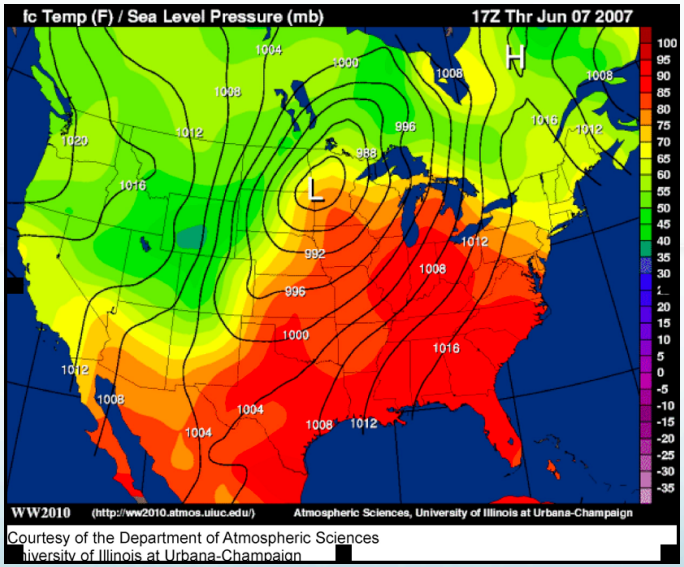
Chapter 8
High and Low Pressure Systems



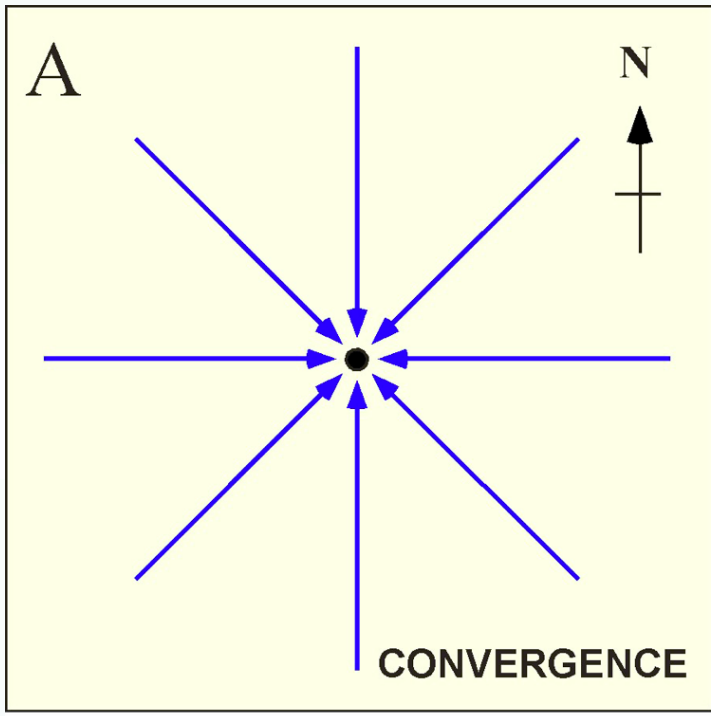
Courtesy of the Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

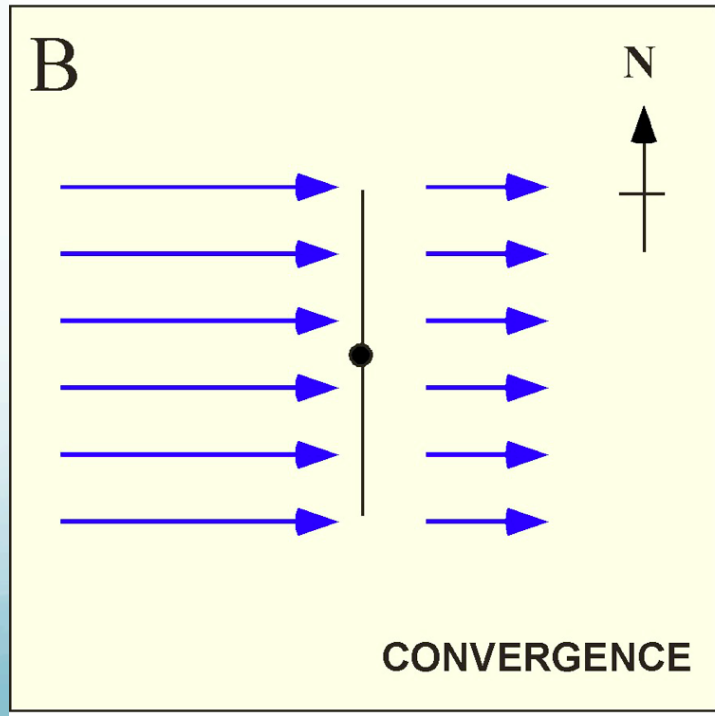
Highs and Lows

- How do high and low pressure systems develop?
- Think about what pressure means for a given column of air…
- For higher pressure to develop, more air must enter the column of air than leaves it
  - Net gain of air molecules to the column of air = higher air pressure in that column
- For lower pressure to develop, more air must leave the column of air than enters it
  - Net loss of air molecules to the column of air = lower air pressure in that column

Convergence

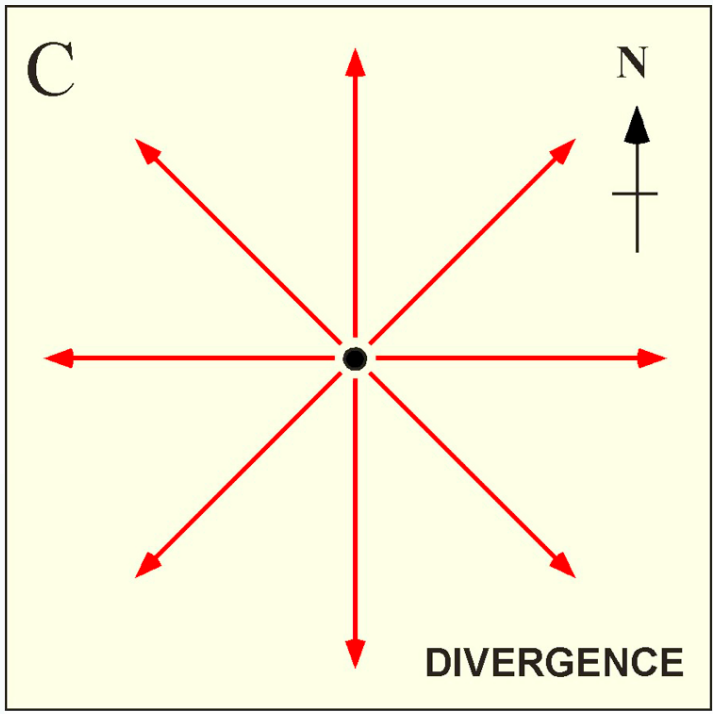
- **Convergence** – a net inflow of air molecules into a region of the atmosphere
- Convergence within an air column is always associated with increasing surface pressure, since the mass per unit area, or weight of the column, will increase with time.

