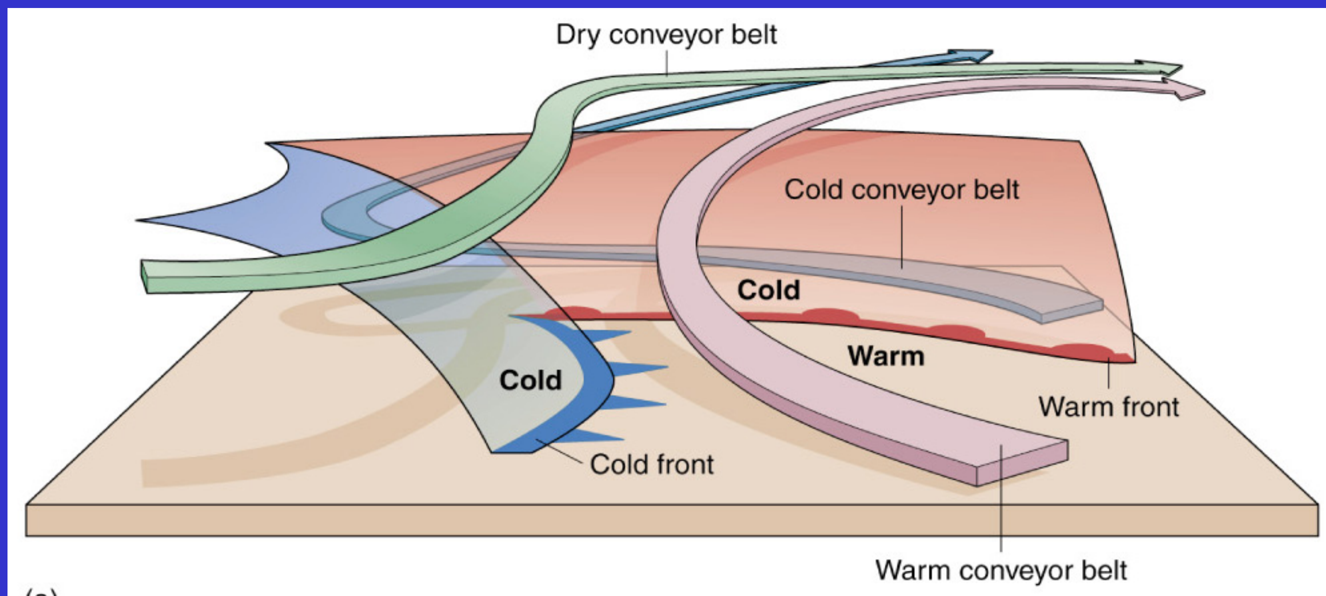
Chapter 10: Mid-latitude Cyclones



- ❑ Life Cycle of Cyclone
- ❑ Cyclone Structures
- ❑ Steering of Cyclone

Mid-Latitude Cyclones

- Mid-latitude cyclones form along a boundary separating polar air from warmer air to the south.

- These cyclones are large-scale systems that typically travels eastward over greart distance and bring precipitations over wide areas.

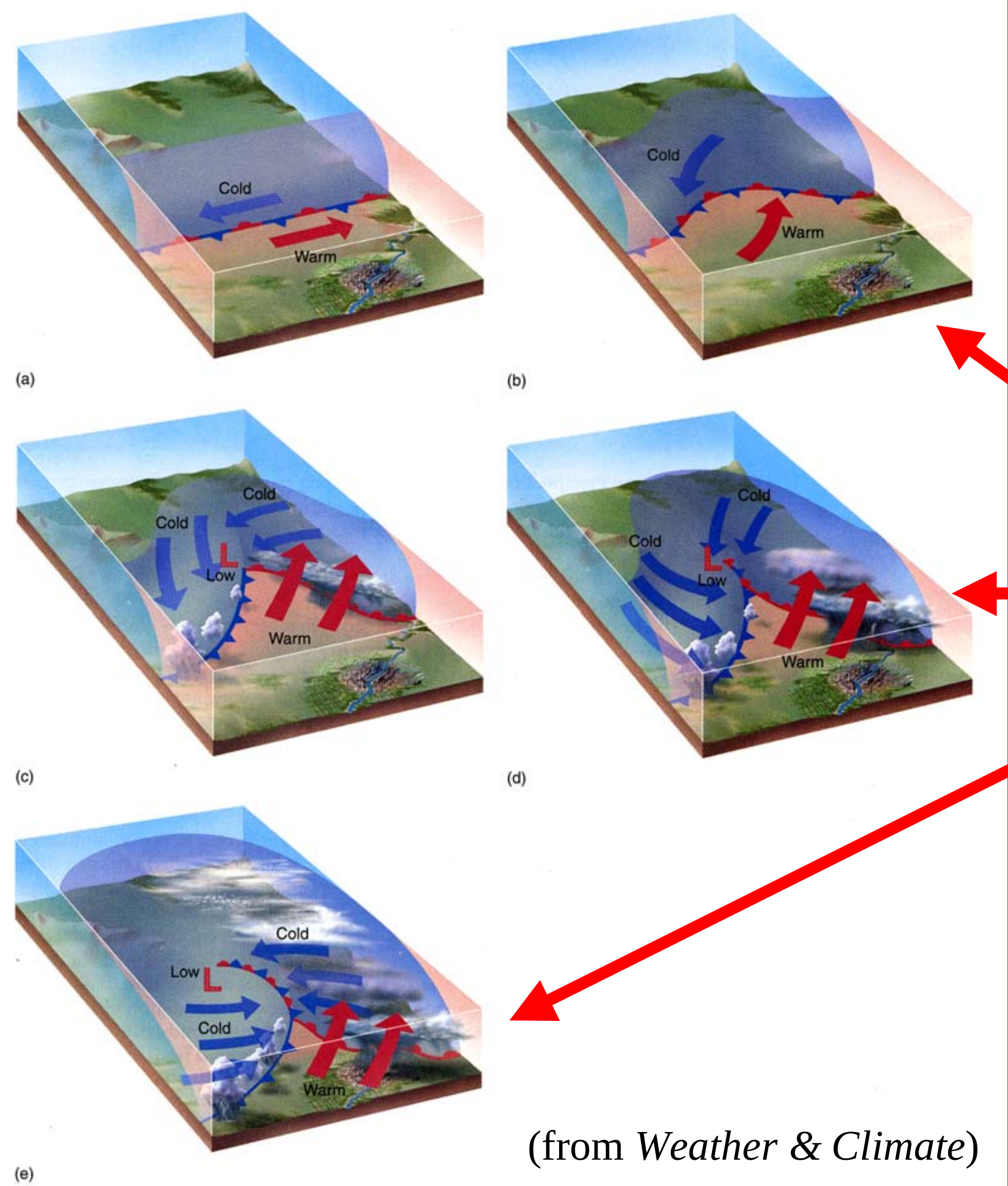
- Lasting a week or more.

Polar Front Theory

Vilhelm Bjerknes (1862-1951)

- ***Bjerknes,*** the founder of the Bergen school of meteorology, developed polar front theory during WWI to describe the formation, growth, and dissipation of mid-latitude cyclones.

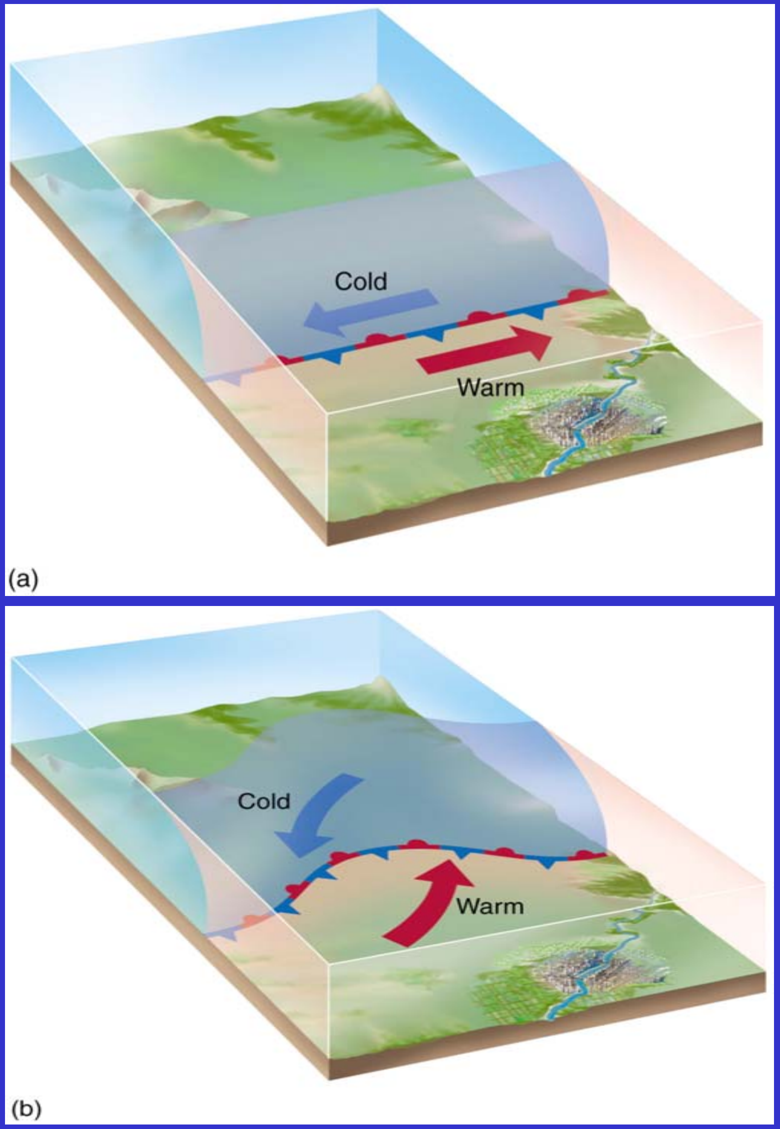
Life Cycle of Mid-Latitude Cyclone



(from *Weather & Climate*)

