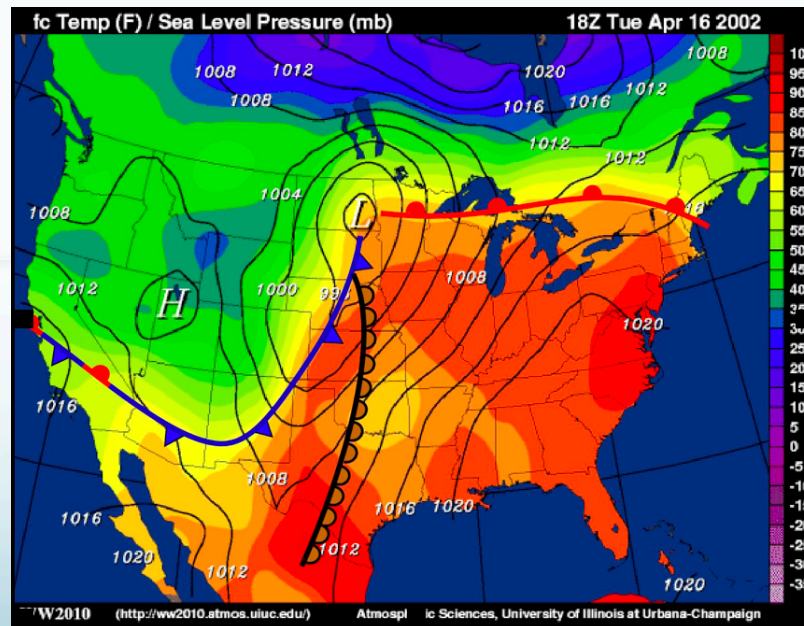


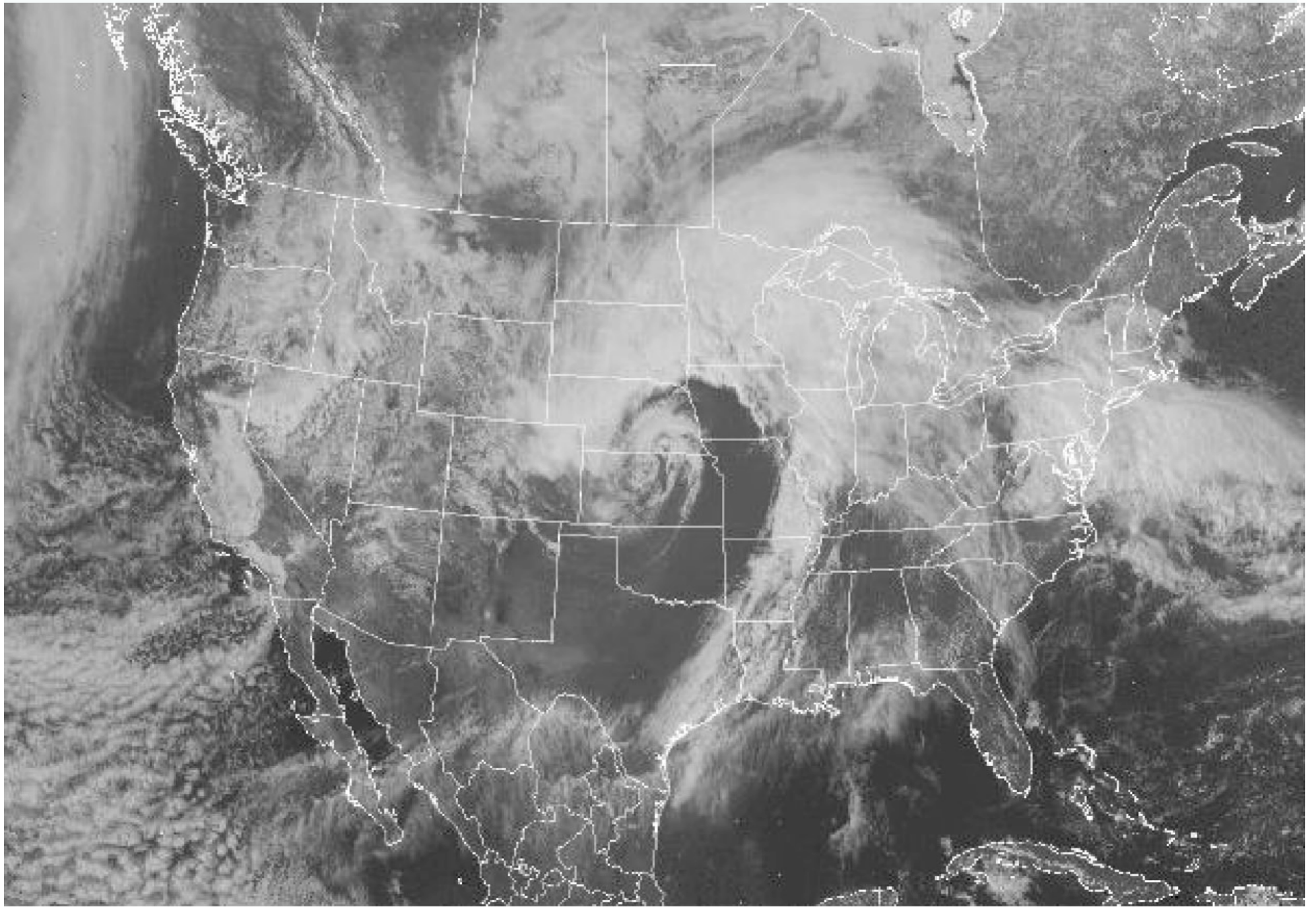
Chapter 10

Extratropical Cyclones East of the Rockies



What is an Extratropical cyclone?

- **Extratropical cyclone** – a storm system that forms along the jetstream between about 30 and 70 degrees latitude
 - These storms are also called mid-latitude cyclones.
- What role do they play?
 - Nature's way of balancing the temperature differences between the poles and equator (in the horizontal) and between the upper and lower troposphere (in the vertical)



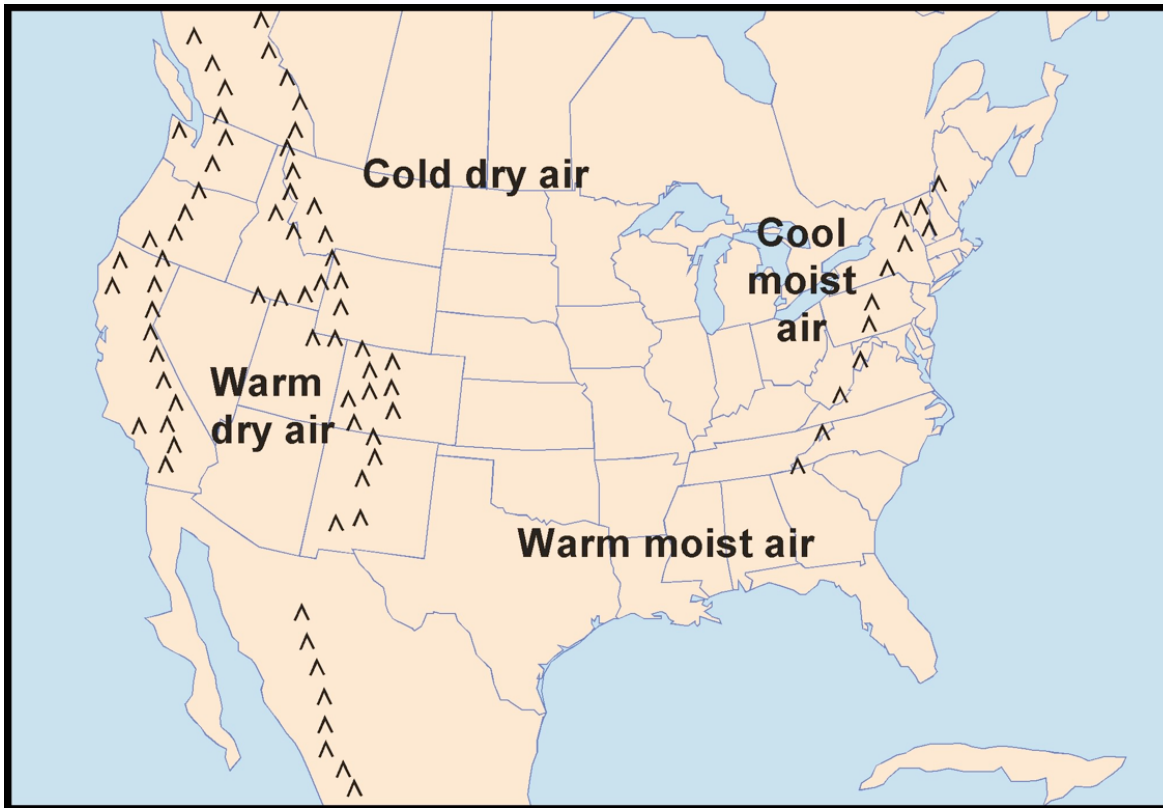
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Characteristics

