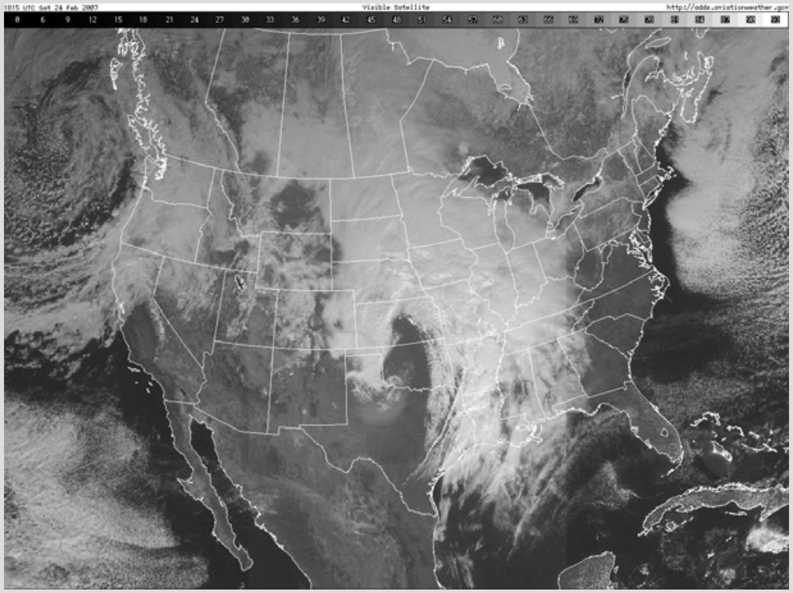
NATS 101
Section 13: Lecture 23

Mid-Latitude Cyclones



Mid-latitude cyclone example

Late February 2007

Weather fronts are typically associated with mid-latitude cyclones (or extratropical cyclones). ***These have a very organized structure.***

What is the purpose of mid-latitude cyclones in the general circulation?

Transport _________ toward ___________ and upward.
Transport _________ toward ___________ and downward.

This process is called *baroclinic instability*—a type of instability in the atmosphere which arises due to ______________________.

Questions for today's discussion

How do mid-latitude cyclones form?

How are they related to weather fronts?

What is their typical life cycle?

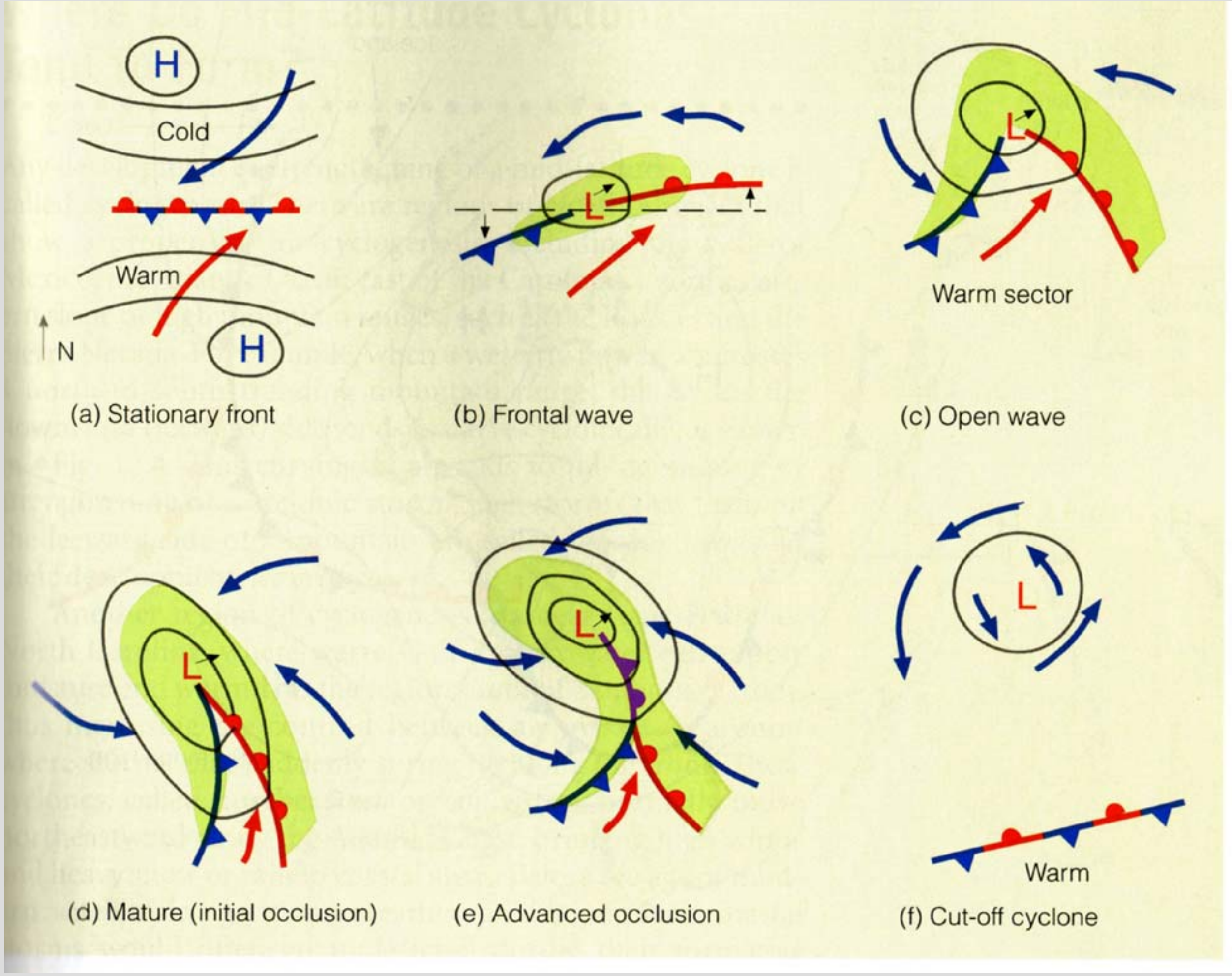
How are they associated with upper-level features?

The idealized model for the development of a mid-latitude cyclone is from Norwegian meteorologist Vilhelm Bjerknes.

He was also the one who coined the term “front” around World War I, as I discussed last time.

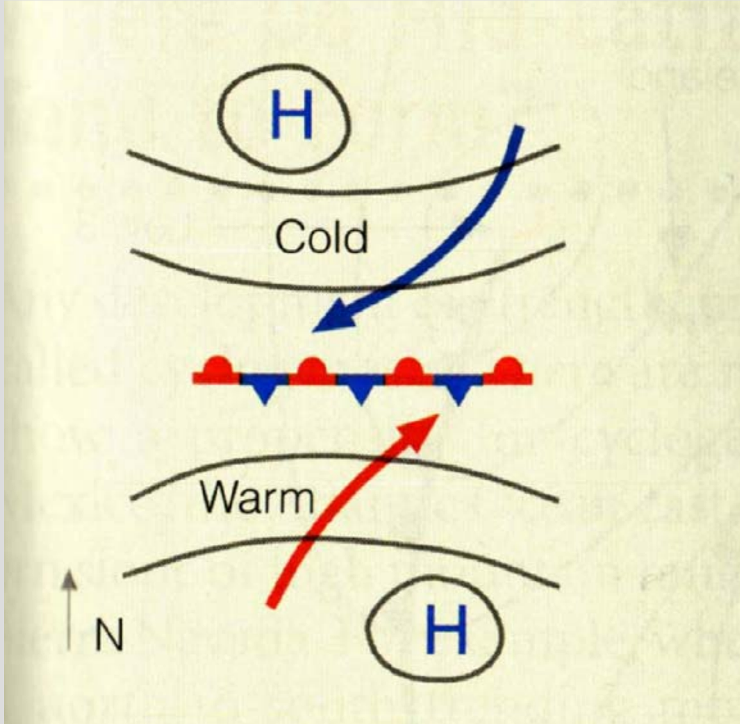
Vilhelm Bjerknes

Bjerknes Polar Front Model



This sequence of events typically lasts on a timescale of days to a week.

Bjerknes Polar Front Model
Step 1: Stationary Front

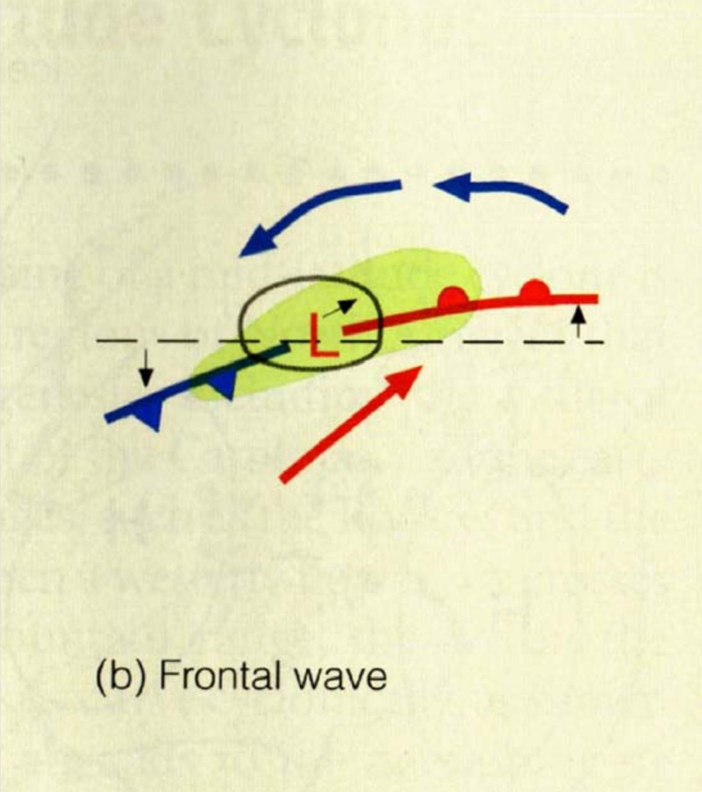


(a) Stationary front

A stationary frontal boundary forms between cold and warm air.