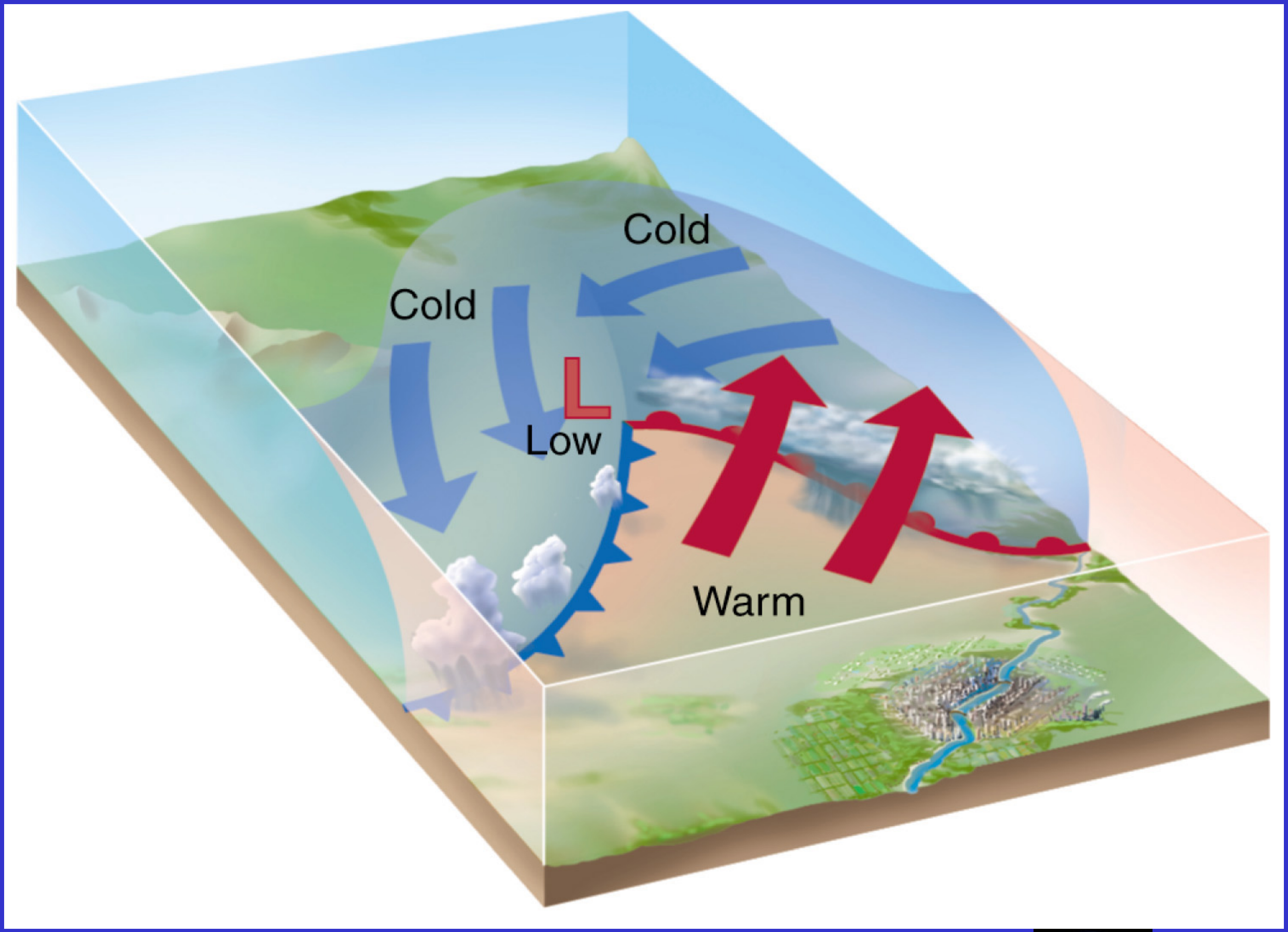
- ❑ Cyclogenesis
- ❑ Mature Cyclone
- ❑ Occlusion

Cyclogenesis

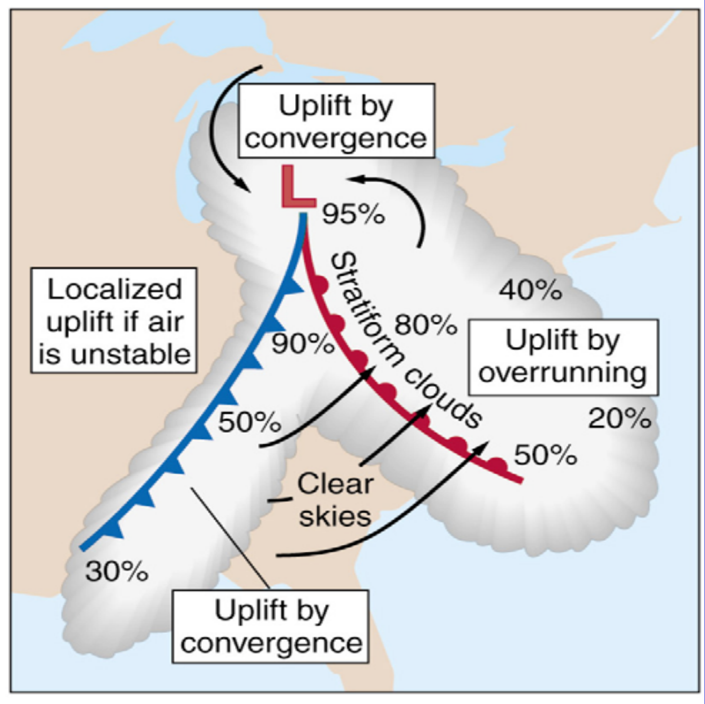


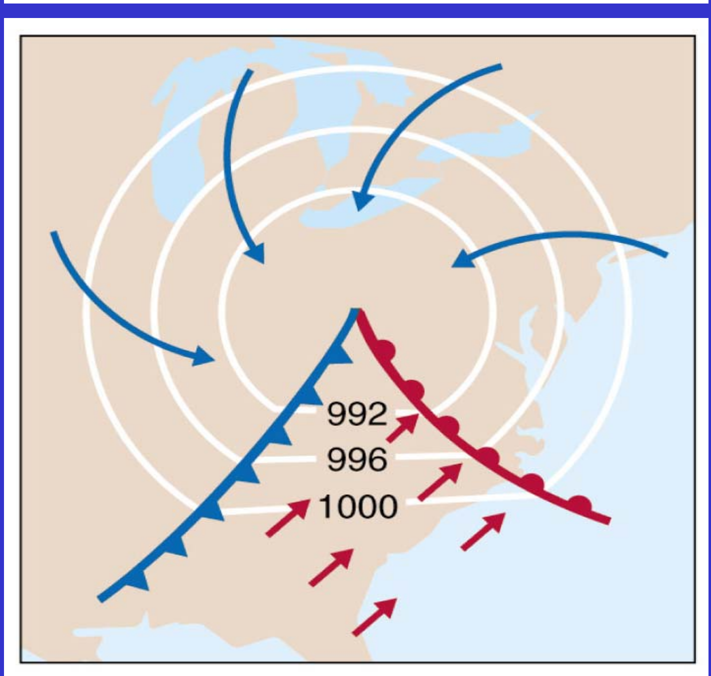
- ***Cyclogenesis*** typically begins along the polar front but may initiate elsewhere, such as in the lee of mountains.
- Minor perturbations occur along the boundary separating colder polar easterlies from warmer westerlies.
- A low pressure area forms and due to the counterclockwise flow (N.H.) colder air migrates equatorward behind a developing cold front.
- Warmer air moves poleward along a developing warm front (east of the system).
- Clouds and precipitation occur in association with converging winds of the low pressure center and along the developing fronts.