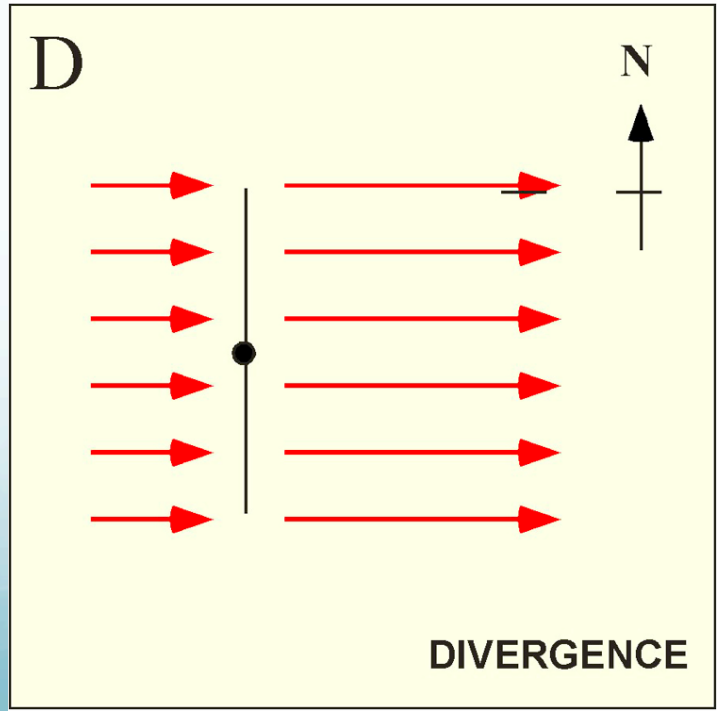




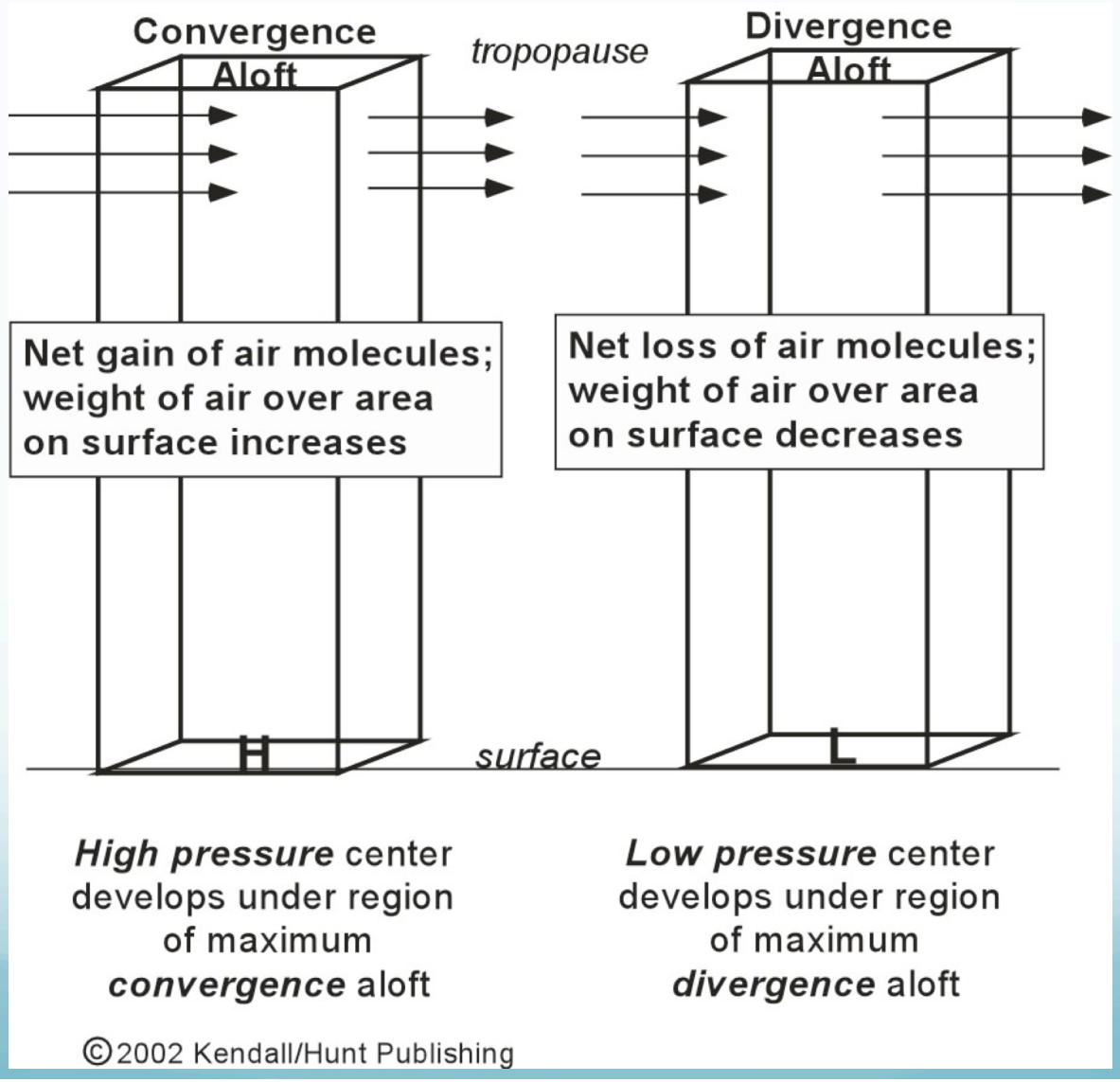
Divergence

- **Divergence** – a net outflow of air molecules from a region of the atmosphere (the opposite of convergence)
- Divergence within an air column is always associated with decreasing surface pressure, since the mass per unit area, or weight of the column, will decrease with time.



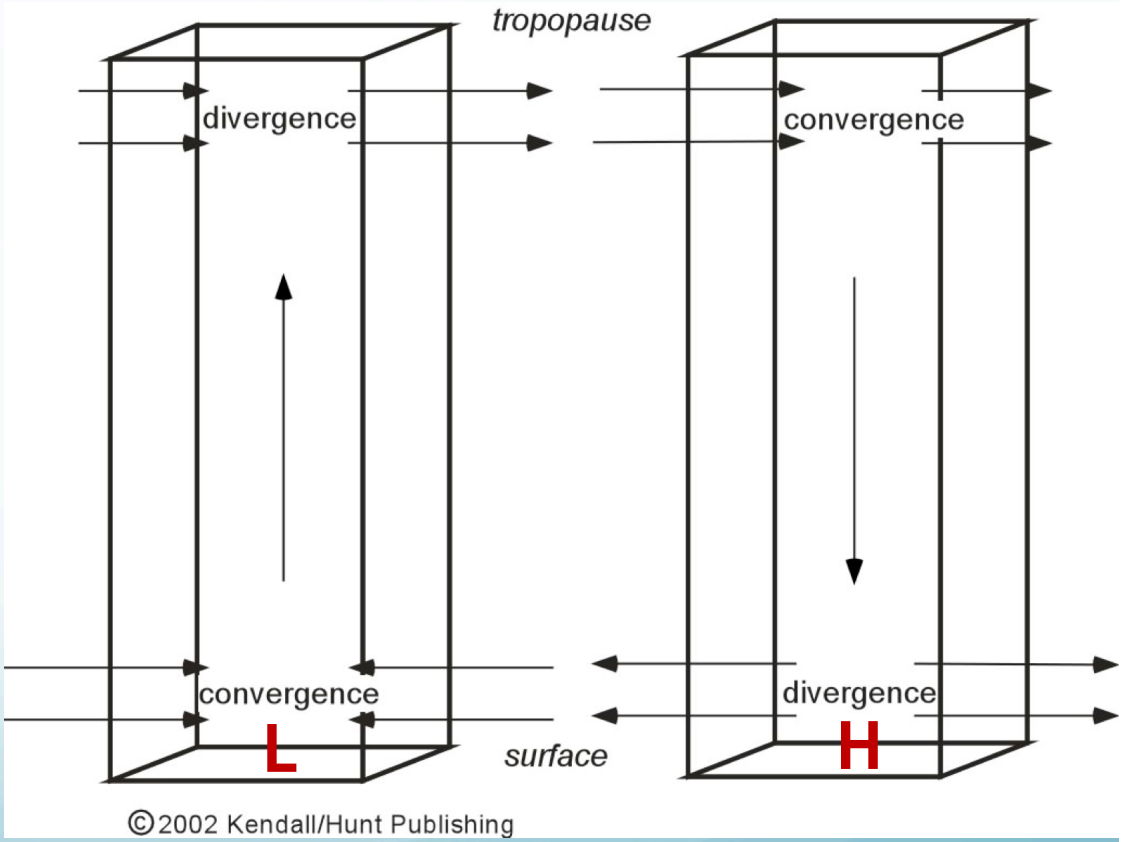


Convergence or divergence *aloft*



Convergence, divergence, and vertical motion

- Why does air rise in the column with divergence aloft (on left)? And why does air sink in the column with convergence aloft (on right)?
  - To maintain hydrostatic balance, and fill in void left by divergence



What kind of weather would we associate with each scenario?

Recall: Air parcel vertical motion

- What happens to an air parcel as it rises in the atmosphere?
  - Temperature — Decreases adiabatically
  - Saturation vapor pressure — Decreases with decreasing temperature
  - Relative humidity — Increases with decreasing saturation vapor pressure
- What happens to an air parcel as it descends in the atmosphere?
  - Temperature — Increases adiabatically
  - Saturation vapor pressure — Increases with increasing temperature
  - Relative humidity — Decreases with increasing saturation vapor pressure

Typically, rising motion is associated with clouds and precipitation while sinking motion is associated with clear skies.

