
MUSEO DE SITIO INTIÑAN
Camino del Sol
LAT: 00°00'00"
QUITO - ECUADOR
Ecuador in the middle of the world
LATITUD: 00°00'00"
calculated with G.P.S.


ANTI - SUYO
este
CAYAM
PIEDRA INDICE CUATRO ESTACIONES
0

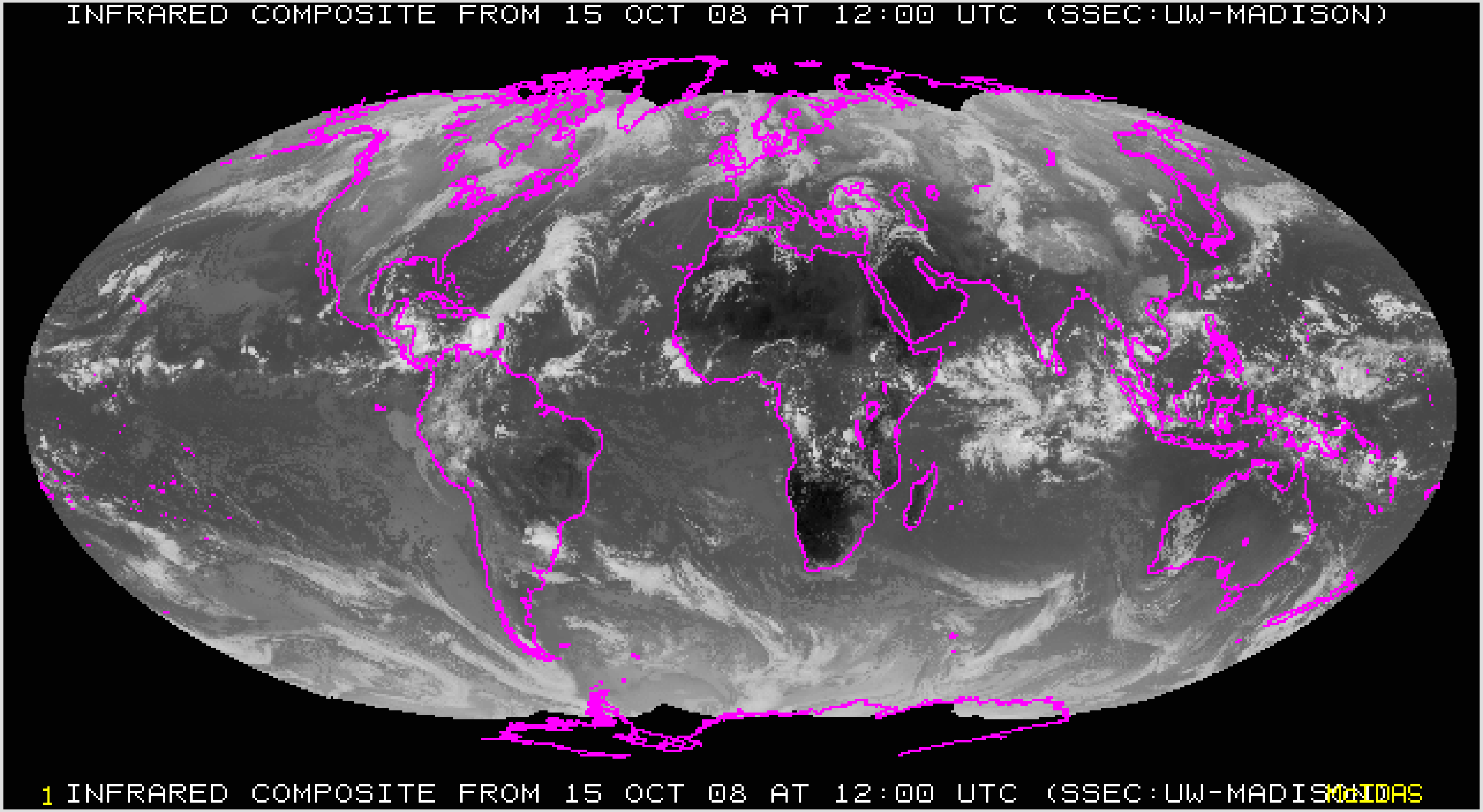
"ACELERATION OF CORIOLIS"

F=2mw^v

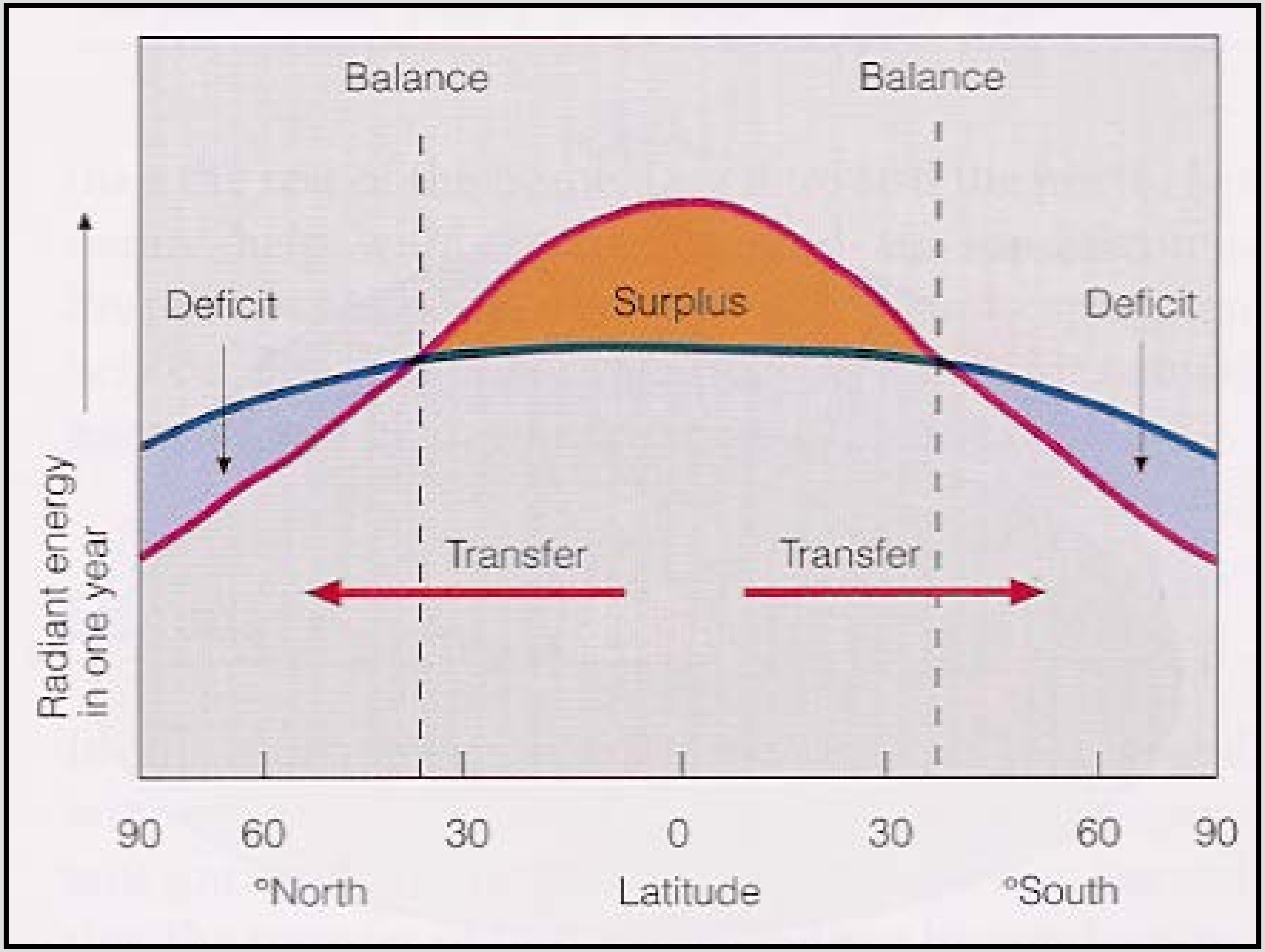
The maximum force of deviation towards the poles is called Aceleration of Coriolis. This force formed by the earth´s rotation at Lat. 00º00´00˝ (Ecuador) is zero. On the equator this trajectory is in a straight line and perpendicular according to the laws of momentum in which any body in movement in a straight line continues in that direction while no other force from another direction affects it.

Movements are produced by distinct forces: thermal, atmospheric, gravitational, magnetic, of radiations, of pressure and by clashing of molecules.


OESTE



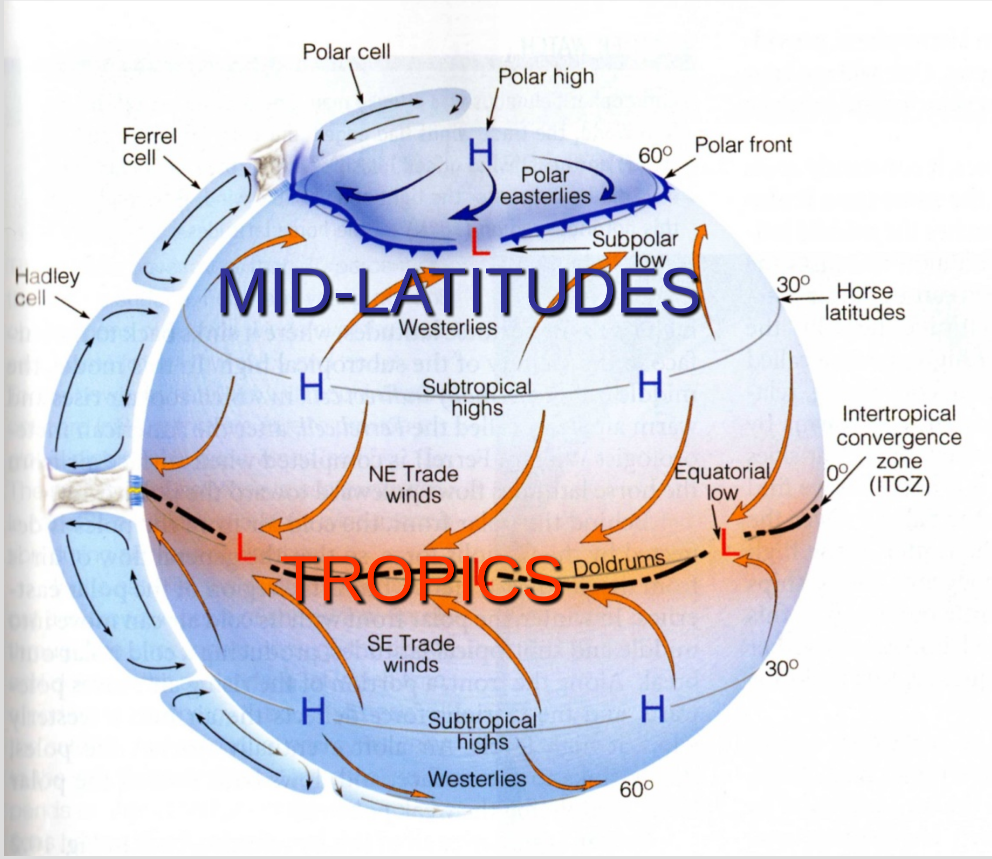
http://www.ssec.wisc.edu/data/composites.html



Red curve: Incoming solar radiation

Blue curve: Outgoing infrared radiation.

Three-cell model of general circulation



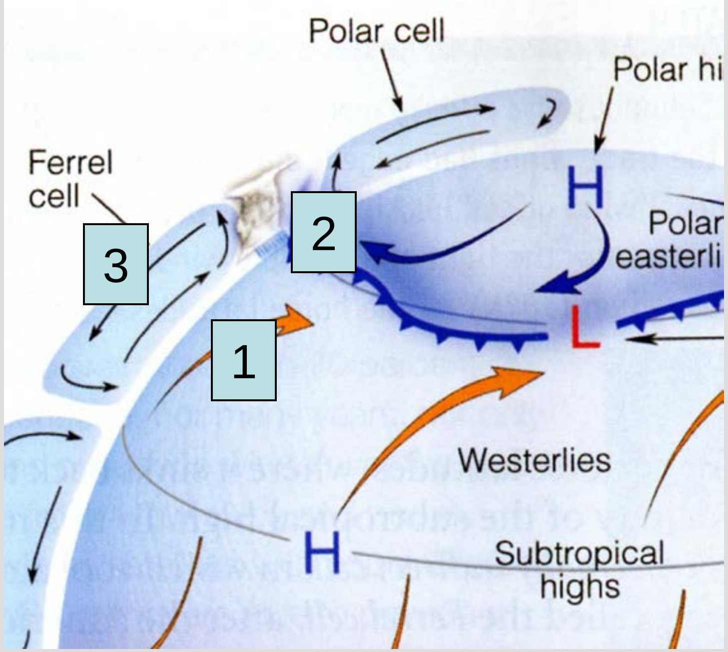
Mid-latitudes: 30° to 60° latitude

Mid-latitude cyclones do the job of transporting heat poleward.

