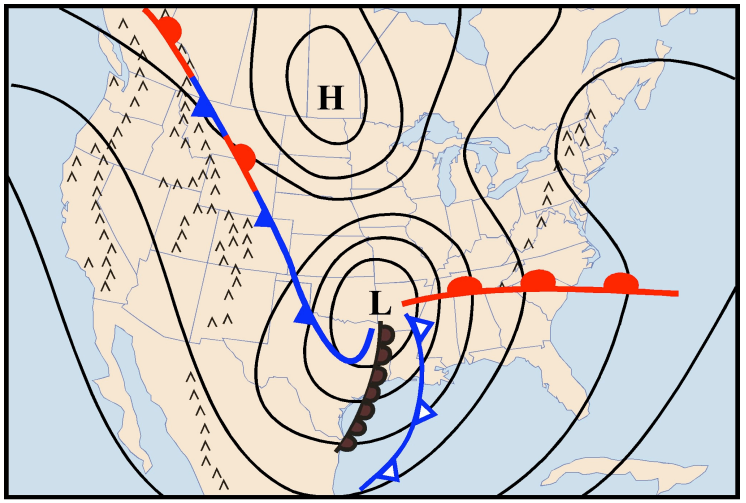
Weather Systems

Air Masses, Fronts & Cyclone Development

- ✓ What is an Air Mass?
- ✓ Source Regions
- ✓ Classifying Air Masses
- ✓ Properties of North American Air Masses
- ✓ Fronts
- ✓ Cyclone Development

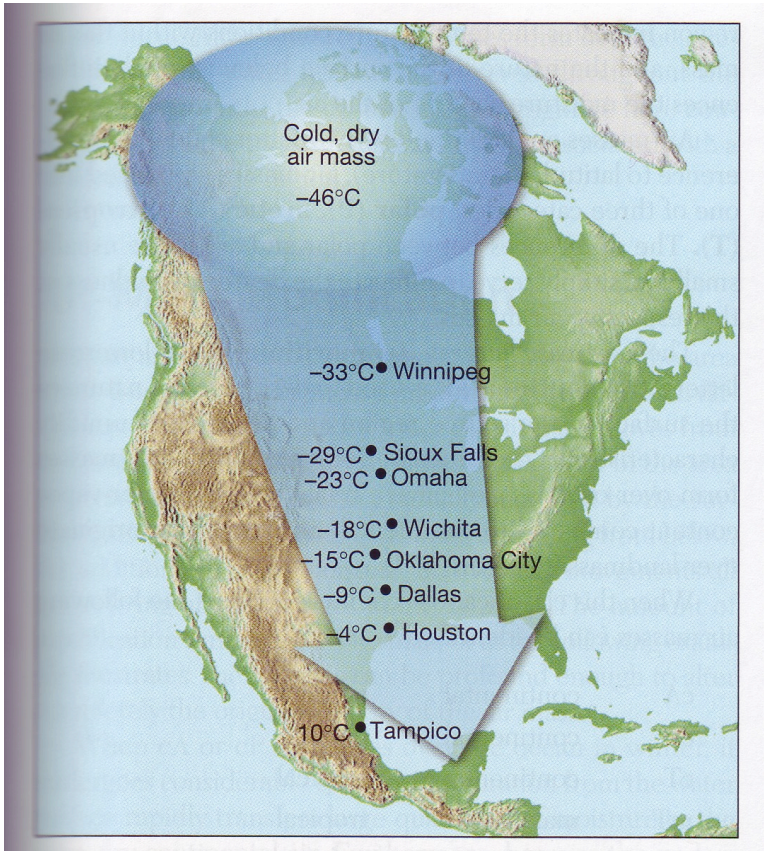


©Kendall/Hunt Publishing



What is an Air Mass

- The weather patterns are the result of the movements of large bodies of air, called air masses.
- An air mass is an immense body of air, usually
  - 1,600 km (1,000 miles) or more cross
  - Several kilometers thick
  - Characterized by homogeneous physical properties (such as temperature and moisture) at any given altitude



What is an Air Mass

- When the air masses move out of their origin, they carry their physical properties (temperature and moisture) elsewhere.
- The air masses are modified as they move, but they also modify the weather in the areas over which they move.
- Because it may take several days for an air mass to traverse an area, the region under its influence will probably experience generally constant weather conditions, a situation is called air-mass weather.



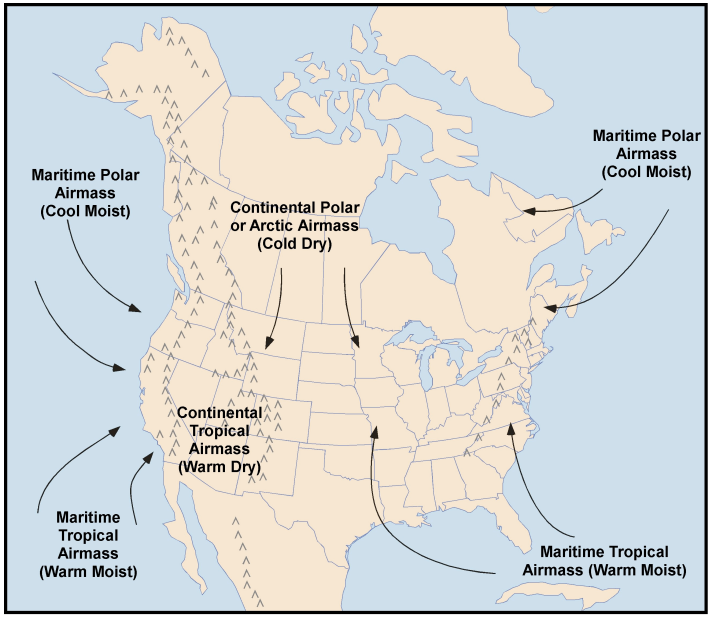
Source Regions

- Where do air masses form?
- What factors determine the nature and degree of uniformity of an air mass?
- These two questions are closely related.
- An ideal source region must meet two essential criteria
  - First, it must be an extensive and physically uniform area
  - Second, the area be characterized by a general stagnation of atmospheric circulation so that air will stay over the region long enough to come to some measure of equilibrium with the surface.



Source Regions

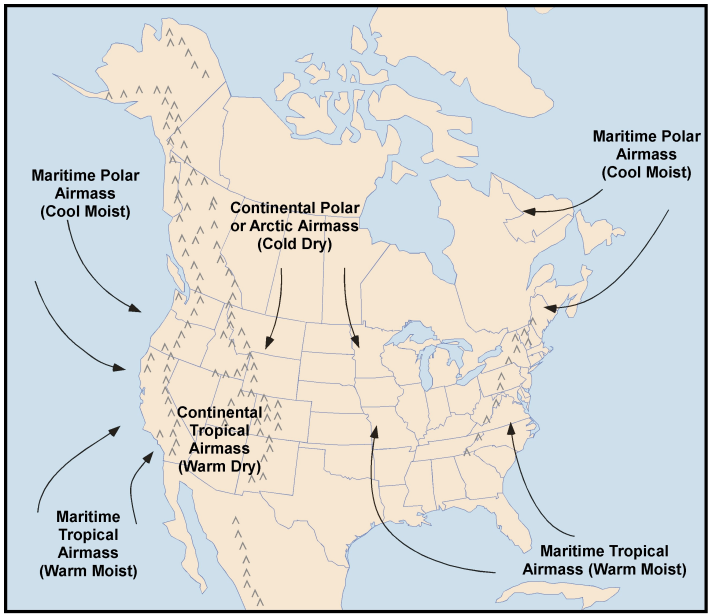
- The figure shows the source regions that produce the air masses that most often influence North America.
- The Gulf of Mexico and Caribbean Sea yield warm air masses.
- In contrast, the snow and ice covered areas and adjacent ocean yield cold air masses.
- The size and intensity of the source regions change seasonally.
- No major source regions in the middle latitudes.
- The middle latitudes are the site where cold and warm air masses clash, one of the stormiest region on the planet.



©Kendall/Hunt Publishing

Classifying Air Masses

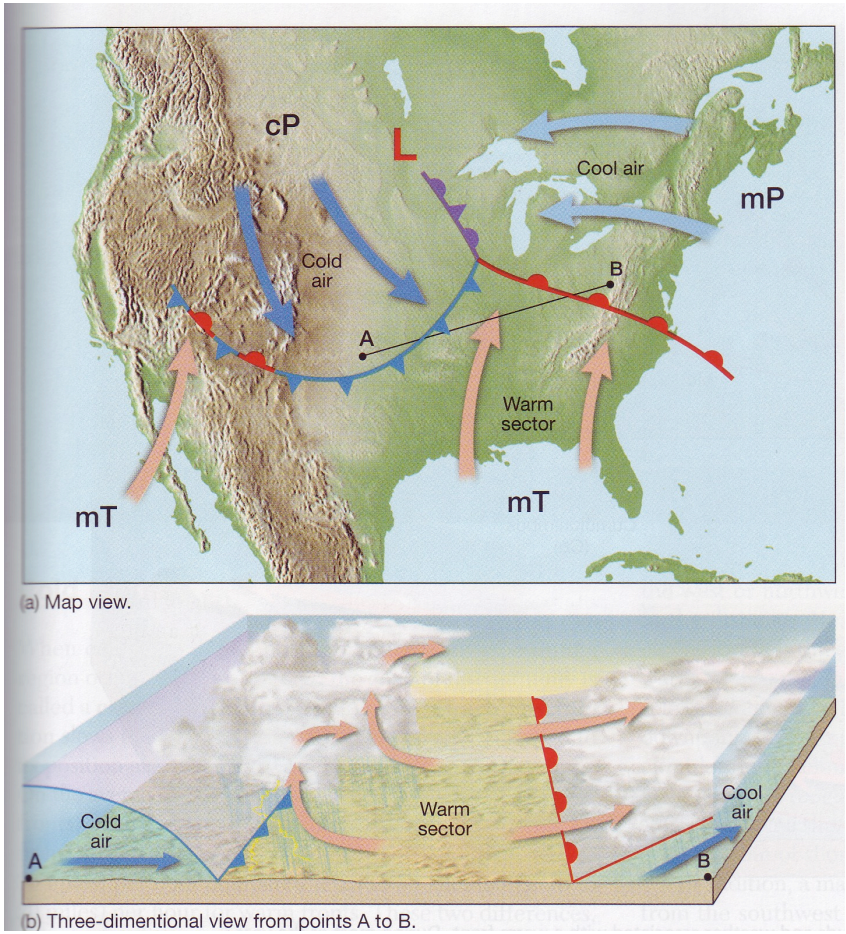
- The classification of an air mass depends on the latitude of the source region and the nature of the surface in the area of origin – ocean or continent.
- The latitude influences temperature conditions within the air mass.
- The nature of the surface below influences the moisture content of the air.
- With reference to latitude, there are 3 categories: polar (P), arctic (A), or tropical (T)
- With reference to the surface, there are 2 categories: maritime (M) and continental (C).



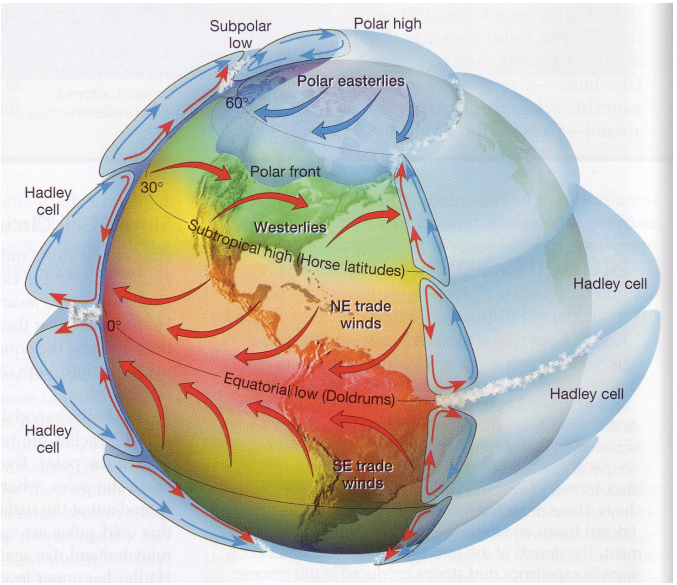
©Kendall/Hunt Publishing

Fronts

- ✓ Mid latitude cyclones are low pressure systems with 1000 km diameters and about a week lifetime.

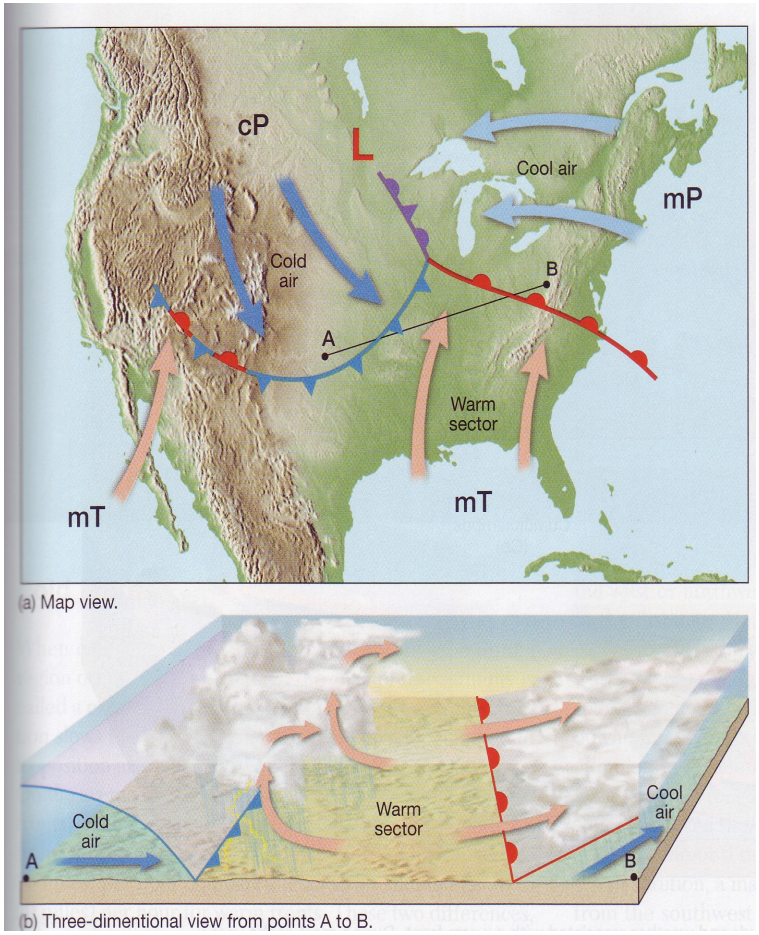


- ✓ Mid-latitude cyclones develop in conjunction with the polar front.
- ✓ During the cool months, the polar front is generally well defined and forms a nearly continuous band around Earth.
- ✓ It is along frontal zones where cold, equatorward moving air collides with warm, poleward moving air that most middle latitude cyclones form.
- ✓ Since fronts play an important role in mid latitude cyclone developments, let us first consider the nature of fronts.



