting off the rising humid air.
- **Process may repeat in *multicell* thunderstorms**



Multicell Thunderstorms

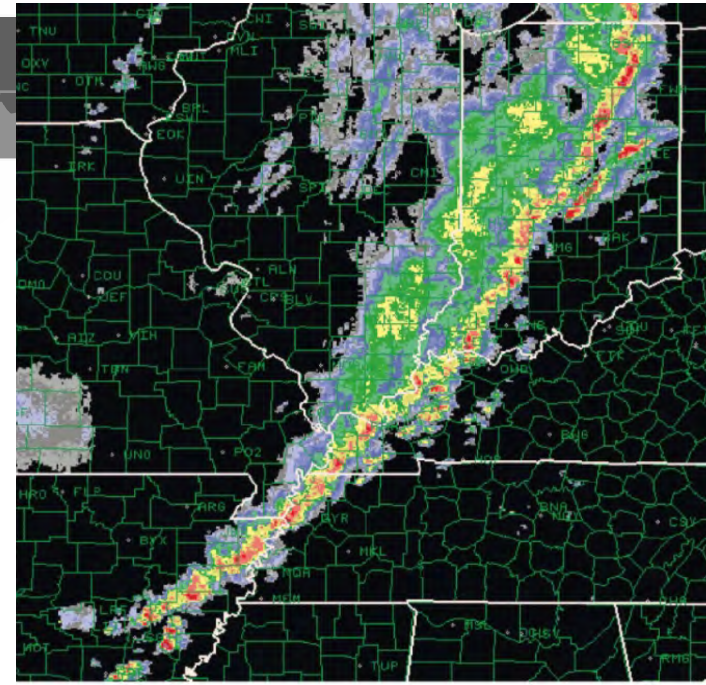


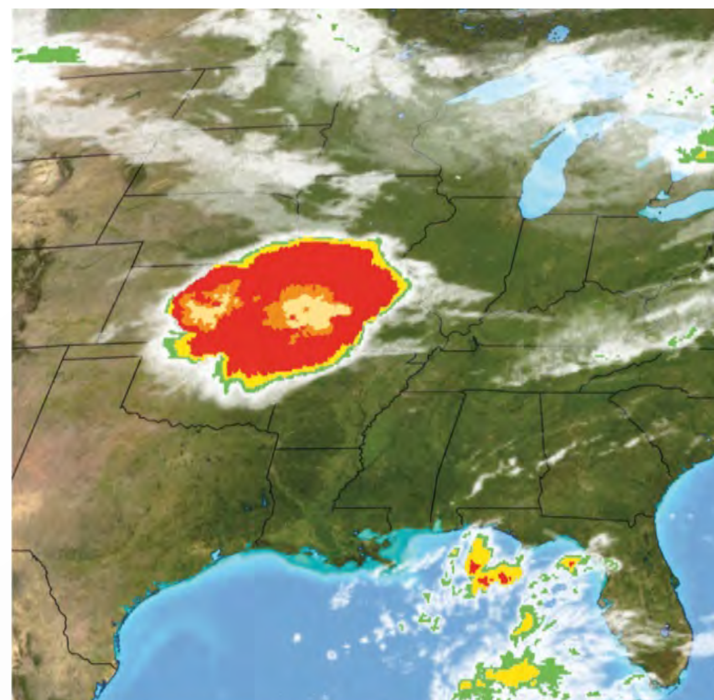
Ahrens: Fig. 13.3

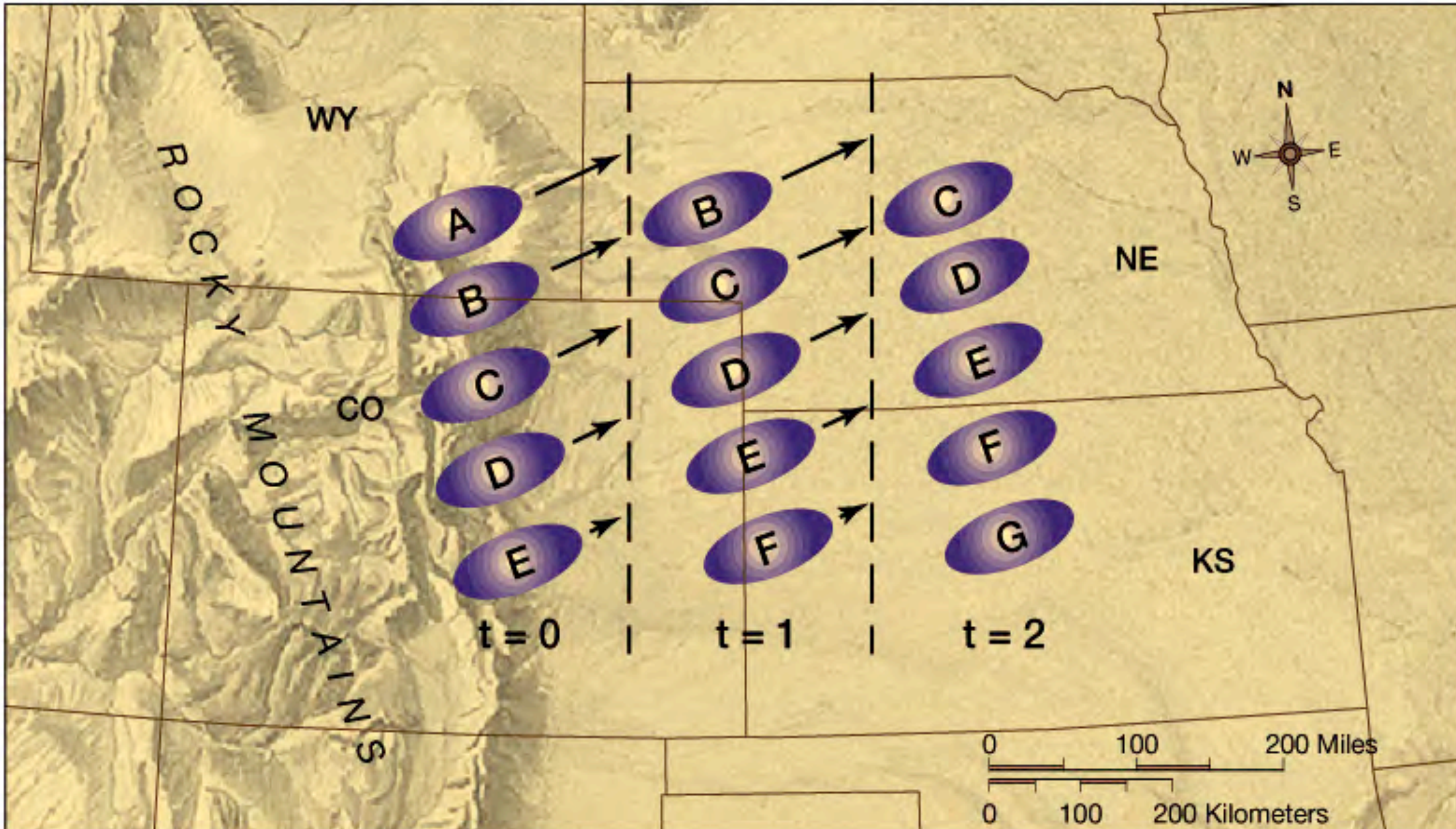
Multicell storms

- Squall line
  - A line of thunderstorms
  - Severe squall lines may form along or in front of a cold front.
- Mesoscale Convective Complex (MCC)
  - Oval or roughly circular organized systems
  - Self-propagating
  - Downdrafts lead to the formation of new, powerful cells nearby