This sets up a wind shear zone along the front.

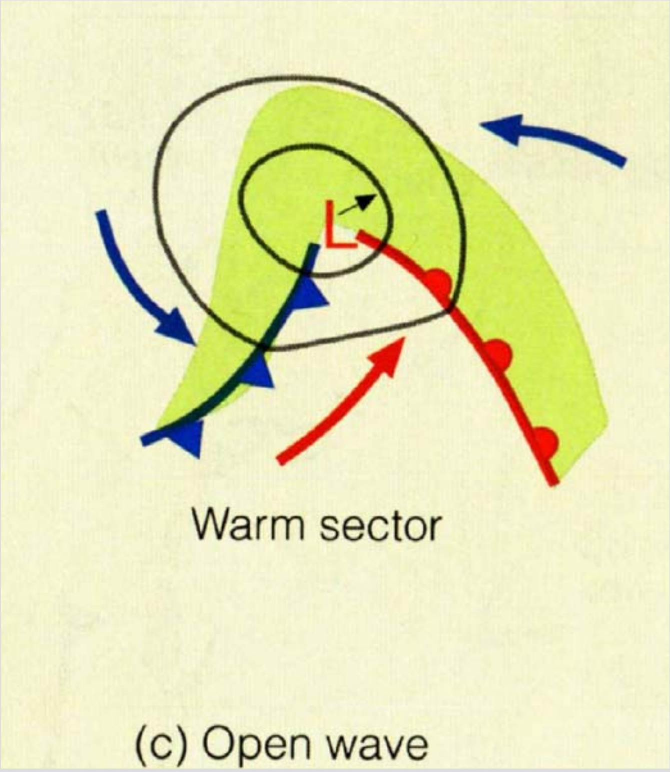
Bjerknes Polar Front Model
Step 2: Frontal wave



A trigger (usually an upper level trough) causes the formation of low pressure along the front.

Warm and colds fronts begin to form.

Bjerknes Polar Front Model
Step 3: Open wave

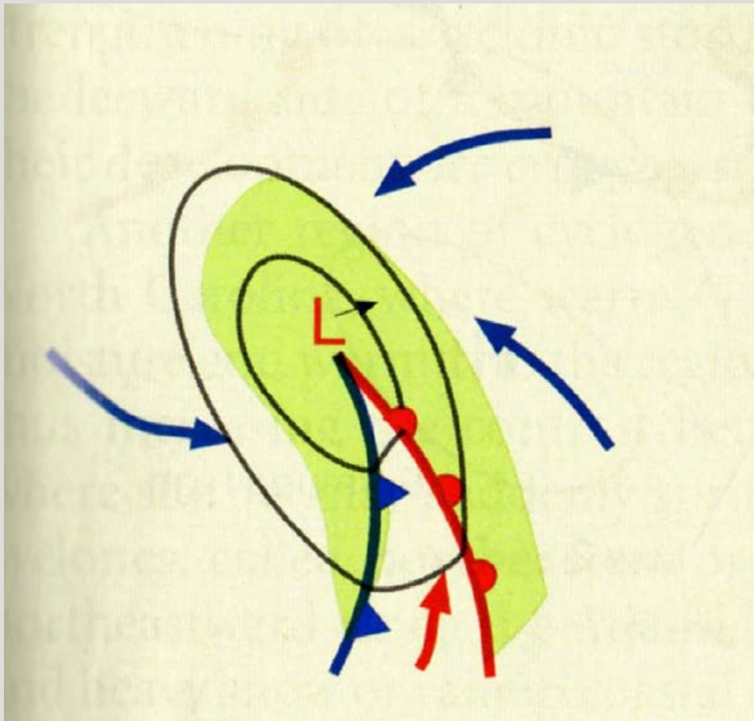


Low pressure begins to deepen.

Warm and cold fronts become more defined.

A warm sector forms ahead of the cold front—and this is typically where the most severe weather occurs.

Bjerknes Polar Front Model
Step 4: Mature cyclone

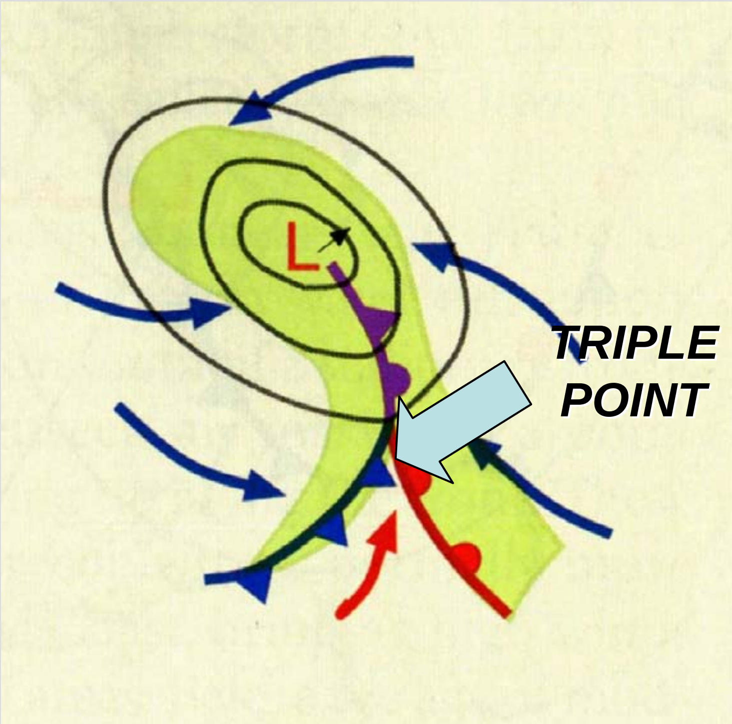


(d) Mature (initial occlusion)

Low pressure deepens more.

Cold front begins to catch up to the warm front near the center of low pressure, forming an occluded front.

Bjerknes Polar Front Model
Step 5: Occluded stage



(e) Advanced occlusion

Mid-latitude cyclone most intense here.

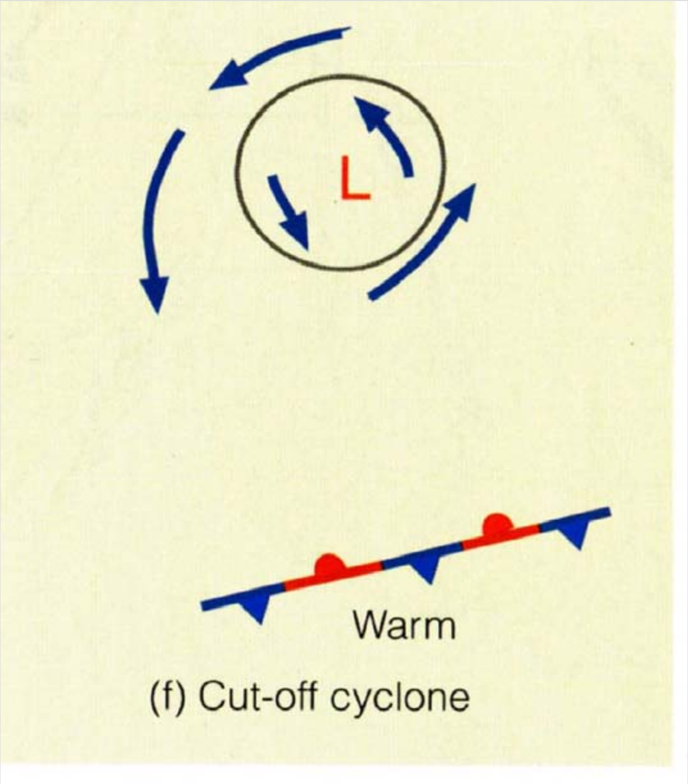
Low deepens to its lowest pressure.

Occluded front near the center of the low pressure.

What are the various types of weather associated with the cyclone at this stage?

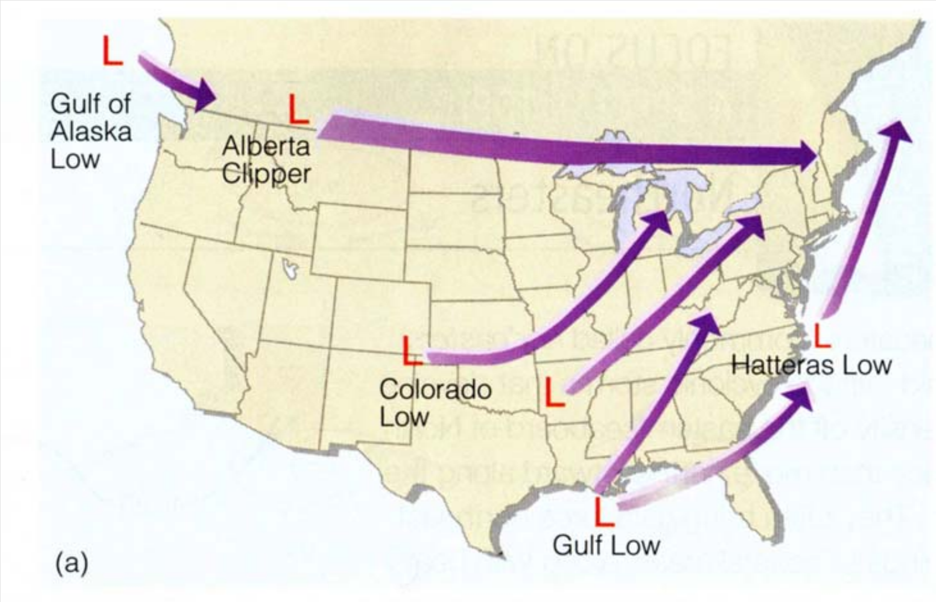
A new area of low pressure may form where all three fronts meet, called the triple point.

Bjerknes Polar Front Model
Step 6: Cut off stage



Center of storm gradually dissipates as cold air removes the occluded front, depriving the storm of warm and moist air.

