Midlatitude Cyclones

GEOG/ENST 2331 – Lecture 15

Ahrens: Chapter 12

Last lecture

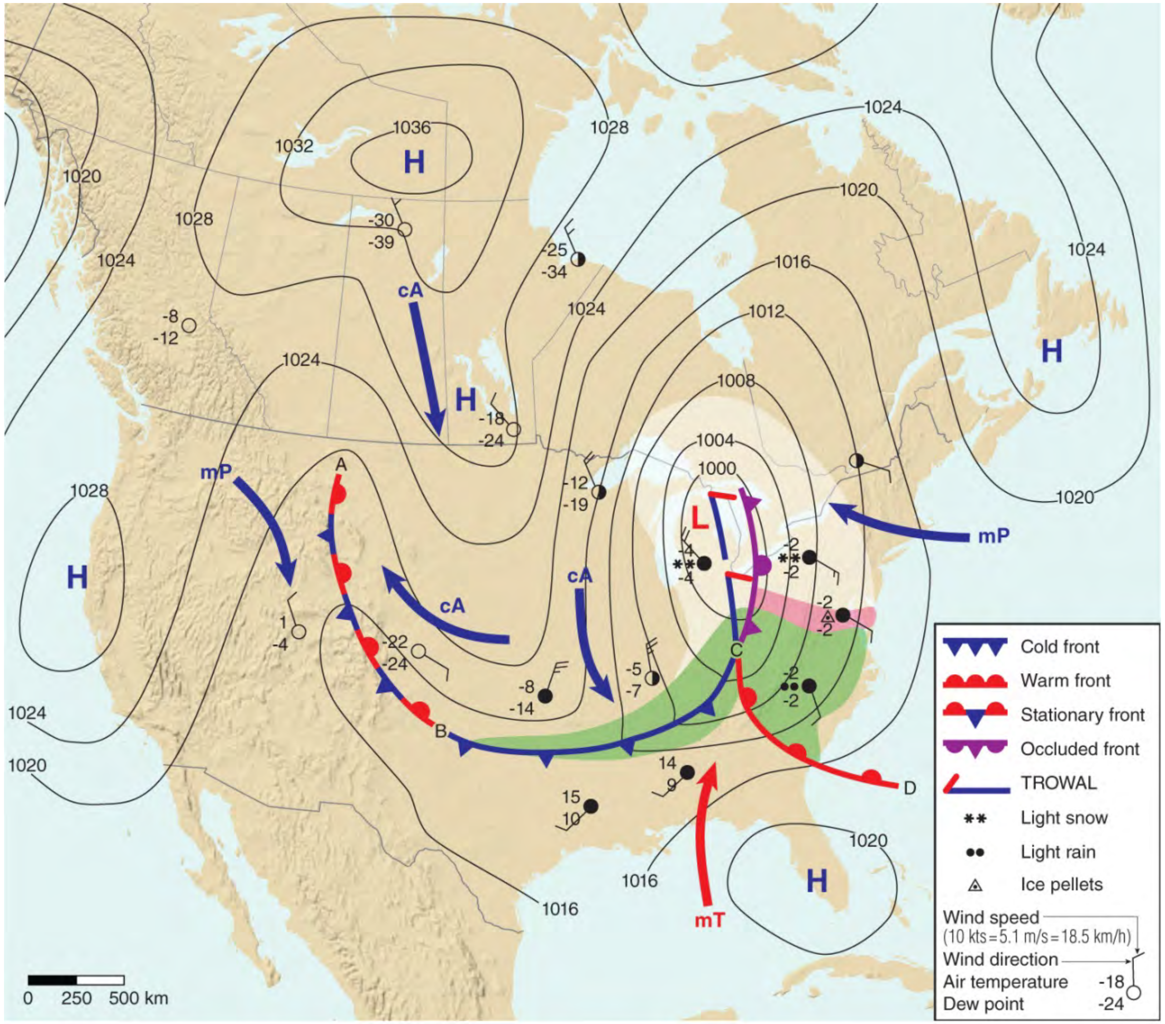
- Fronts
  - Warm and cold fronts
  - Warm and cold occluded fronts
  - Drylines
- Station model
  - Reading temperature, pressure, etc.
- Intro: Midlatitude cyclones

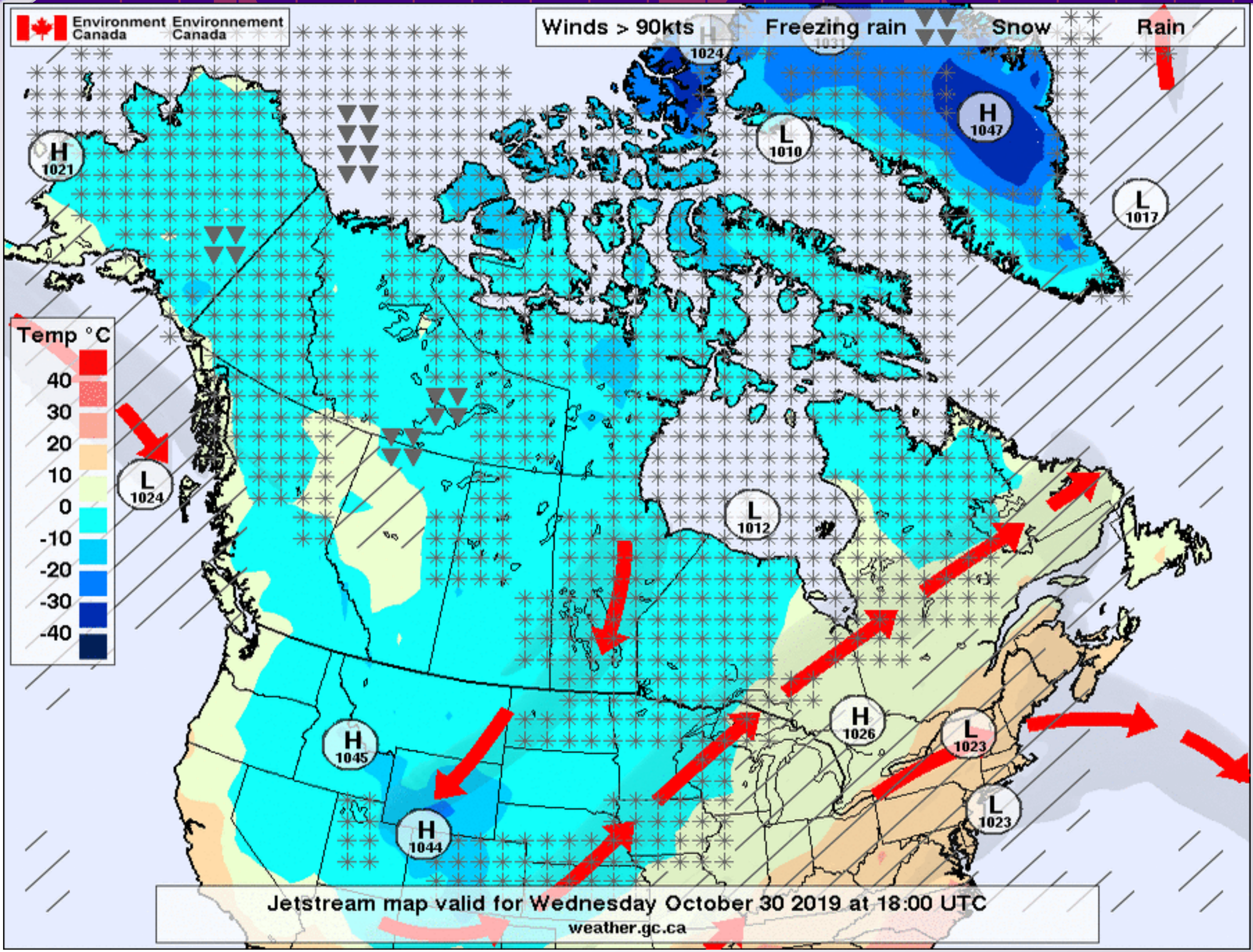
Midlatitude cyclone

Kink in the polar front

Cold and warm fronts rotate around a central low

Wedge of warm air to the south





Environment Canada Environnement Canada
Winds > 90kts
Freezing rain
Snow
Rain
Temp °C
40
30
20
10
0
-10
-20
-30
-40
H 1021
H 1024
H 1047
L 1010
L 1017
L 1024
L 1012
H 1026
L 1023
H 1045
H 1044
L 1023
Jetstream map valid for Wednesday October 30 2019 at 18:00 UTC
weather.gc.ca

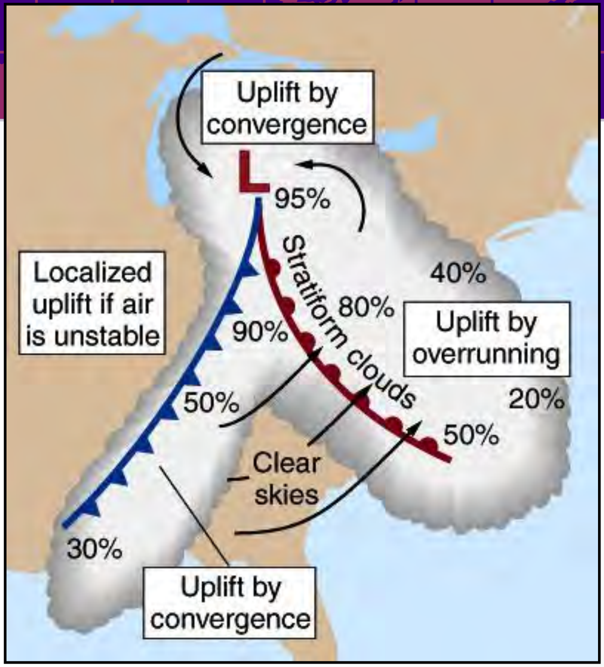
Midlatitude cyclones

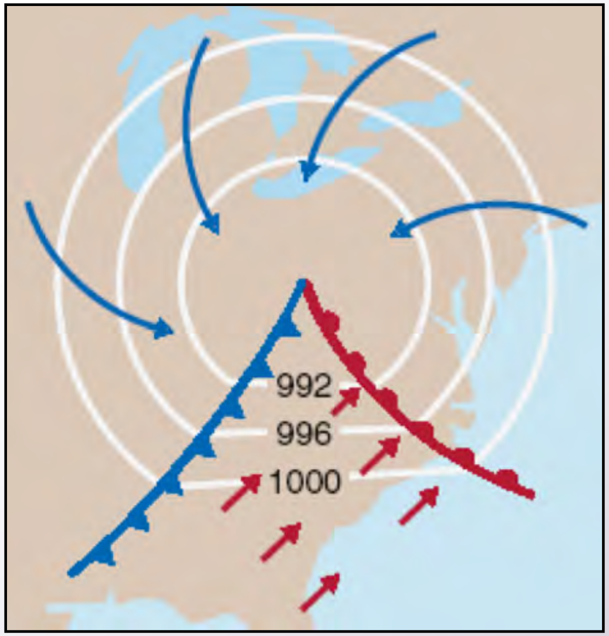
- **Life cycle of a cyclone**
  - **Polar front theory**
- Upper level divergence
  - Baroclinic instability
  - Vorticity
  - Lower atmosphere influence