Tropics: 0 to about 30° latitude

A thermally direct circulation (Hadley cell) transports heat poleward.

General circulation in mid-latitudes

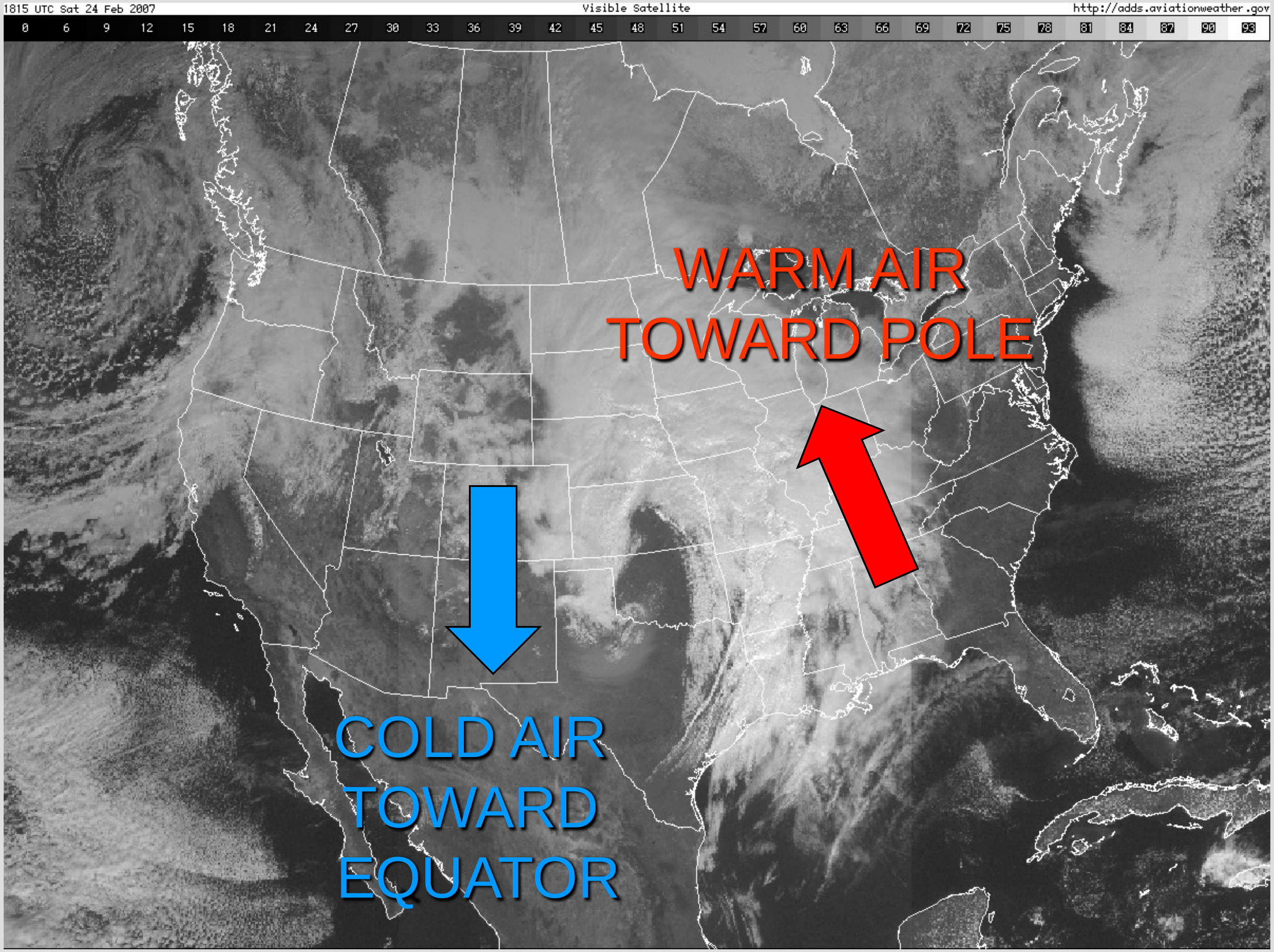


1. Air flows away from the subtropical high toward the polar front, or boundary between warm subtropical air and cold polar air. Because of the Coriolis force, the winds are westerly.

2. Air converges and rises at the polar front. Mid-latitude cyclones (or areas of low pressure) develop along the polar front. The mid-latitude cyclones transport warm air toward the pole and cool air toward the equator.

3. Some of the air returns toward the subtropics, completing an indirect thermal circulation (Ferrel cell).

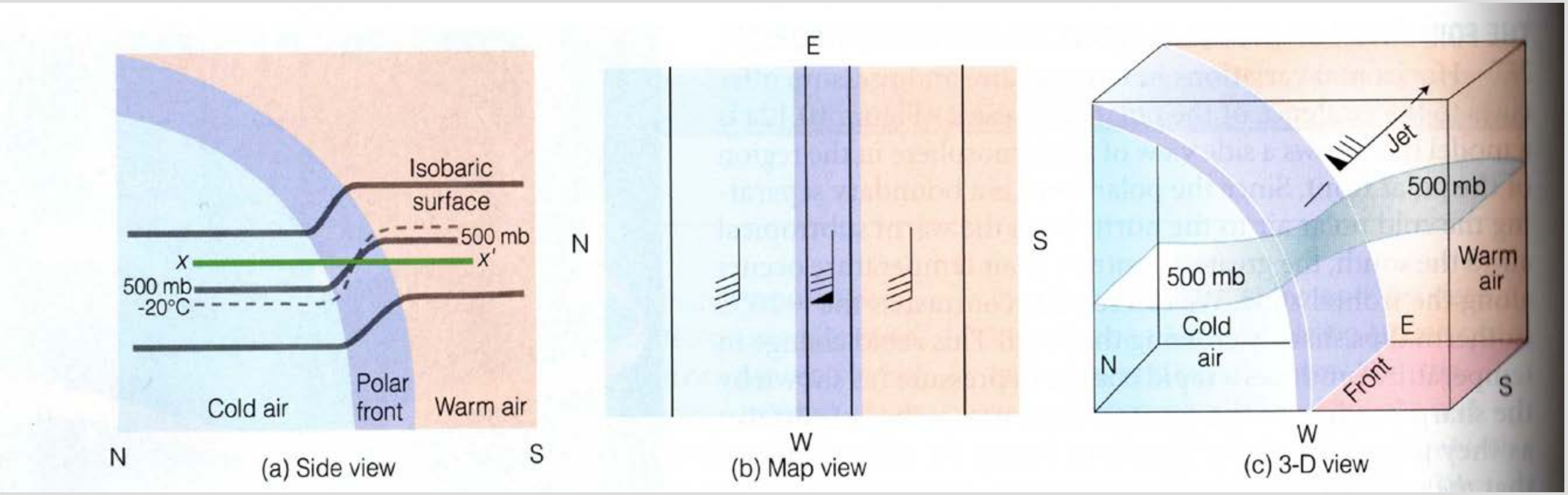
Mid-latitude cyclone example (Major Midwest storm)



WARM AIR TOWARD POLE

COLD AIR TOWARD EQUATOR

Polar Jet Stream
Result of the polar front boundary



(a) Side view

(b) Map view

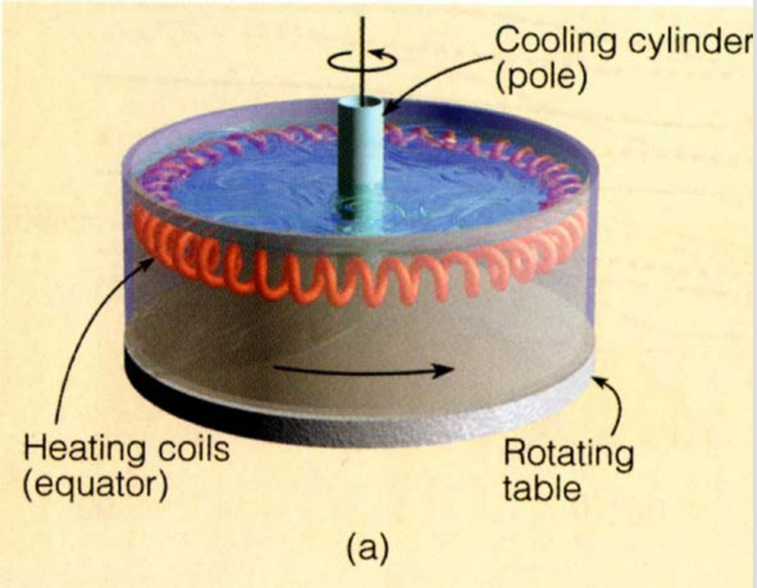
(c) 3-D view

The rapid change between warm and cold air along the polar front results in a strong pressure gradient, and winds, there.

This upper-level wind is called the *polar jet stream*.

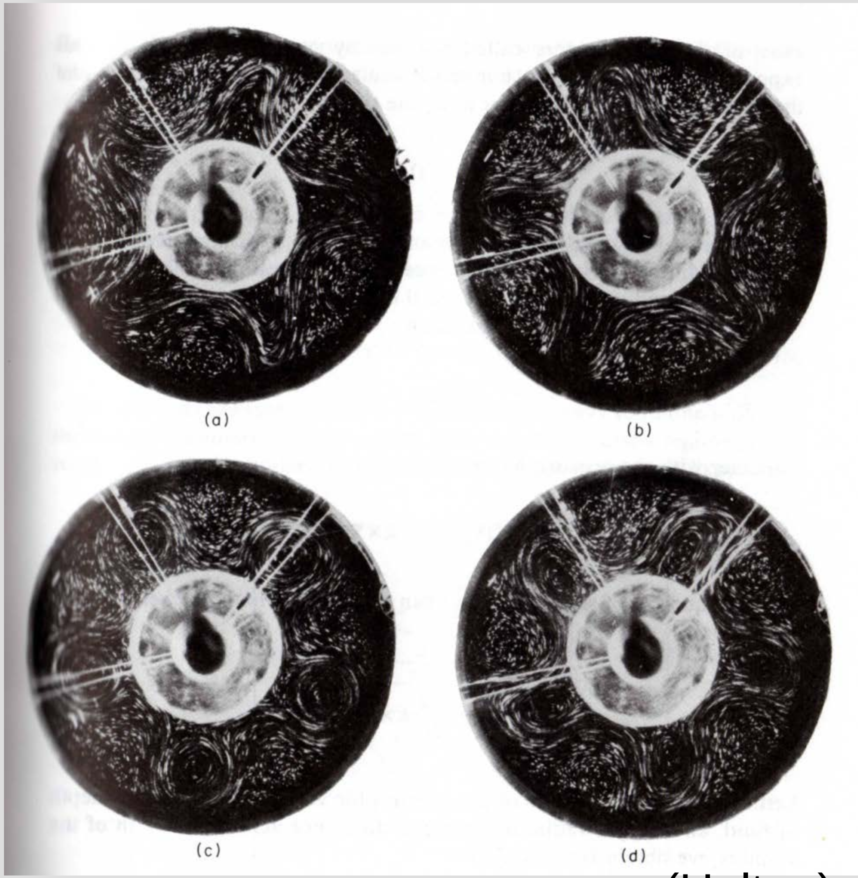
Dishpan experiment

View looking down on the
rotating dishpan (in rotating frame)