Clicker Question

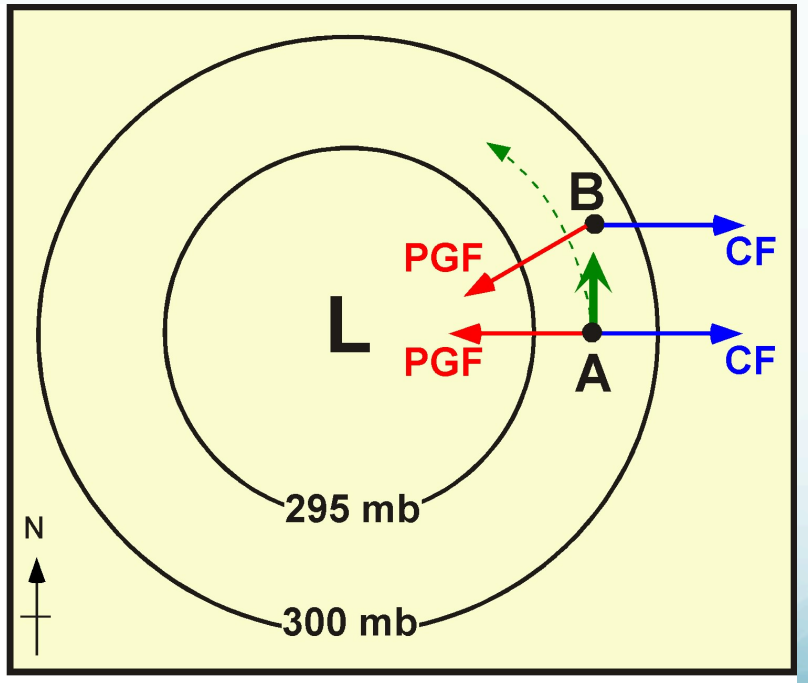
- A surface low pressure system is typically associated with _____ weather because of the generally _____ air motion associated with it.
  - A. Clear and sunny, sinking
  - B. Cloudy and rainy, sinking
  - C. Clear and sunny, rising
  - D. Cloud and rainy, rising

Clicker Question

- _____ aloft yields higher pressure in the air column (and thus at the surface), and then yields _____ at the surface due to the sinking motion within the column.
  A. Divergence, convergence
  B. Convergence, divergence
  C. Divergence, divergence
  D. Convergence, convergence

Curved Flow

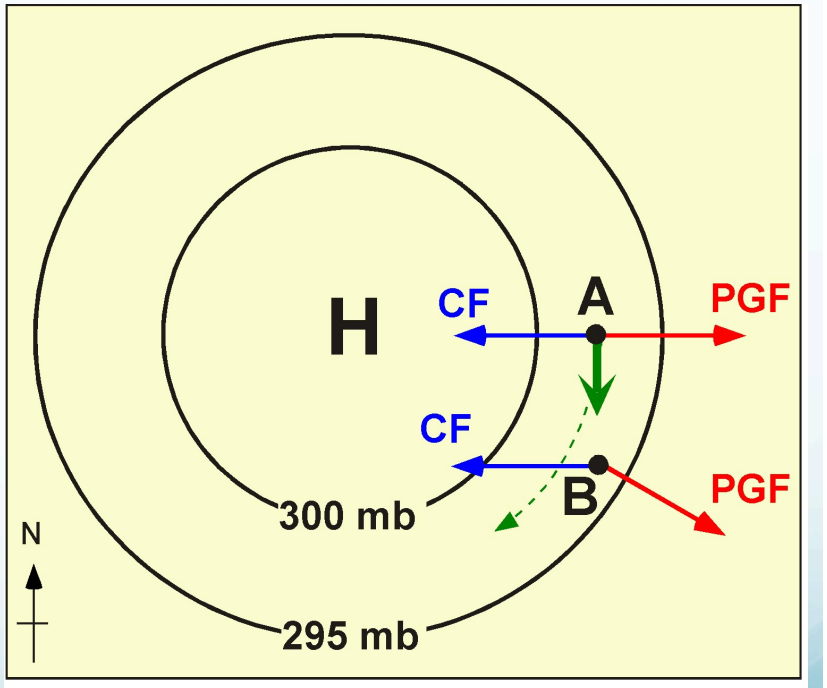
- Here we examine curved flow around a circular low pressure center above the boundary layer
- At point A the wind is initially in geostrophic balance and the PGF and CF are equal.
- At point B is the magnitude of the PGF and the CF equal?
- What does this imply about the wind speed compared to the geostrophic wind speed at point B?



In flow around a circular low pressure center (or any cyclonic flow), above the boundary layer, the true flow will be slower than the geostrophic value.

Curved Flow around a High

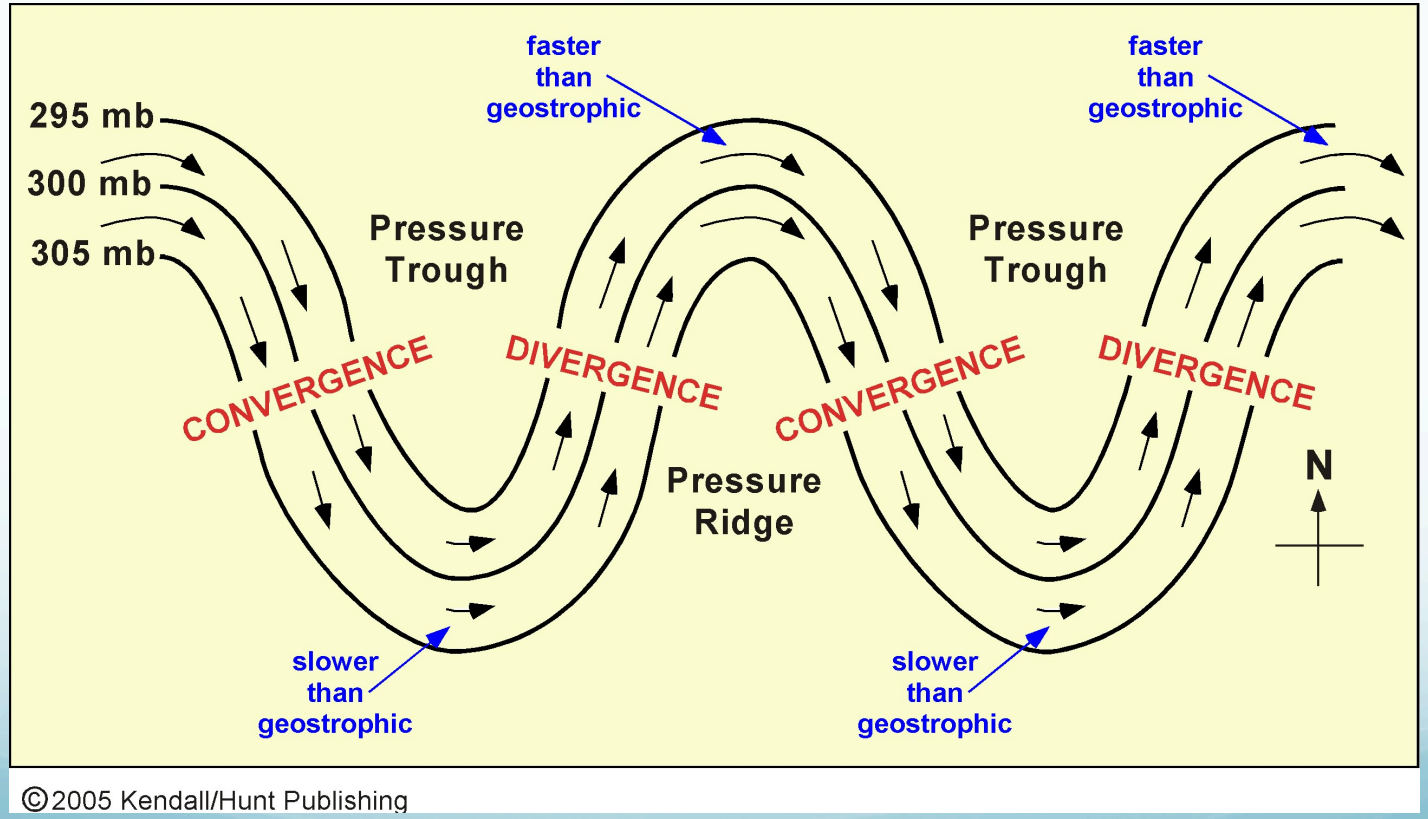
- Flow around a circular high pressure center above the boundary layer
- At point A the wind is initially in geostrophic balance and the PGF and CF are equal.
- At point B is the magnitude of the PGF and the CF equal?
- What does this imply about the wind speed compared to the geostrophic wind speed at point B?



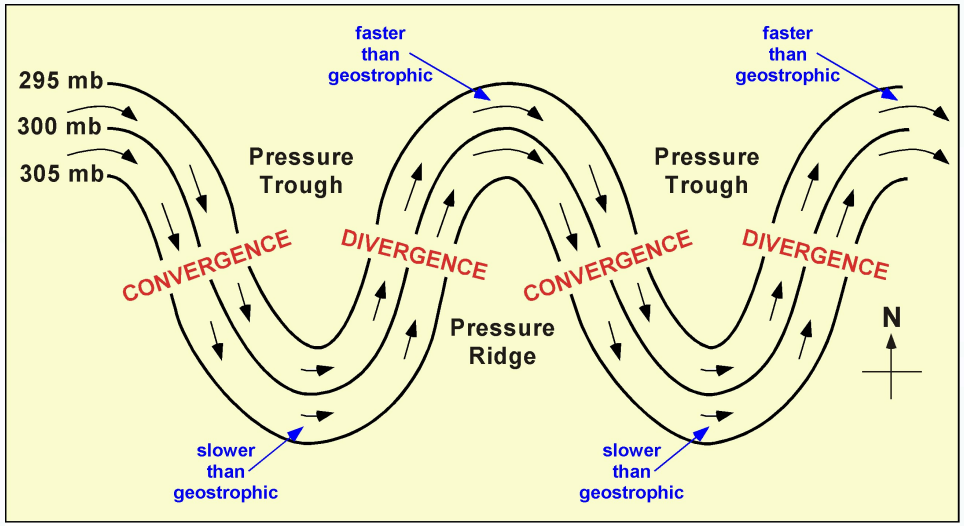
In flow around a circular high pressure center (or any anticyclonic flow), above the boundary layer, the true flow will be faster than the geostrophic value.