Mature Cyclone



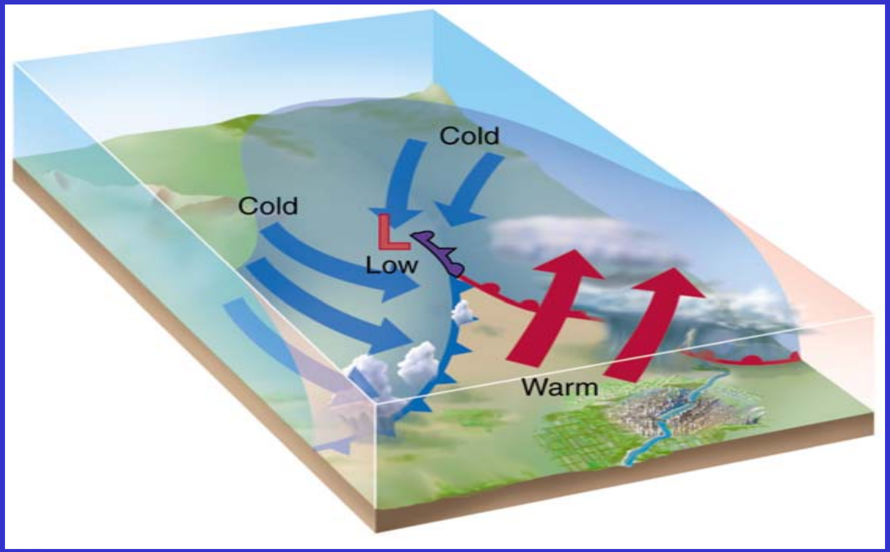
Mature Cyclones

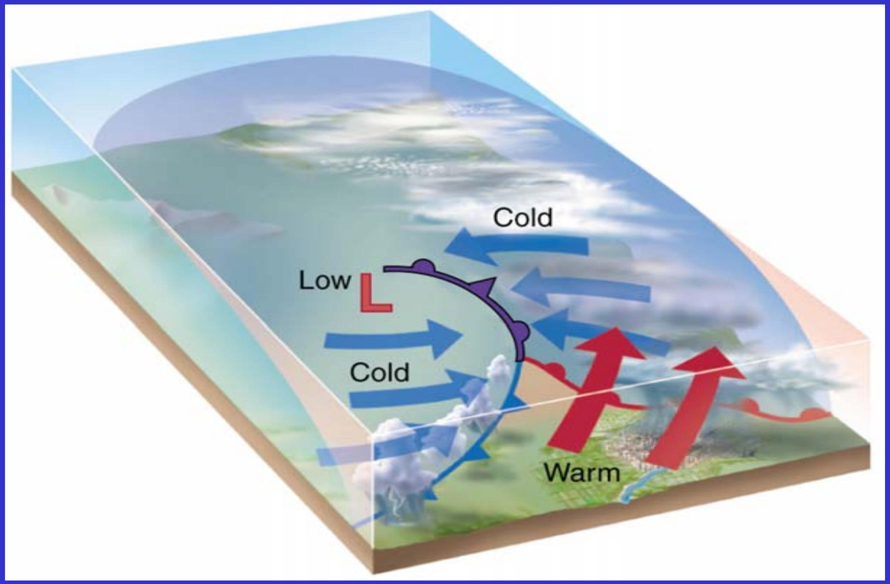




- Well-developed fronts circulating about a deep low pressure center characterize a mature mid-latitude cyclone.
- Heavy precipitation stems from cumulus development in association with the cold front.
- Lighter precipitation is associated with stratus clouds of the warm front.
- Isobars close the low and are typically kinked in relation to the fronts due to steep temperature gradients.

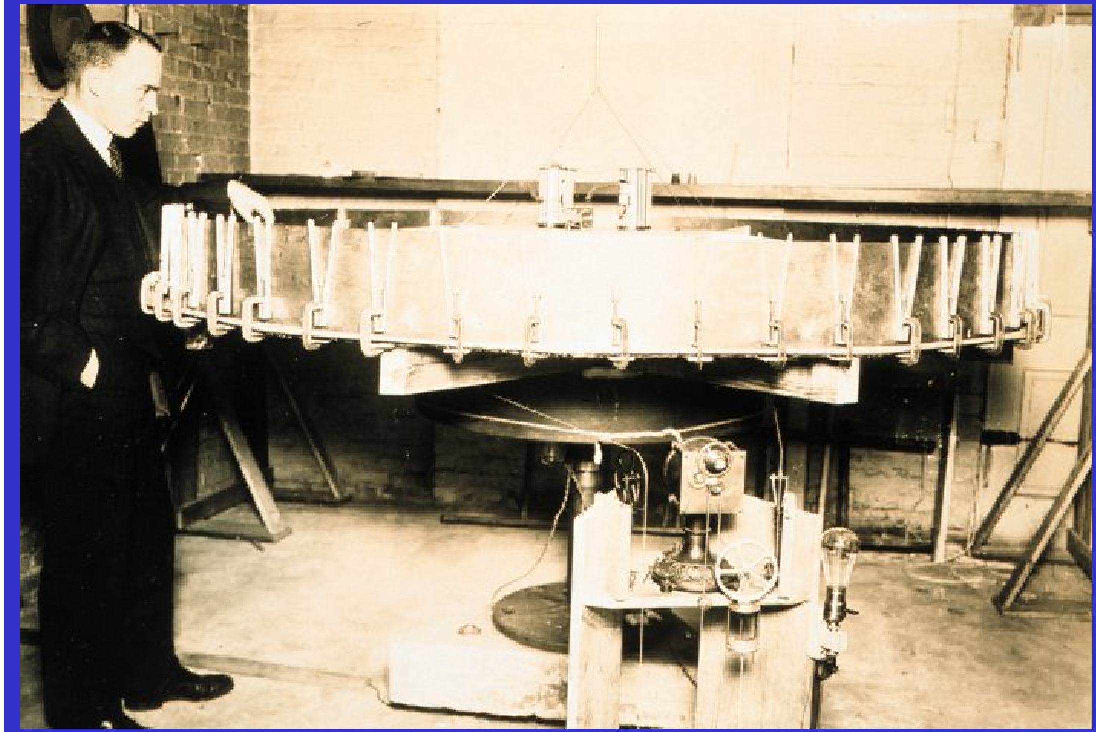
Occlusion





- ❑ When the cold front joins the warm front, closing off the warm sector, surface temperature differences are minimized.
- ❑ The system is in occlusion, the end of the system's life cycle.