Heat applied to outer ring
Cooling applied to inner ring

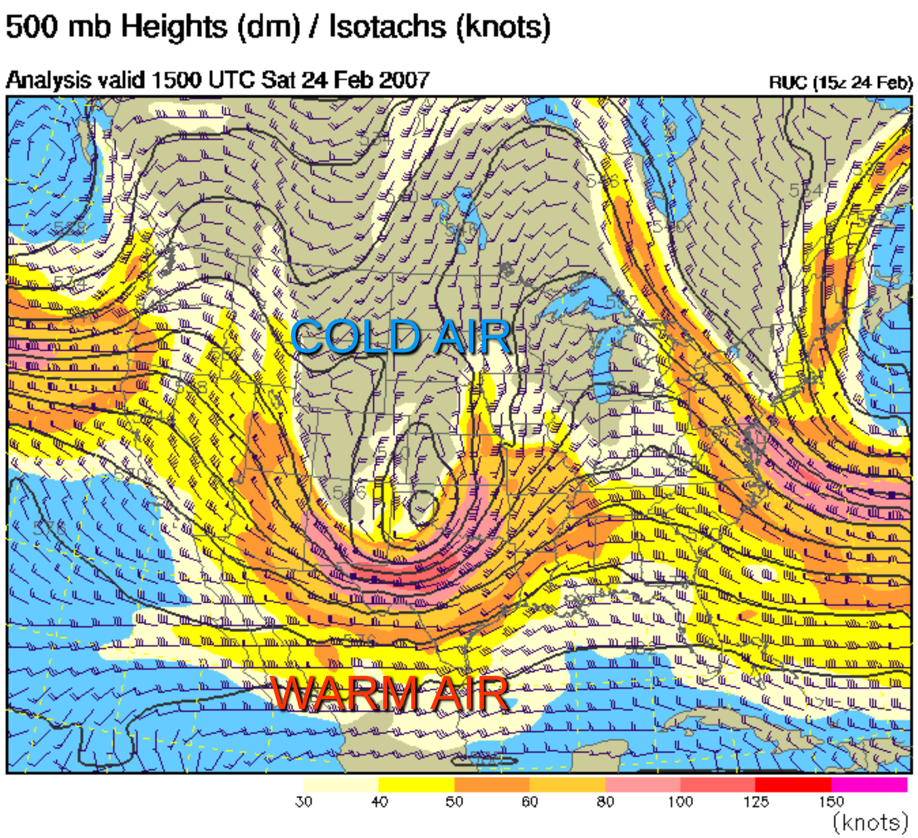
Add a particle tracer to the fluid…



(Holton)

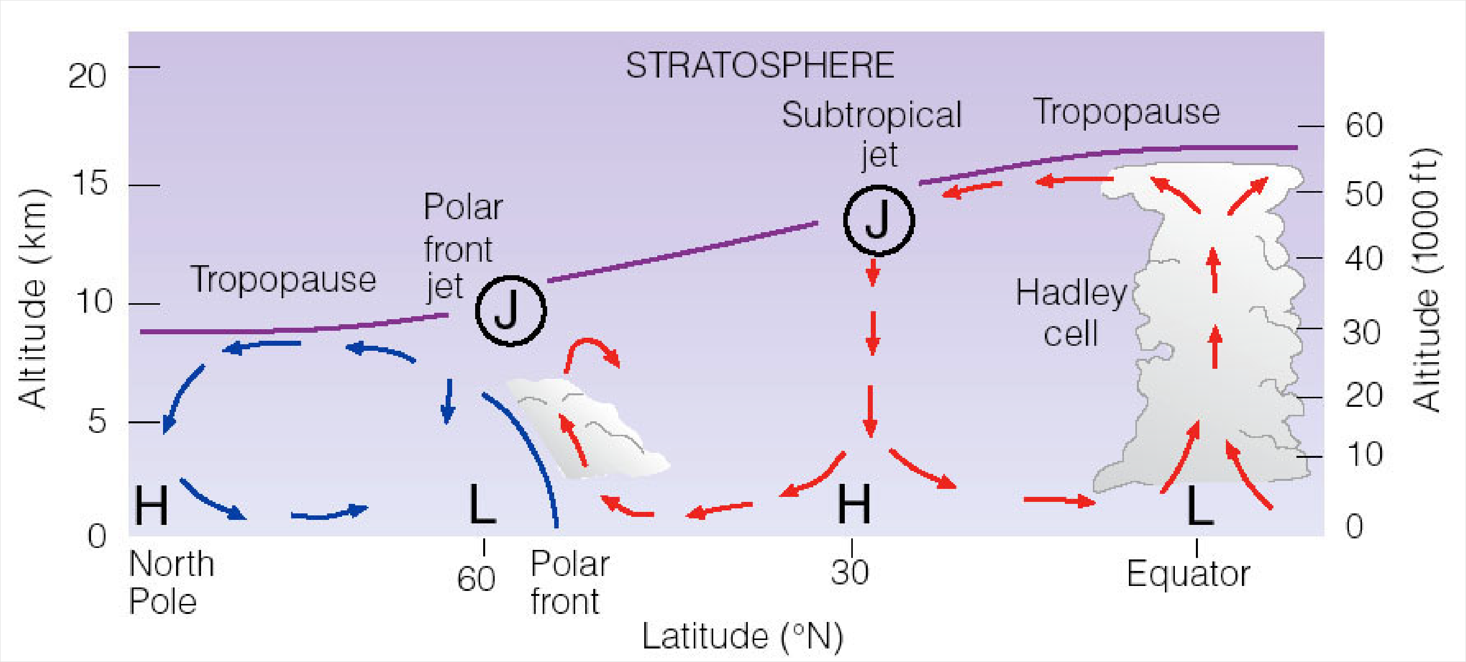
https://wikis.mit.edu/confluence/display/PAOCLABG/General+Circulation+Wiki

Polar jet stream in Midwest storm example



Note the very strong winds around the trough of low pressure.

Integrated picture of Jet Streams and the three-cell general circulation model.

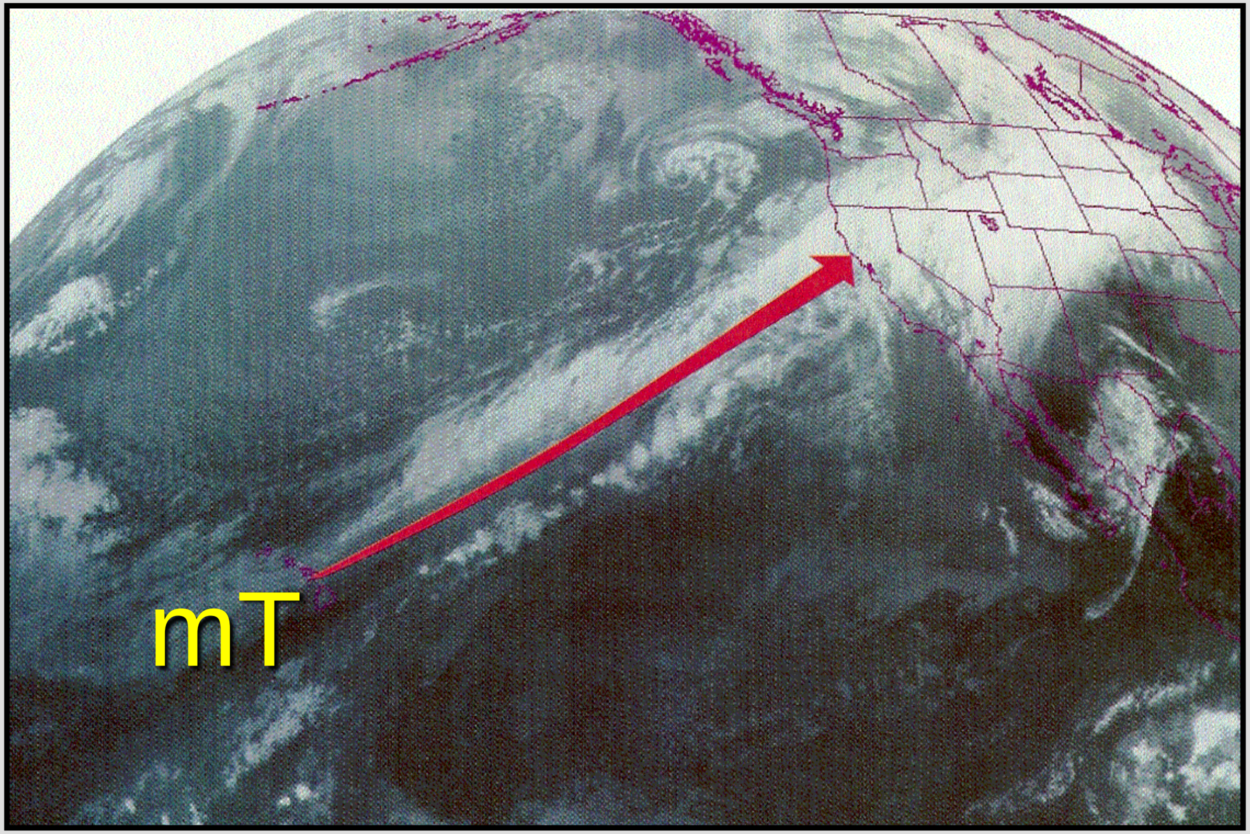


Jet streams occur near the tropopause.

Subtropical jet defines the limit of the Hadley Cell.

Polar jet is equatorward of the polar front.

The Pineapple Express
An example of an atmospheric river



If the jet stream picks up this moisture from the tropics, this can result in very heavy rains along the west coast in winter.

Air Mass Classification System

First Lowercase Letter:

Indicates whether air originates over an ocean or continent

m = Maritime
c = Continental

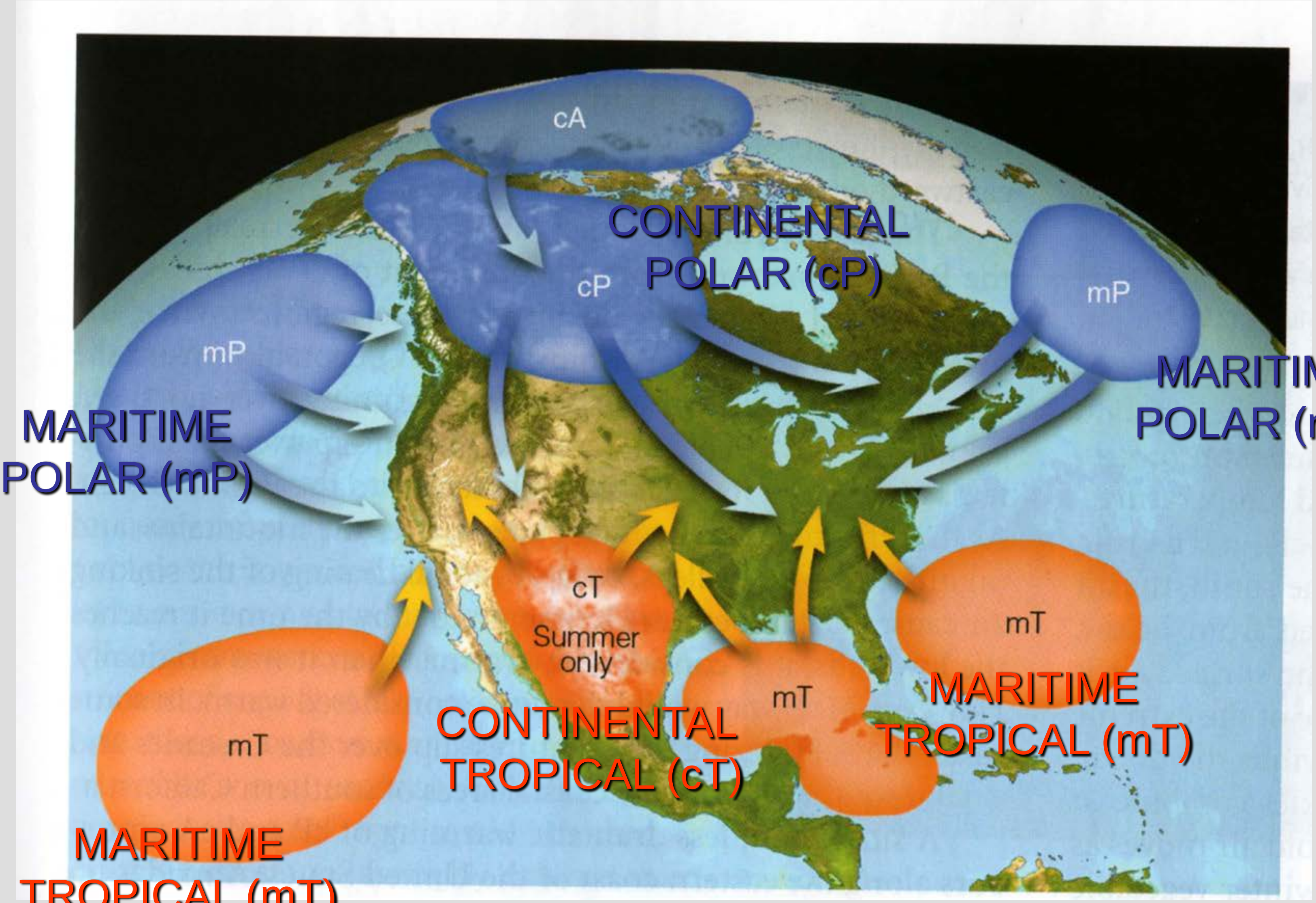
Second Uppercase Letter

Indicates whether air originates over tropical or polar latitudes.