Favored Mid-Latitude Cyclone Genesis Areas



Typical mid-latitude cyclone tracks in North America.

<u>Lee of mountain ranges</u>

Air going downslope tends to induce formation of surface lows.

Examples: Colorado Lows, Alberta clippers.

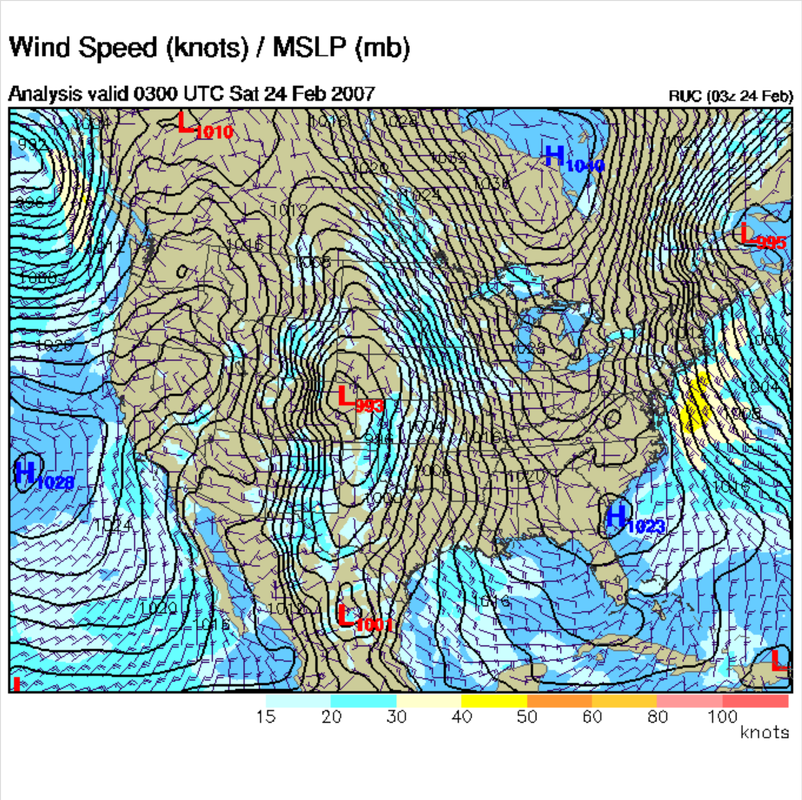
<u>Over warm water</u>

Provides a source of energy due to latent heat release in clouds

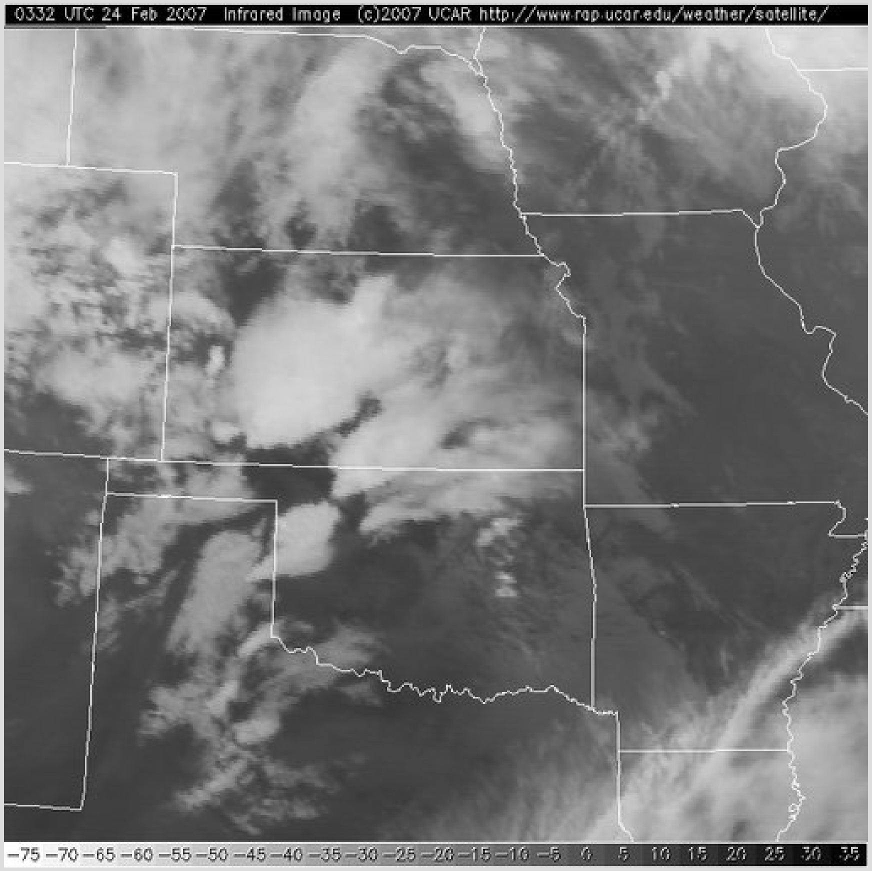
Examples: Gulf of Mexico Lows, Nor'esters.

The late February 2007 case we’ve been looking at is a good example of a Colorado low.

Open Wave Stage
0300 UTC, Saturday, Feb. 24, 2007

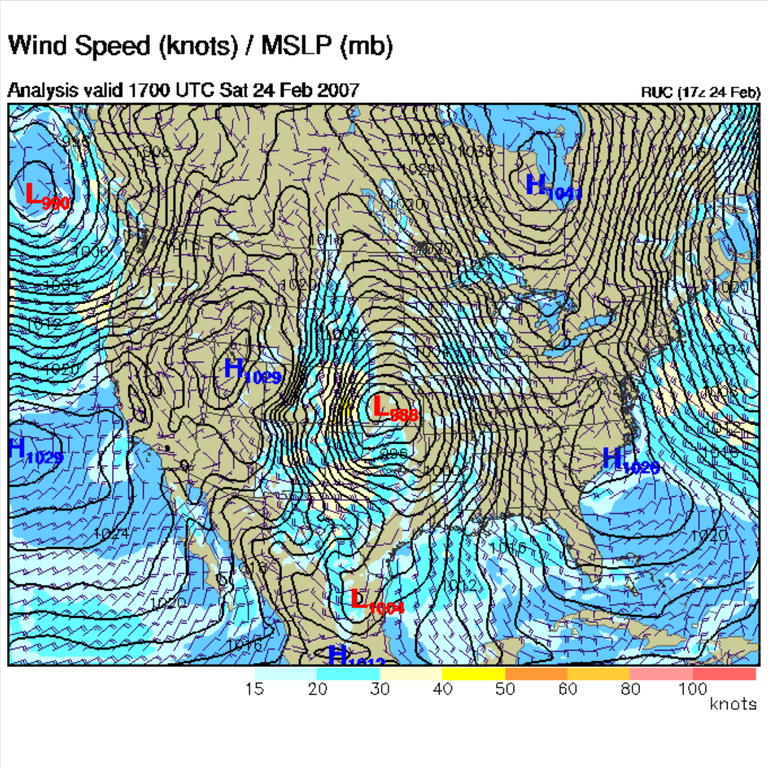


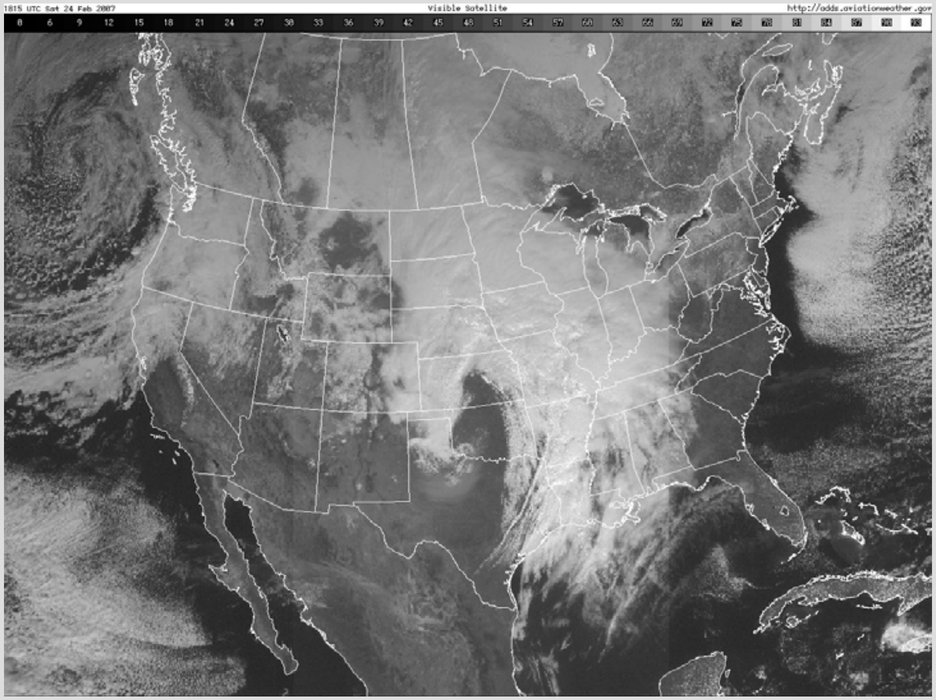
Note formation of low pressure in eastern CO.