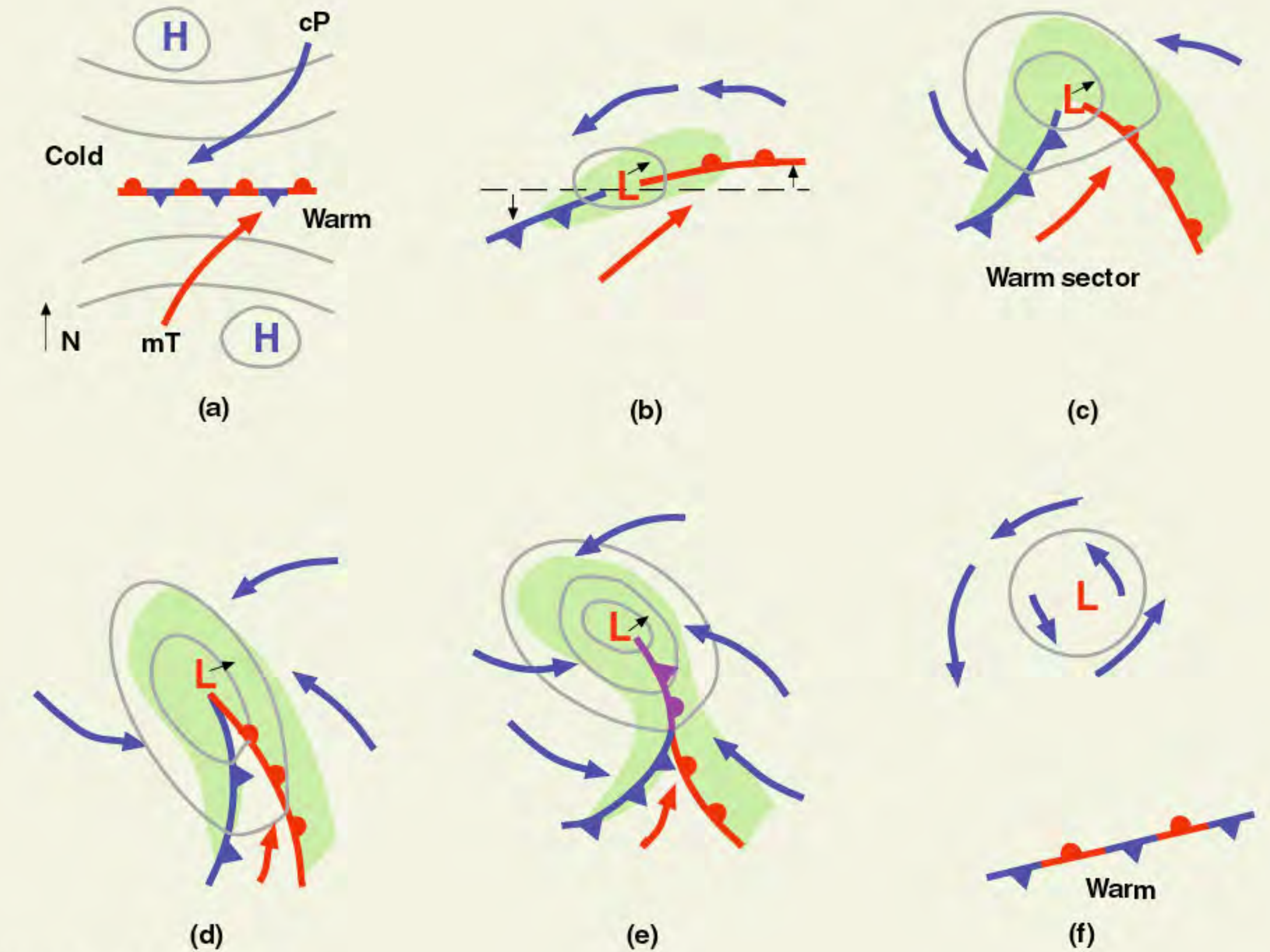
Midlatitude Cyclone

- The principal 'weather maker' in midlatitudes
- Development of a low pressure begins with a small perturbation or disturbance along the polar front