Ahrens: Figs. 13.9 and 13.13



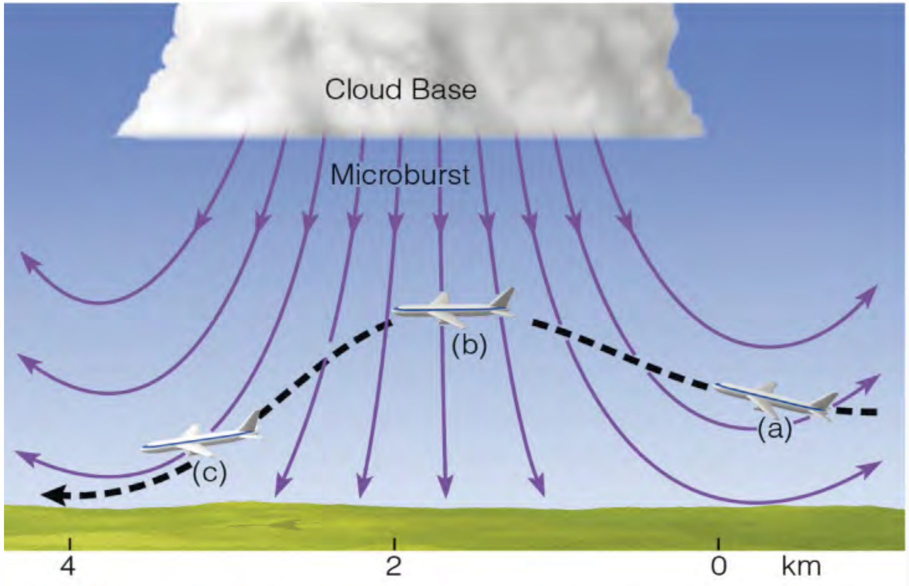




Thunderstorm movement in an Mesoscale Convective Complex

Downbursts

- Strong downdrafts may also create downbursts
  - Wind speed over 270 km/h
- Spread outward in all directions at surface
- Downbursts with diameters of less than 4 km are called *microbursts*
  - Potentially deadly problem near airports



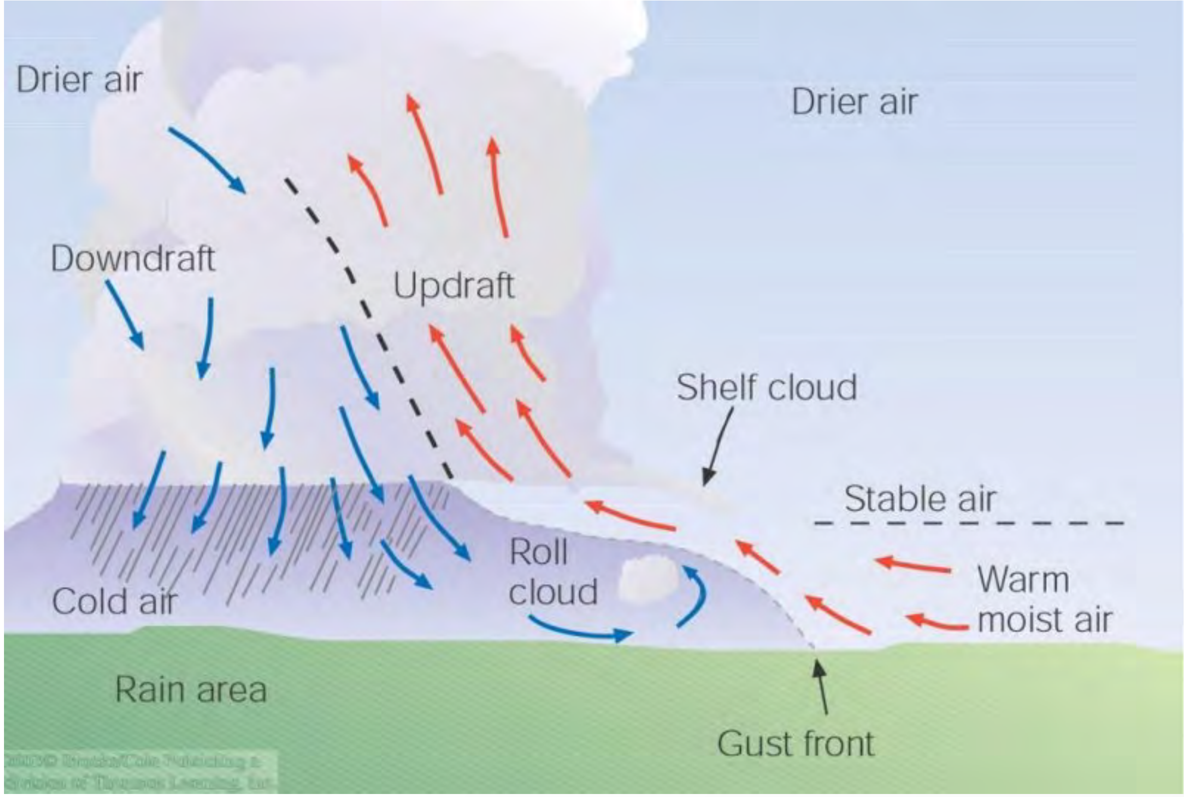
Ahrens: Figs. 14.10 and 13.8

Supercell thunderstorms

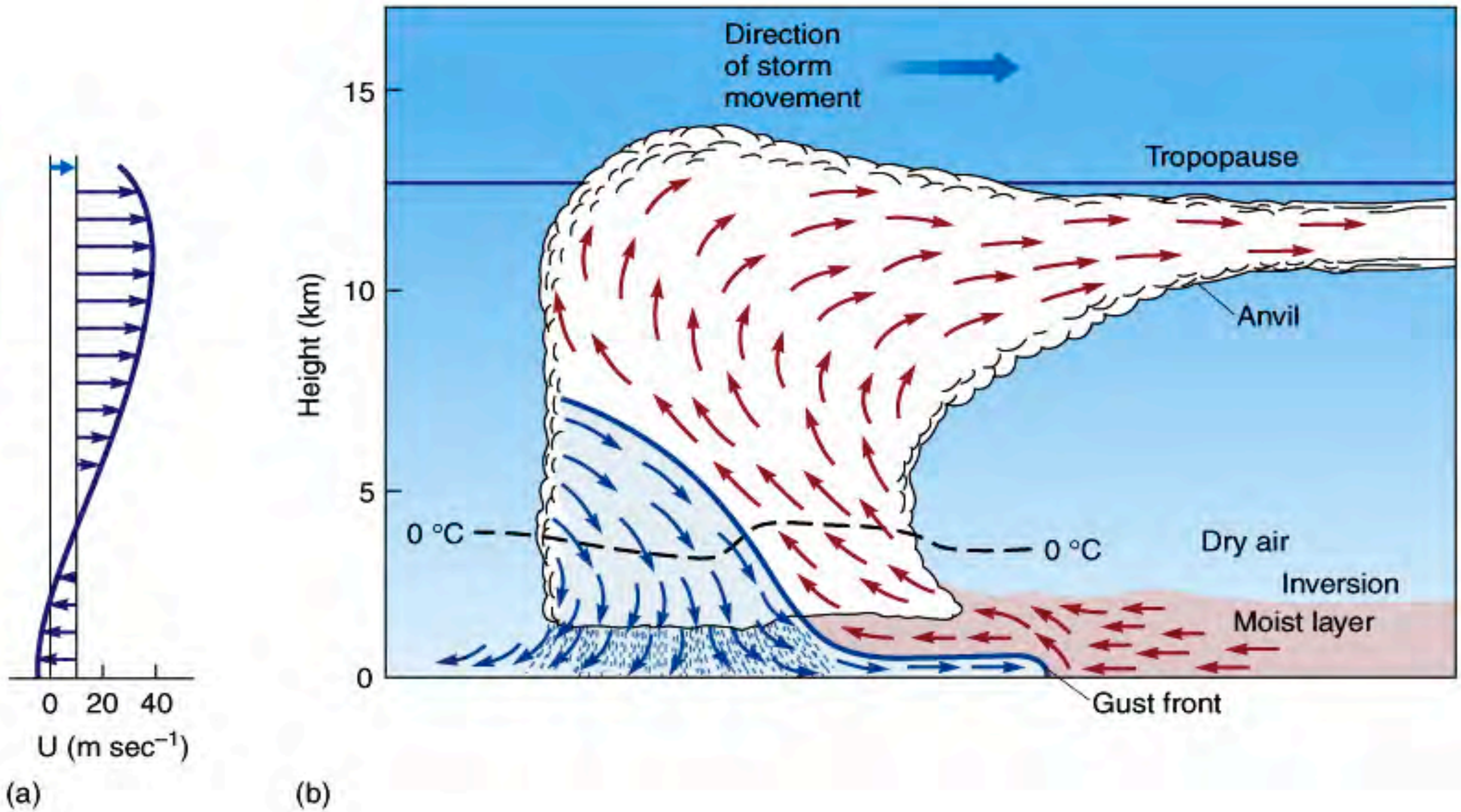
Severe thunderstorms can form in areas where there is strong *vertical wind shear*

