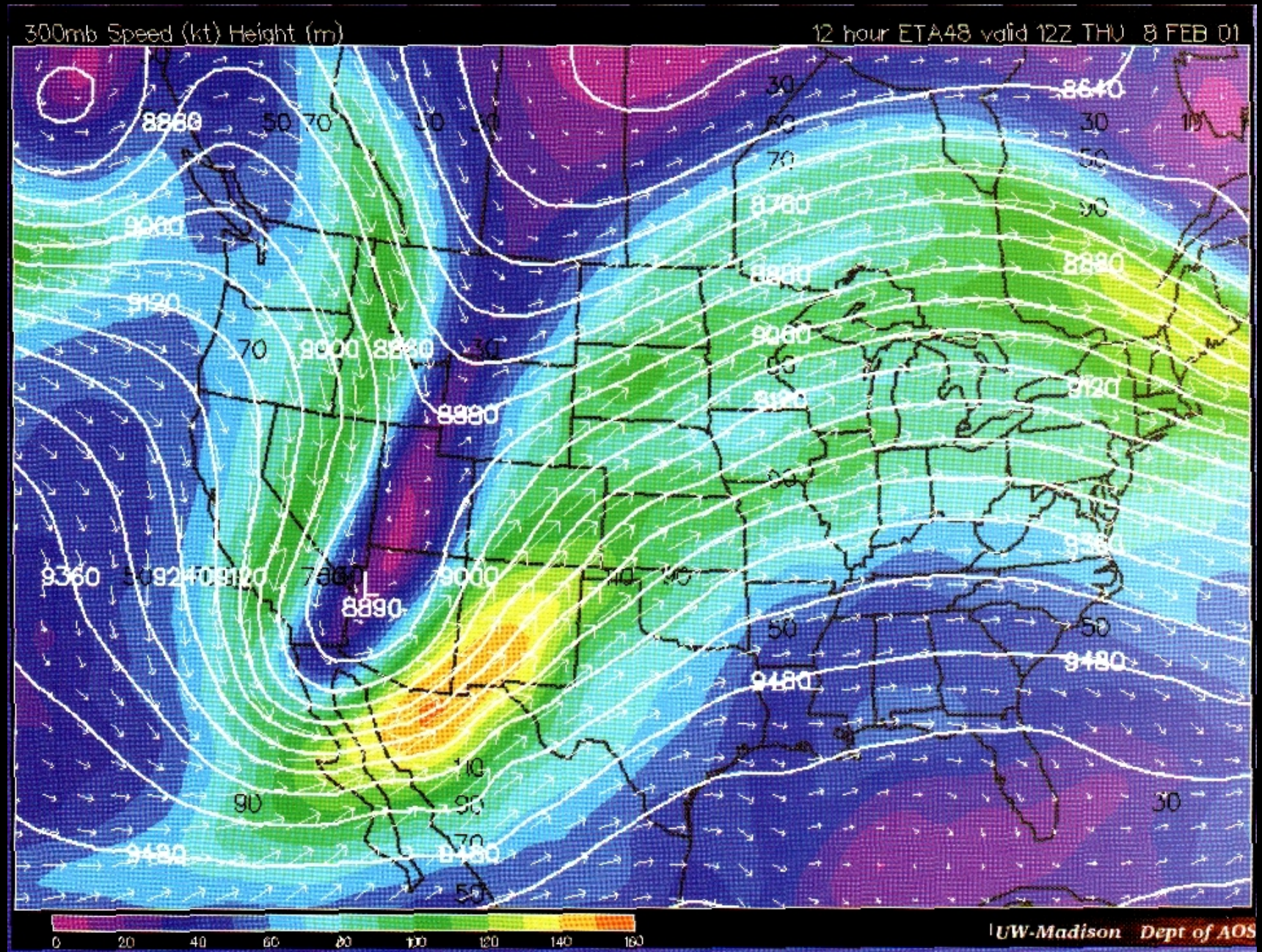
MET 4300/5355

Lecture 8:
Pressure System Development (CH8)

Extratropical cyclones

- Parent storms of many types of hazardous weather (from severe thunderstorms to snow storms)
- Develop from the imbalance between PGF and Coriolis force (far from geostrophic balance), primarily at the level of jetstream
- Dissipate due to friction