Flow around troughs and ridges

- Flow around a trough is cyclonic flow and flow around a ridge is anticyclonic flow.



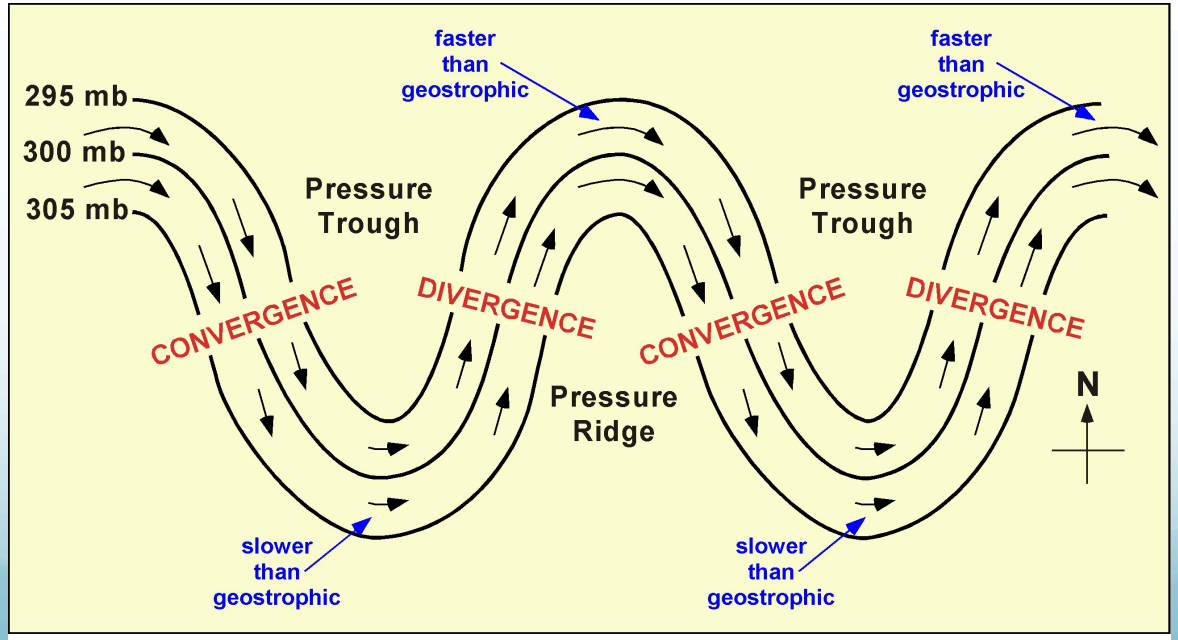
Sample winds and isobars in the upper troposphere (~9.5 km altitude)



- How does the wind speed change as an air parcel moves from the base of the trough to the crest of the ridge?
  - Speeds up
  - Does this change in wind speed cause convergence or divergence?
- How does the wind speed change as an air parcel moves from the crest of the ridge to the base of the trough?
  - Slows down
  - Does this change in wind speed cause convergence or divergence?
- Where would you expect the surface pressure to decrease based on the figure above?
  - Below upper level divergence, so ahead of the crest of the trough

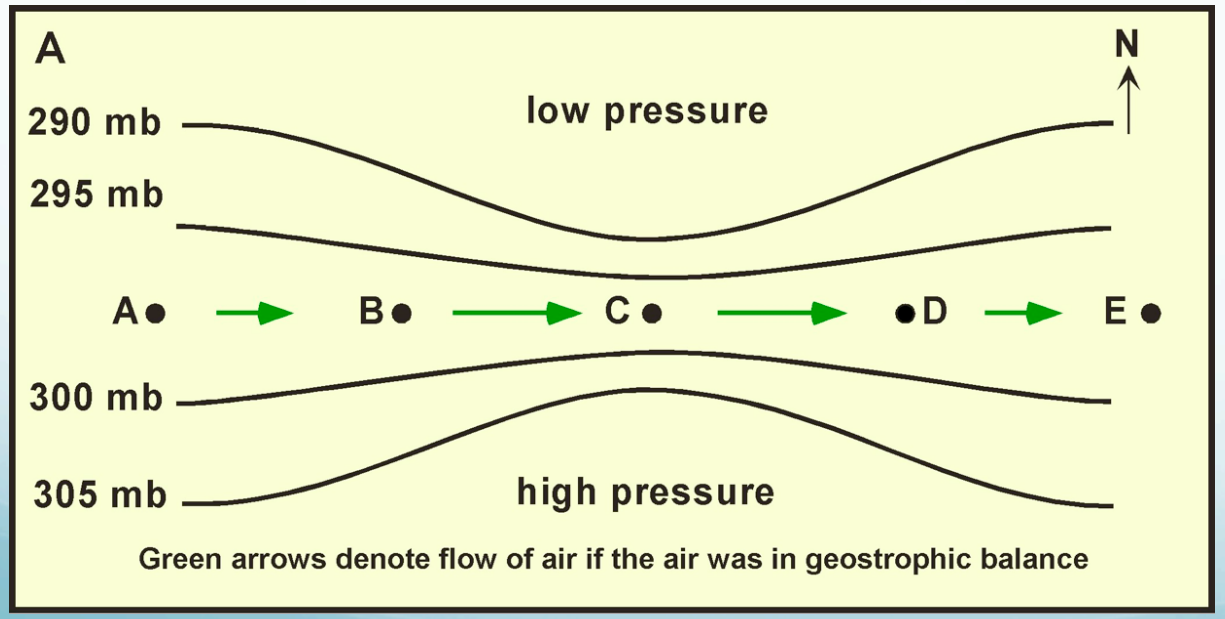
Summary

Movement from trough to ridge:	Movement from ridge to trough:
Air speeds up Divergence Rising motion Decreasing surface pressure	Air slows down Convergence Sinking motion Increasing surface pressure



Recall: Jetstreaks

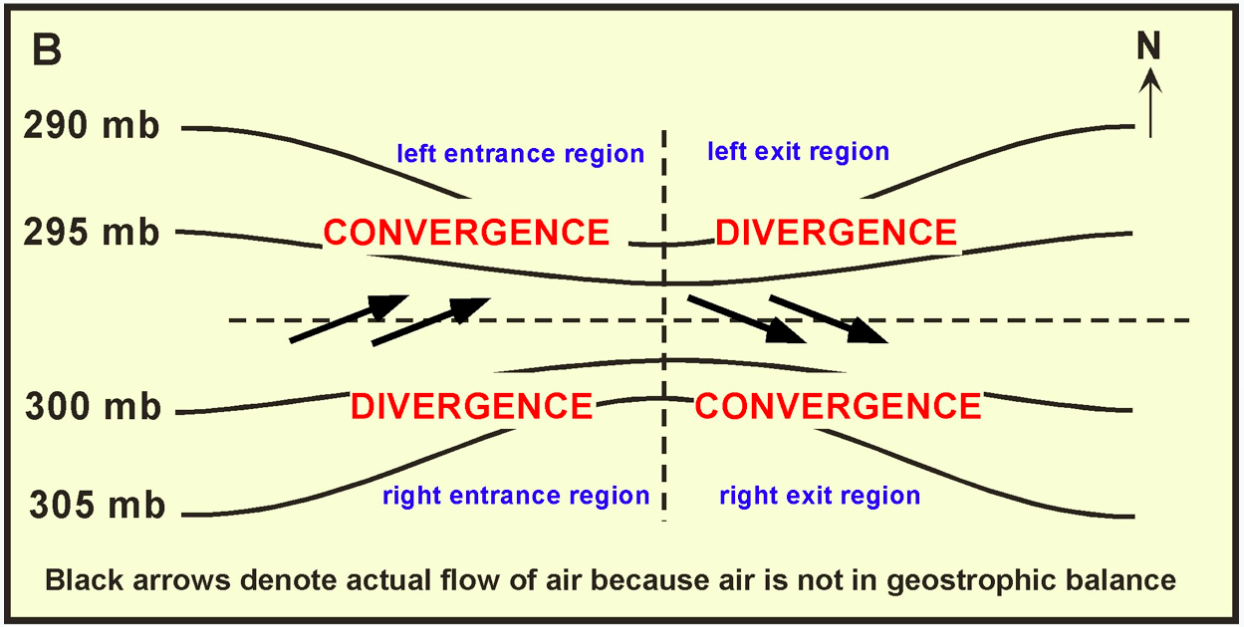
- **Jetstreak** – regions of exceptionally strong winds in the jetstream
  - Jetstreaks occur where the isobars (or height contours) are very closely spaced.



How does the PGF and CF change between points A and B?

How does the PGF and CF change between points C and D?

