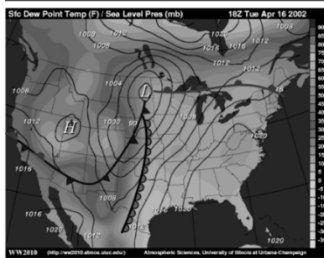


## Chapter 10: Cyclones: East of the Rocky Mountain



Courtesy of the Department of Atmospheric Sciences  
University of Illinois at Urbana-Champaign

- Environment prior to the development of the Cyclone
- Initial Development of the Extratropical Cyclone
- Early Weather Along the Fronts
- Storm Intensification
- Mature Cyclone
- Dissipating Cyclone



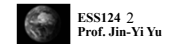
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## Extratropical Cyclones in North America



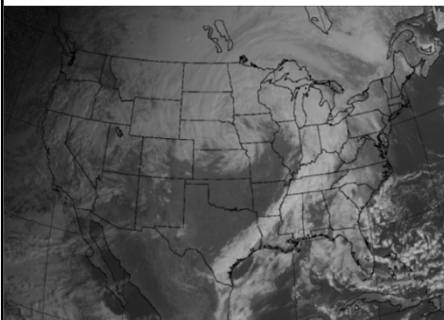
Cyclones preferentially form in five locations in North America:

- (1) East of the Rocky Mountains
- (2) East of Canadian Rockies
- (3) Gulf Coast of the US
- (4) East Coast of the US
- (5) Bering Sea & Gulf of Alaska



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## Extratropical Cyclones



Courtesy of the Department of Atmospheric Sciences  
University of Illinois at Urbana-Champaign

Visible satellite image of an extratropical cyclone covering the central United States

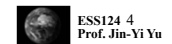
- Extratropical cyclones are large swirling storm systems that form along the jetstream between 30 and 70 latitude.
- The entire life cycle of an extratropical cyclone can span several days to well over a week.
- The storm covers areas ranging from several hundred to thousand miles across.



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## 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.



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## Polar Front Theory



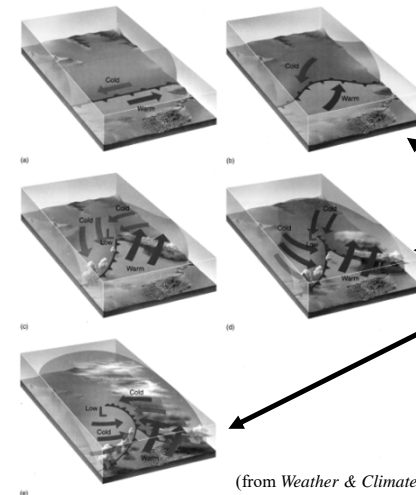
Vilhelm Bjerknes (1862-1951)

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



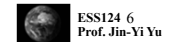
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## Life Cycle of Mid-Latitude Cyclone



(from Weather & Climate)

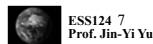
Cyclogenesis  
Mature Cyclone  
Occlusion



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## Life Cycle of Extratropical Cyclone

- Extratropical cyclones form and intensify quickly, typically reaching maximum intensity (lowest central pressure) within 36 to 48 hours of formation. → development (cyclogenesis) phase
- The storms can sometime maintain a peak intensity for one to two days. → mature phase
- Dissipation of a cyclone to a point where its clouds and circulations are no longer coherent can take several more days to over a week. → occlusion phase.



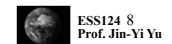
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## Extratropical Cyclones in North America



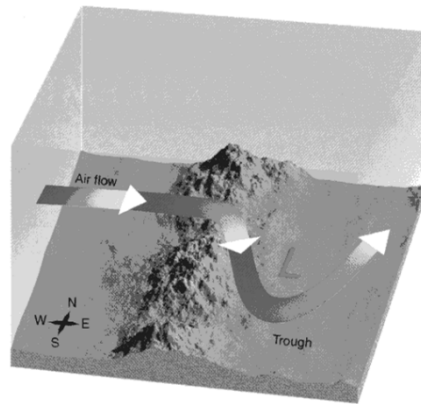
Cyclones preferentially form in five locations in North America:

- (1) East of the Rocky Mountains
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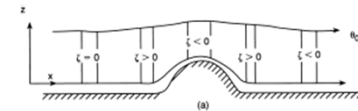
## Lee-Side Lows



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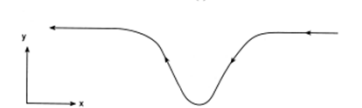
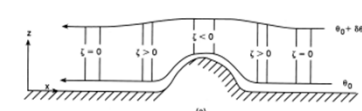
## Flows Cross Over a Mountain

### Westerly over mountain



Steady westerly flow over a large-scale ridge will result in a cyclonic flow pattern immediately to the east of the barrier (the lee side trough) followed by an alternating series of ridges and troughs downstream.