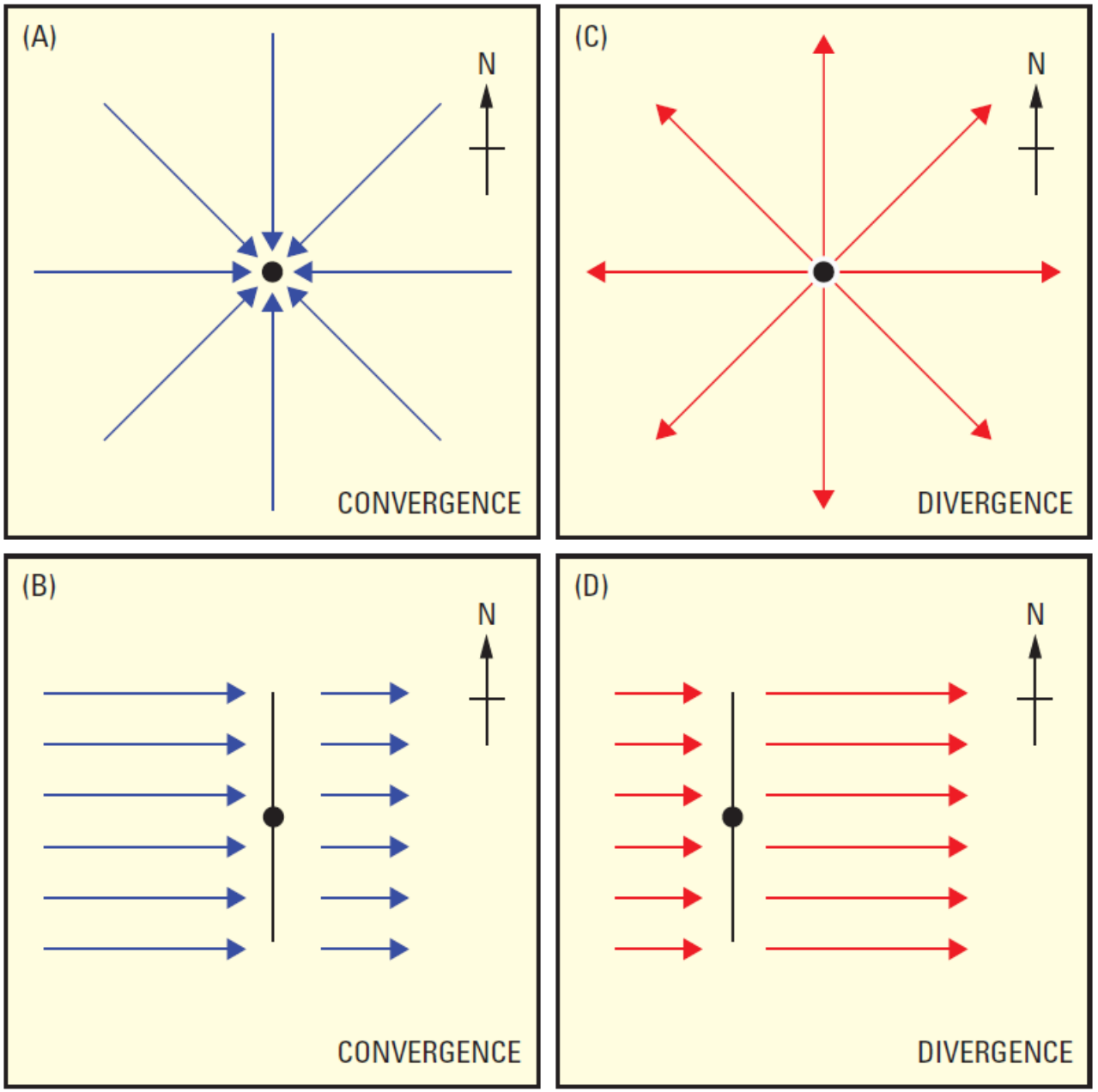
Jet Stream and Jeststreaks



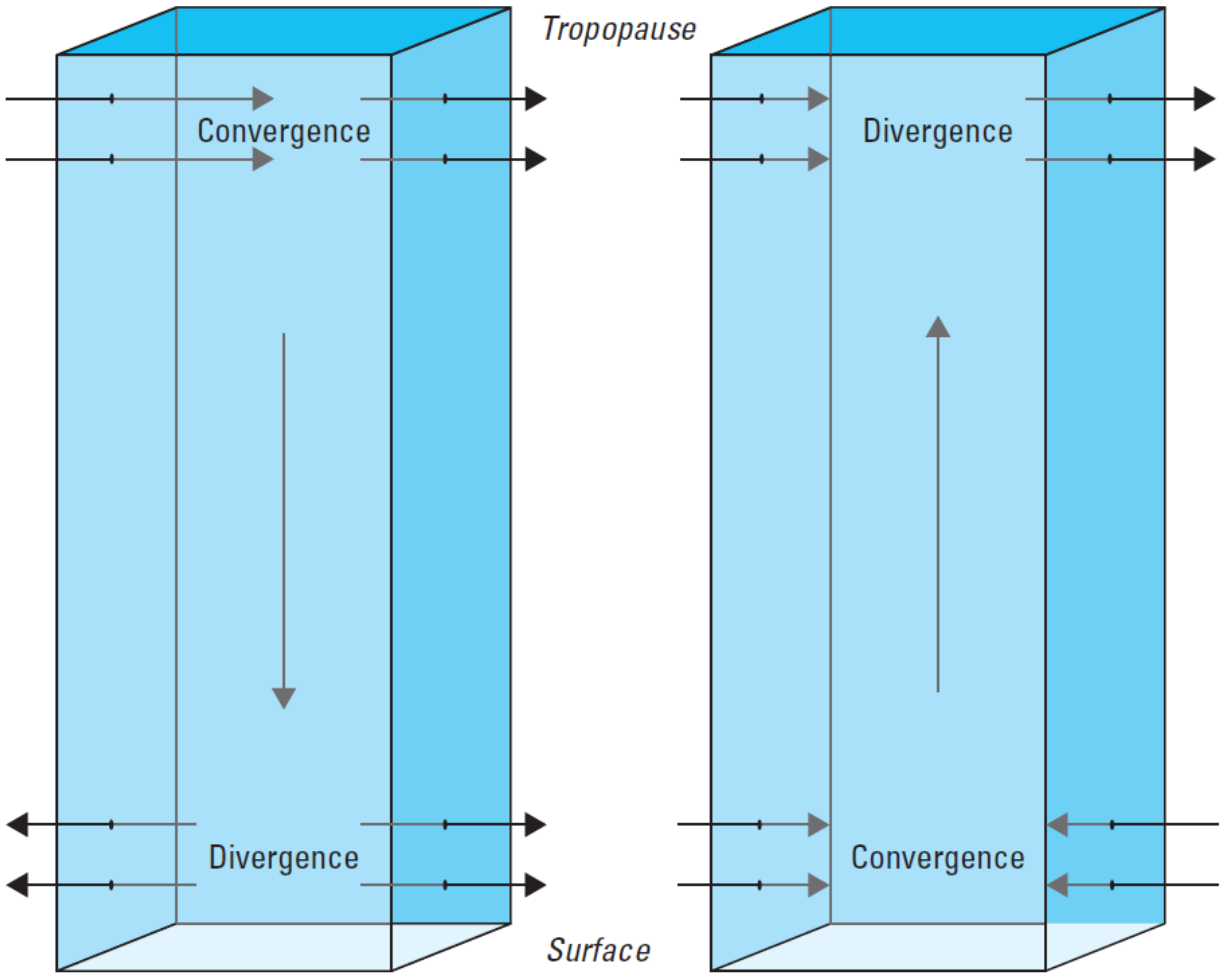
Divergence & Convergence

1. Convergence within an air column (upper level) → **increasing air mass and surface pressure**
Divergence within an air column (upper level) → **decreasing air mass and surface pressure**

2. Since air can't be created or destroyed, areas of convergence and divergence produce **vertical motion**



Dines' Compensation



Convergence over divergence and divergence over convergence

High-pressure Center (Anticyclone; clear skies)

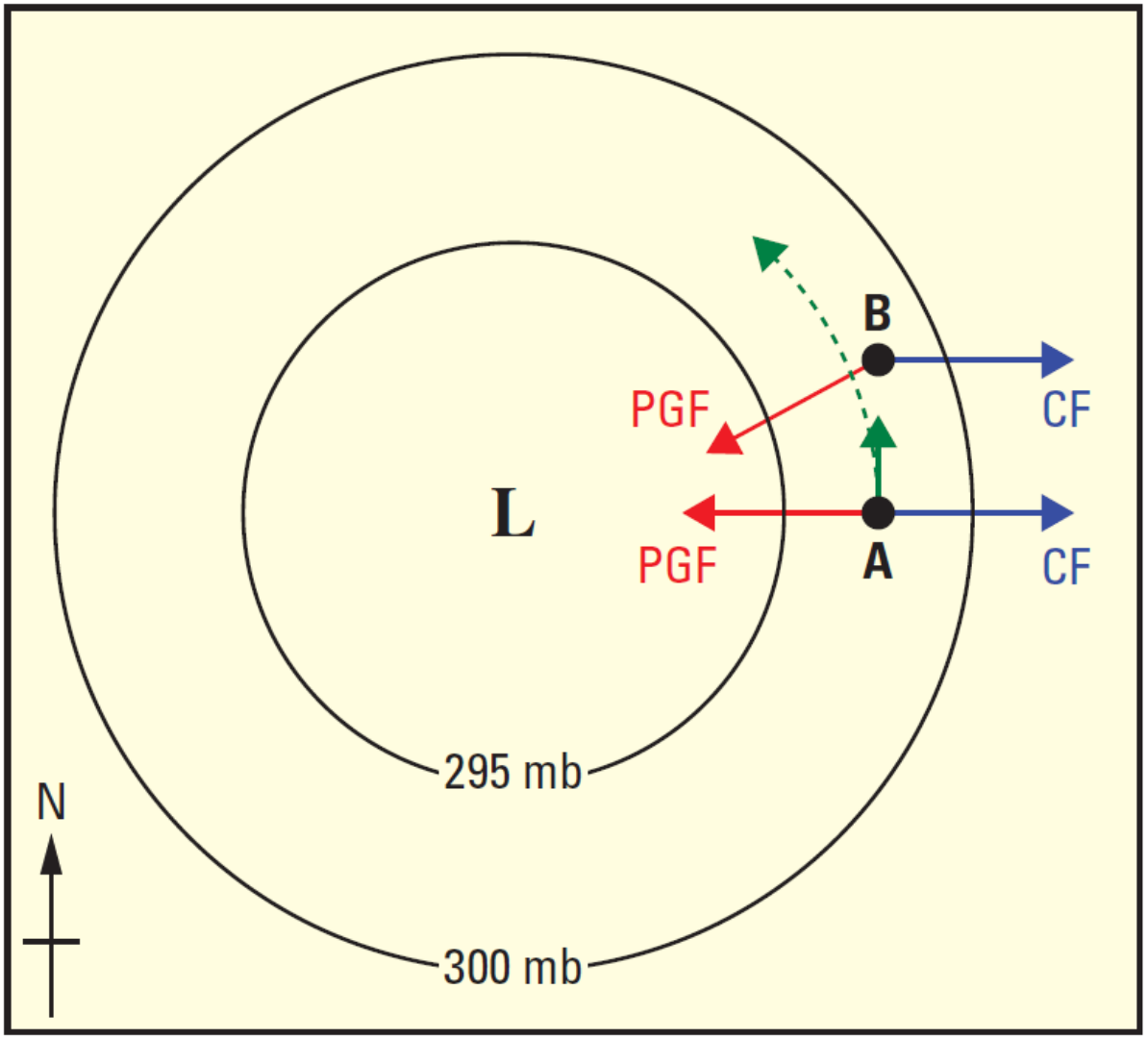
Low-pressure Center (Cyclone; clouds & precipitation)

What are the causes of convergence and divergence?

- **Imbalance between PGF and Coriolis force:**
  1. Curvature effect
  2. Jetstreaks
  3. Friction
- **Diabatic heating and cooling**

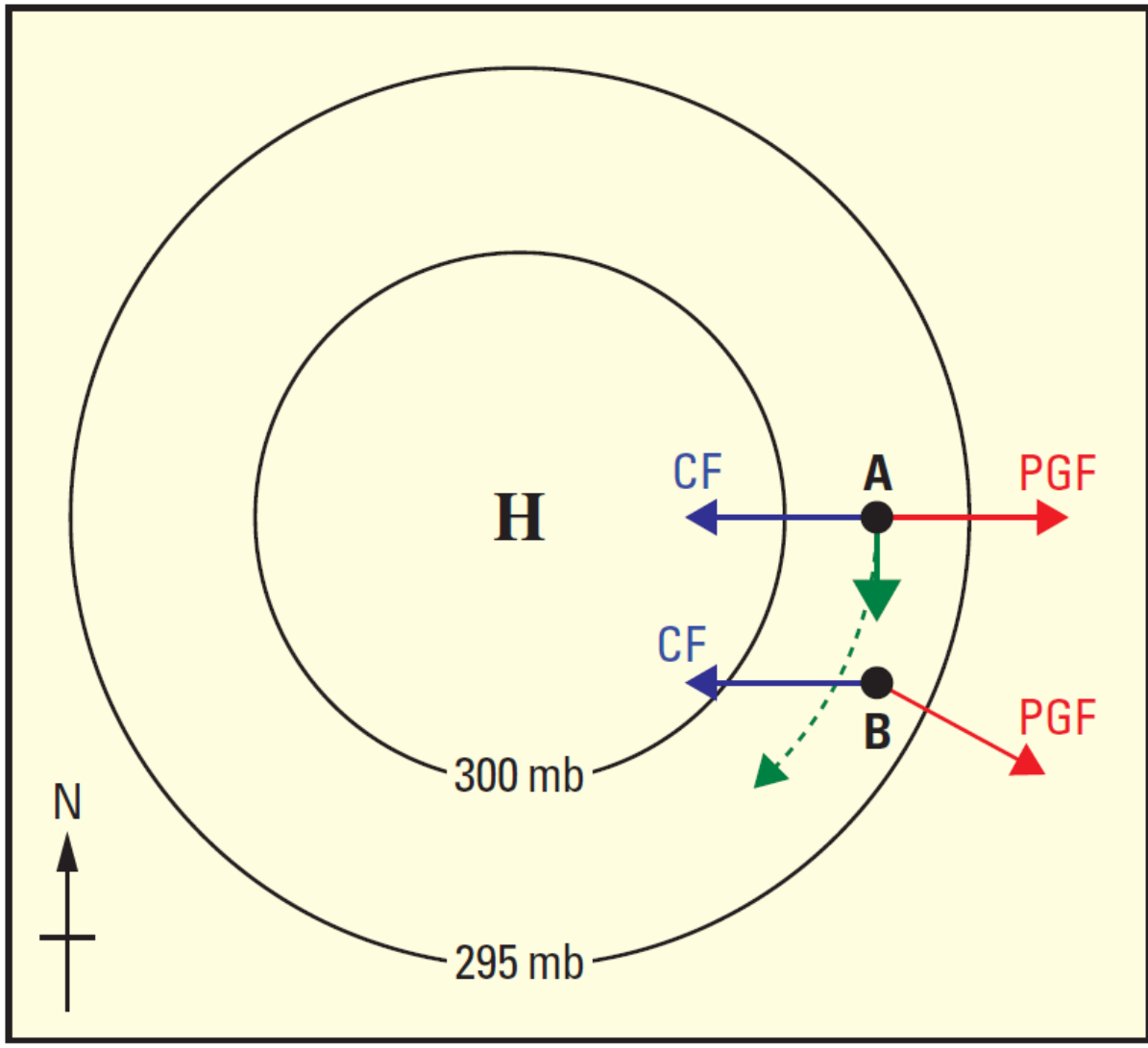
Force Imbalance in Cyclonically Curved Flow