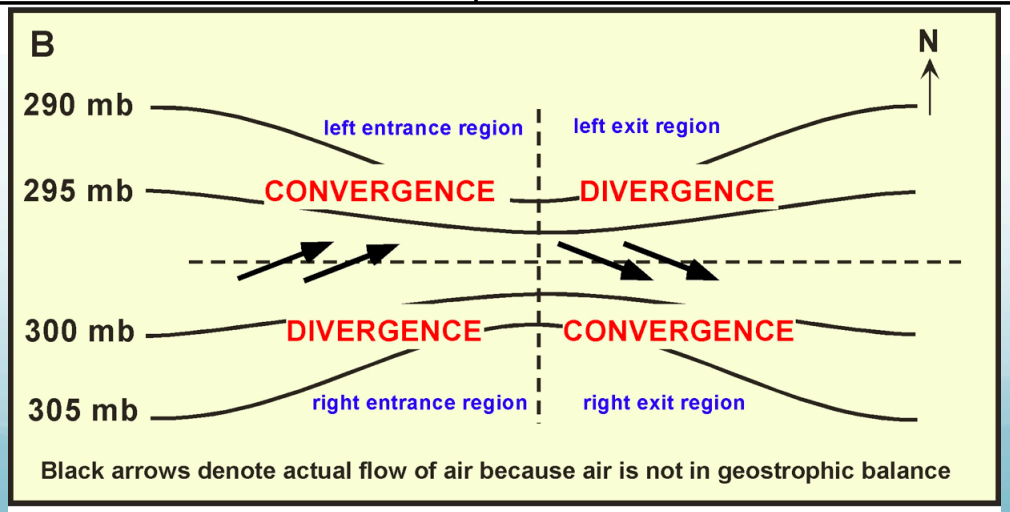
Jetstreak quadrants



- Air parcels are displaced northward in the entrance region of the jetstreak and southward in the exit region of the jetstreak.
  - Due to wind speed change without time for Coriolis to balance
- Where does divergence and convergence occur in a jetstreak?
- Where would you expect the surface pressure to decrease based on the figure above?

Summary

Left entrance region: Convergence Sinking motion Increasing surface pressure	**Left exit region:** Divergence Rising motion Decreasing surface pressure
Right entrance region: Divergence Rising motion Decreasing surface pressure	**Right exit region:** Convergence Sinking motion Increasing surface pressure



Clicker Question

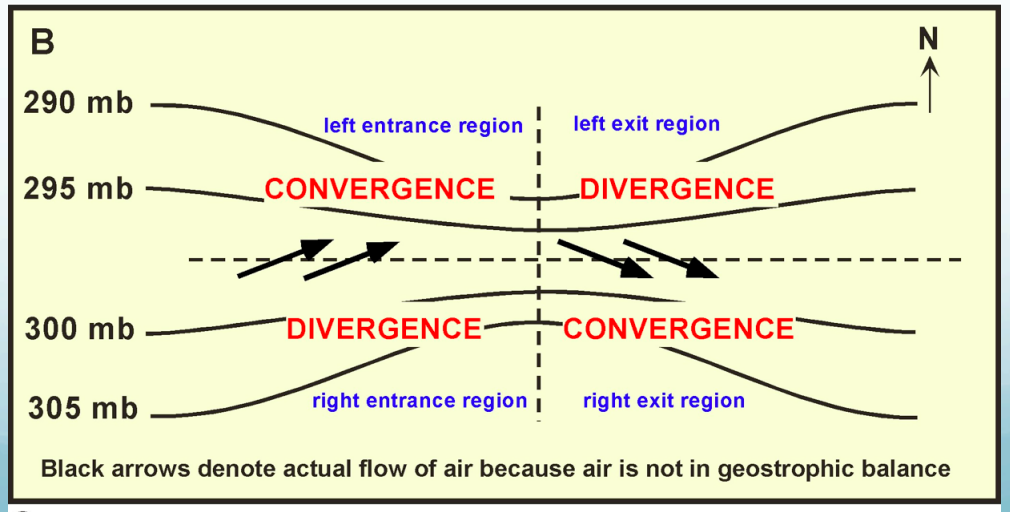
- The wind speed around a low pressure center (or a trough) will be _____ the geostrophic wind speed.
  A. Less than
  B. Greater than
  C. Equal to

Clicker Question

- The surface pressure will typically _____ ahead of an approaching upper level trough.
  A. Increase
  B. Decrease
  C. Not change

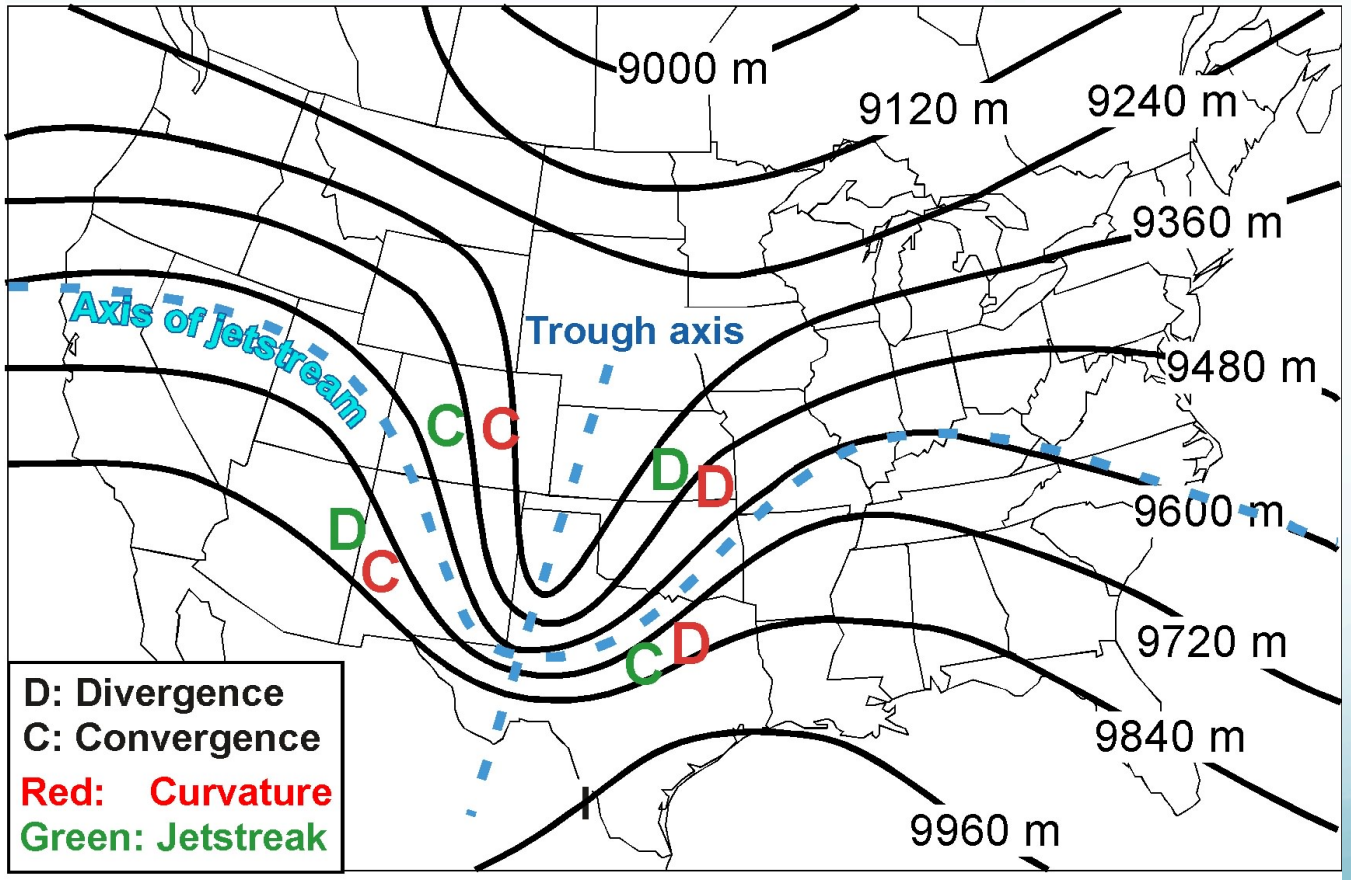
Clicker Question

- The surface pressure will typically increase below the _____ quadrant of a jetstreak.
  - A. Right entrance, right exit
  - B. Left entrance, left exit
  - C. Right entrance, left exit
  - D. Left entrance, right exit



Curvature and Jetstreaks

- What happens when a jetstream and curved flow occur in the same location?