IR Imagery

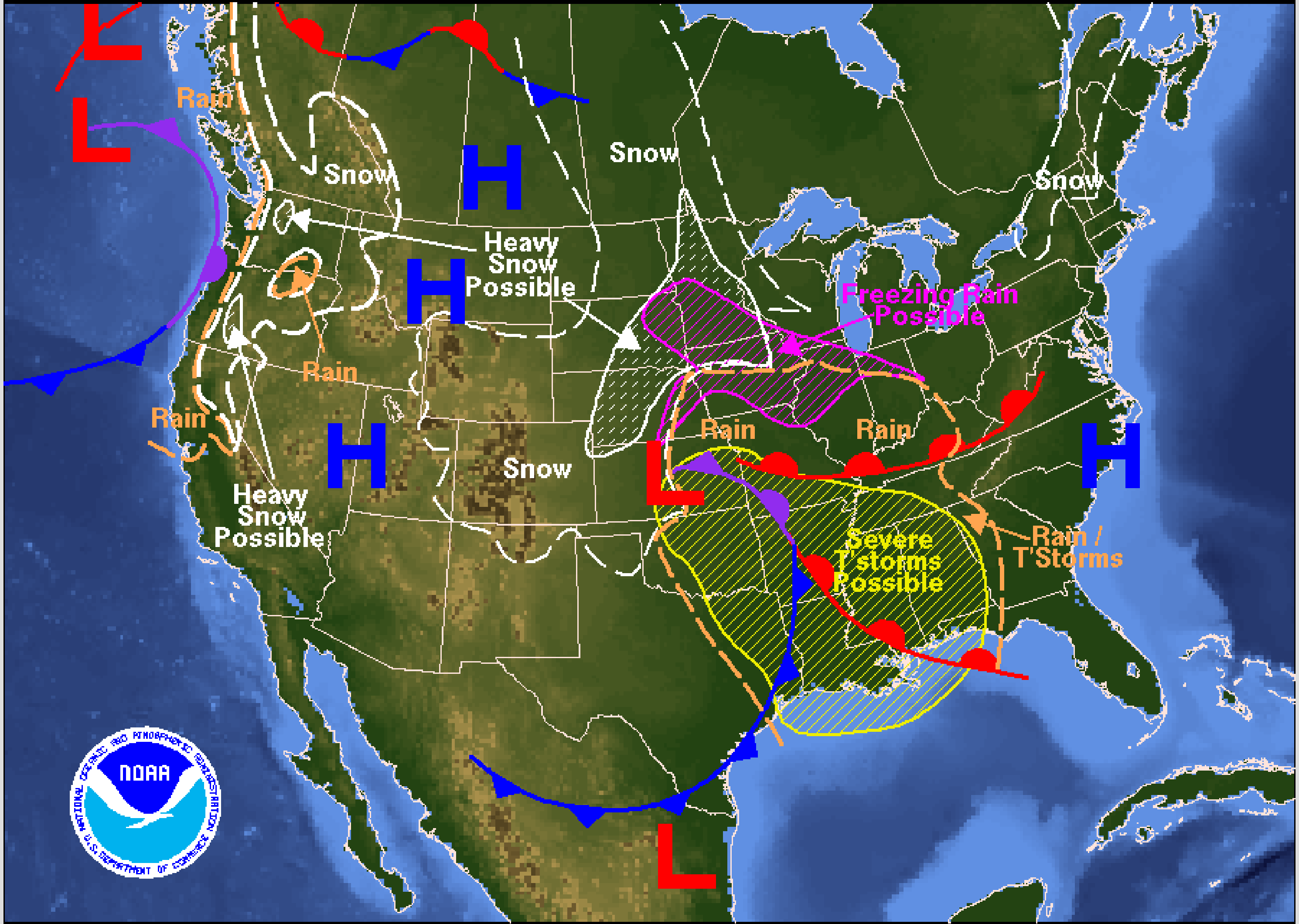
Mature Cyclone, Occluded Stage
1700 UTC, Saturday, Feb. 24, 2007





IR Imagery

This was the period used in the last lecture in the discussion of fronts.



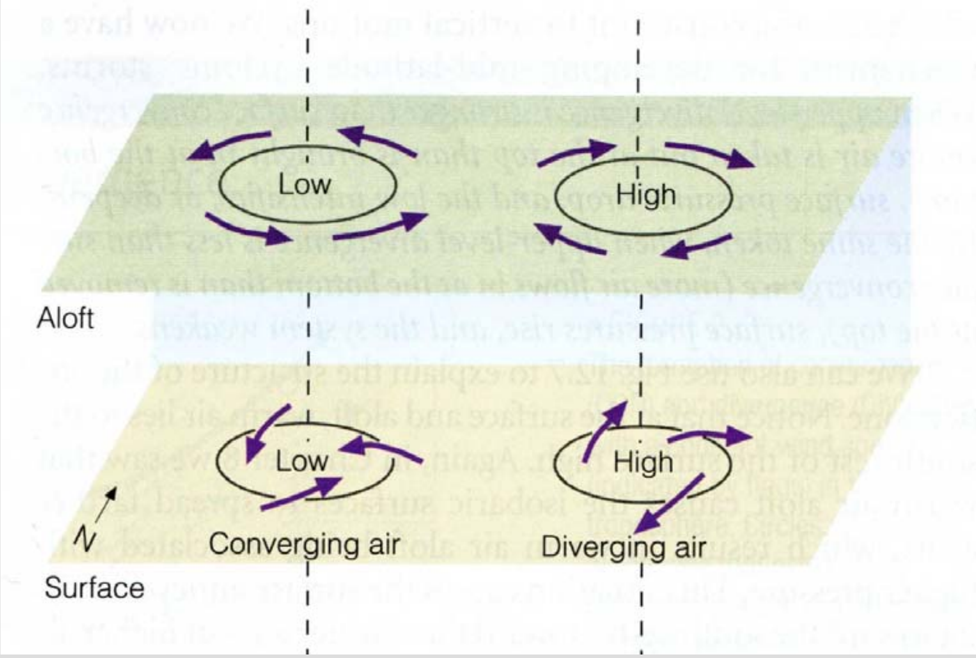
Weather Forecast for Saturday, February 24, 2007
DOC/NOAA/NWS/NCEP/Hydrometeorological Prediction Center
Prepared by Kong based on HPC, SPC, and TPC forecasts.

What is happening at upper-levels in a mid-latitude cyclone?

Key idea is that for a mid-latitude cyclone to keep intensifying it needs:

_______________ below
_______________ aloft

A vertically stacked system
Unfavorable for mid-latitude cyclone generation



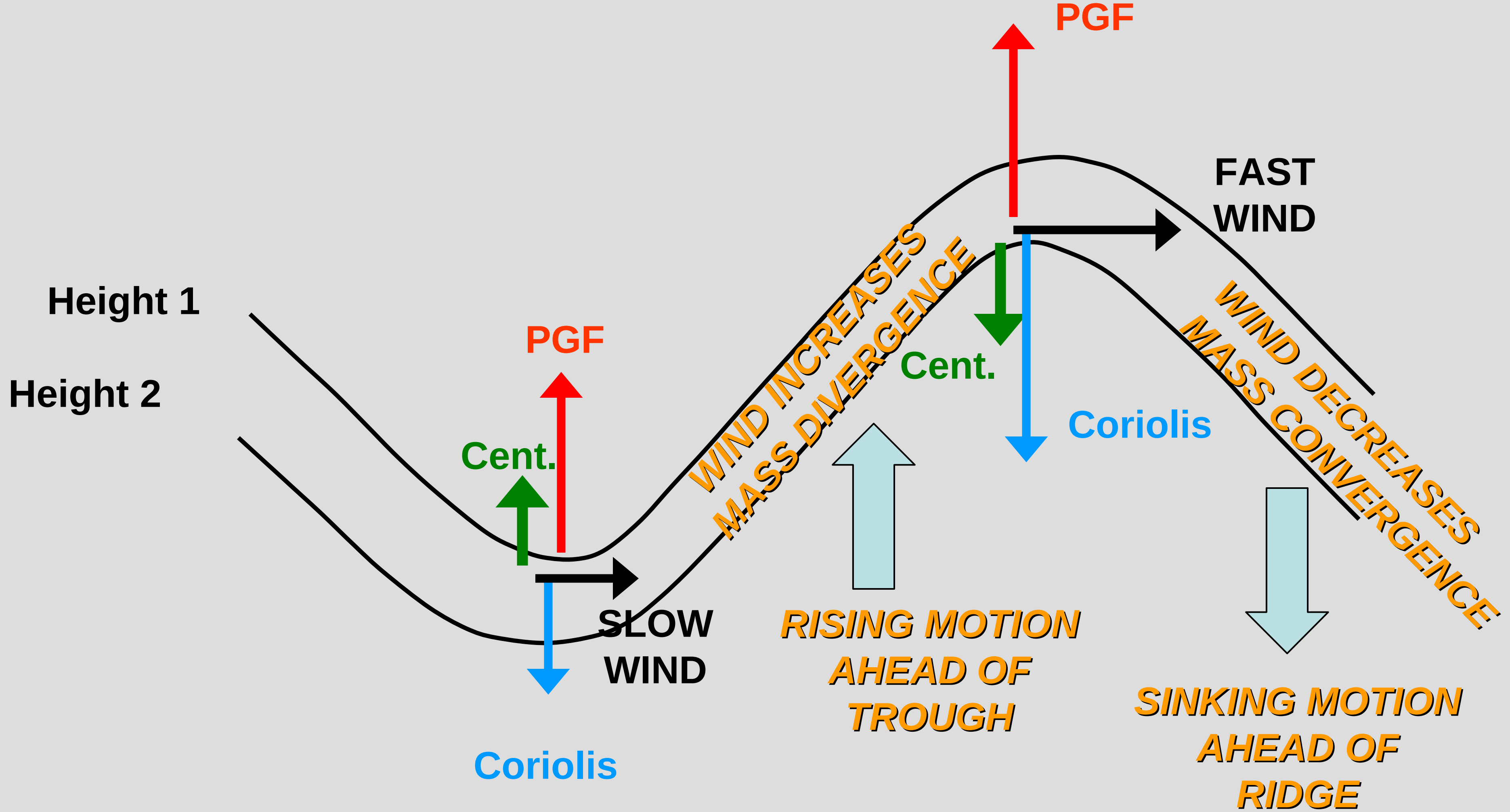
If low and high pressure are vertically stacked in the atmosphere:

Converging air into a surface low causes the pressure to rise.

Diverging air away from the surface high causes pressure to fall.

What happens in this case?

Relationship between upper level troughs and ridges and vertical motion



Recall differences in wind speed due to curvature of the flow induce vertical motion.