- Assume point A is in geostrophic balance
- Then the air parcel will remain traveling at a constant speed in a straight line motion.
- Move the air parcel forward a very small distance to point B
- At B, CF doesn't change (CF=fv), but PGF direction will change to as shown.
- The southward component of PGF will slow down the wind, **reducing the CF, causing force imbalance: PGF> CF**
- The original geostrophic balance assumption is wrong! Should be in **gradient wind balance PGF=CF+Cen (centifugal force)**!

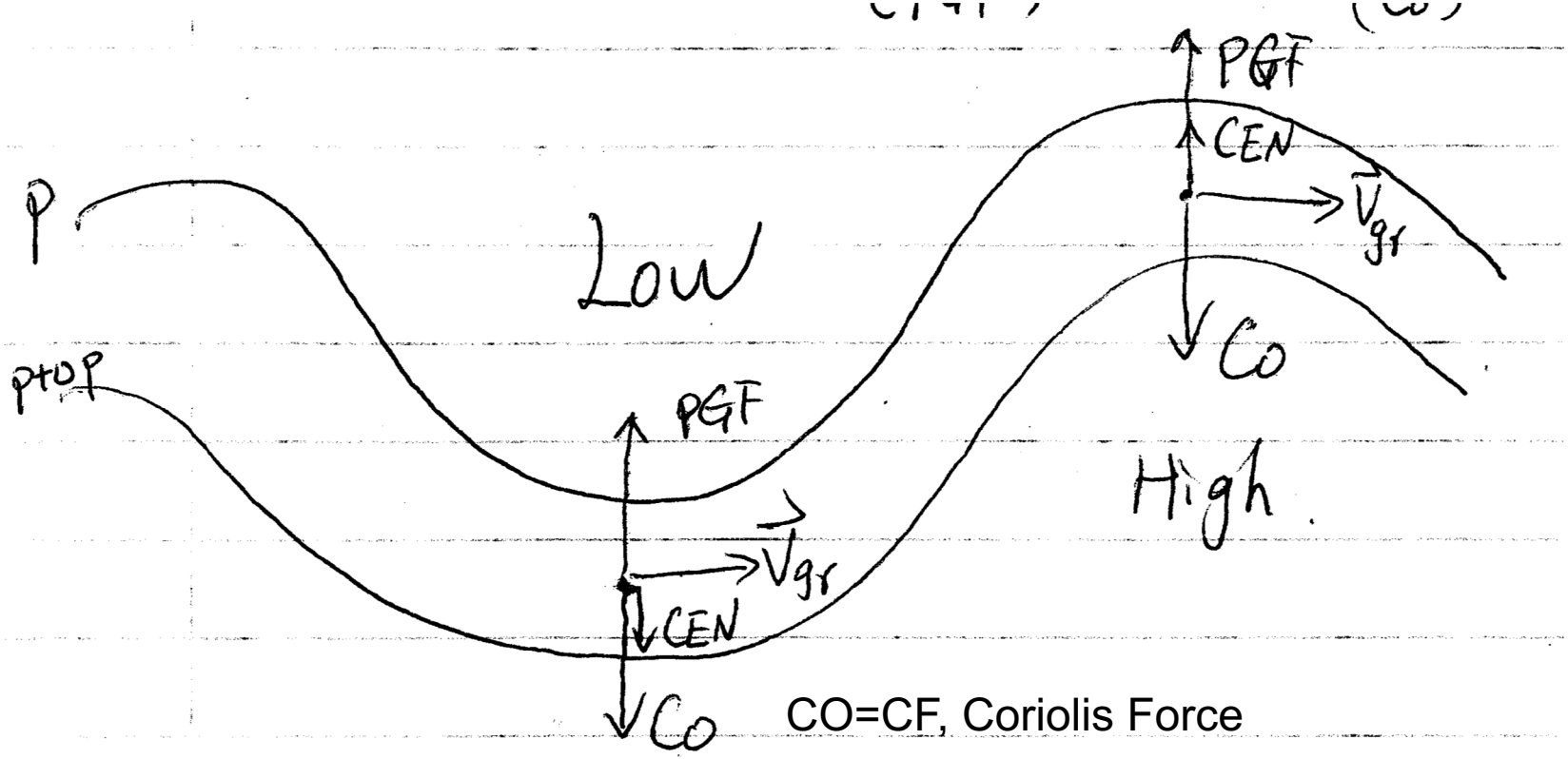


Force Imbalance in Anticyclonically Curved Flow

- Assume point A is in geostrophic balance
- Then the air parcel will remain traveling at a constant speed in a straight line motion.
- Move the air parcel forward a very small distance to point B
- At B, CF doesn't change (CF=fv), but PGF direction will change to as shown.
- The southward component of PGF will accelerate the wind, **increasing the CF, causing force imbalance: PGF< CF**
- The original geostrophic balance assumption is wrong! Should be in **gradient wind balance CF=PGF+Cen (centrifutal force)**!



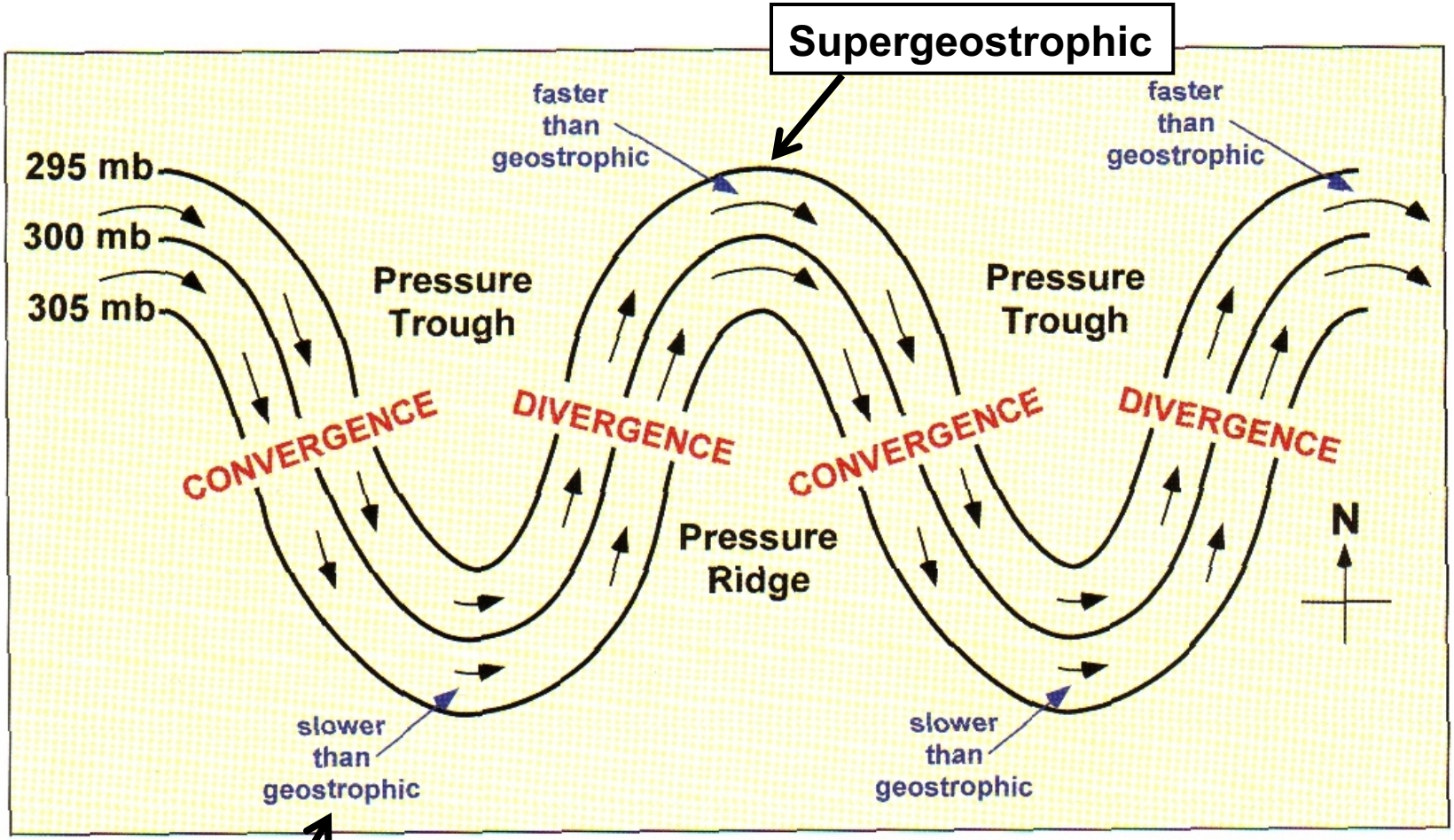
Gradient wind balance around low and high pressure centers