T = Tropics
P = Poles

From combining these four, all the air masses can be described.

Air masses that affect North America



CONTINENTAL POLAR (cP)

MARITIME POLAR (mP)

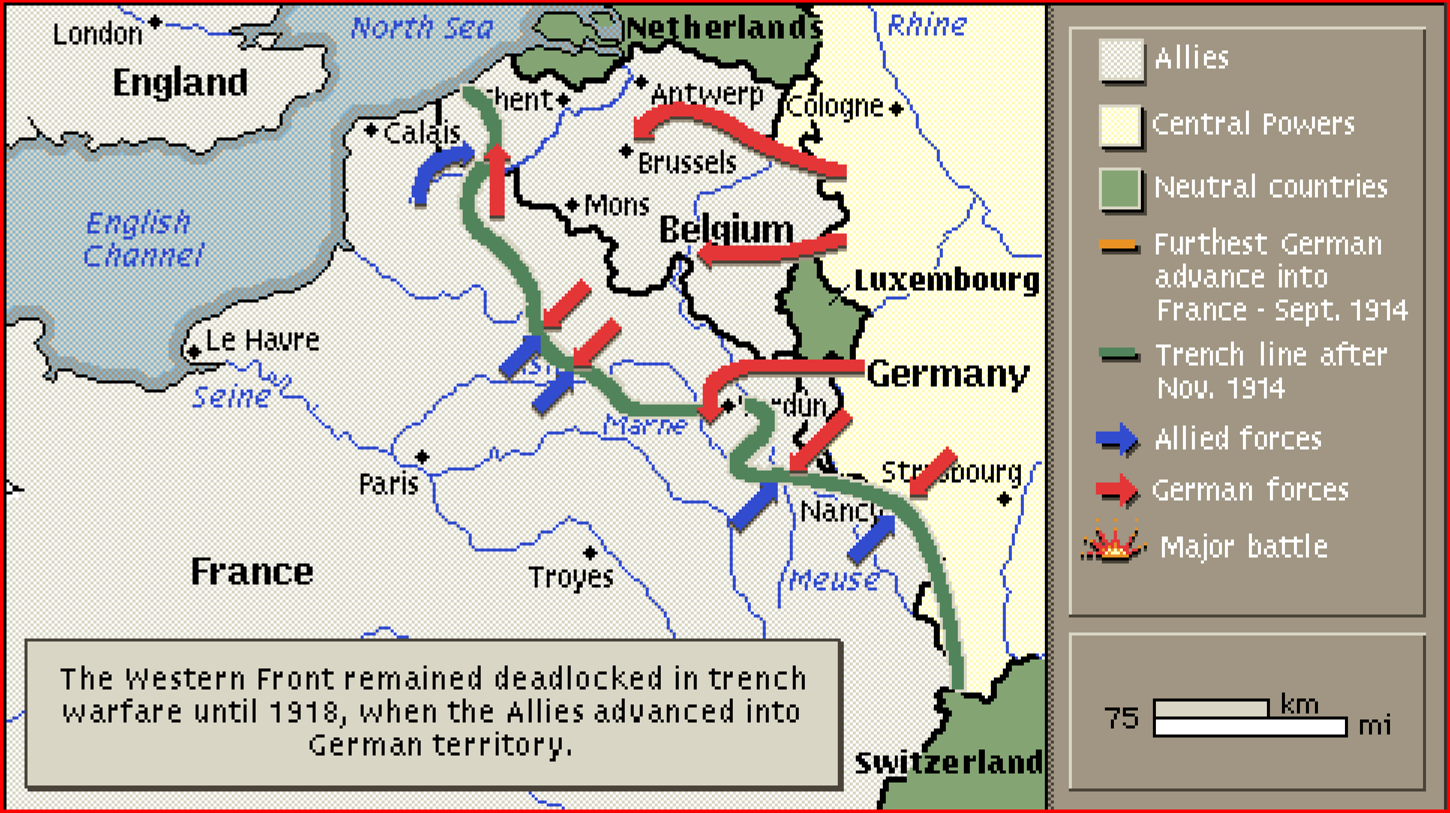
MARITIME POLAR (mP)

CONTINENTAL TROPICAL (cT)

MARITIME TROPICAL (mT)

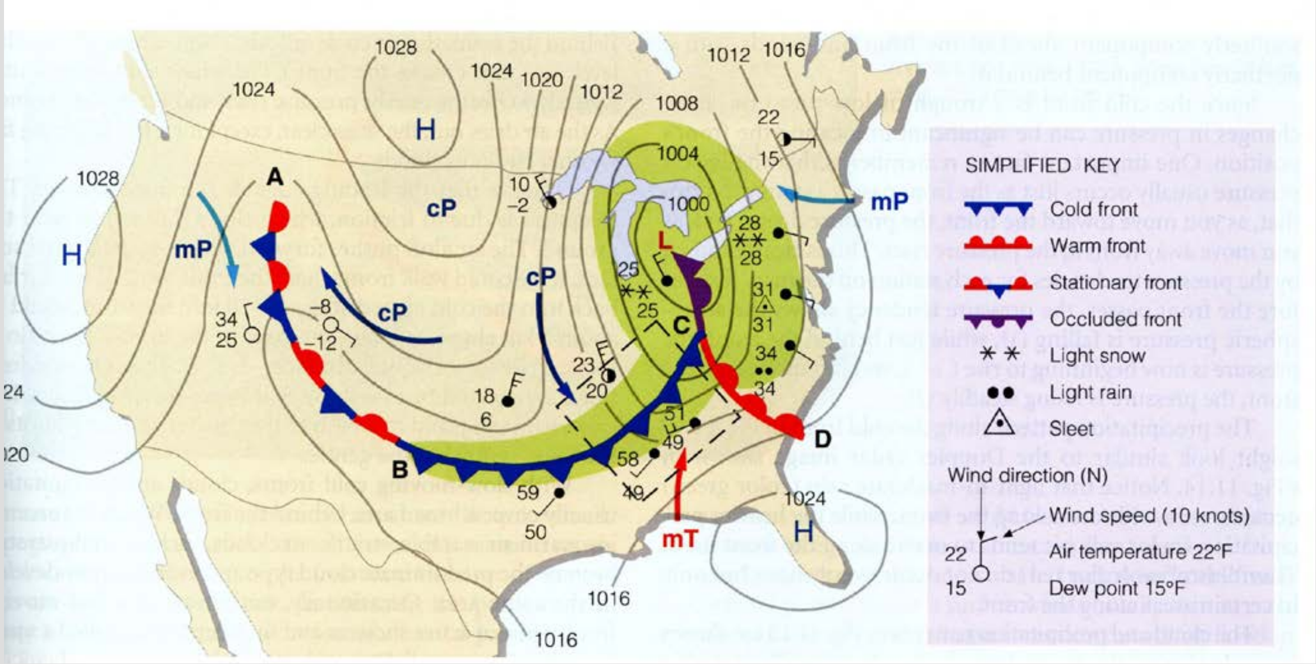
MARITIME TROPICAL (mT)

World War One, The Western Front



The Western Front remained deadlocked in trench warfare until 1918, when the Allies advanced into German territory.

Four types of fronts



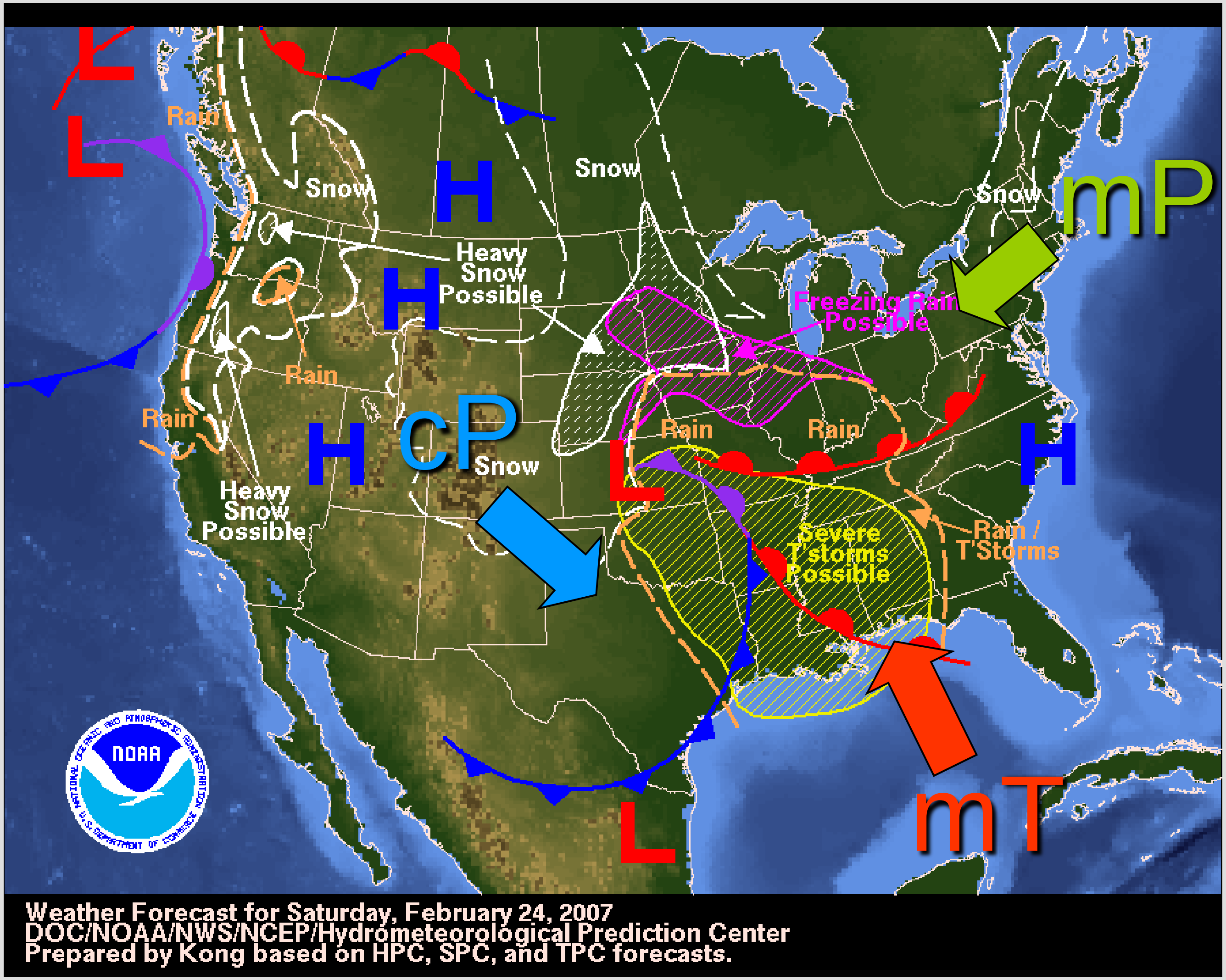
COLD FRONT: Cold air overtakes warm air. *B to C*