E.g. between the fronts of a midlatitude cyclone

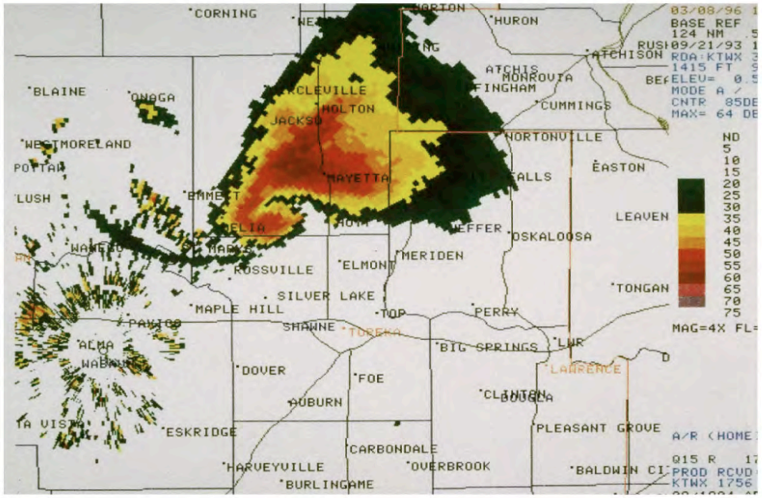
Upper level winds push the updraft away from the precipitation.