Gradient wind balance around a low pressure in NH:
Slower than geostrophic → subgeostrophic

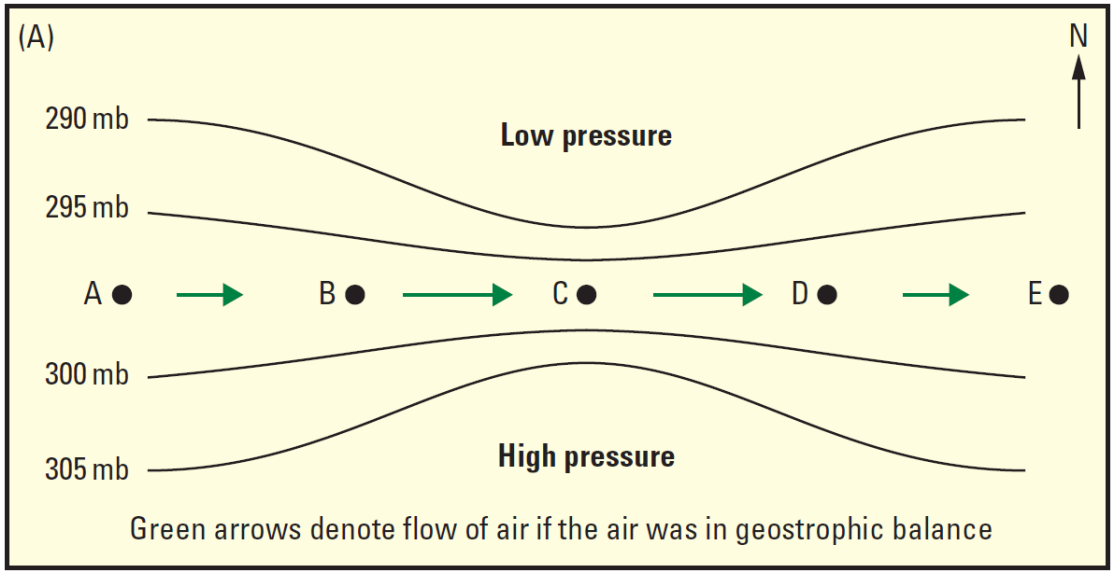
Gradient wind balance around a high pressure center in NH:
Faster than geostrophic → supergeostrophic

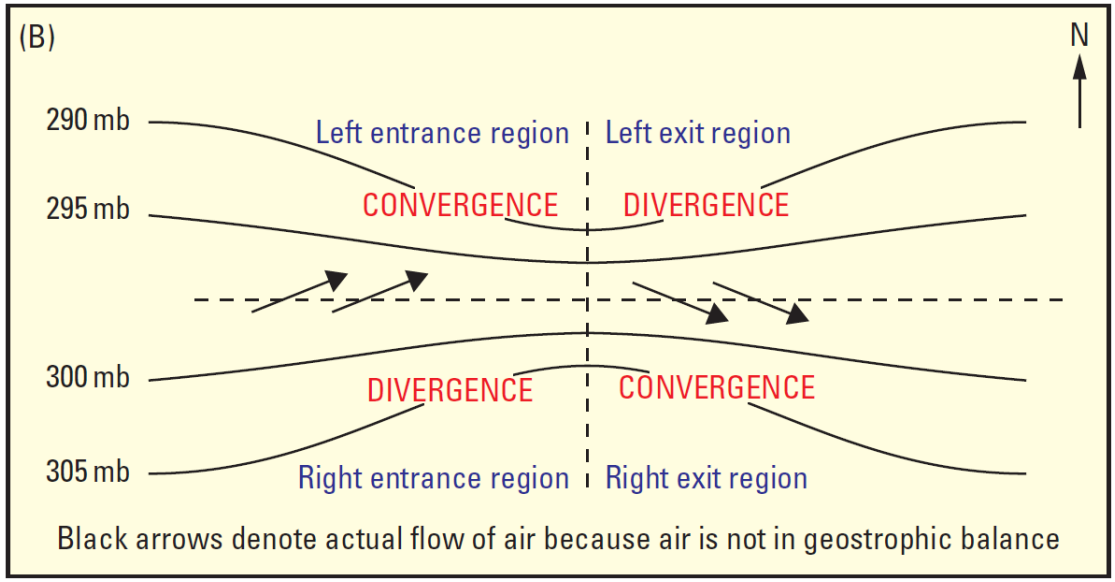
Curvature Effect on an upper level flow with troughs and ridges: create surface low & high pressure centers



Jet Streaks and Ageostrophic Flow

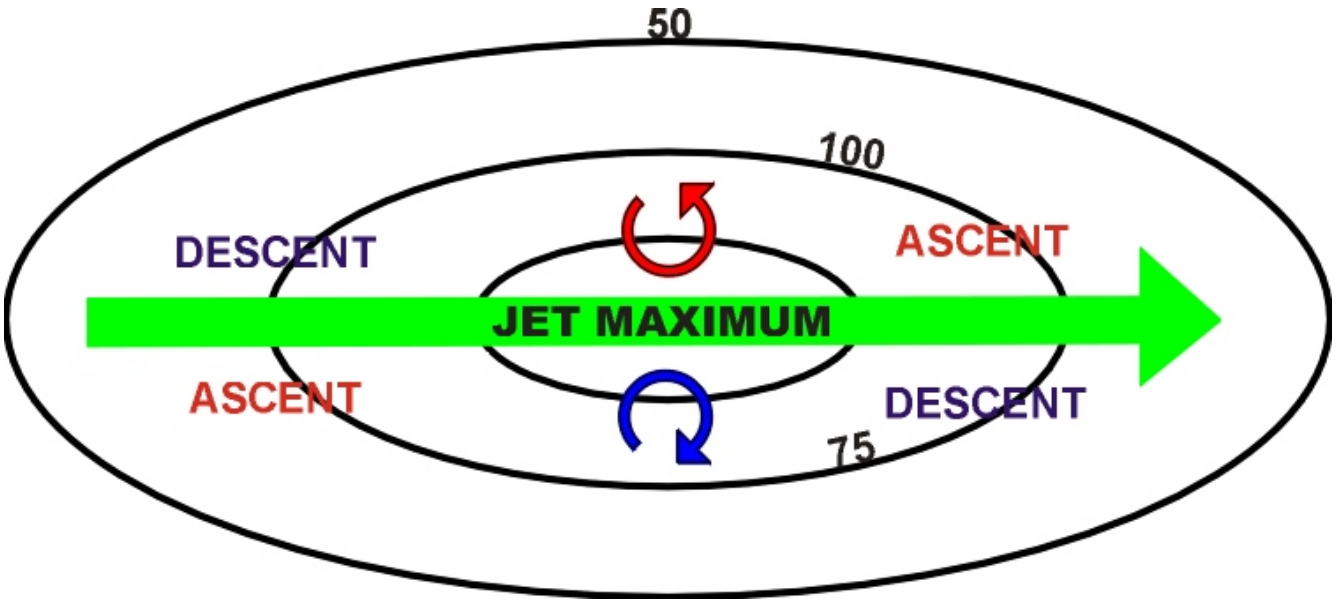
- Assume point A is in geostrophic balance
- Then the air parcel will remain traveling at a constant speed in a straight line motion.
- Move the air parcel forward a very small distance to point B
- At B, CF doesn't change (CF=fv), but PGF will increase (stronger pressure gradient closer to the low center).
- Whiling moving eastward, the air parcel will begin to accelerate northward across the jet **(Panel B)**.
- At the core of the jet streak, the balance of forces shifts, PGF will decrease, causing a southeast motion as shown in the exit region of panel B