WARM FRONT: Warm air overtakes cold air. *C to D*

OCCLUDED FRONT: Cold air catches up to the warm front.
C to Low pressure center

STATIONARY FRONT: No movement of air masses. *A to B*

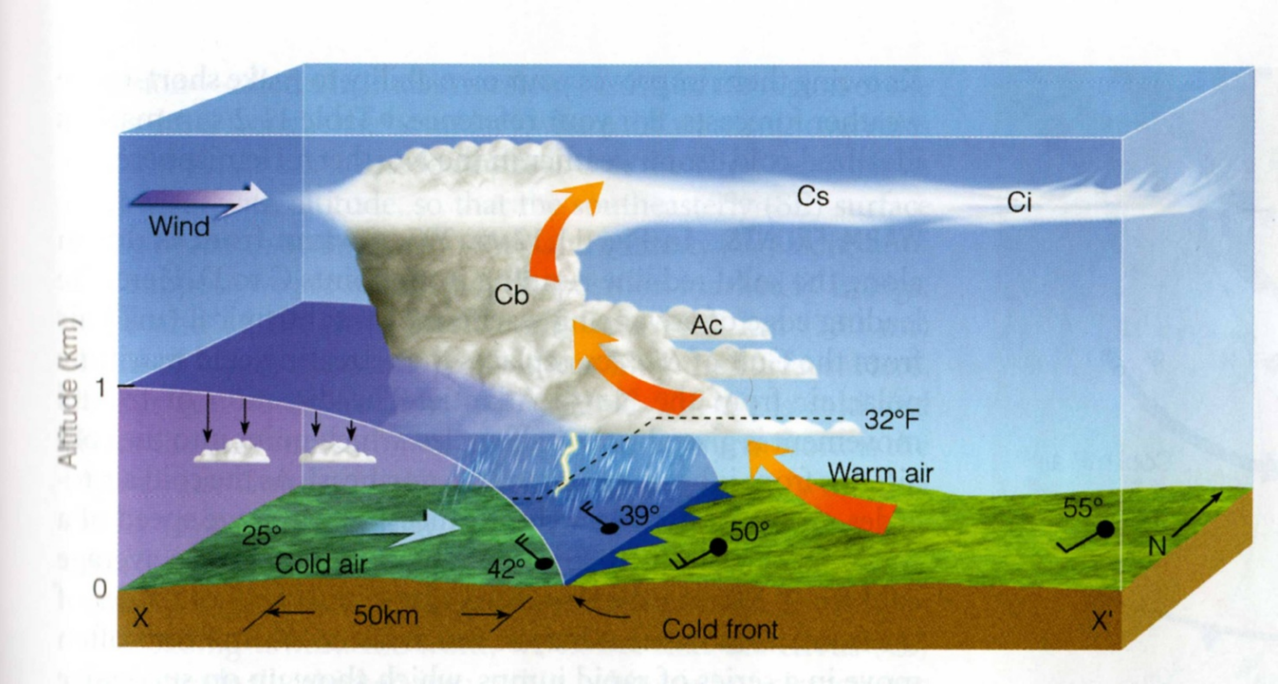
Type of weather and air masses in relation to fronts: Feb. 24, 2007 case



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

Characteristics of a front

1. Sharp temperature changes over a short distance
2. Changes in moisture content
3. Wind shifts
4. A lowering of surface pressure, or pressure trough
5. Clouds and precipitation



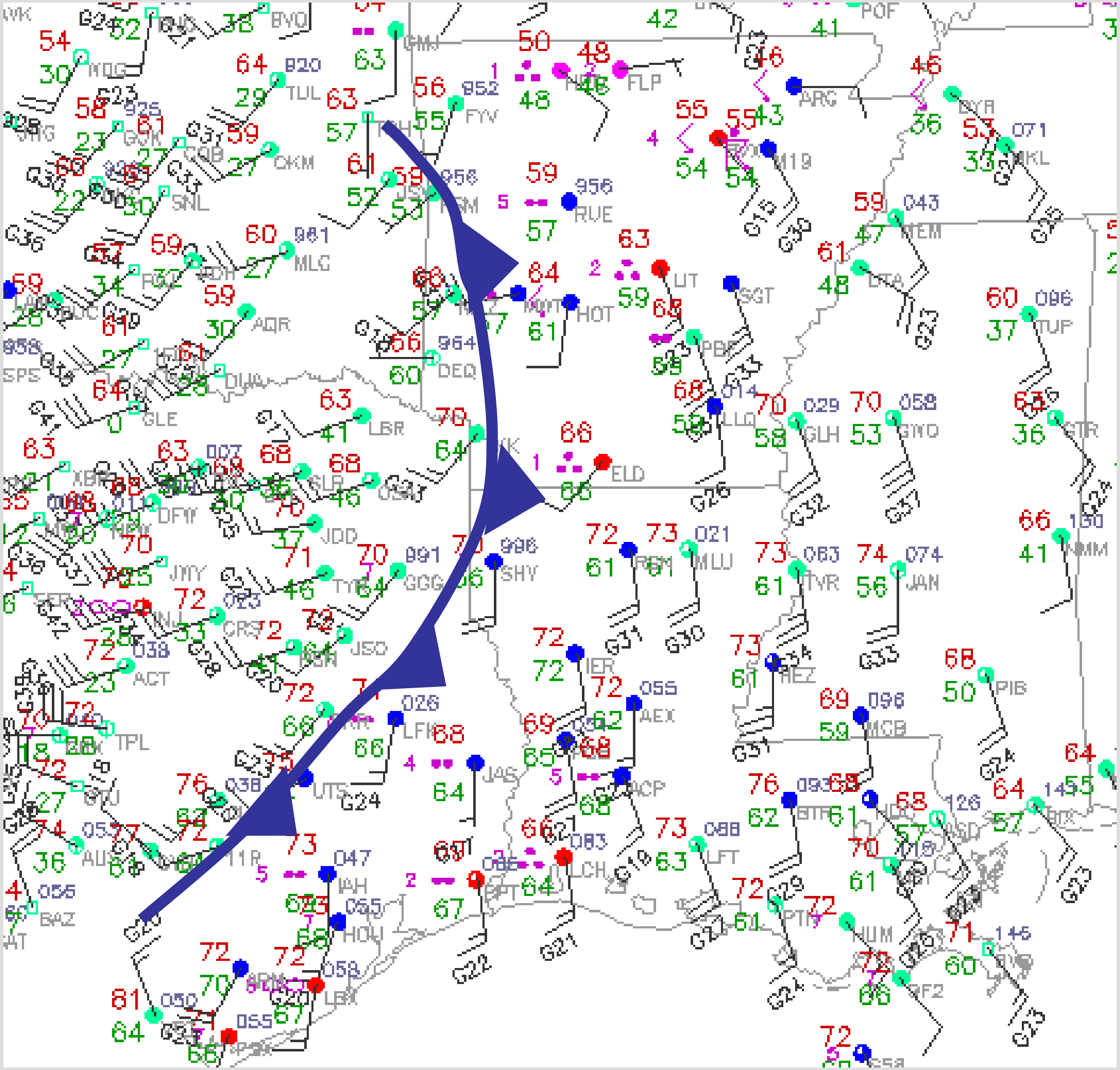
COLD FRONT

Horizontal extent: About 50 km

AHEAD OF FRONT: Warm and southerly winds. Cirrus or cirrostratus clouds. Called the warm sector.

AT FRONT: Pressure trough and wind shift. Area of rain showers, which can be thunderstorms if the air ahead of the front is warm and moist enough. Unstable, vertically developed clouds.