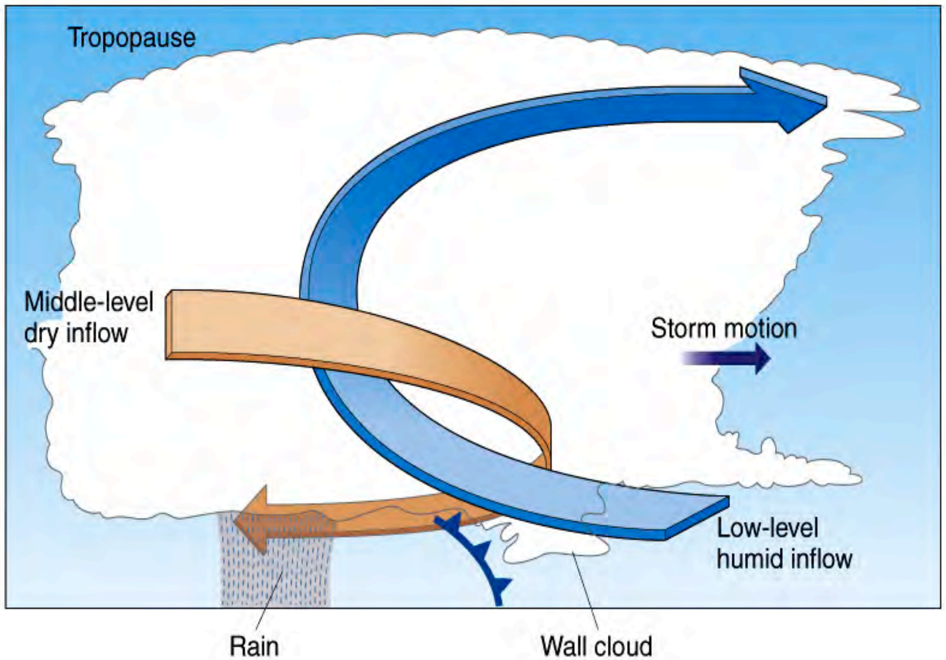
Self Propagating Severe Thunderstorms

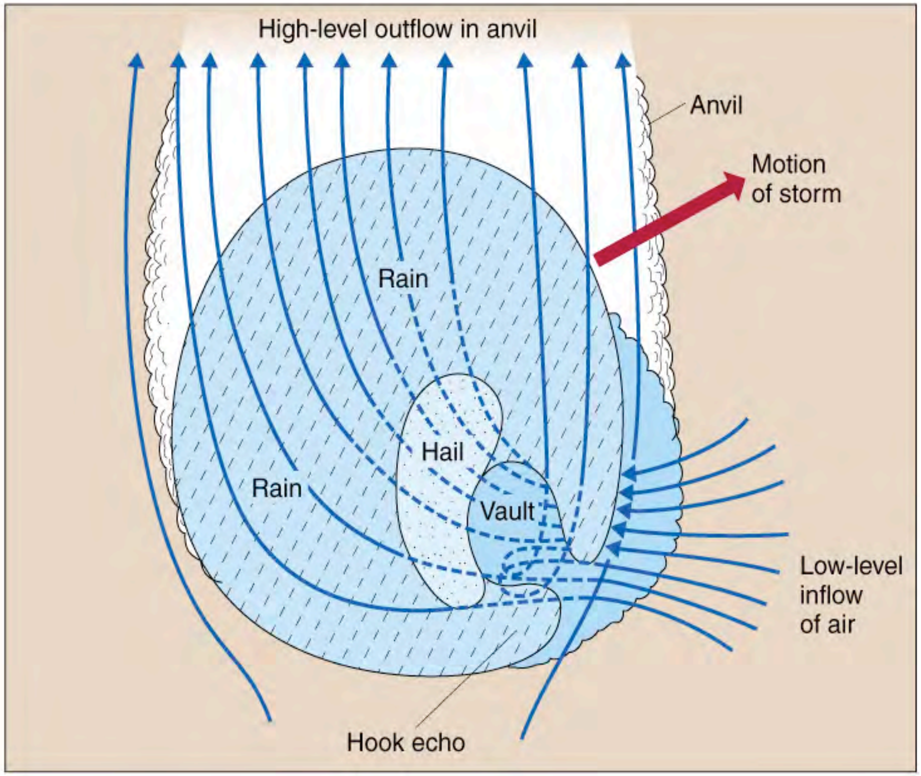


Supercell Storms

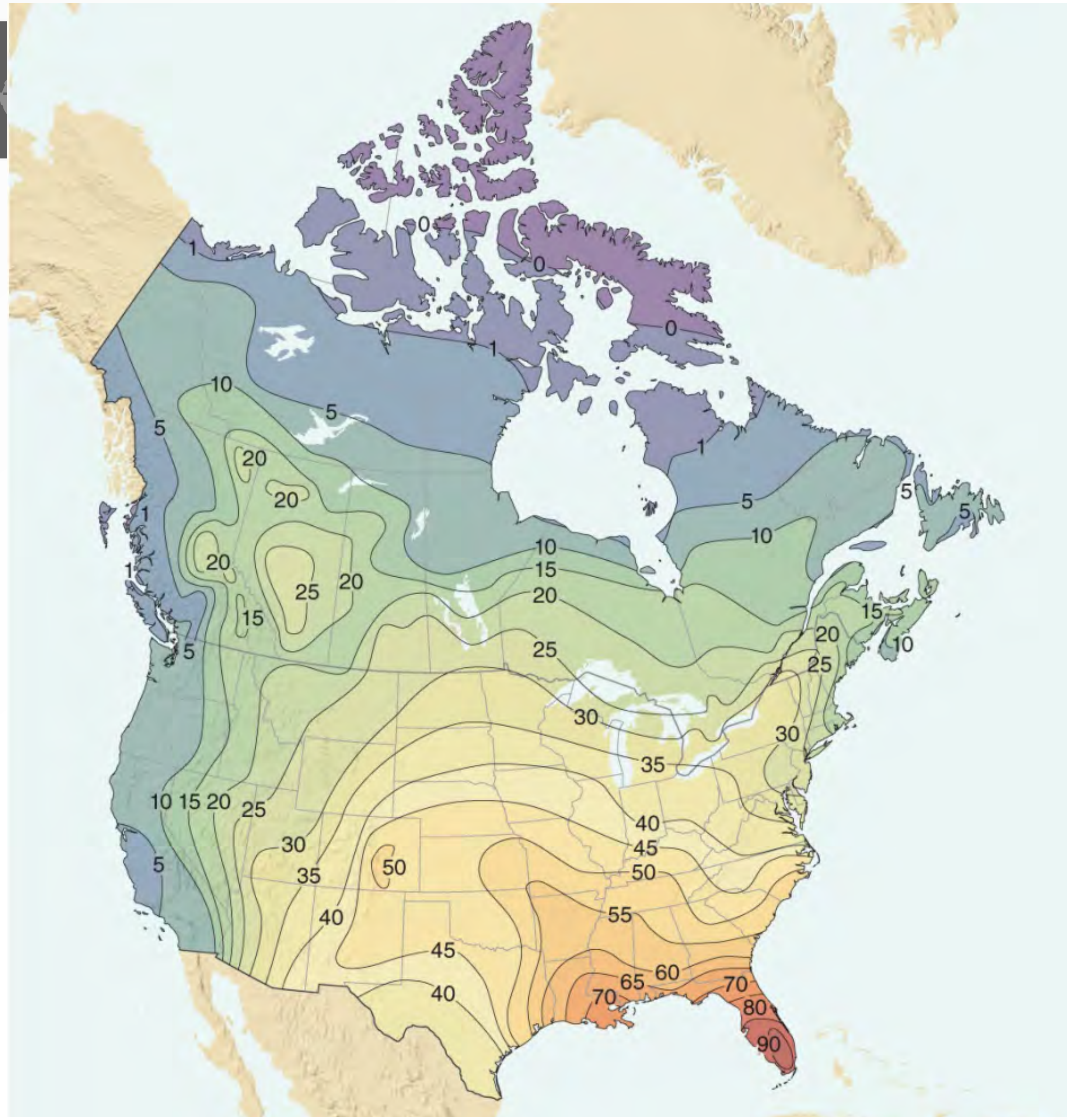


Below: Internal structure of a supercell
Right : Organization of a supercell as seen on a radar image





Supercell Thunderstorms

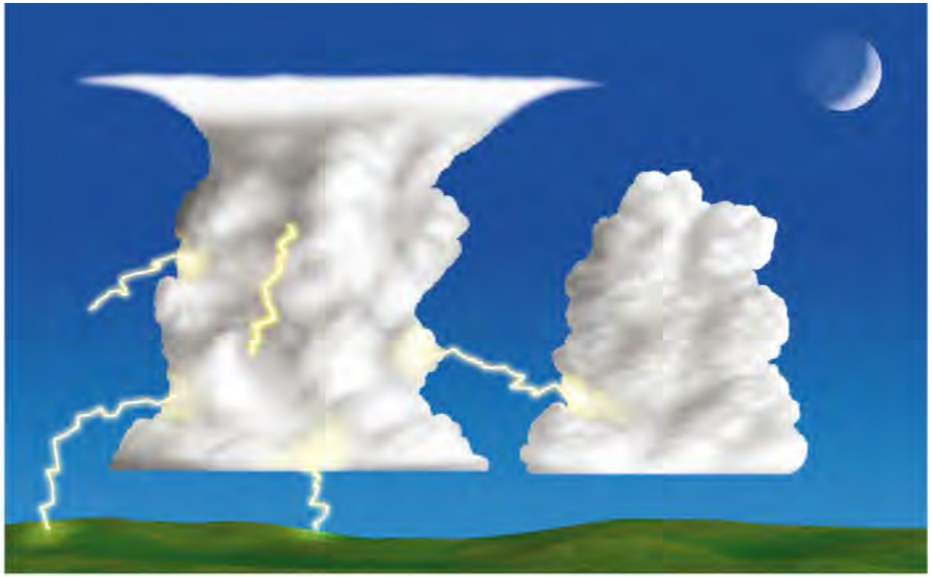


Thunderstorm distribution

Ahrens: Fig. 13.19

Lightning

- Giant sparks travelling through the air
- Air is heated to extremes such as 30,000°C
- Rapid expansion causes a thunderous shockwave
- The majority of strikes occur within the clouds; roughly 1 in 5 hits the ground.