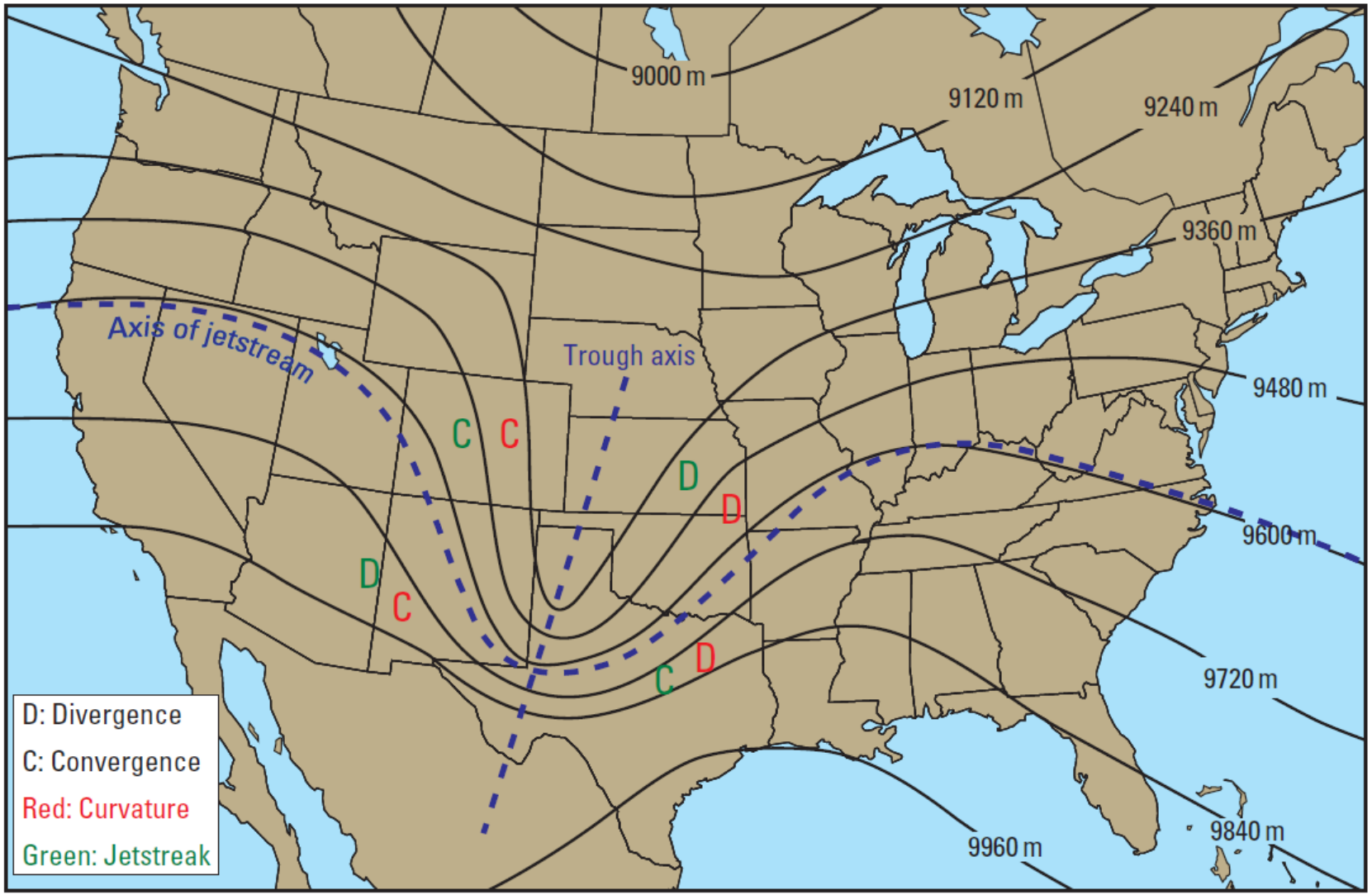


Jetstreaks

- Intimately connected with surface weather
- Move more slowly than the wind so that air moves through the pattern rear-to-front
- Well defined (4 quadrant) pattern of ascent and descent
  - Ascent in right entrance and left exit
  - Descent in left entrance and right exit
- Becomes more complicated if the MAX is curved.
- Vorticity is the dominant factor
- Jetstreaks control frontal cyclone formation