There are several possible ways to increase the upward motion ahead of a trough.

All of them increase the centripetal acceleration by either:

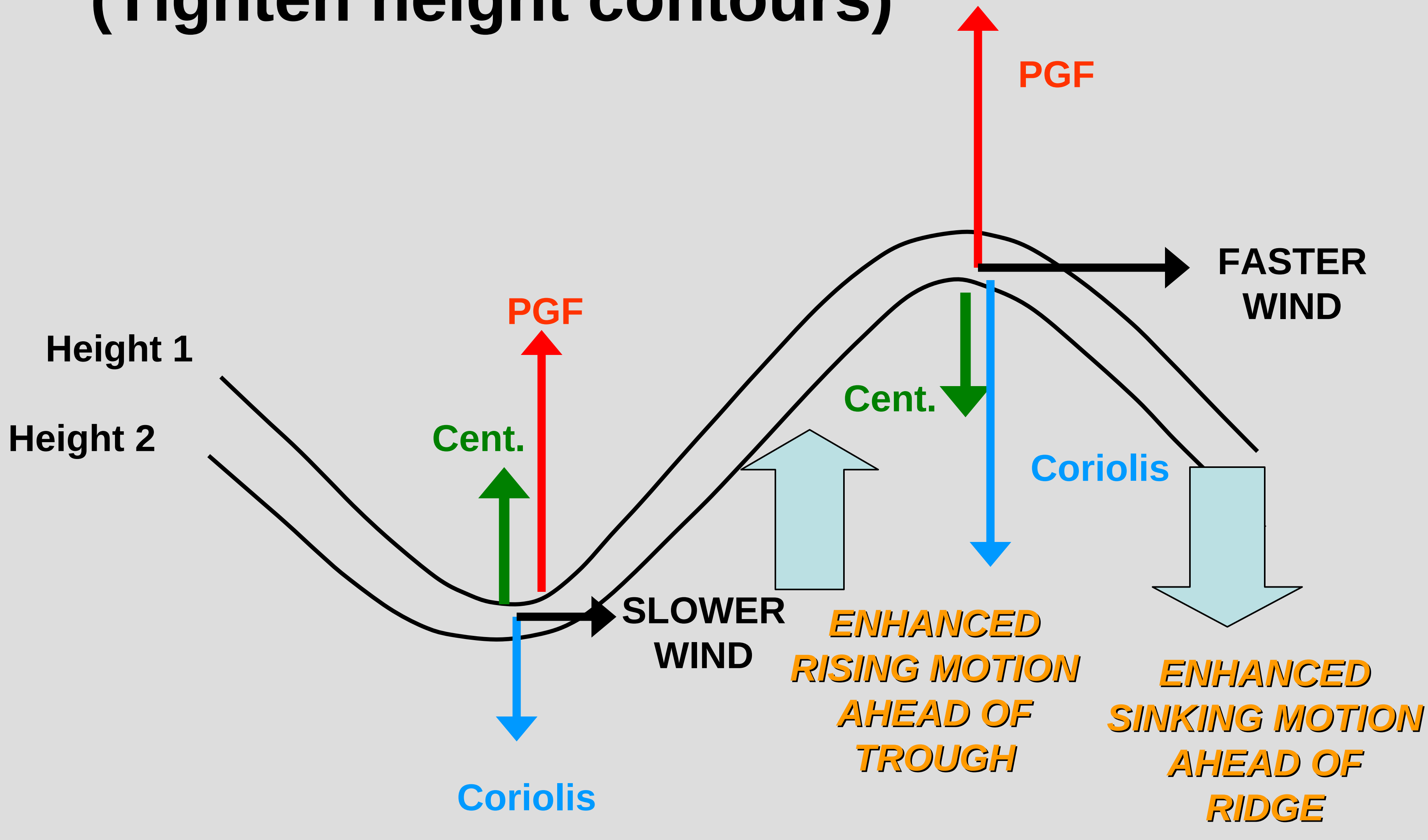
1. Increasing wind speed (bigger *v*)

2. Increasing the curvature around the axis of rotation (smaller *r*).

Net result is a greater difference in wind speed between the base of the trough and top of a ridge.

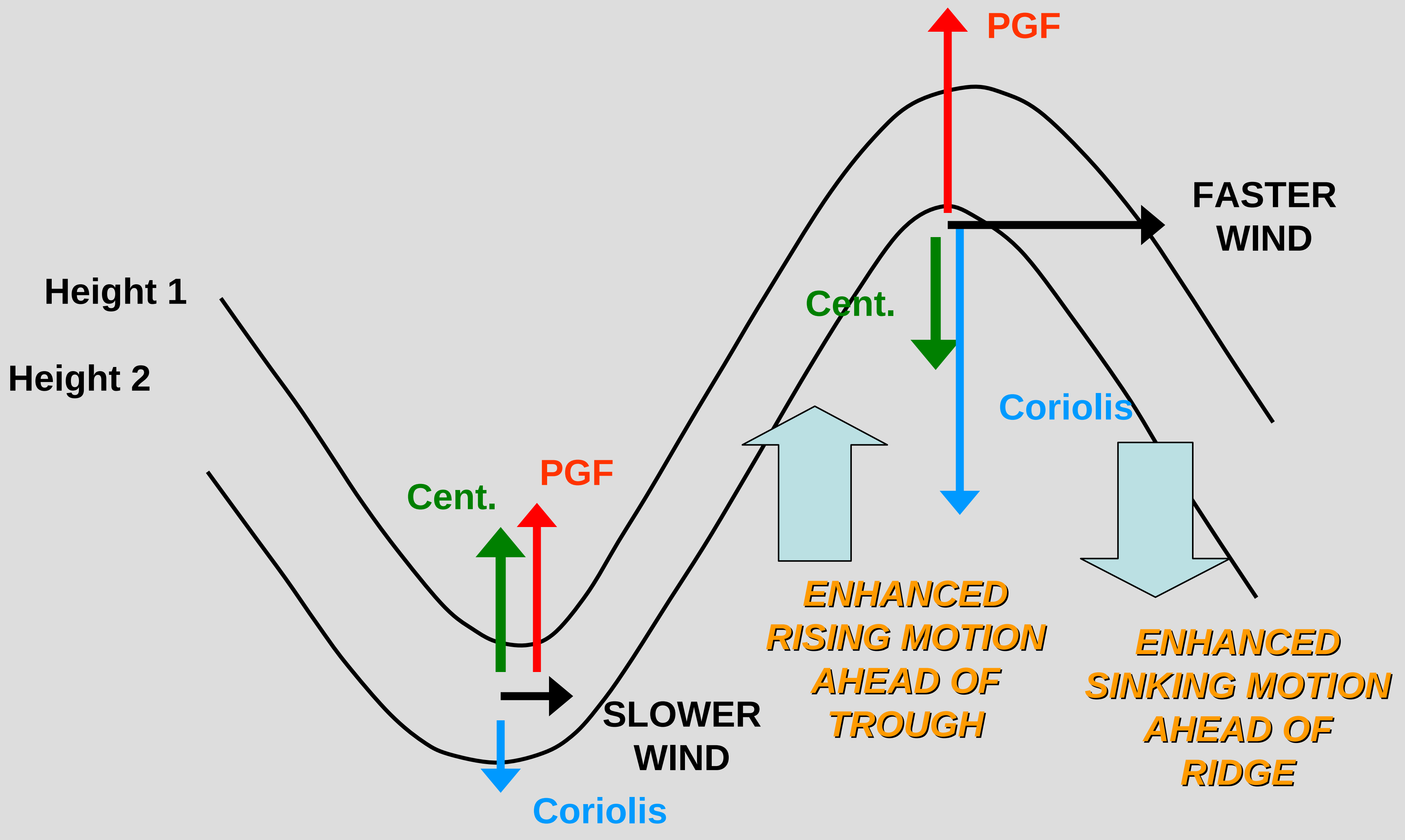
$$\text{Centripetal Force} = -\frac{V^2}{r}$$

Increase pressure gradient (Tighten height contours)

