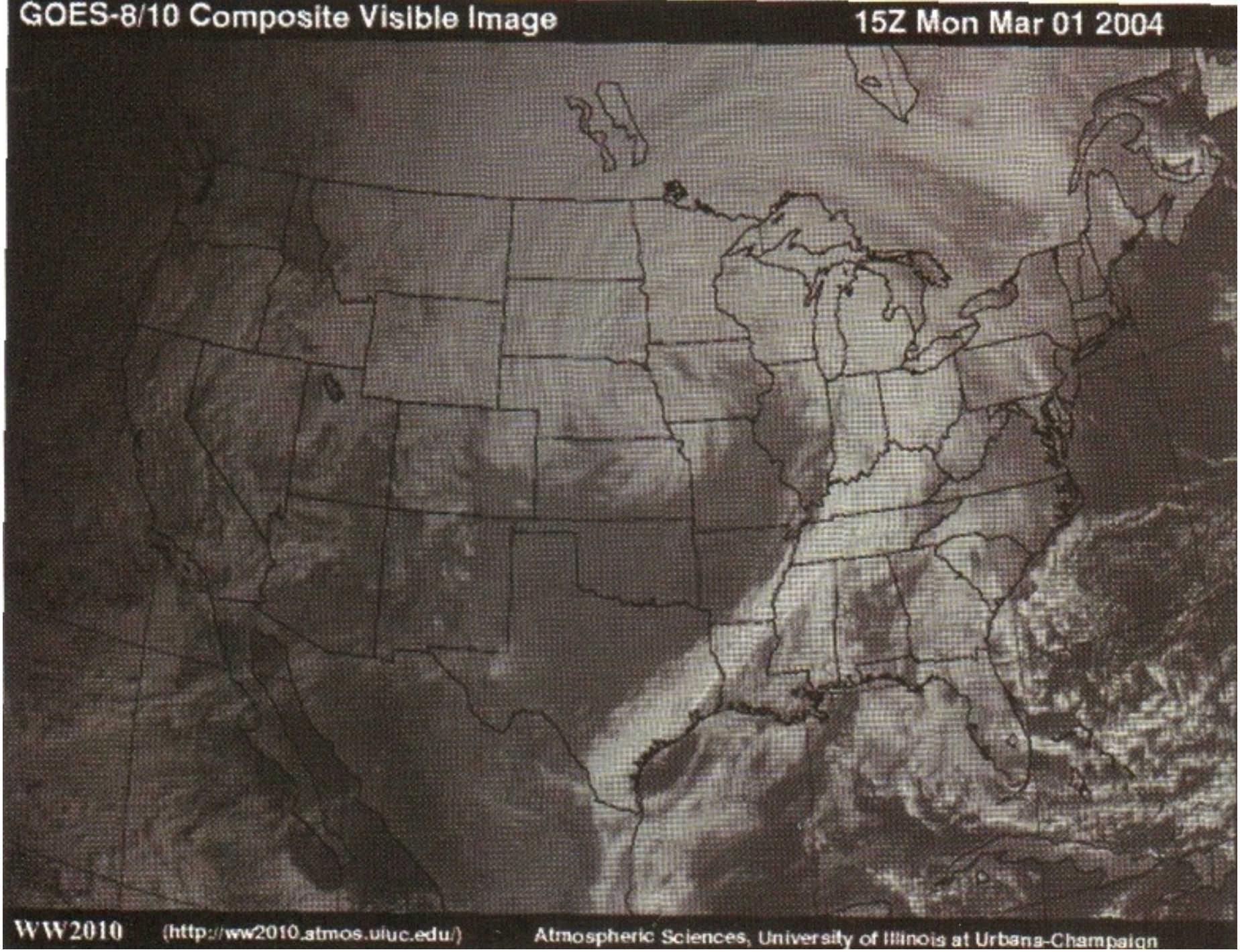
MET 4300/5355

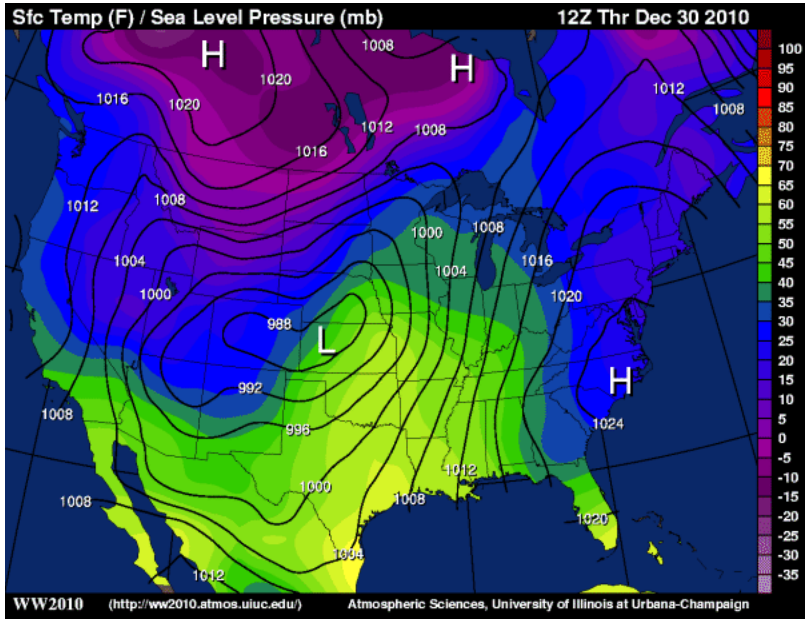
Lecture 10:
Extratropical Cyclones
Forming East of the Rockies
(Lee Cyclones, CH10)