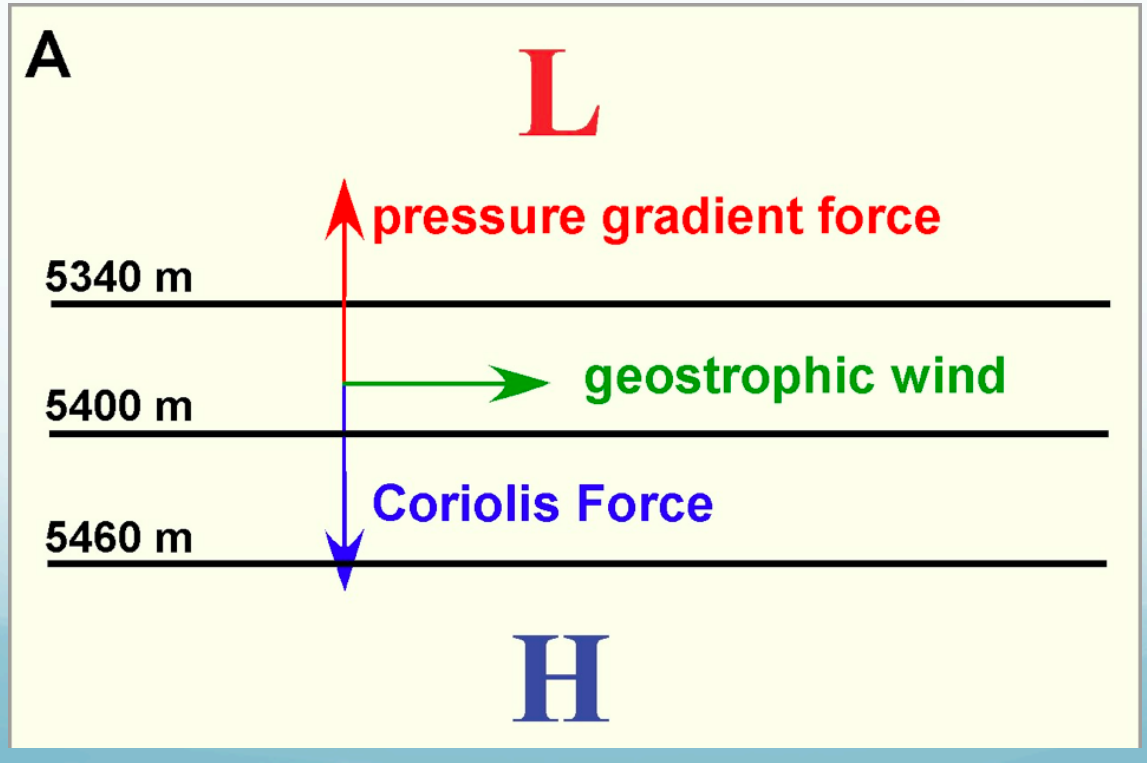
Where does the convergence associated with the jetstreak and the convergence associated with the curved flow coincide?

Where does the divergence associated with the jetstreak and the divergence associated with the curved flow coincide?

Where would you expect the surface pressure to decrease most rapidly?

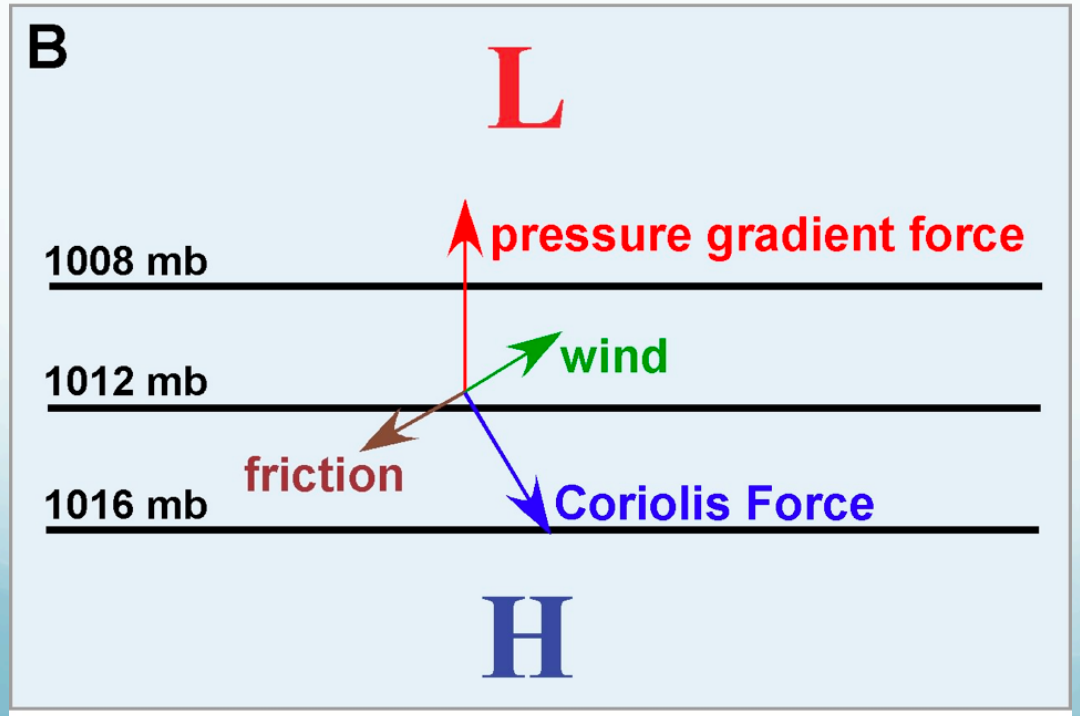
Recall: Geostrophic Balance

- At upper levels the flow is nearly geostrophic.
  - What forces do we need to consider for geostrophic flow?
  - Horizontal pressure gradient force and Coriolis



The Friction Layer

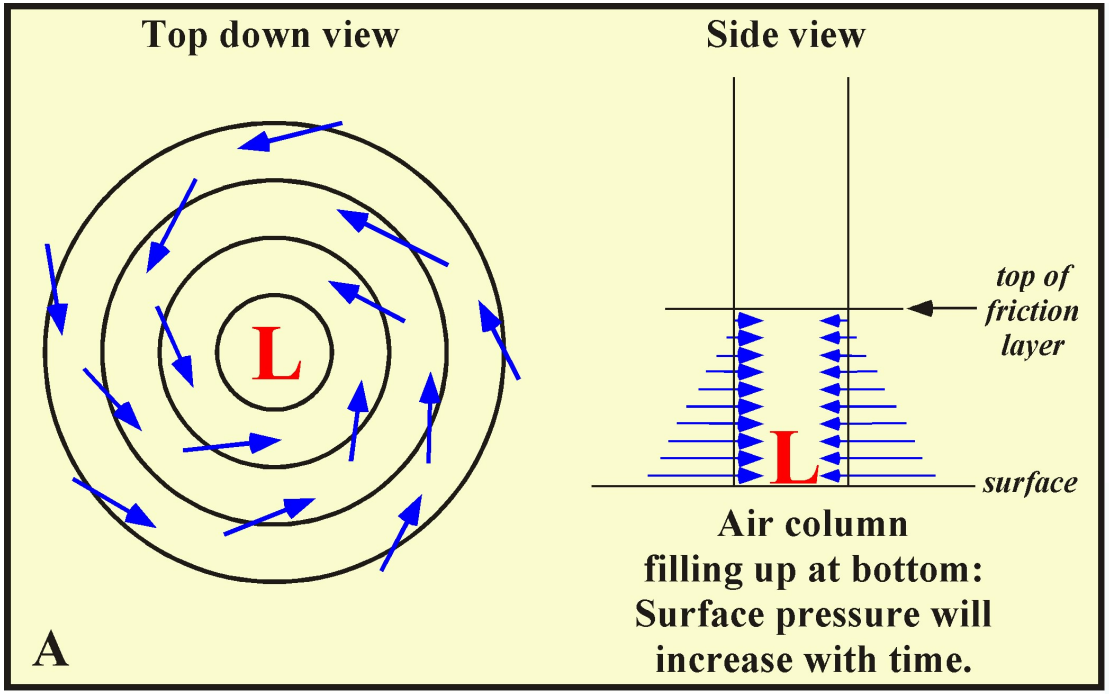
- Near the surface friction becomes important.
  - What forces do we need to consider for horizontal flow in the friction layer?
  - Horizontal pressure gradient, Coriolis, and frictional forces