- Characteristics of extratropical cyclones:
 - Sea level pressure
 - Low pressure center
 - Airflow at the surface
 - Cyclonic, or counterclockwise, in northern hemisphere
 - Size and appearance
 - Several 100 to several 1000 miles across (~1/3 lower 48 states)
 - Cyclone life cycle
 - Several days to over a week
- Where do extratropical cyclones typically form in North America?
 - Generally 5 locations: east of Colorado Rockies, east of Canadian Rockies, TX-LA coastline, along US east coast, over Bering Sea and Gulf of Alaska in northern Pacific ocean
 - We will focus on those forming east of the Colorado Rockies

Development environment

- What airmasses are present prior to cyclone formation?

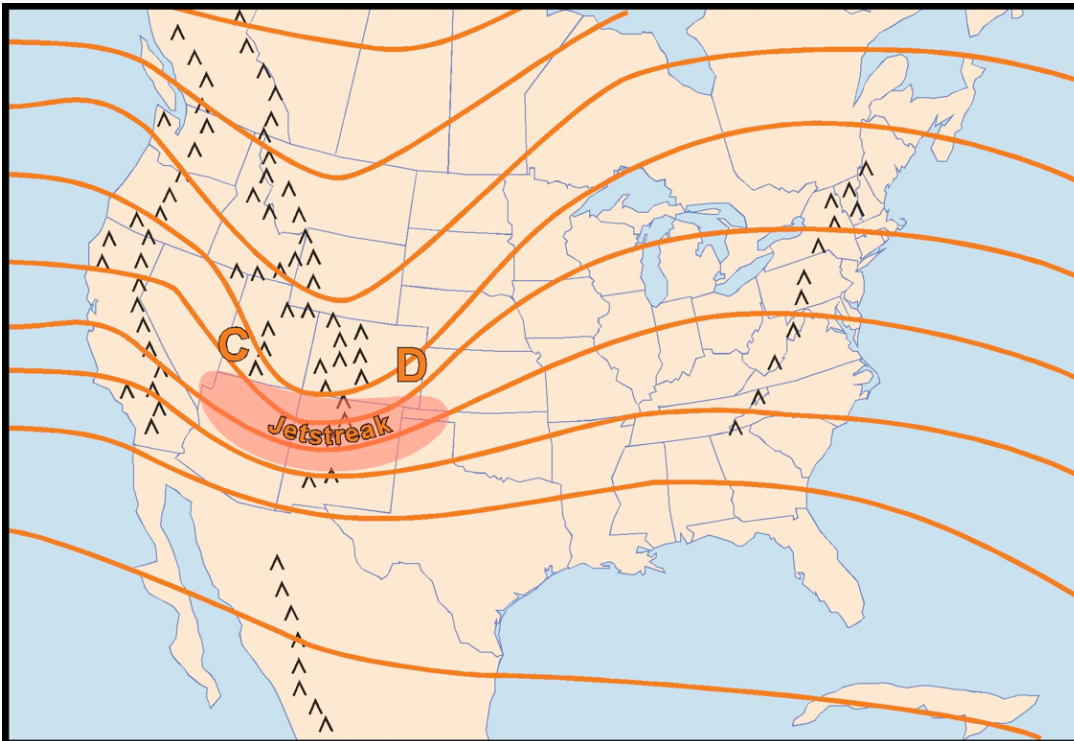


Surface airmasses

Upper level
airmasses

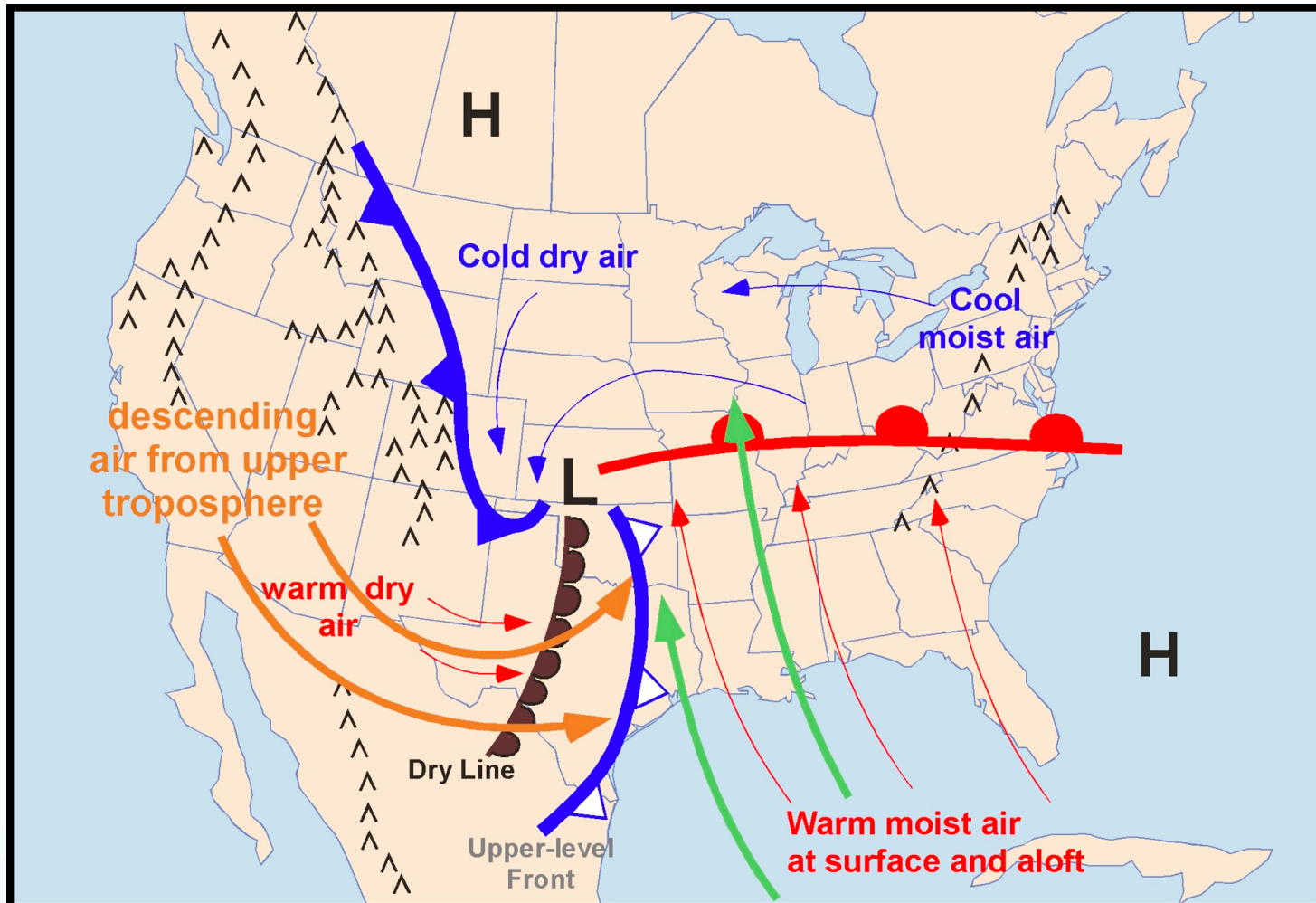
Initial development

- How does low pressure form at the surface?
- What atmospheric features, at upper levels, are associated with cyclone formation at the surface?