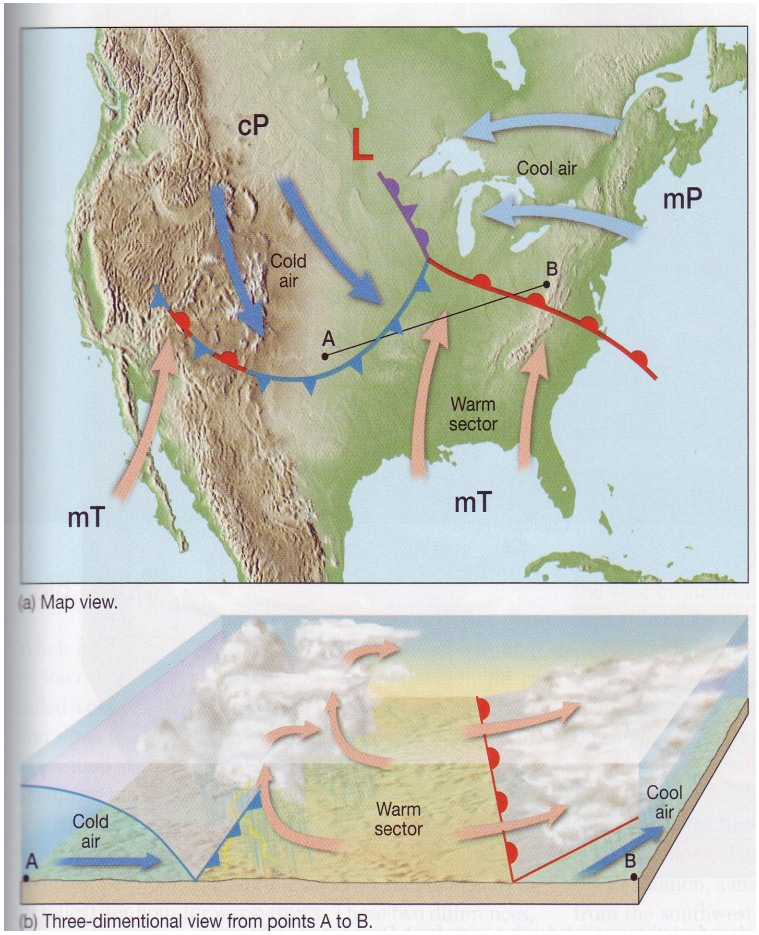
Fronts

- ✓ Fronts are boundary surfaces that separate air masses of different densities.
- ✓ One air mass is usually warmer and often contains more moisture than the other.
- ✓ Above the ground the frontal surface slopes at a low angle so that warmer air overlies cooler air.
- ✓ In the ideal case, the air masses on both sides of the front would move in the same direction and at the same speed.



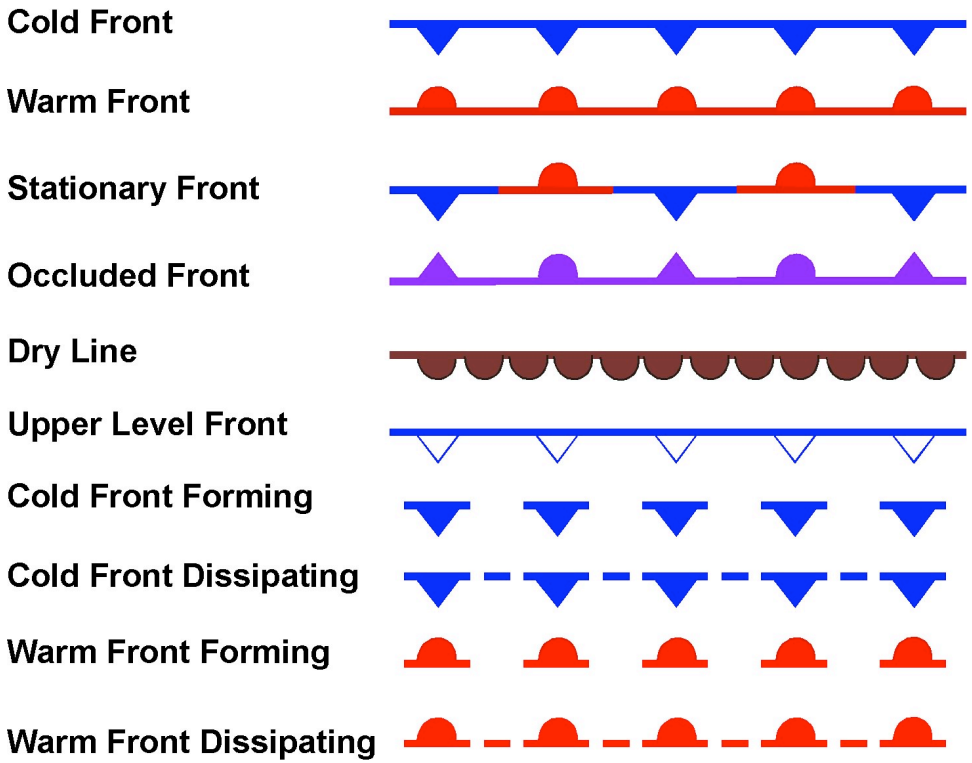
Fronts

- However, generally, one air mass moves faster.
- Thus, one air mass actively advances into another and "clashes" with it.
- It is along these zones of conflicts (fronts) that mid latitude cyclones develop and produce much of the precipitation and severe weather in the belt of the westerlies.
- It is always the warmer, less dense air forced aloft, whereas the cooler, denser air acts as a wedge on which lifting takes place.



Fronts

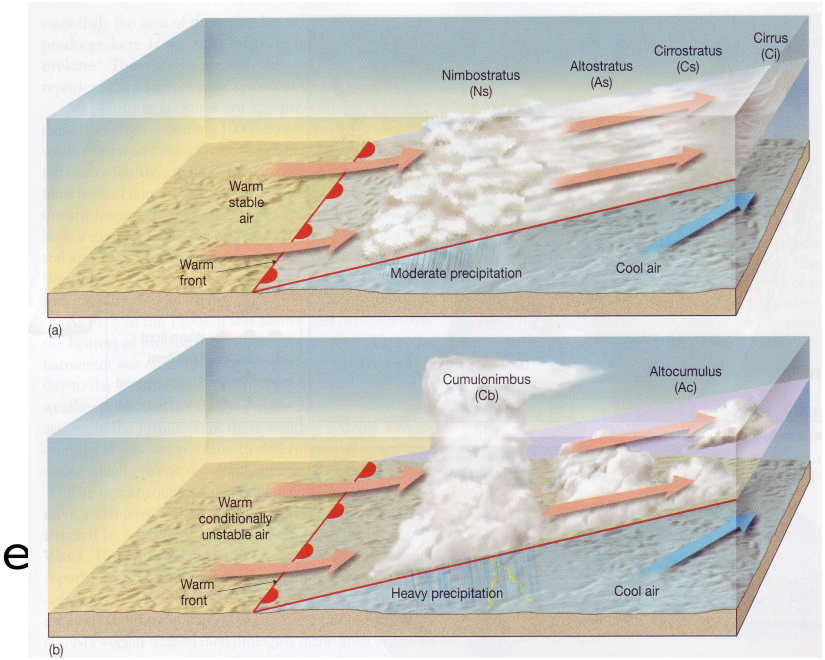
- There are 5 types of fronts;
  - Warm fronts
  - Cold fronts
  - Stationary fronts
  - Occluded fronts
  - Drylines.



©Kendall/Hunt Publishing

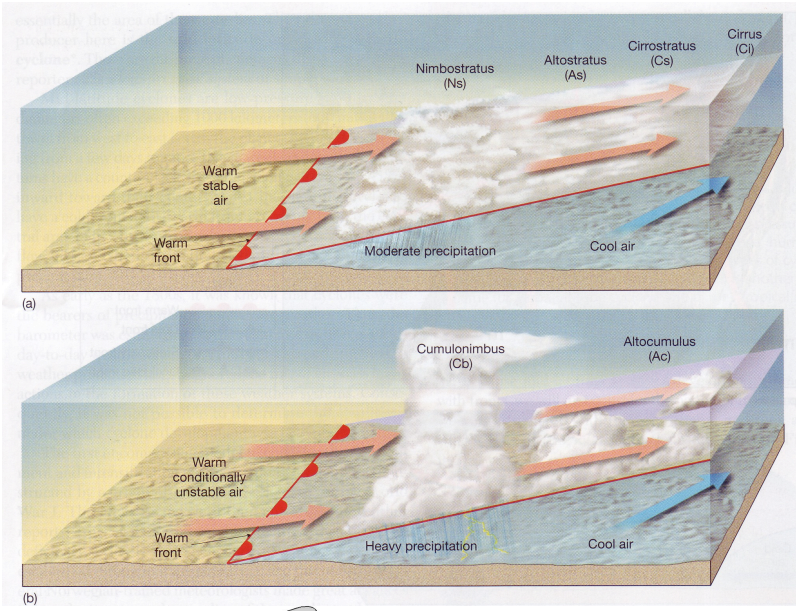
Warm Fronts

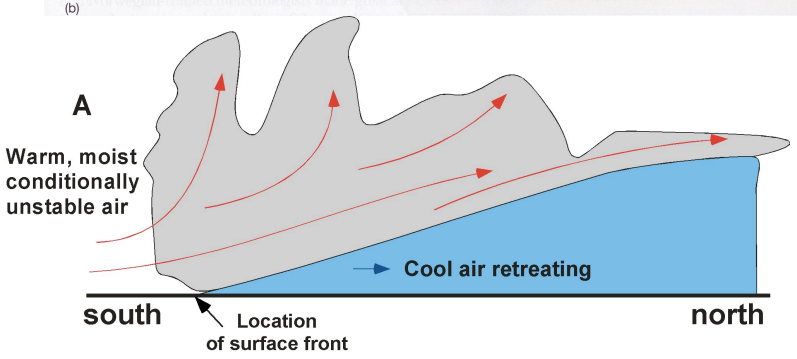
- When the surface (ground) position of a front moves so that warm air occupied formerly covered by cooler air, it is called warm front.
- This boundary separating two air masses acquires a very gradual slope.
- The slope of warm front averages only about 1:200.
- As warm air ascends the retreating wedge of cold air, it expands and cools adibatically, causing moisture in the ascending air to condense into clouds that often produce precipitation.
- The first sign of the approaching warm front is cirrus clouds.

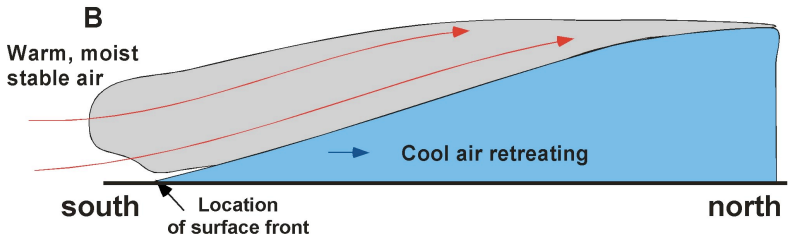


Warm Fronts

- Warm fronts tend to produce light-to-moderate precipitation over a wide area for an extended period.
- When a warm front passes, temperatures gradually rise.
- Moreover, a wind shift from the east to the southwest is generally noticeable.
- The moisture content and stability of the warm air mass largely determine the time period required for clear skies to return.



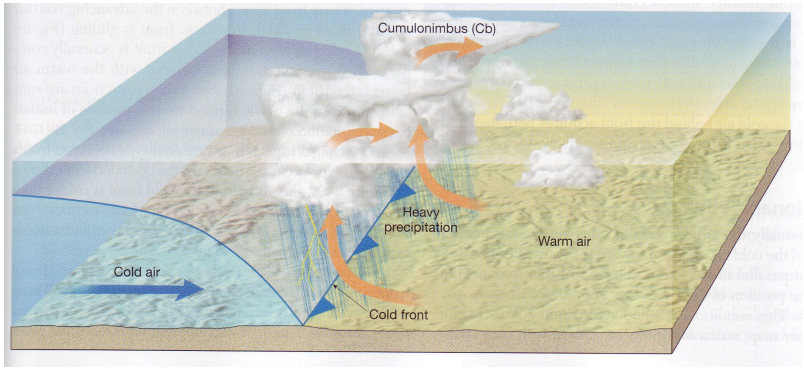


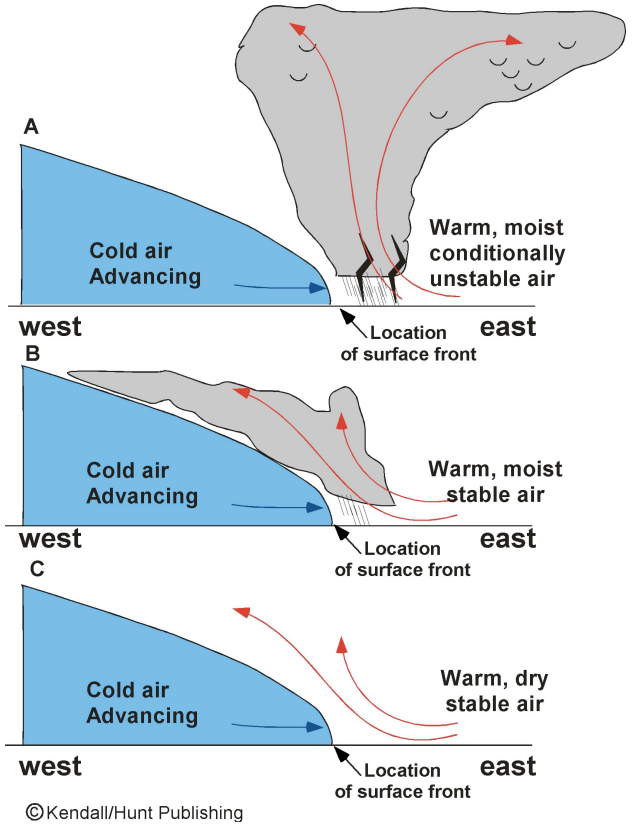


©Kendall/Hunt Publishing

Cold Fronts

- When cold, continental polar air actively advances into a region occupied by warmer air, the zone of discontinuity is called a cold front.
- Friction slows the surface position of a cold front compared to its position aloft.
- Thus, the cold front deepens as it moves.
- On the average, cold fronts are about twice as steep as warm fronts, having a slope of perhaps 1:100.
- In addition, cold fronts advance at speeds around 35 to 50 kilometers per hour compared to 25 to 35 kilometers per hour for warm fronts.
- These differences account for the more violent nature of cold front weather.