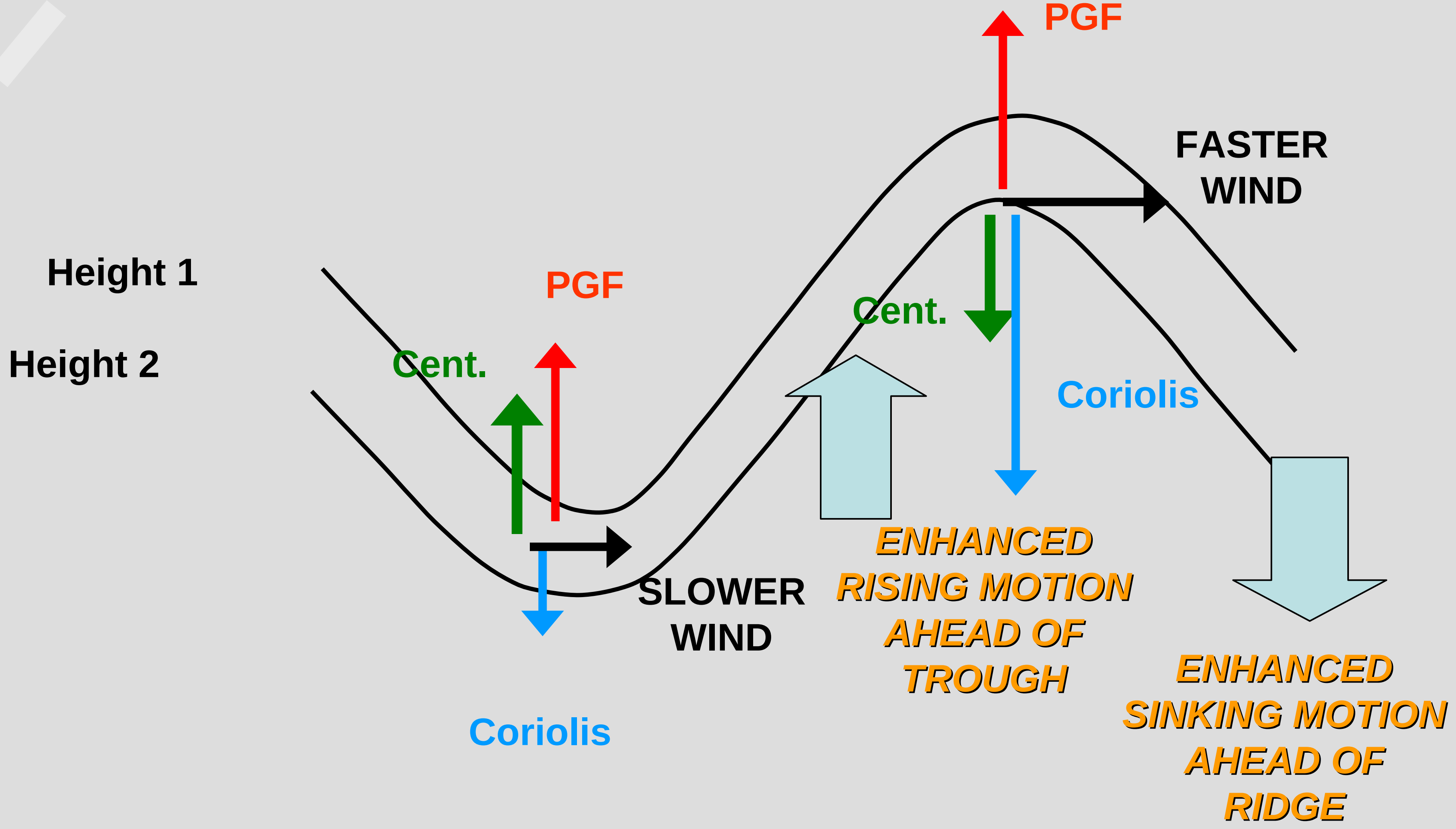


This is what happens in the polar jet stream.

Increase amplitude of troughs and ridges



Decrease the wavelength (or distance between trough and ridge)



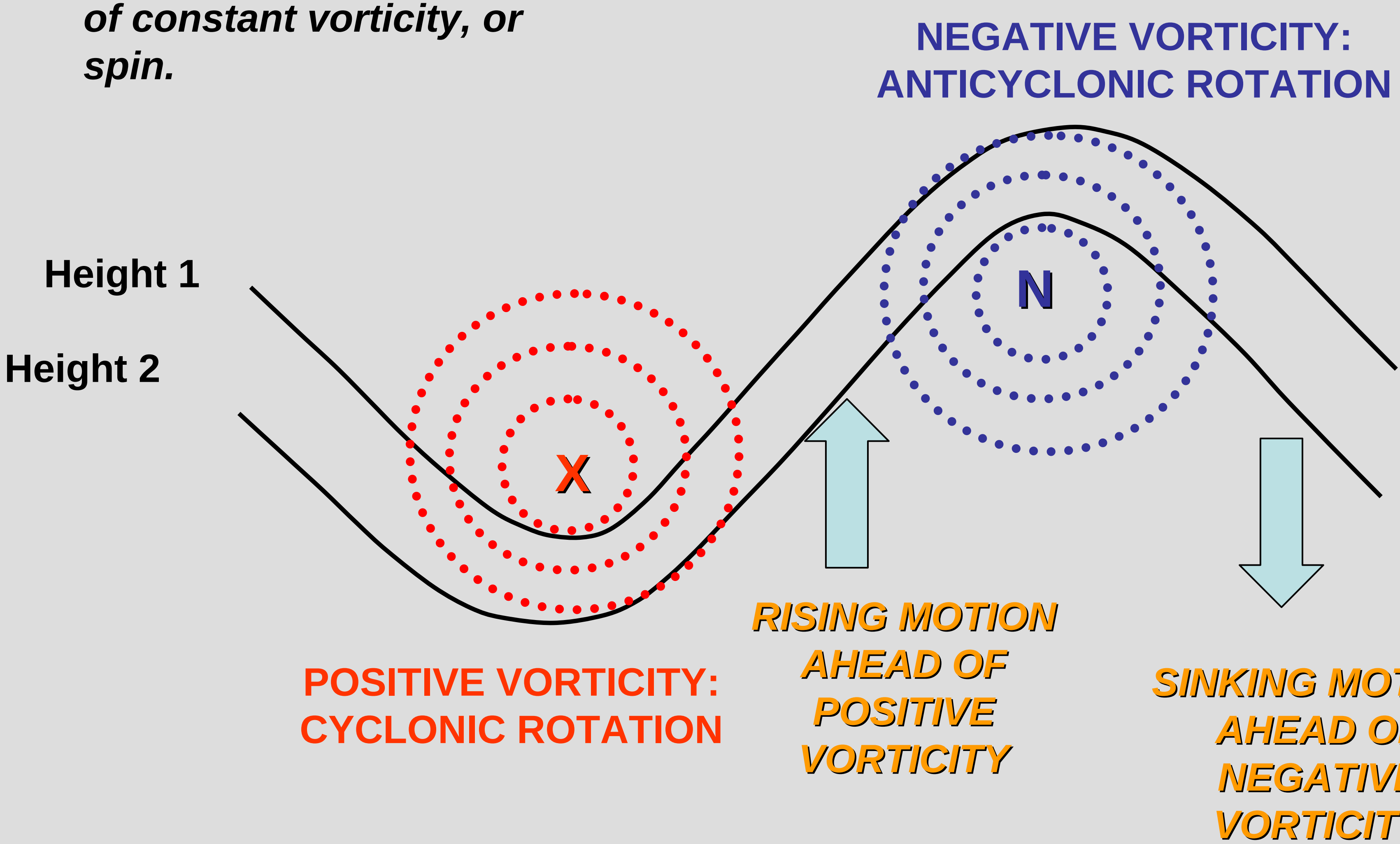
Another way to look at it is with the concept of vorticity, or “spin” in the atmosphere.

This is more the norm in reading an actual weather chart.

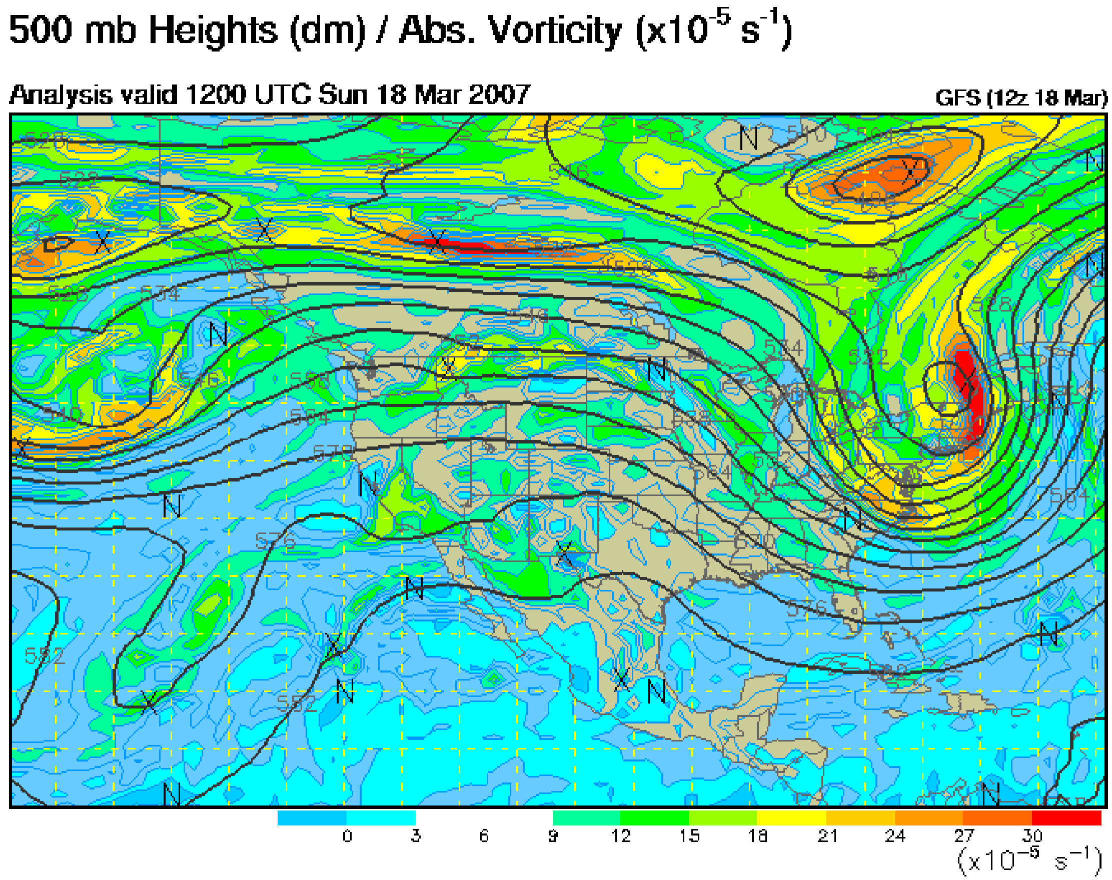
Greater curvature → More vorticity.

Troughs, Ridges and Vorticity

Dashed lines indicate lines of constant vorticity, or spin.



The vorticity maximum (X or N) defines the axis of rotation.