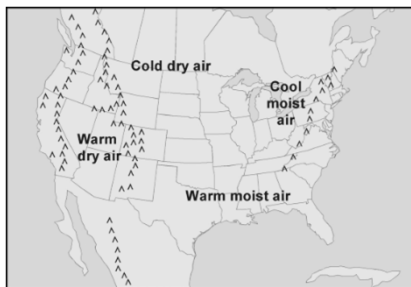
### Easterly over mountain



In the case of an easterly wind, the disturbance in the streamlines damps out away from the barrier.

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## Typical Environment Prior the Cyclone



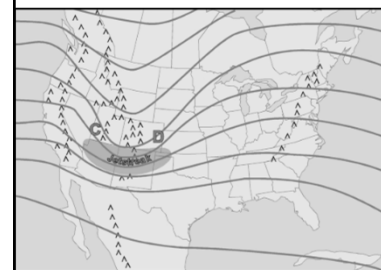
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- A cold, dry airmass over Canada and the northern US
- A warm, humid airmass over the southern and eastern US
- A warm, dry airmass over the higher elevations of the western US and Mexico
- A cool moist airmass over the northeastern US and Canada.

- This four-airmasses model may vary from season to season and day to day.
- A fifth airmass originates in the upper troposphere, and is typically found aloft, and its leading edge is the "upper-level front".

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## Initial Development of the Cyclone



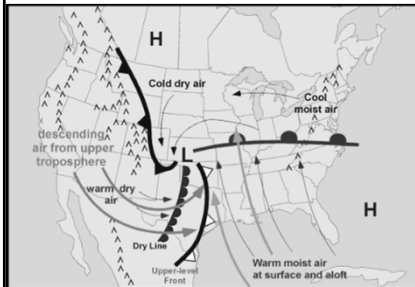
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- Cyclones form east of the Rockies when a wave and/or a jetstream move across the Rockies from the west at jetstream level.
- A cyclone appears as a center of low pressure on surface chart.
- Low pressure forms when divergence occurs aloft associated with embedded jetstreams and changes in curvature within the jetstream.

• As soon as low pressure begins to develop, air in the lower troposphere will start to circulate about the low-pressure center. A cyclone has begun to form.

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## Initial Movement of the Cyclone at Surface



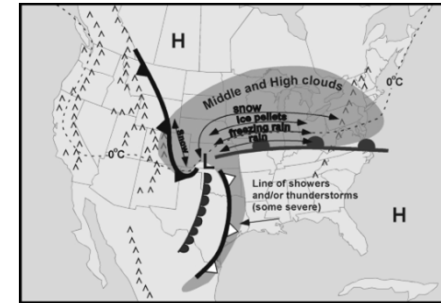
- East and south of the low-pressure center, warm and humid air from the Gulf of Mexico move northward to form the warm front.
- To the southwest of the low, a dry line develops as desert air from the Rockies into the Great Plains and meet moist air from the Gulf.

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- Cold air typically lies along the east slope of the Rockies northwest of the low-pressure center, and later flows southward to the west of the low center.
- The cold air is not deep enough to cross the Rockies and stays between the Rockies and the low center, whose leading edge is a cold front.
- An upper-level front forms at 700mb, where the dry, descending upper tropospheric air on the west of the jetstreak meets the northward-flowing moist air in the upper and middle troposphere.

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## Early Weather Along the Front

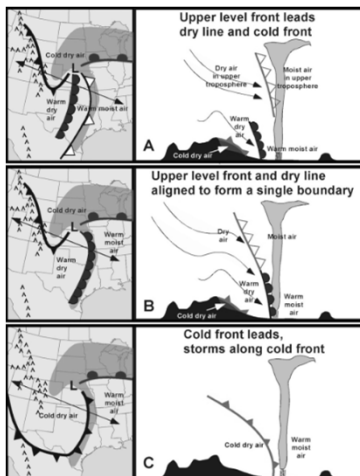


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- **East of the Cyclone:** A wide region of clouds develops north of the warm front. The clouds are deepest close to the surface position of the front and become thin and high far north of the front.
- **Northwest of the Cyclone:** Air north of the cyclone center flows westward and rises on the slope of the Rockies, which produces heavy snow and blizzard conditions along the east side of the Rockies and eastward onto the Great Plains.

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## South of the Cyclone Center

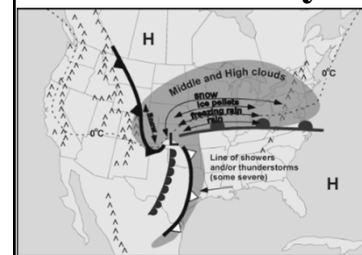


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- Three airmasses at the surface and an additional airmass aloft; three scenarios could occur,
- **Scenario A:** Warm moist air from the Gulf extends to the dry line at the surface and to the upper-level front aloft. Lifting ahead of the front aloft produces a line of thunderstorms and showers. If the moist air ahead of the dry line is unstable enough, a second line of thunderstorm may occur ahead of the dry line.
- **Scenario B:** Dry line and upper-level front form a single boundary and produce weather ahead of the dry line.
- **Scenario C:** This happens when the Canadian cold front moves rapidly to take over the dry line. Weather will be produced ahead of the cold front.