A&B: Figure 10-2





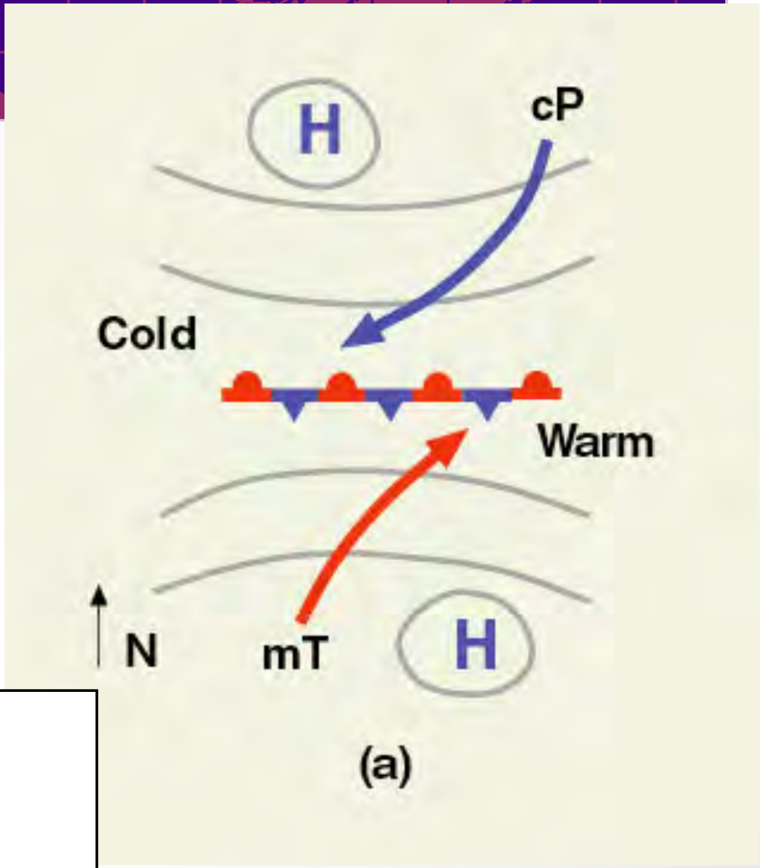


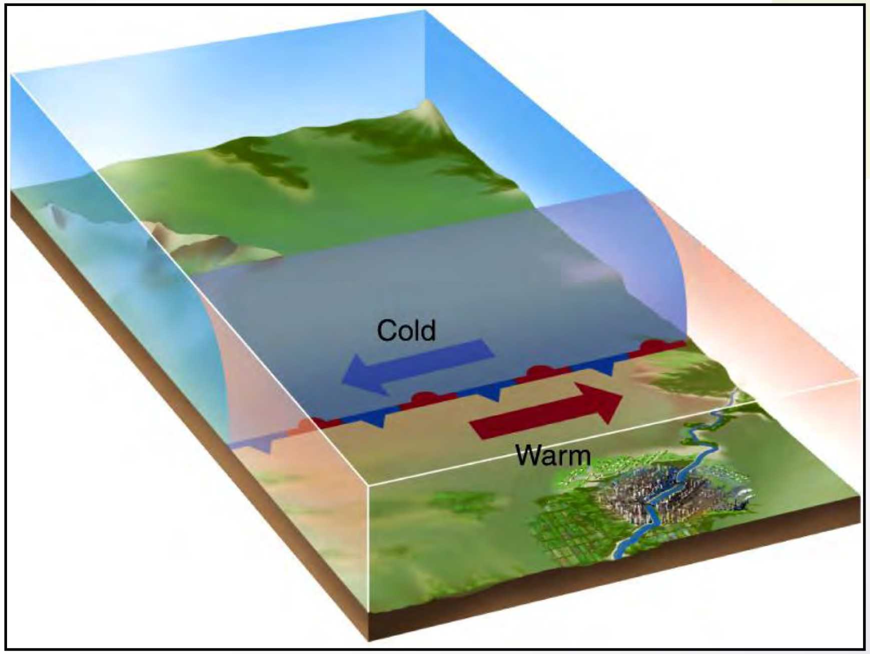
Ahrens: Figure 12.1

Stationary front

Step One

Stationary front with a strong horizontal wind shear



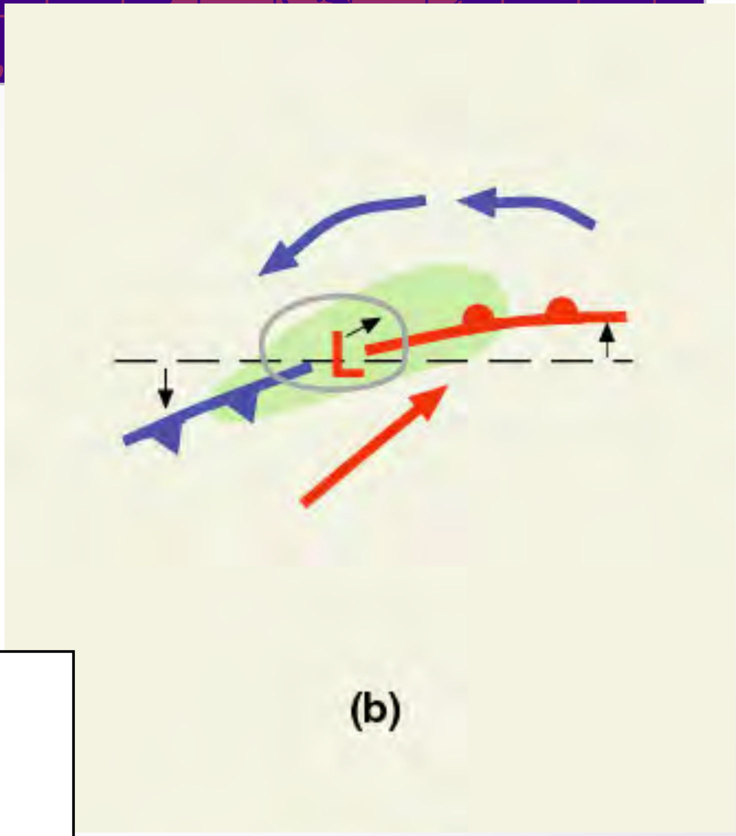


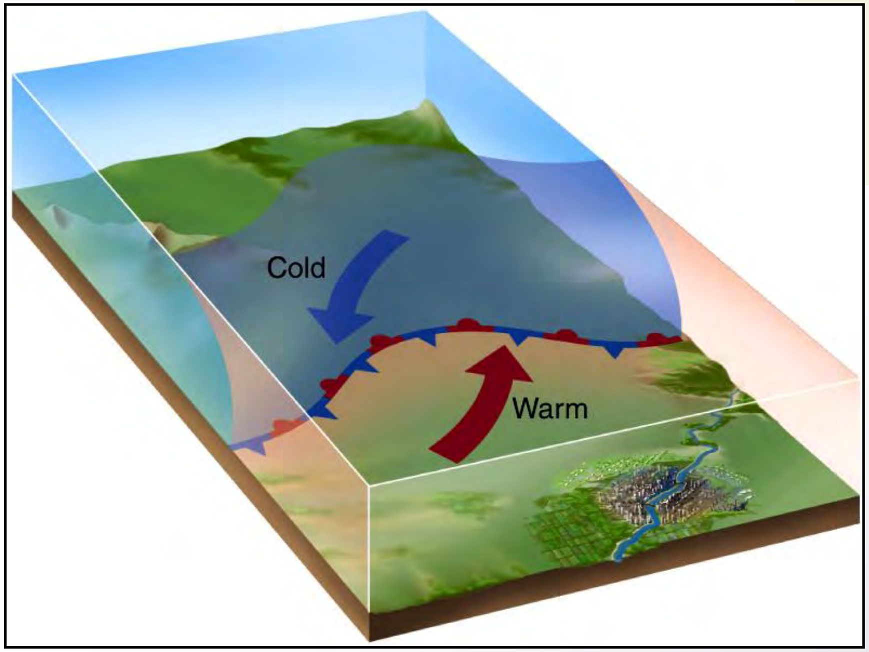
A&B: Figure 10-1

Cyclogenesis begins

Step Two

Under certain conditions a kink or small disturbance forms along the polar front





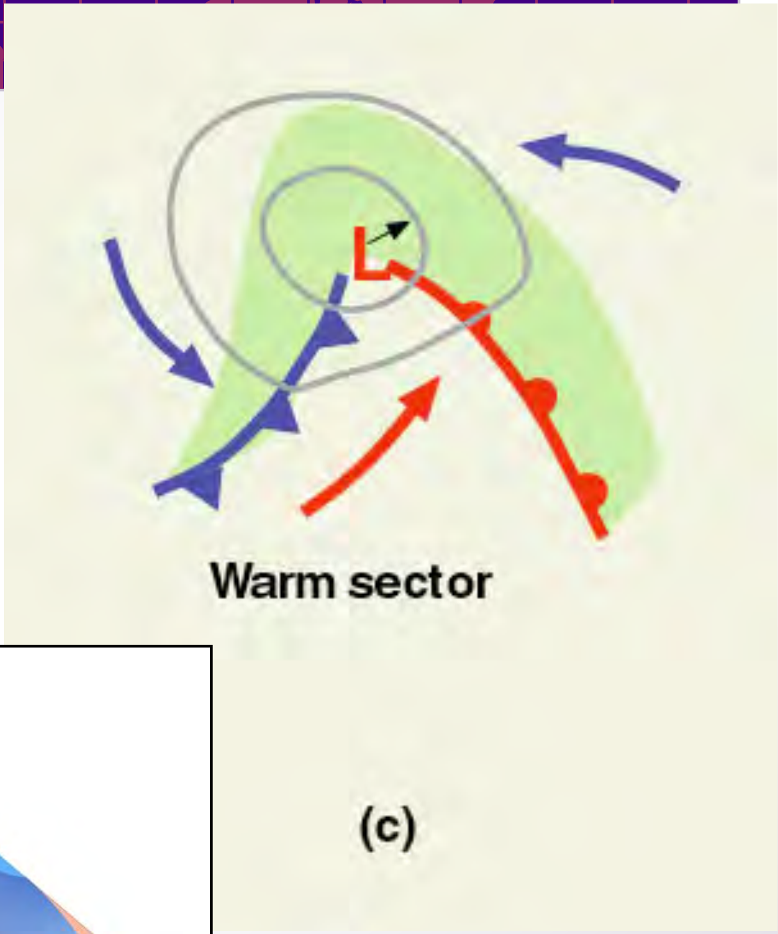
A&B: Figure 10-1

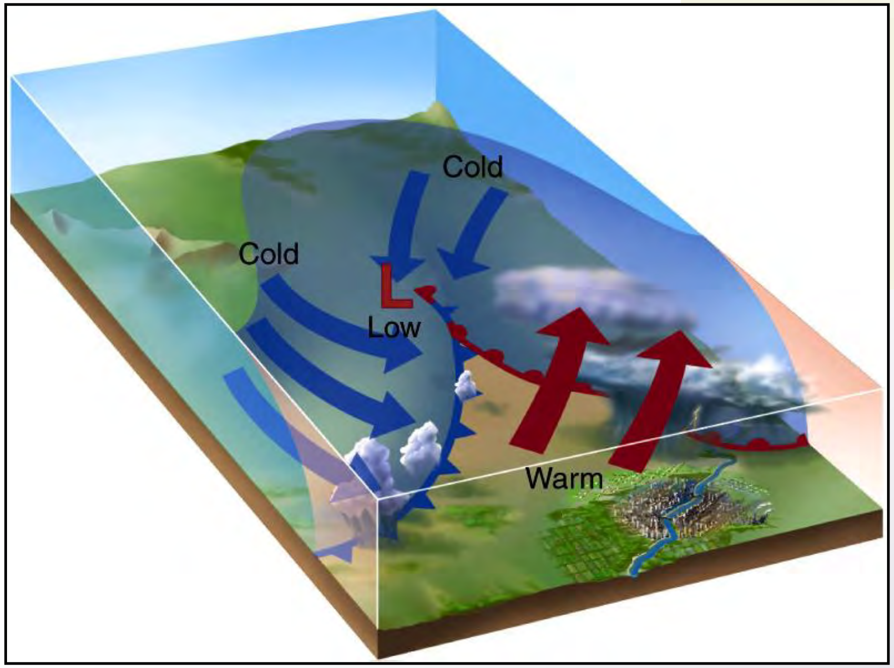
Mature cyclone

Step 3

Fully developed wave

The wave moves east or northeast. It takes 12 to 24 hours to reach this stage of development





A&B: Figure 10-1

Occlusion

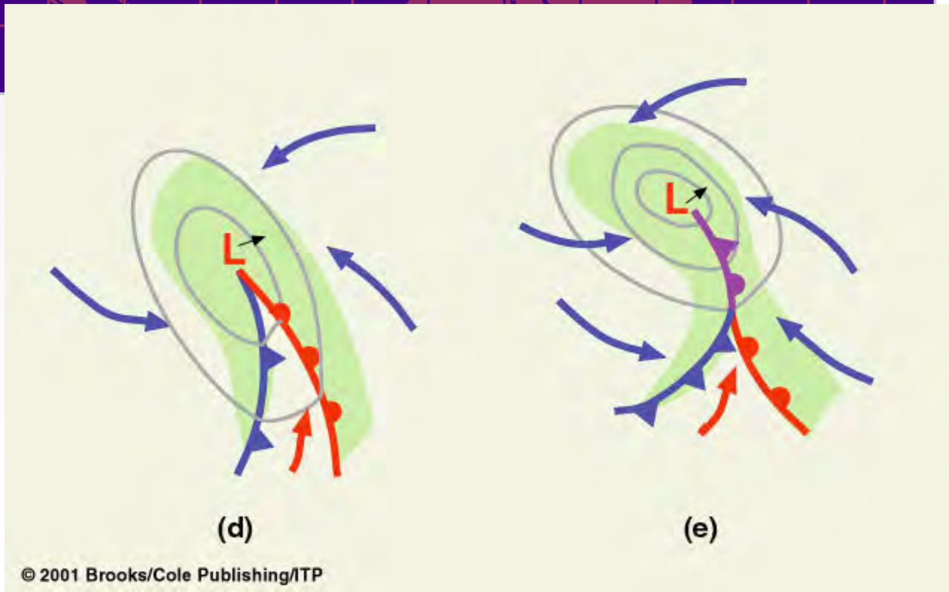
Step 4

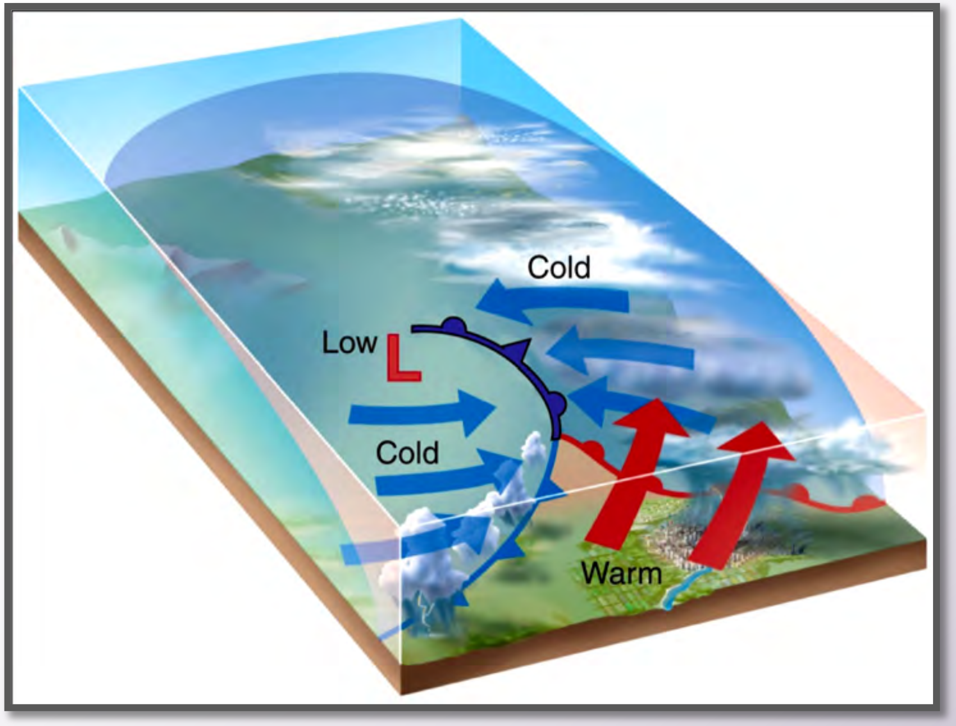
The faster moving cold front catches up with the warm front.

Step 5

Occlusion occurs.

Low pulls back from the fronts.