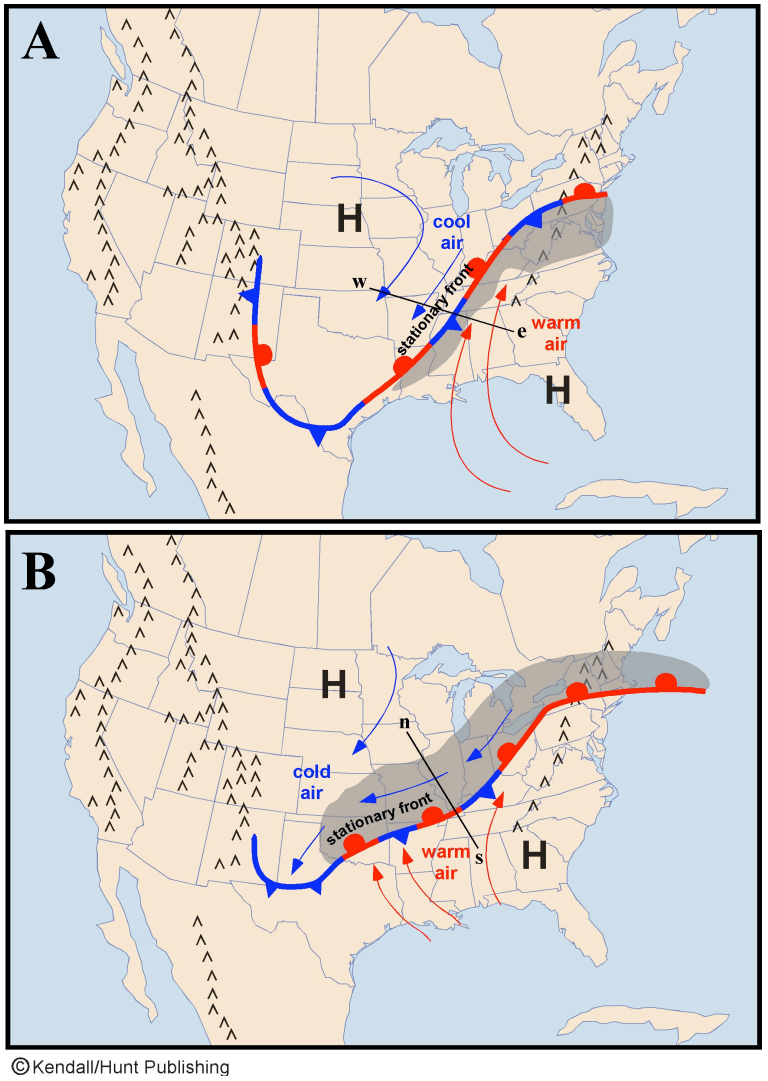




©Kendall/Hunt Publishing

Stationary Fronts

- ✓ Occasionally, the airflow on both sides of a front is neither toward the cold air mass nor toward the warm air mass, but almost parallel to the line of the front.
- ✓ Consequently, the surface position of the front does not move, or moves very slowly.
- ✓ This condition is called a stationary front.
- ✓ Stationary fronts produce moderate precipitation.
- ✓ They remain over an area for several days, in which case flooding is possible.



©Kendall/Hunt Publishing

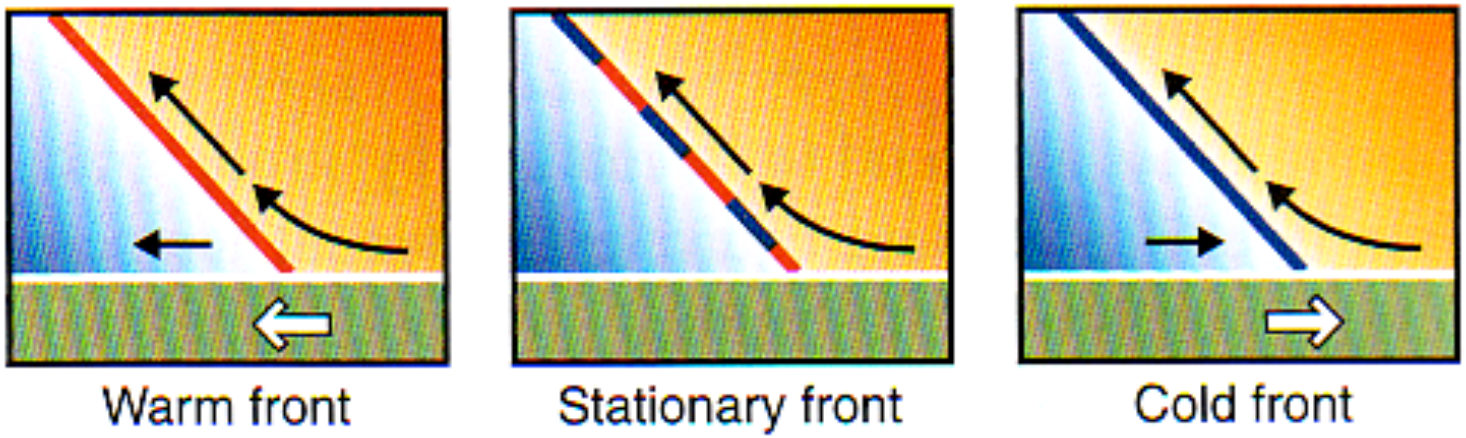
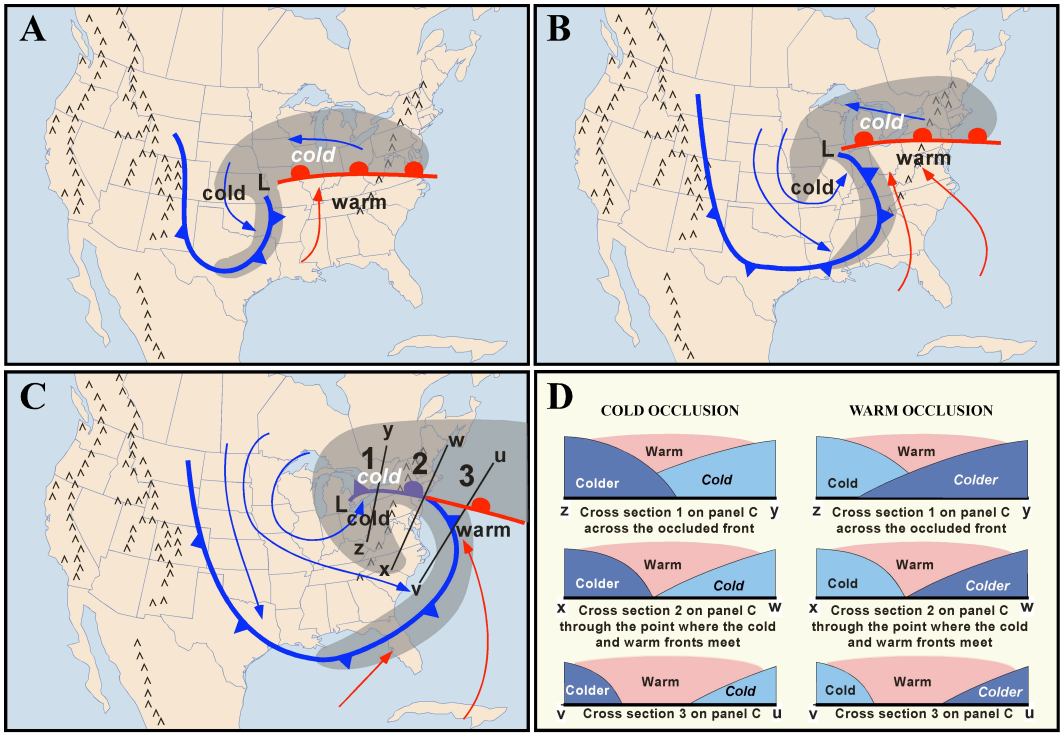


Fig. 8.9 Idealized cross sections through frontal zones showing air motions relative to the ground in the plane transverse to the front. Colored shading indicates the departure of the local temperature from the mean temperature of the air at the same level. (a) Warm front, (b) stationary front with overrunning warm air, and (c) cold front. Heavy arrows at the bottom indicate the sense of the frontal movements.

Occluded Fronts

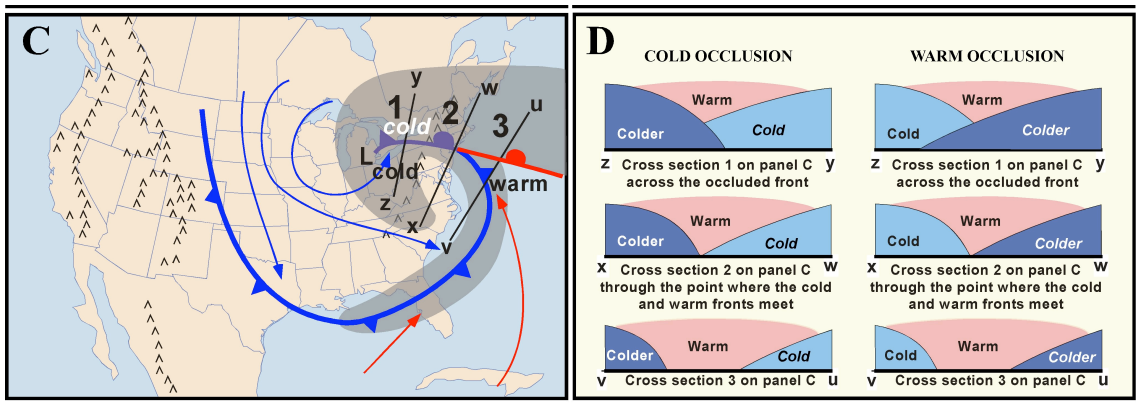
- ✓ A rapidly moving cold front overtakes a warm front.
- ✓ As the cold air wedges the warm front upward, a new front forms between the advancing cold air and the air over which the warm front is gliding.
- ✓ Then, the most precipitation associated with the warm air is forced aloft.



©Kendall/Hunt Publishing

Occluded Fronts

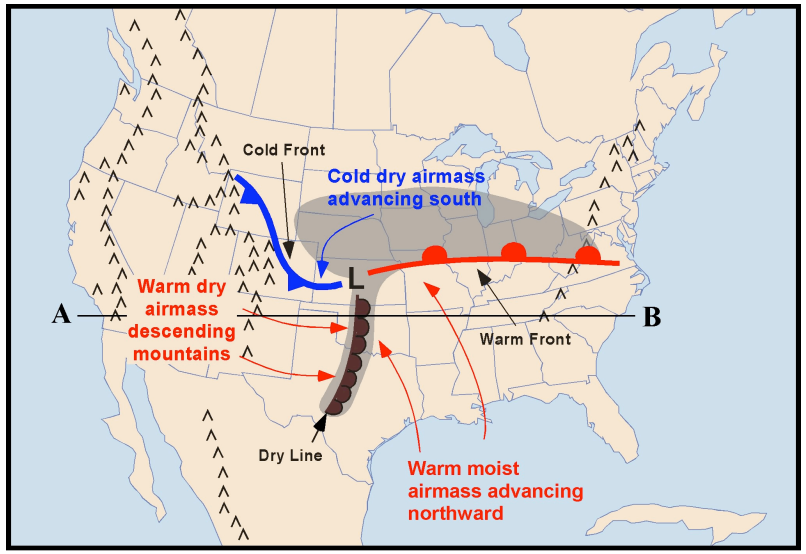
- ✓ There are 2 types of occluded fronts; 1) cold type occluded front and 2) warm type occluded front.
- ✓ When the air behind the cold front colder than the cool air it is overtaking, it is called cold type occluded front.
- ✓ This is the most common type of occluded front east of the Rockies.
- ✓ It is also possible for the air behind the advancing cold front to be warmer than the cold air it is overtaking.
- ✓ These warm type occluded fronts frequently occur along the Pacific Coast, where milder MP air invades more frigid polar air that had its origin over the continent.

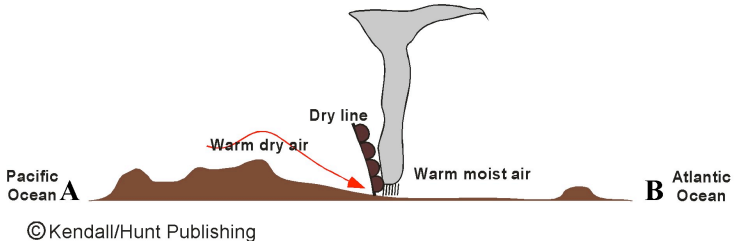


©Kendall/Hunt Publishing

Drylines

- ✓ Humidity is also important in frontal boundary, as humidity influences the density of air, with humid air is less dense than dry air.
- ✓ In the summer, air masses originated over the northern Great Plains displace warm, humid air over the lower Mississippi Valley.
- ✓ Along the frontal boundary, the drier air is denser and forcefully lifts the moist air in its path, just like a cold front.
- ✓ This is called a dryline.
- ✓ Dryline often produces tornadoes and severe weather.