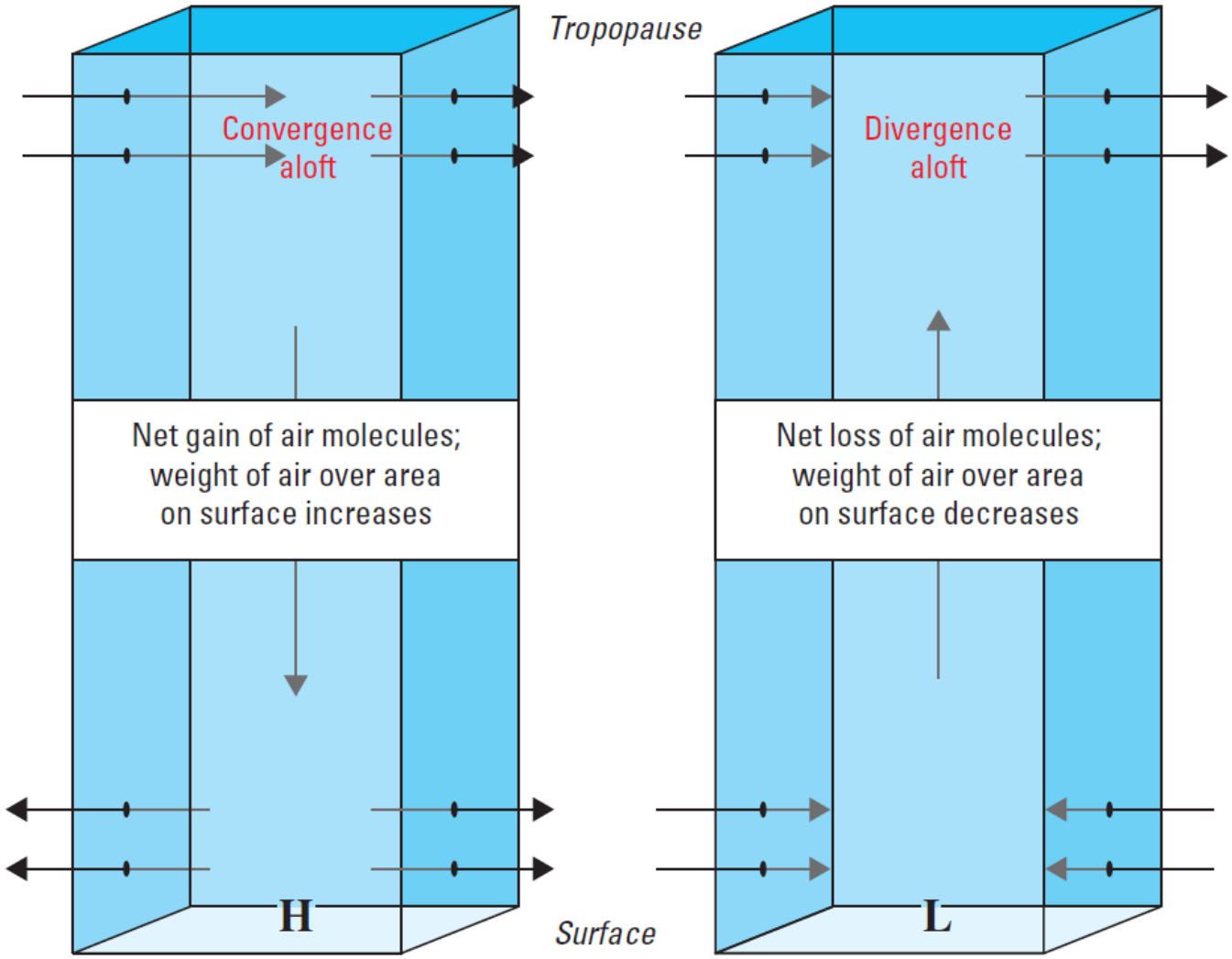


Combined Effects of Curvature and a Jetstream

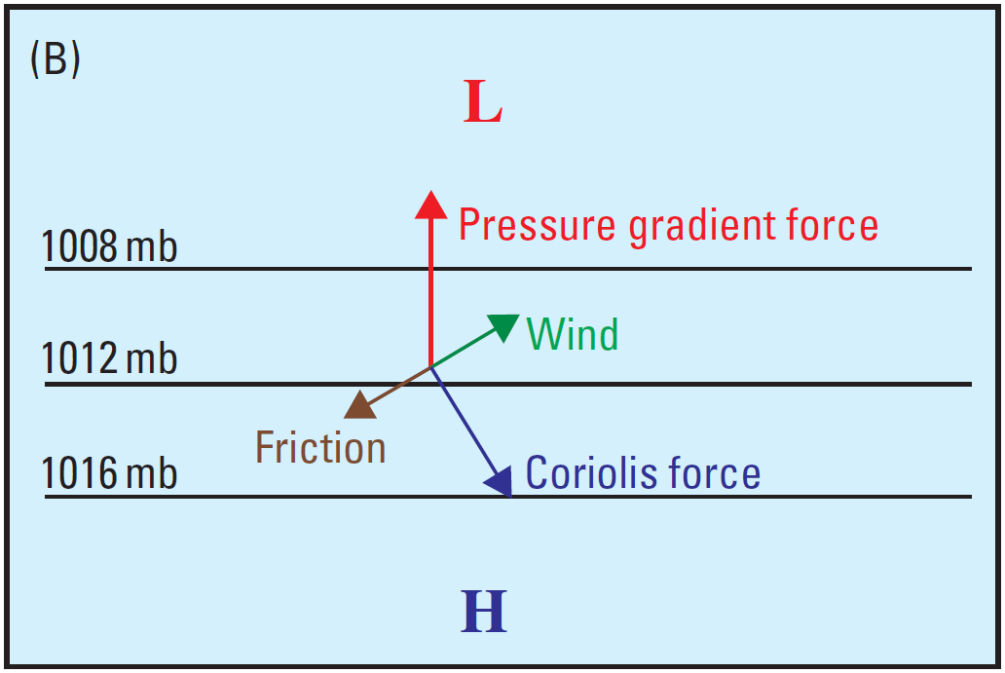


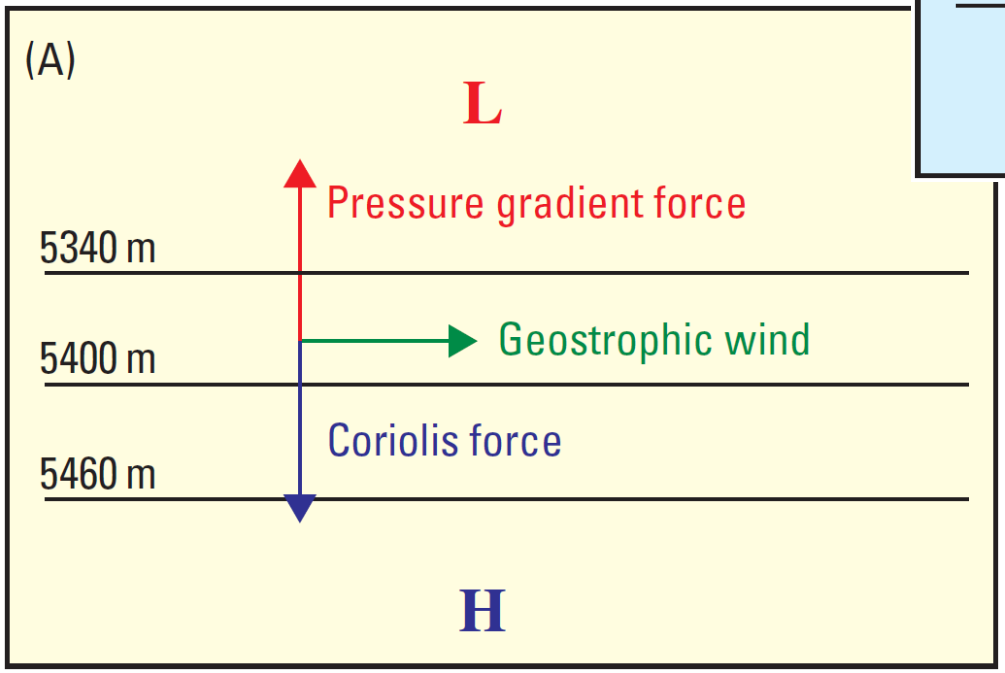
The strongest divergence aloft occurs on the northeast side of the trough (left exit region of the jetstreak) → strong surface cyclone development

Often Dines compensation does not fully compensate



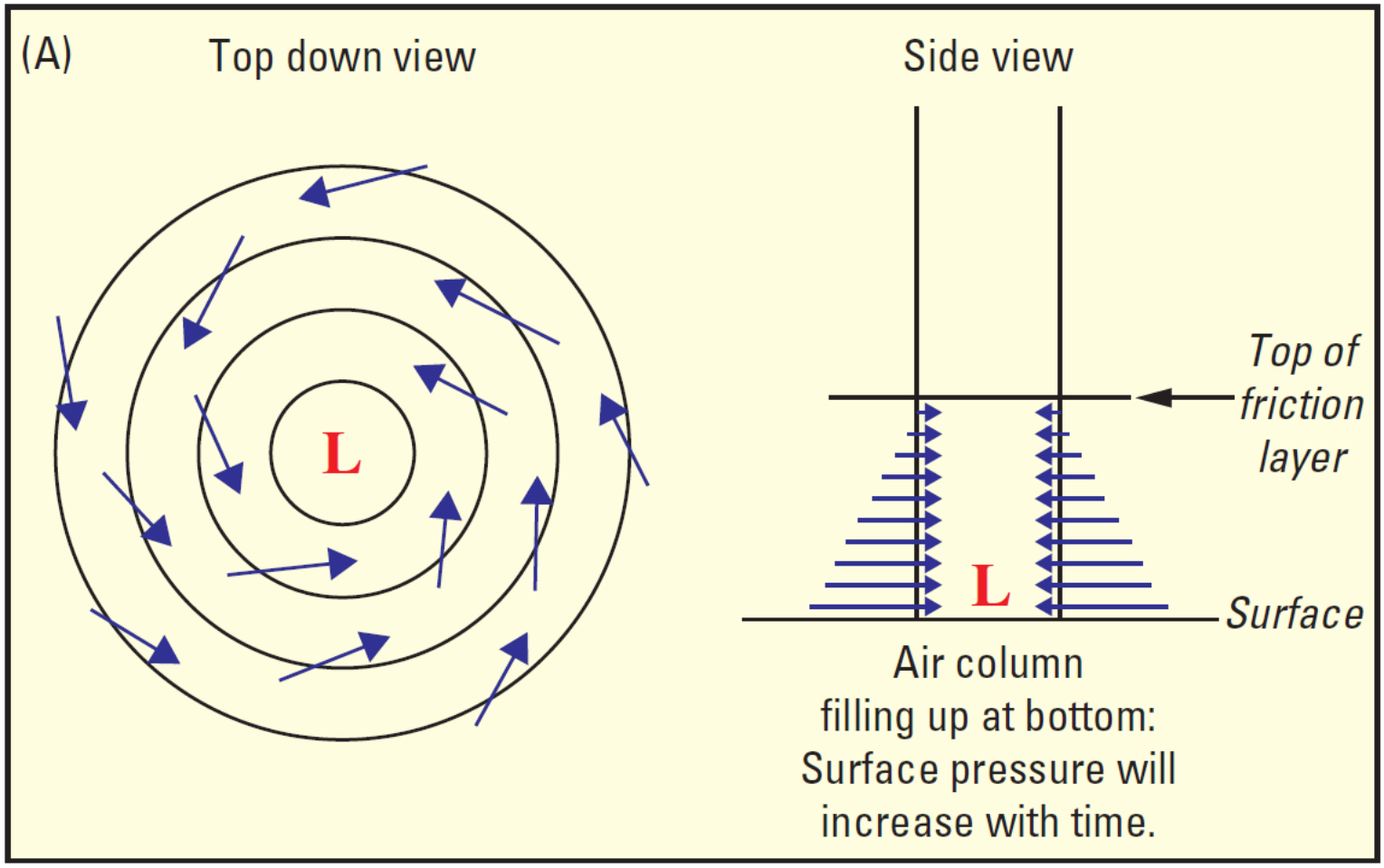
Effect of Friction





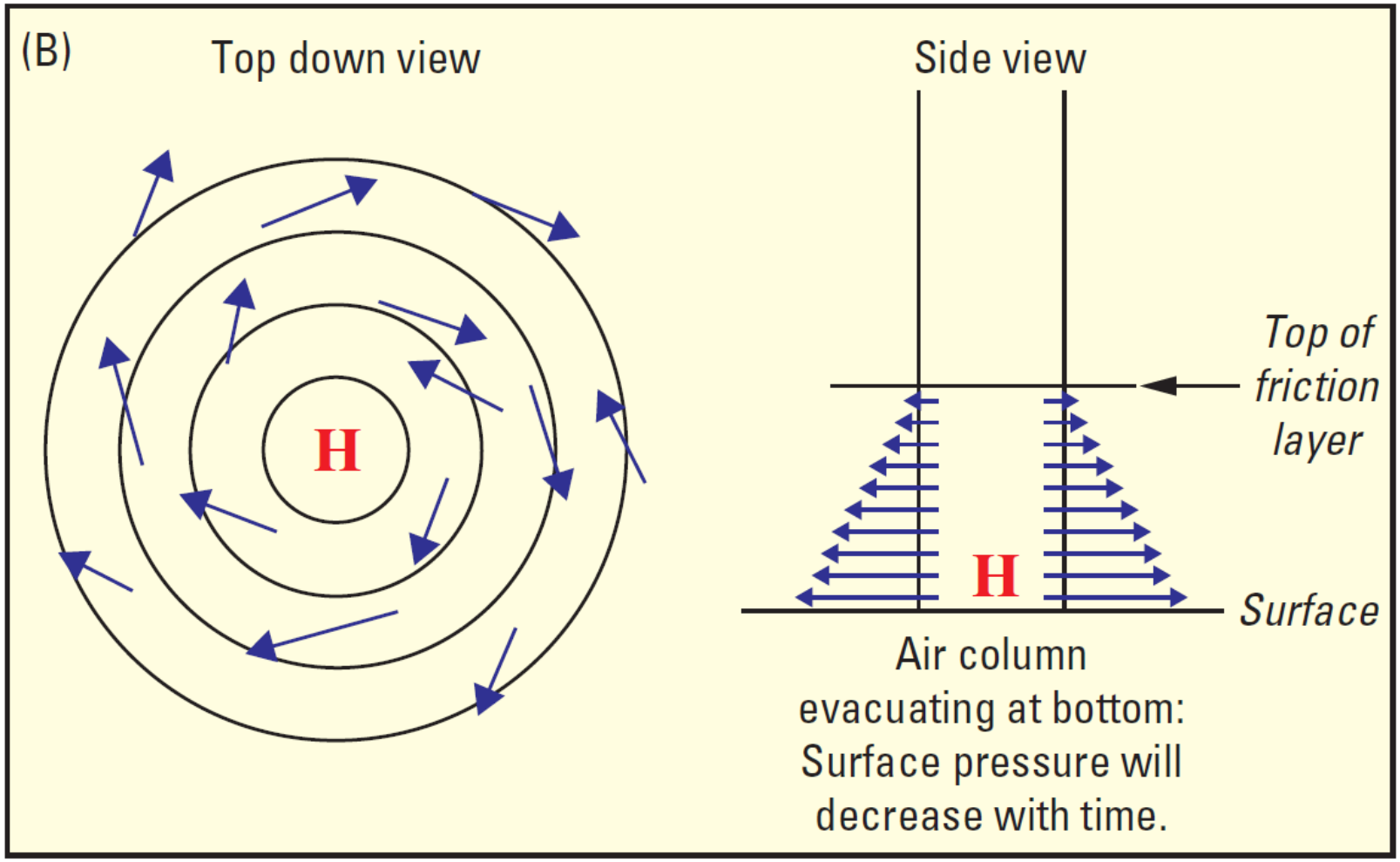
Slows wind so that PGF is stronger than the Coriolis force **causing near-surface winds to turn "leftward" such that the flow has a component from high pressure toward lower pressure**