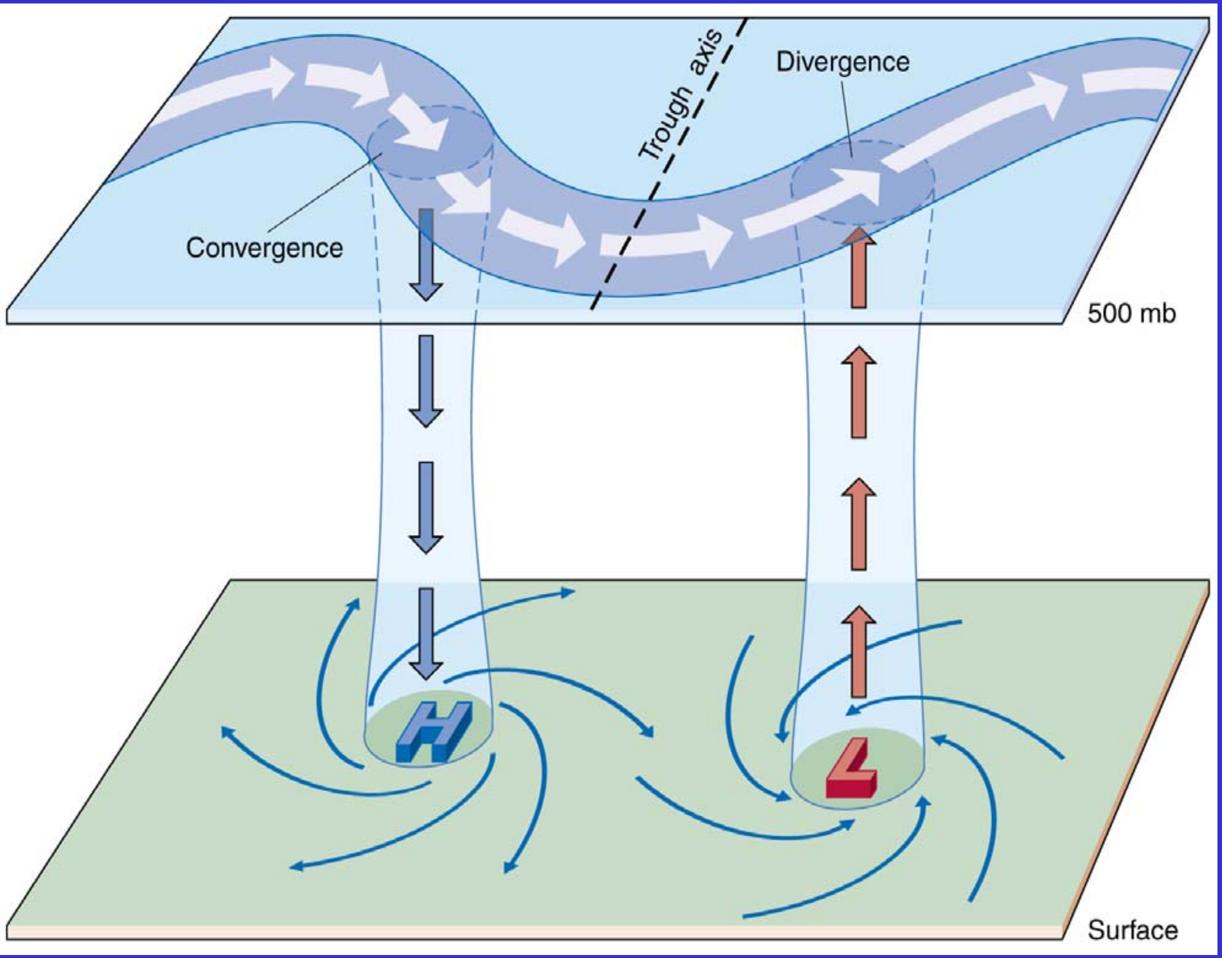
New Understanding of Cyclone after WWII



Carl Gustav Rossby (1898-1957)

- Carl Rossby athematically expressed relationships between mid-latitude cyclones and the upper air during WWII.
- Mid-latitude cyclones are a large-scale waves (now called Rossby waves) that grow from the “baroclinic” instabiloity associated with the north-south temperature differences in middle latitudes.

Rossby Wave and Surface Cyclone/Anticyclone



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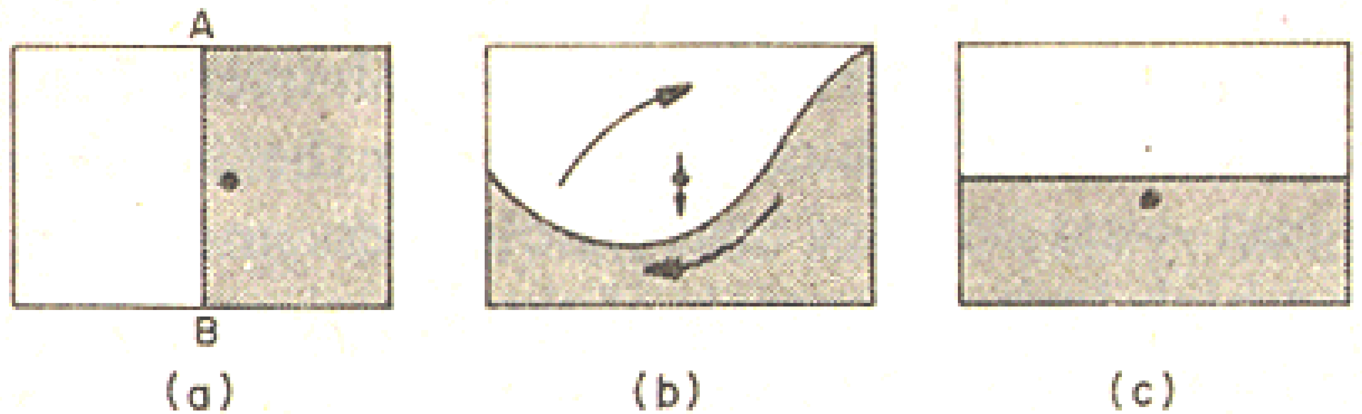
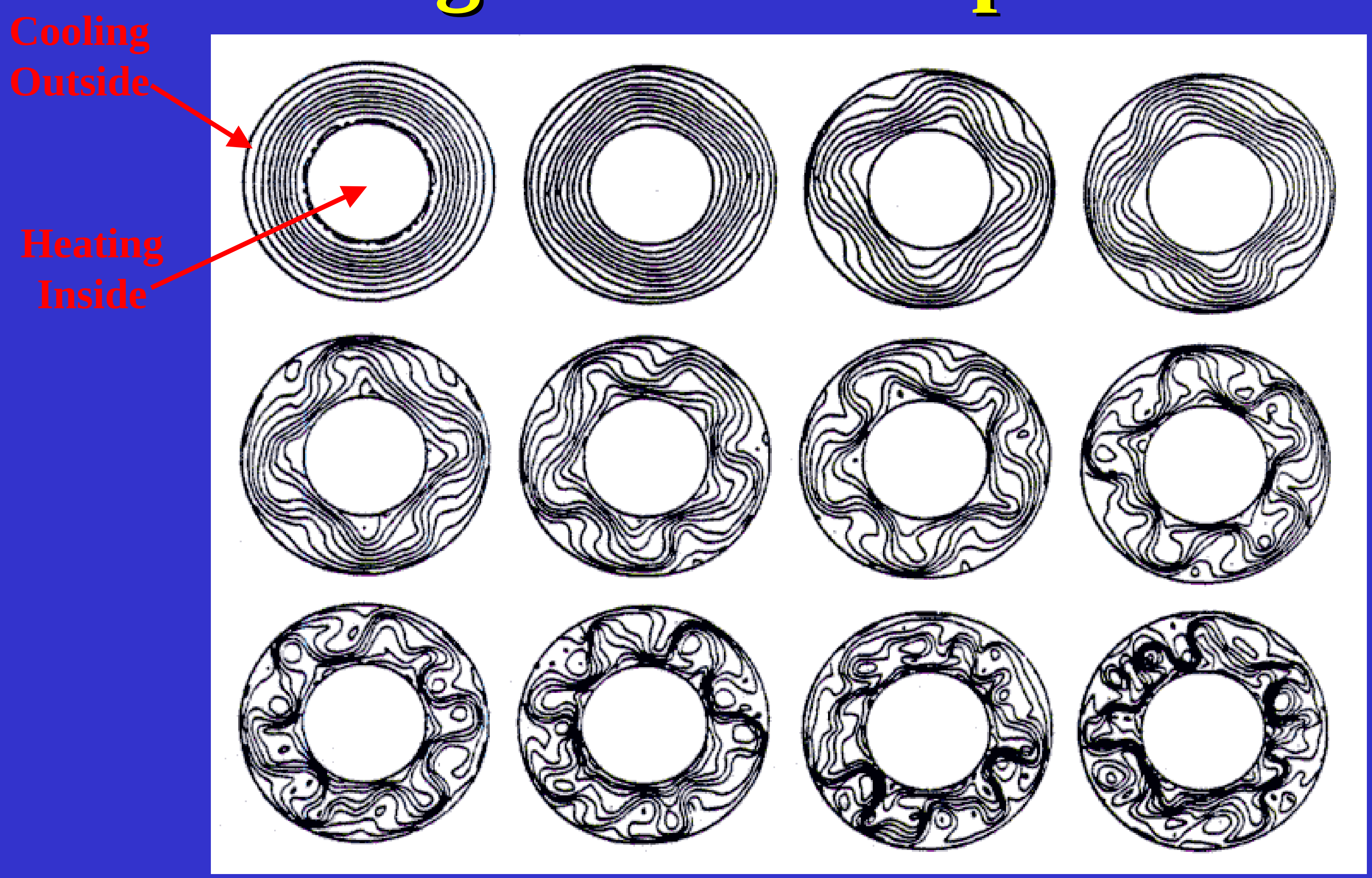
Available Potential Energy



Rotating Annulus Experiment



(from *"Is The Temperature Rising?"*)

Parameters Determining Mid-latitude Weather

- Temperature differences between the equator and poles
- The rate of rotation of the Earth.

Vorticity

- The rotation of a fluid (such as air and water) is referred to as its vorticity.

