



# **MET 3502/5561 Synoptic Meteorology**

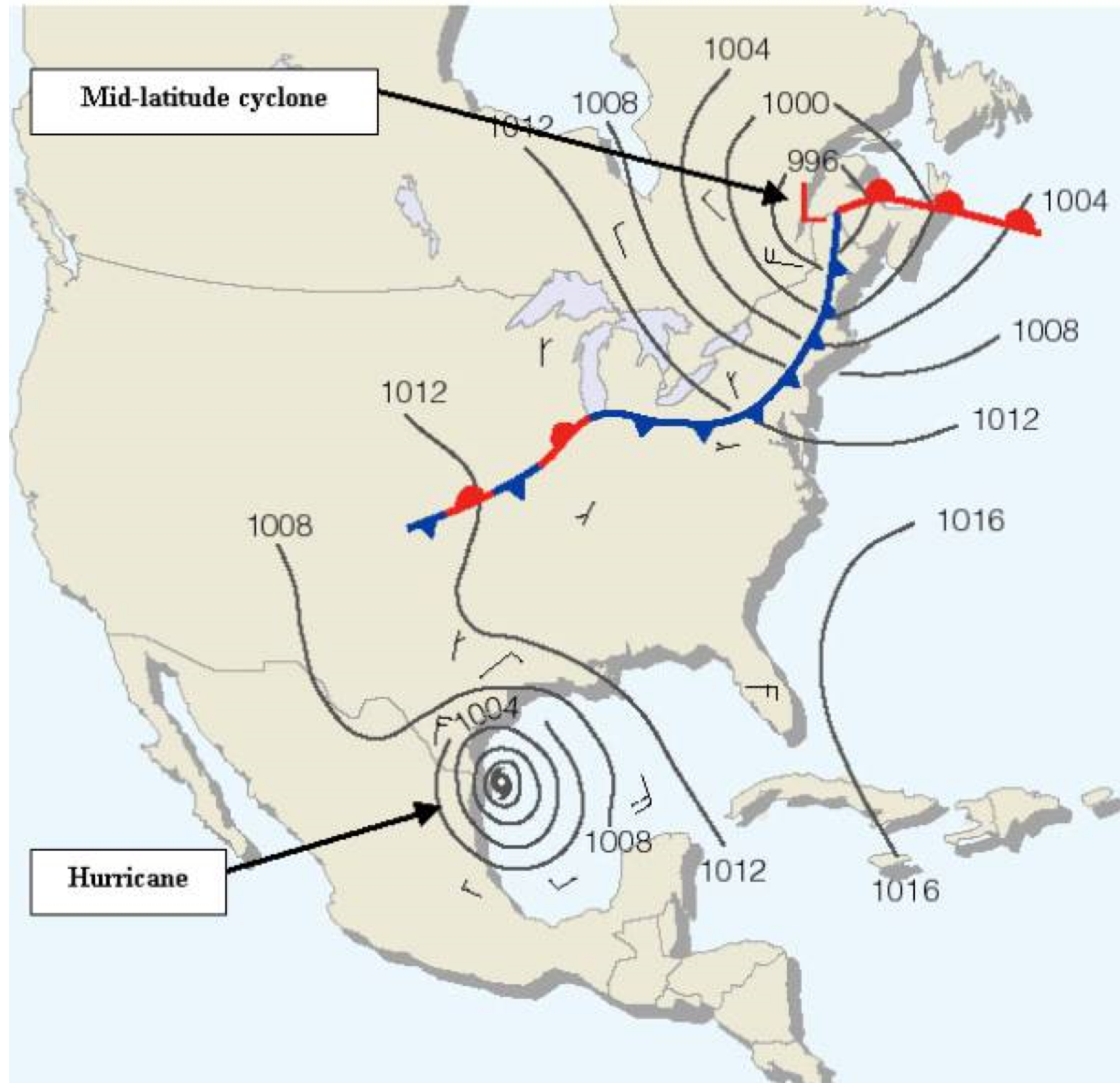
## **Lecture 17:**

**Life Cycle of the Mid-Latitude  
Cyclone  
and Forecasting Mid-Latitude  
Cyclone**

# What is a mid-latitude cyclone?

- The mid-latitude cyclone is a synoptic scale low pressure system that has cyclonic (counter-clockwise in northern hemisphere) flow that is found in the middle latitudes (i.e., 30°N-55°N)
- IT IS NOT A HURRICANE OR TROPICAL STORM
  - 1) There is a location (tropics vs. mid-latitudes) and size difference between hurricane and mid-latitude cyclone
  - 2) Typical size of mid-latitude cyclone = 1500-5000km in diameter
  - 3) Typical size of a hurricane or tropical storm = 200-1000km in diameter

Here is a picture of a typical mid-latitude cyclone and hurricane. Notice the size difference.



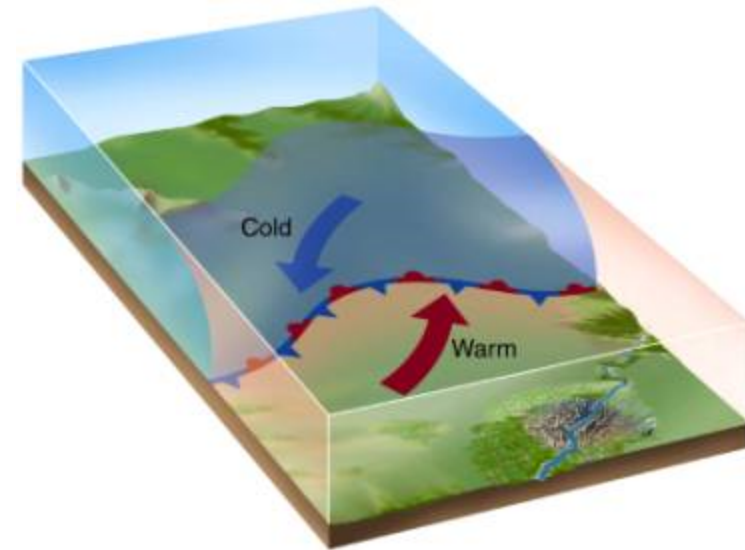
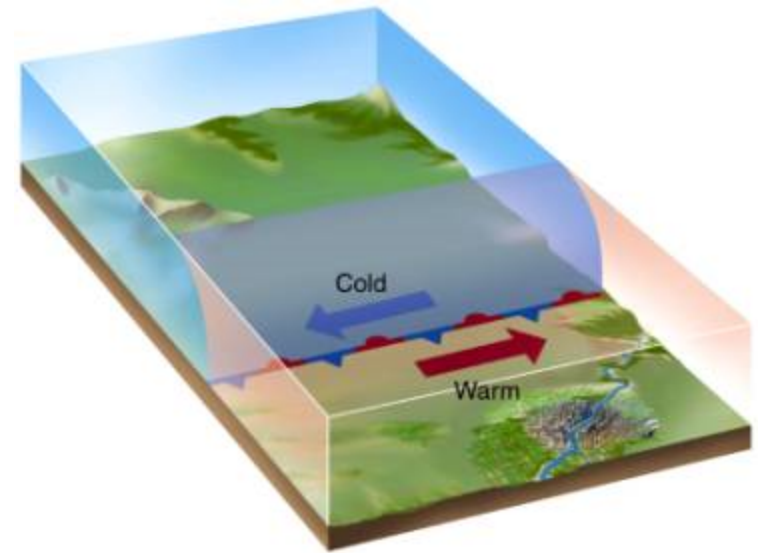
# How does the mid-latitude cyclone form?

## History:

- Polar front theory: developed by Univ. of Bergen in Norway after the end of World War I
- Norway Cyclone Model (NCM): About the structure and life cycle of mid-latitude cyclone
- Explained evolution of midlatitude cyclones in terms of surface patterns
- Suffered from lack of knowledge of upper atmospheric patterns
- Provided a good description of how surface patterns evolve, but couldn't explain why

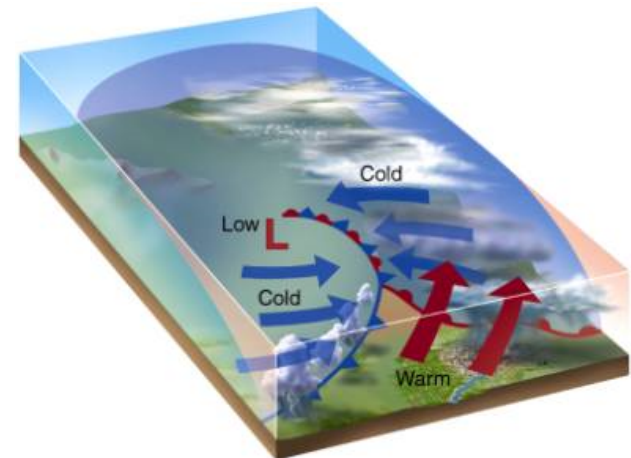
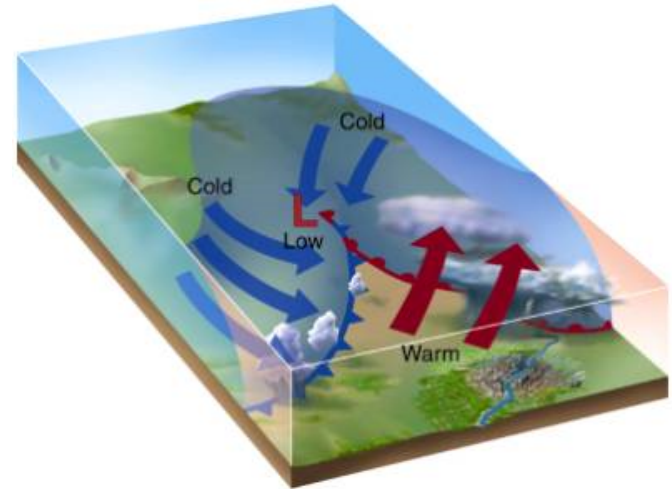
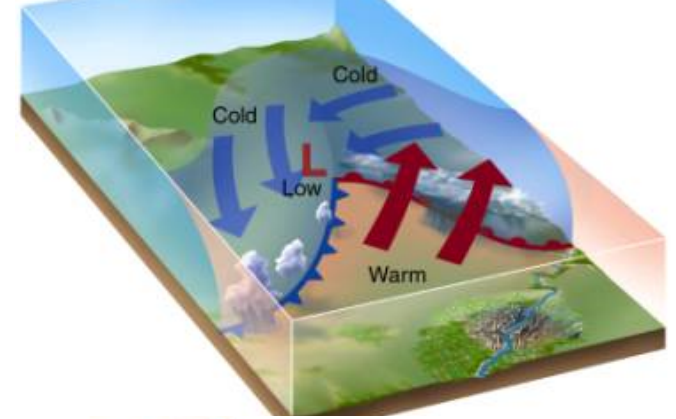
# Classical Model

1. Background State: There is boundary between cP and mT airmass in mid-latitude (Baroclinic Zone).
2. Perturbation Stage: Along this boundary a counter-clockwise circulation can set up at the surface, which acts to take warm air up from the south and cold air down from the north. This is called cyclogenesis.



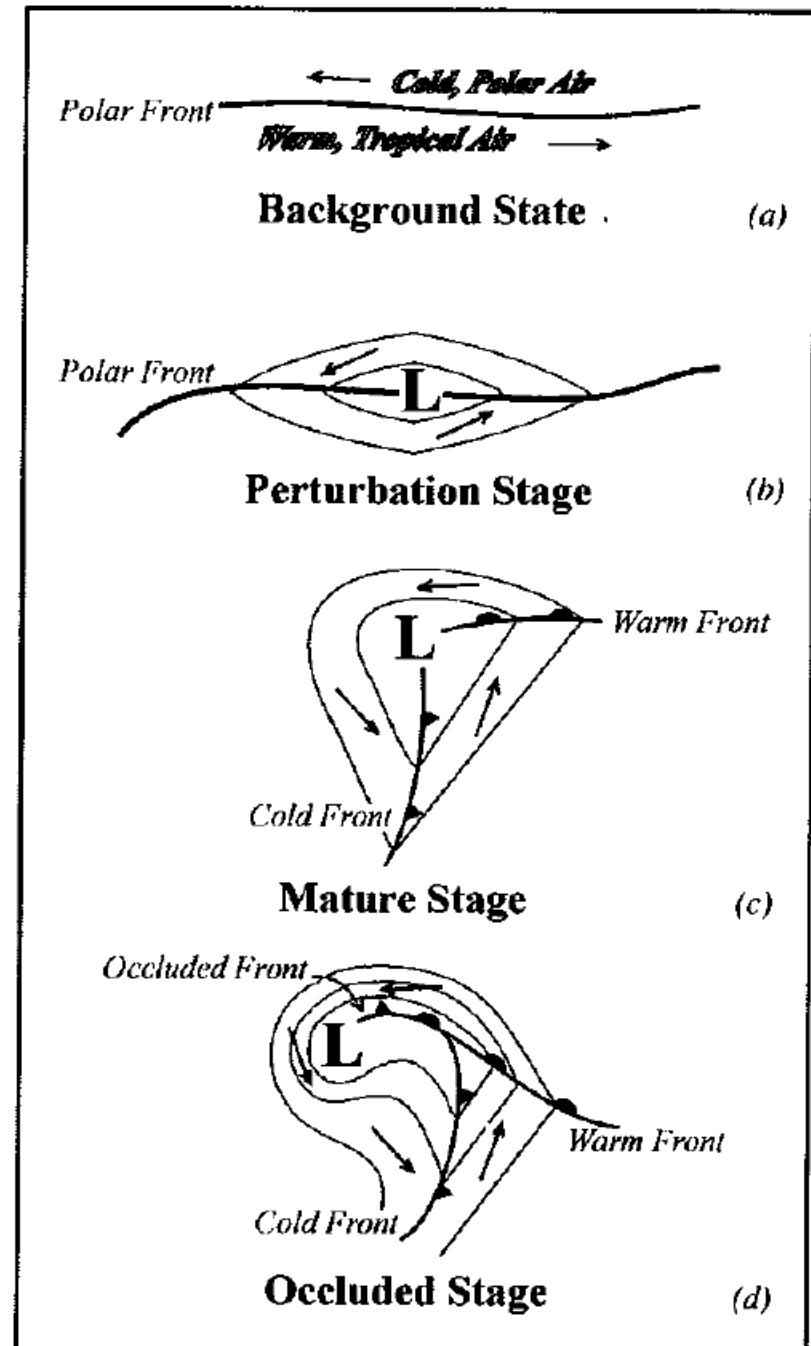
# Classical Model

3. **Mature Stage:** If the upper levels are favorable, then the mid-latitude cyclone will continue to develop and bring up mT air in the warm sector and bring down cP air in the cold sector. Once the mid-latitude cyclone is fully developed, well-defined fronts appear.
4. **Occluded Stage:** As the mid-latitude cyclone reaches maturity, the central pressure will be at its lowest and the occluded front will begin to form (as the cold front catches up to the warm front, closing warm sector).