Wave – a ripple in the jetstream

How often do waves in the jetstream cross the Rocky Mountains?



- How do the airmasses at the surface move in response to the cyclone?
- What airmasses are present at upper levels of the troposphere?
- What types of fronts are associated with the cyclone, and where are these fronts located relative to the low pressure center?

Clicker Question

- On an infrared satellite image an extratropical cyclone often appears like _____.
 - A. A question mark
 - B. An exclamation point
 - C. A comma
 - D. A semi-colon

Clicker Question

- Extratropical cyclones are important in the atmosphere because they transport warm air towards the _____ and cold air towards the _____ in the Northern hemisphere.
 - A. North, north
 - B. North, south
 - C. South, south
 - D. South, north

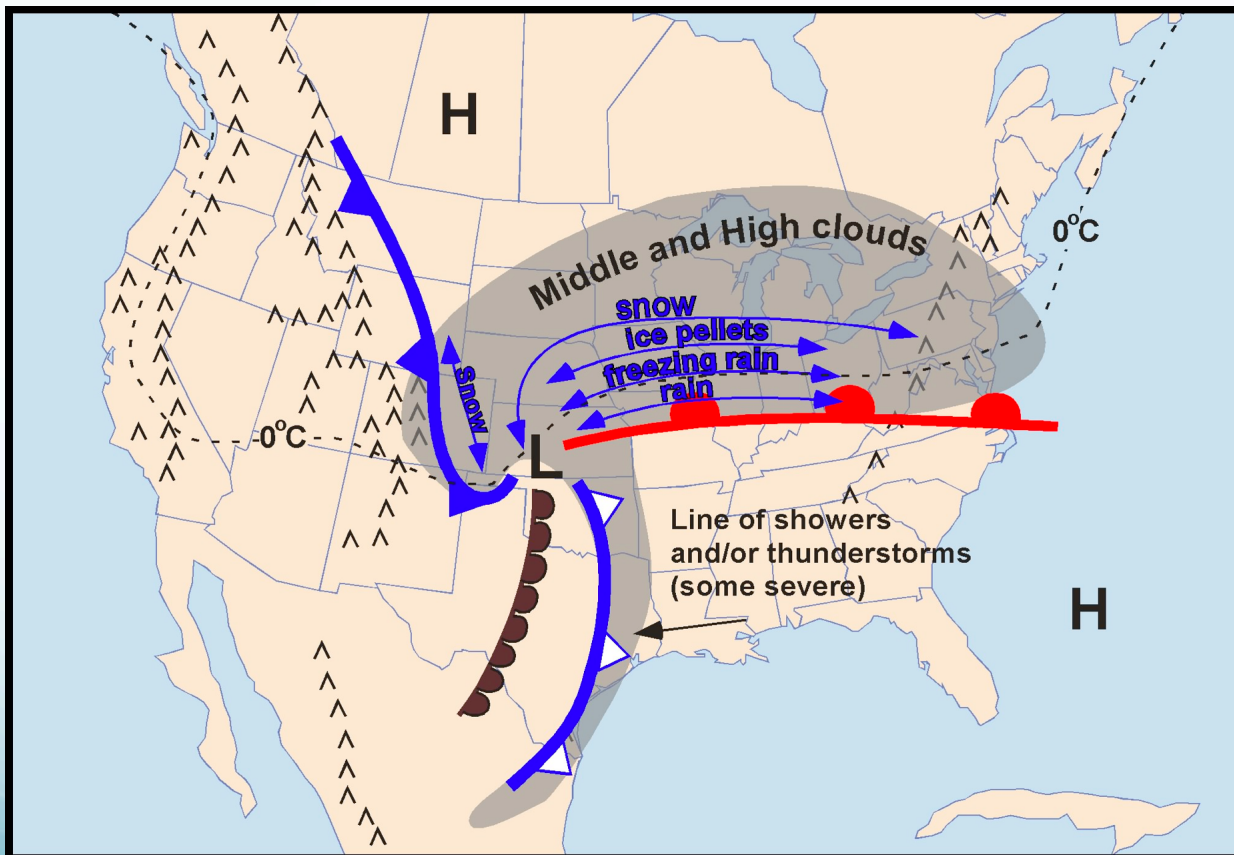
Clicker Question

- Extratropical cyclones do not typically form _____.
- A. Just east of the Colorado Rocky Mountains
- B. Along the Texas-Louisiana Gulf coast
- C. Over southern California
- D. Over the Gulf of Alaska

Clicker Question

- You would expect to find divergence in the upper troposphere _____ and in the _____ region of a jetstreak.
 - A. ahead of a trough, right-exit
 - B. ahead of a trough, left-exit
 - C. behind a trough, right-exit
 - D. behind a trough, left-exit

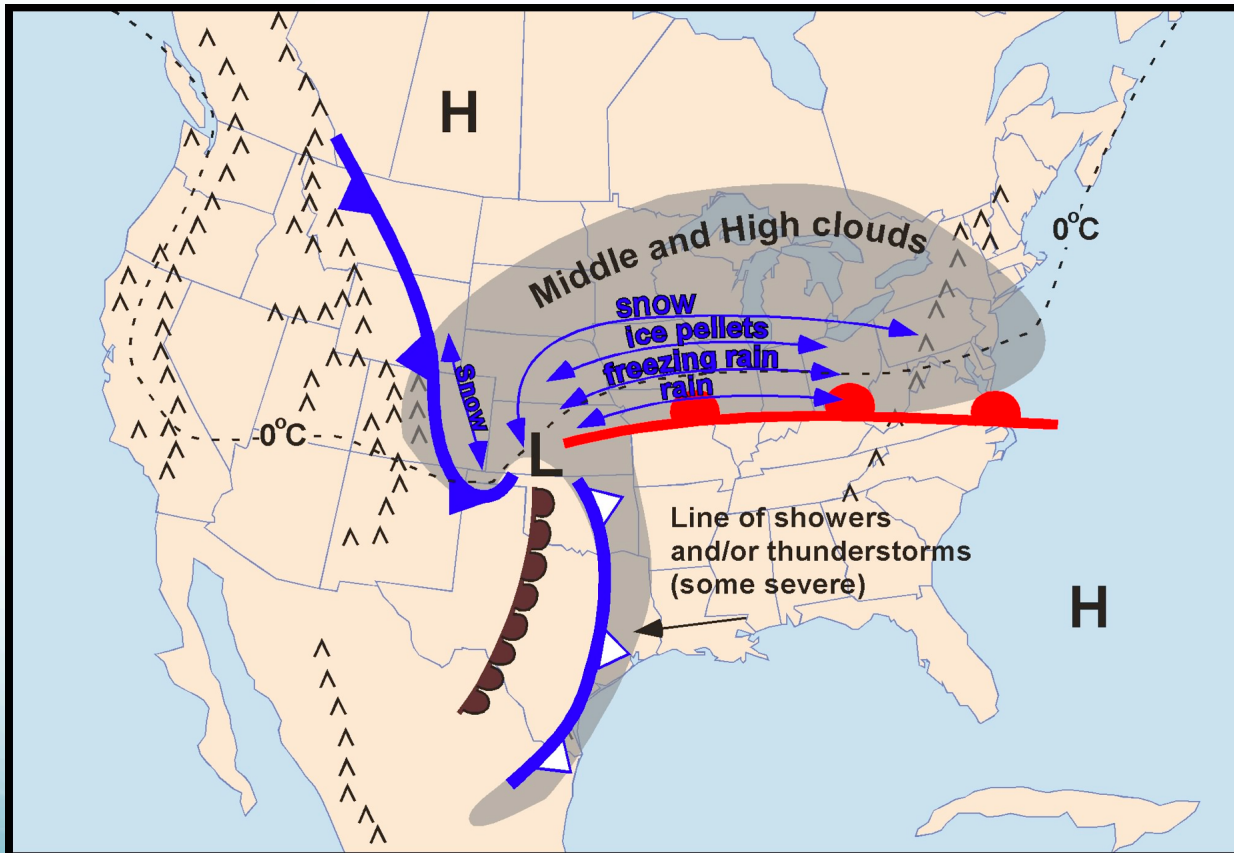
Weather along the fronts: East of cyclone center



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- What type of front is located east of the cyclone center?
- Where are the clouds and precipitation associated with this front located?
- How do the clouds and precipitation change as you move north of the warm front?
- What determines if the precipitation associated with the warm front will be steady or showery?