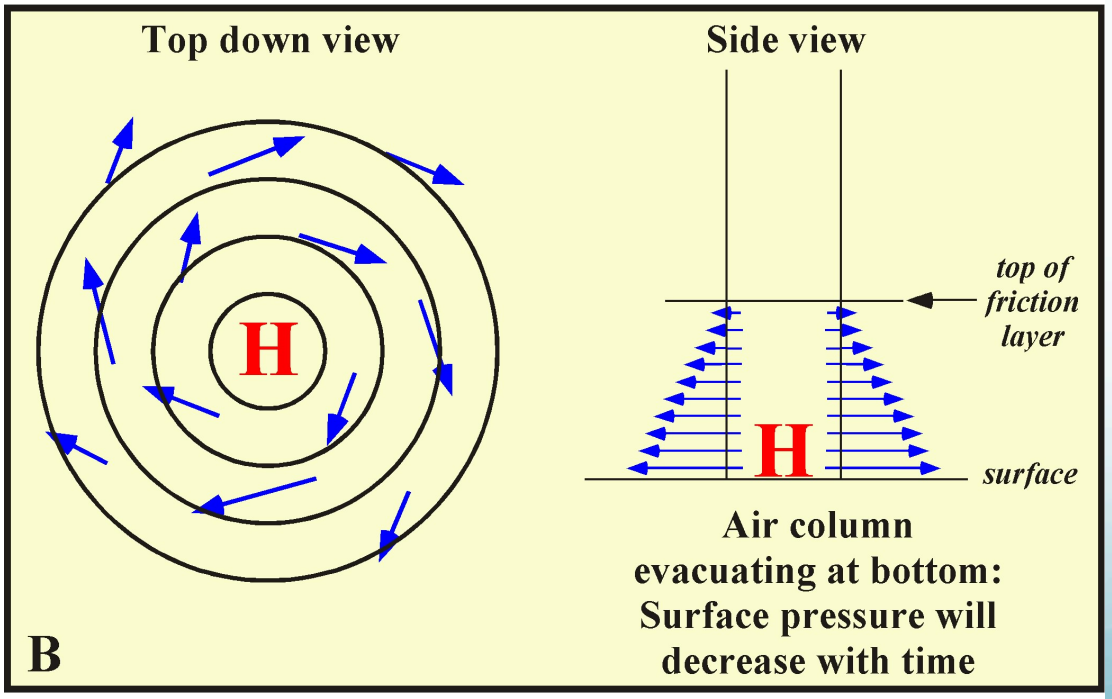


Friction always decreases the wind speed

This causes the PGF to be larger than the CF.

Friction always acts to turn the wind such that the flow has a component from higher pressure to lower pressure.

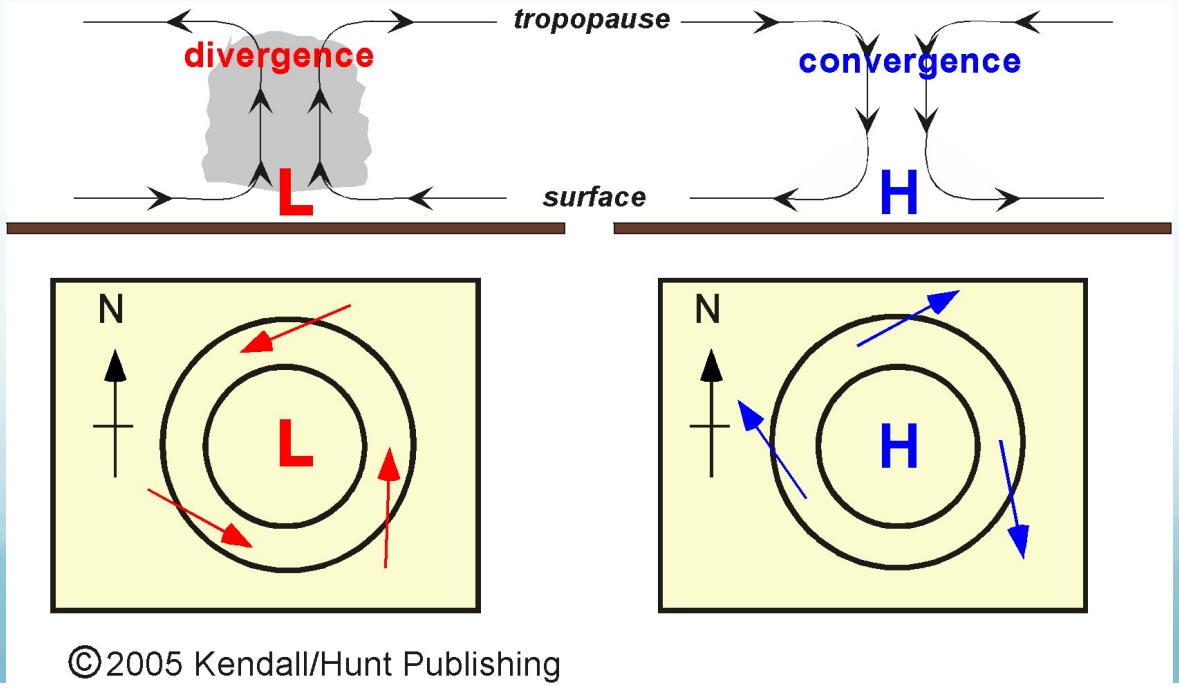




- The larger the effect of friction the more the wind will turn to flow from higher pressure to lower pressure.
- Friction decreases as you move up and away from the surface.

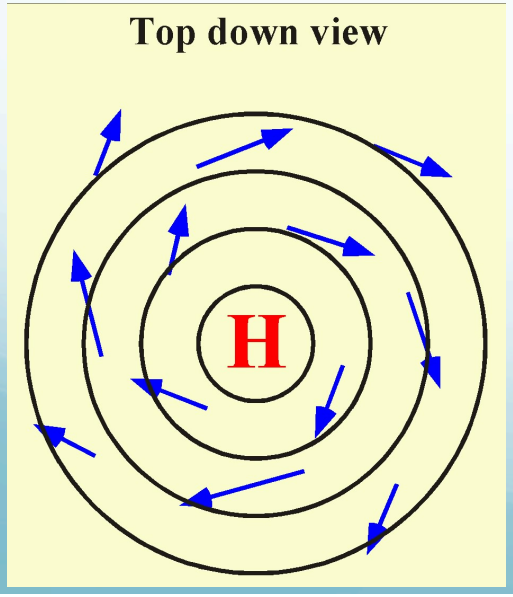
Three-dimensional flow

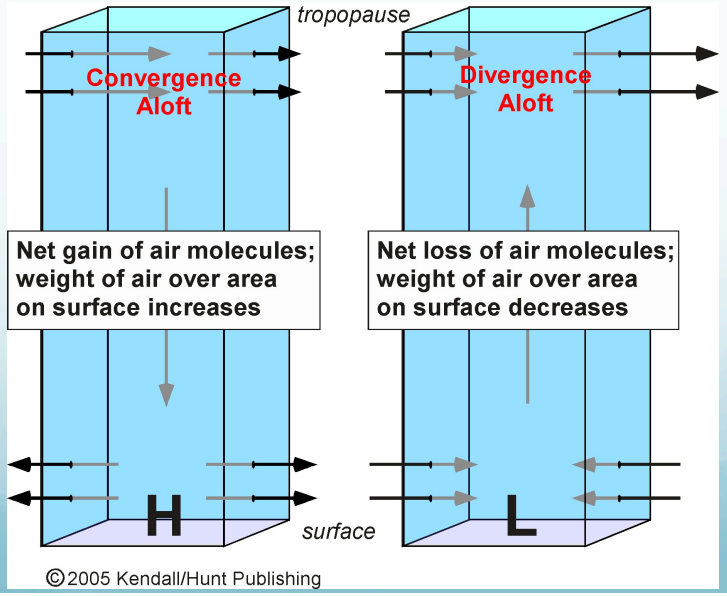
- Air flows in towards a low pressure center at the surface and rises. This rising air is associated with clouds and precipitation. The air then diverges at upper levels of the troposphere.
- Air flows outward from a high pressure center at the surface, leading to sinking motion above the high pressure center. This sinking motion is typically associated with clear skies. At upper levels air often converges above a high pressure center.

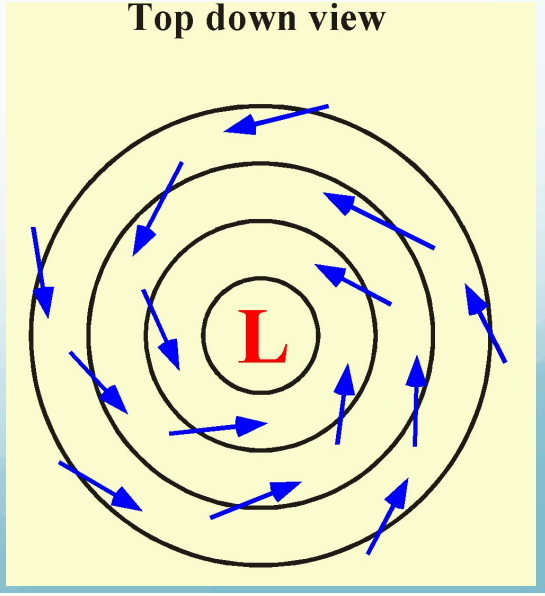


Summary

High pressure center:	Low pressure center:
Wind spirals out from high pressure center	Wind spirals in towards low pressure center
Divergence	Convergence
Sinking motion (clear skies)	Rising motion (cloudy skies)
Decreasing surface pressure	Increasing surface pressure
Weakening high pressure	Weakening low pressure