# Classical Model

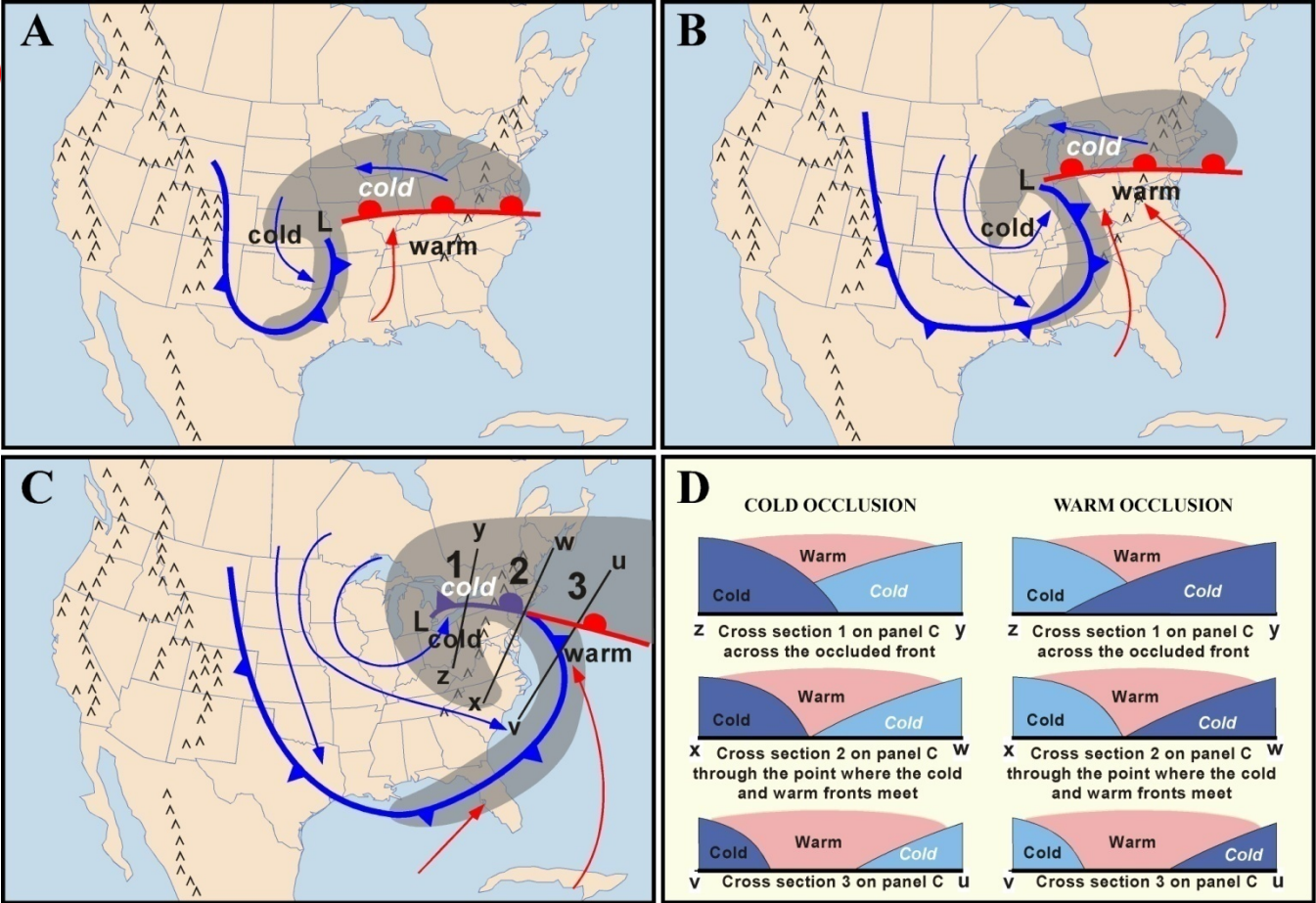
- Background state: Baroclinic Zone
- Perturbation stage: Unstable open-wave cyclone with cyclonic circulation
- Mature stage: cold front and warm front are well defined
- Occlusion stage: Cold front catches up with warm, closing warm sector



# Occluded fronts (Classical description)

Cold air to the west of the cyclone advances rapidly southward around the center of low pressure

Cool air to the north of the warm front retreats northward slowly.

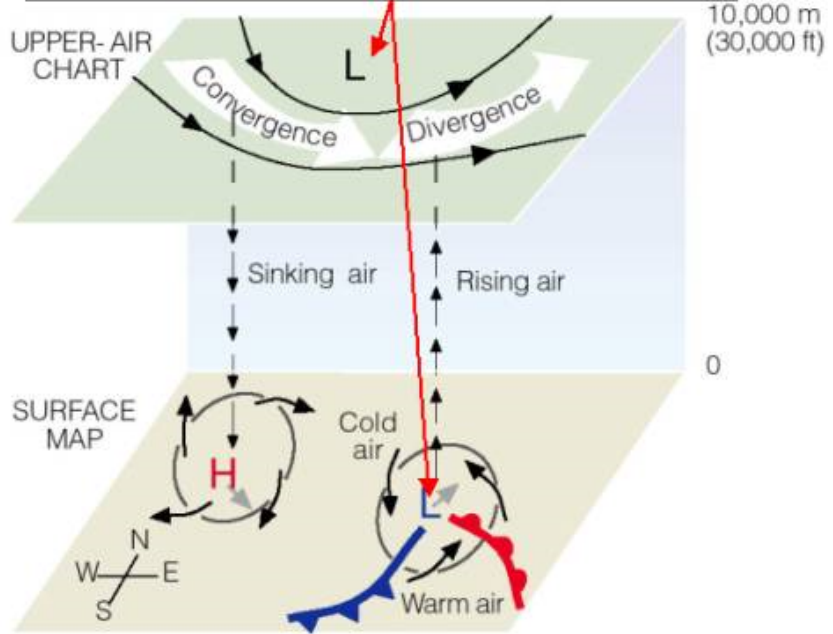


Cold air will then progress northeastward, approaching the warm front. When cold air comes in direct contact with the cool air north of the warm front, a new airmass boundary is created called an *occluded front*.

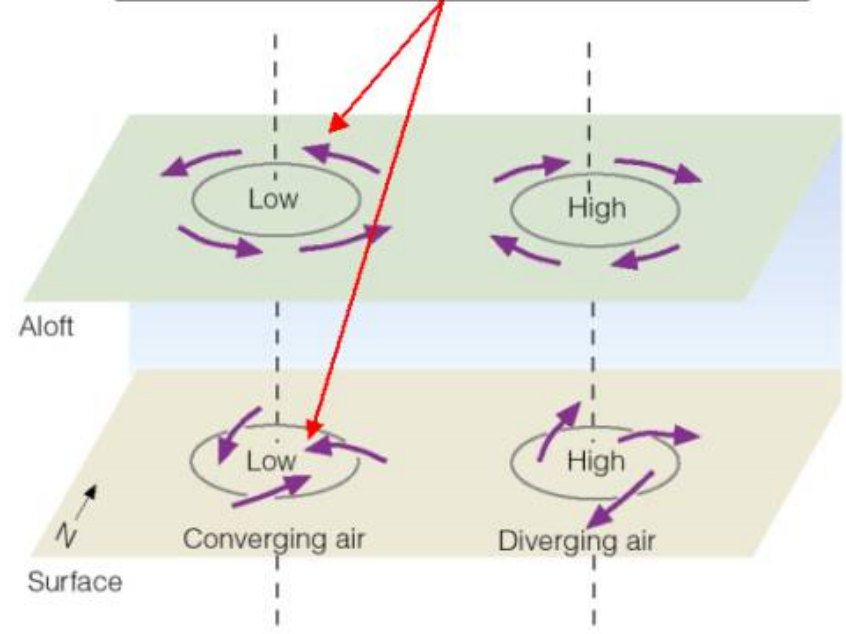


# How do upper-level conditions help surface cyclone develop?

\*\*\***Favorable condition**\*\*\* the surface Low is to the *East* of the upper level low (or trough). The divergent region aloft is directly above the convergent region at the surface



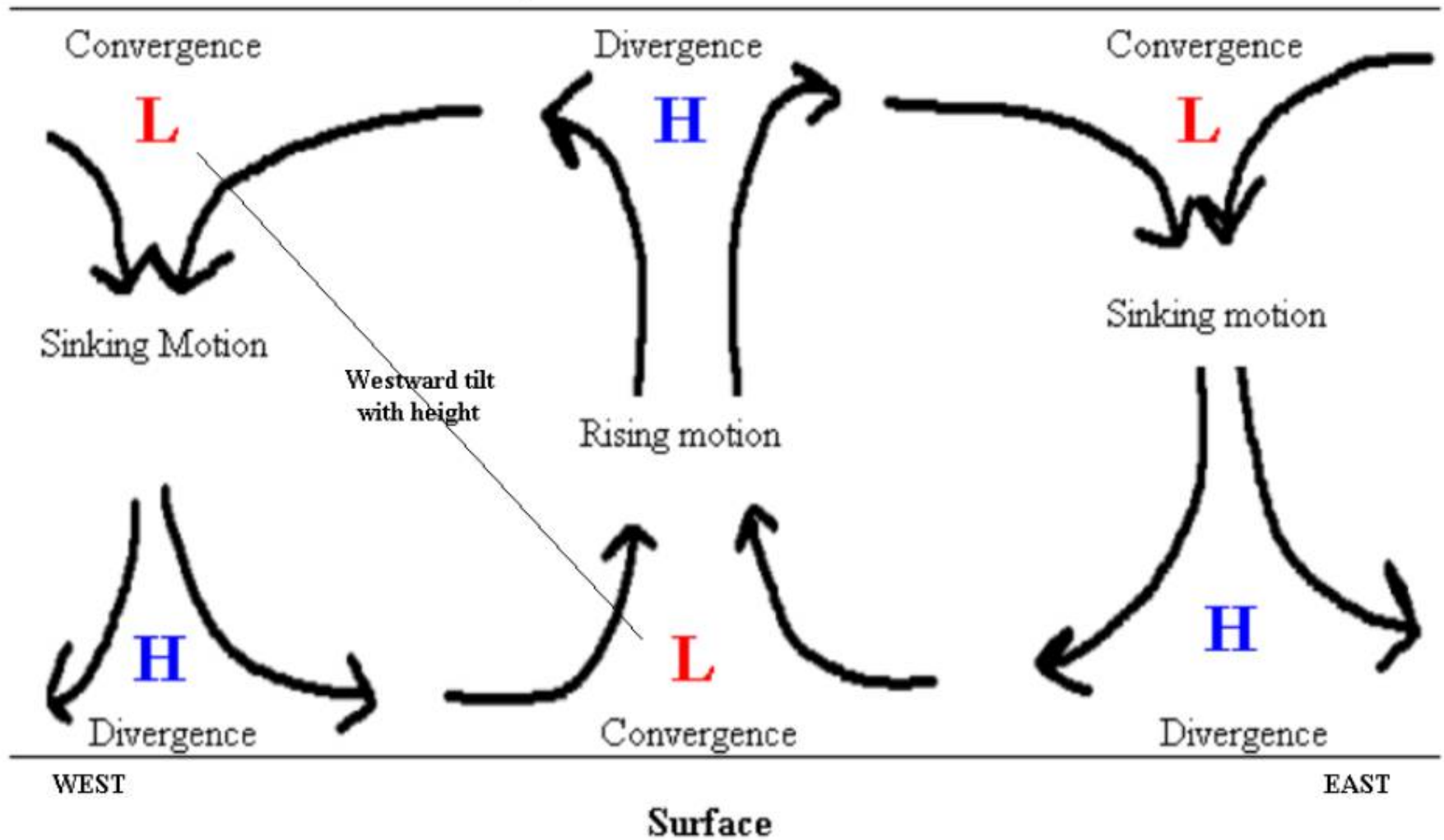
\*\*\***Un-Favorable condition**\*\*\* the surface Low is below the upper level low (or trough) Therefore the converging surface winds can't go up because there is also convergence aloft!