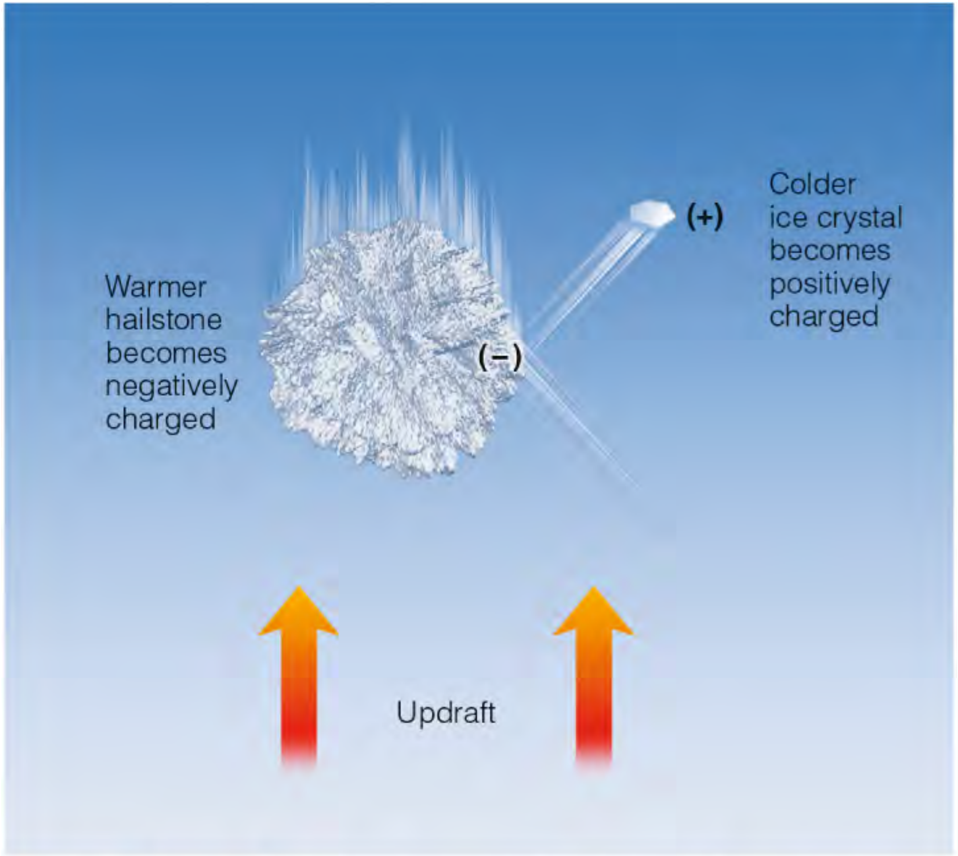
Ahrens: Fig. 13.21

Lightning

Ahrens: Fig. 13.22

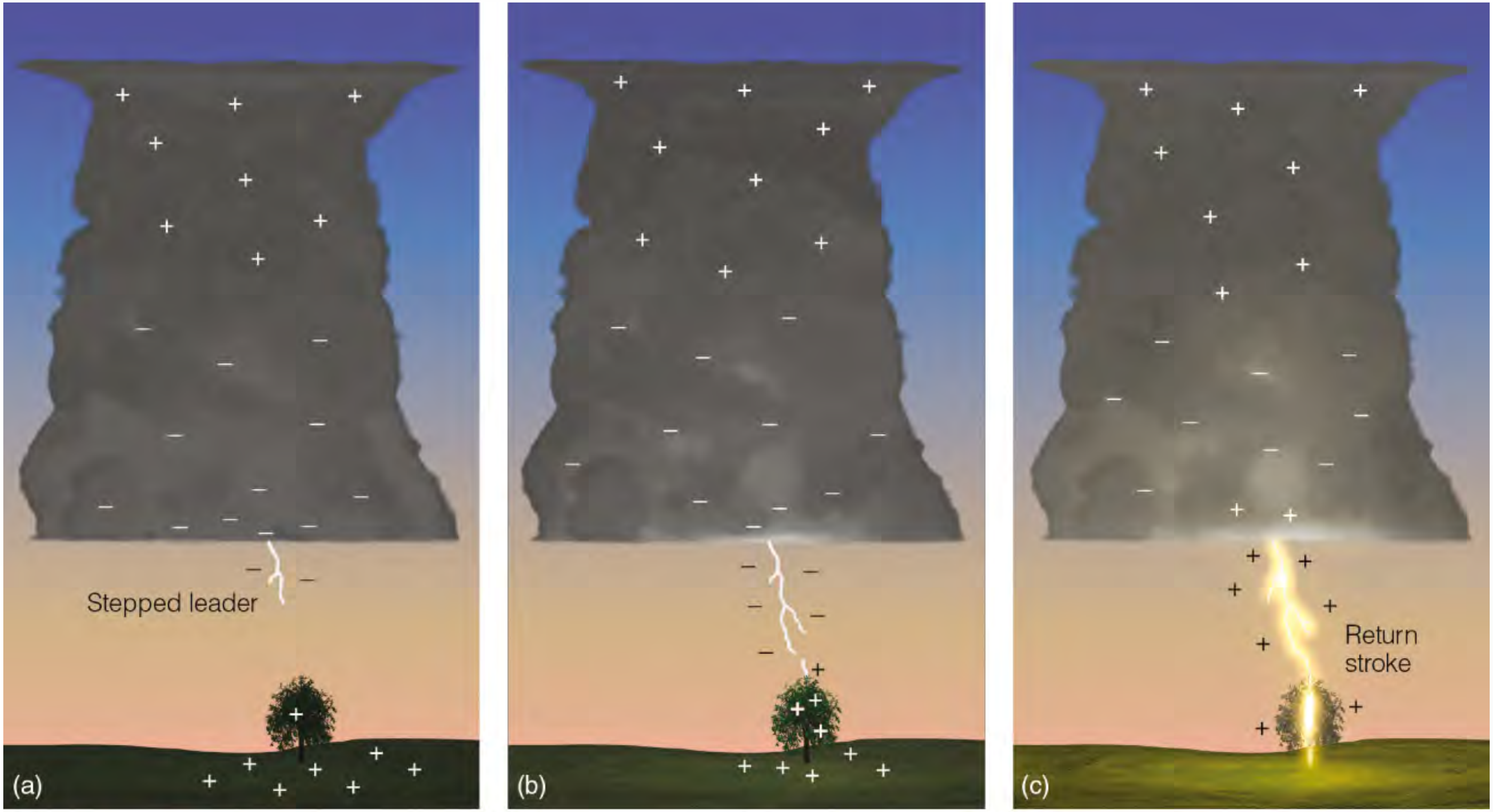
Lightning

- Uncertainties how clouds become electrically charged
- One theory is that when precipitation particles with different temperatures collide they become charged
- Updrafts sweep up the little particles creating a physical separation between charges.



Ahrens: Fig. 14.27 (previous edition)

Lightning



Ahrens: Active Fig. 13.23

Thunder

- The rapid expansion of air associated with a lightning stroke causes thunder
- The slower speed of sound, with reference to light, causes a lag between the stroke and the resulting thunder
- To estimate the distance (in km), count the seconds between the light and sound and divide by 3

Lecture outline

- Thunderstorms
- **Tornadoes**
  - **Necessary conditions**
  - **Development**
  - **Climatology**

Tornadoes

Rotating column of air with extremely violent winds

- 100-500 km/hr

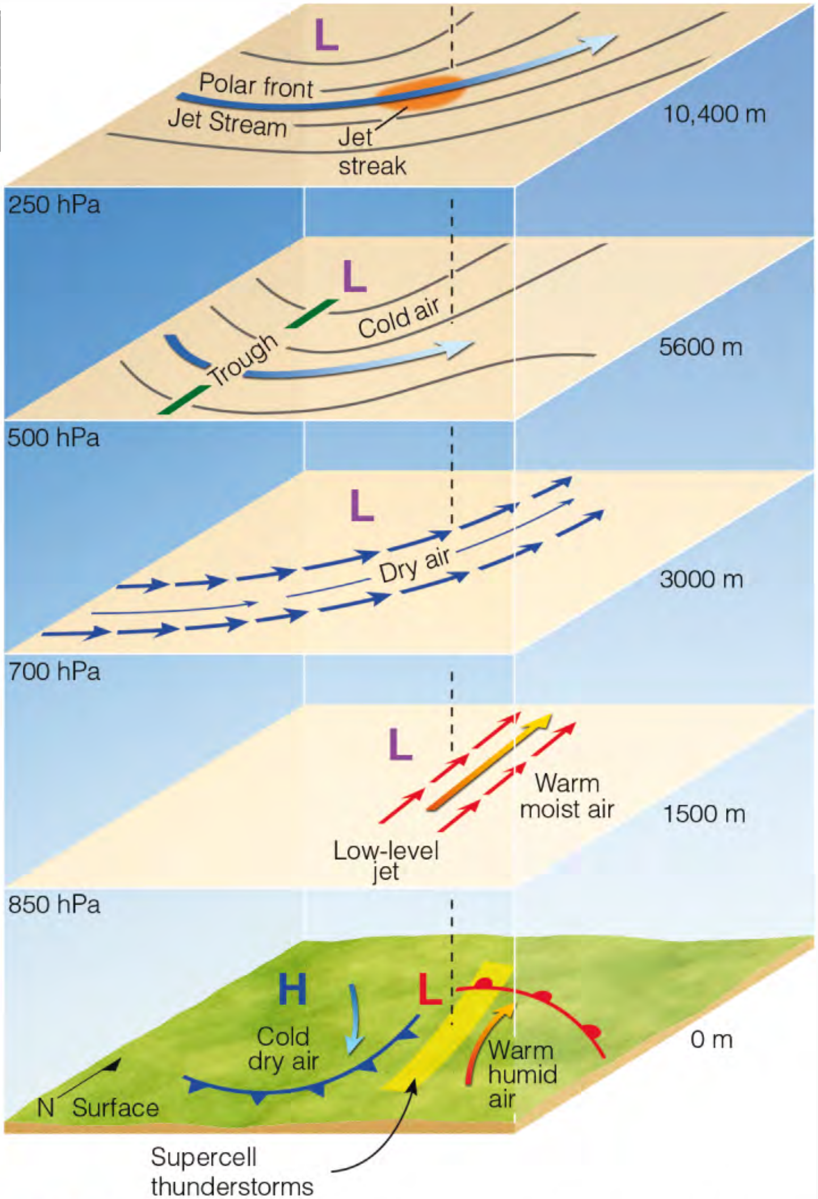
Elie, Manitoba, 2007

- F5 Tornado
  - Strongest confirmed in Canada
- No-one injured or killed
  - Several houses demolished
- Video