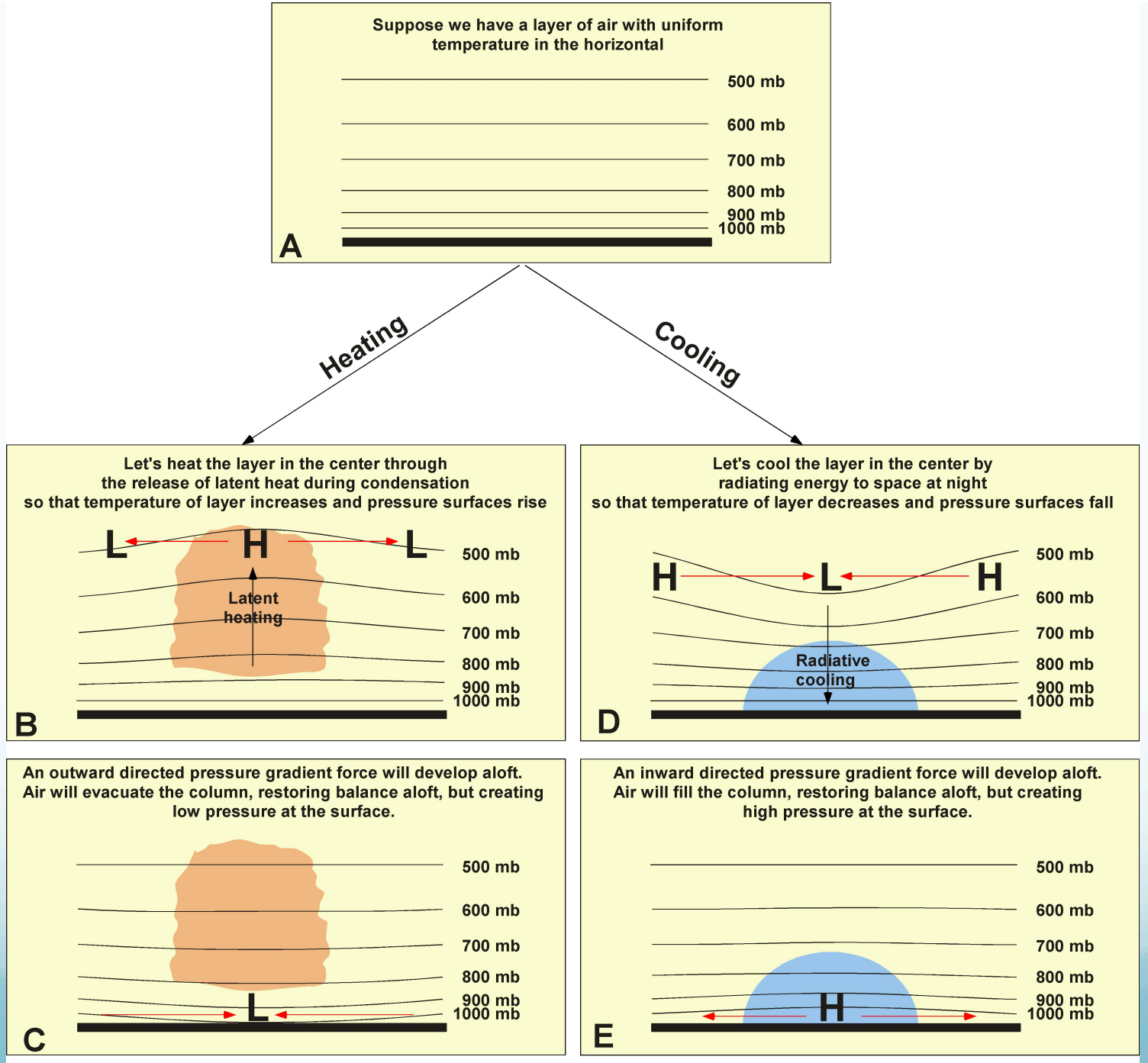






Effects of heating and cooling

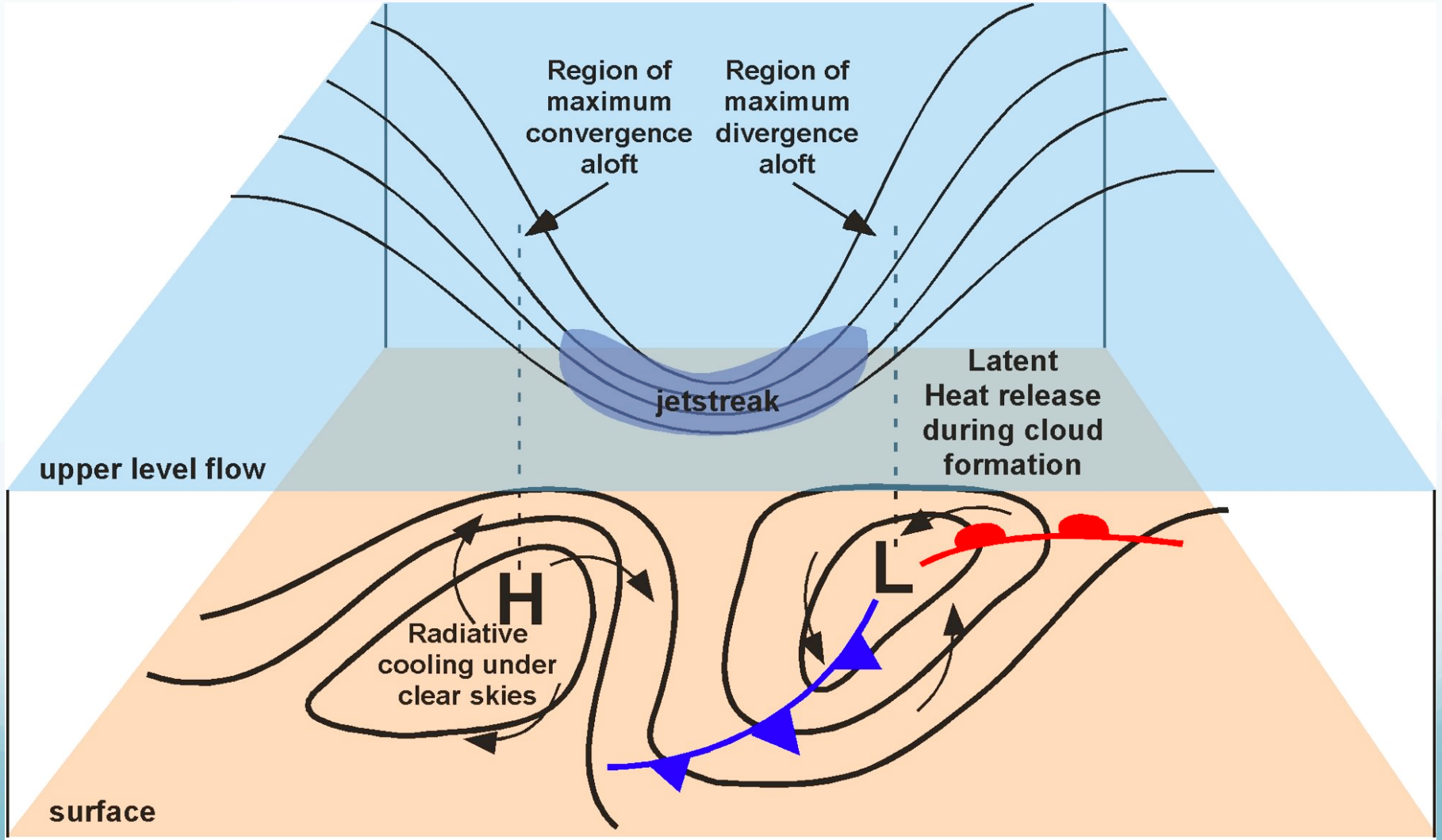
- How does heating or cooling of the atmosphere change the surface pressure?



Effects of heating and cooling

- How does heating or cooling of the atmosphere change the surface pressure?
  - **Warming of the atmosphere will lead to the formation of low pressure at the surface.**
  - **Cooling of the atmosphere will lead to the formation of high pressure at the surface.**

Development of high and low pressure centers



Synthesis of Chapter

- Dynamic processes (curvature, jetstreaks, and friction) and thermodynamic processes (heating and cooling) cause a redistribution of mass in the atmosphere and create high and low pressure centers.
- We need to consider all of these processes (curvature, jet streaks, friction, heating, and cooling) to understand why high and low pressure centers form in a particular location.
- **Low pressure at the surface usually forms initially due to upper level features such as troughs and jetstreaks**
- **High pressure at the surface usually forms due to cooling of the air**

Clicker Question

- True or false: Sinking motion in the atmosphere is typically associated with clear skies.
  A. True
  B. False

Clicker Question

- For anticyclonic flow above the boundary layer the true flow will be _____ the geostrophic value.
  A. Greater than
  B. Less than
  C. Equal to

Clicker Question

- In the friction layer you would expect the winds to _____ a low pressure center leading to _____.
  A. spiral in towards, convergence
  B. spiral in towards, divergence
  C. spiral out from, convergence
  D. spiral out from, divergence

Clicker Question

- Heating a column of air will lead to _____ in the surface pressure.
  A. an increase
  B. a decrease
  C. no change