BEHIND FRONT: Rapid clearing and drying in the cold air. Pressure rises. Winds typically northerly or westerly.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MEM
MLC
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UTA
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SGT
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AQR
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DUA
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SHV
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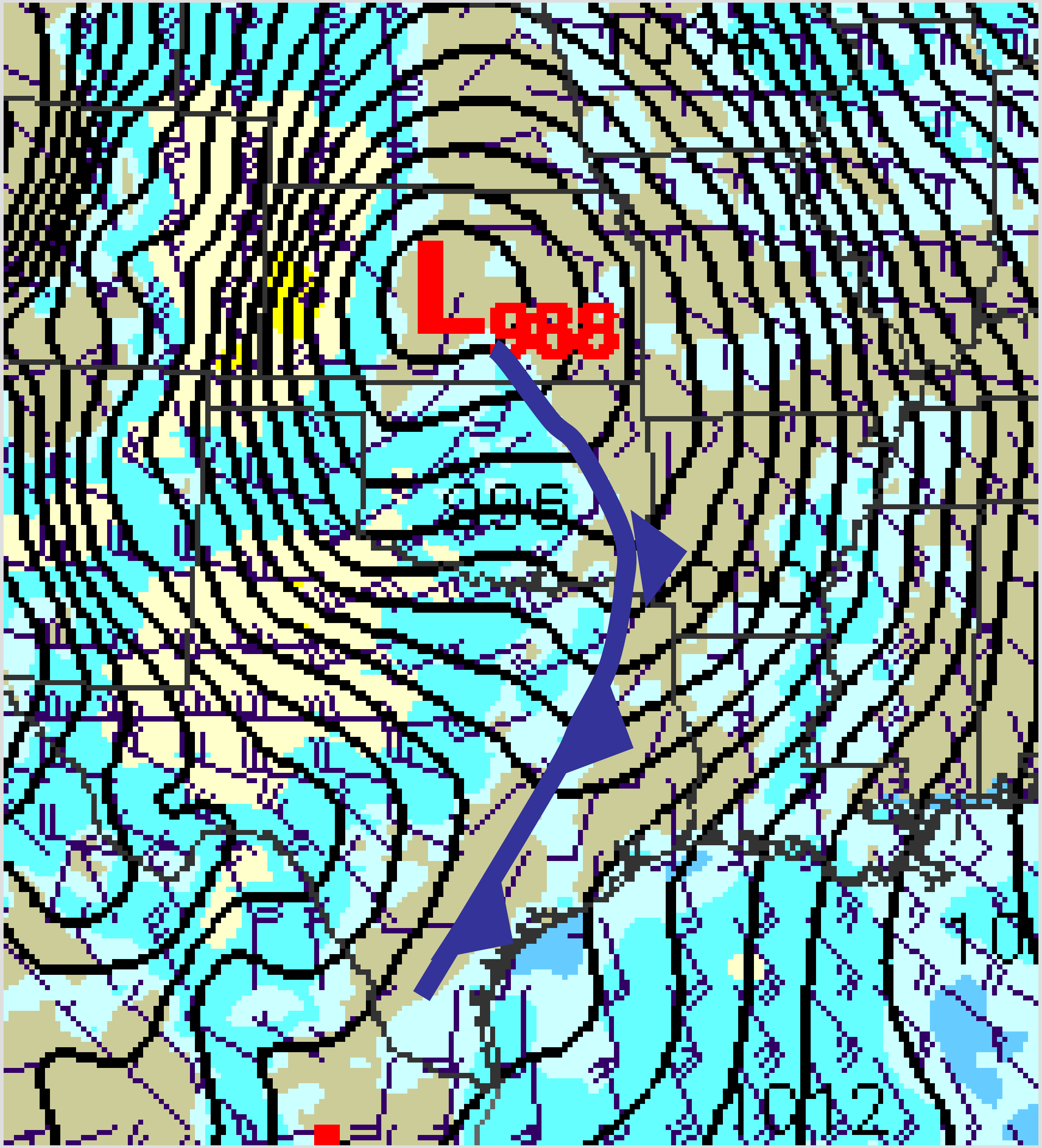
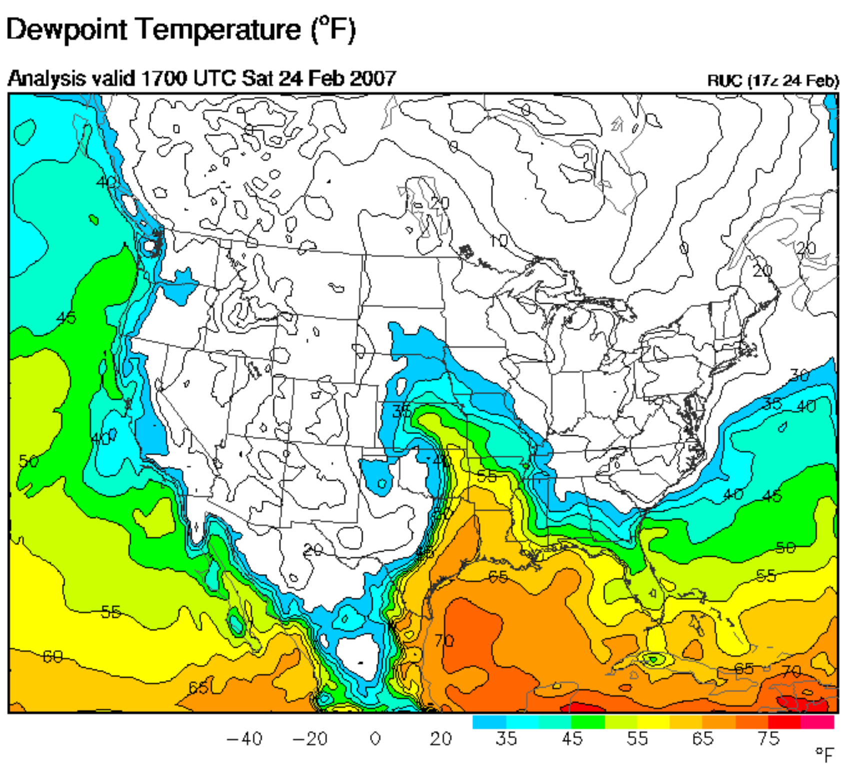
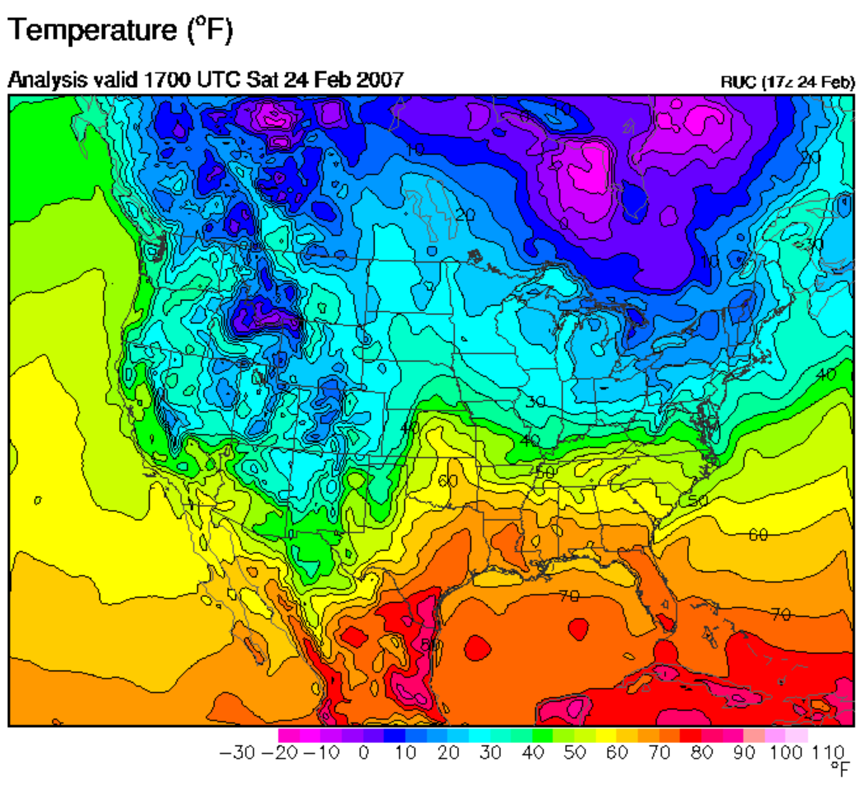
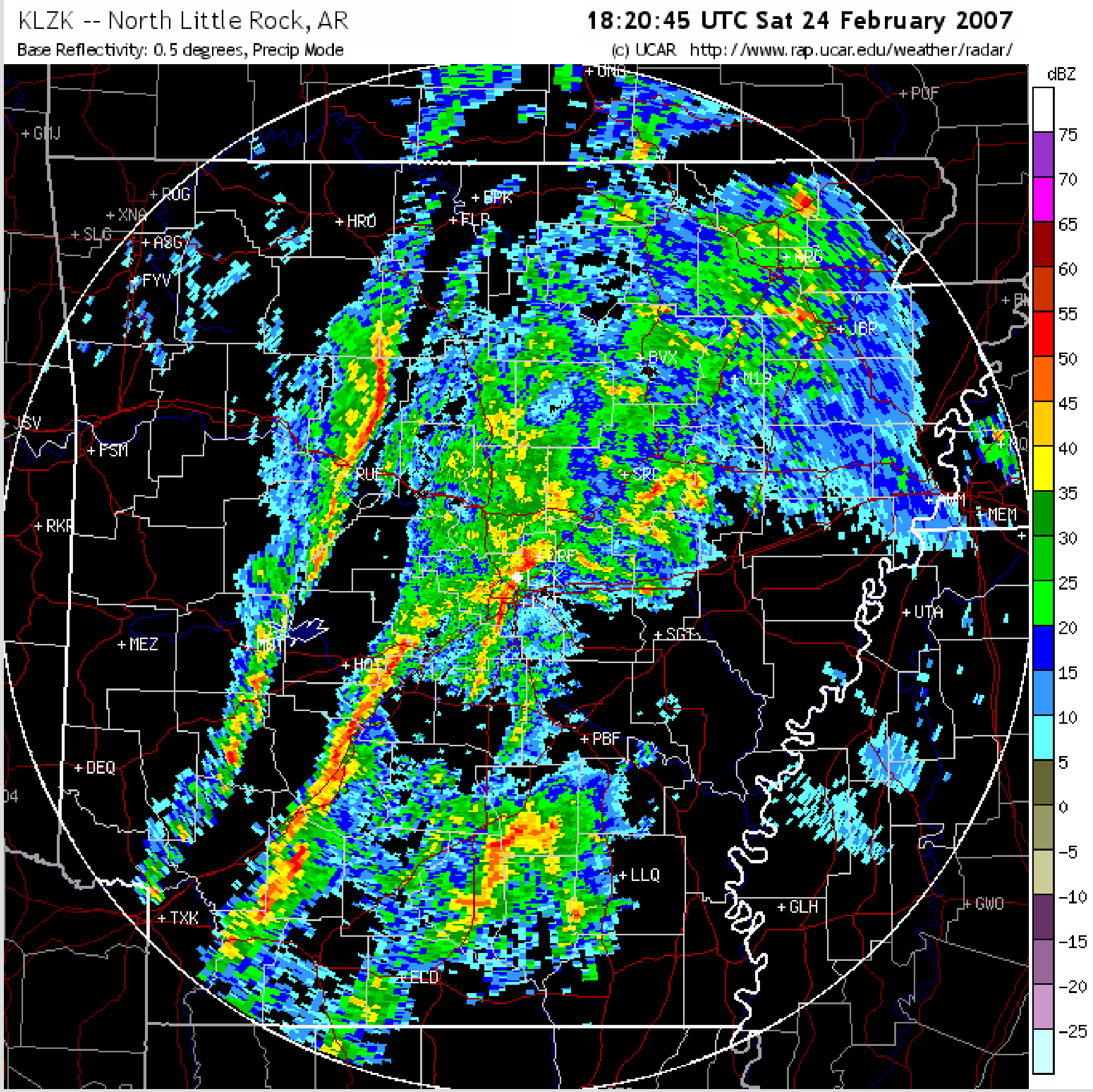


Fronts follow the pressure trough





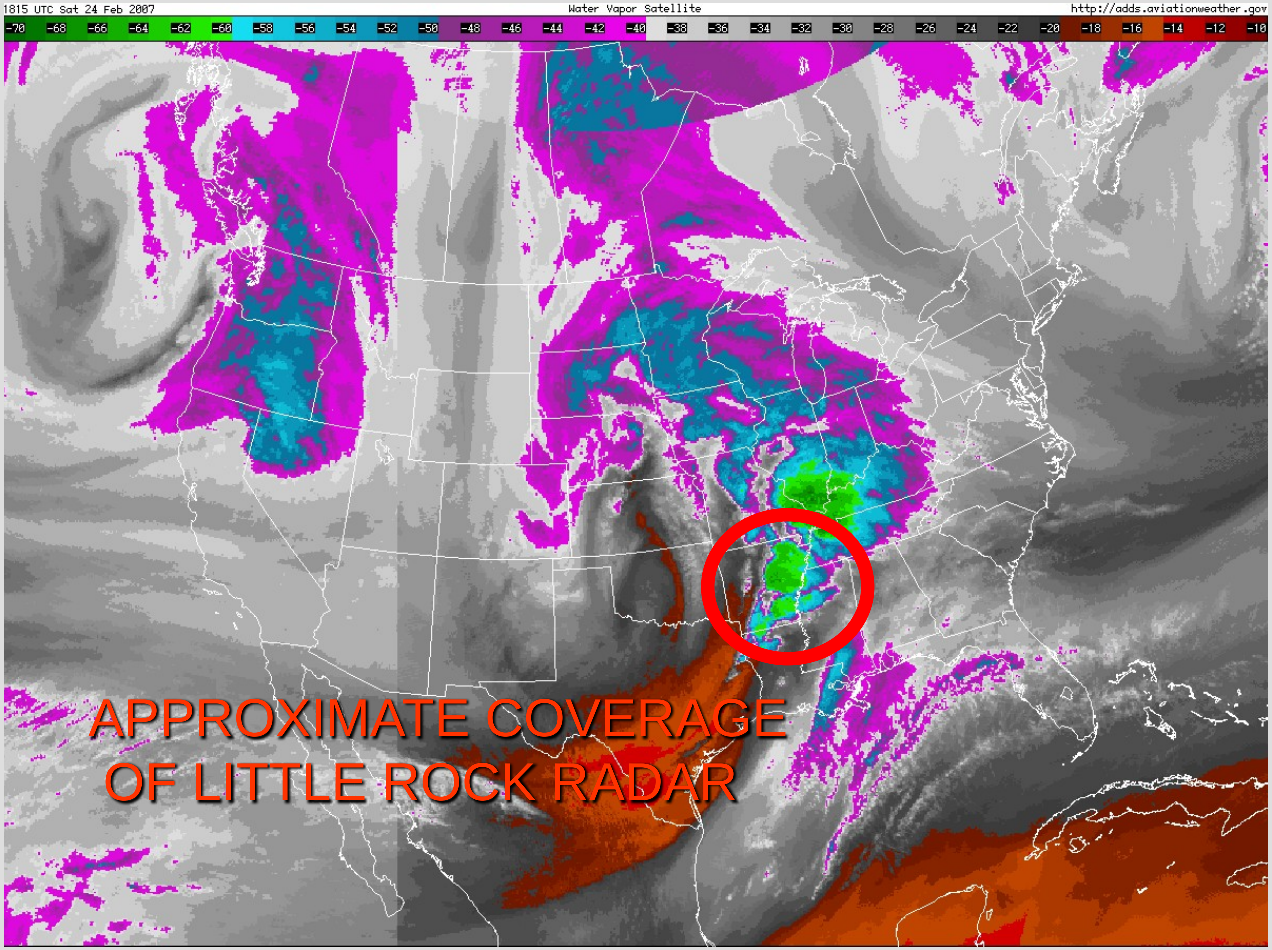
Note rapid change in dew point temperature and temperature in the vicinity of the cold front.



Typically a line or lines of showers or thunderstorms on a cold front.