Weather along the fronts: South of cyclone center

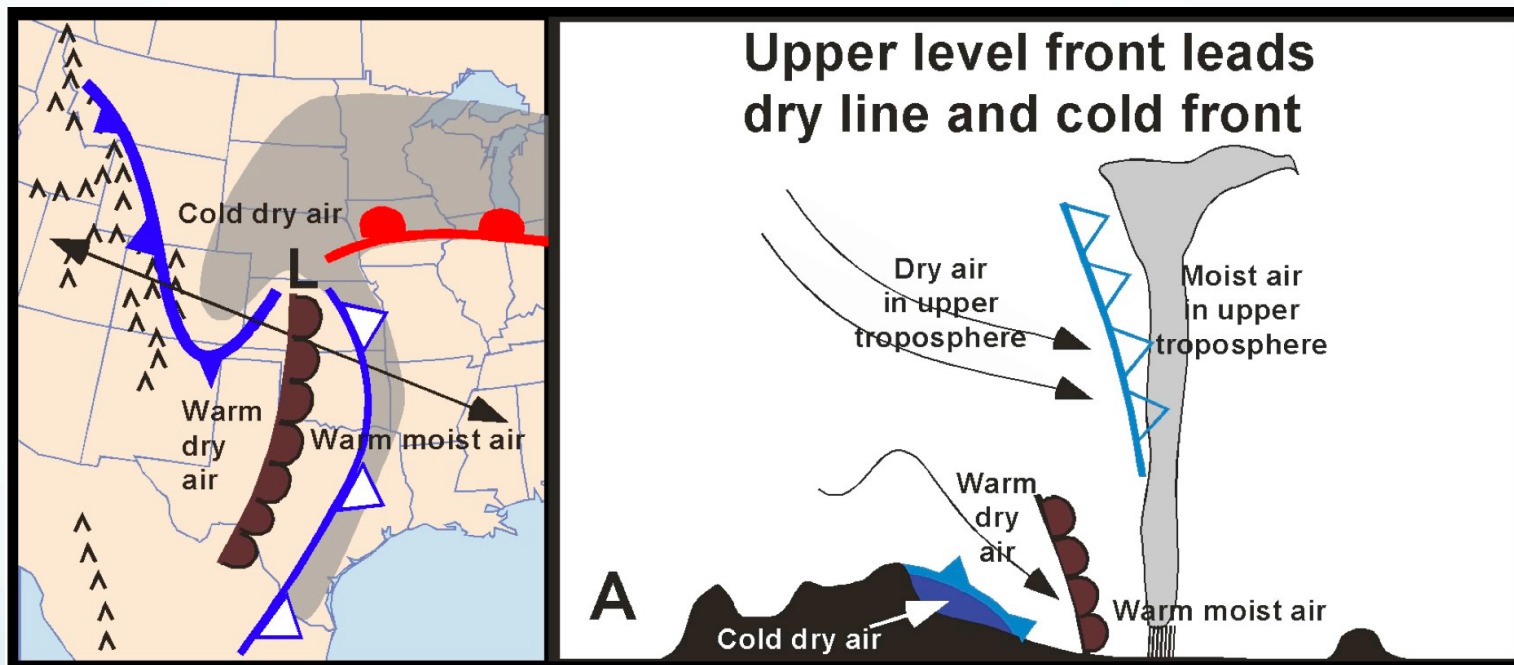


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- What types of airmasses are located south of the cyclone center?
- What types of fronts are located south of the cyclone center?
- The position and types of fronts south of the cyclone center may be different from one cyclone to another.