Ahrens: Fig. 14.34

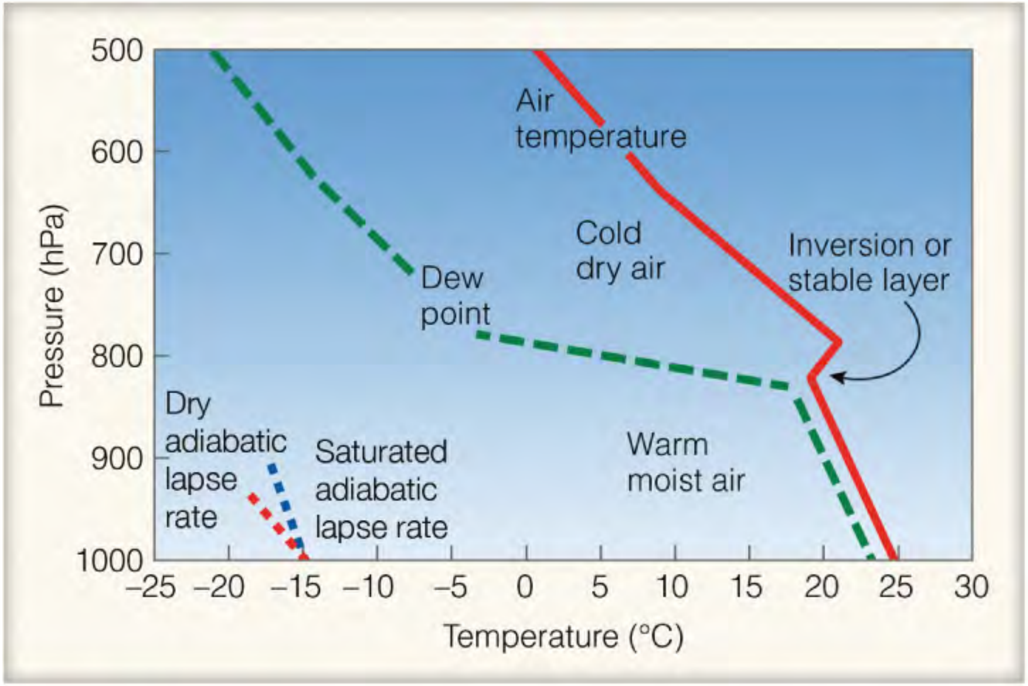
Tornadoes

- Typical ingredients:
  - Open wave cyclone
  - Very humid air at the bottom
  - Low-level jet of warm air from the south
  - Above, cold air flowing in from the southwest
  - Upper level divergence
  - Conditionally unstable atmosphere



Ahrens: Fig. 14.21

Tornado ingredients



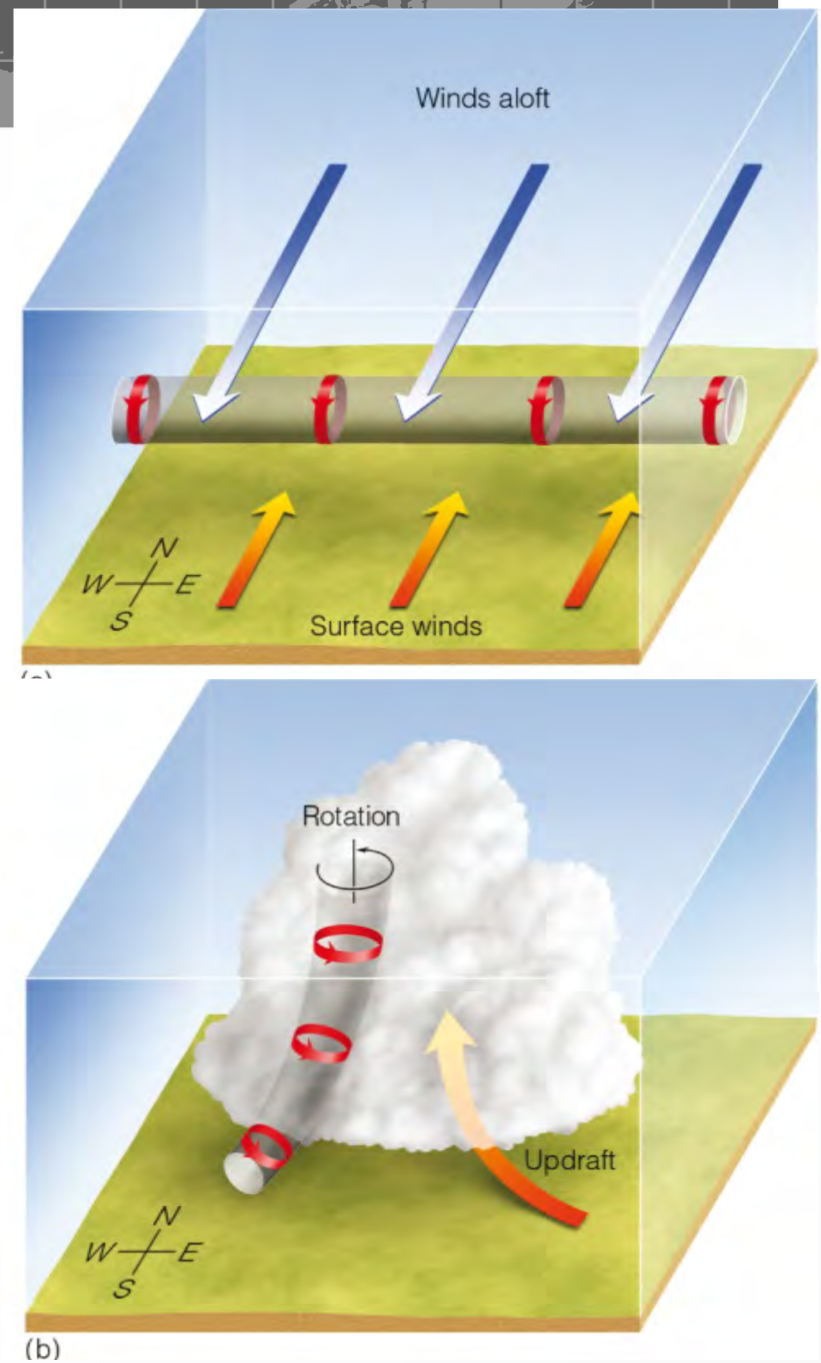
Ahrens: Fig. 14.22
(previous edition)

- Very humid up to around 800 hPa
- *Inversion* acts like a lid on the warm, moist air
- Cold dry air above the lid
  - *Absolute instability*
- Rapid thunderstorm development