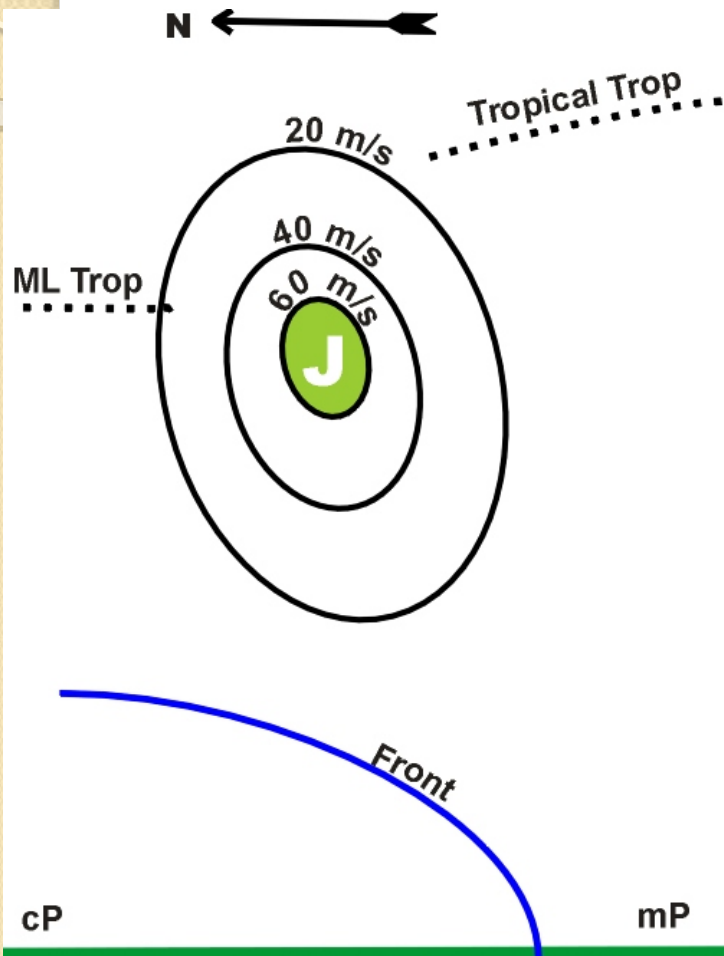
- At perturbation stage, in the center of this circulation, there is mass convergence. When all that air hits the center, there is rising motion because it has nowhere else to go. If the upper levels are favorable for cyclone development, then there is a region of divergence aloft above the developing Low-pressure center. This will help pull the air that is converging at the surface upward and continue to develop the surface cyclone. The upper levels also steer the system and make it progress east.

*Upper level low is to the west of the surface low – this situation sets up the best environment for mid-latitude development*

## Tropopause

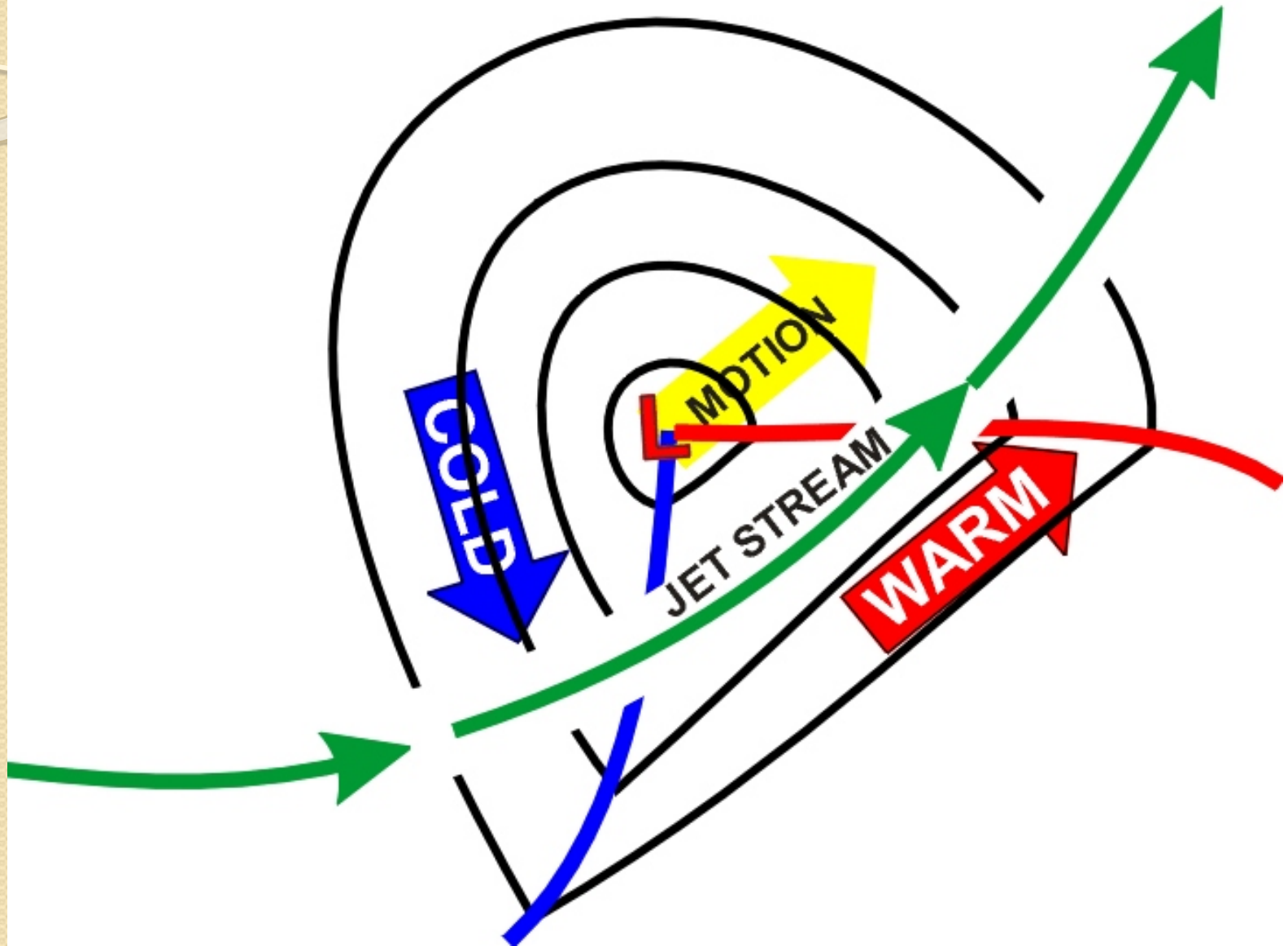


# Polar-Front Jet Stream



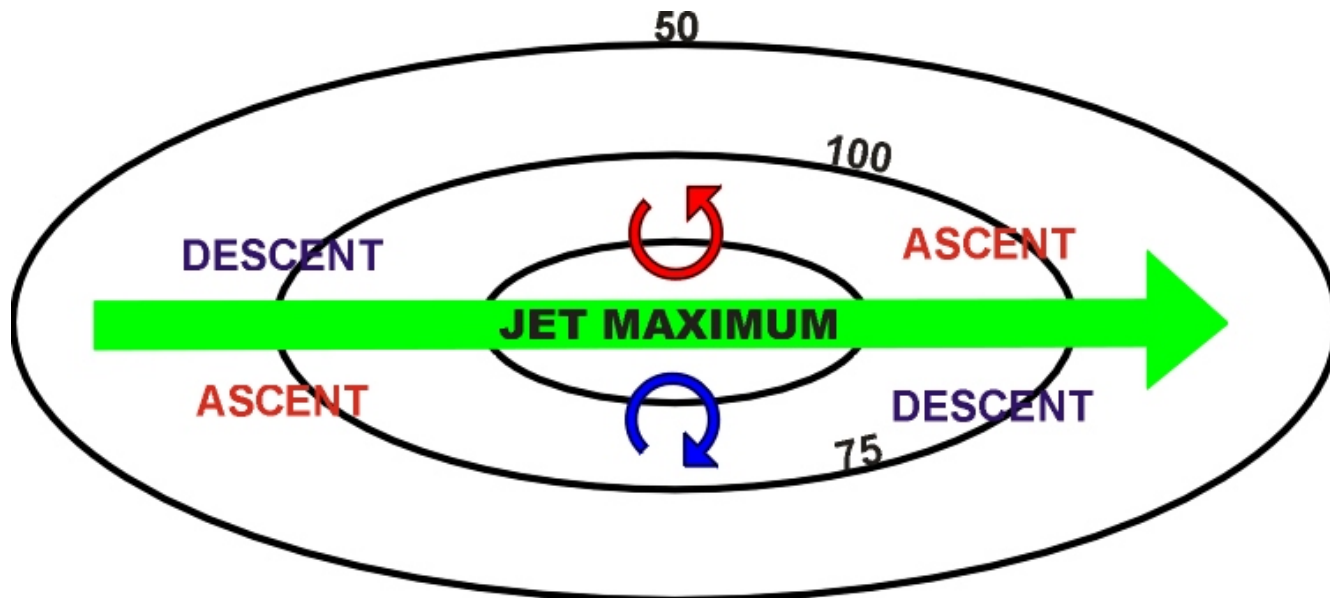
- Narrow band of strong (50 m/s) wind circling the globe.
- More or less coincident with polar front
- Thermal wind due to strong horizontal temperature gradient
- Also coincides with a break between the tropical tropopause (~15 km) and the middle latitude tropopause (7-10 km)
- There is also a subtropical jet at the northern margin of the upper branch of the Hadley Cell

# Relation to Frontal Cyclones



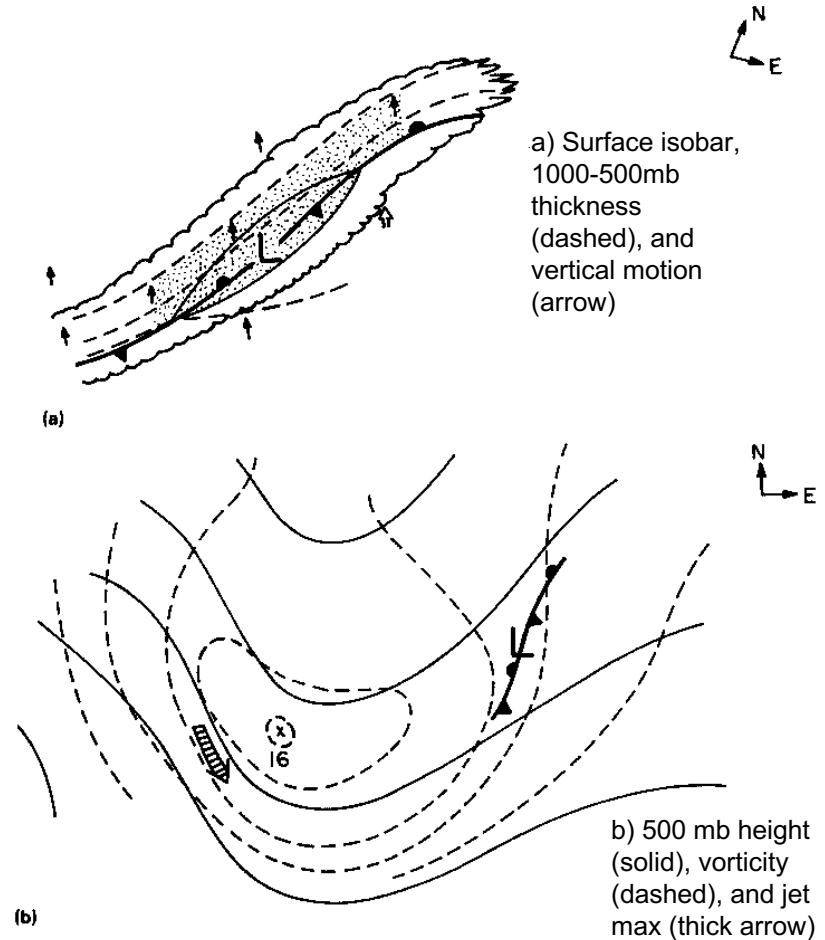
# Jet Maxes

- 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
- Jet MAXes control frontal cyclone formation