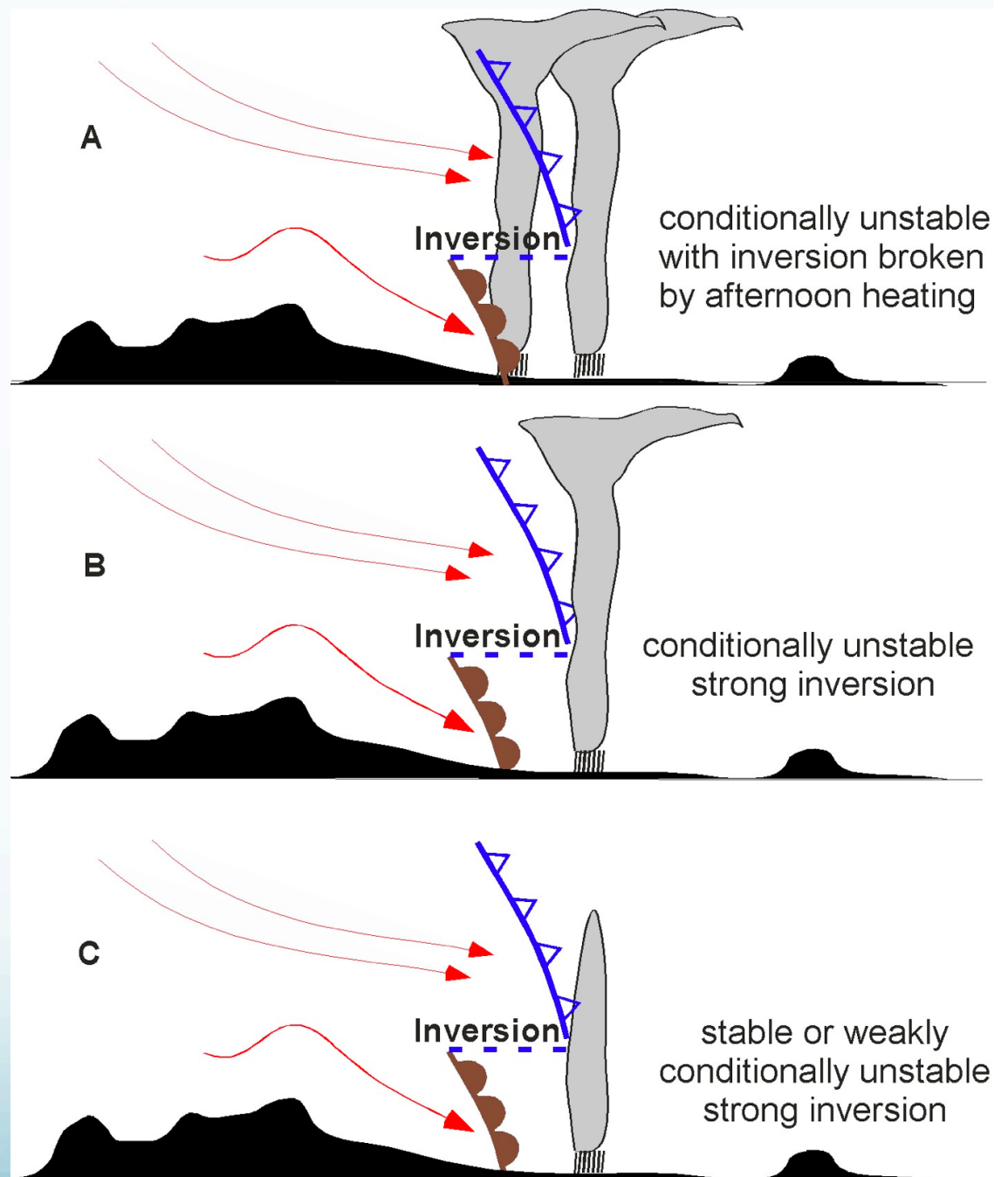
Case 1

- Upper level front leads dry line and cold front



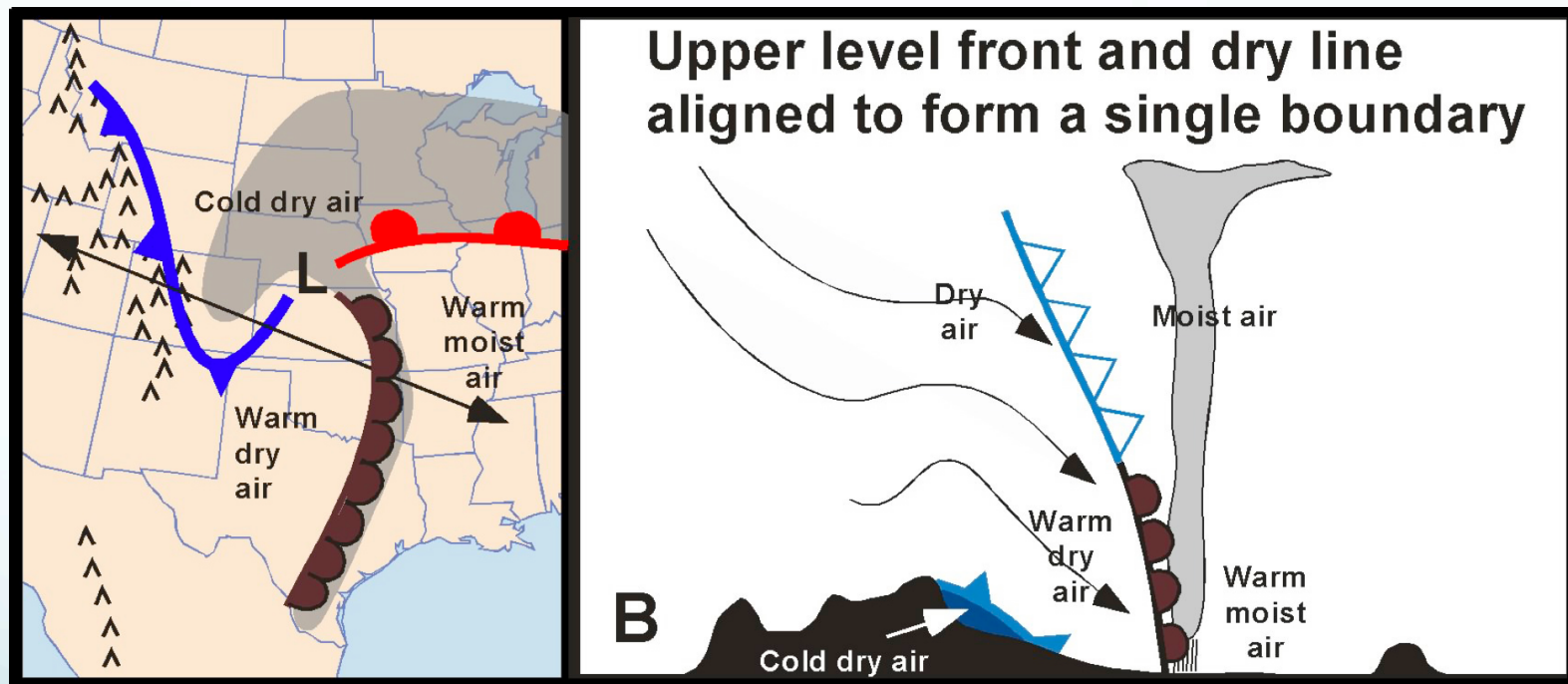
- Warm, moist air is ahead of the dry line at the surface and ahead of the upper level front aloft.

- For this situation, what weather is associated with the
 - Upper level front?
 - Dry line?
 - Cold front?
- General rule:
 - Thunderstorms will form if a front is lifting warm, moist, conditionally unstable air.
 - No clouds will form if a front is lifting dry air.



Case 2

- The Upper Level Front and Dry Line are Aligned

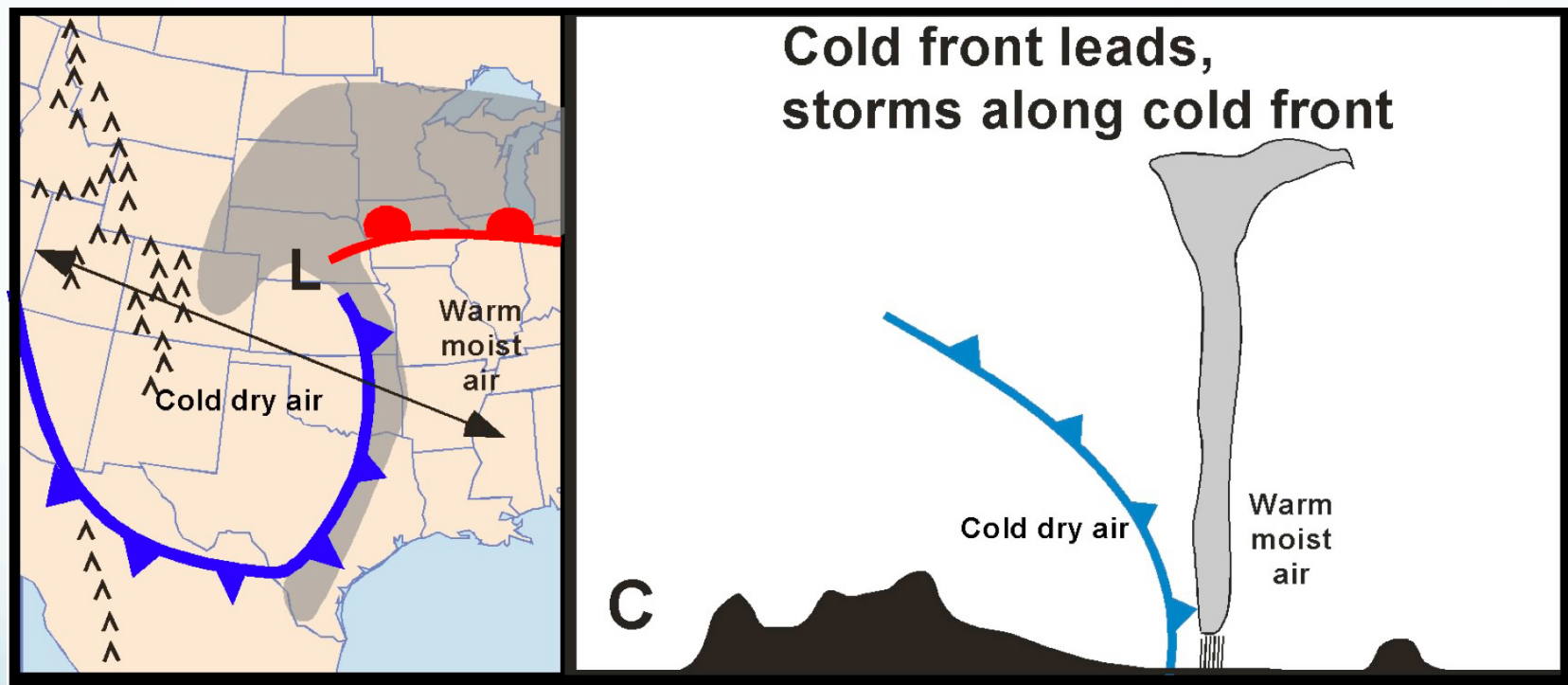


What types of weather occur along the dry line / upper level front?

What types of weather occur along the cold front?