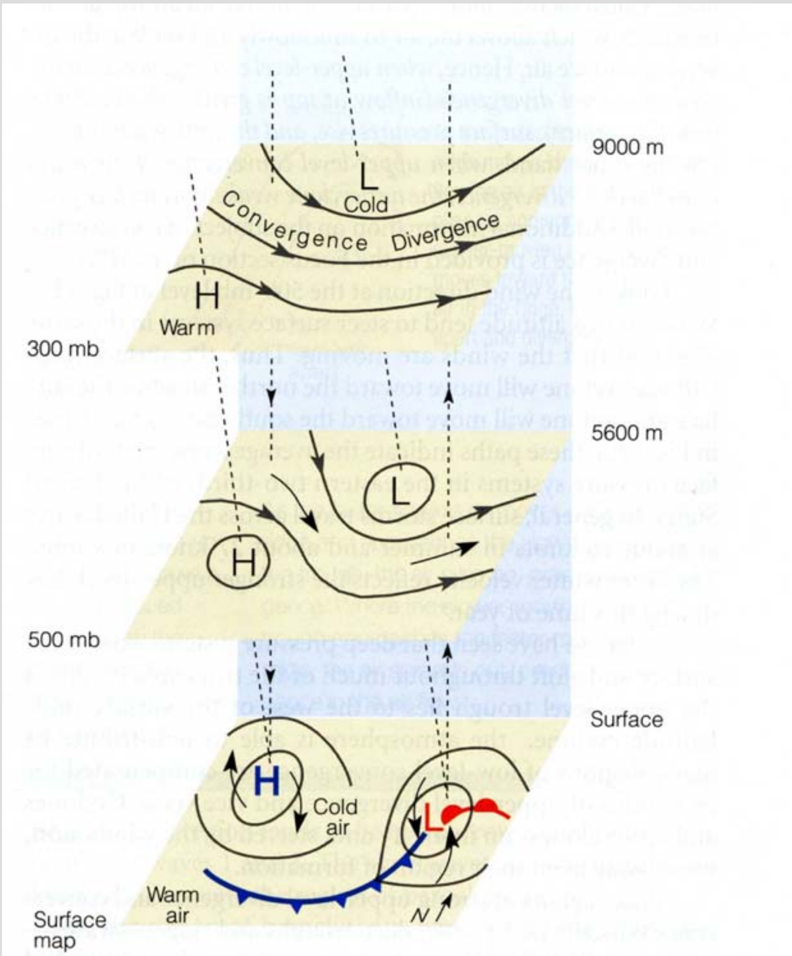
Note

Absolute vorticity includes the effects of Earth's rotation, so it is always positive.

"X" = relative vorticity maximum

"N" = relative vorticity minimum

Integrated picture of upper and low level features in mid-latitude cyclone



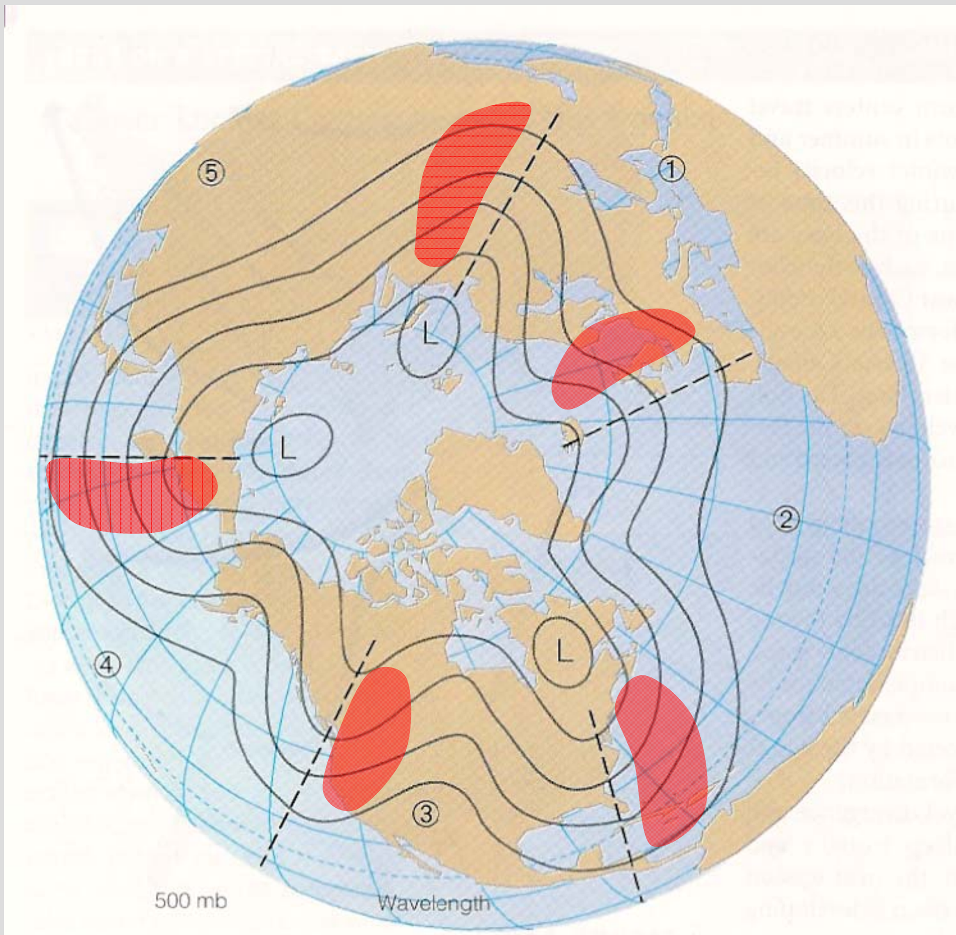
An amplifying mid-latitude cyclone has a _____________structure.

What does this permit?

Upper level high to _______ of surface high.

Upper level low to ________ of surface low.

Longwaves and Shortwaves

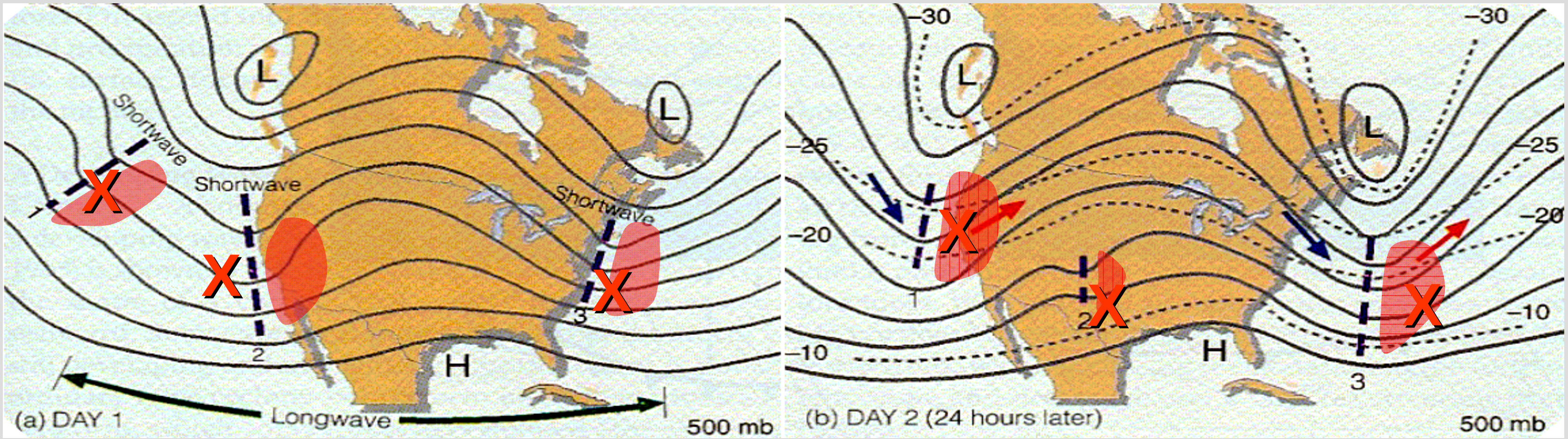


Longwaves or planetary waves arise because of the equator to pole temperature gradient

These have modest levels of upper-level divergence (shaded red areas).

Analogous to dishpan experiment discussed in the general circulation lecture.

Longwaves and Shortwaves



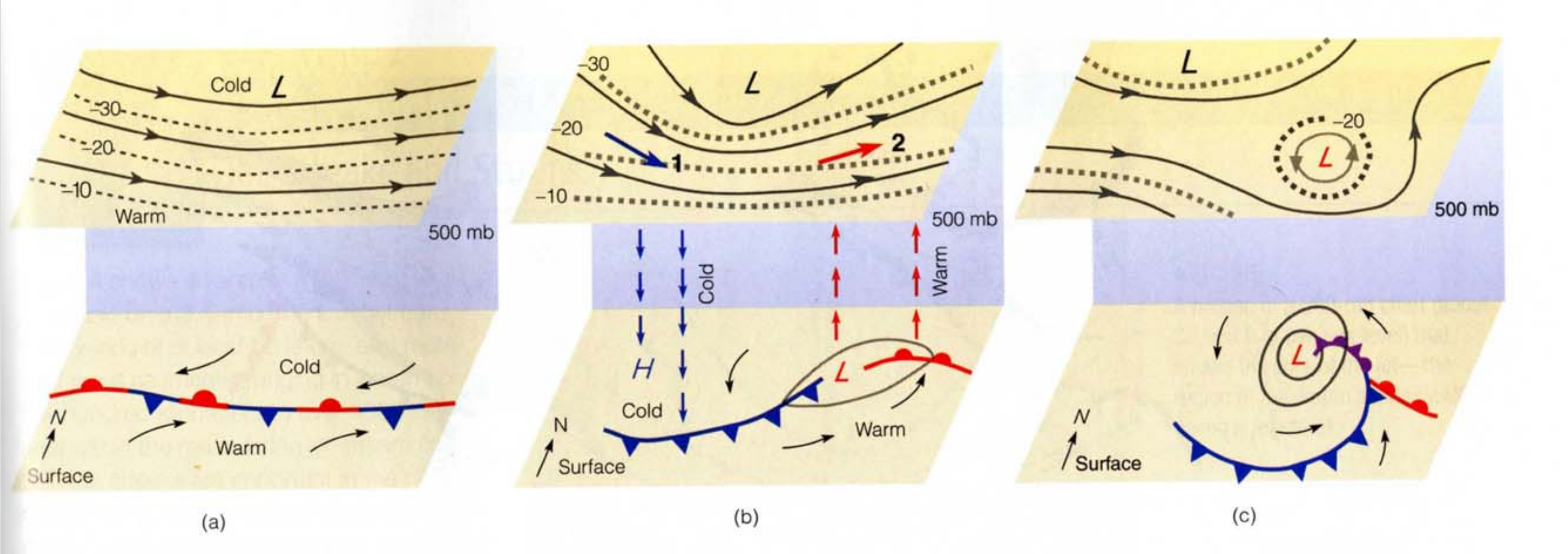
***Shortwaves* are smaller scale disturbances imbedded in the flow, or local maximums of positive vorticity (X). These provide an additional source of upper-level divergence.**

Initiates cyclone development and deepens the longwave troughs and ridges.