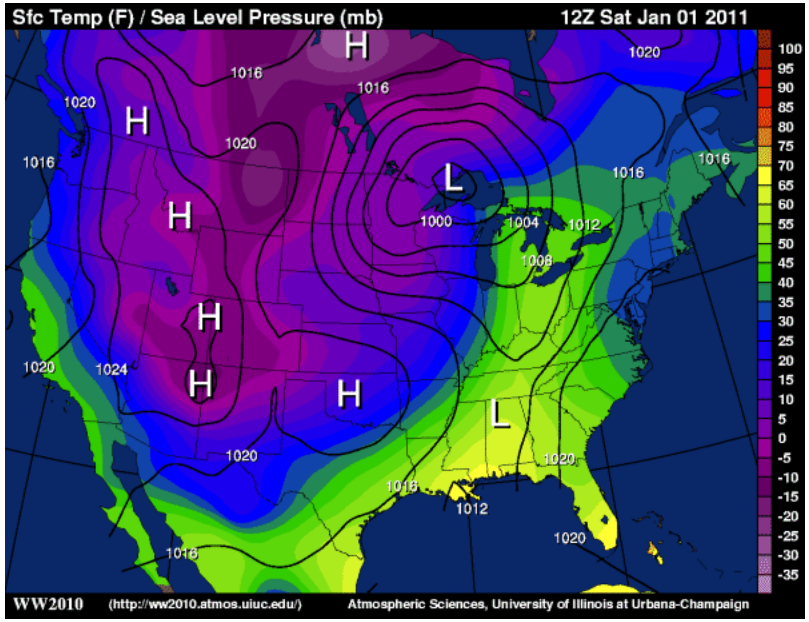
Extratropical Cyclones

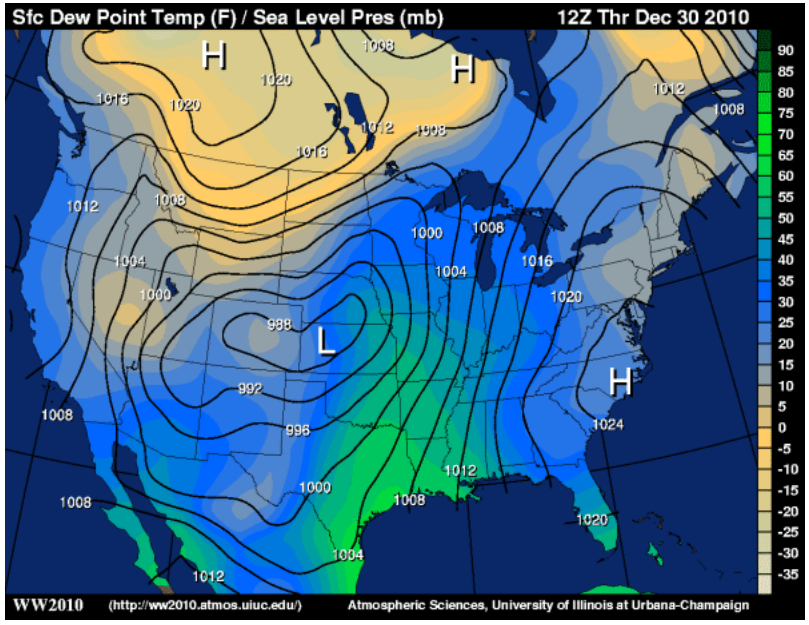
- Large swirling storm systems that form along the jetstream between 30 and 70 degree latitude
- Parent storm of severe weather
- Life span: several days to well over a week
- Dimension: several hundred to a thousand mile
- Transporting warm air northward and upward
- Seasons: mainly in late fall, winter, and spring
- providing beneficial rainfall for agriculture
- Shape on satellite image:
  - Comma tail: squall lines, thunderstorms
  - head: heavy rain, heavy snow, freezing rain

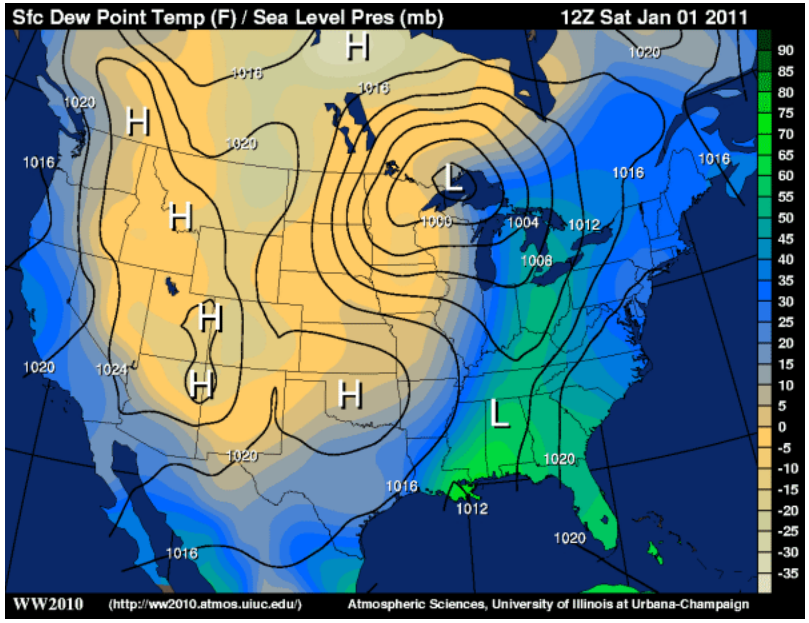

GOES-8/10 Composite Visible Image
15Z Mon Mar 01 2004
WW2010
(http://ww2010.atmos.uiuc.edu/)
Atmospheric Sciences, University of Illinois at Urbana-Champaign

A Colorado cyclone forming east of the Rockies; the same cyclone shown 48 hours later on the plains