Case 3

- The Cold Front Leads



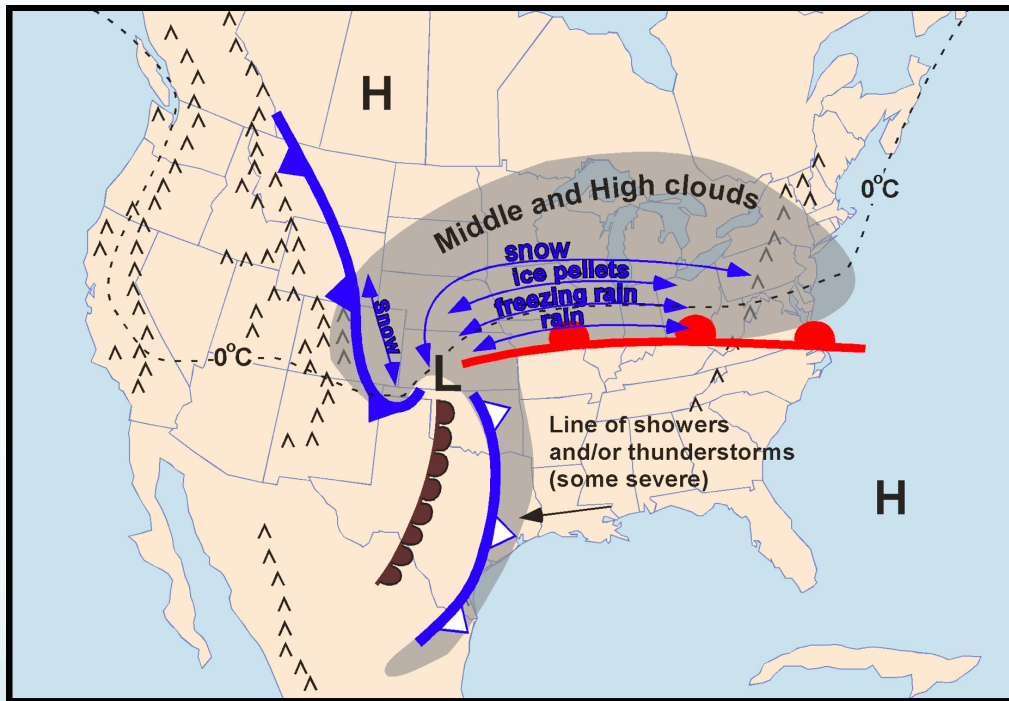
What conditions favor the cold front being the leading front south of the low pressure center?

What types of weather occur along the cold front?

The tail of the comma cloud

- For each of the cases discussed above the clouds that form along the front, or fronts, south of the low pressure center form the tail of the comma cloud signature often seen in satellite images of mid-latitude cyclones.

Weather along the fronts: Northwest of cyclone center



- What is the wind direction north of the cyclone center?
- **Upslope flow** – air is forced to rise as it flows from lower elevations to higher elevations
- What wind direction creates upslope flow in Boulder?
- What happens to air as it is forced to rise?
- What types of weather are associated with upslope flow?

Alberta clipper – an extratropical cyclone that is similar to extratropical cyclones that form east of the Colorado Rocky Mountains, but that forms east of the Rocky Mountains in Alberta, Canada.

Clicker Question

- You would most likely find a warm, dry airmass moving _____ on the _____ side of an extratropical cyclone in the central United States.
 - A. Towards the west, north
 - B. Towards the east, north
 - C. Towards the west, south
 - D. Towards the east, south

Clicker Question

- For an extratropical cyclone that has just developed east of the Rocky Mountains in the United States you would expect to find a warm front _____ of the low pressure center and a cold front _____ of the low pressure center.
 - A. East, west
 - B. North, south
 - C. West, east
 - D. South, north

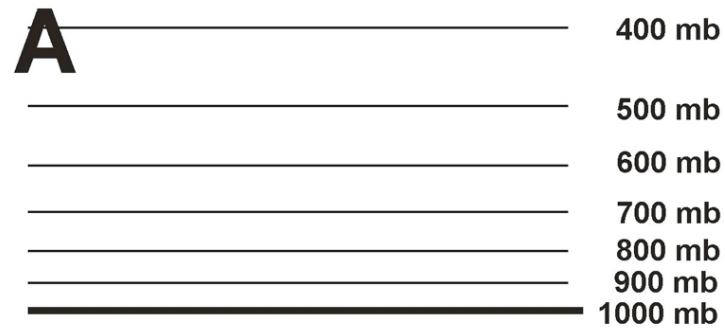
Clicker Question

- Where is a broad area of clouds and precipitation most likely to form in an extratropical cyclone?
 - A. Ahead of the cold front
 - B. Ahead of the warm front
 - C. Behind the warm front
 - D. Behind the dry line

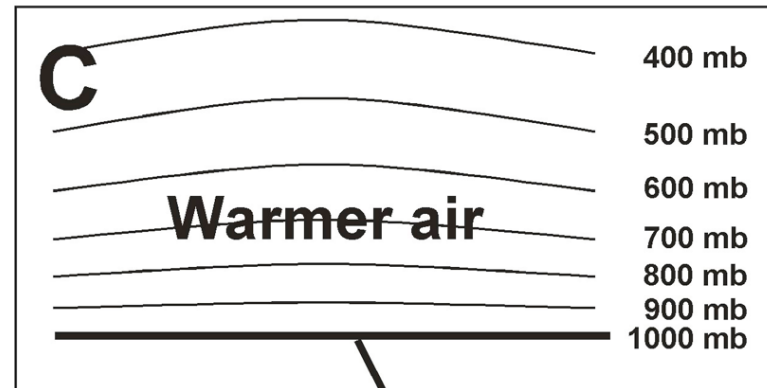
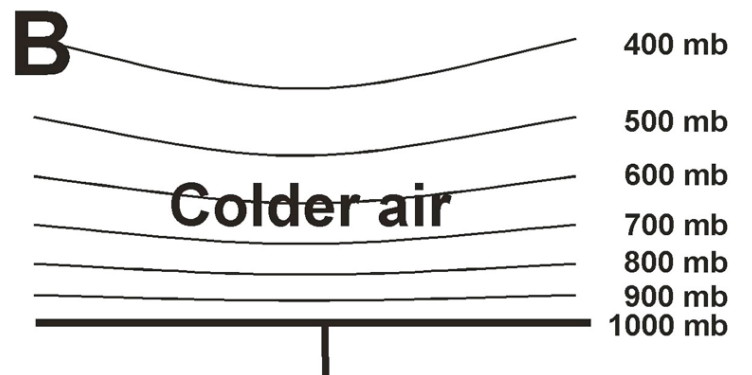
Storm intensification

- A cyclone is said to intensify when the pressure at the surface decreases.
- What factors will cause the surface pressure to decrease?
- How does the weather associated with a cyclone change as the surface pressure decreases?
 - Pressure gradient
 - Increases
 - Wind speed
 - Increases
 - Movement of airmasses
 - Temperature and moisture gradients along fronts become tighter = heavier precipitation and possibility for severe weather

Pressure surfaces fall as cold air moves southward under trough

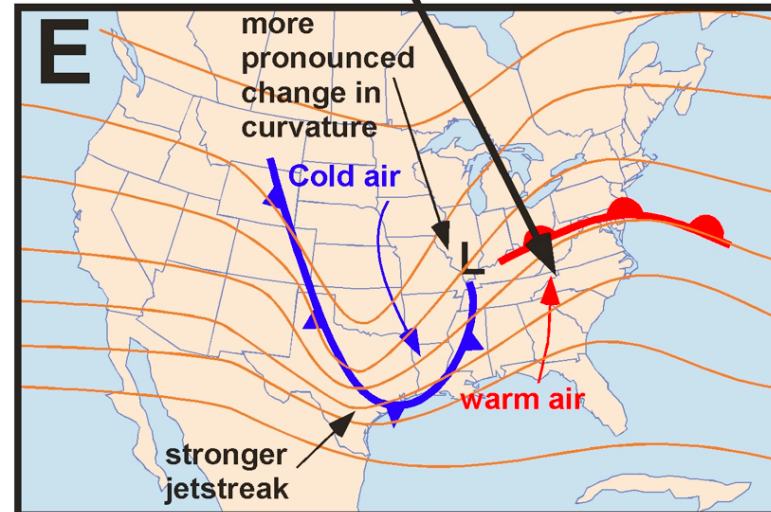
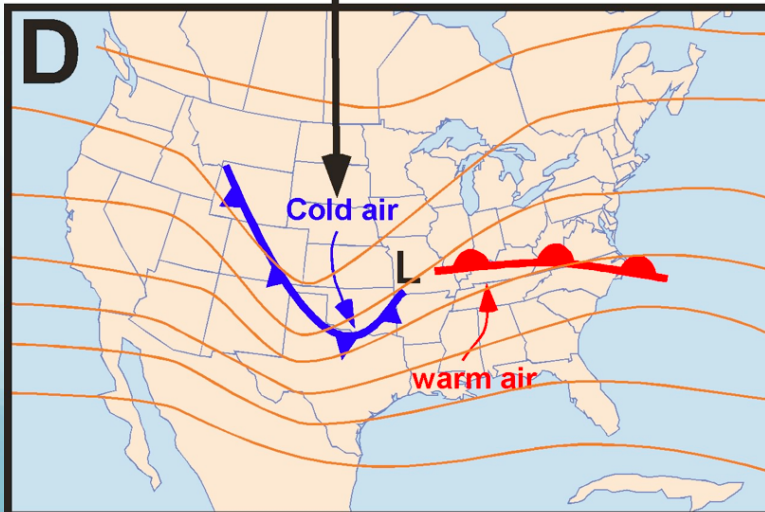