What a meteorologist looks for to forecast storm development—*this is what your TV weather forecaster sometimes calls "a piece of energy"*

Bjerknes cyclone development model with upper levels included

NACENT *AMPLIFYING* *DECAYING*



Stationary front

Stationary front in longwave trough

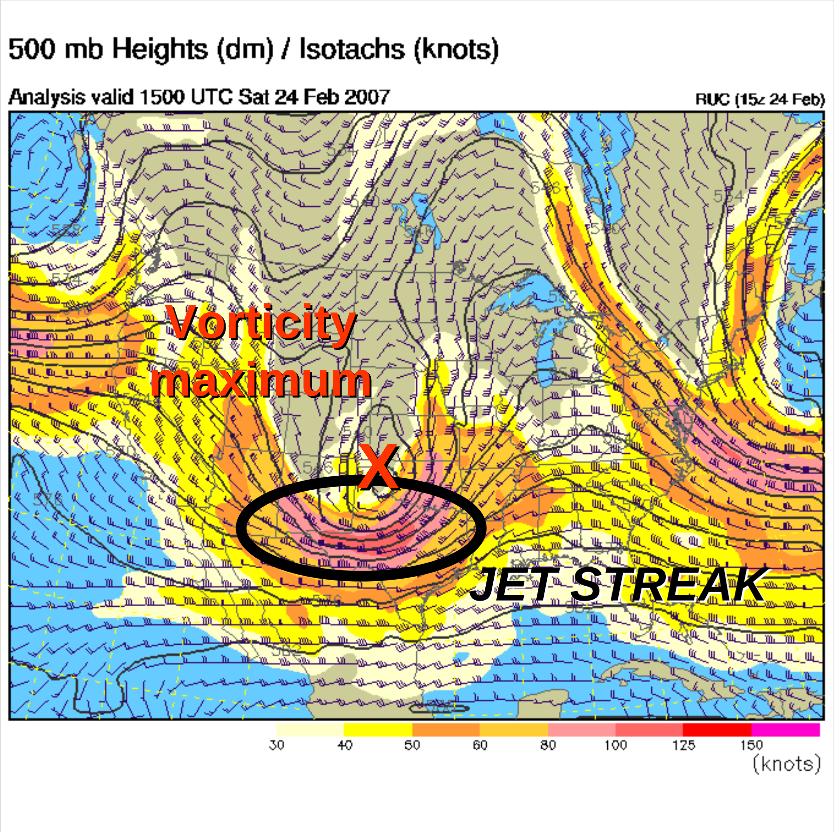
Maturing cyclone

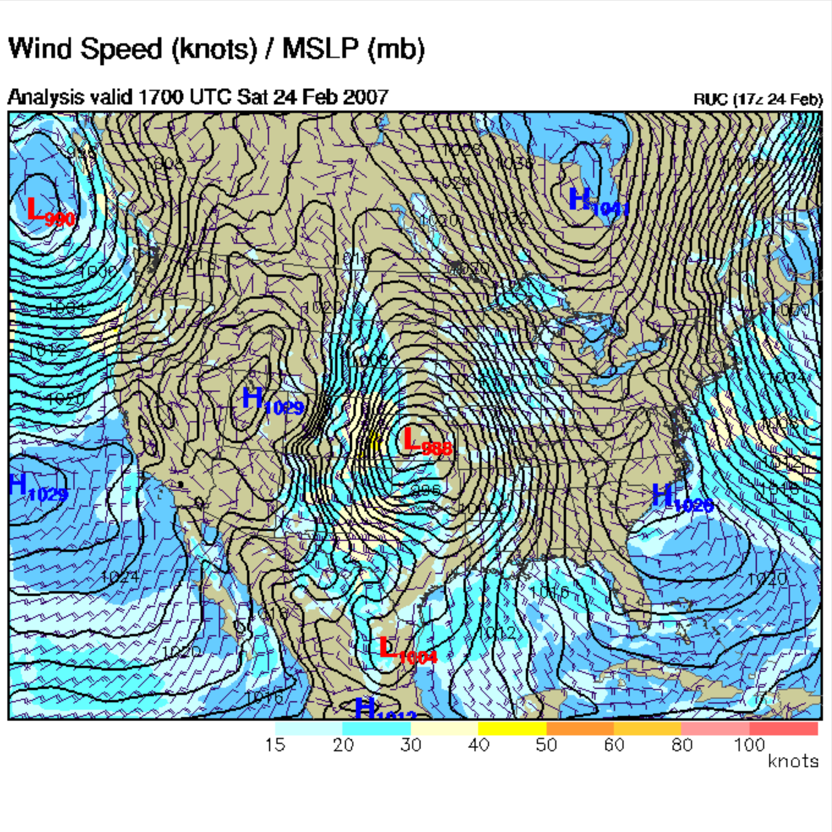
Shortwave initiates deepening of trough and vertical motion to develop a mature mid-latitude cyclone.

Cut off stage

System becomes vertically stacked and upper level divergence over surface low ceases.

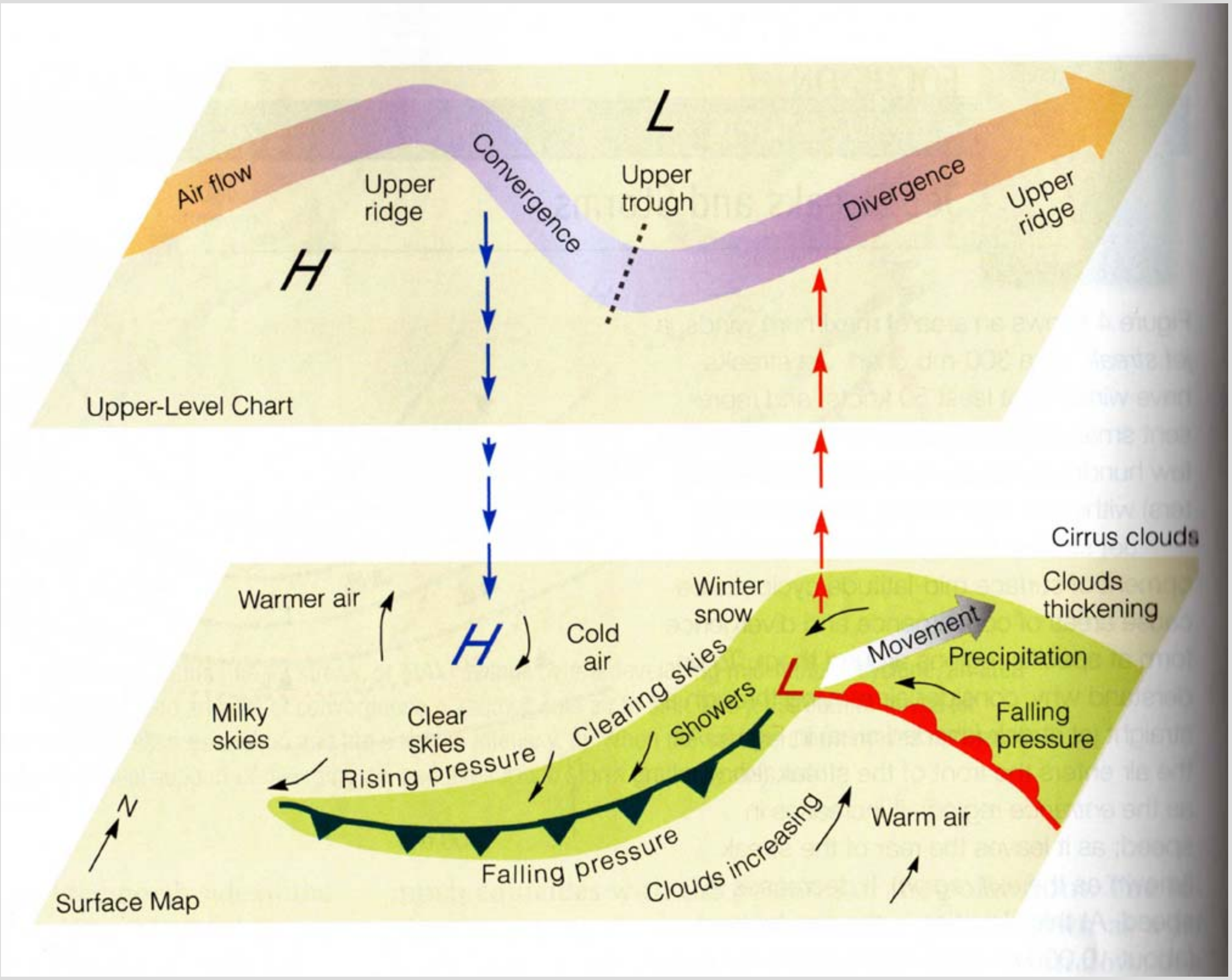
Upper level vs. surface features
February 2007 example case





Surface low will form to the north and east of the jet streak because the upper level divergence is most favorable there (see discussion in text).

Summary of Lecture 23



Reading Assignment and Review Questions

Reading: Chapter 13

<u>Chapter 12 Questions</u>

Questions for Review (8th ed.): 1,2,3,4,5,6,7,8,9,10,11,12,14,17
(9th ed.): 1,2,3,4,5,6,7,8,9,10,11,12,13,15,18

Questions for Thought: 2,5,7,8

Problems and Exercises: 1,2