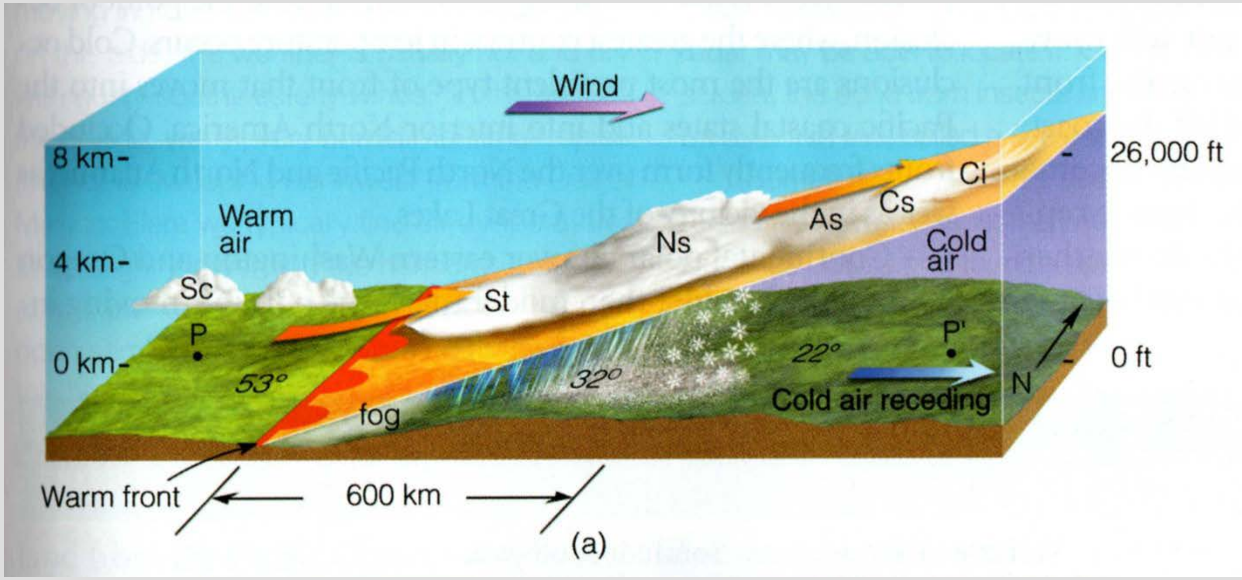
These are called *squall lines*.

ENHANCED IR SATELLITE IMAGE



APPROXIMATE COVERAGE OF LITTLE ROCK RADAR

Very cold, highly vertically developed clouds along the cold front in Arkansas where the squall lines are.



WARM FRONT

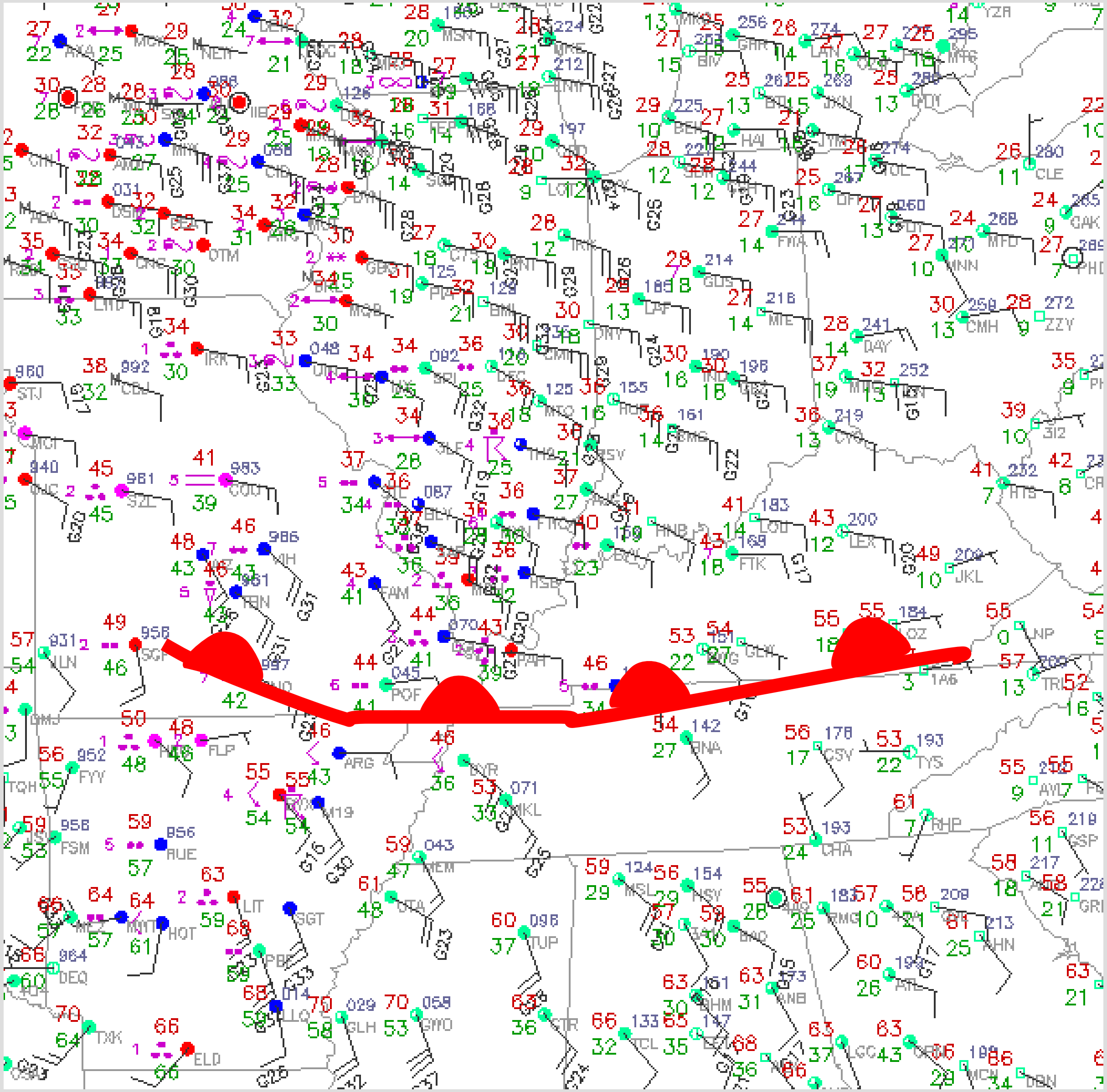
Horizontal extent: About 600 km

<u>AHEAD OF FRONT</u>: Easterly to Southeasterly winds. Widespread precipitation from stable clouds like nimbostratus. May include fog.

As get father north away from the front precipitation typically transitions because the cold air layer gets deeper
rain → freezing rain and sleet → snow

<u>AT FRONT</u>: Pressure trough and wind shift to the south.

<u>BEHIND FRONT</u>: Warming, rising pressure and southerly winds.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ELD
TXK
DEQ
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FYY
FLP
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JLN
POF
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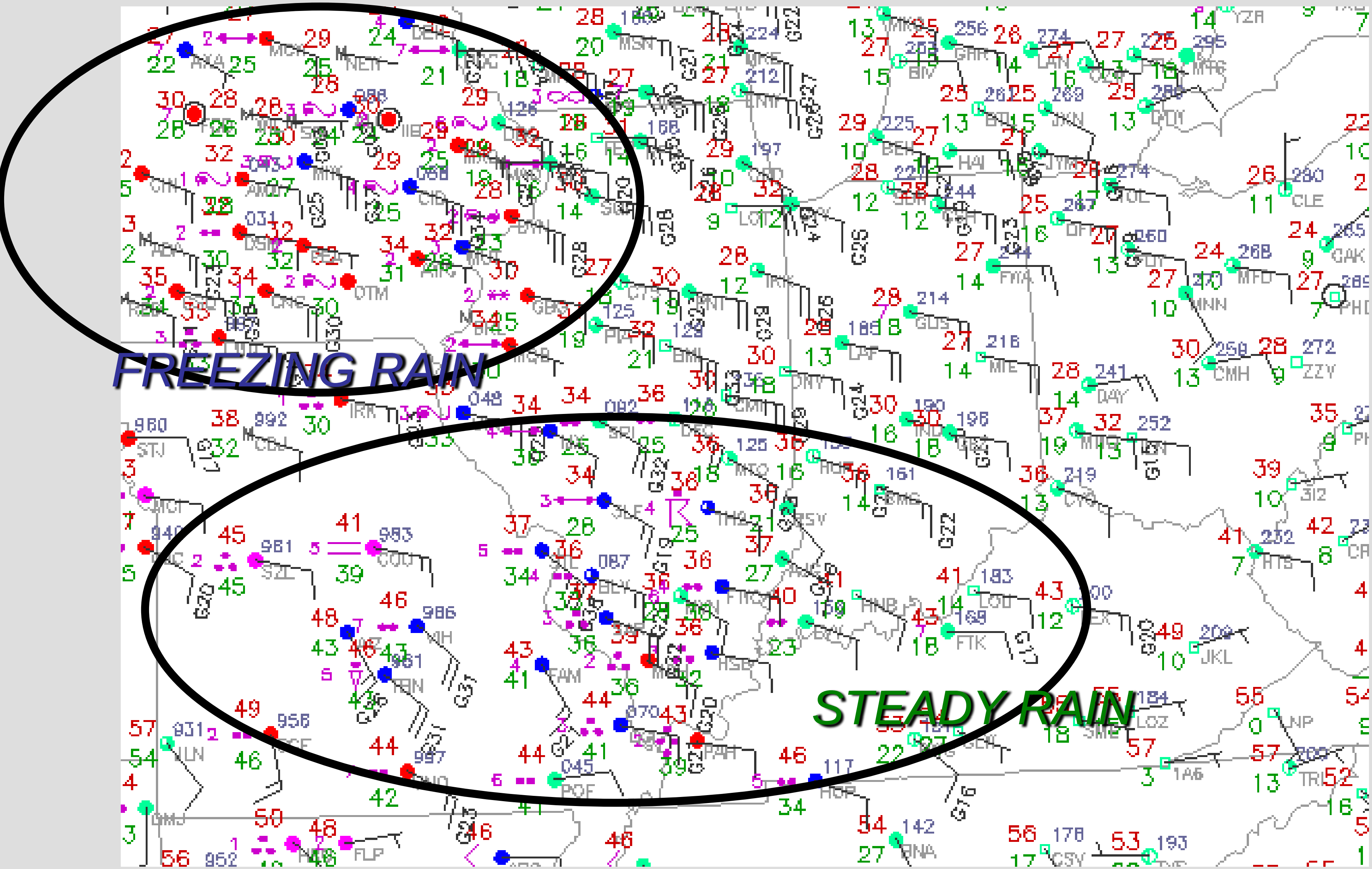
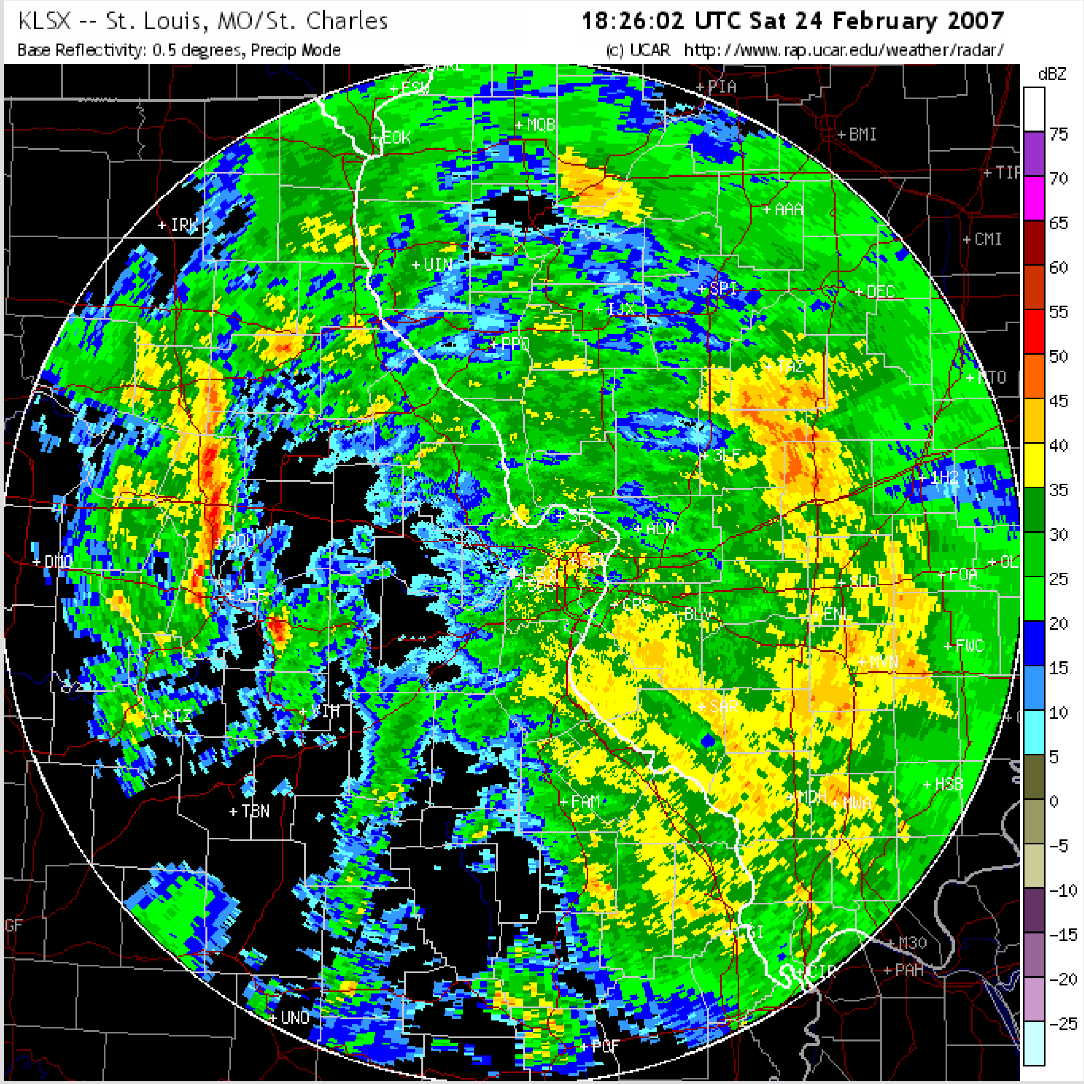
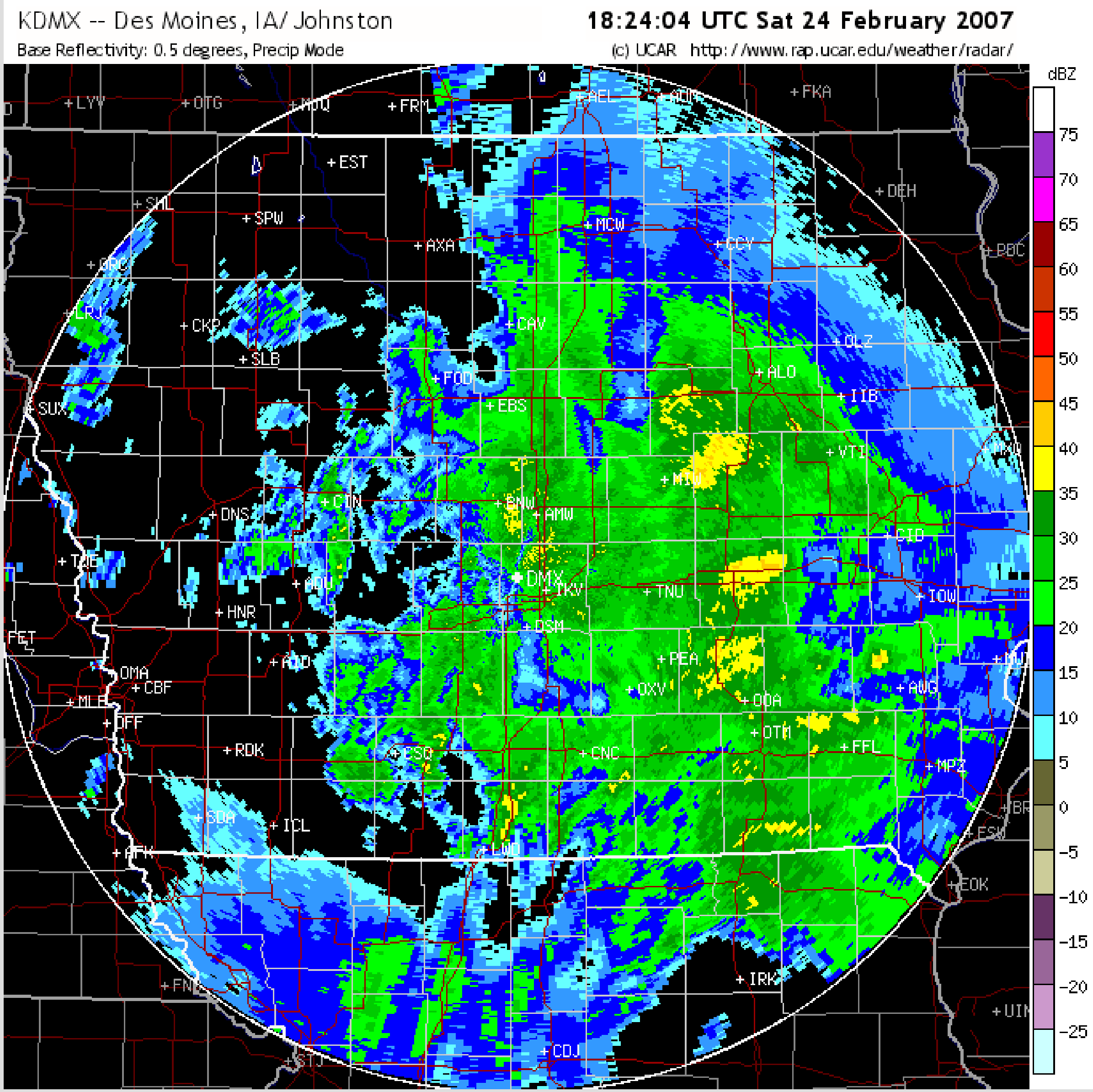