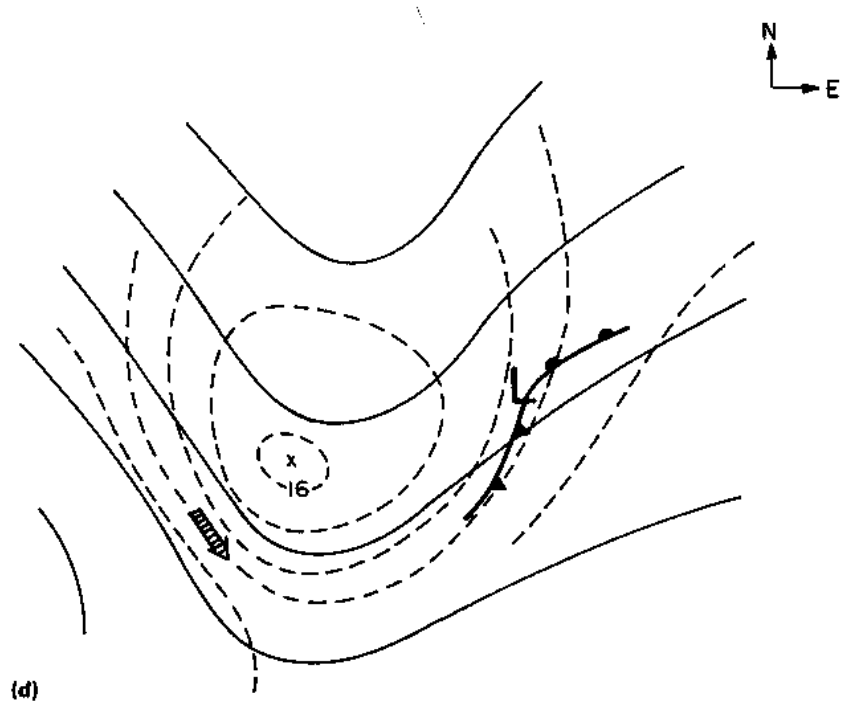
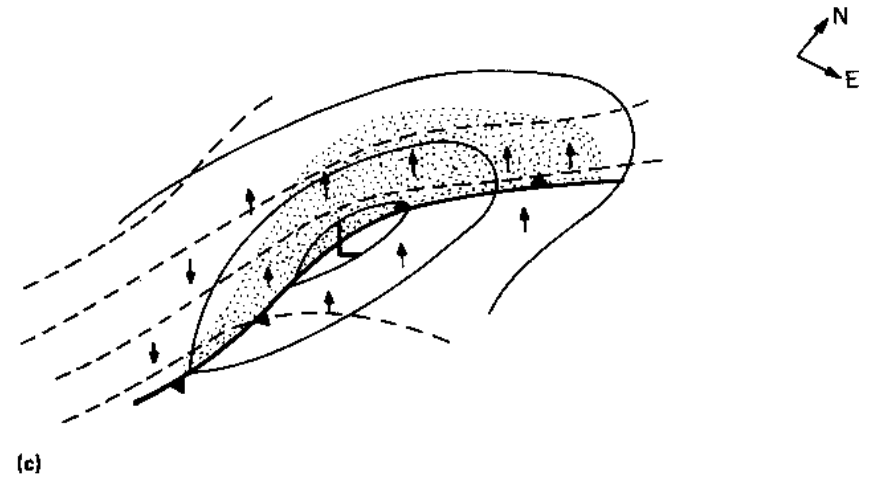
# Stage I

- Surface low center & front located downstream of a diffluent, short-wave trough at 500mb;
- Strong vorticity on its left side;
- Positive vorticity advection over the surface low  $\rightarrow$  rising motion  $\rightarrow$  pressure falls;
- Jet max appears on the west side of the trough.



# Stage 2

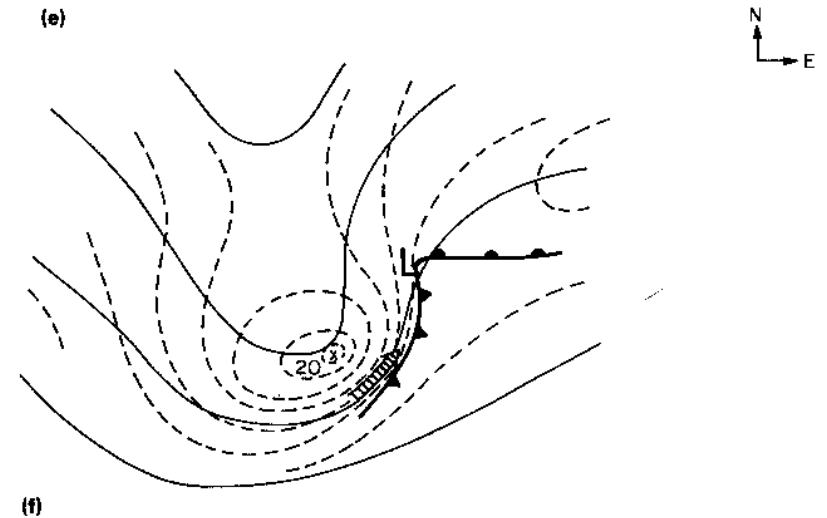
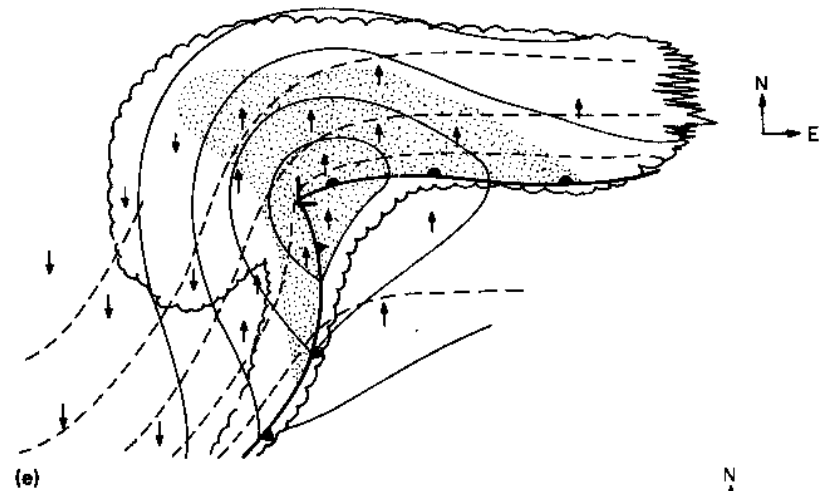
- As surface pressure falls, warm (cold) advection on east (west) side of the surface low, inducing rising motion NE of the low.
- Thermal advection becomes more important than vorticity advection.
- Jet MAX begins to turn the corner.
- Its upper vorticity starts to induce rising motion over the frontal zone.
- Front begins to bend, forming an open wave; leaf cloud.



**Figure 10.4** (c) Same convention as in (a) except for stage 2 (open wave stage) in cyclone development. (d) Same convention as in (b) except for stage 2 in cyclone development.

# Stage 3

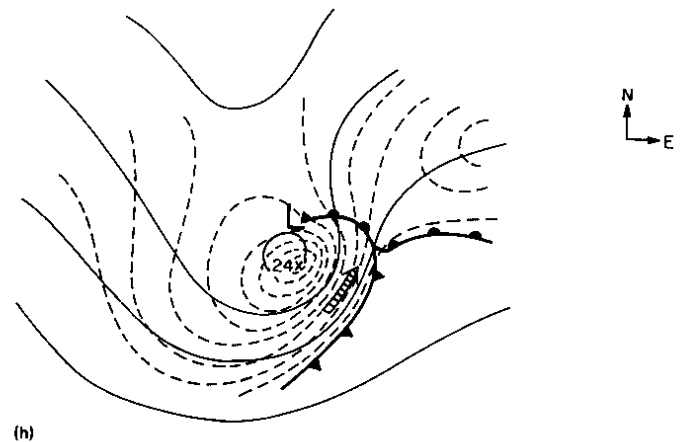
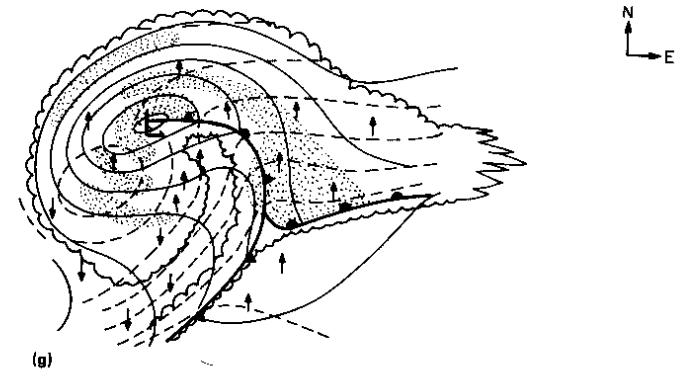
- Cyclone development feedback affect mid-level, and 500 mb height falls noticeably. Vorticity max increases.
- Jet MAX is over the west side of the warm sector and the cold front
- Cyclone intensifies unstably
- Classic appearance in surface analysis
- Comma cloud appears in satellite images