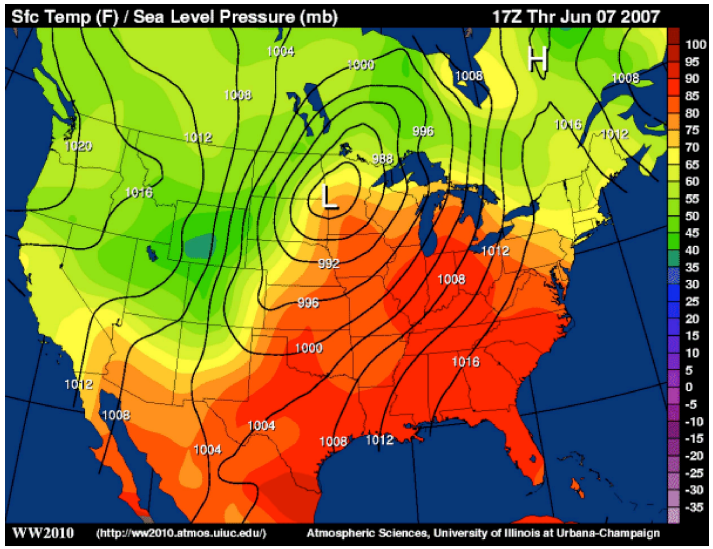




©Kendall/Hunt Publishing

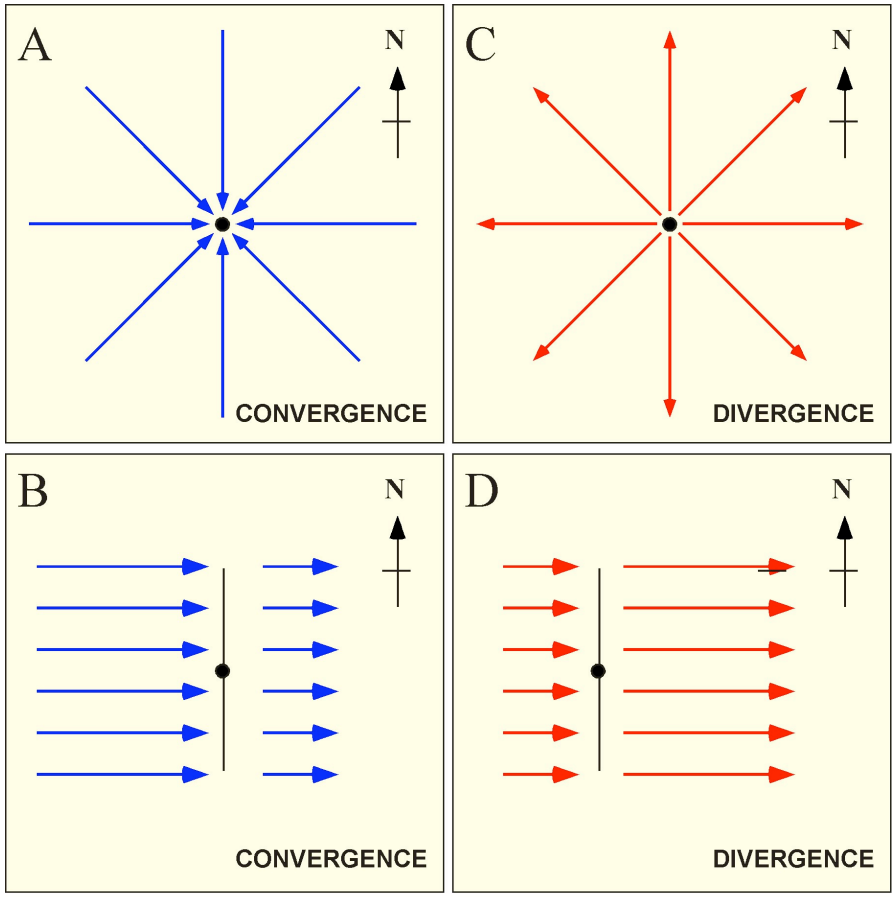
Development of High & Low Pressure Systems

- ✓ We examined the dynamics of atmospheric motions.
- ✓ We are now ready to apply our knowledge to an understanding of day-to-day severe weather patterns in the mid latitudes.
- ✓ Mid latitudes refers to the region between southern Florida and Alaska, the area of westerlies.
- ✓ Middle-latitude cyclones (i.e., lows & highs) are the primary weather producer.



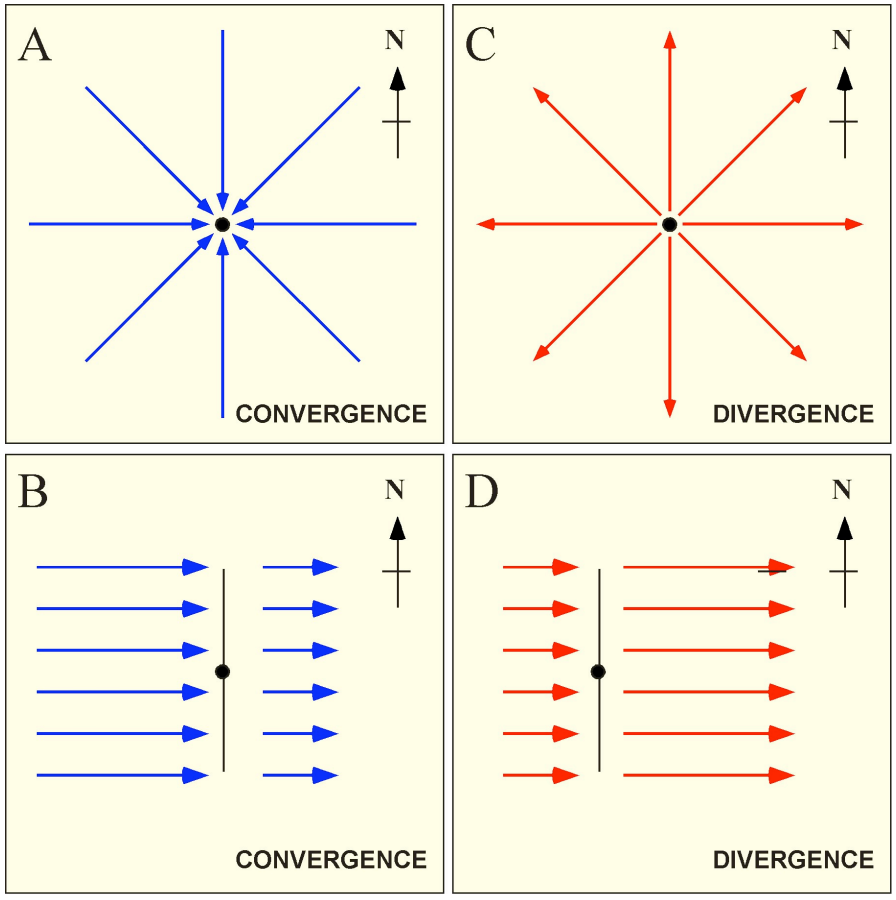
Courtesy of the Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

- Convergence occurs as air flows toward a central point (A), or decelerates (B).
- Upward motion develops.
- Divergence occurs as air flows away from a central point (C), or accelerates (D).
- Sinking (downward) motion develops.



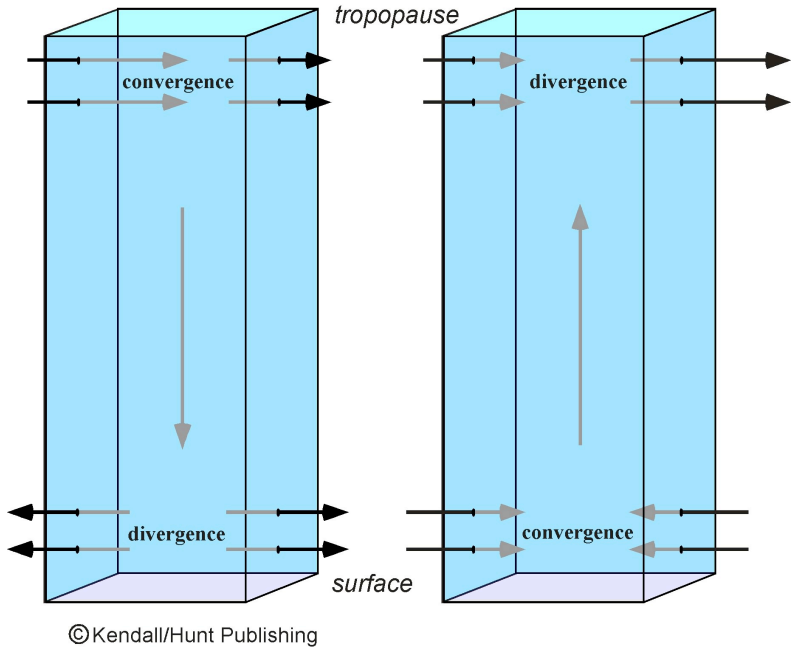
©Kendall/Hunt Publishing

- The movement of air can also cause variations in air pressure.
- For example, in situations of convergence, the air piles up and pressure increases.
- By contrast, in regions of divergence, the surface pressure drops.

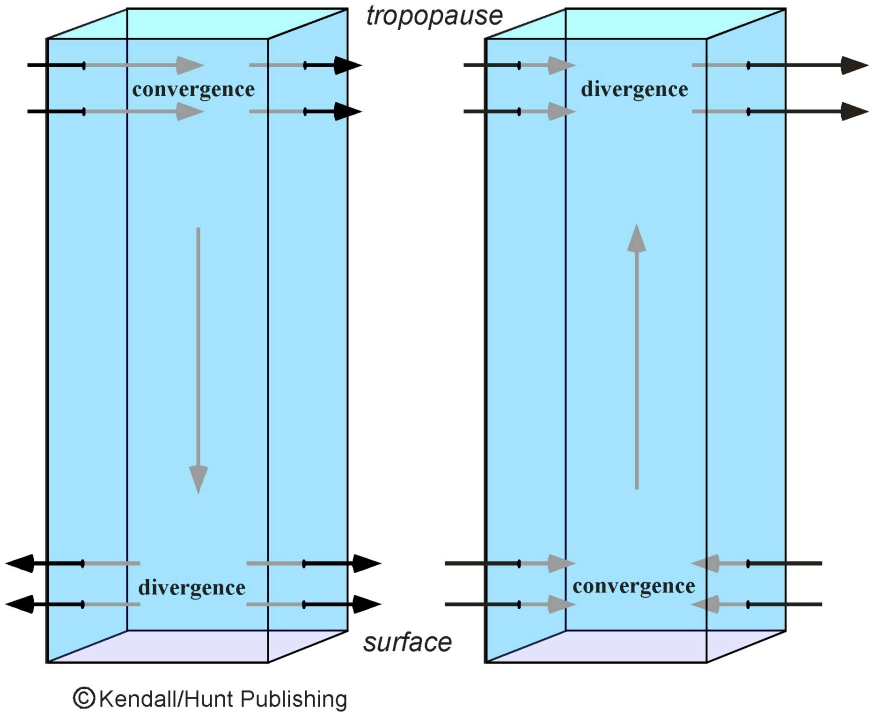


©Kendall/Hunt Publishing

- ✓ Horizontal and vertical motions are related.
- ✓ There must be a continuity of flow; i.e., a closed circuit must be formed to prevent the creation of "holes" in the atmosphere.
- ✓ The total mass of air in the column must remain constant.
- ✓ Therefore, height must increase or decrease.
- ✓ The vertical velocities of such systems are about a few cm/s (1 mile/day)



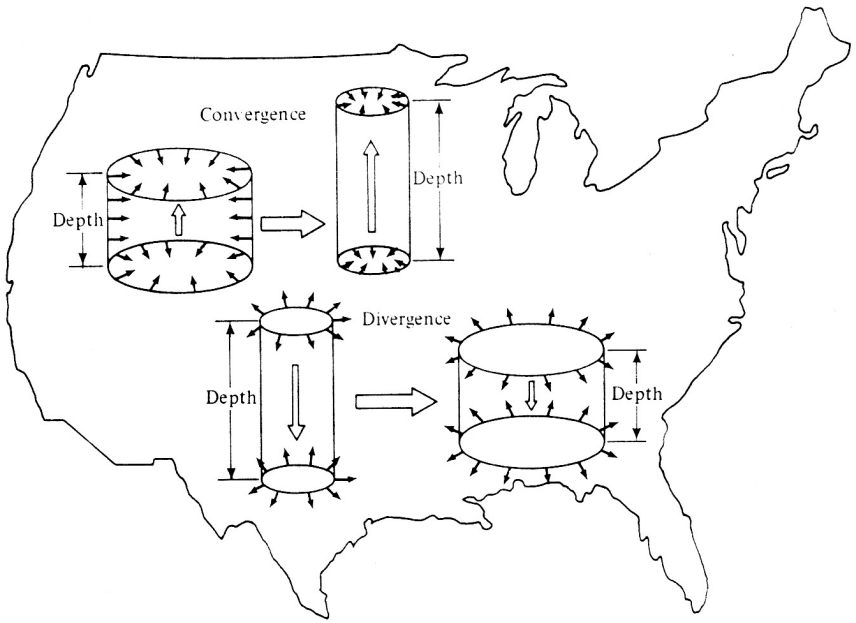
- ✓ In summary, cold, dry air masses are dense and associated with high pressure
- ✓ Warm, humid air masses are less dense and tend to exhibit low pressure.
- ✓ Surface pressure increases when there is a net convergence in the region.
- ✓ Surface pressure decreases when there is a net divergence in the region.
- ✓ Differences in pressure creates our weather.



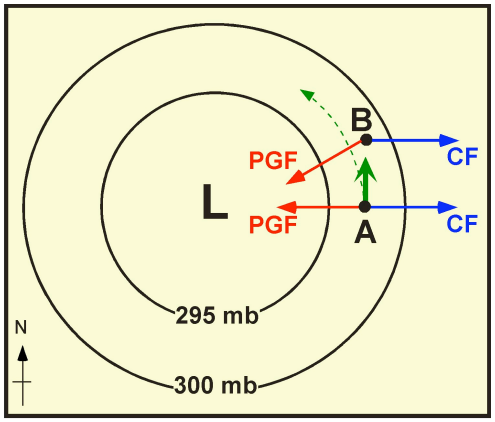
High-pressure center or anticyclone

Low-pressure center or cyclone

- ✓ Divergence and convergence above the friction layer result from imbalances between the pressure gradient and Coriolis forces.
- ✓ To maintain hydrostatic balance, air within the column must rise in response to the compression of air into the bottom and the evacuation of air from the top.
- ✓ This is important to understand hurricanes and cyclones.

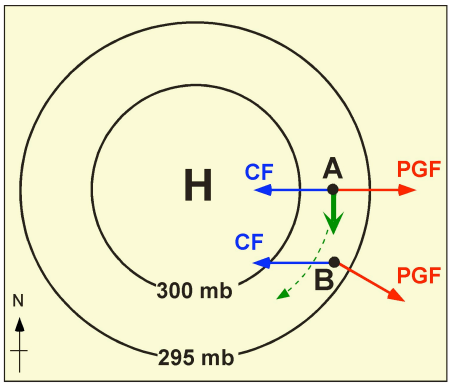


- ✓ At point A, the flow is in Geostrophic balance.
- ✓ At point B, the orientation of PGF will change, directed toward the center of the low.
- ✓ Geostrophic balance is no longer exist, rather there is a net inward directed force, centripetal acceleration.
- ✓ So, the air parcel will orbit the Low. So that it is in "gradient wind balance".
- ✓ Note that with curved flow around the low, the true flow will be slower than its Geostrophic value.