Absolute Vorticity (viewed from space)

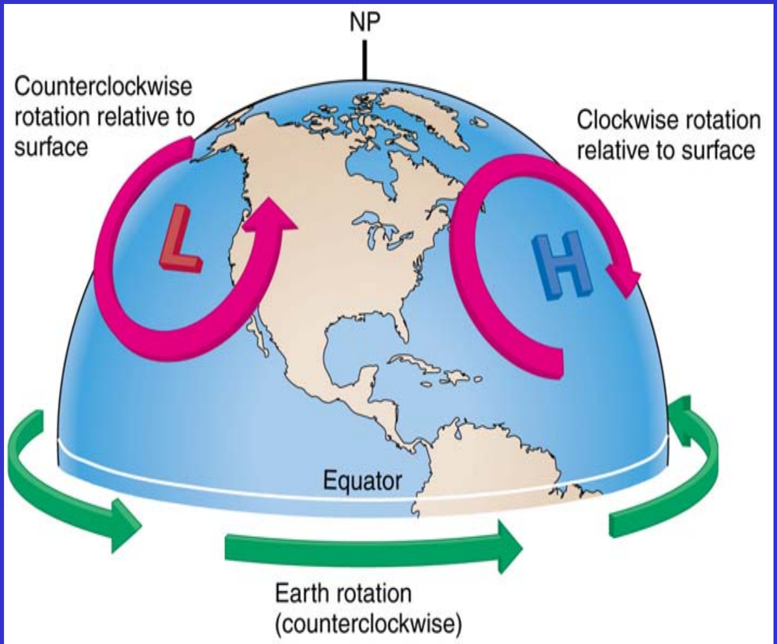
=

Earth (or Planetary) Vorticity

+

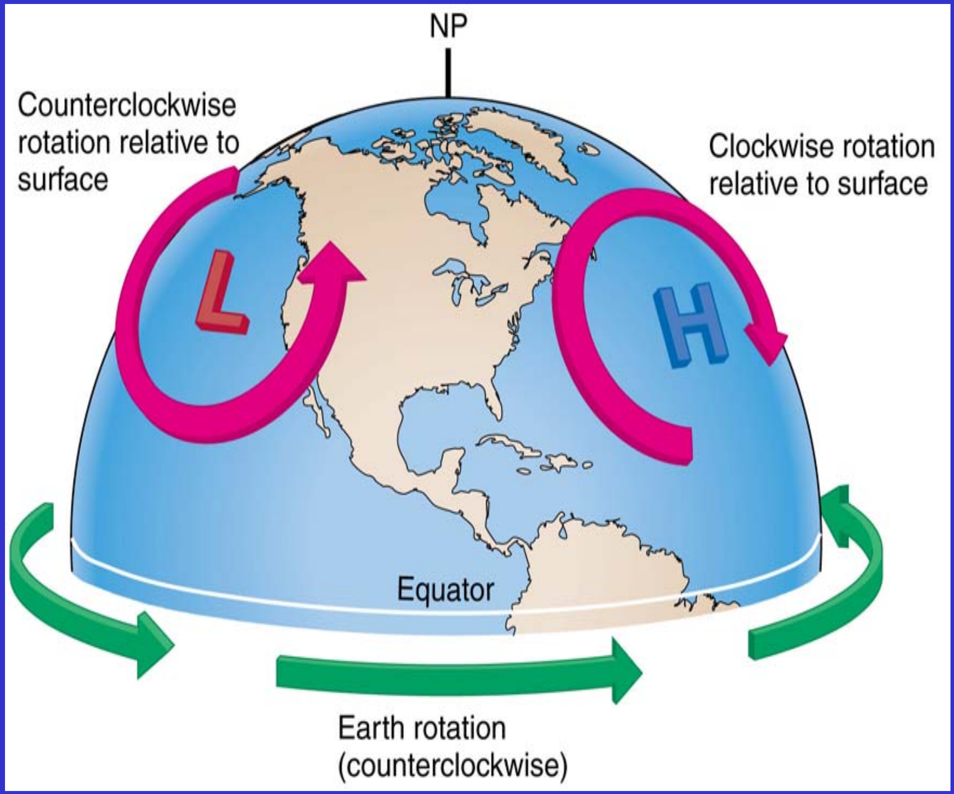
Relative Vorticity (relative to the Earth)

Earth (Planetary) Vorticity



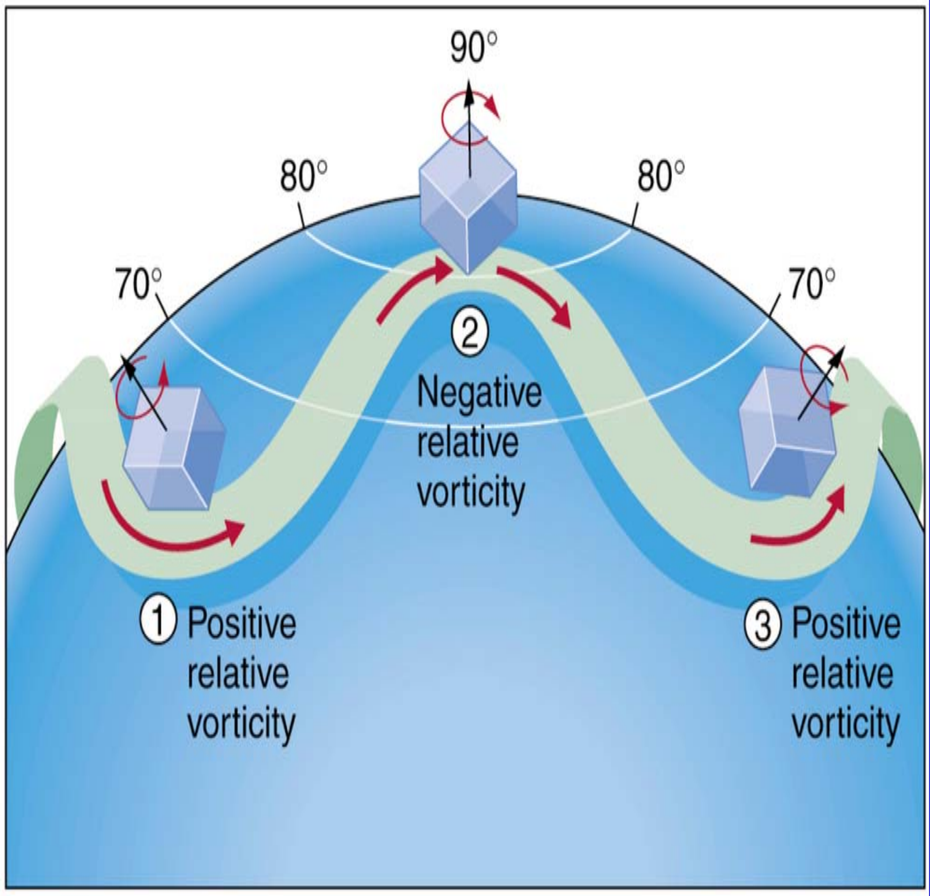
- Earth vorticity is a function solely of latitude.
- The higher the latitude, the greater the vorticity.
- Earth vorticity is zero at the equator.

Relative Vorticity



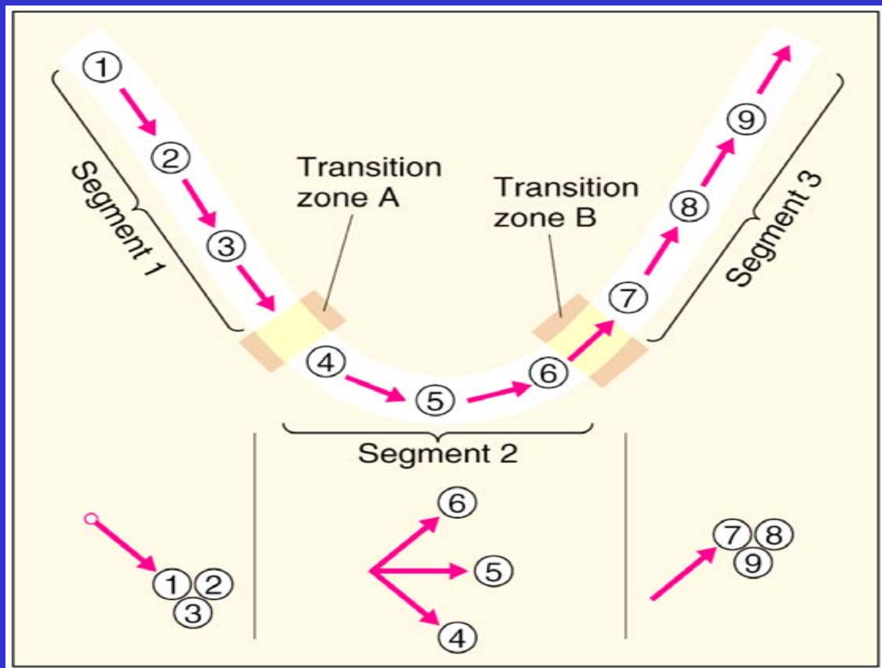
- Air which rotates in the direction of Earth's rotation is said to exhibit positive vorticity.
- Air which spins oppositely exhibits negative vorticity.