Pressure surfaces rise as warm air moves northward under ridge



Developing stage

Most intense stage

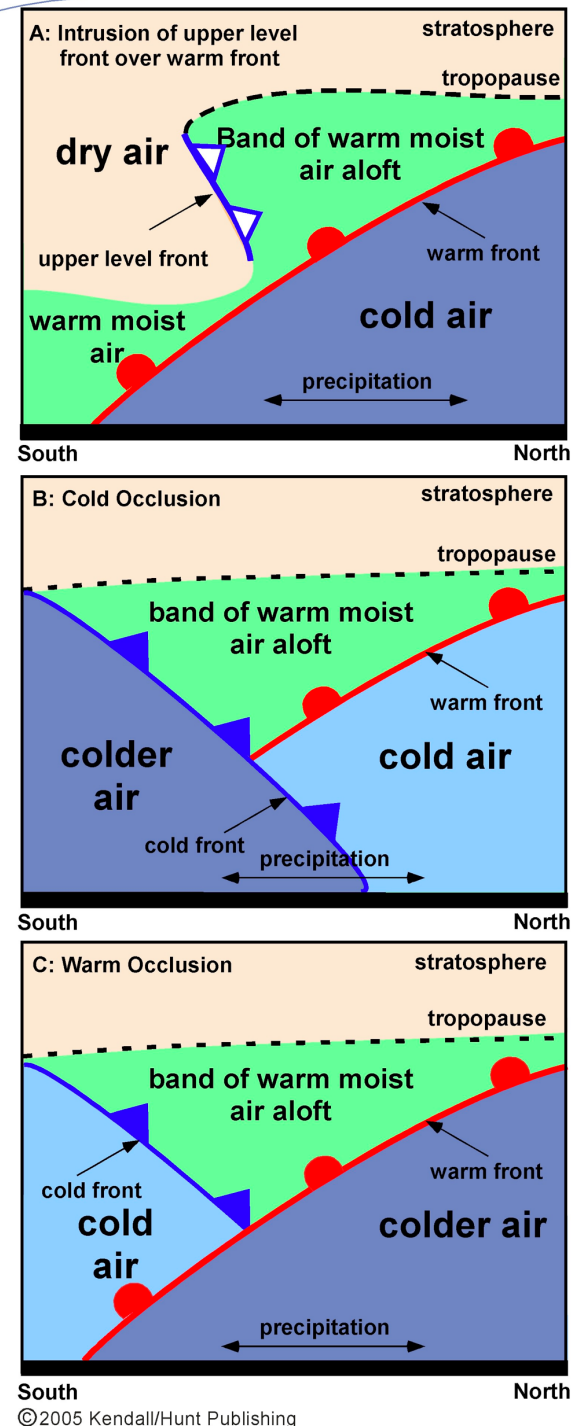


Recap of intensification

- As cold air advances south, on the west side of the low pressure center, the height of upper level constant pressure surfaces will decrease, causing the upper level trough to deepen.
- As warm air advances north, on the east side of the low pressure center, the height of the upper level constant pressure surfaces will increase, causing the upper level ridge to amplify.
- Both the deepening trough and the amplifying ridge lead to:
 - Increased curvature between the trough and the ridge
 - Increased wind speed in the jetstreak
- How do these upper level changes impact the surface cyclone?
 - Lower surface pressure = intensification!

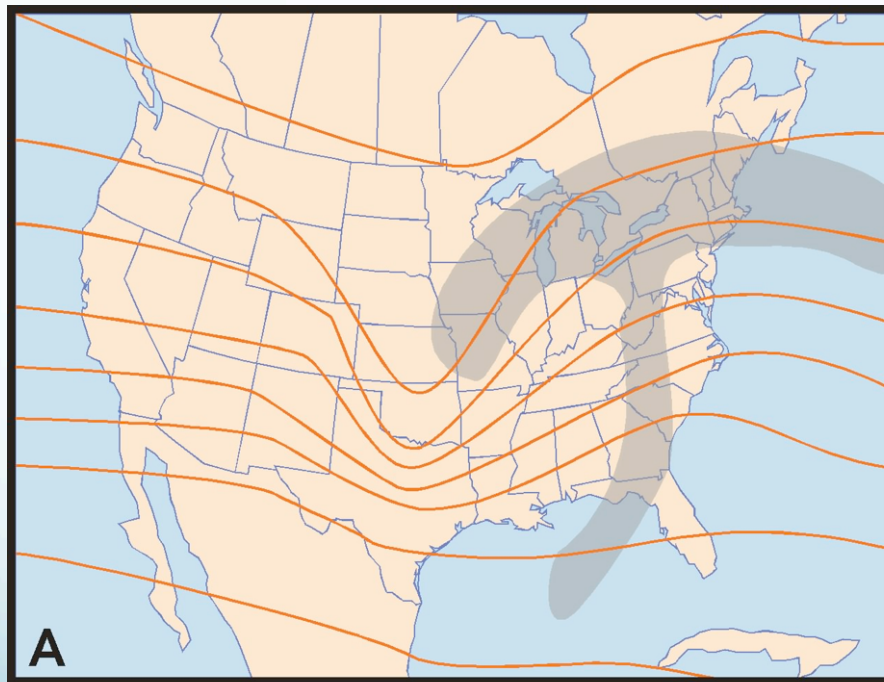
The trowal

- **Trowal** – a “wrap-around” band of warm, moist air aloft (trough of warm air aloft)
- How does the trowal form?
 - Upper level front (A)
 - Occluded front (B,C)
- What type of weather is associated with the trowal?
 - Warm, moist air trapped above cold air
 - Depends how cold the air below is
 - Yields steady snow in winter
 - Yields steady rain in summer