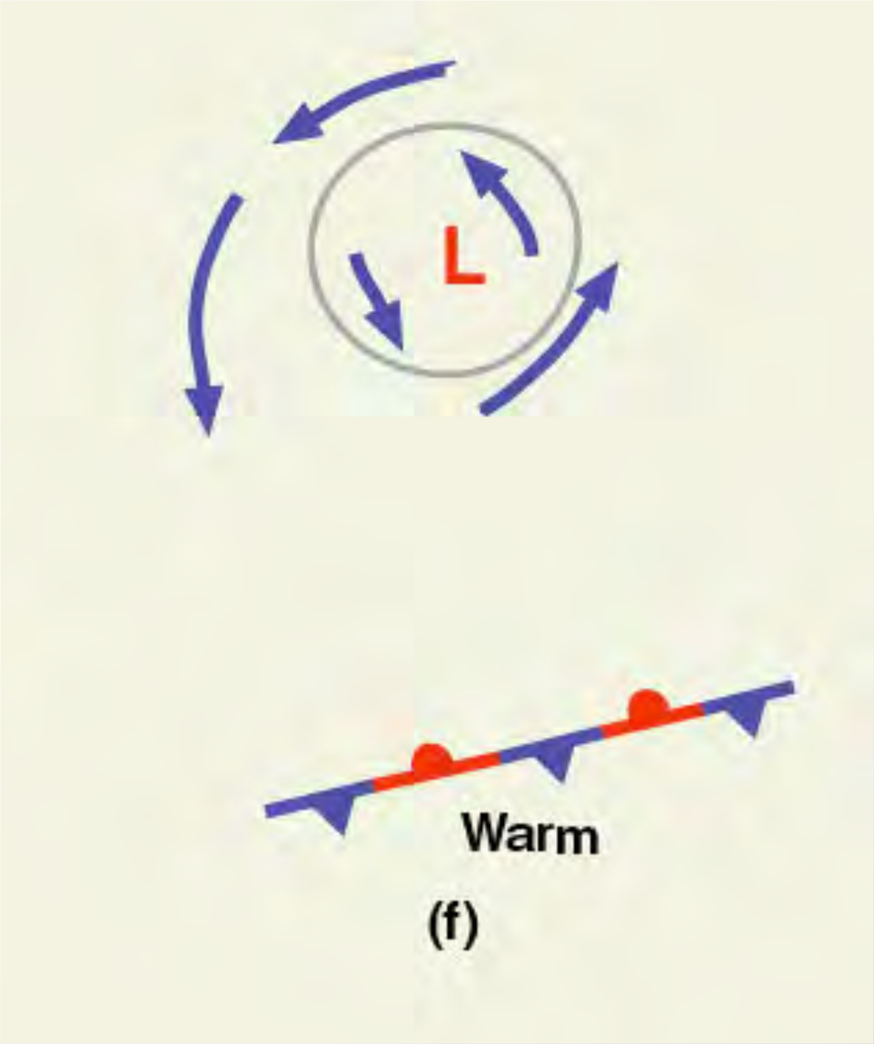


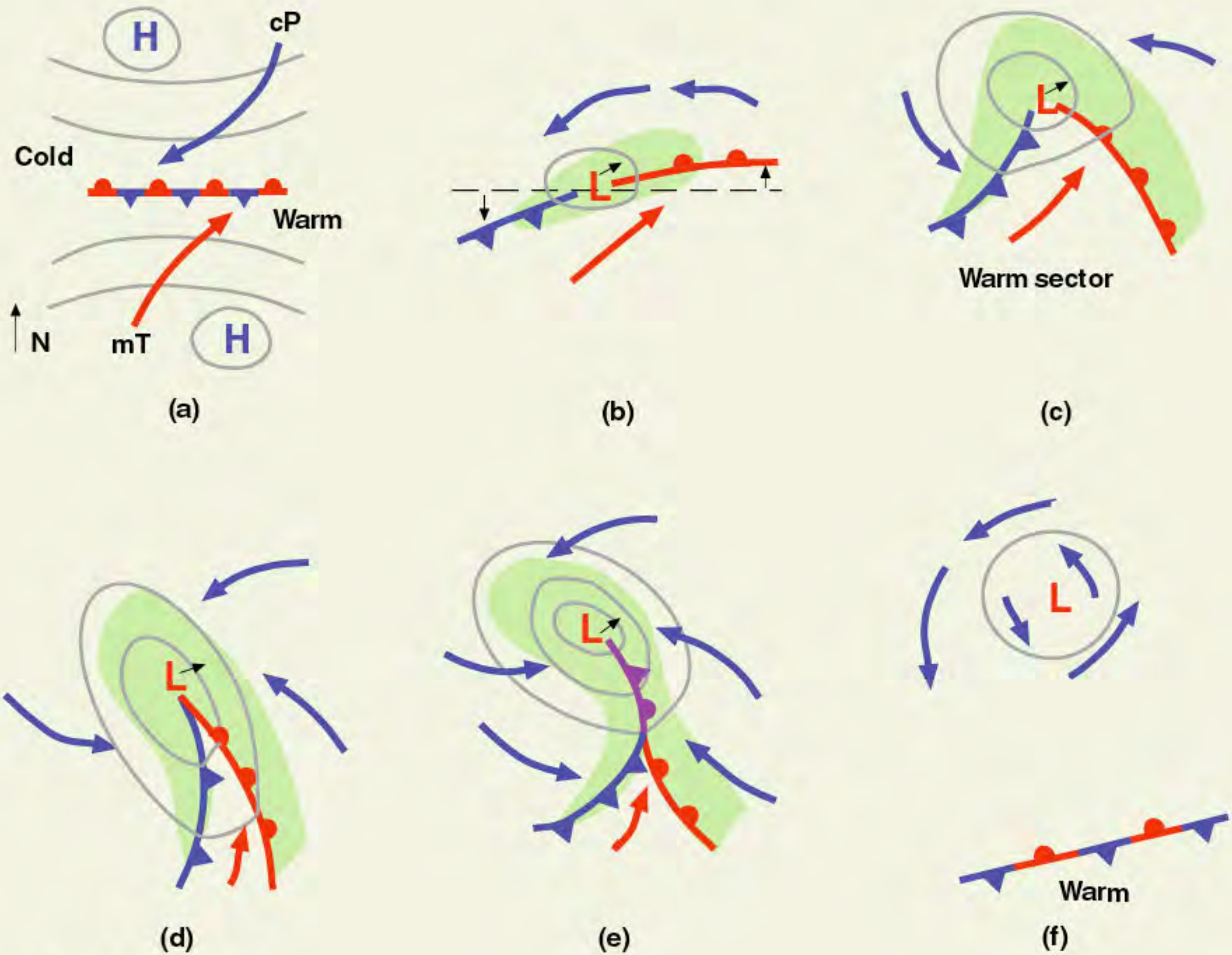
A&B: Figure 10-1

Dissipation

Step 6

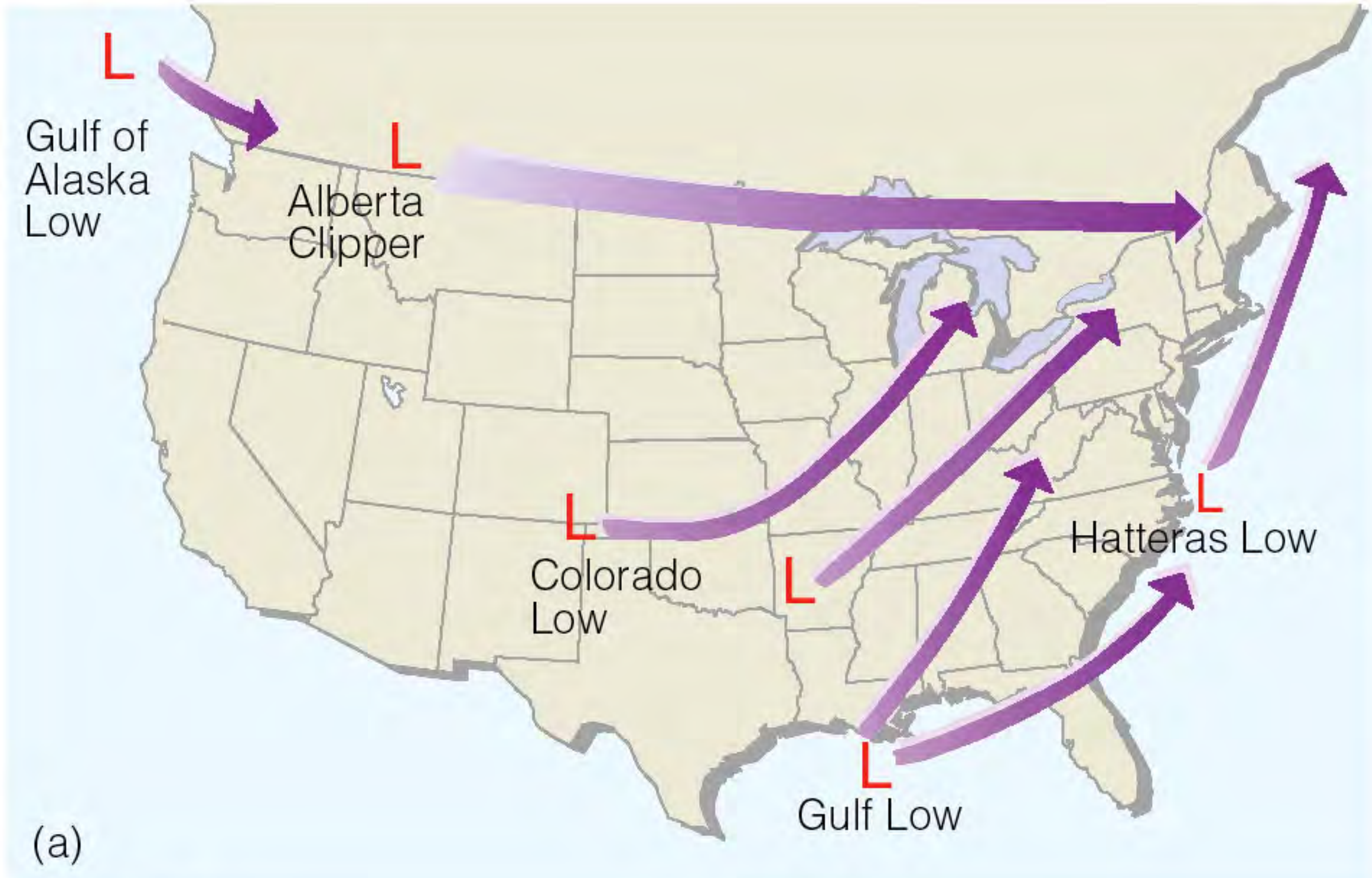
Storm dissipates after occlusion. The source of the energy (rising mT air) has been cut off.




cP
H
Cold
Warm
N
mT
H
(a)
L
(b)
L
Warm sector
(c)
L
(d)
L
(e)
L
Warm
(f)

Typical Winter Cyclone Paths

Ahrens: Fig. 12.5


L
Gulf of Alaska Low
L
Alberta Clipper
L
Colorado Low
L
L
Hatteras Low
L
Gulf Low
(a)