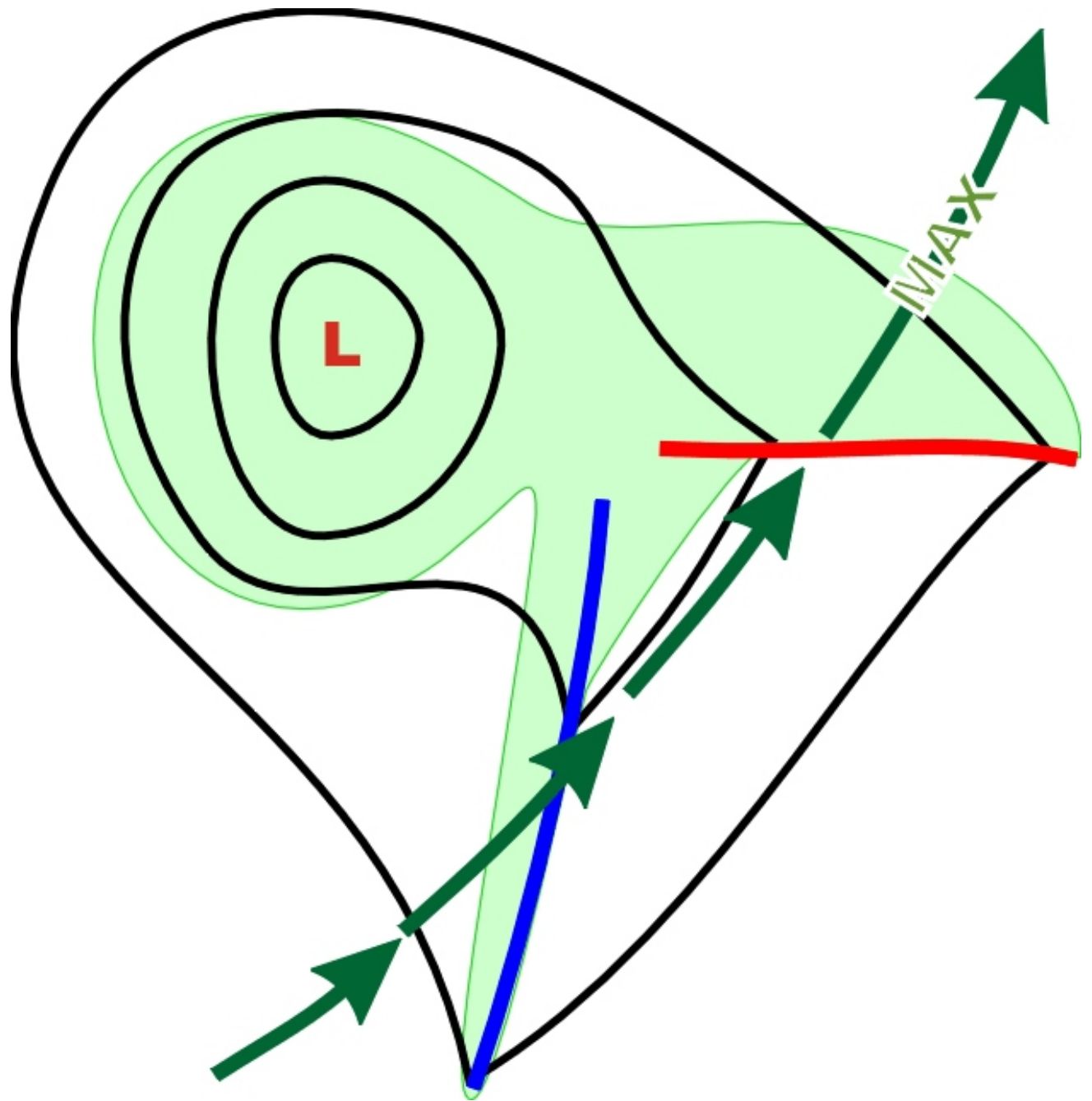


# Stage 4

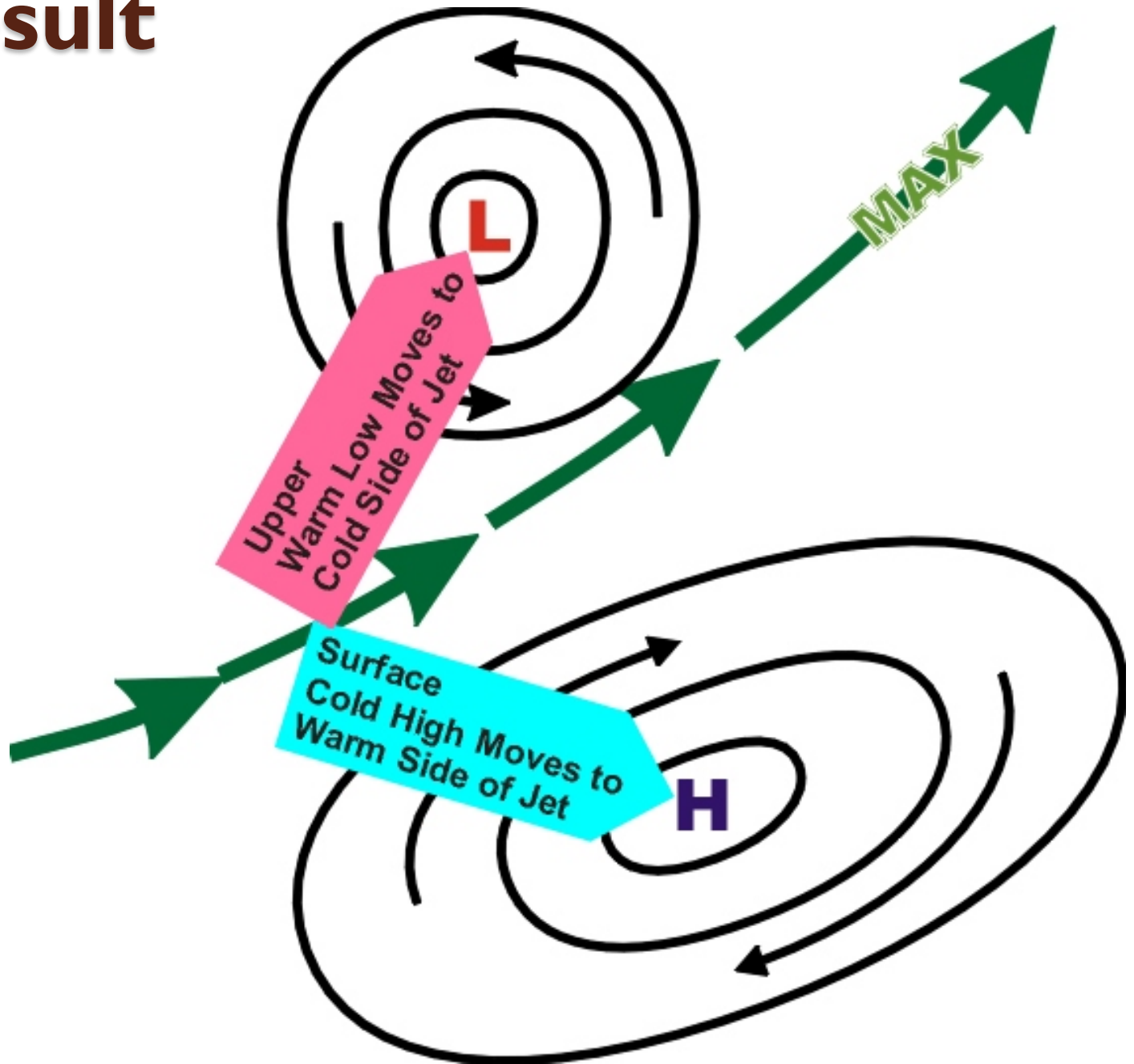
- Cyclone center detaches from the peak of the warm sector and moves into the cold air
- Jet MAX passes the peak of the warm sector (or crosses the occluded front)
- Baroclinic growth ends



# New Way of Drawing Occlusions



# The Result



# Where do mid-latitude cyclones typically form (in North America in winter)?

- **Lee side of the Rockies = Lee Cyclones**

1. **Alberta Clippers:** FAST MOVING and usually don't have too much precip associated with them because they are far from a moisture source

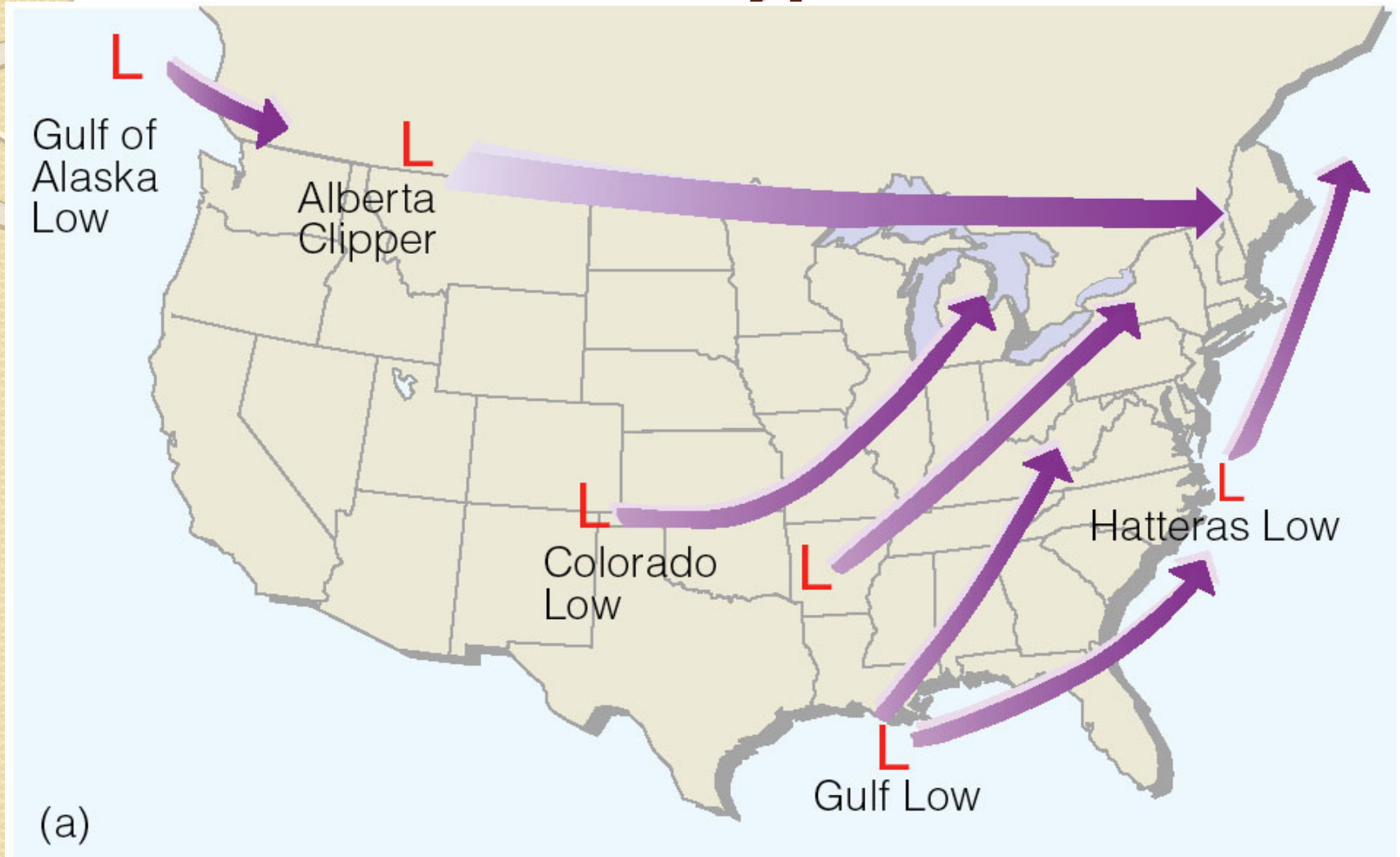
2. **Colorado Low:** Intense Low, with strong warm air advection in the warm sector, very cold temps in the cold sector. If there is a lot of gulf moisture to work with, they there is usually sleet, freezing rain and rain associated with the warm front, strong thunderstorms along the southern edge of the cold front and snow along the backside and to the NW of the Low (even BLIZZARDS)

- **Along the East Coast**

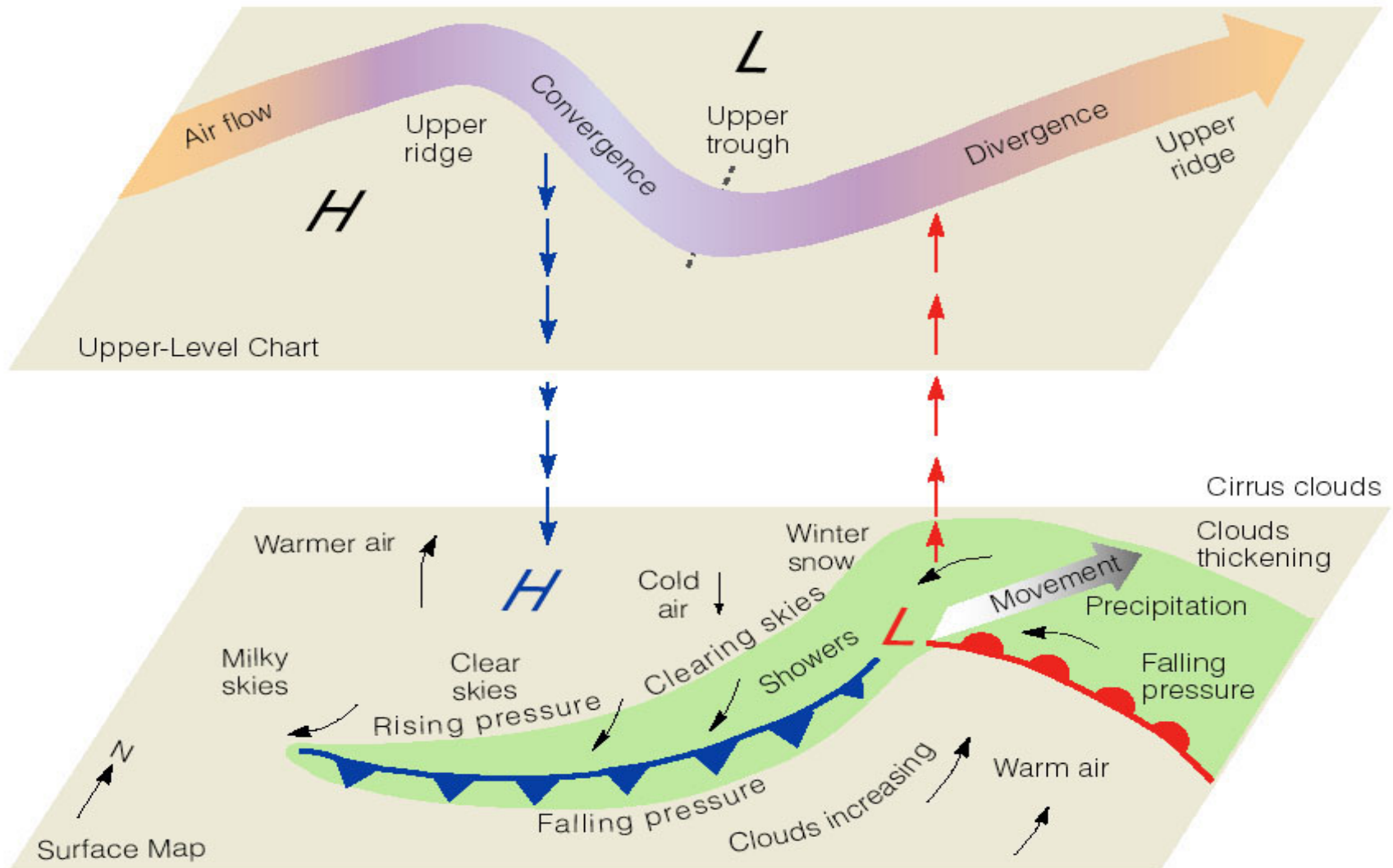
1. **Gulf Low:** Form along the southern coast where there is a thermal boundary between the warm ocean and cool land. Usually have a lot of precip associated with them because they are so close to the ocean

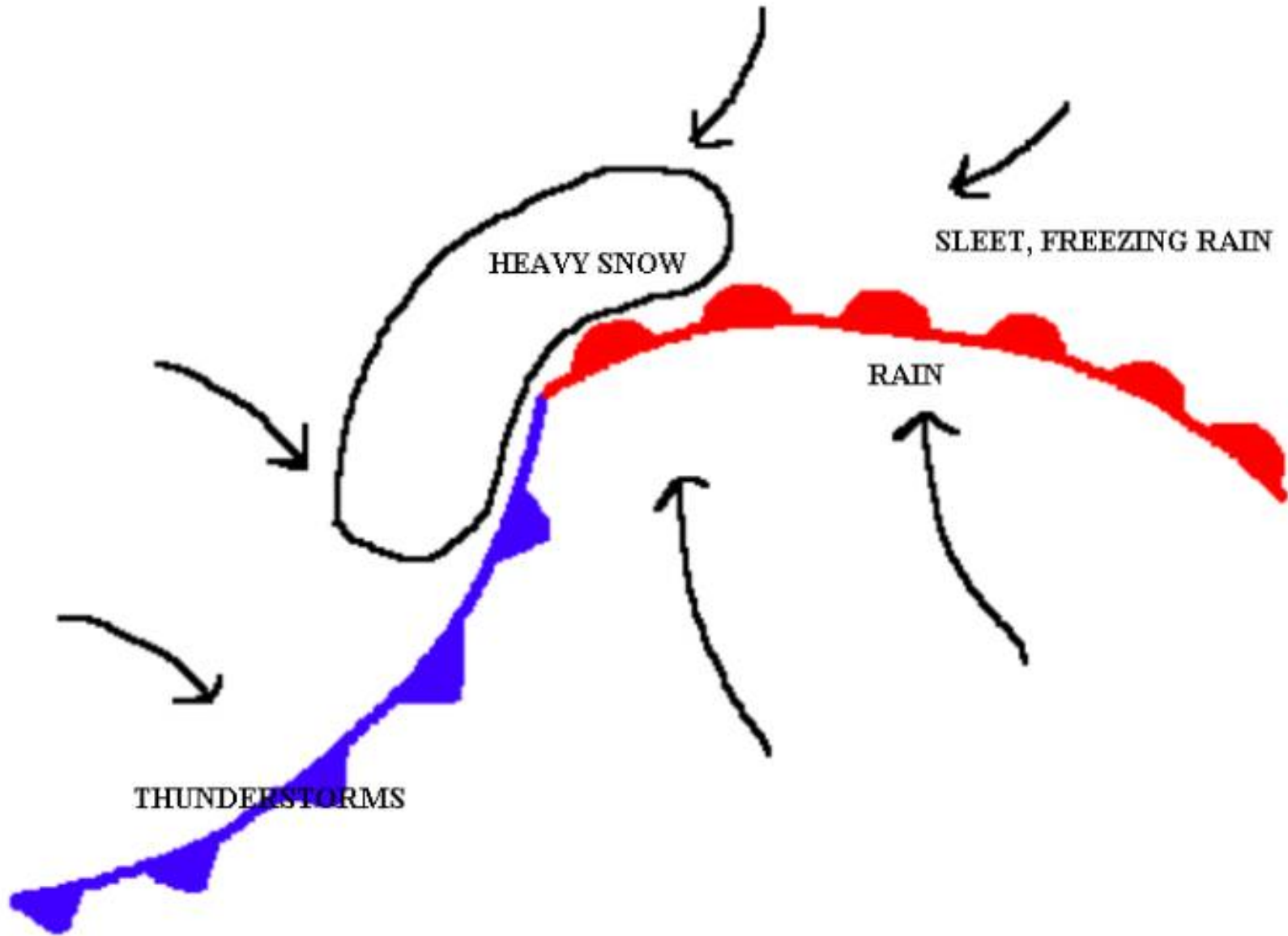
2. **Hatteras Low and Northeasters:** These are the MOST INTENSE systems and they form along the thermal boundary between the warm Gulf Stream and the cold Atlantic coast. They can bring flooding rains along the coast and several feet of snow further inland as they use the ocean as a vast source of the moisture. These also develop very quickly and sometimes have pressure drops of 24mb in a single day. With a pressure drop of this magnitude you can imagine how fast the winds are around these things.