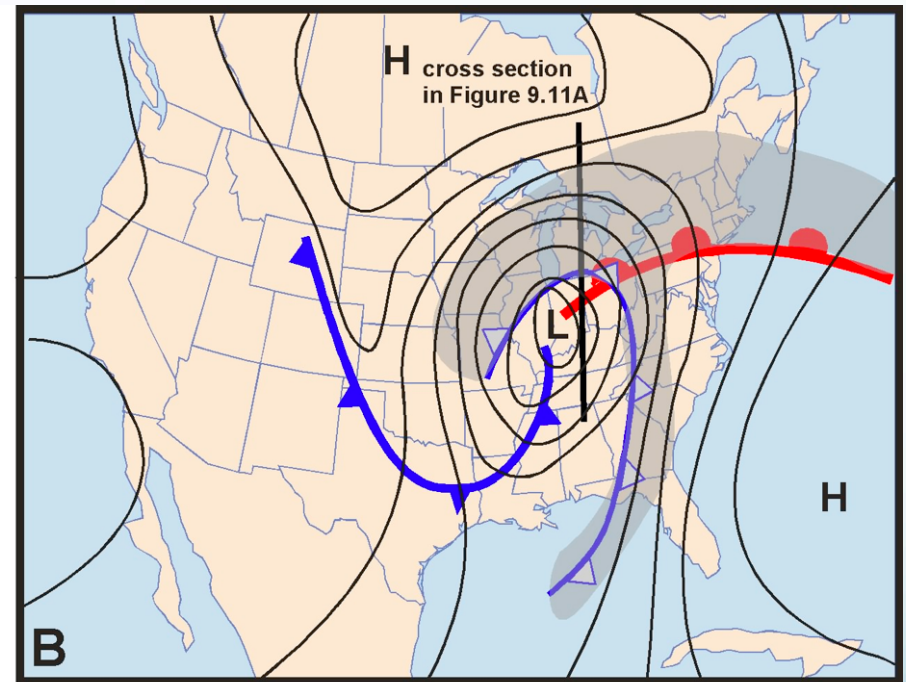


Mature cyclone with an upper level front

Upper level features

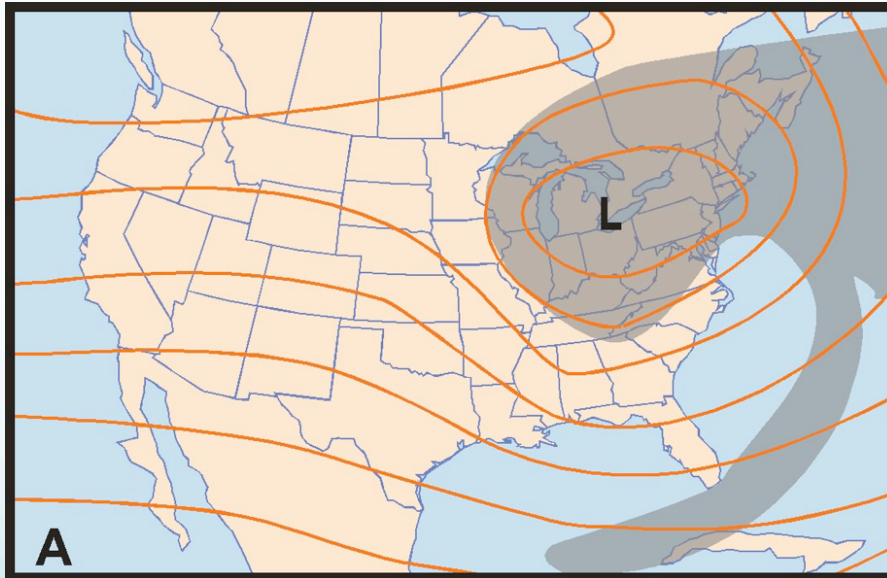


Surface features

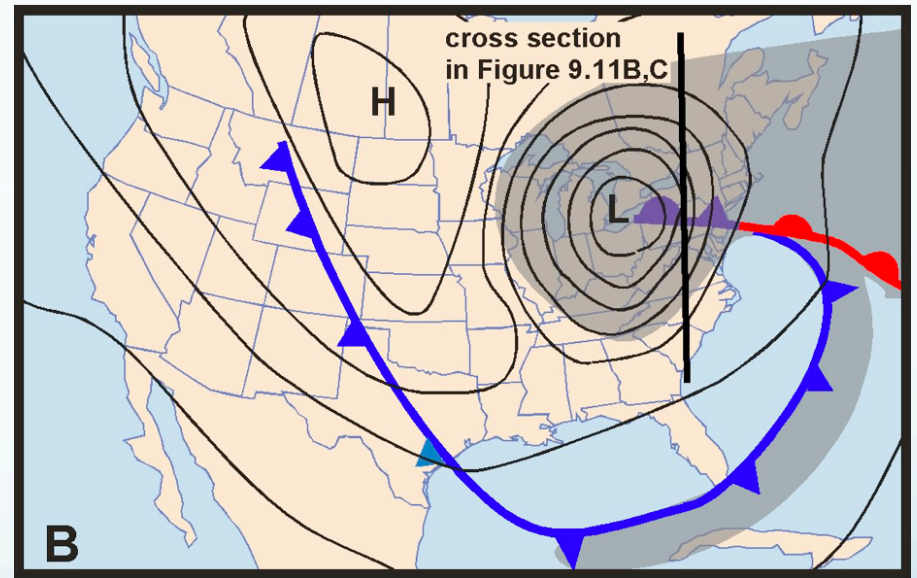


Mature cyclone with an occluded front

Upper level features



Surface features

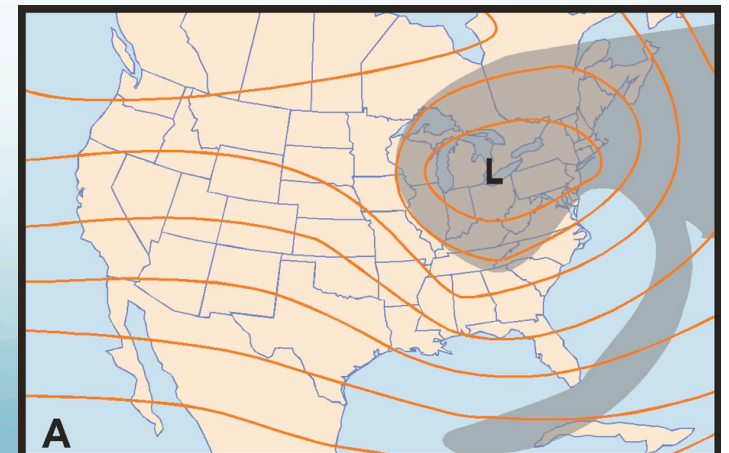


Mature cyclone

- Where is “warm” severe weather (thunderstorms and tornadoes) most likely to form in a mature cyclone?
 - On the leading edge of the cold or upper level front (whichever is the most eastward), south of cyclone center, in the warm air sector
 - Comma “tail”
- Where is “cold” severe weather (blizzards and ice storms) most likely to form in a mature cyclone?
 - Northwest of cyclone center, associated with the trough
 - Comma “head”

The dissipating cyclone

- What type of front forms when cold air has completely wrapped around the cyclone?
 - Occluded front!
- How does the upper level pattern change once the cold air wraps around the cyclone at the surface?
 - At upper levels a cutoff low forms, as cold air wraps completely around the cyclone at low levels.
- How does the upper level divergence change as the flow changes from an upper level trough and ridge pattern to a cutoff low pattern?
 - No **change** in flow curvature from counterclockwise (trough) to clockwise (ridge) anymore – always counterclockwise
 - Divergence becomes insignificant



Final steps of dissipation

- First the occlusion, then the cutoff low, what next?
- What happens to the jetstreak once the cutoff low forms?
 - Migrates through the trough to its east side and weakens as it moves into the ridge to the east
- How does this impact the intensity of the surface cyclone?
 - Divergence with the jetstreak becomes insignificant as it weakens
 - Increasing surface pressure as divergence aloft weakens
- How long does it take for the surface cyclone to dissipate once the cutoff low forms at upper levels?
 - Few days to week—surface friction causes air to converge in center of low, since no divergence aloft to support rising motion, it increase central pressure of surface low rapidly
- What type of weather is associated with the dissipating cyclone?
 - The trowal helps produce steady snow (in winter, rain in summer) during dissipating phase

Clicker Question

- True or false: You would expect a low pressure center to form or intensify at the surface when divergence is greater than convergence in a column of the atmosphere.
 - A. True
 - B. False

Clicker Question

- As cold air moves south on the west side of a surface low pressure center the height of the 300 mb pressure surface aloft would _____.
 - A. Increase
 - B. Decrease
 - C. Not change

Clicker Question

- Once an occluded front forms in an extratropical cyclone the surface low pressure center is surrounded by _____.
 - A. Cold air on all sides
 - B. Warm air on all sides
 - C. Cold air to the north and warm air to the south
 - D. Warm air to the north and cold air to the south

Clicker Question

- What type of weather would you expect to observe with a dissipating extratropical cyclone?
 - A. Clear skies and no precipitation
 - B. Broad area of clouds and snow
 - C. Broad area of clouds and rain
 - D. Narrow band of clouds and rain
 - E. Either b or c