Colorado Lows

The Final Voyage of the Edmund Fitzgerald

November 9, 1975

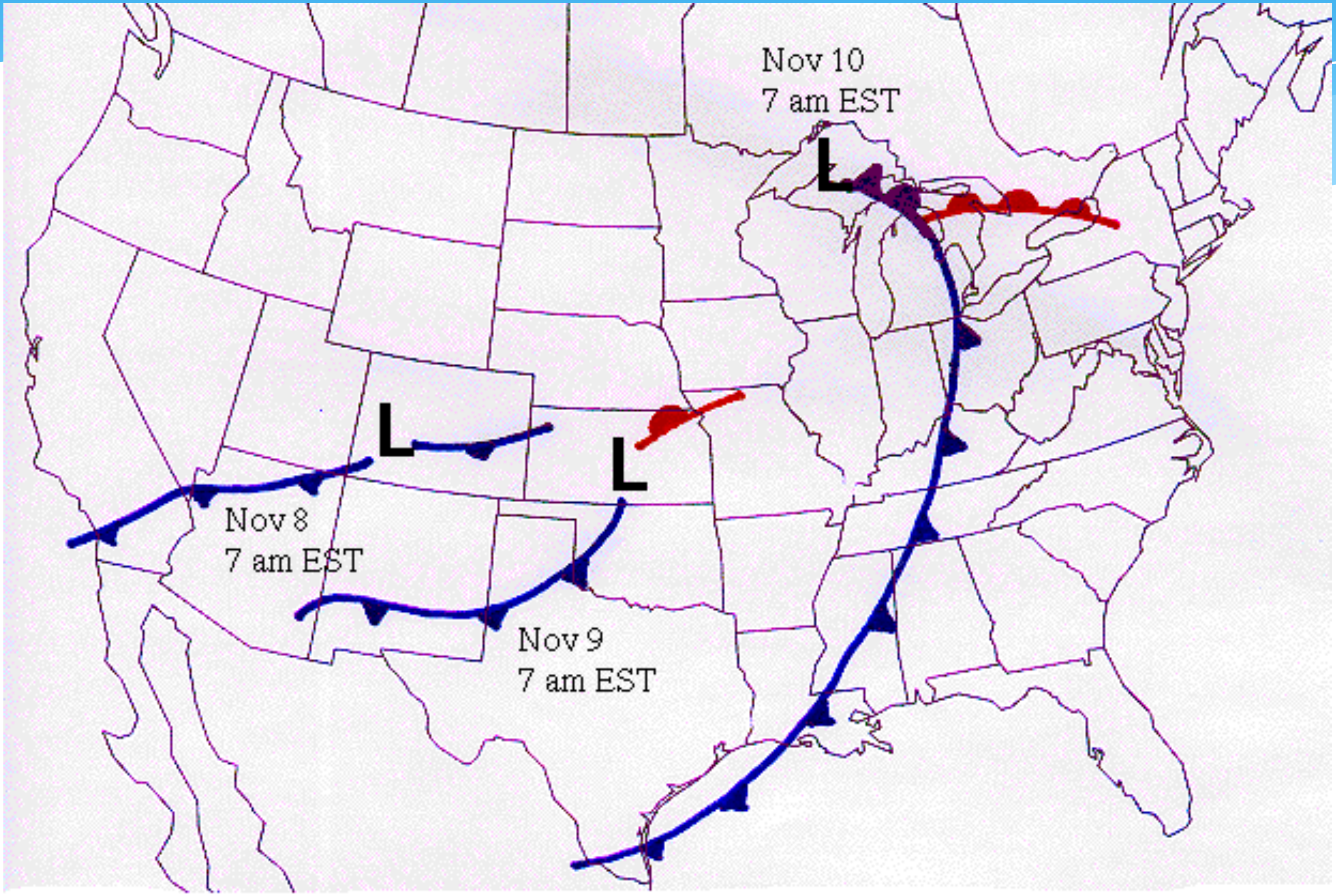
The Edmund Fitzgerald, docked in Superior, Wisconsin and began taking on its cargo on November 9 at 8:30 a.m. **40 years ago**.

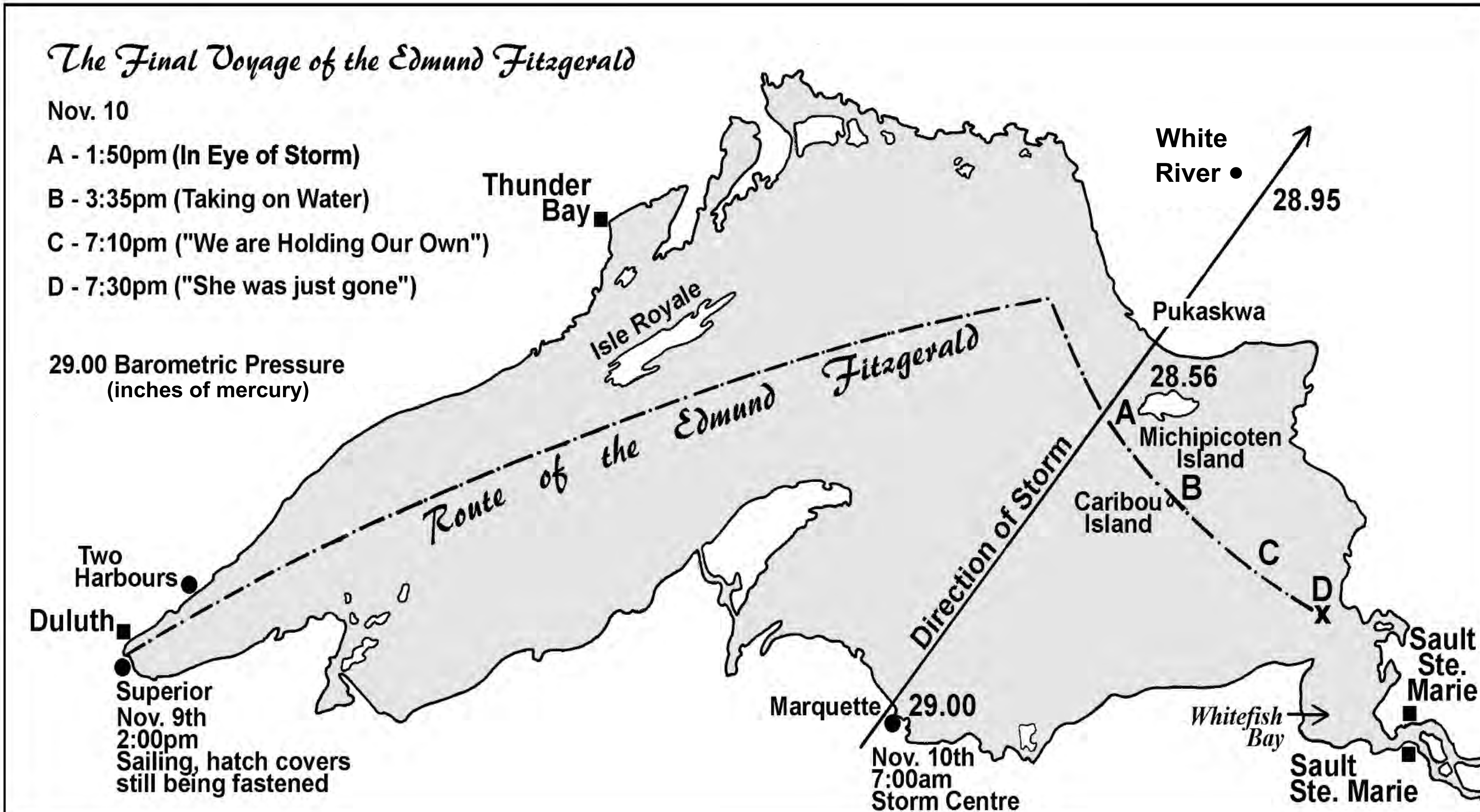
Loading of such a ship is a precise procedure - 21 hatches.

The ship left port about 1415 and sailed into nearly flat waters.

At 1630 – joined by the Arthur M. Anderson, near Two Harbors, Minnesota under Captain Bernie Cooper.

Weather history: November 8 to 10, 1975




The Final Voyage of the Edmund Fitzgerald
Nov. 10
A - 1:50pm (In Eye of Storm)
B - 3:35pm (Taking on Water)
C - 7:10pm ("We are Holding Our Own")
D - 7:30pm ("She was just gone")
29.00 Barometric Pressure
(inches of mercury)
Thunder Bay
Isle Royale
Route of the Edmund Fitzgerald
White River
28.95
Pukaskwa
28.56
A
Michipicoten Island
B
Caribou Island
C
D
X
Direction of Storm
Two Harbours
Duluth
Superior
Nov. 9th
2:00pm
Sailing, hatch covers
still being fastened
Marquette
29.00
Nov. 10th
7:00am
Storm Centre
Whitefish Bay
Sault Ste. Marie
Sault Ste. Marie

The Final Hours

The two ships continued SE toward the shelter of Whitefish Bay. The winds shifted to the NW and Captain McSorley reported that his ship was "rolling some".

Six-Fathom Shoal

East of Caribou Island.

Pumps operating

Ship was reported as "listing"

The Final Hours

1630 East of Caribou Island. Captain Cooper noted winds at 58 knots and waves of 5 to 7 m were breaking over the deck of his boat.

Wind gusts to 75 knots (140 km/hr) were noted minutes later. Winds tore the Fitzgerald's radar equipment from the pilothouse around this time. The ship was now dependent on the Anderson's radar and radio reports.

Captain Cooper observed two "rogue" waves of more than 10 metres.

1910 Anderson radioed a radar report and asked for an update on the problems of the ship.

"We are holding our own", was the reply.

Pilothouse showing massive damage

* Captain Ernest McSorley transmitted his final radio message from this Pilothouse. "We are holding our own," in reference to shipboard problems.
* Source: Photo by Frederick J. Shannon, 1994

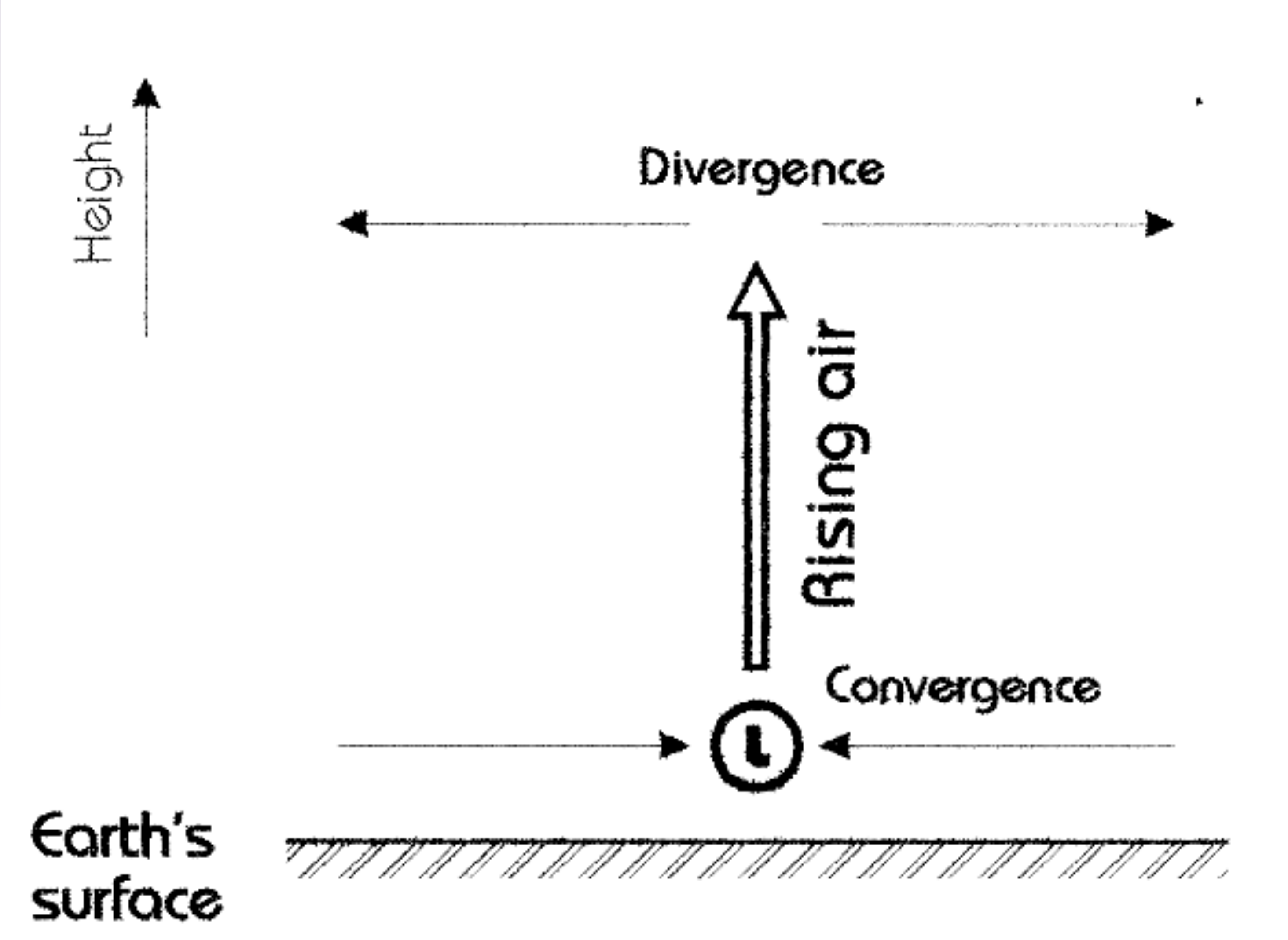
What caused the tragedy?