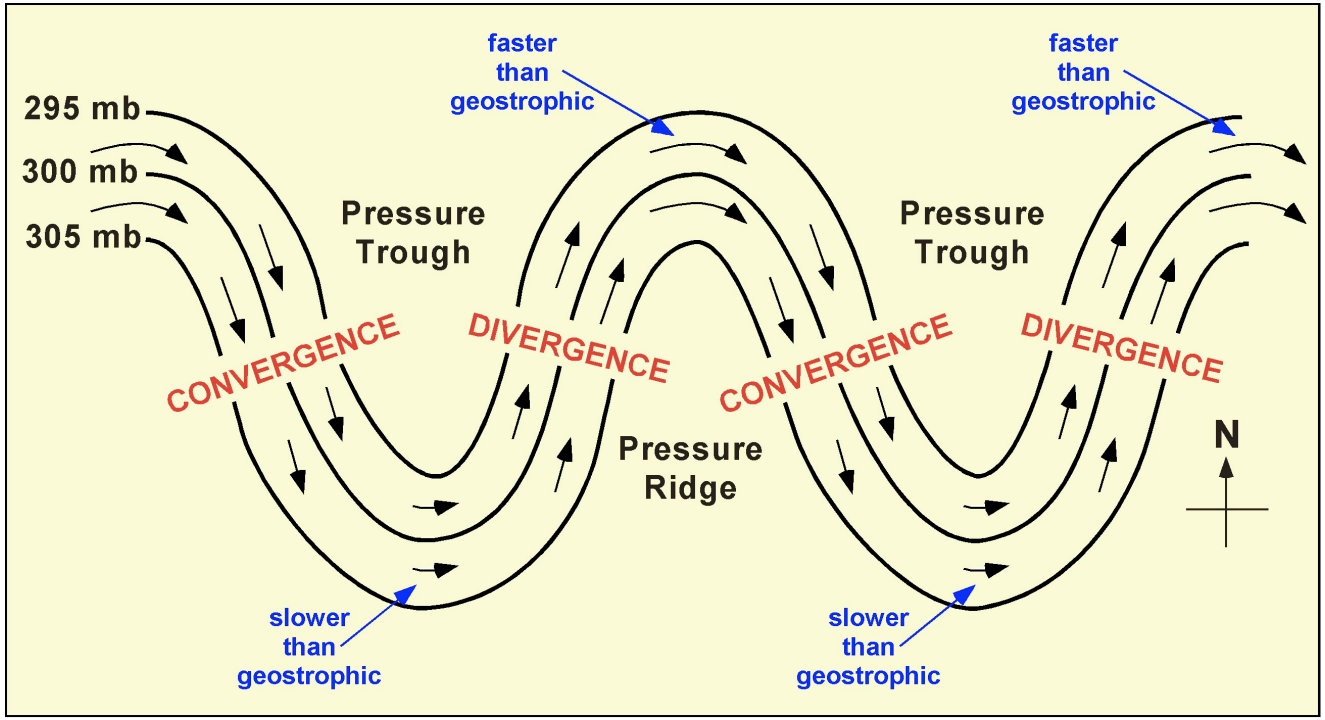
©Kendall/Hunt Publishing

- ✓ At point A, the flow is in Geostrophic balance.
- ✓ At point B, the orientation of PGF will be directed to southeastward.
- ✓ This will accelerate the flow relative to its geostrophic value, increasing the magnitude of the Coriolis force.
- ✓ This acceleration causes the Coriolis force to always exceed the outward directed PGF so that flow is no longer in geostrophic balance.
- ✓ Note that with curved flow around the high, the true flow will be faster than its geostrophic value.



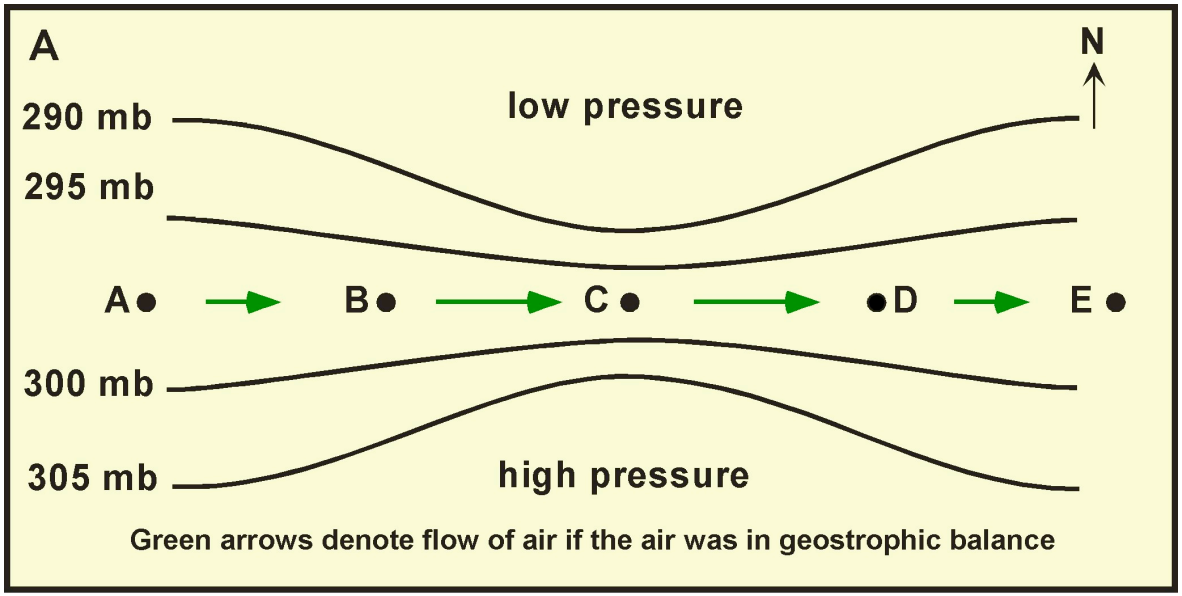
©Kendall/Hunt Publishing

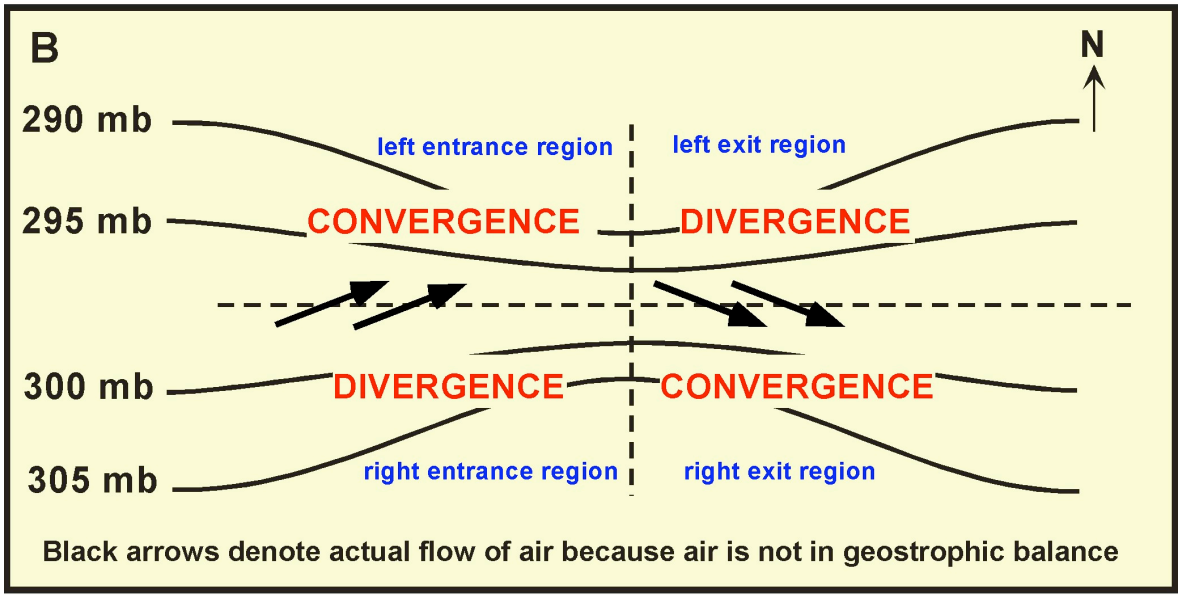
- ✓ Most flow fields in the atmosphere possess some curvature above friction layer, are nearly in gradient wind balance.
- ✓ Trough is an elongated area of low pressure, while a ridge is an elongated area of high pressure.