# What are their typical tracks?



# Precip patterns (and types), winds, temperatures, fronts, upper level flow and clouds that are around a typical mid-latitude cyclone in winter.





# Summary I

- Classical model
  - Unstable surface frontal zone
  - Open wave forms
  - Then and occlusion and isolated low N of front
- Polar Front Jet: Narrow band of strong winds
- Jet MAX:
  - Patch of extra strong wind that moves along the JET more slowly than the wind itself
  - Ascent ahead and to the left of MAX; descent behind
  - Triggers frontal cyclone formation when it moves over a surface baroclinic zone
- New model of occlusion
  - Warm upper low engulfed by cold air
  - Cold surface high engulfed by warm air
- Moves heat and cyclonic rotation poleward and cold and anticyclonic rotation equatorward

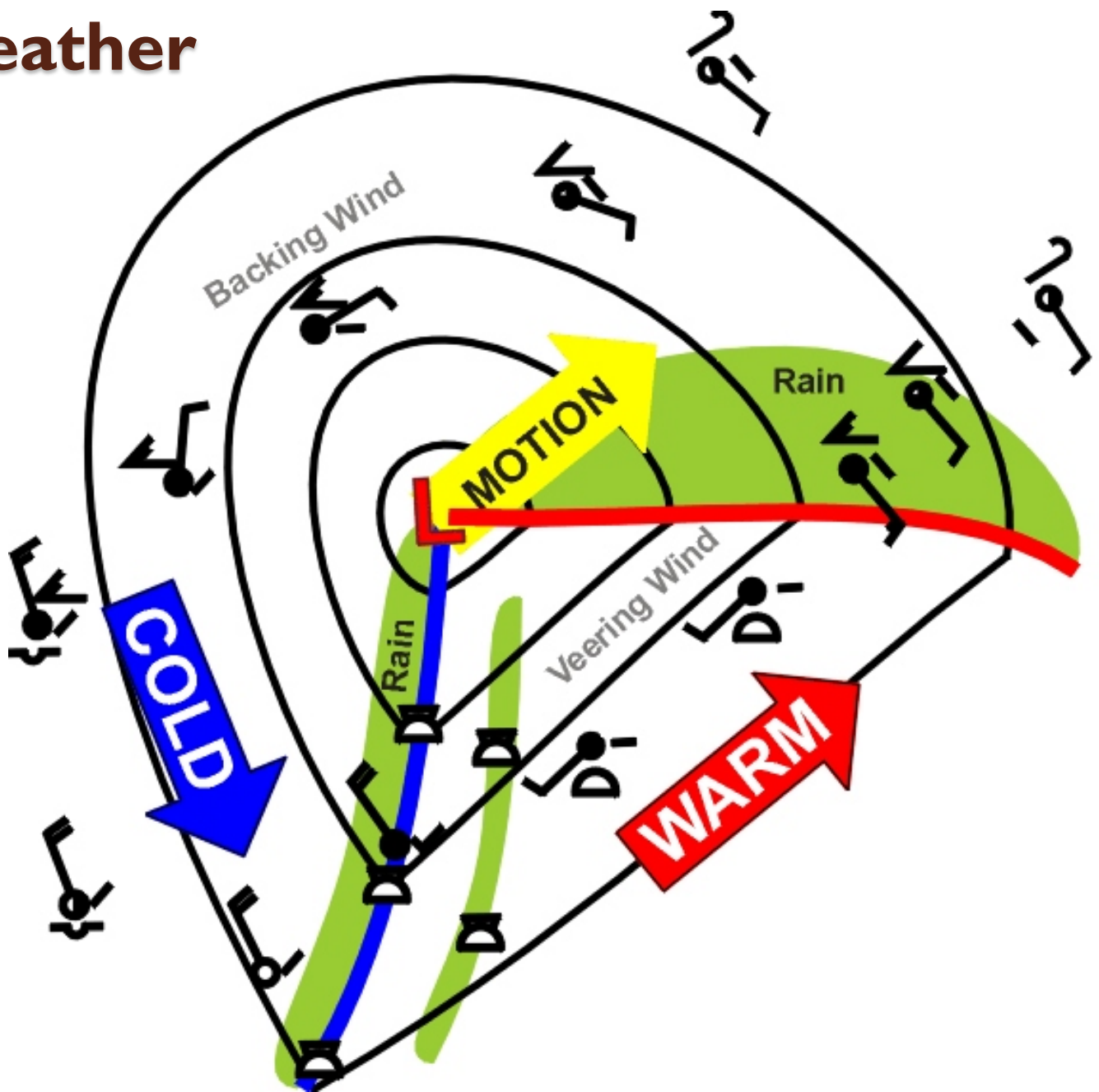


# Frontal Cyclone Forecasting

## Changes of Wind With Time

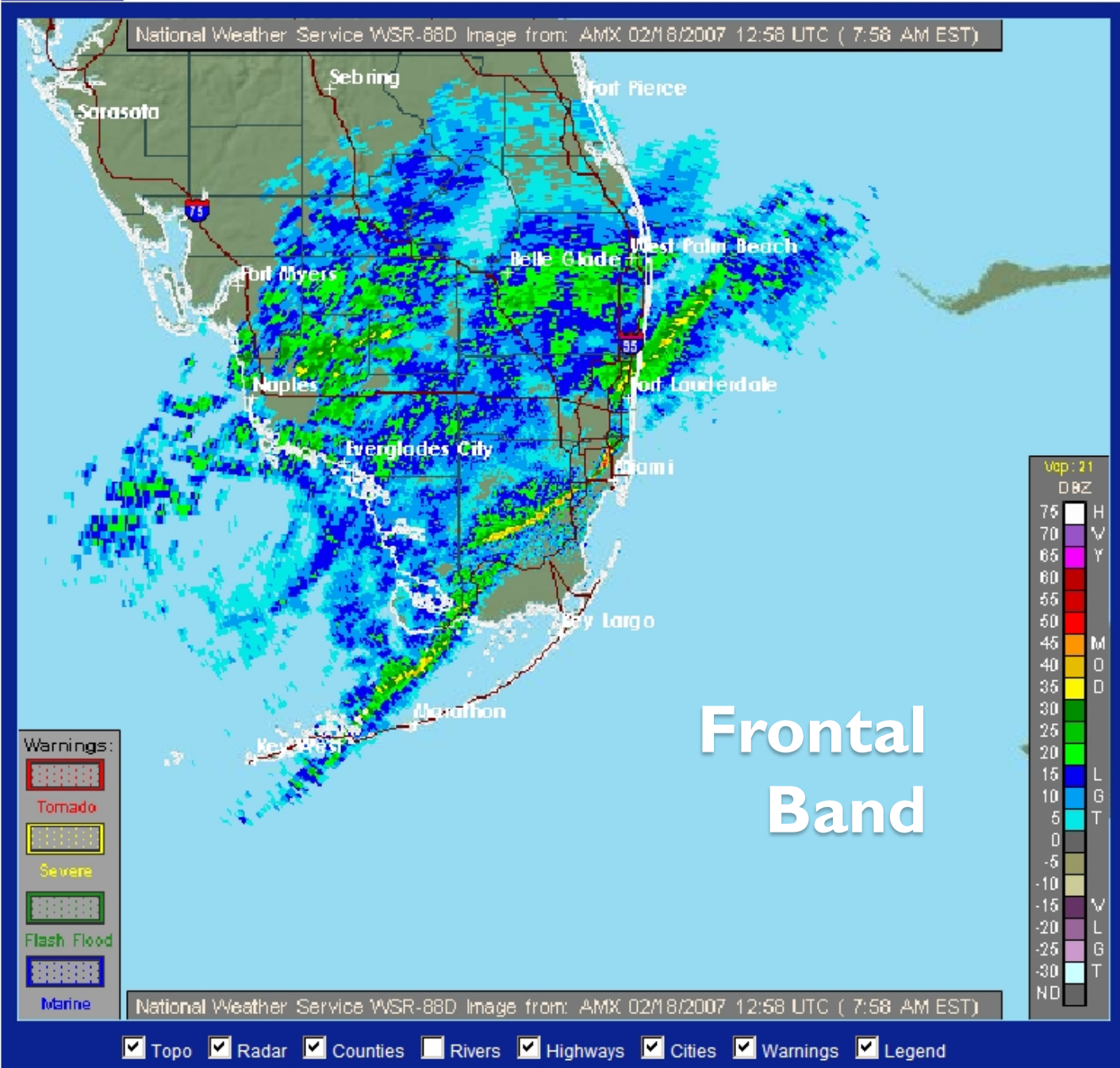


# Cyclone Weather



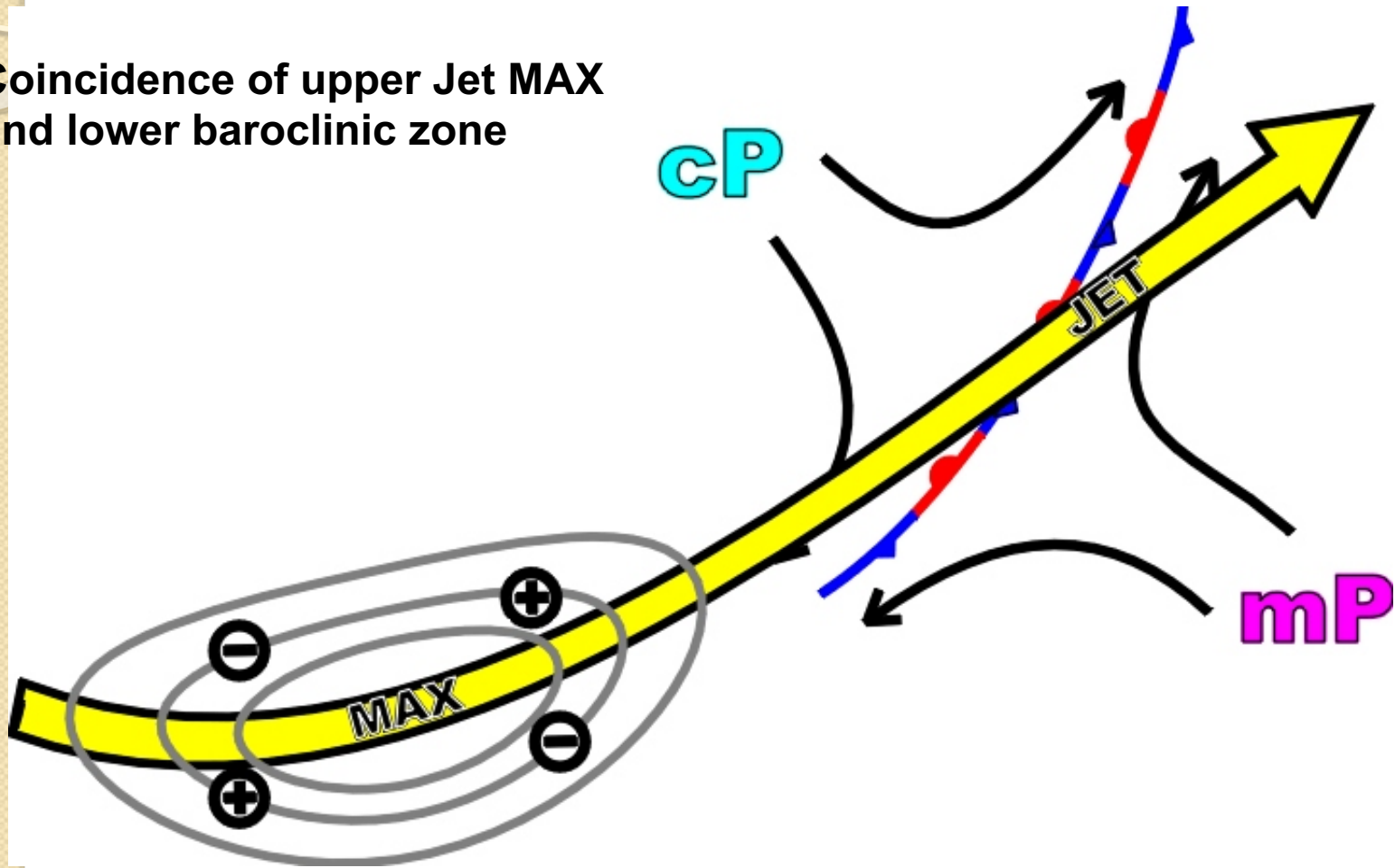
# Weather Sequences

- To the RIGHT of storm track wind VEERS with time
  - Clouds increase from Ci → As → Ns in S winds as the warm front approaches
  - Increasing precipitation and falling barometer
  - Some clearing, SW wind, Cu or TCU, and showers after frontal passage
  - Barometer steady
  - Convective rain, Cb's, wind VEERS from N or NW, and rising barometer after cold frontal passage
  - Followed by clearing or Sc
- To the LEFT of storm track wind BACKS with time
  - Increasing clouds from Ci → As → Ns in S → SE winds as the cyclone approaches
  - Increasing precipitation and falling barometer
  - Winds from the E or NE when the barometer is lowest
  - Wind BACKS from NE then (perhaps) N as the barometer rises.
  - Clearing may be abrupt in N or NE winds as the comma cloud moves away from the station