Friction in Cyclonically Curved Flow



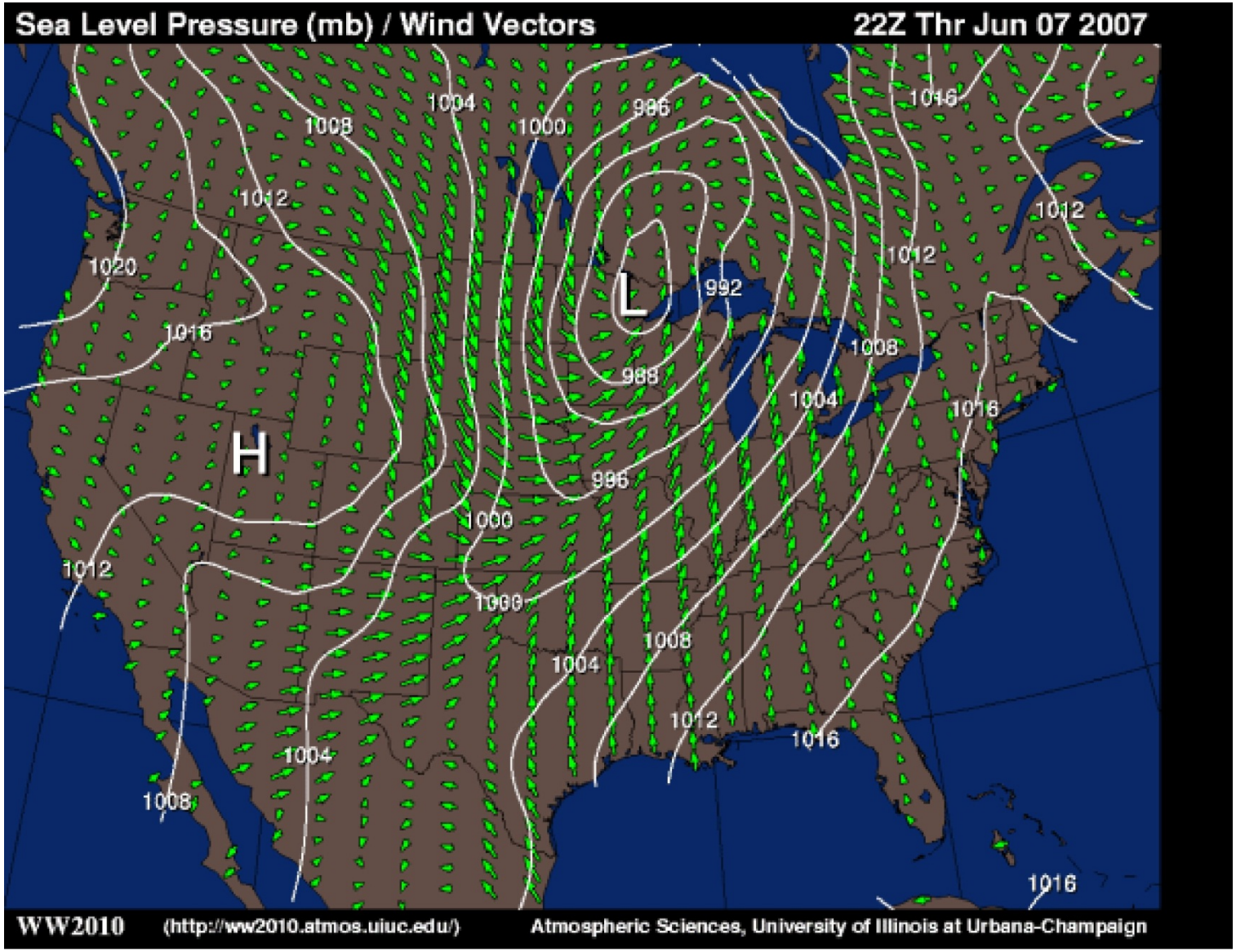
Causing Convergent cyclonic flow: tend to increase the surface pressure