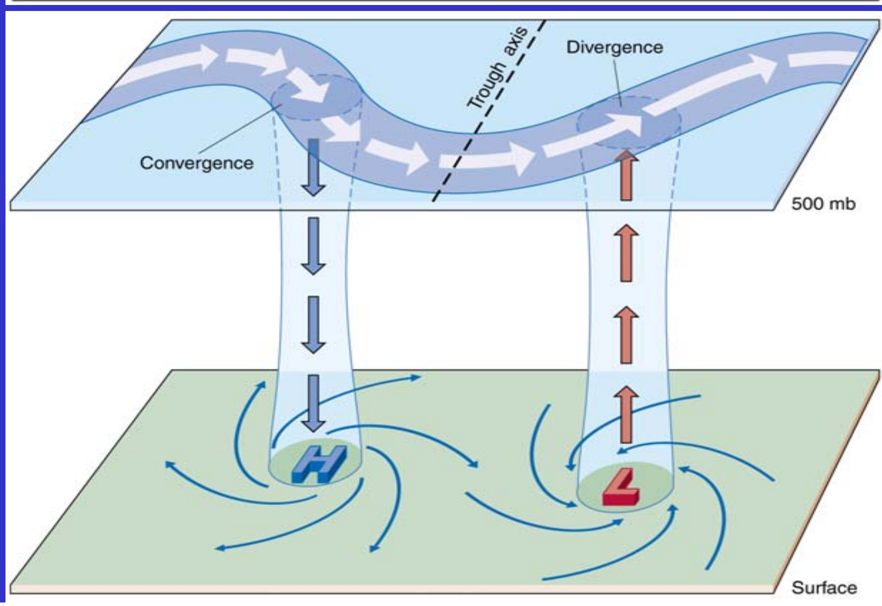
Vorticity and Rossby Wave



- Rossby waves are produced from the conservation of absolute vorticity.
- As an air parcle moves northward or southward over different latitudes, it experiences changes in Earth (planetary) vorticity.
- In order to conserve the absolute vorticity, the air has to rotate to produce relative vorticity.
- The rotation due to the relative vorticity bring the air back to where it was.

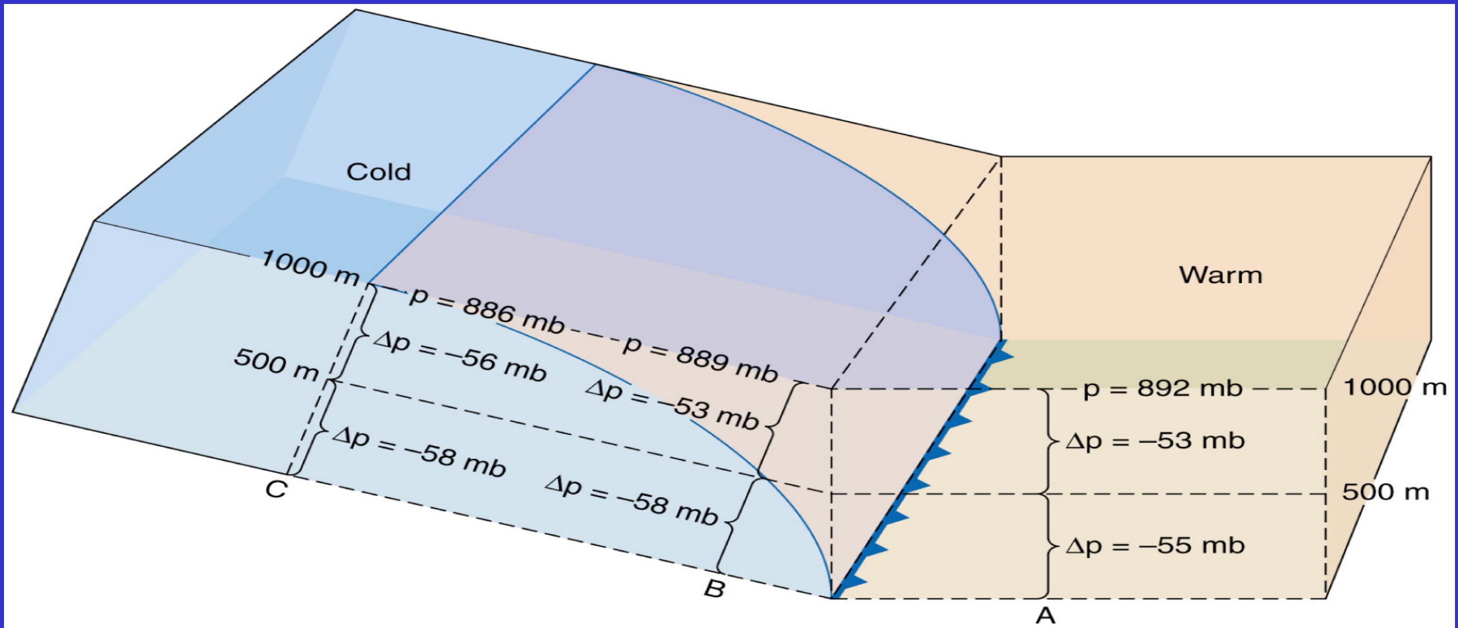
Vortocity and Divergence





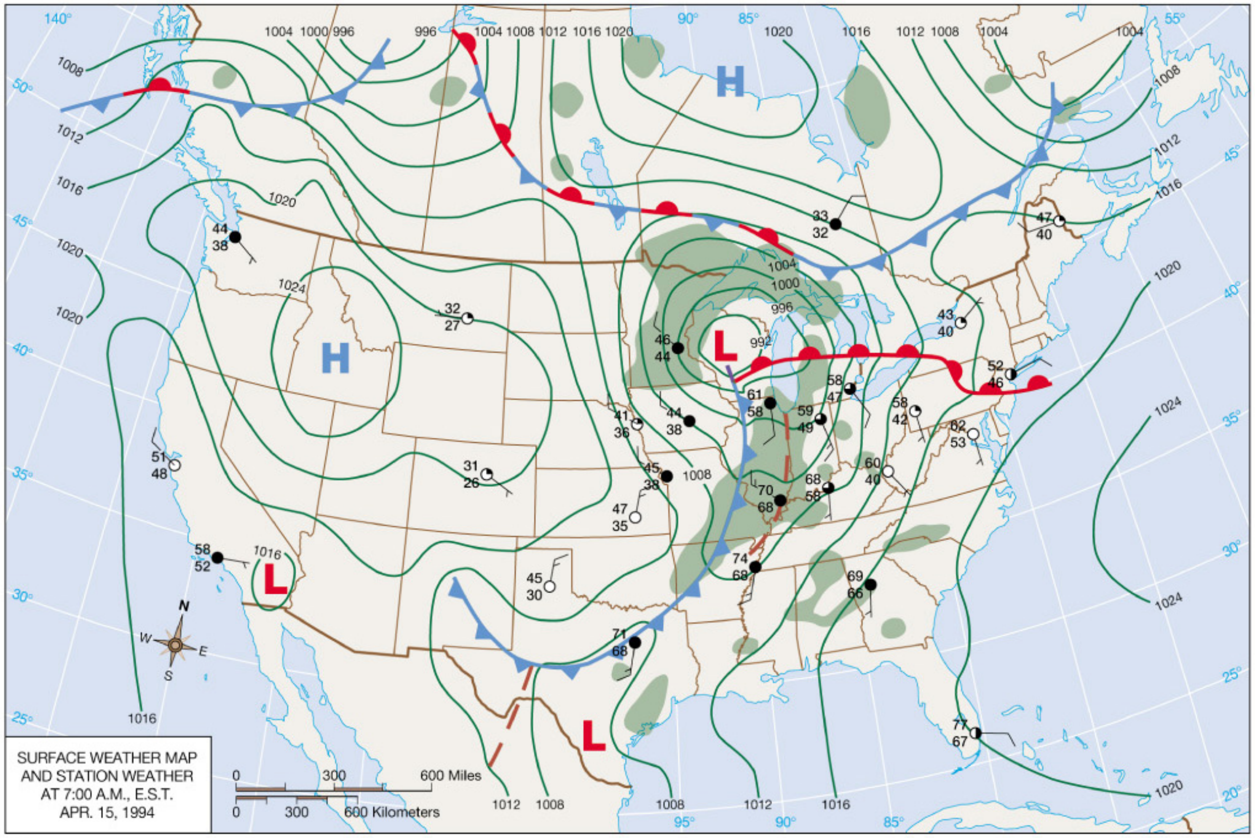
- Decreasing vorticity in the zone between a trough and ridge leads to upper air convergence and sinking motions through the atmosphere, which supports surface high pressure areas.
- Increasing vorticity in the zone between a ridge and trough leads to upper air divergence and rising motions through the atmosphere, which supports surface low pressure areas.

Trough and Cold Front



- Upper air troughs develop behind surface cold fronts with the vertical pressure differences proportional to horizontal temperature and pressure differences.
- This is due to density considerations associated with the cold air.
- Such interactions also relate to warm fronts and the upper atmosphere.