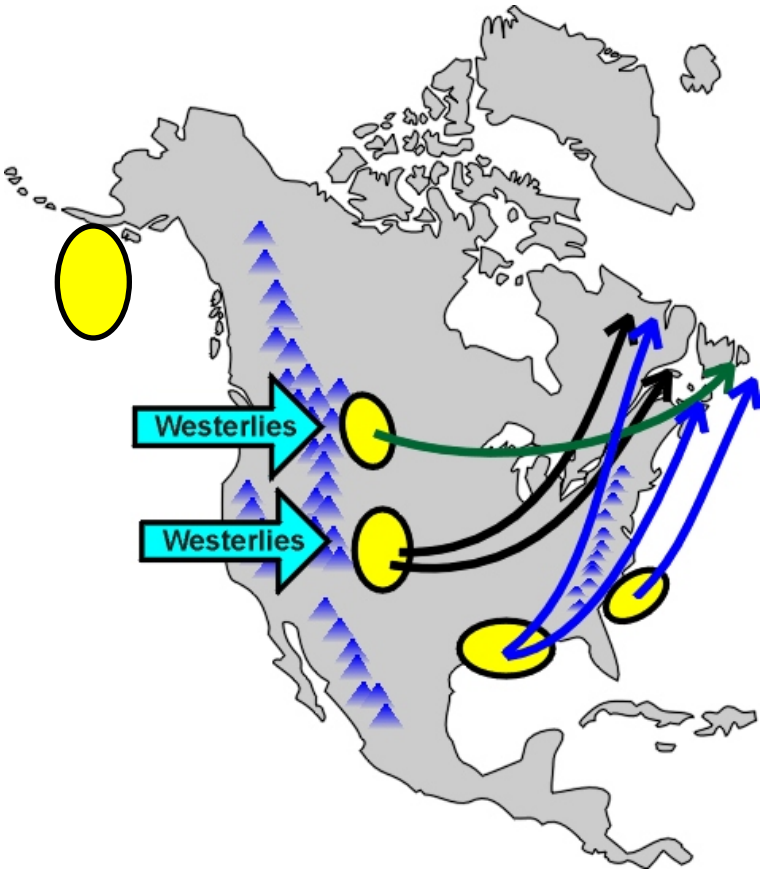




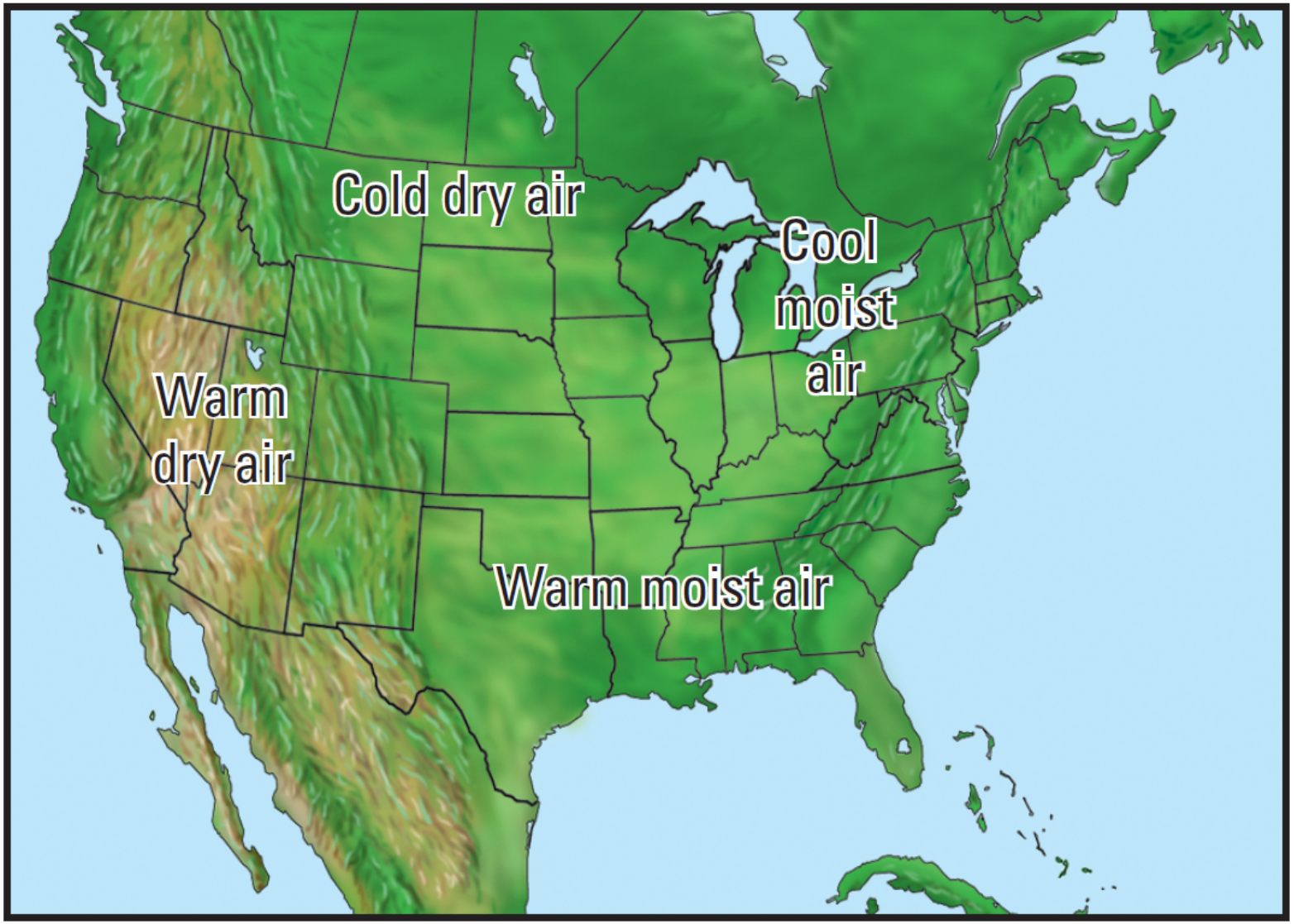


Where Do US Frontal Cyclones Form?

- Lee of the Rocky Mountains (Lee Cyclones)
  - Alberta (Alberta Clippers)
  - Colorado Wyoming, New Mexico (Colorado Low)
- East & Gulf Coasts
  - TX-LA boarder (Gulf Low)
  - Off Georgia-Carolinas Coast (Northeasters)
- Bering Sea & Gulf of Alaska in the Pacific Ocean (Alaska Low)



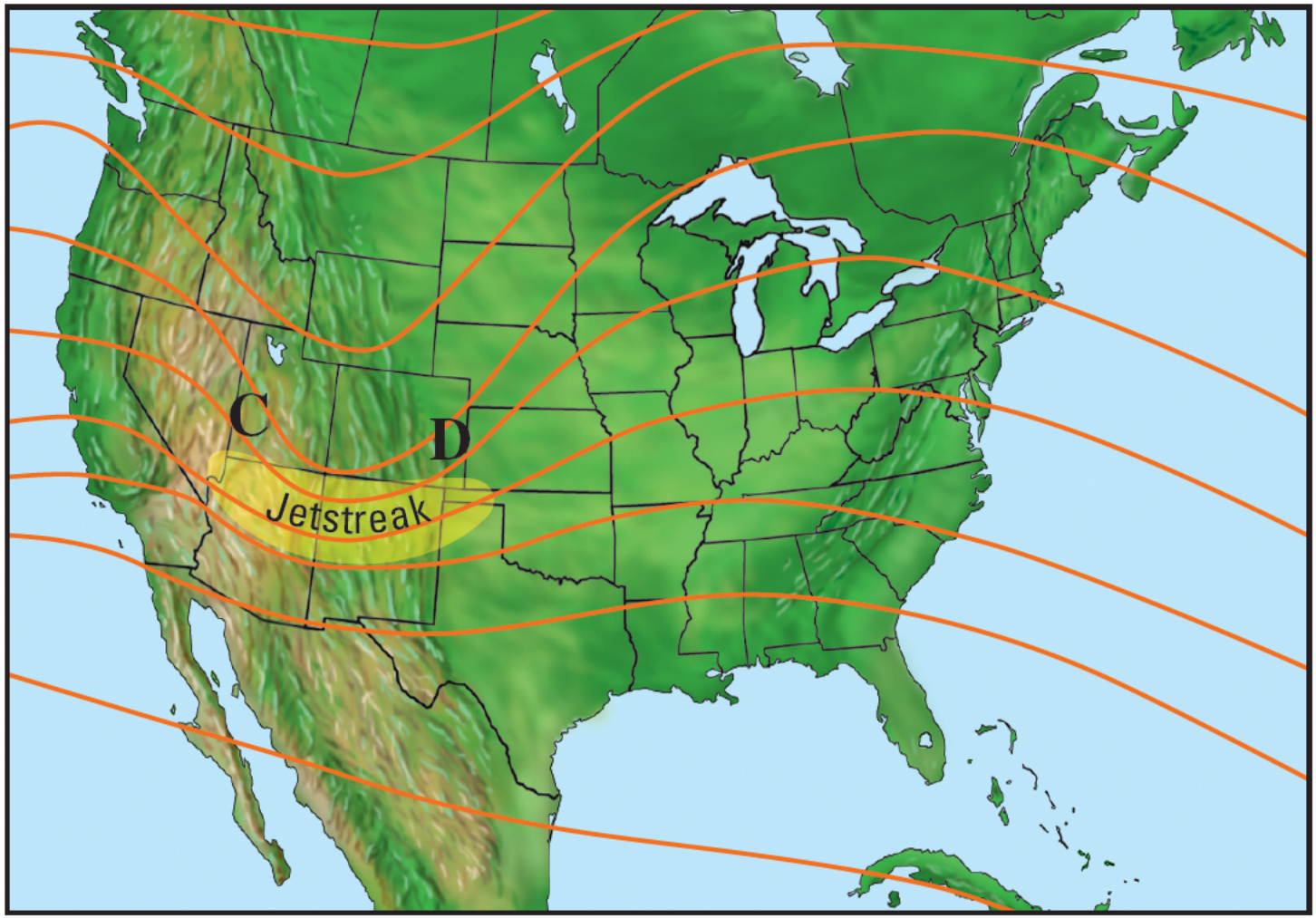
Environment Prior to the Cyclone development



Four airmass model

Initial Development of a Cyclone:

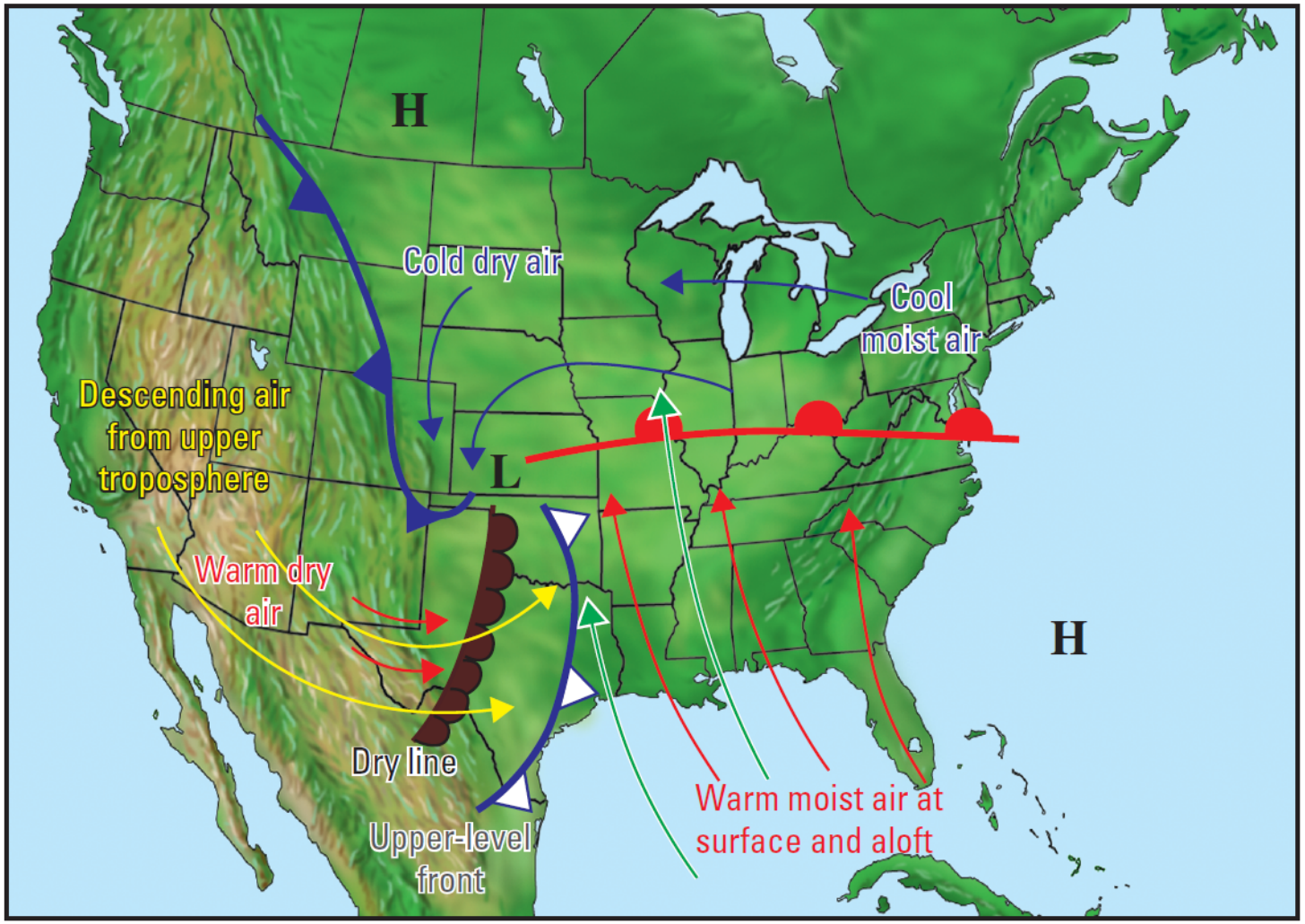
A upper level wave with Jet Max passes over the Rockies & the plains –triggering formation



Curvature effect and jetstreak effect

Initial Movement of the Airmasses:

Fronts form between the boundaries of airmasses



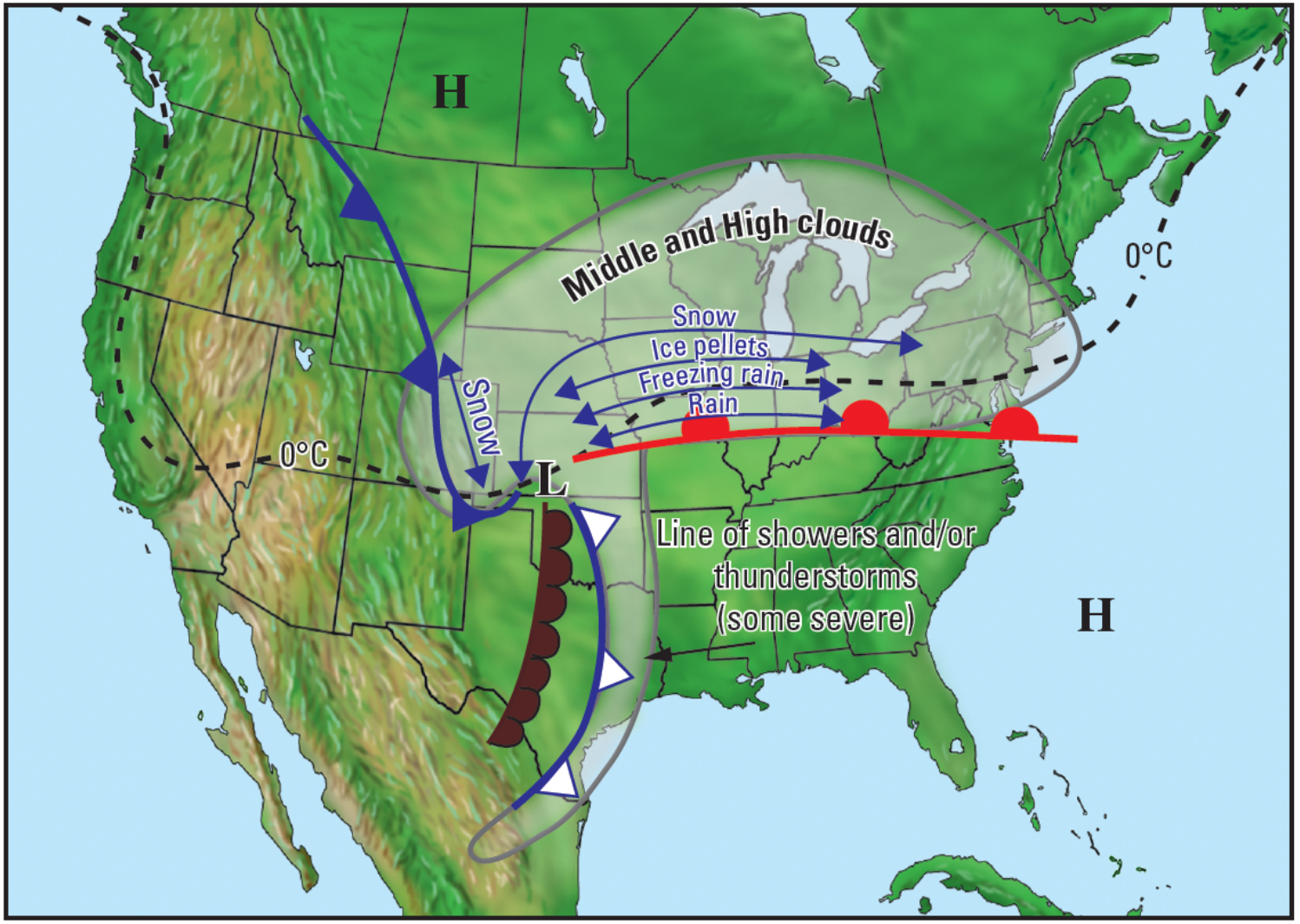
Cold front

warm front

dry line

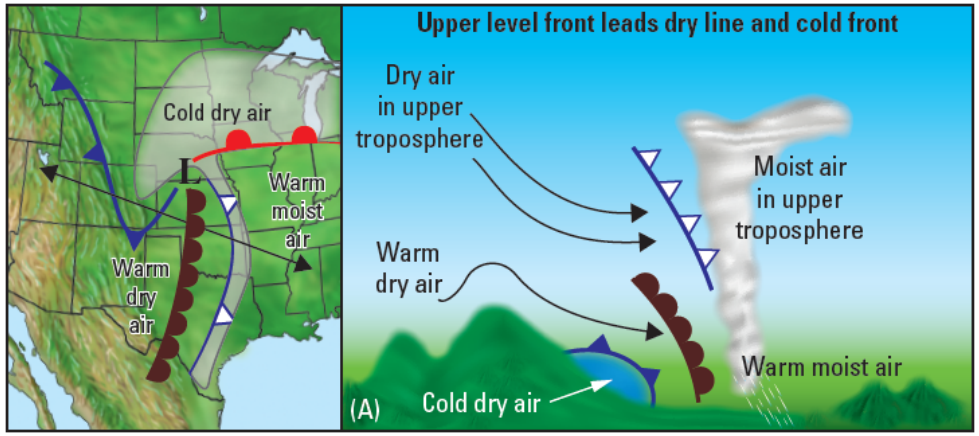
upper-level front

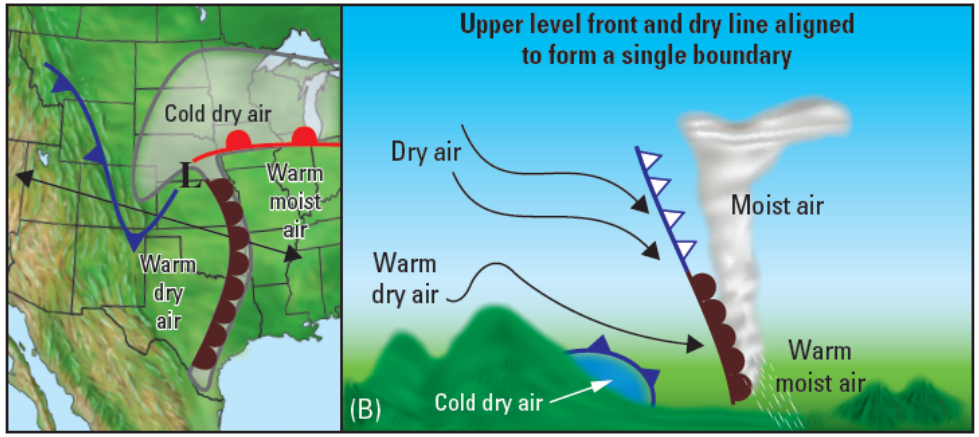
Early Weather Along the Fronts

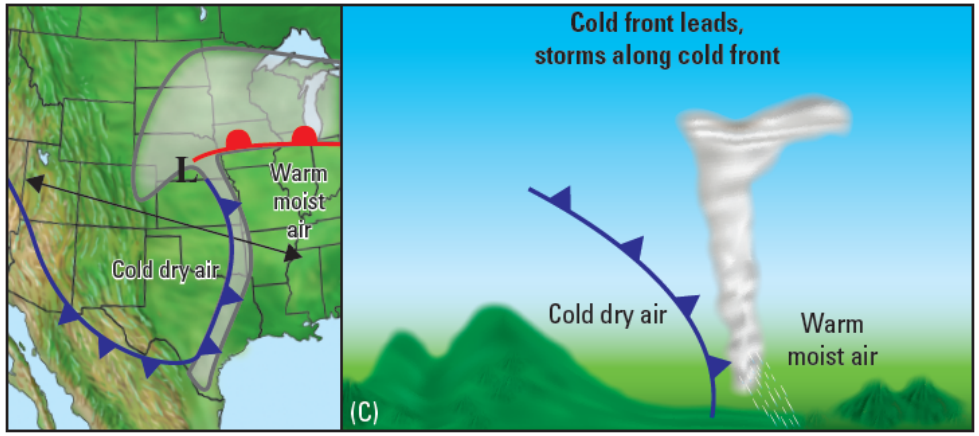


Summary of Early Weather

- **East of the cyclone center**: Widespread clouds and precip. Nimbostratus to stratus to altostratus to cirrostratus from South to North. At N of warm front → rain, freezing rain, and/or snow
- **South of the cyclone center**: a line of showers or T-storms along the leading east-most boundary (tail of the comma); second line of T-storms may develop along the next boundary to the west
- **Northwest of the cyclone center**: as air flows upward from the valley to the Rockies, upslope flow produces snow in winter (blizzard)



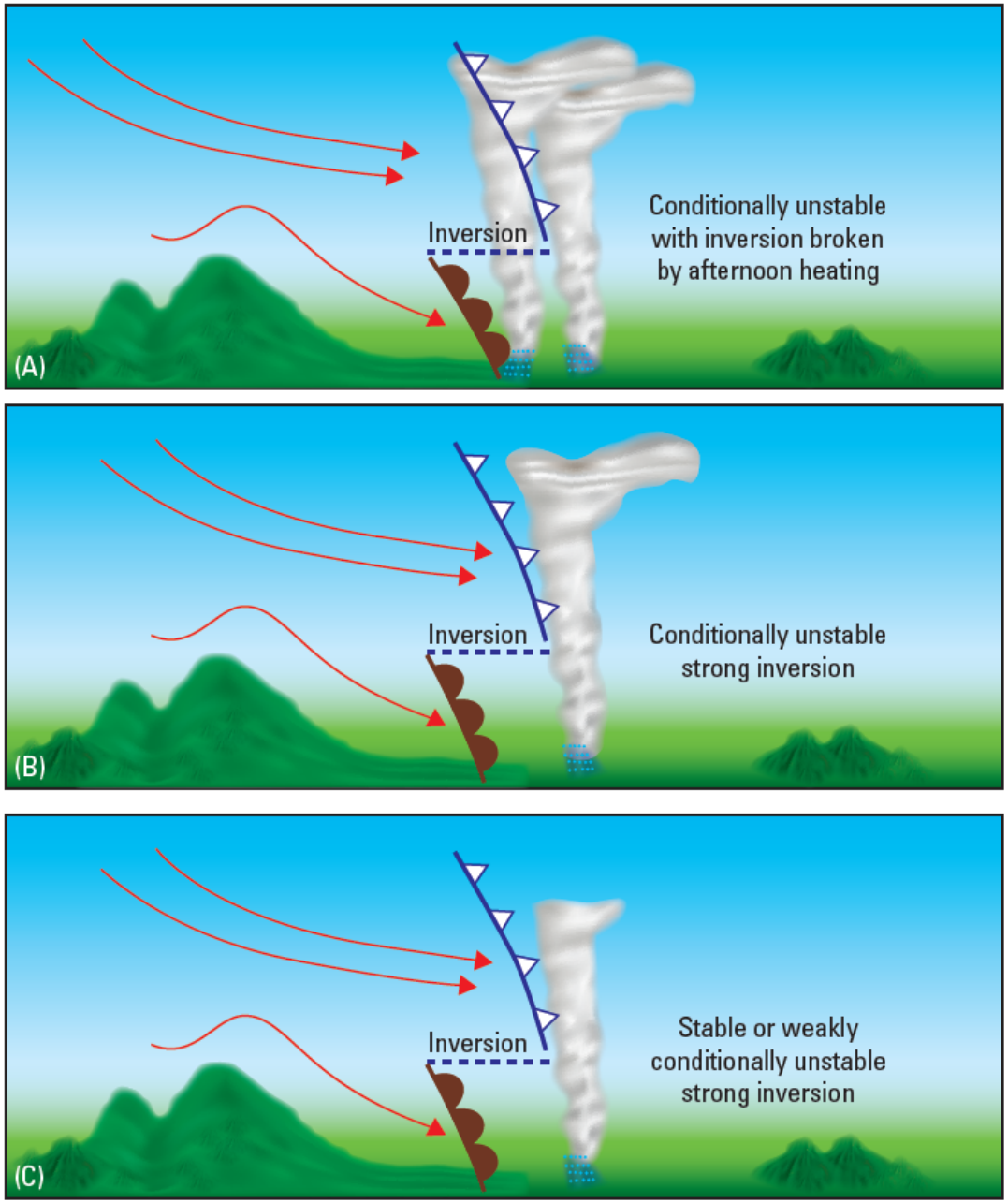




South of the Cyclone Center (3 scenarios)

- **(A) Upper front ahead of dryline & cold front:** Convergence ahead of the front triggers showers.
  - Convection between the dry line and upper front is <u>often</u> suppressed
- **(B) A Pacific Front: the Upper Front (from the Pacific) and Dry Line Aligned,** ahead of the Canadian cold front:
- **(C) Cold front (from Canada) only**: If the air behind the front is very cold, the surface front may be the main boundary