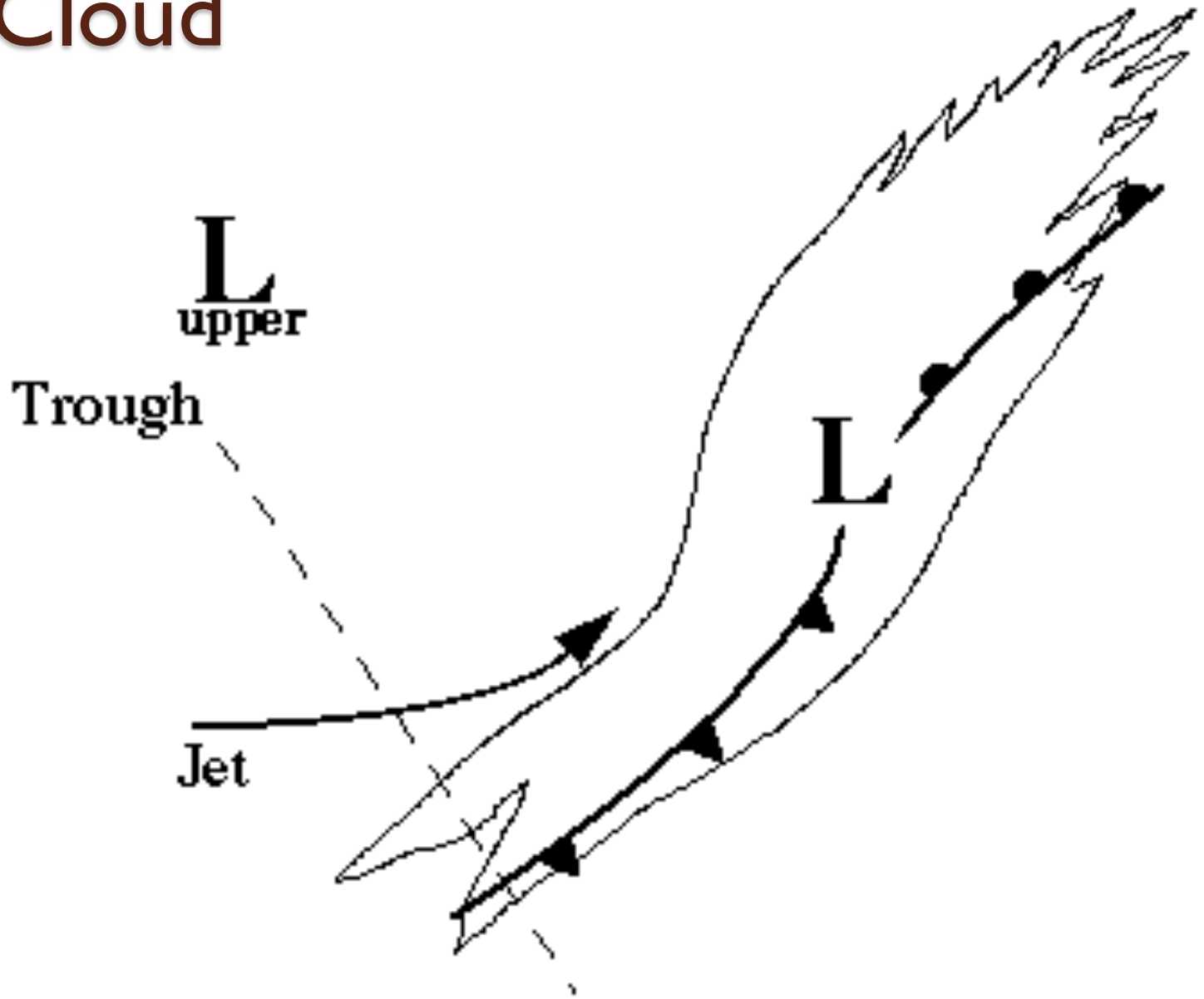
# Frontal Cyclogenesis

Coincidence of upper Jet MAX  
and lower baroclinic zone

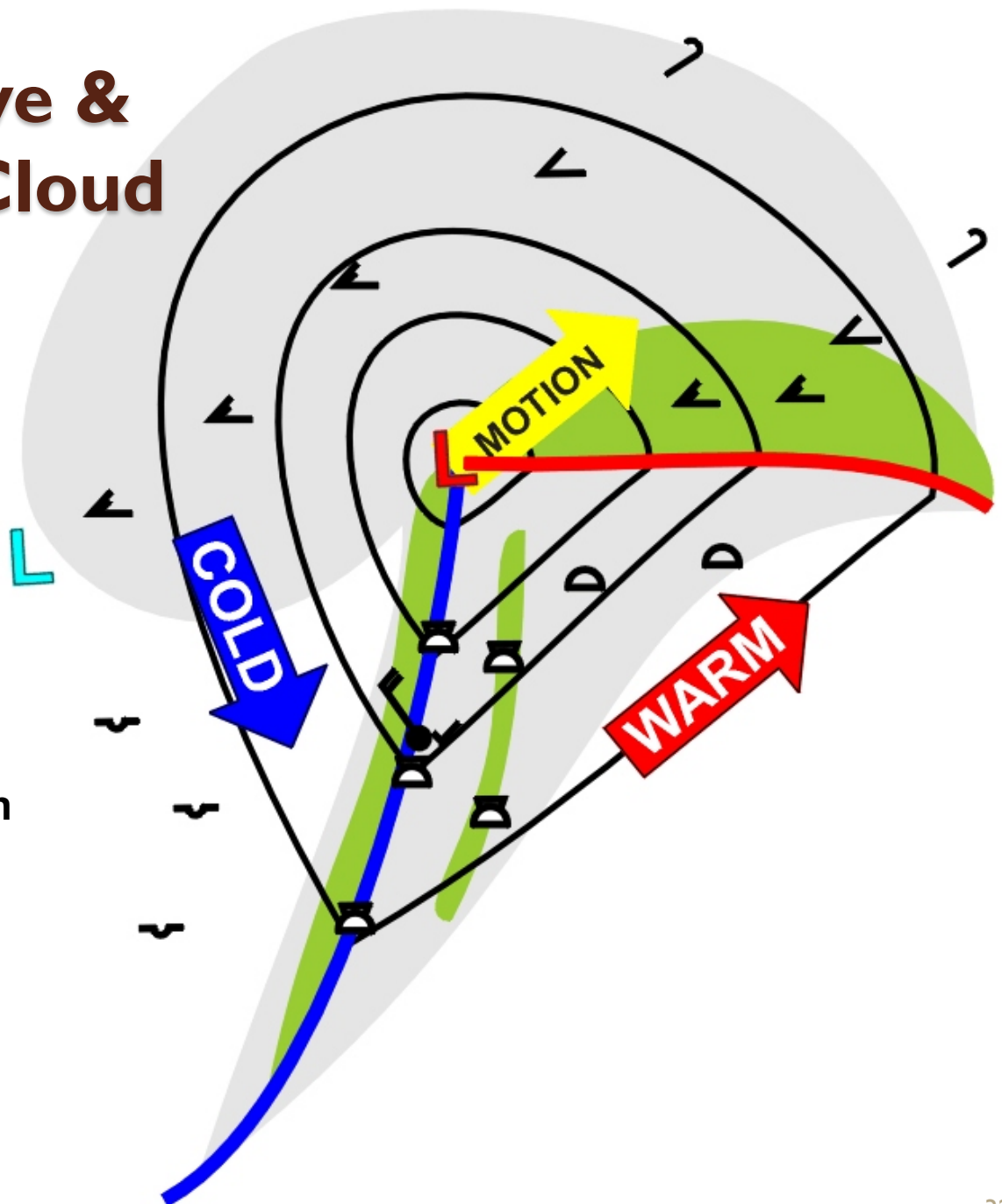




# Leaf Cloud

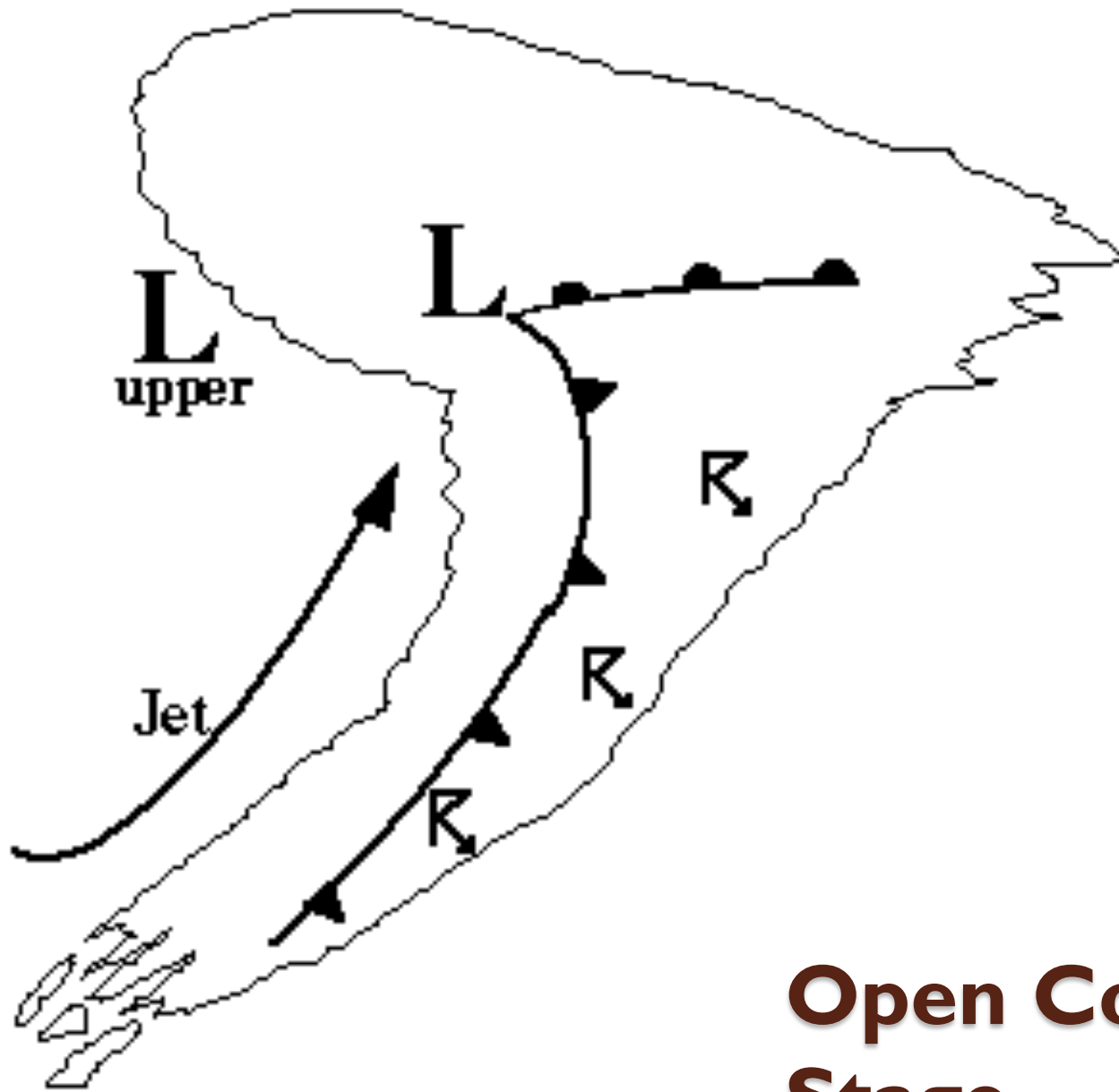


# Open Wave & Comma Cloud



Leaf cloud becomes a comma cloud as the open wave intensifies through baroclinic instability