©Kendall/Hunt Publishing

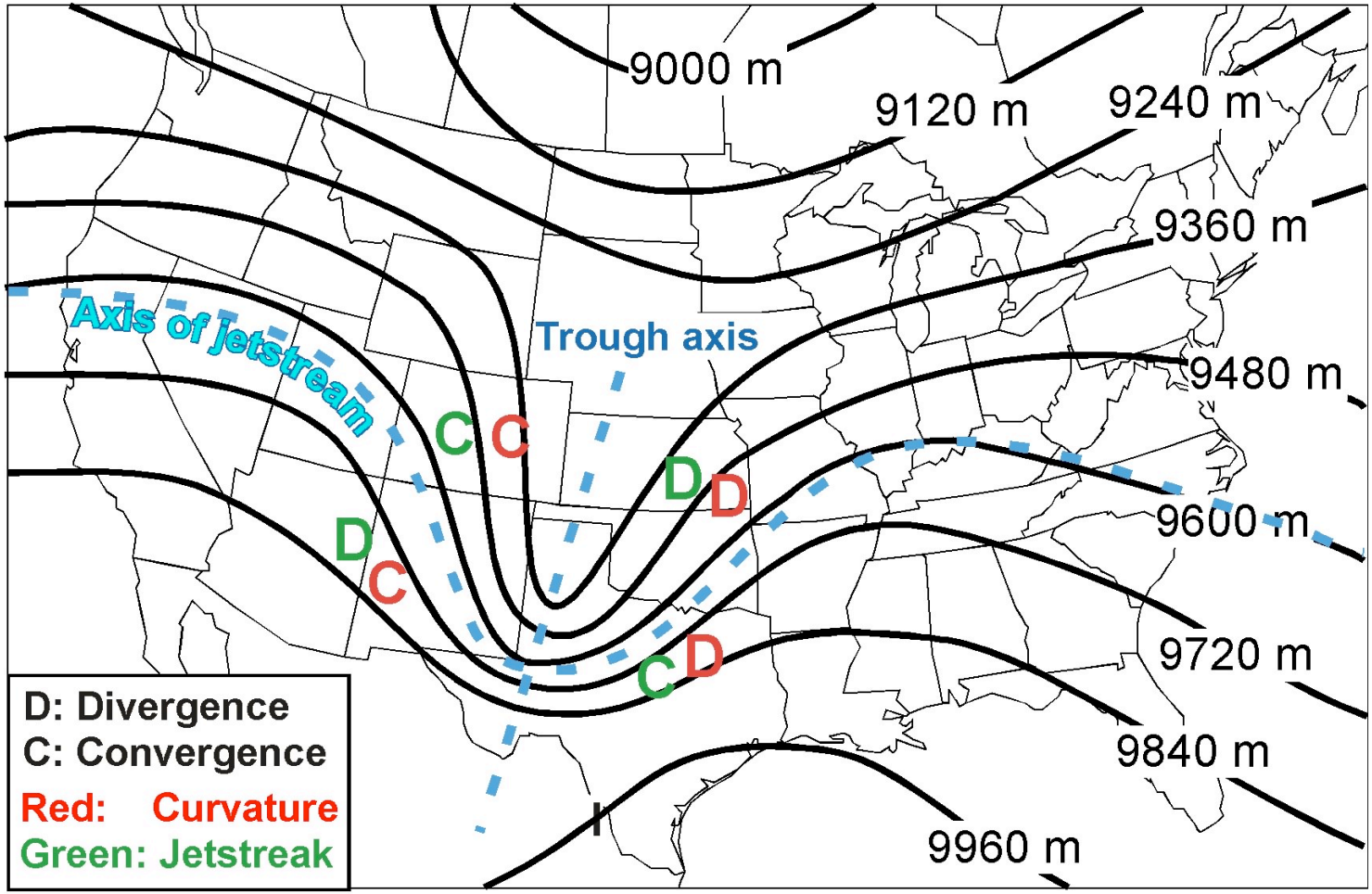
Jetstreaks



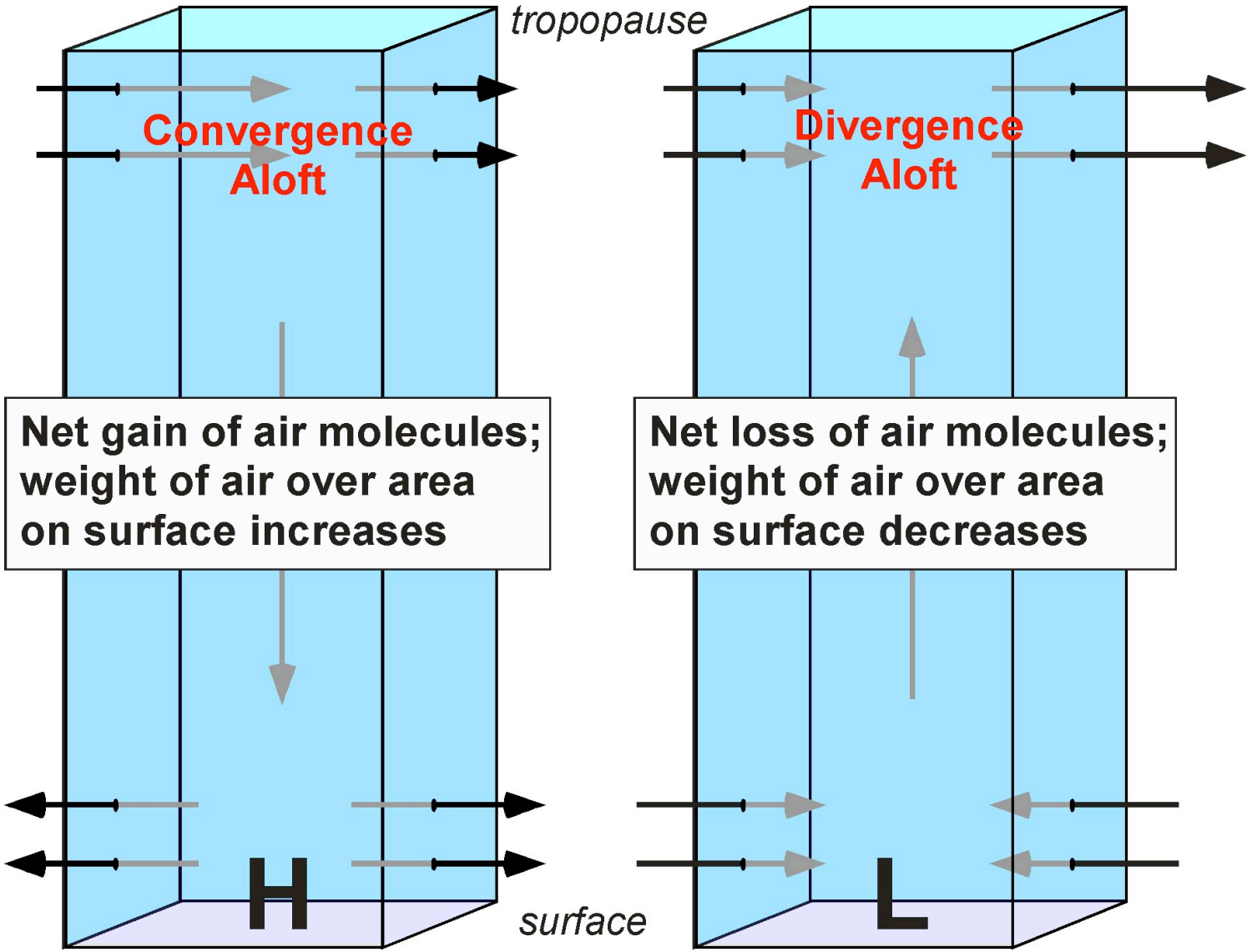


©Kendall/Hunt Publishing

Combined effect of curvature and jetstreaks



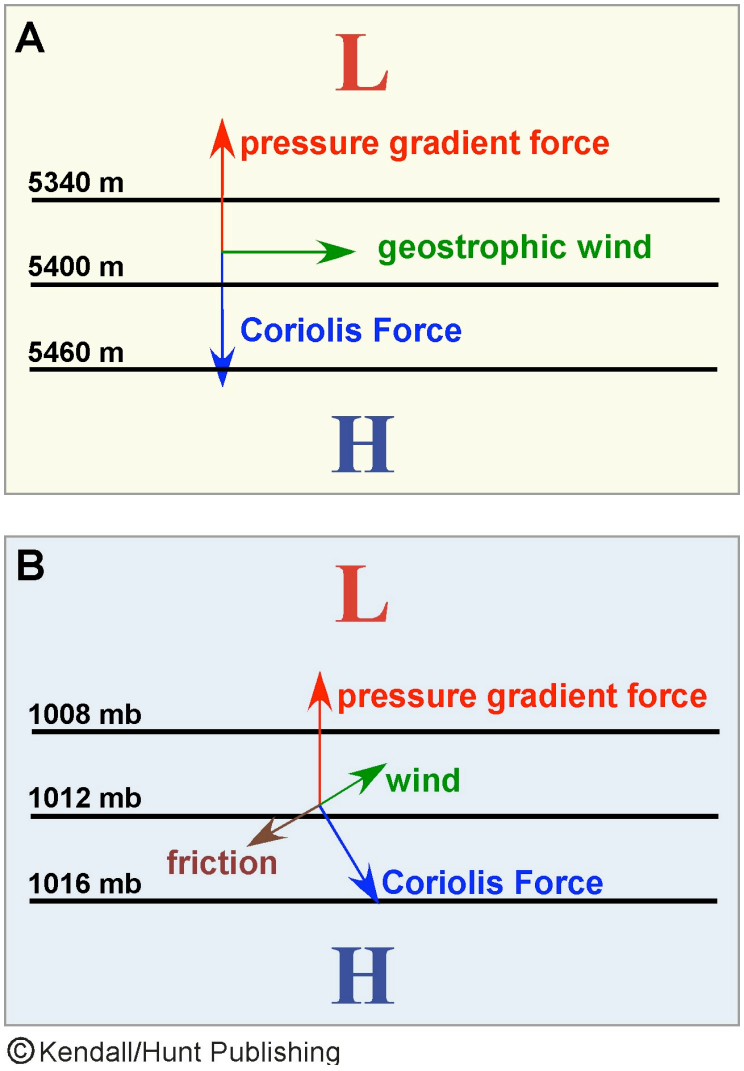
©Kendall/Hunt Publishing



©Kendall/Hunt Publishing

The Friction Layer

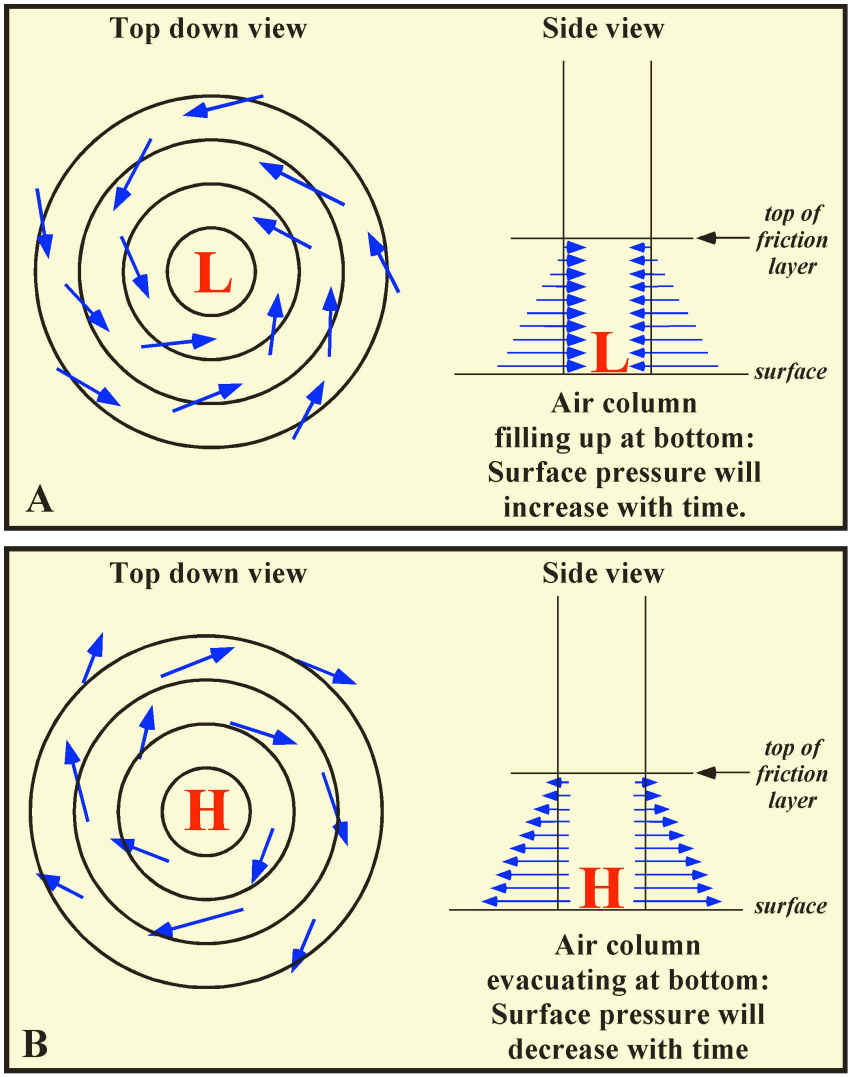
- ✓ Friction always reduces the wind speed.
- ✓ As the wind speed decreases, the Coriolis force is also reduced.
- ✓ PGF is unchanged and become a dominant force.
- ✓ Hence, friction leads to a deflection to the left of the geostrophic wind direction toward the low.
- ✓ The Coriolis force always remains to the right of the wind and the friction always opposes the wind direction.



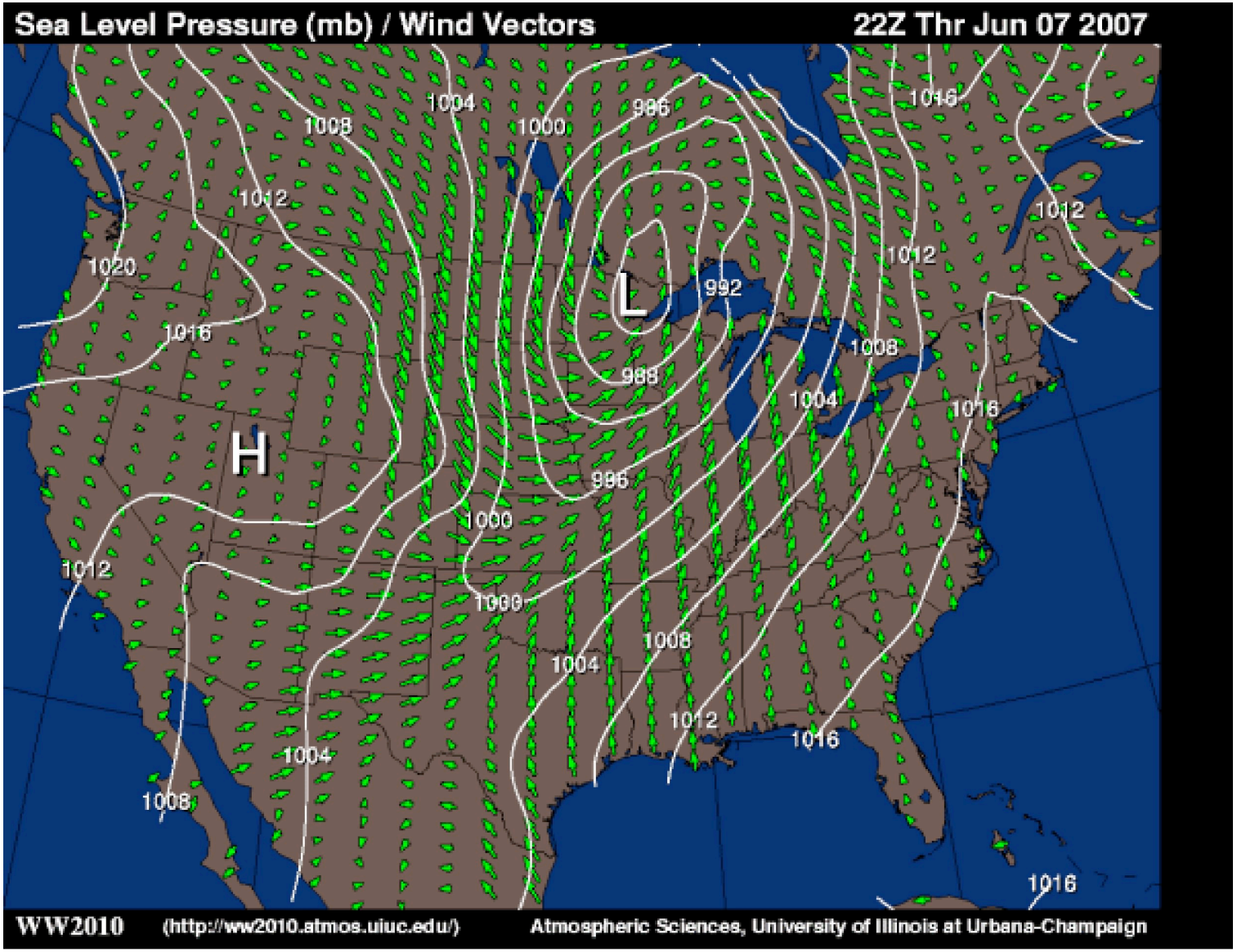
©Kendall/Hunt Publishing

The Friction Layer

- ✓ Friction always contributes to weakening of both surface high & low pressure centers.