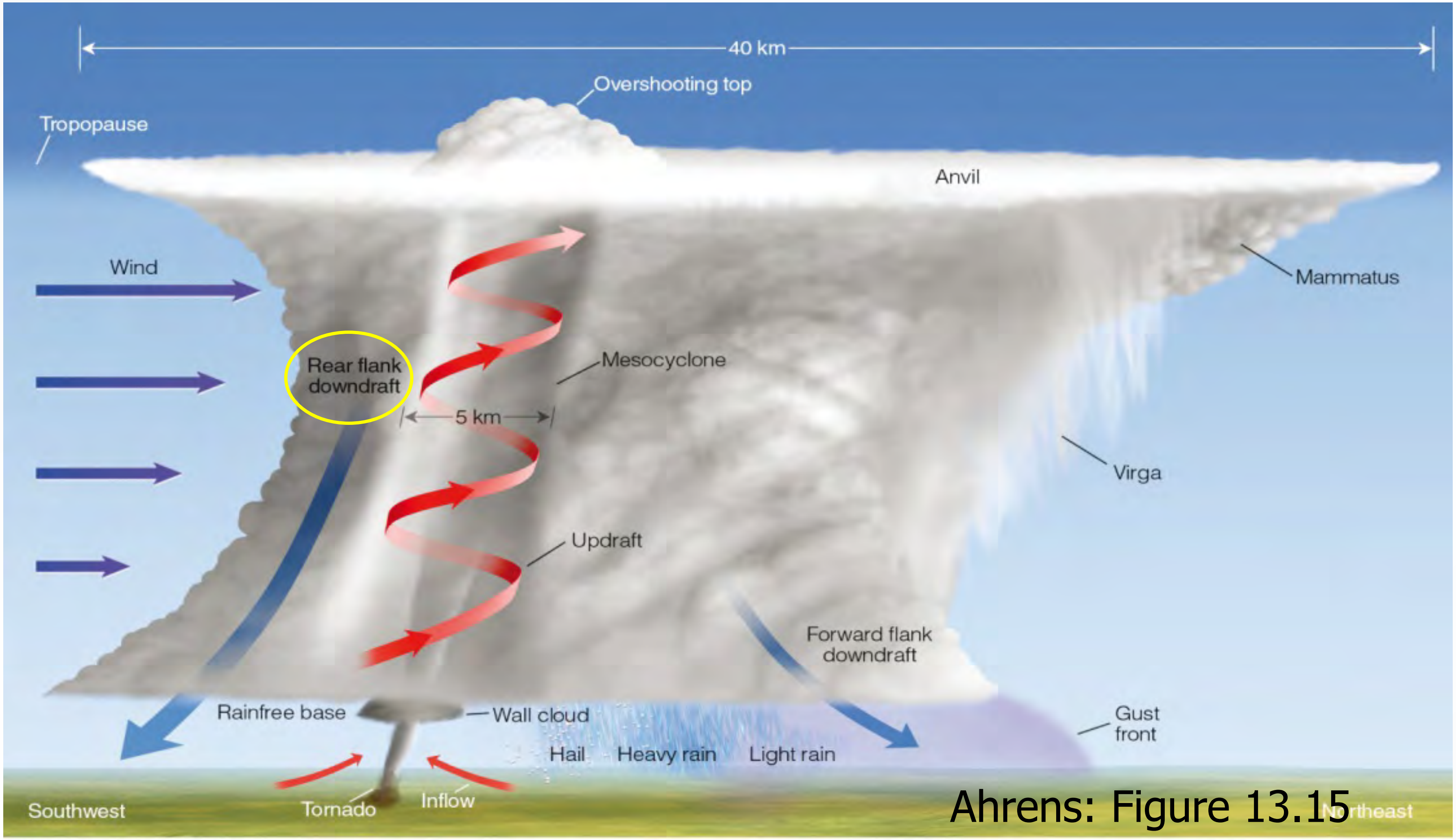
Tornadoes

- Recall: in a supercell storm, strong wind shear can set up horizontal rotation
- *Vortex tube* of spinning air

- Strong updrafts can tilt the tube and draw it up into the storm
- Creates a rising, spinning column of air called a *mesocyclone*



Ahrens: Fig. 13.36



Ahrens: Figure 13.15

- Swirling water and ice caught up in the mesocyclone may lead to a *rear flank downdraft*
- When it hits the ground it creates a second inflow and may interact to form a tornado
- Around 15% of supercell thunderstorms produce a tornado

Tornadoes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Tornado classification

Fujita Scale

Ted Fujita (1920-1998)

A&B: Table 11-2

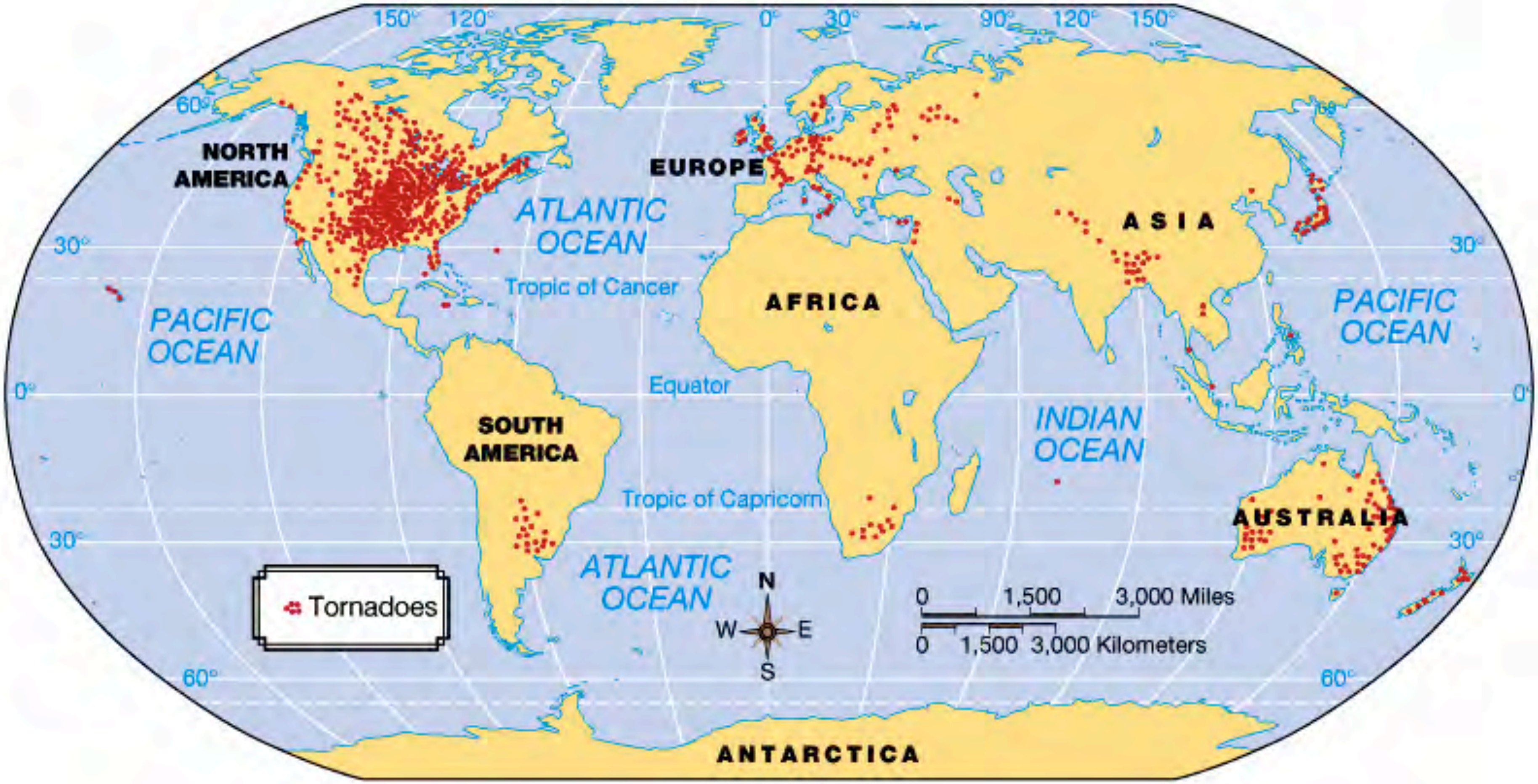
Intensity	Wind Speed (km/hr)	Wind Speed (mph)	Typical Amount of Damage
F0	< 116	< 72	Light: Broken branches, shallow trees uprooted, damaged signs and chimneys.
F1	116–180	72–112	Moderate: Damage to roofs, moving autos swept off road, mobile homes overturned.
F2	181–253	113–157	Considerable: Roofs torn off homes, mobile homes completely destroyed, large trees uprooted.
F3	254–332	158–206	Severe: Trains overturned, roofs and walls torn off well-constructed houses.
F4	333–419	207–260	Devastating: Frame houses completely destroyed, cars picked up and blown downwind.
F5	420–512	261–318	Incredible: Steel-reinforced concrete structures badly damaged.
F6	>513	>319	Inconceivable: Might possibly occur in small part of an F4 or F5 tornado. It would be difficult to identify the damage done specifically by these winds, as it would be indistinguishable from that of the main body of the tornado.