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## Summary of Early Weather



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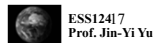
WEEK	DATE	TOPICS	CHAPTER
Week 1	1/8 1/10	Properties of the Atmosphere Meteorological Measurements Weather Map	Ch. 1 Ch. 2 Ch. 3
Week 2	1/15 1/17	Atmospheric Instability Forces and Force Balances	Ch. 6 Ch. 7
Week 3	1/22 1/24	The Development of High- and Low-Pressure Systems Air Masses and Fronts	Ch. 8 Ch. 9
Week 4	1/29 1/31	Extratropical Cyclones East of the Rocky Mountains Extratropical Cyclones Along the East and Gulf Coasts	Ch. 10 Ch. 11
Week 5	2/5 2/7	Freezing Precipitation and Ice Storms Lake-Effect Snowstorms	Ch. 12 Ch. 13
Week 6	2/12 2/14	Midterm Examination Cold Waves Great Plains Blizzards	Ch. 1-13 Ch. 14 Ch. 15
Week 7	2/19 2/21	Mountain Snowstorms Mountain Winterstorms	Ch. 16 Ch. 17
Week 8	2/26 2/28	Thunderstorms Tornadoes	Ch. 18 Ch. 19
Week 9	3/5 3/7	Hailstorms Lightning Downbursts	Ch. 20 Ch. 21 Ch. 22

- **East of the Cyclone:** widespread clouds and precipitations to the north of the warm front in the forms of rain, freezing rain, and/or snow.
- **South of the Cyclone:** a line of showers or thunderstorms forms along the leading eastern-most boundary, which could be the upper-level front, dry line, or a cold front.
- These two precipitation centers (east and south) form a “Comma” cloud.
- **Northwest of the Cyclone:** Snow forms along the up-slope side of the Rockies.

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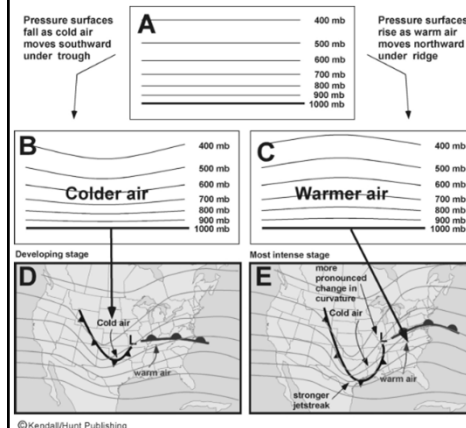
## Cyclone Intensification

- A cyclone intensifies as its central pressure lowers and the pressure gradients surrounding the low-pressure center strengthen.
- Intensification of low-level pressure gradients causes an increase in wind speed throughout the cyclone, tightening the temperature and moisture gradients in the vicinity of the fronts, and creating heavier precipitation and more possibility for severe weather.
- The central low pressure within a cyclone will intensify if the divergence aloft (due to jetstreak and curvature) exceeds the convergence into the low in the boundary layer due to friction.



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## How to Produce Storm Intensification

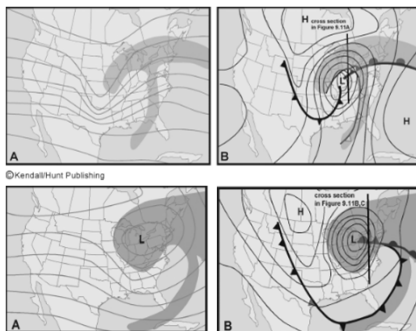


- Cyclone intensification is related to the southward moving of cold air to the west of the cyclone and the northward moving of the warm air to the east of the cyclone.
- These movements cause an upper-level deepening of the trough west of the low and an intensification of the ridge east of the low.
- As a result, the curvature between the trough and the ridge increases, and the jetstreak at the base of the trough enhanced due to a stronger pressure gradient.
- These changes intensify the divergence aloft, leading to an intensification of the surface low-pressure center.



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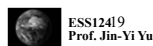
## The Mature Cyclone



- In a mature cyclone, “warm” severe weather (thunderstorms and tornadoes) occurs ahead of either the upper-level front or the cold front.

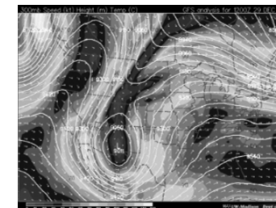
- “Cold” severe weather (blizzards and ice storms) occurs just northwest of the low-pressure center (under the comma head).

- Occlusion processes also begin with either an upper-level front catches the warm front or the cold front catches the warm front.

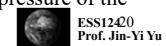


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## The Dissipating Cyclone



- Dissipation of the cyclone can take several days to over a week depending on the maximum intensity of the storm.
- During this time, active weather still occurs along the frontal boundary.
- As cold air continues to move southeastward, the upper-level trough will continue to deepen and will eventually cut off from the main flow.
- This “cutoff low” aloft has cold air in the center.
- The low at the surface is directly underneath the cutoff low aloft, and the whole system slowly spin down as frictional convergence raises the pressure of the surface low.



ESS12420  
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