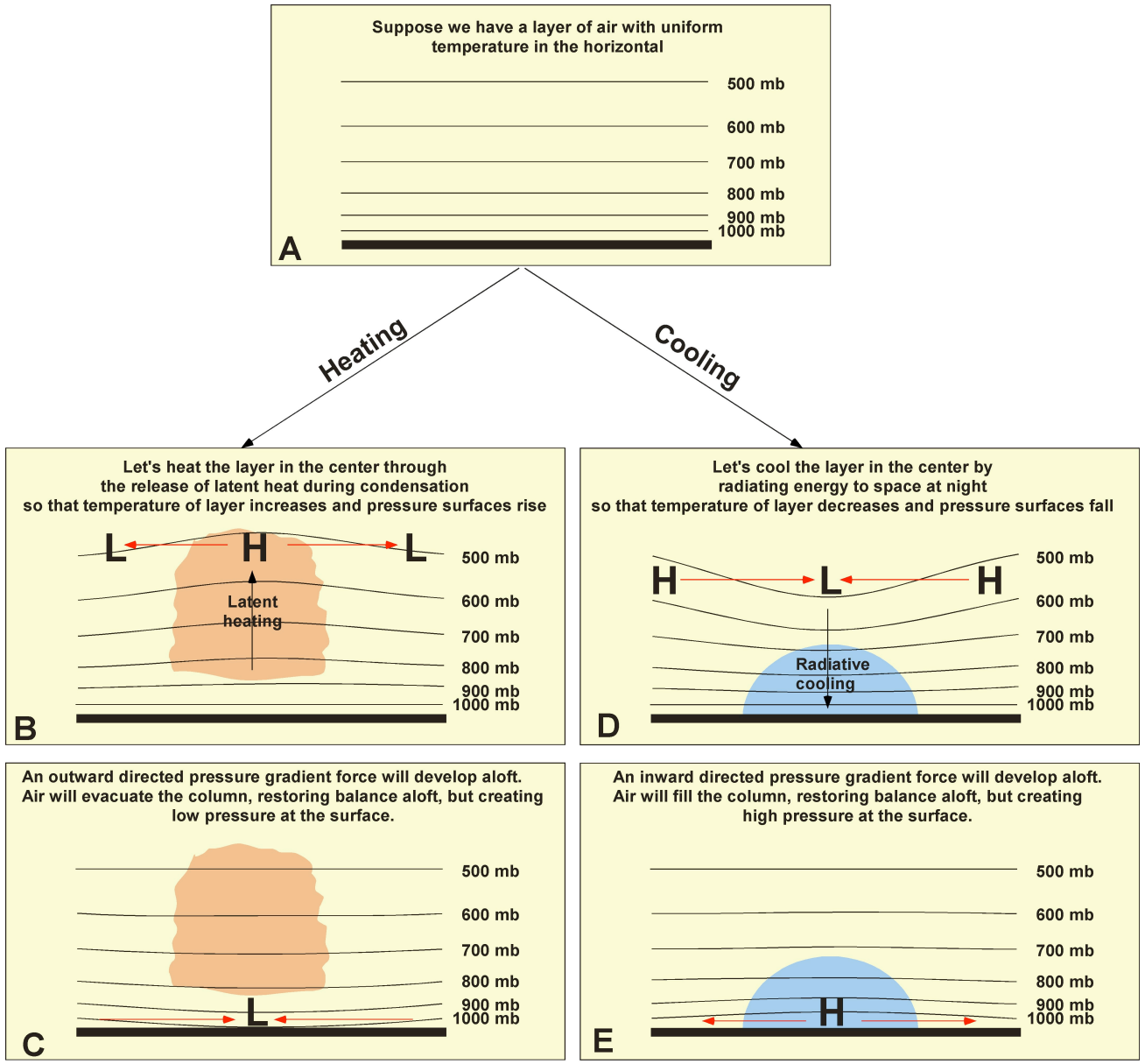


©Kendall/Hunt Publishing

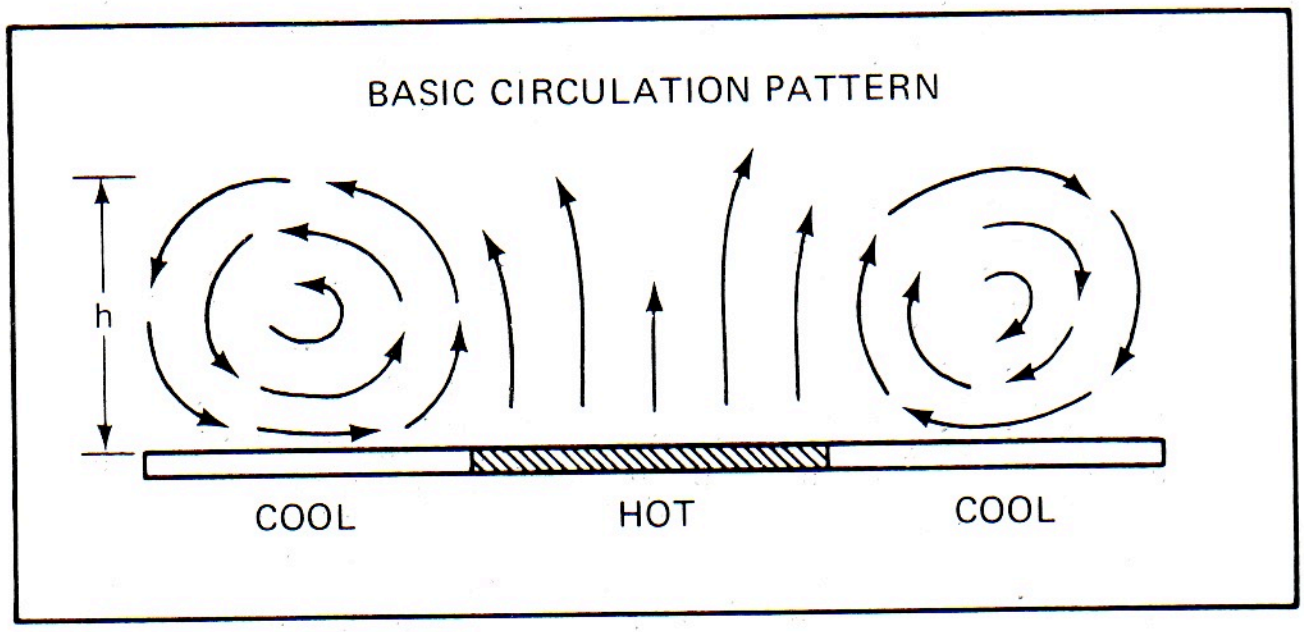


Courtesy of the Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

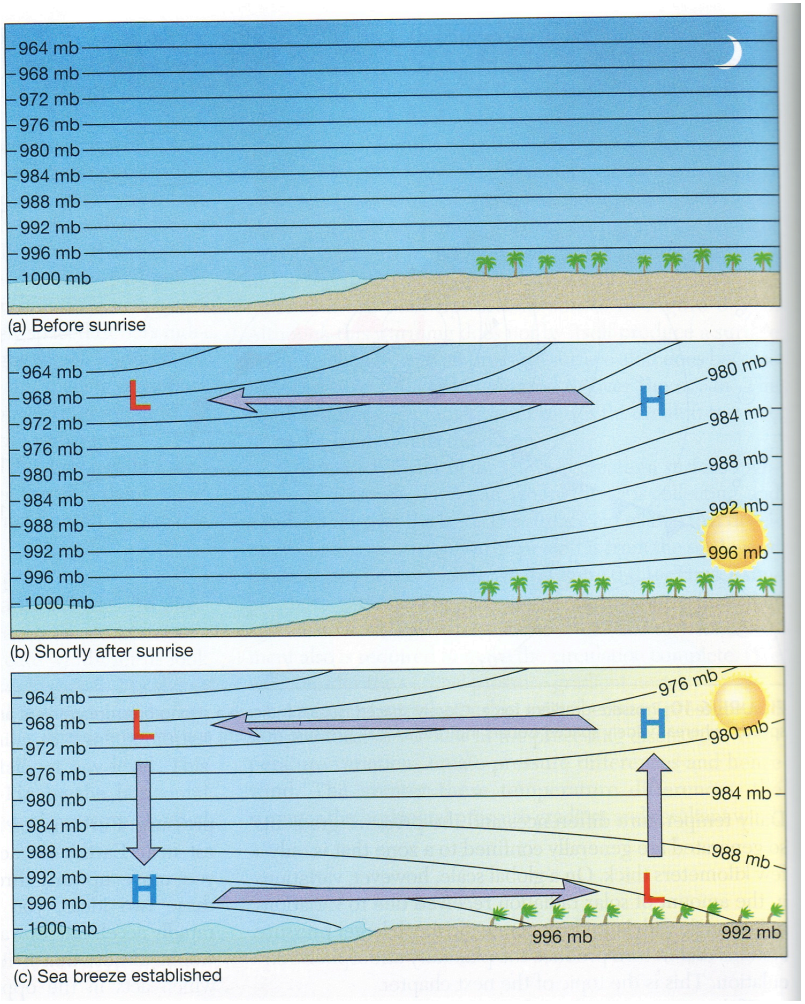
Effects of Heating & Cooling



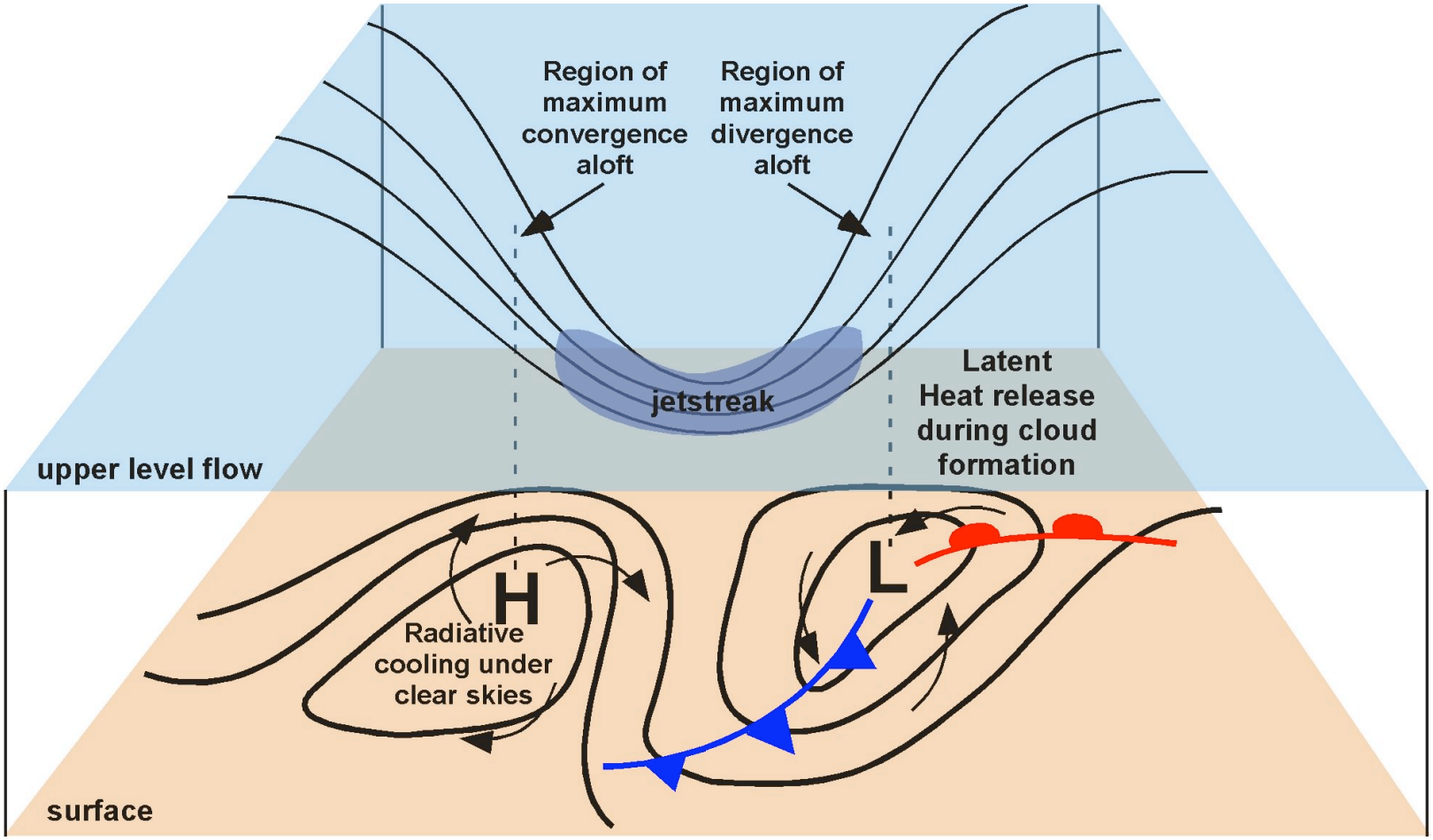
©Kendall/Hunt Publishing


BASIC CIRCULATION PATTERN
h
COOL
HOT
COOL

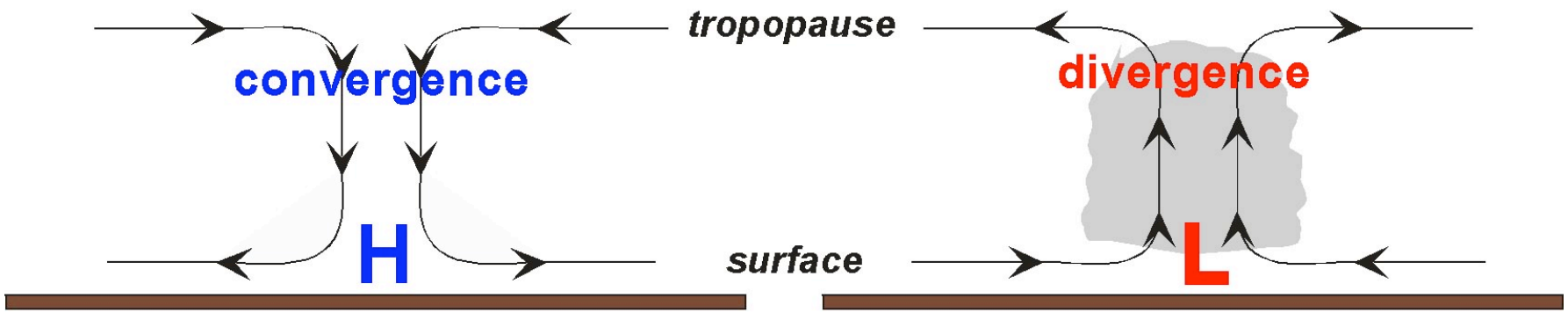
- ✓ Before sunrise, equal pressure at equal height (i.e., PG = 0 and hence Wind = 0).
- ✓ After sunrise, the unequal rates at which land & water heat will initiate pressure differences and hence airflow.
- ✓ Later, during day, a simple thermal circulation develops, called sea breeze.
- ✓ Note that vertical movement also is required to make the circulation complete.