The Bell from the Edmund Fitzgerald

The bell was retrieved in 1995.

Source: Photos by Alan R. Kamuda

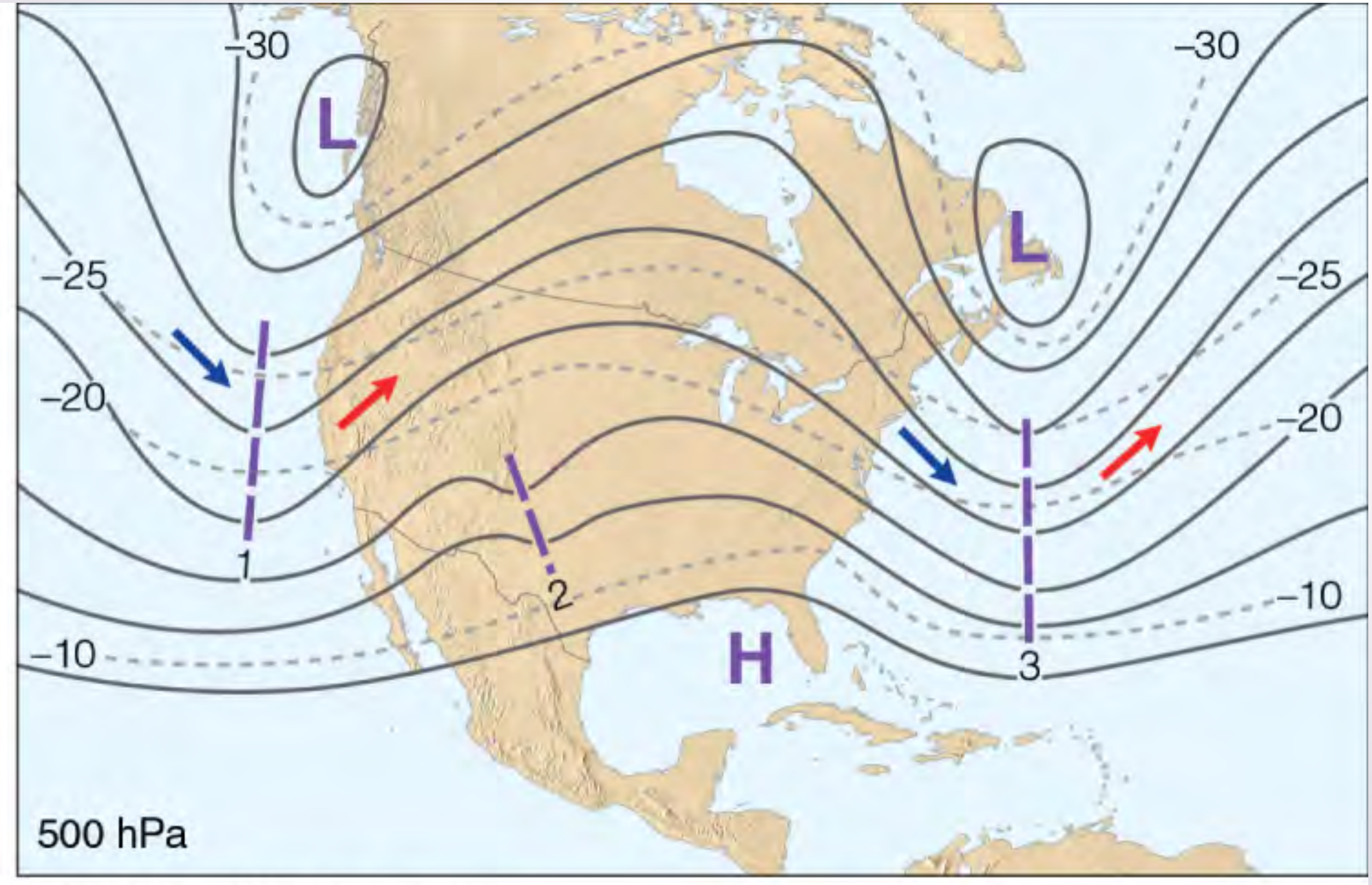
Surface winds and vertical motion



Lecture outline

- Life cycle of a cyclone
  - Polar front theory
- **Upper level divergence**
  - **Baroclinic instability**
  - **Vorticity**
  - **Lower atmosphere influence**

Rossby Waves



Ahrens: Fig. 12.9b

Baroclinic Wave Theory

Barotropic

- Isotherms are parallel with isobars.
- No temperature advection.

Baroclinic

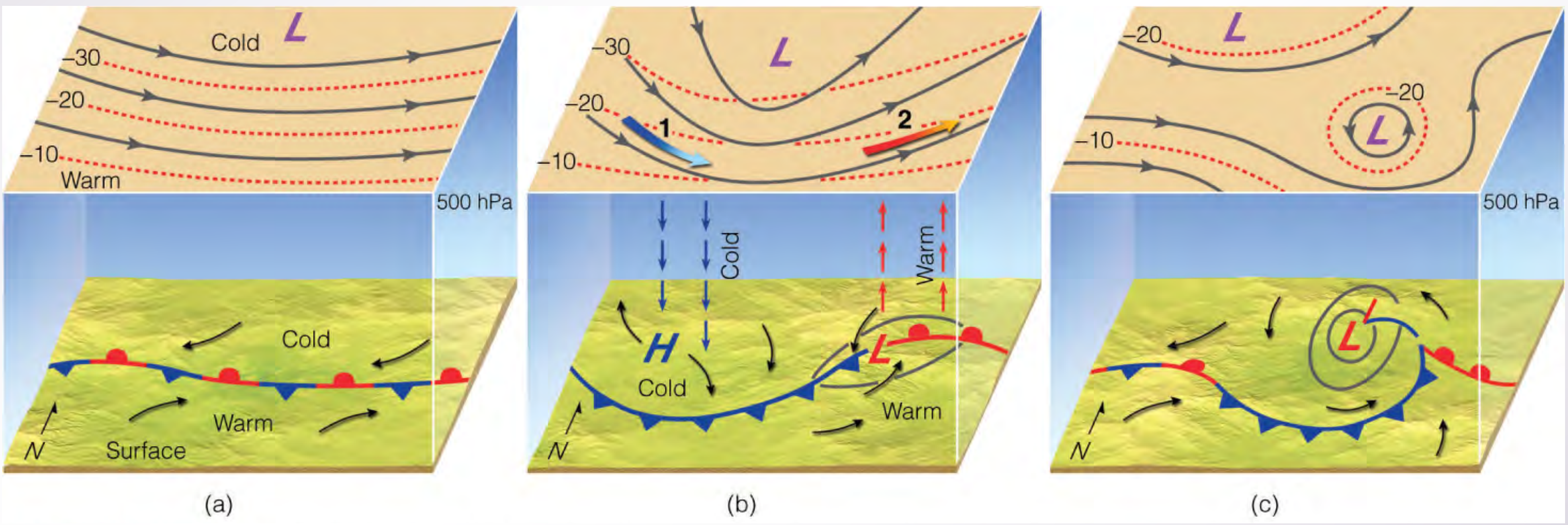
- Isotherms cross isobars.
- Geostrophic flow produces temperature advection.