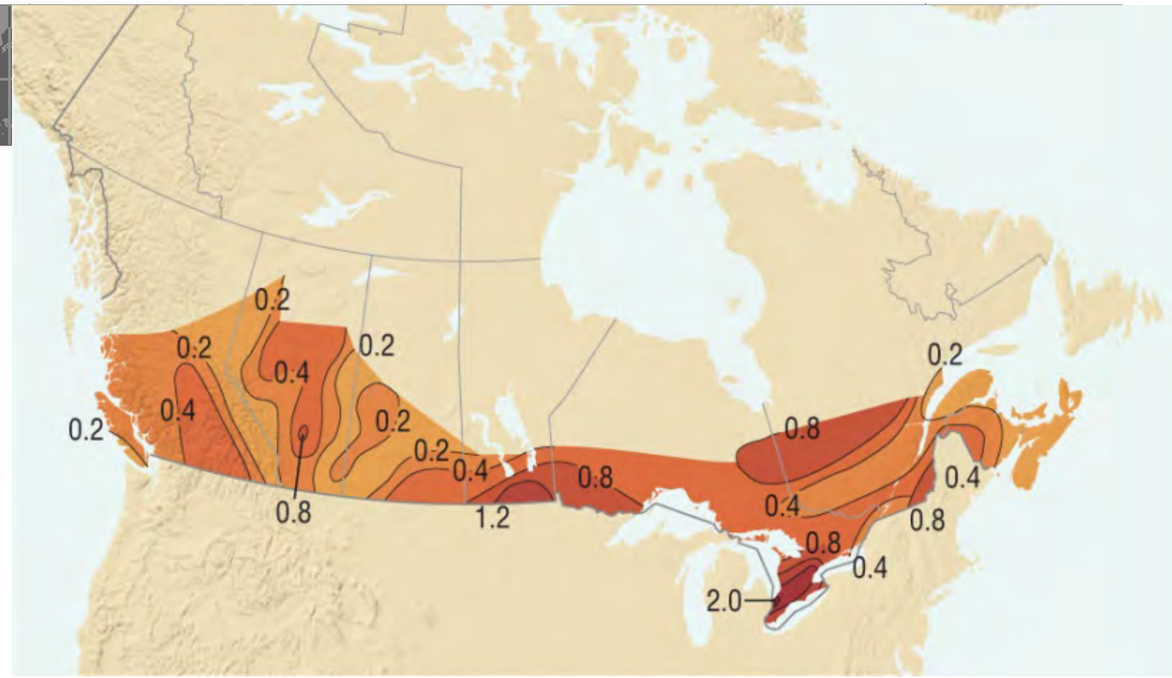
Table 14.3 Modified (EF) Fujita Scale for Damaging Winds

EF SCALE	km h^{-1}*	KNOTS
EF0	105–137	57–74
EF1	138–177	75–96
EF2	178–218	97–118
EF3	219–266	119–144
EF4	267–322	145–174
EF5	> 322	> 174

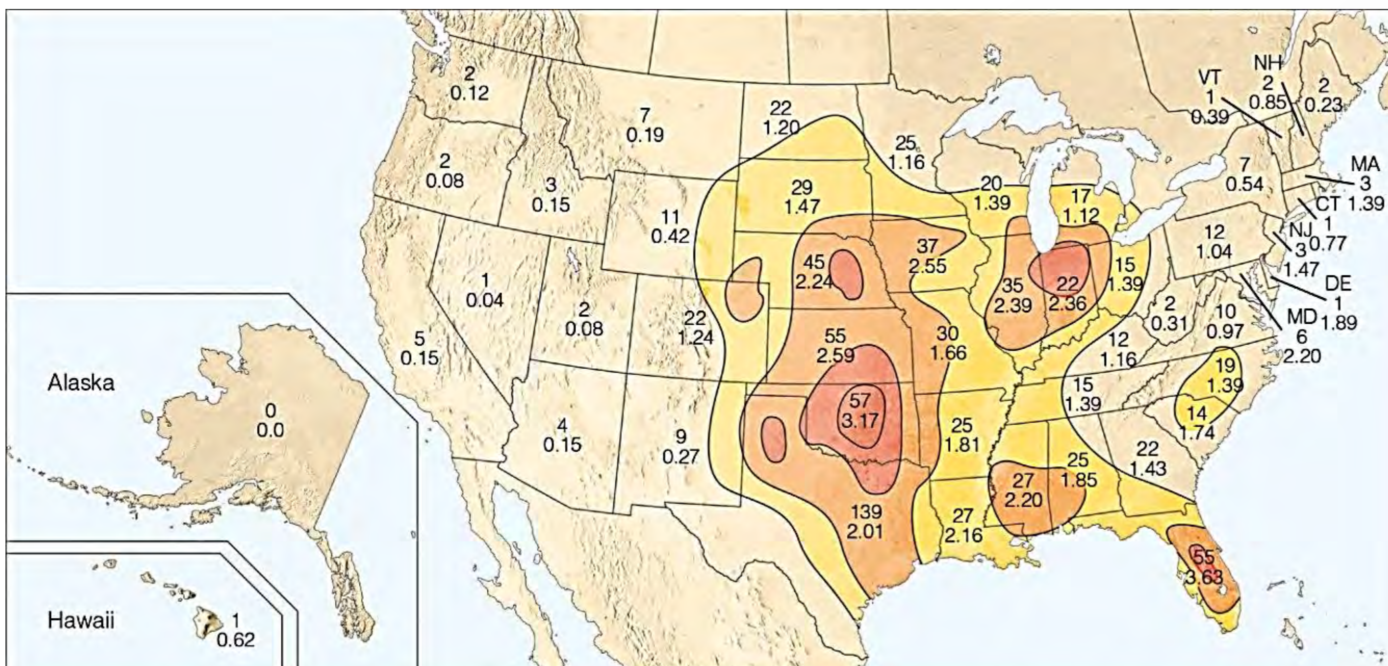
*The wind speed is a three-second gust estimated at the point of damage, based on a judgment of damage indicators.

Global tornado frequencies



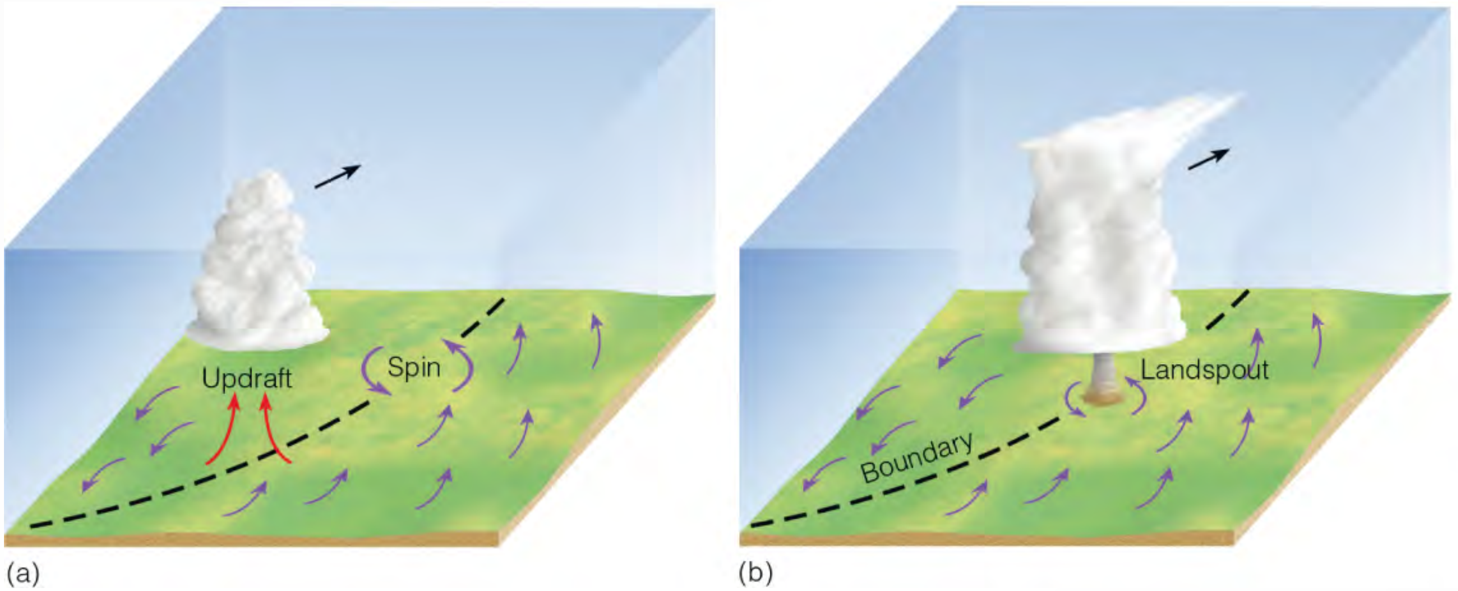


Annual average per 10,000 km



Ahrens: Figs. 14.36 and 14.35 (previous edition)

Landspouts



- Weaker tornadoes can be formed under different conditions
- E.g. a 'landspout':
  - At the boundary between two winds, the air will spin
  - If the updraft of a developing storm passes over it, rotating air will be sucked up into the cloud
  - Conservation of angular momentum will dramatically increase the wind speeds

Next lecture

- Hurricanes: Lecture 17
- Ahrens: Chapter 14