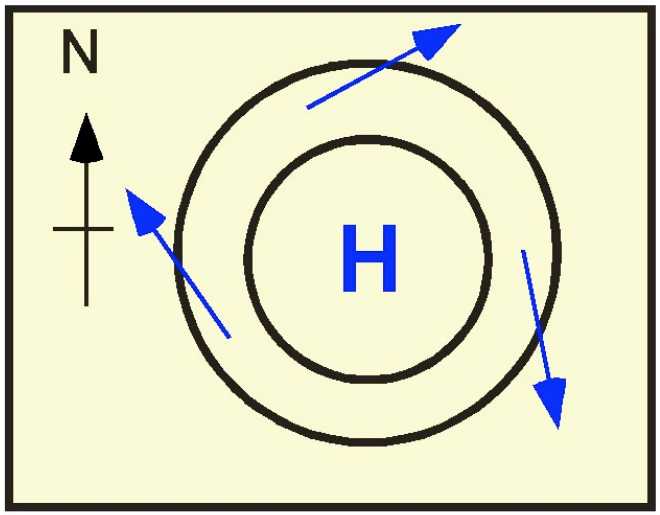


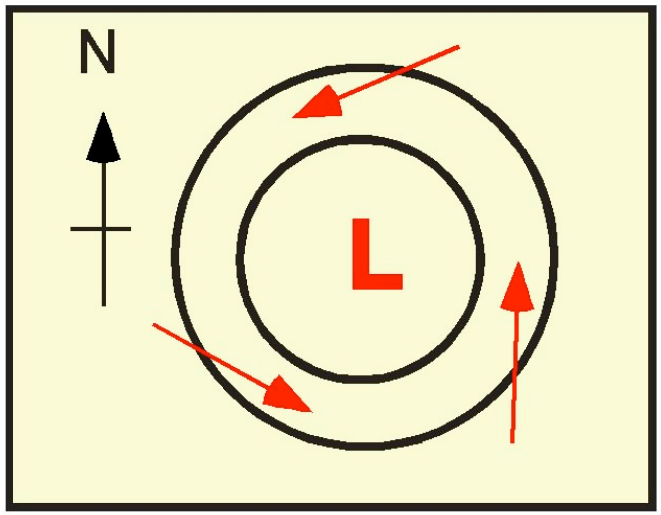
Dynamic and Thermodynamic Processes



©Kendall/Hunt Publishing





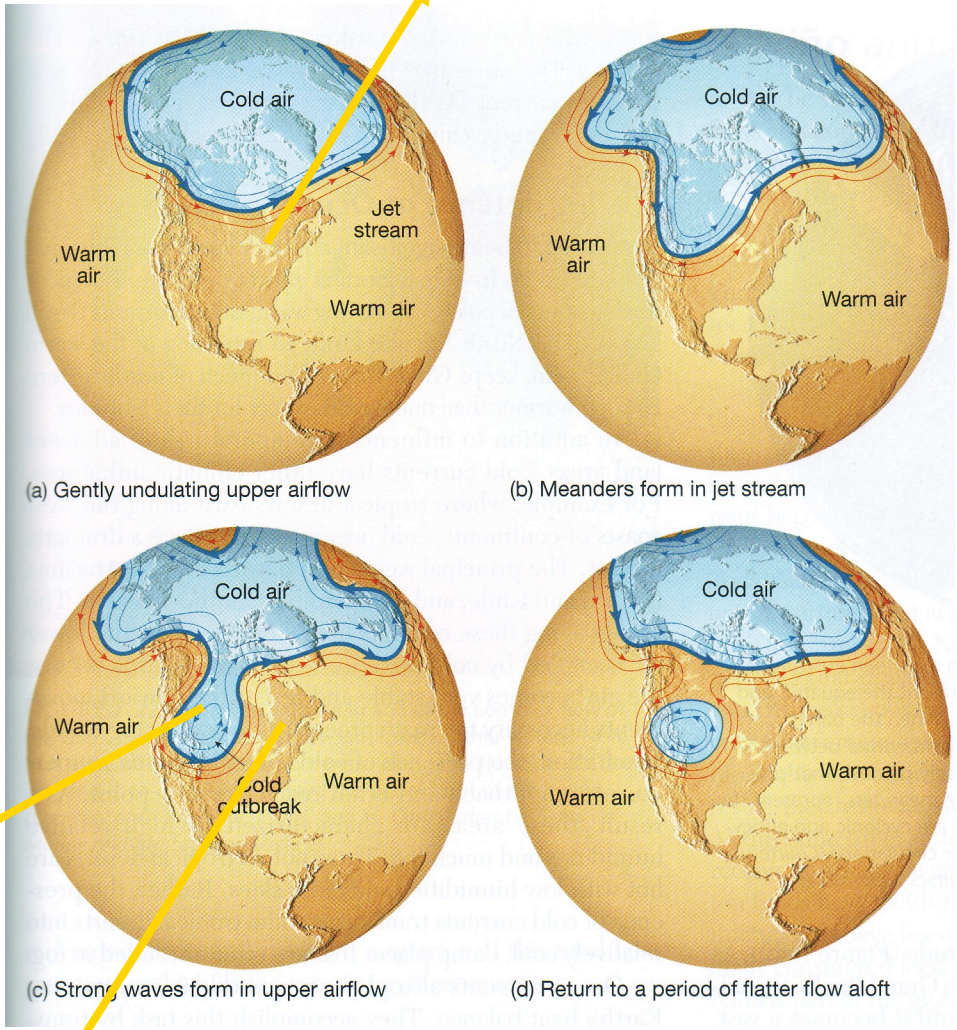


©Kendall/Hunt Publishing

Westerlies & Earth's Heat Budget

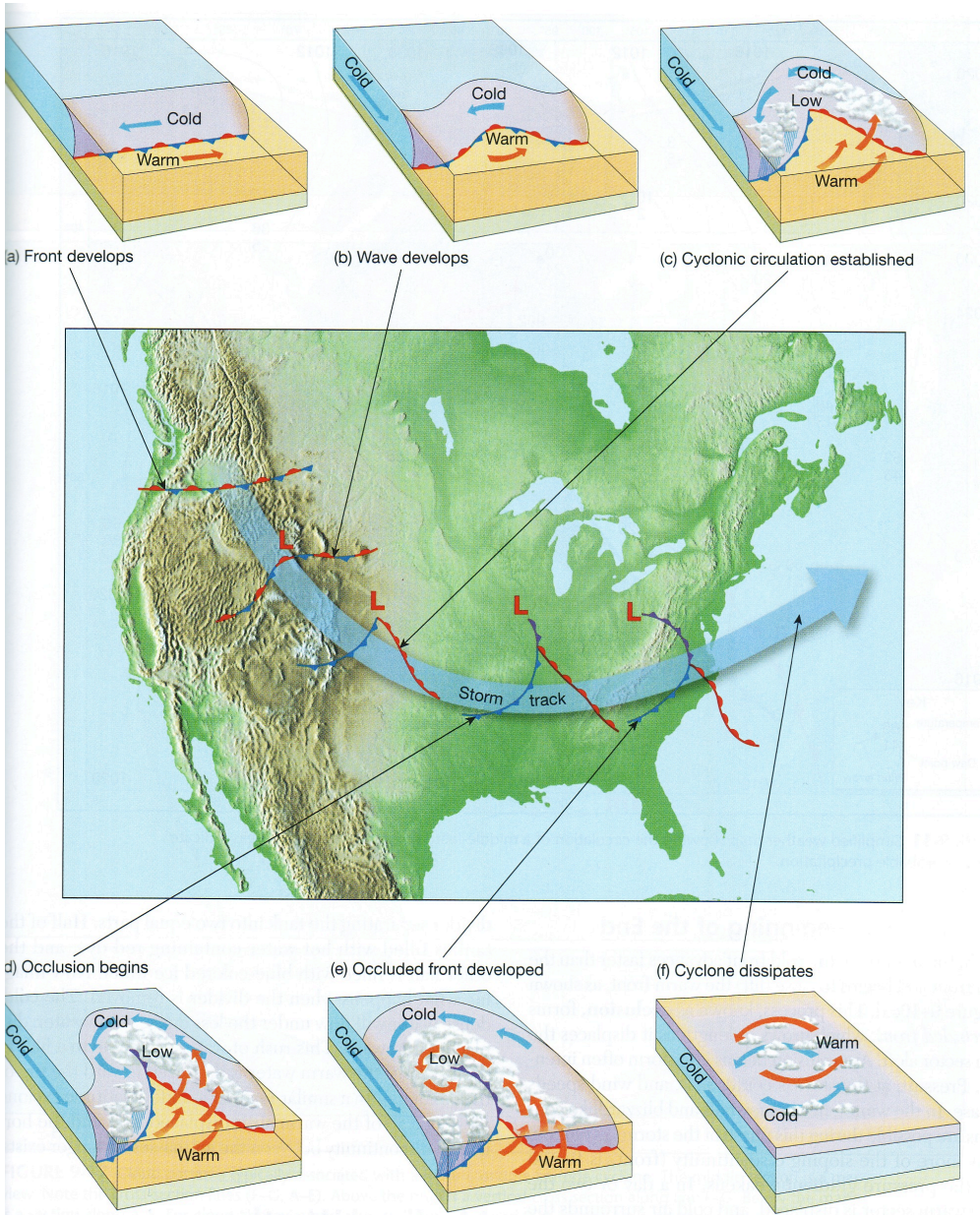
- The equator has excess heat, whereas the poles experience a deficit.
- The flow near the equator is somewhat meridional (north to south), but at most other latitudes the flow is zonal (west to east).
- The reason for the zonal flow is the Coriolis force.
- Now, the question is How can wind with a west-to-east flow transfer heat from south to north?

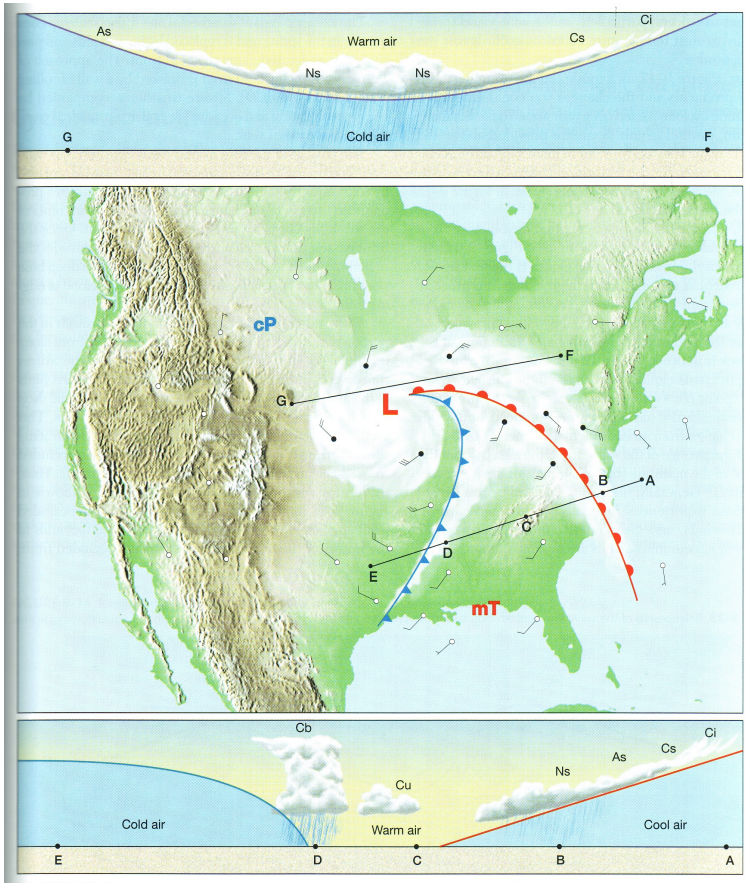
Few disturbances



Large amplitude waves, eddies produce weather

Strong cyclonic activities last 1-6 weeks redistribute heat


Cold
Warm
(a) Front develops
Cold
Warm
(b) Wave develops
Cold
Low
Warm
(c) Cyclonic circulation established
L
L
L
L
Storm track
(d) Occlusion begins
Cold
Low
Warm
(e) Occluded front developed
Cold
Low
Warm
(f) Cyclone dissipates
Warm
Cold


As
Warm air
Cs
Ci
Ns
Ns
G
Cold air
F
cP
G
F
L
B
A
C
D
E
mT
Cb
Cu
Ci
Cs
As
Ns
Cold air
Warm air
Cool air
E
D
C
B
A

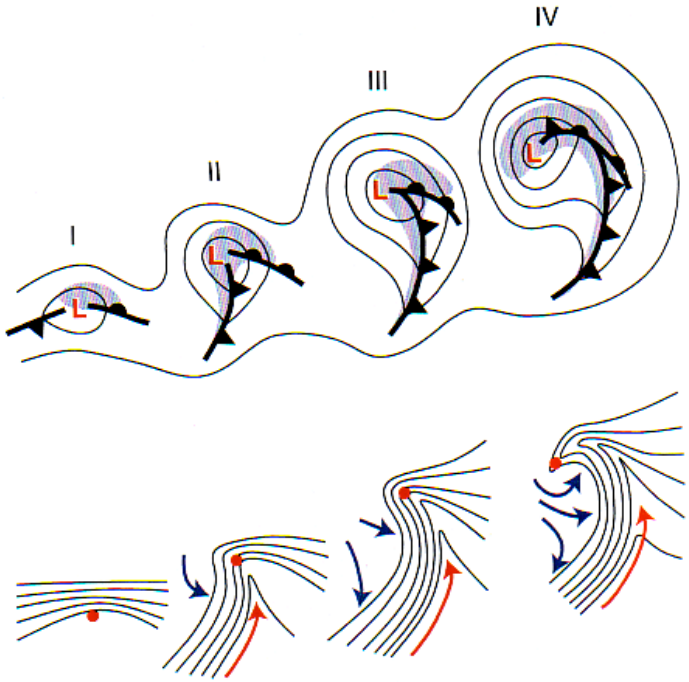


Fig. 8.31 Schematic showing four stages in the development of extratropical cyclones as envisioned in the Norwegian polar front cyclone model. Panels I, II, III and IV represent four successive stages in the life cycle. (Top) Idealized frontal configurations and isobars. Shading denotes regions of precipitation. (Bottom) Isotherms (black) and airflow (colored arrows) relative to the moving cyclone center (red dot). Red arrows indicate the flow in the warm sector, and blue arrows indicate the flow in the cold air mass. Frontal symbols are listed in Table 7.1. [Adapted from *Mon. Wea. Rev.*, **126** (1998) p. 1787.]

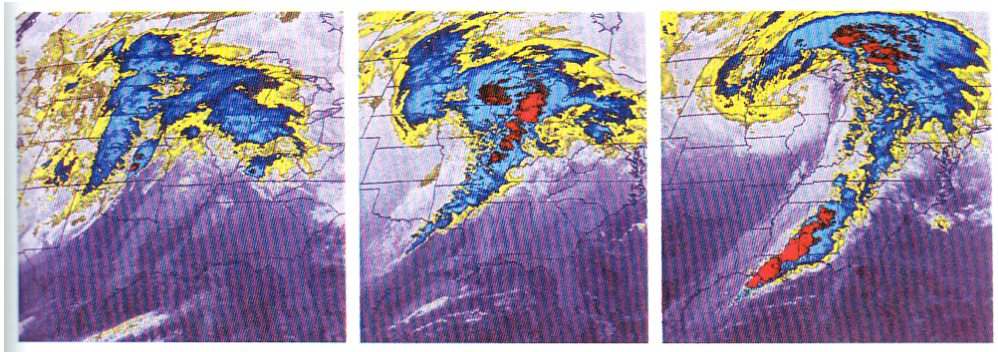


Fig. 8.17 Infrared satellite imagery for 00, 09, and 18 UTC Nov. 10, 1998, based on radiation in the 10.7-μm channel, in which the atmosphere is relatively transparent in the absence of clouds. Radiances, indicative of equivalent black-body temperatures T_E of the Earth's surface or the cloud top, are rendered on a scale ranging from black for the highest values (indicative of cloud-free conditions and a warm surface) with progressively lighter shades of gray indicative of lower temperatures and higher cloud tops. Color is used to enhance the prominence of the coldest (highest) cloud tops in the image.

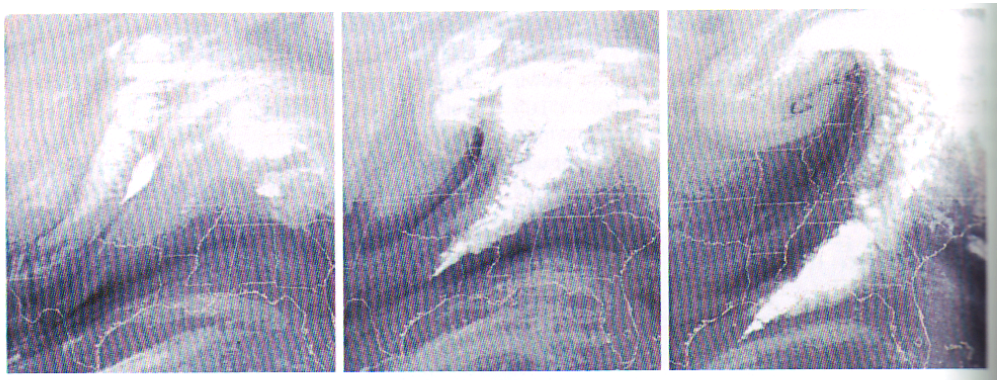


Fig. 8.18 Satellite imagery for 00, 19 and 18 UTC Nov. 10, 1998, based on the 6.7 μm "water vapor channel." The radiances in this band provide a measure of the mid- and upper tropospheric humidity which, in turn, is determined by the air trajectories. Air that has been rising tends to be moist, resulting in a high optical depth, a low equivalent blackbody temperature and a low radiance, and vice versa. Low radiances, indicative of ascent are rendered by the lighter gray shades and high radiances, indicative of subsidence, by the darker shades. The brightest features in the images are clouds with high, cold tops.