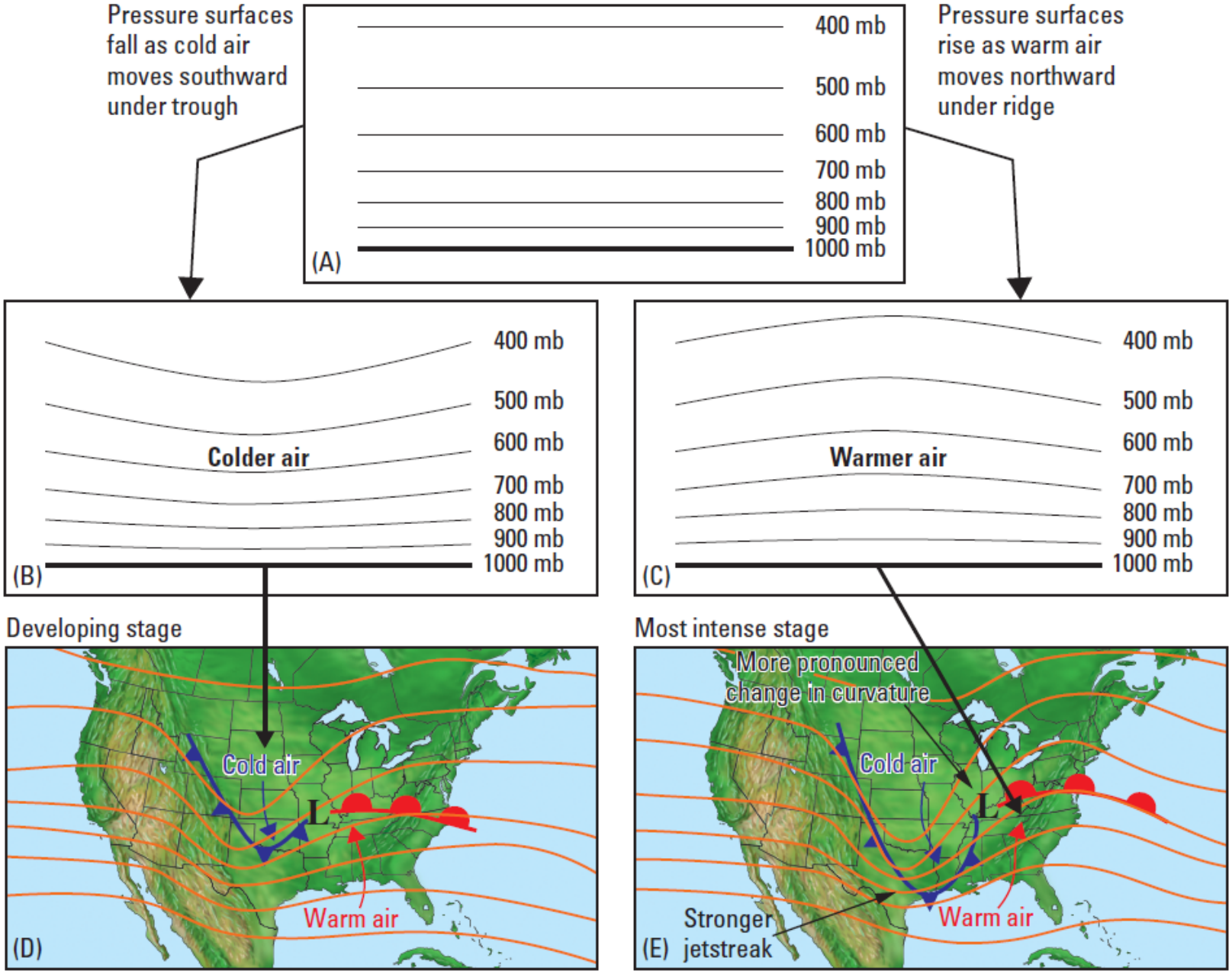
Variations in Scenario (A) Upper-level front ahead of dry line and cold front



- **An inversion often occurs between dry line and upper-level front**
- **Top:** On a warm day with plenty of conditional instability in the warm air, convection breaks through the inversion, producing lines of TR along both the dryline and upper front
- **Middle:** If the inversion is strong but so is the instability, only the upper front will have convection.
- **Bottom:** If the instability is really weak there will be weak convection along the upper front and none on the dryline

Storm intensification

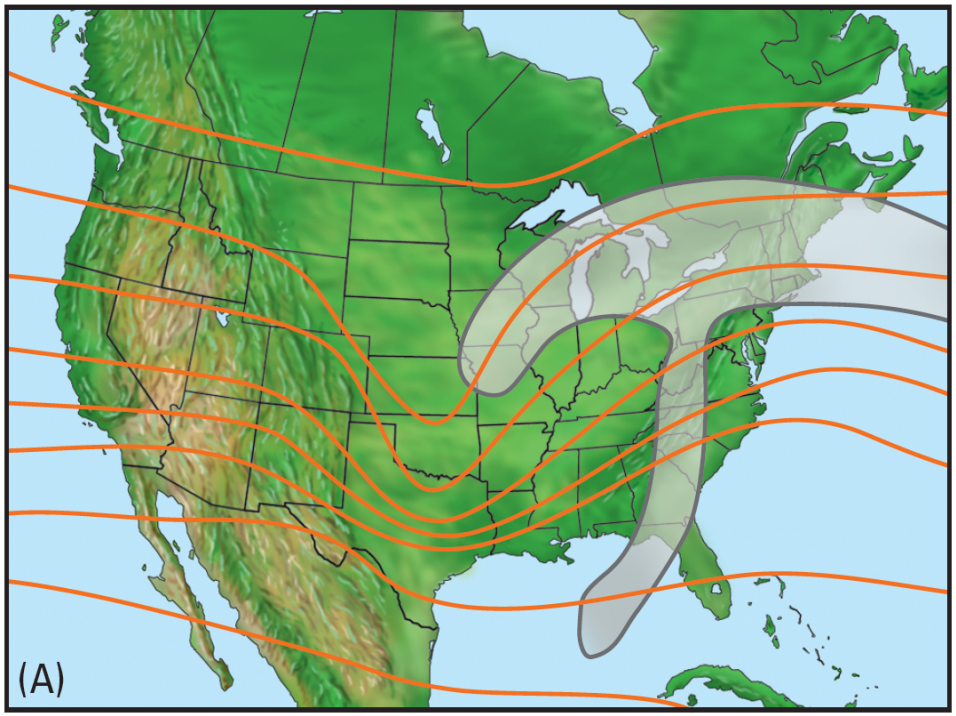
- **Pressure becomes lower, T & Td gradients become tighter, precipitation becomes heavier**
- **How? Divergence aloft > convergence by friction in the boundary layer → storm intensifies**
- **Positive feedback processes in storm itself: spin-up process typically occur over a period of a few hours in a weak cyclone, to as long as 24 to 36 hours in a very strong cyclone.**