Development of a Baroclinic Wave

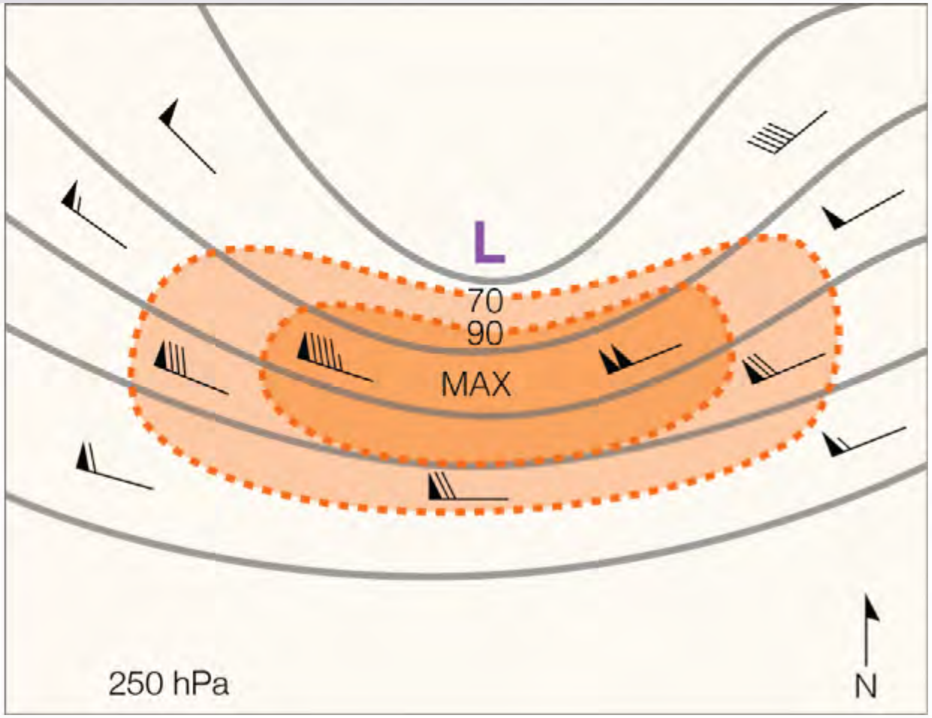
Barotropic

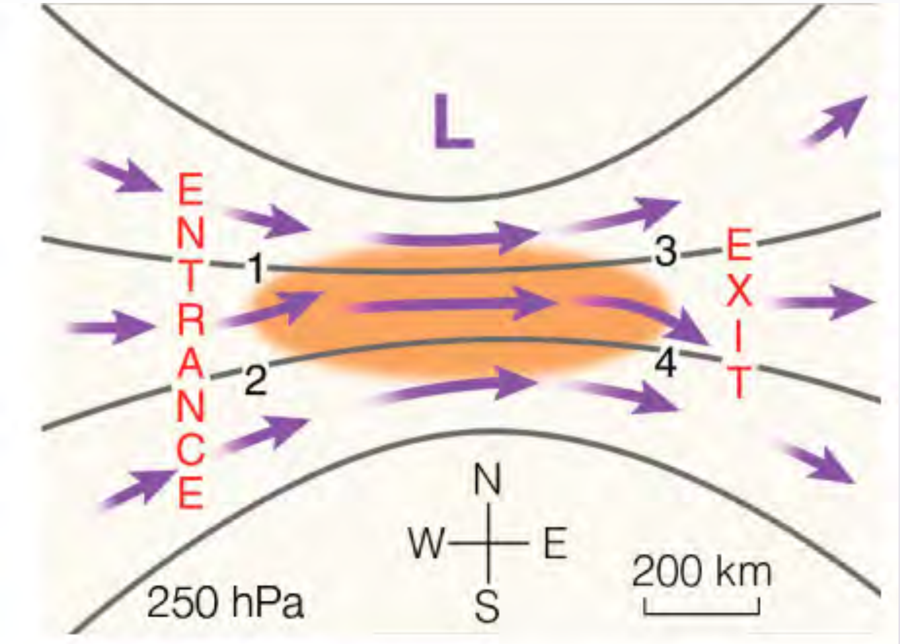
Baroclinic

Barotropic



Jet streaks

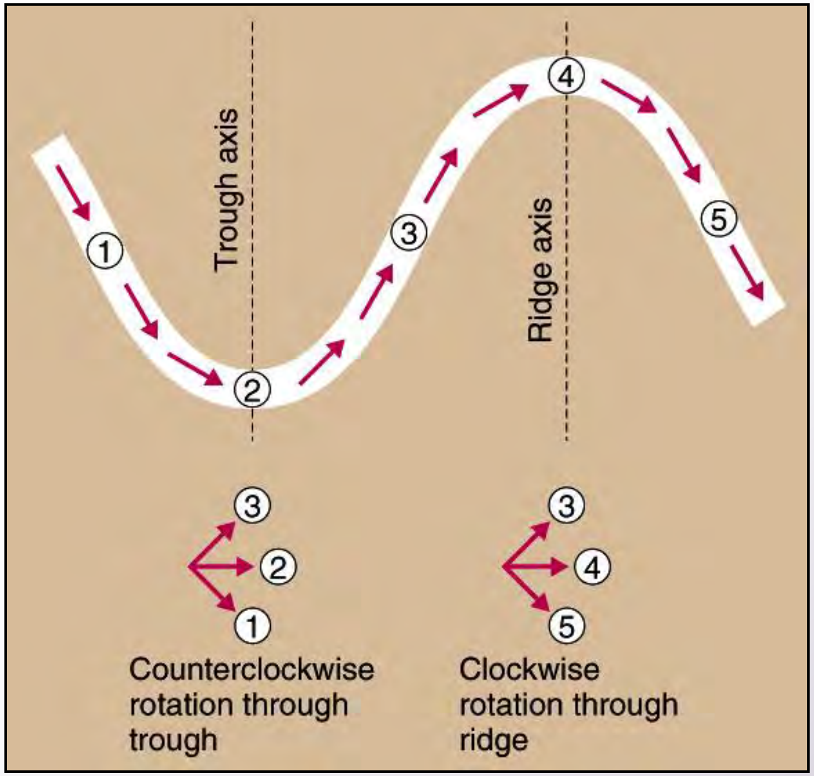




Ahrens: Figs. 4 and 5, p. 364

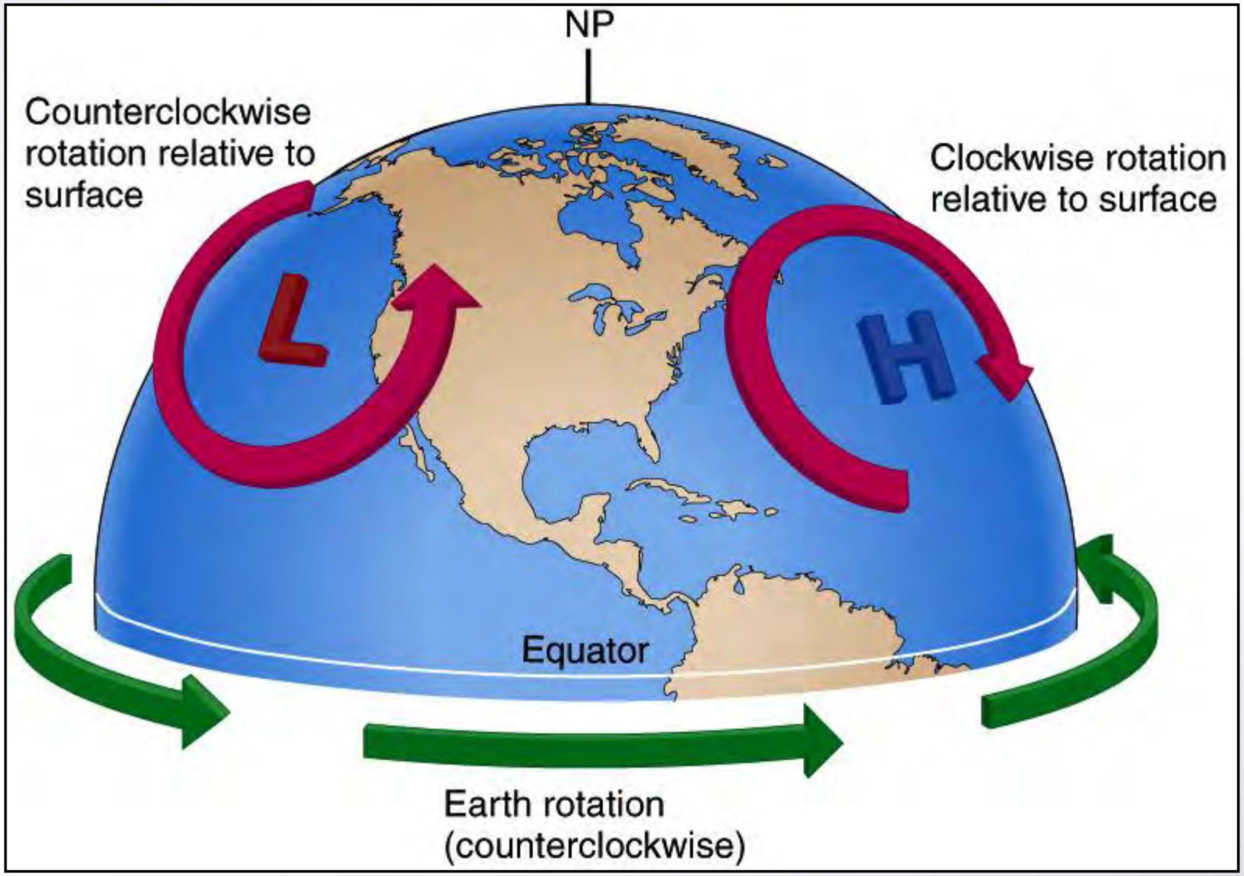
Vorticity

- Rotation of a fluid
- Direction of rotation changes between troughs and ridges



A&B: Figure 10-4

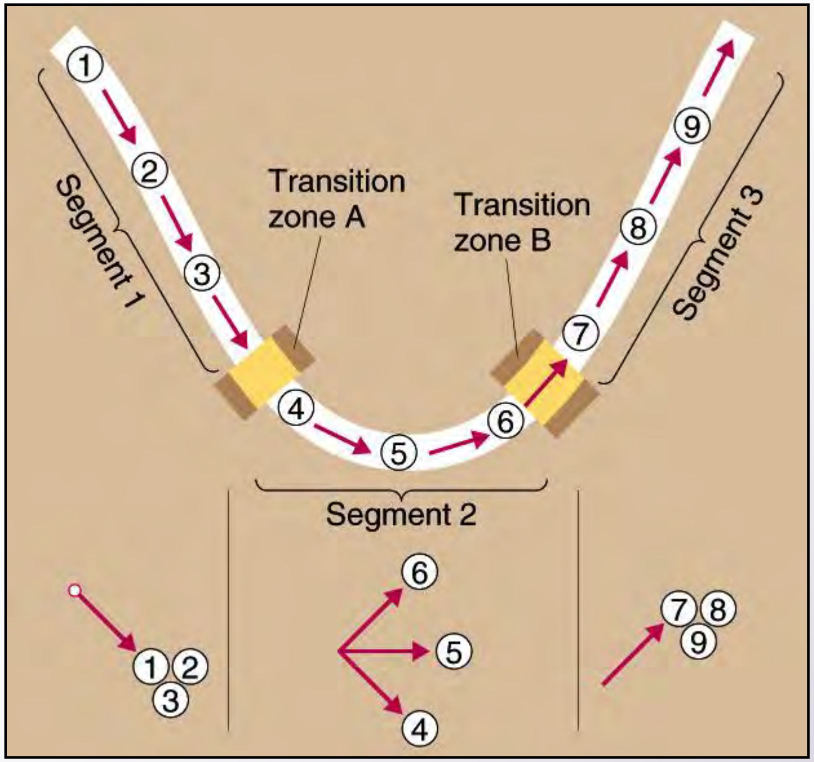
Positive and negative vorticity



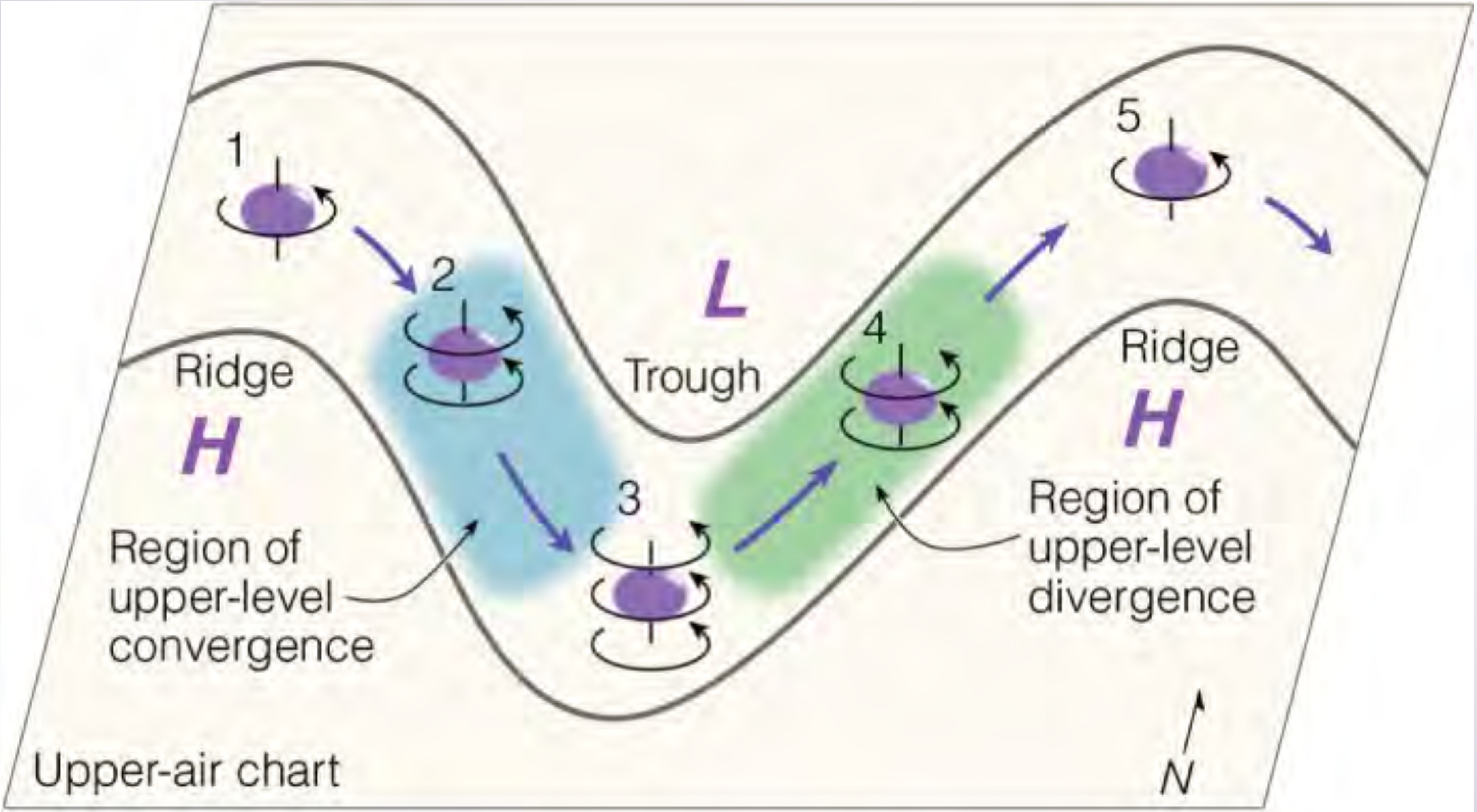
A&B: Figure 10-5

Vorticity and divergence

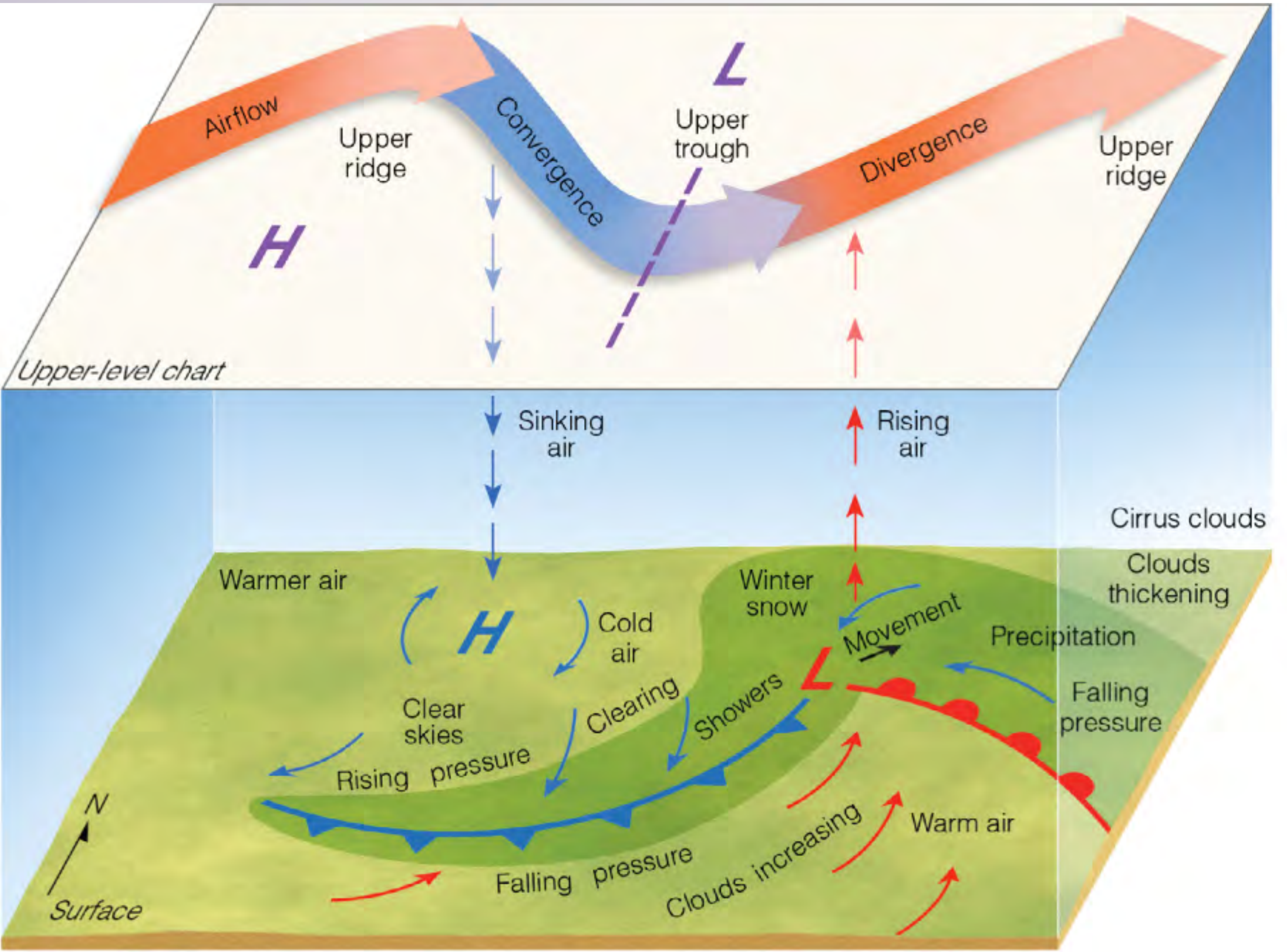
- A: Increasing spin
  - Angular momentum stays constant
  - Radius shrinks
  - Convergence
- B: Decreasing spin
  - Radius increases
  - Divergence

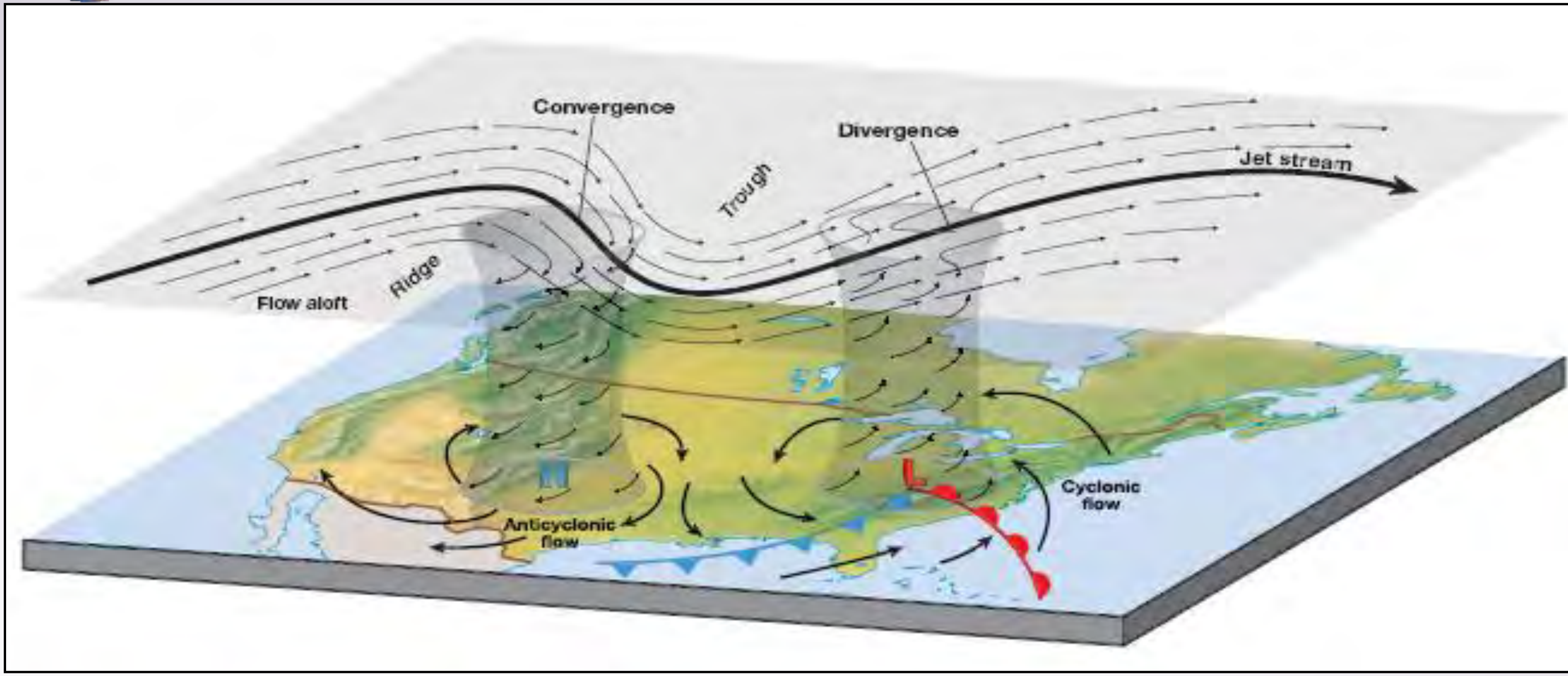


A&B: Figure 10-6



Vorticity Advection
Ahrens: Fig. 12.22


Airflow
Upper ridge
Convergence
L
Upper trough
Divergence
Upper ridge
H
Upper-level chart
Sinking air
Rising air
Cirrus clouds
Clouds thickening
Warmer air
Winter snow
H
Cold air
Movement
Precipitation
L
Clear skies
Clearing
Showers
Falling pressure
Rising pressure
N
Warm air
Clouds increasing
Falling pressure
Surface



Dynamic pressure systems

Cyclones form in areas of upper-level divergence

Path of the cyclone most frequently follows the course of upper level flow

A&B: Figure 10-7

Summary

- Midlatitude cyclones caused by upper troposphere divergence
  - Baroclinicity
  - Jet streaks
  - Vorticity
- Cyclones are further fuelled by surface conditions
  - Latent heat added to upper air
  - Occlusion cuts off this source of fuel

Next lecture

- Thunderstorms and tornadoes