An Example



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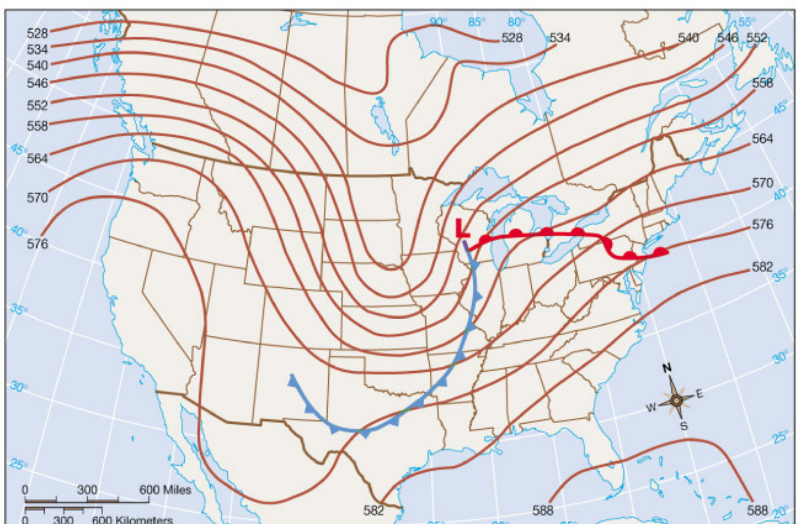

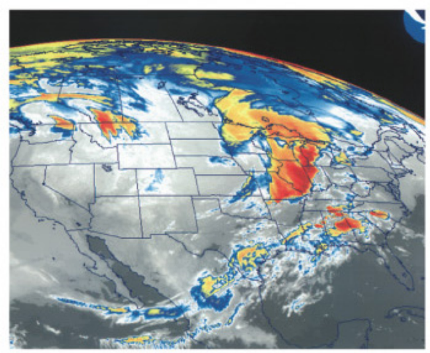

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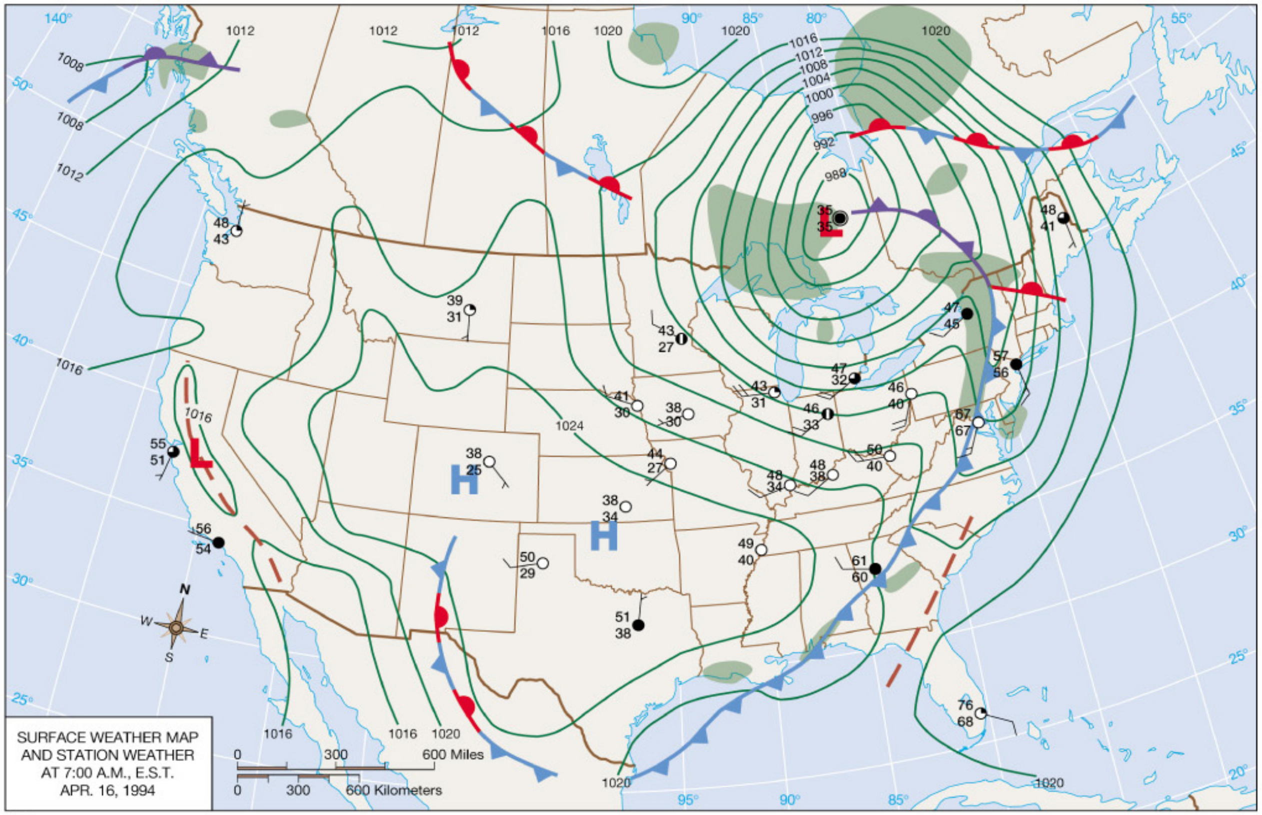

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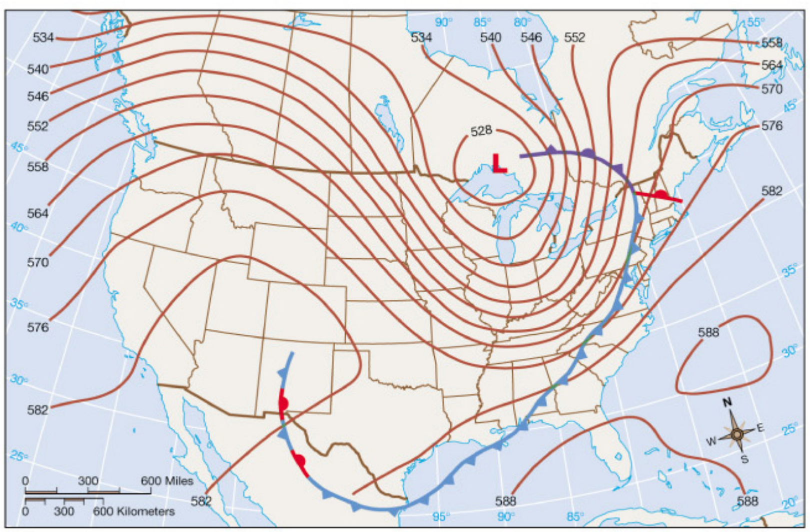
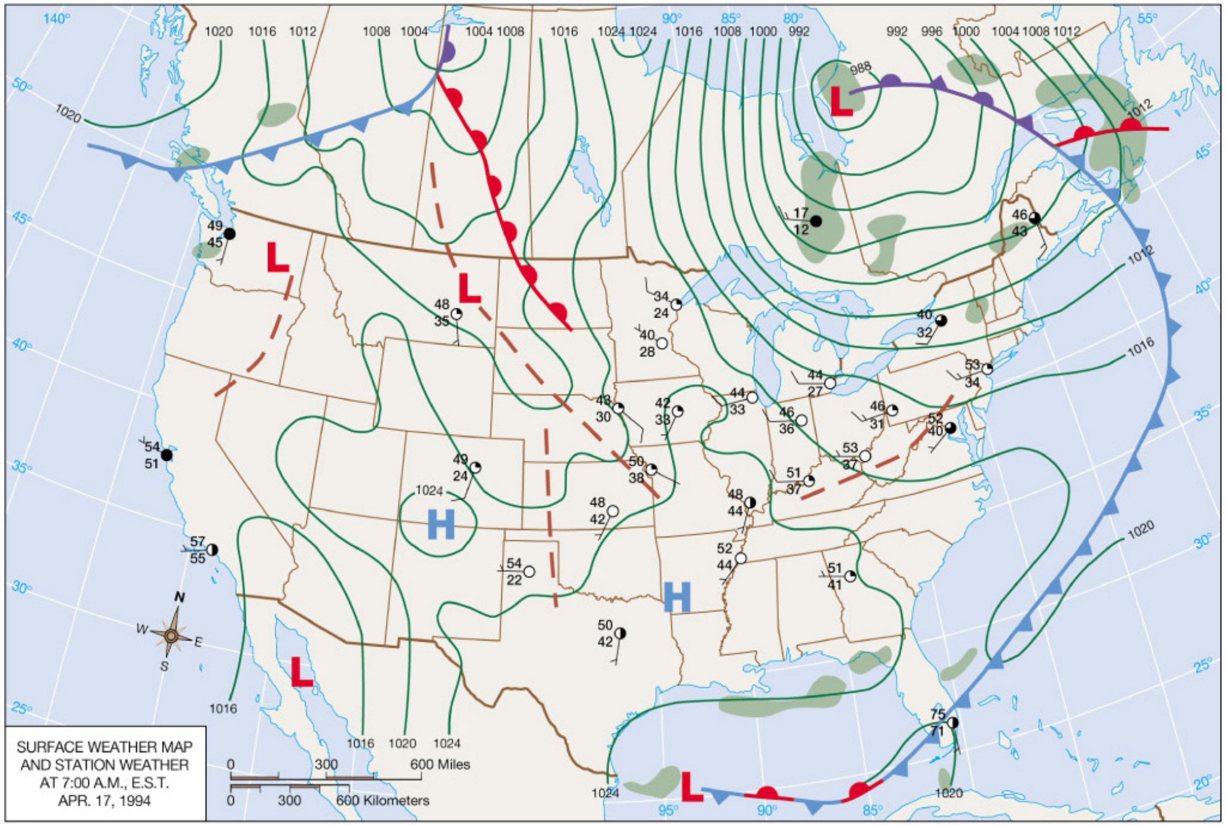