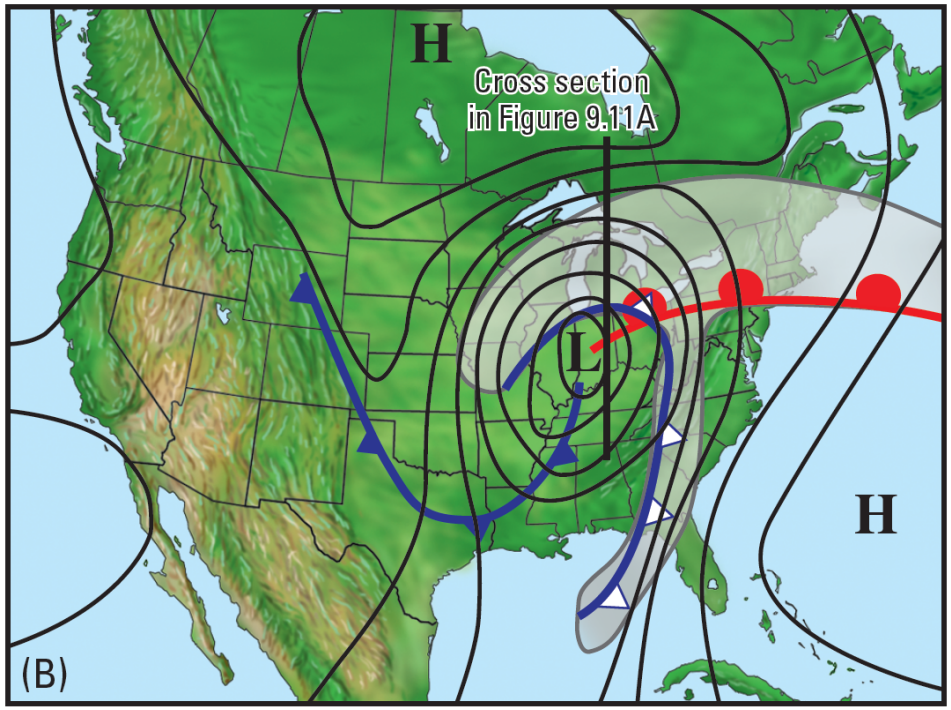

Pressure surfaces fall as cold air moves southward under trough
Pressure surfaces rise as warm air moves northward under ridge
400 mb
500 mb
600 mb
700 mb
800 mb
900 mb
1000 mb
(A)
Colder air
(B)
Warmer air
(C)
Developing stage
Cold air
L
Warm air
(D)
Most intense stage
More pronounced change in curvature
Cold air
L
Warm air
Stronger jetstreak
(E)

Positive Feedback Process During Storm Intensification

- Cold air to the north makes the altitude of the pressure surface decreases
- Warm air to the south makes the altitude of the pressure surface decreases
- On an upper-level chart, these two effects appear as a deepening of the trough west of the surface low and an intensification of the ridge east of the low.
- Two important effects leading to storm intensifications:
  - Curvature effect becomes more intense
  - A stronger wind leading to an enhanced jetsteak
- Second step of the feedback:
  - Stronger low, stronger wind, more rapid transport of cold and warm air causing the trough to deepen more rapidly →further intensification of the surface low!

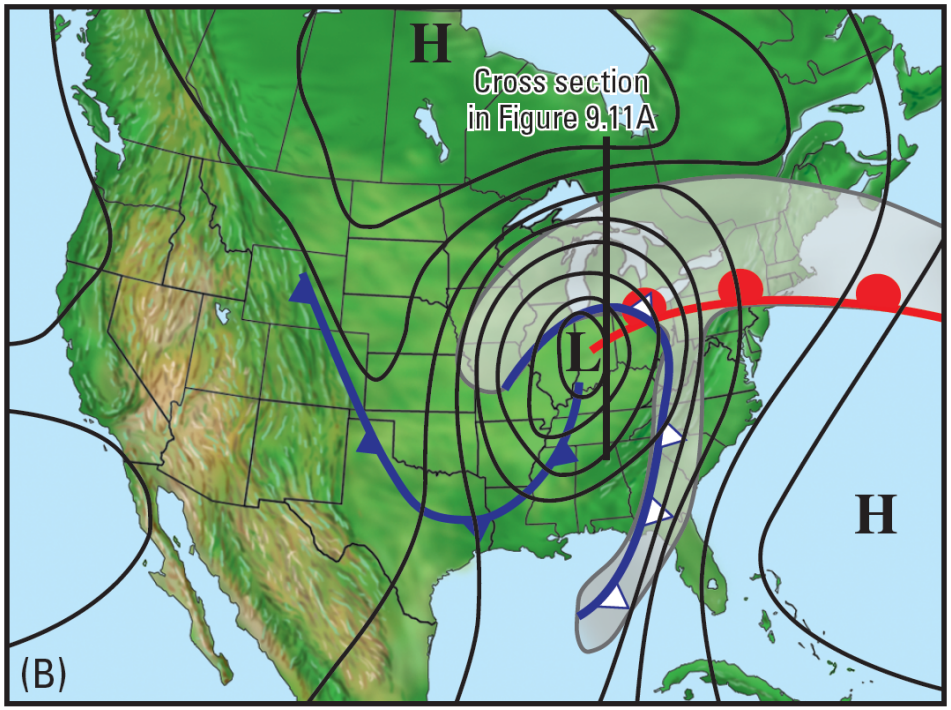
The Mature Cyclone

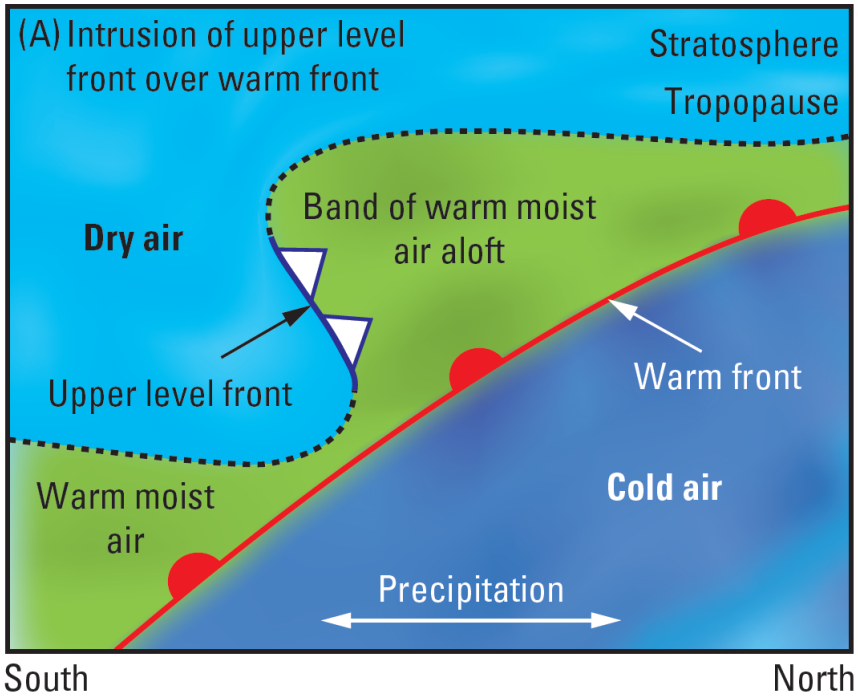




- "Warm" severe weather (thunderstorms and tornadoes) location: ahead of the comma tail (ahead of either upper-level front or cold front). Winds increase with height rapidly, forming a **low-level jet** (CH19).
- "Cold" severe weather (blizzards and ice storms) location: under the comma head (just NW of the surface low center). A **wrap-around band** of moisture and clounds is trapped aloft, leading to the production of steady and heavy snow.

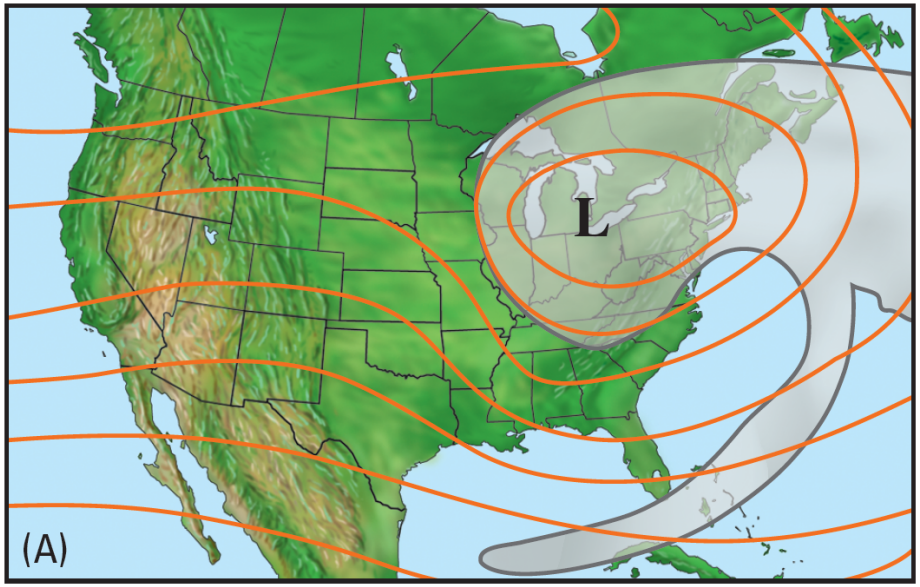
Formation of the Wrap-around Band in a Mature Cyclone

