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 great distance and bring precipitations over wide areas.

- Lasting a week or more.
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.

Vilhelm Bjerknes (1862-1951)
Life Cycle of Mid-Latitude Cyclone

- Cyclogenesis
- Mature Cyclone
- Occlusion

(from *Weather & Climate*)
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 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” instability associated with the north-south temperature differences in middle latitudes.

Carl Gustav Rossby (1898-1957)
Rossby Wave and Surface Cyclone/Anticyclone
Available Potential Energy

(a) B
(b) (c)
Rotating Annulus Experiment

Cooling Outside

Heating Inside

(from “Is The Temperature Rising?”)
Parameters Determining Mid-latitude Weather

- Temperature differences between the equator and poles
- The rate of rotation of the Earth.
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.
Rossby waves are produced from the conservation of absolute vorticity.

As an air parcel 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 brings the air back to where it was.
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.
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
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.
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.
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