(b)


(c)

- ***April 16*** - The northeasterly movement of the storm system is seen through a comparison of weather maps over a 24-hour period
- Occlusion occurs as the low moves over the northern Great Lakes
- In the upper air, the trough has increased in amplitude and strength and become oriented northwest to southeast
- Isobars have closed about the low, initiating a cutoff low



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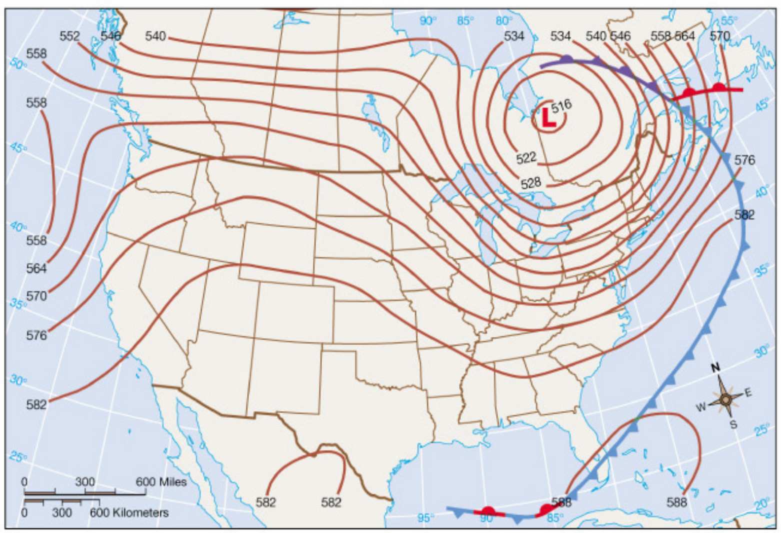

(b)

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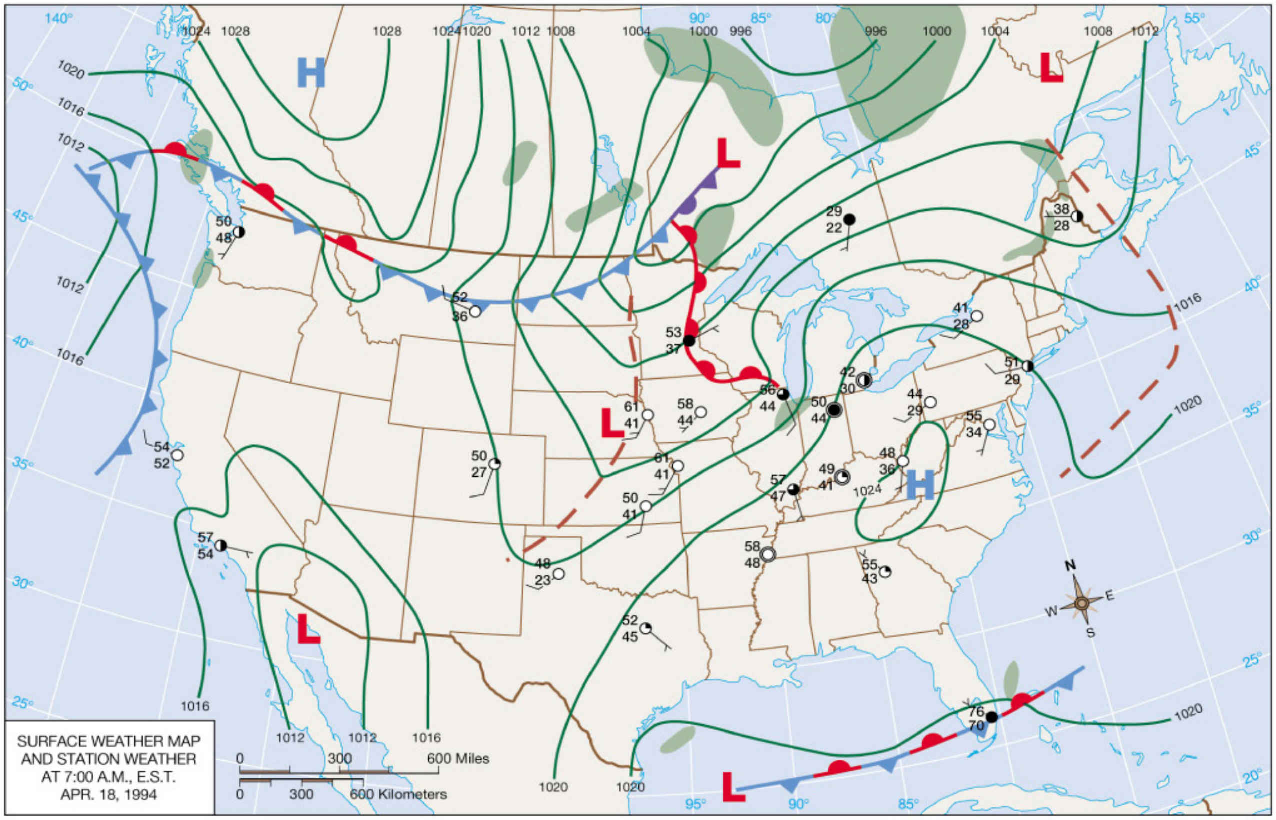
- *April 17* - Continual movement towards the northeast is apparent, although system movement has lessened
- The occlusion is now sweeping northeastward of the low, bringing snowfall to regions to the east
- In the upper air, continued deepening is occurring in association with the more robust cutoff low



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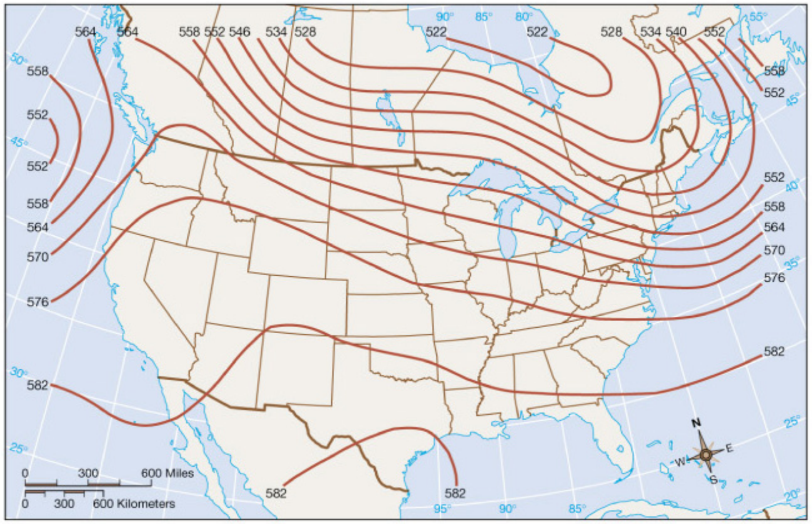

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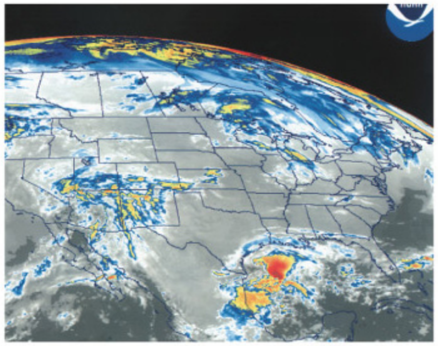

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- ***April 18*** -The system has moved over the northwestern Atlantic Ocean, but evidence persists on the continent in the form of widespread precipitation
- The upper atmosphere also shows evidence of the system, with an elongated trough pattern

Steering of Mid-Latitude Cyclones

- The movement of surface systems can be predicted by the 500 mb pattern.
- The surface systems move in about the same direction as the 500 mb flow, at about 1/2 the speed.
- Upper-level winds are about twice as strong in winter than summer.
- This results in stronger pressure gradients (and winds), resulting in stronger and more rapidly moving surface cyclones.

Typical Winter Mid-latitude Cyclone Paths

- ❑ ***Alberta Clippers*** are associated with zonal flow and usually produce light precipitation.
- ❑ ***Colorado Lows*** are usually stronger storms which produce more precipitation.
- ❑ ***East Coast*** storms typically have strong uplift and high water vapor content.

Modern View of Mid-latitude Cyclones