Friction in Antiyclonically Curved FlOW

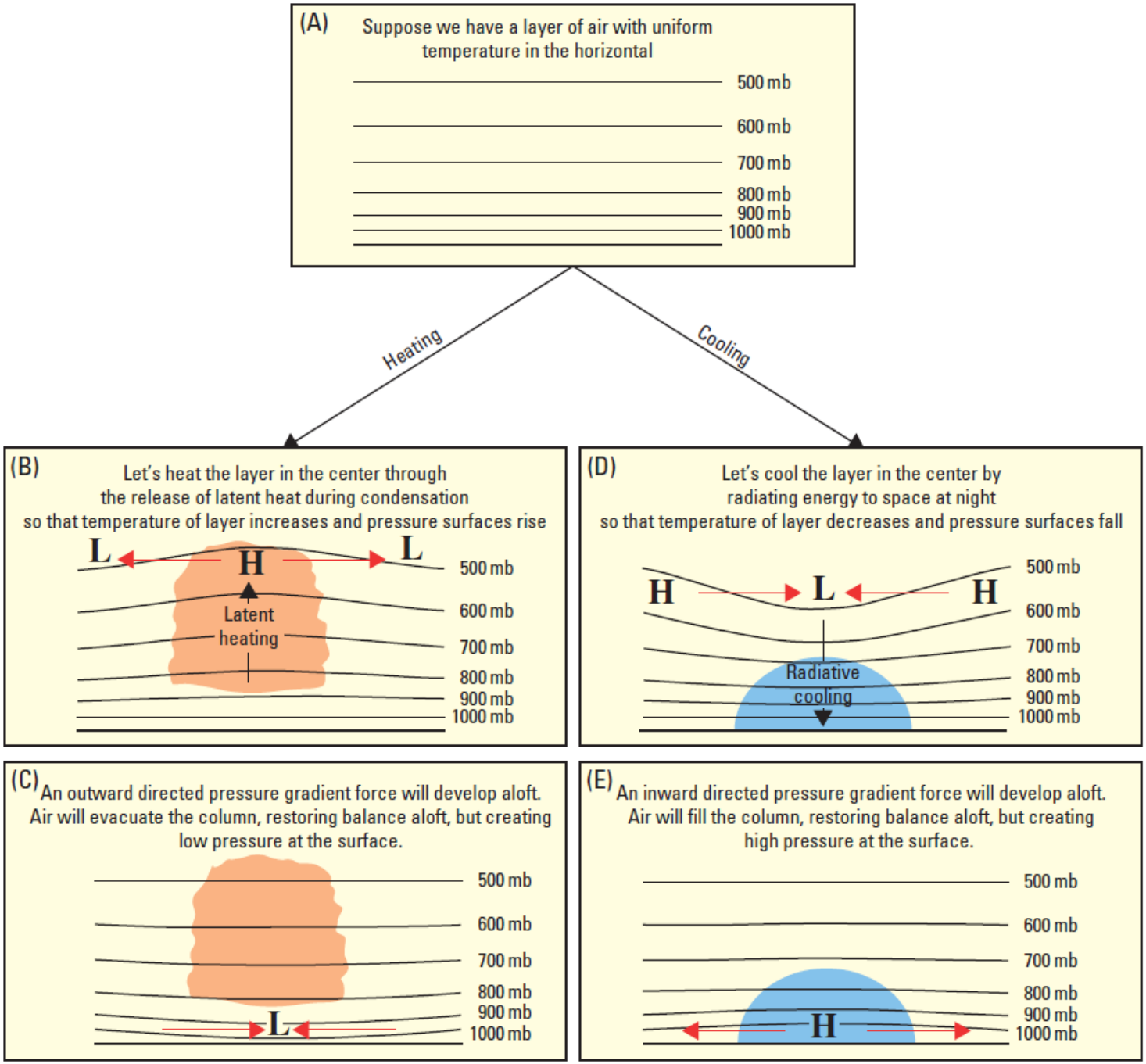


Causing divergent anticyclonic flow: tend to decrease the surface pressure

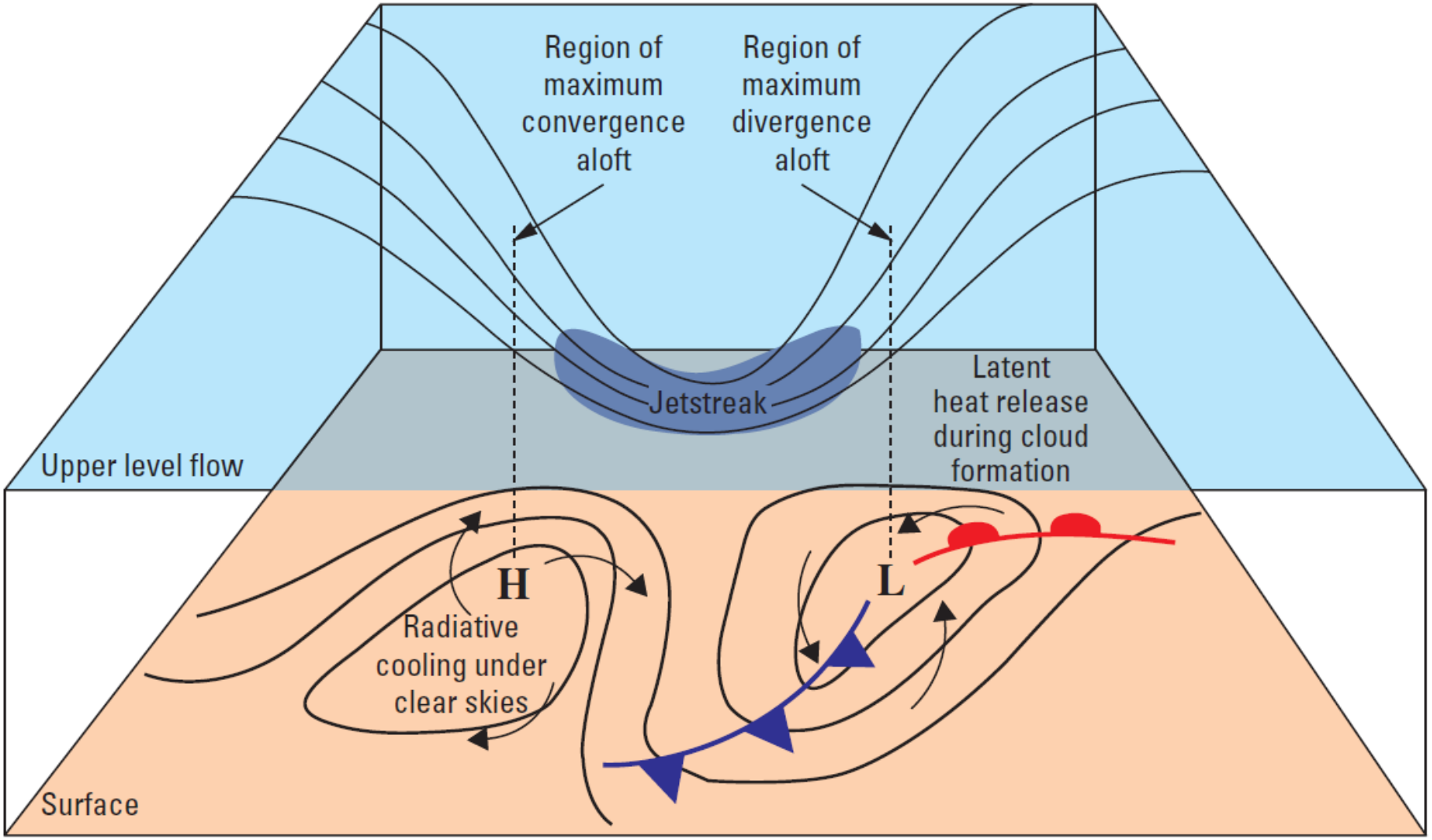
Frictional Inflow in a Real Cyclone



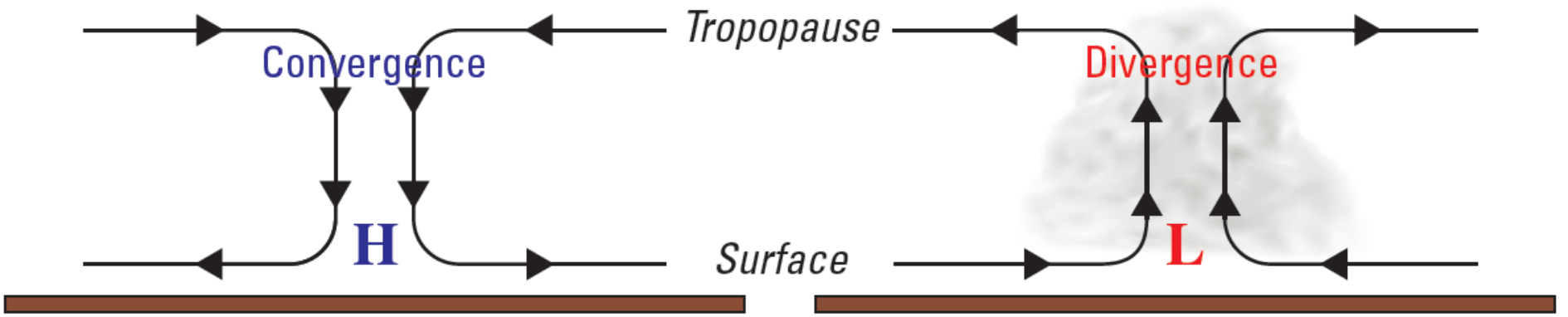
Effects of Heating and Cooling

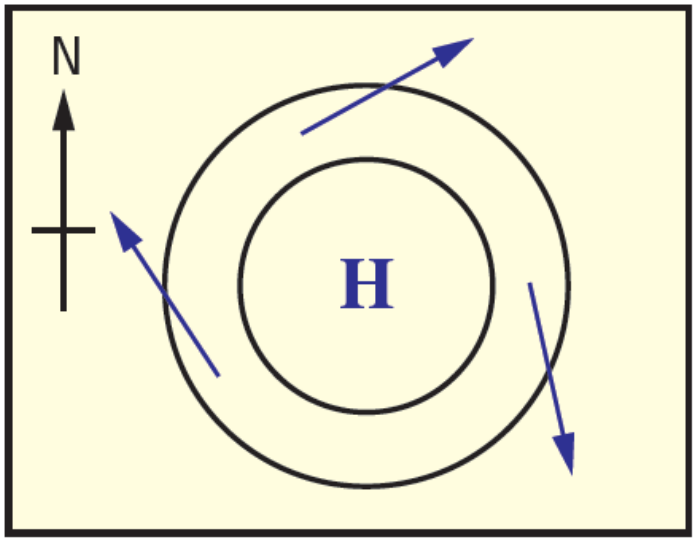


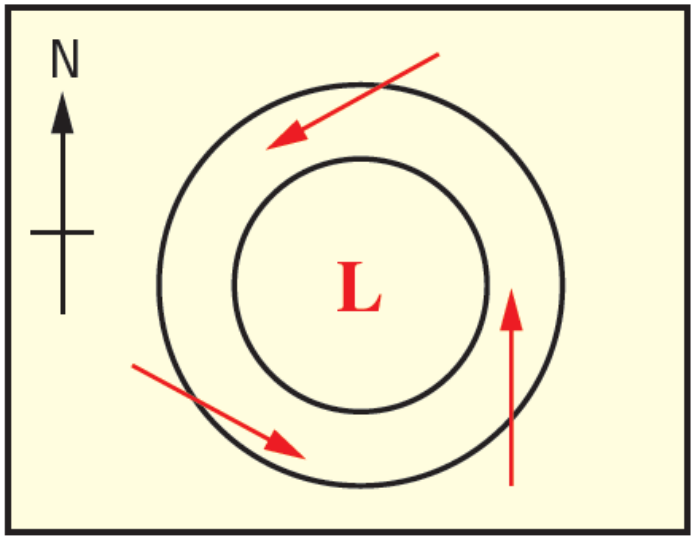
How Does All of This Cause Storms? Combined dynamic and thermodynamic processes!



Role of Updrafts & Downdrafts in Development







Summary

- Divergence and convergence cause vertical motions
- Dines Compensation: Divergence above convergence and convergence above divergence
- Ageostrophic flow in Jetstreaks controls upper divergence and convergence
- Ageostphic flows due to curvature, acceleration, friction…
- Four quadrant model
  - Upper divergence and rising motion in right entrance and left exit
  - Upper convergence and sinking motion in left entrance and right exit
  - Cyclonic curvature produces convergence in entrance and divergence in exit, and conversely for anticyclonic curvature
- Superposition of a jetstreak over a surface frontal zone is the mechanism for formation of frontal cyclones.