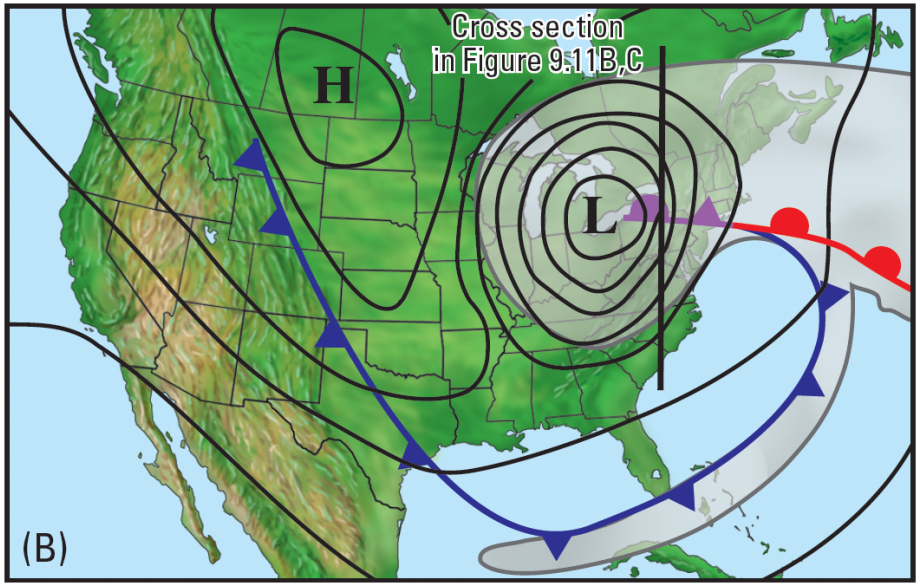


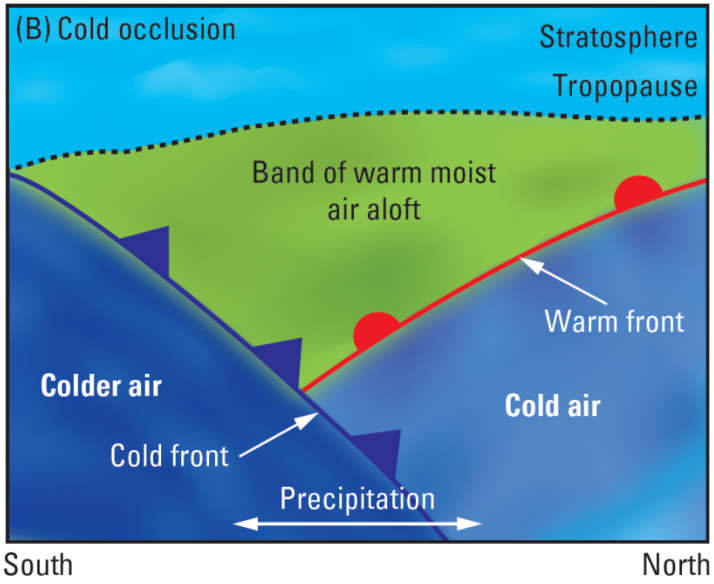


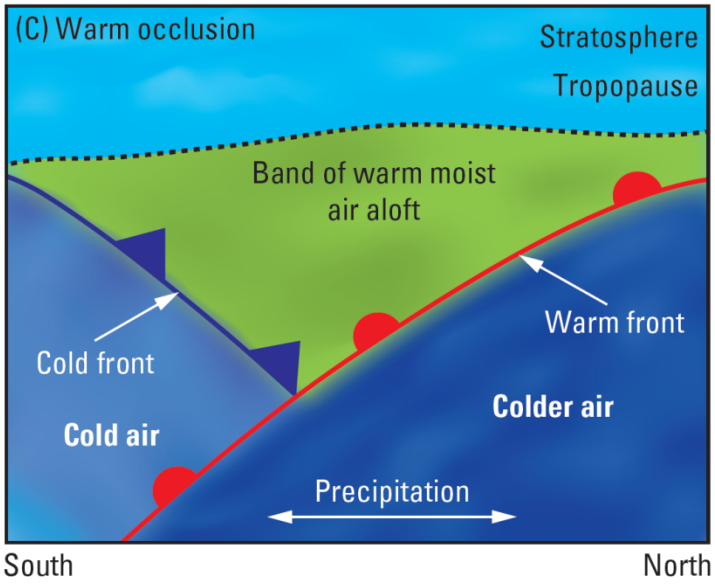
- In a mature cyclone in which **the upper-level front leads the cold front**: dry air behind the upper level front advances northward on the east side of the cyclone, eventually moving over the warm front. A band of warm, moist air aloft (**wrap-around band**) becomes trapped between the dry air and the warm front.

Formation of the Wrap-around Band in an Occluded Cyclone





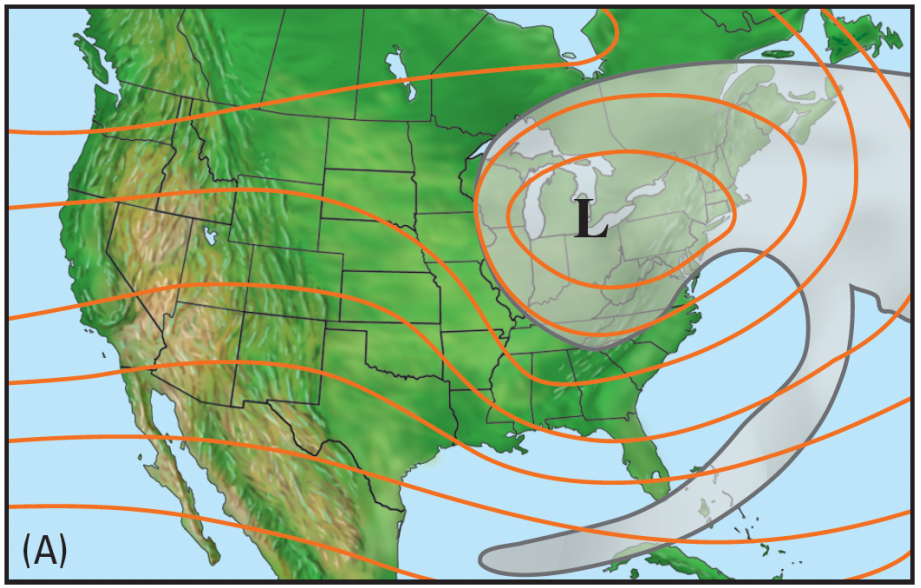




Storm Dissipation

- As the upper-level trough continues to deepen, it may become so large that a pocket of cold air becomes a **cutoff low (pinched off or cut off** from the main flow**)**:
  - Divergence is insignificant due to both curvature effect & jetstreak effect

- Friction becomes important
- In the dissipation stage, a cyclone becomes a deep vortex with a cold center. Surface low is directly underneath the cutoff low aloft. The whole storm spins down.



Summary

- **Over North America, extratropical cyclones form**
  - Lee of the Rockies
  - East & Gulf Coast
  - Gulf of Alaska
- **Lee Cyclogenesis**
  - Four airmass model
  - Jetstreak & curvature effect
  - Fronts form
- **Early Weather along the Fronts**
  - East of the center: A wide region of louds and precipitation
  - South of the center: 3 types of front organization; a line of T-storms
  - Northwest of the center: upslope flow producing heavy snow & blizzard
- **Storm intensification: positive feedback**
- **Mature cyclone**: formation of the wrap-around band
- **Cyclone dissipation:** cut-off low at upper level