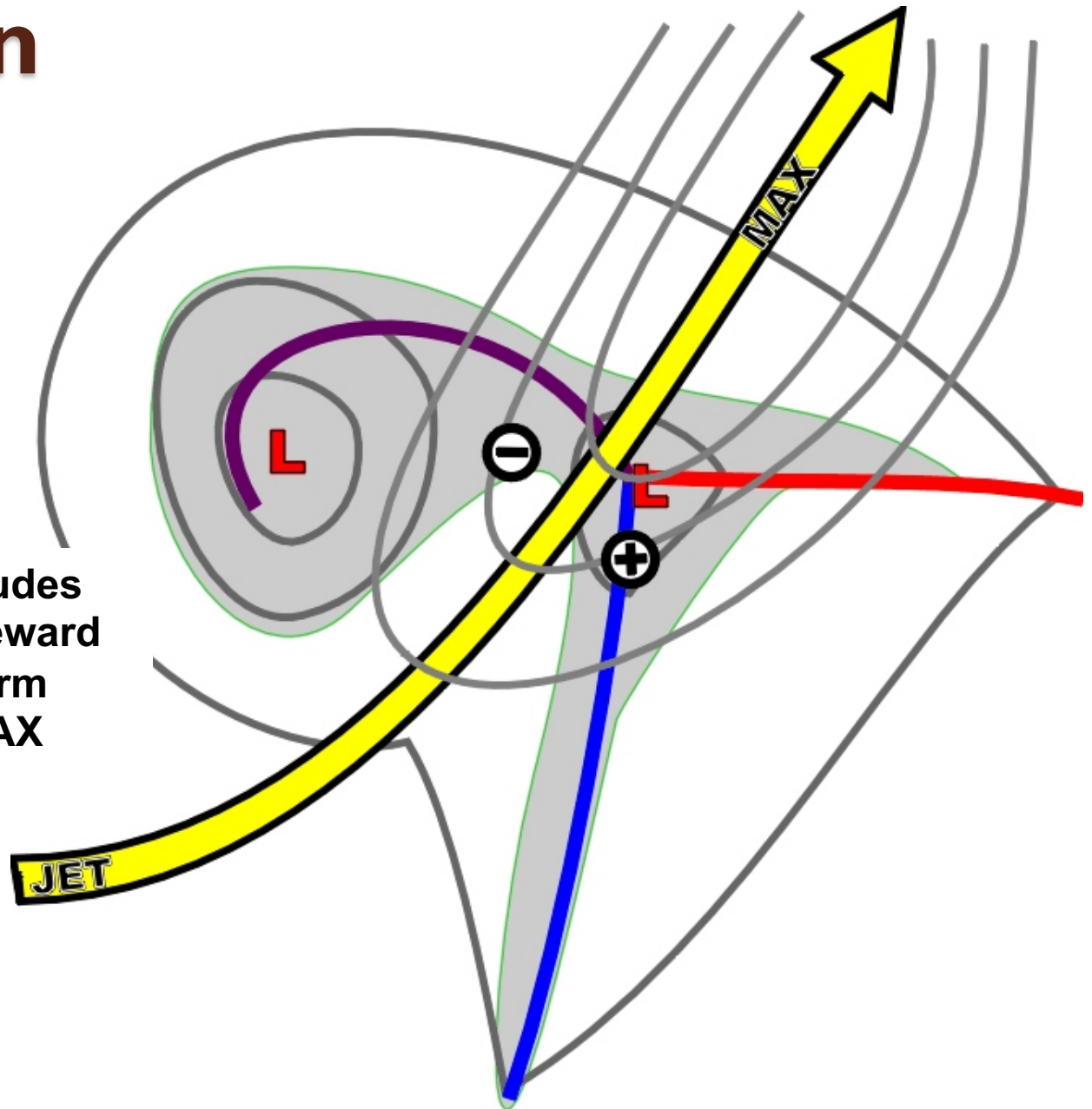


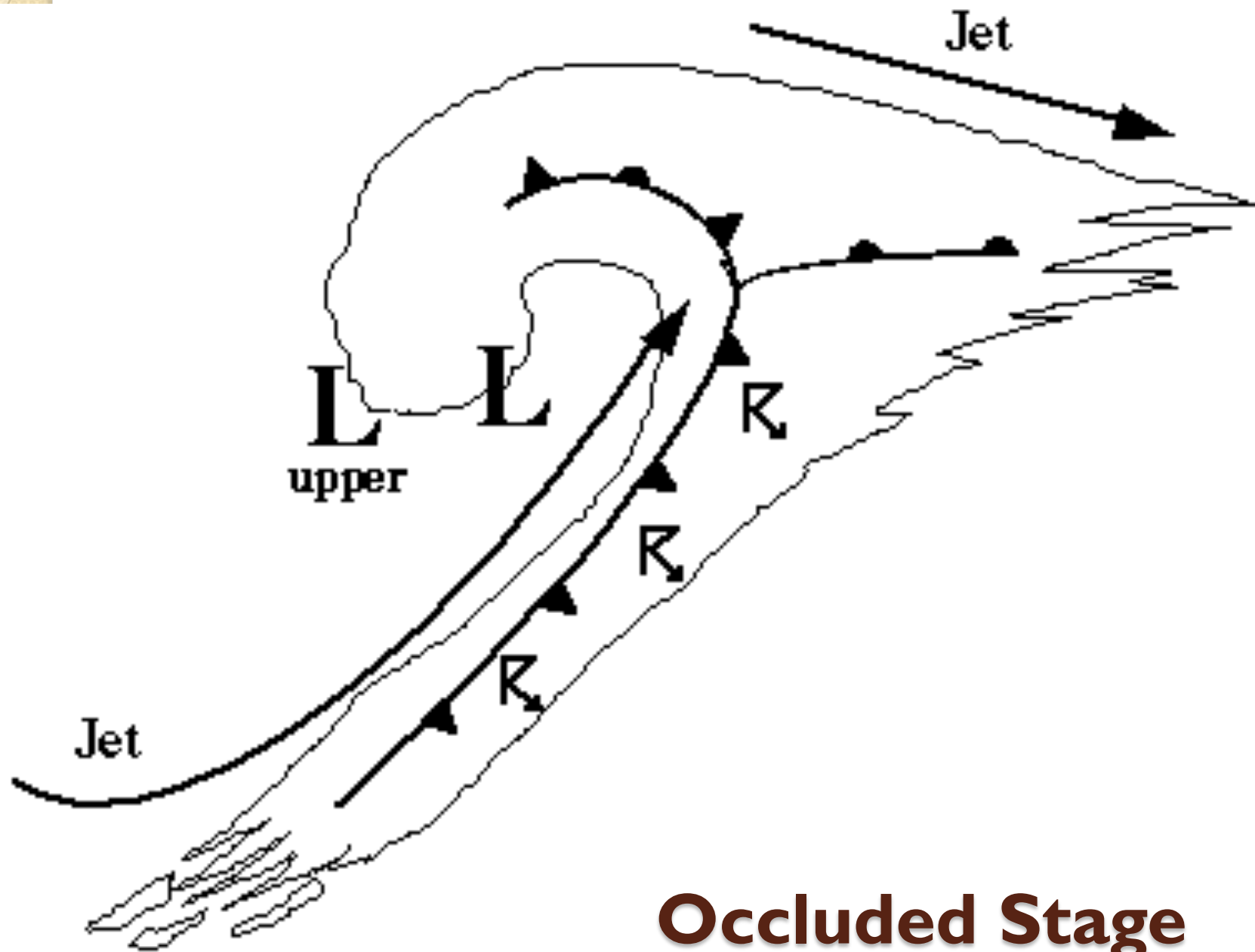


## Open Comma Stage

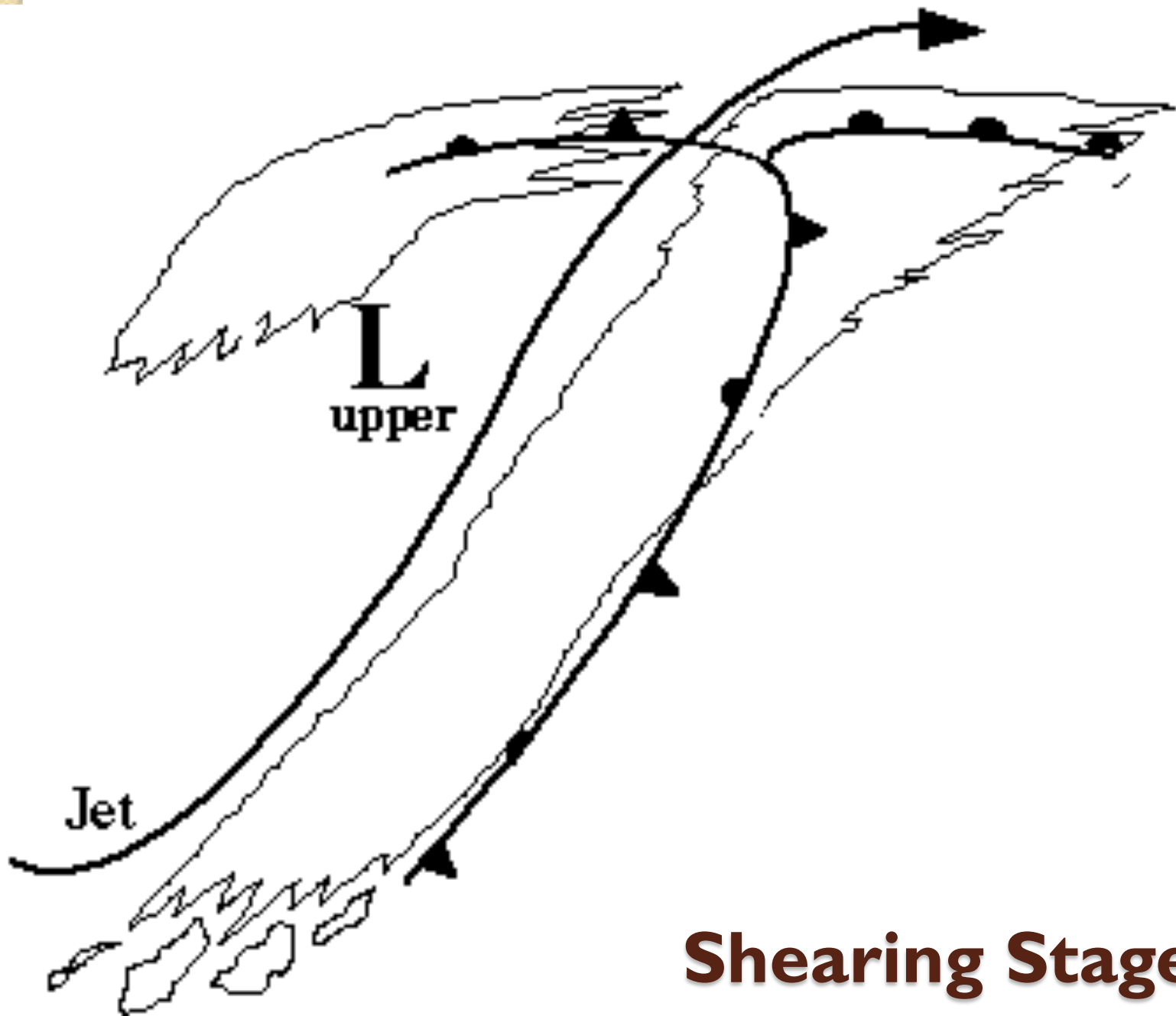
# Occlusion

Frontal cyclone occludes as the jet moves poleward of the apex of the warm sector and the Jet MAX moves past it





## Occluded Stage



## Shearing Stage

# Cyclogenesis Forecasting Rules

- Strong upper-level winds favor cyclogenesis
- Cold advection on the W side of the trough favors cyclogenesis
- Warm advection on the E side of the trough favors cyclogenesis
- Waves are more likely to form on slowly moving fronts
- Cyclongenesis is most likely to occur where cyclonically curved flow crosses the front
- Cyclogenesis is most likely under upper positive vorticity advection

# Intensity Forecasting Rules

- Falling pressures in the warm sector often indicate intensification
- Diffluent, cyclonically curved flow aloft favors intensification
- Lows moving to the left of steering, or toward cold air, generally deepen
- Lows that lean toward cold air (phase lag) deepen

# Motion Forecasting Rules

- East of  $100^{\circ}$  W, most Extratropical Cyclones (XTCs) move toward the NE
- West of  $110^{\circ}$  W, most XTCs move S or SE
- XTCs direction of motion is  $\sim 15^{\circ}$  poleward of upper steering
- XTCs move with 70% of the 700 mb wind
- XTCs move with 50% of the 500 mb wind
- Surface lows follow the area of greatest warm advection
- XTCs move parallel to the isobars (if they are straight) in the warm sector with the wind speed in the warm sector.
- XTCs move toward the center of 3-h pressure falls and away from the center of 3-h rises

# USA

LATITUDE LONGITUDE  
MAP





# Summary 2

- Backing (turns cyclonically) and Veering (turns anticyclonically) on right and left sides of storm track
- Weather sequence as an XTC passes
- Upper Jet MAX and near-surface baroclinic zone are both necessary for cyclogenesis
  - Ascent and vortex stretching in left exit region of Jet Max
  - Leaf cloud becomes the comma cloud
  - Ascent switches sides after MAX passes over cyclone
  - Occlusion occurs when Jet moves poleward of warm sector apex as MAX moves away
  - Dry slot due to receding Jet MAX
- Forecasting rules for formation, intensity, and motion
- Use numerical guidance...