FREEZING RAIN
STEADY RAIN



Rain on a warm front is typically widespread and steady.

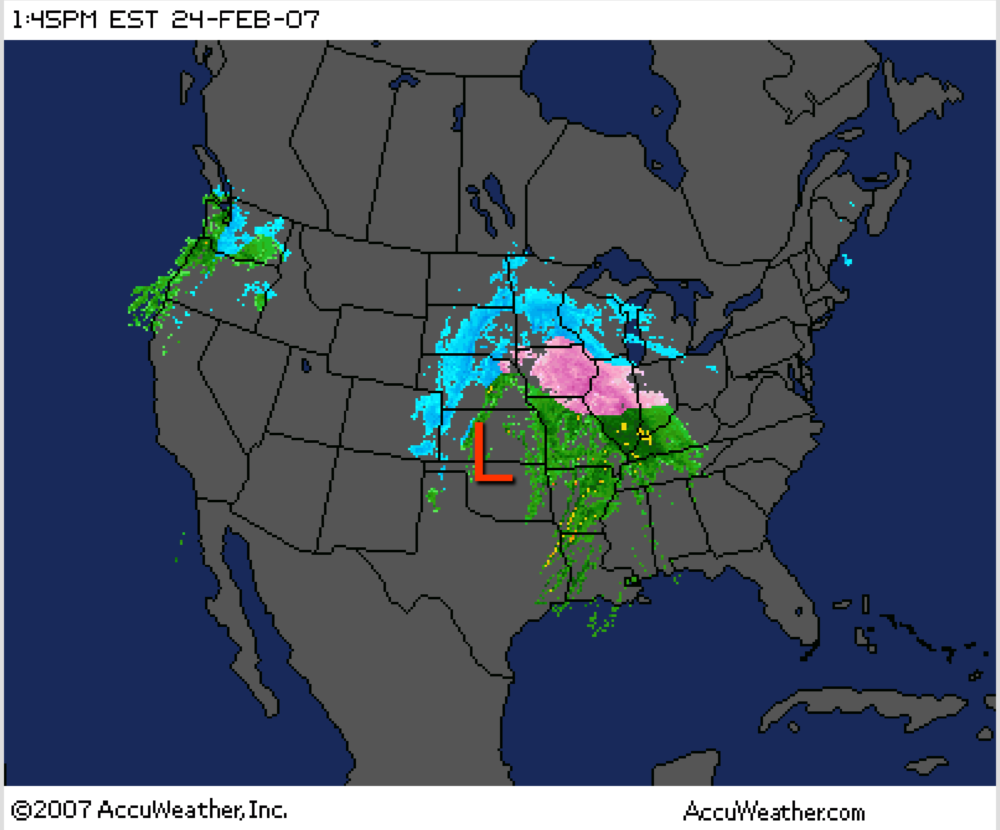
It is also not typically very heavy, as with the thunderstorms on the cold front.

Note the lack of the really strong radar echoes here (i.e. not a lot of orange and red colors).



Freezing rain is occurring in Iowa where the radar reflectivity is highest (yellows)

Far enough north and west of the warm front is typically where the snow happens because the cold air is deep enough.

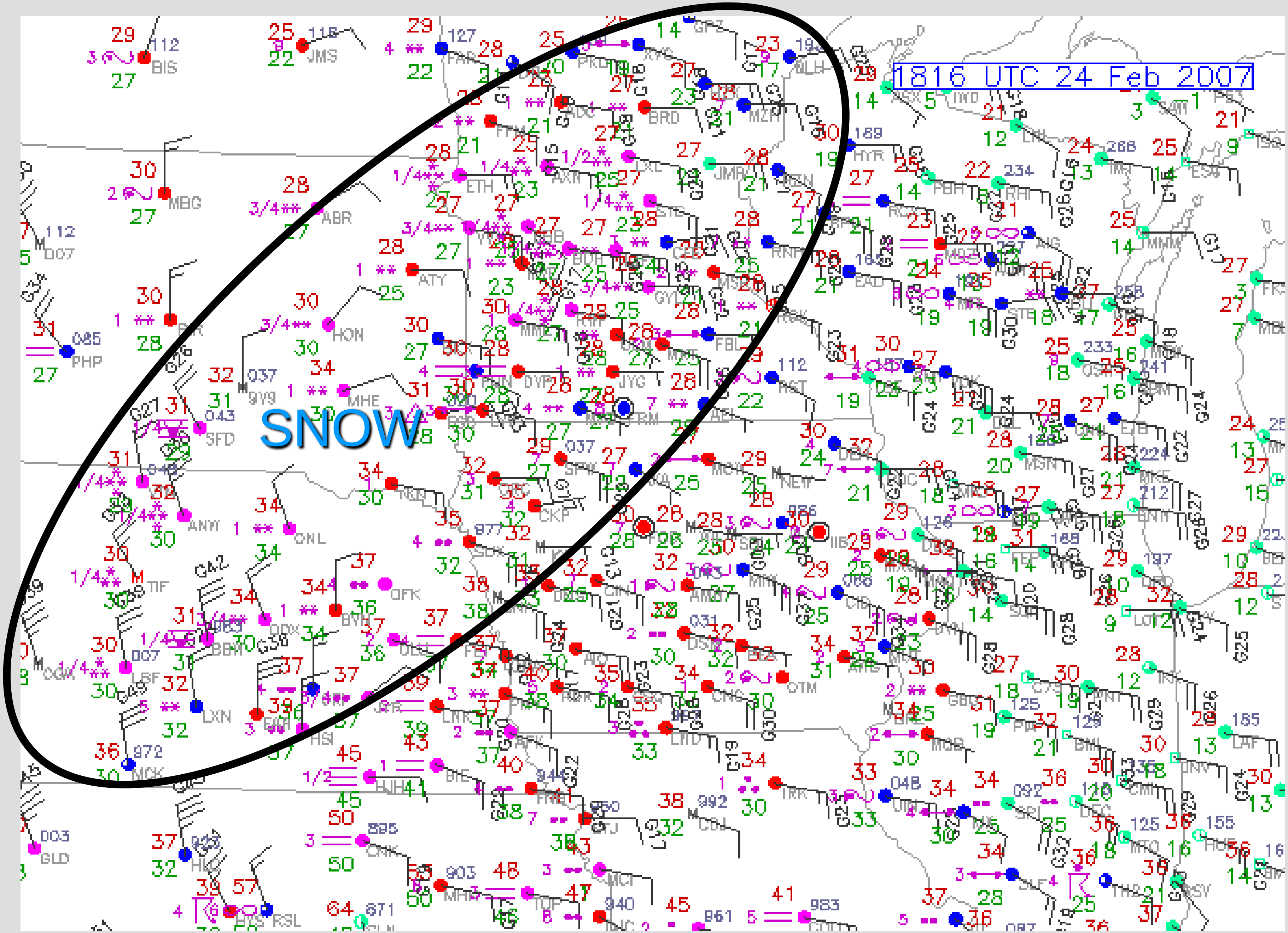


Radar color key

RAIN

FREEZING RAIN or SLEET

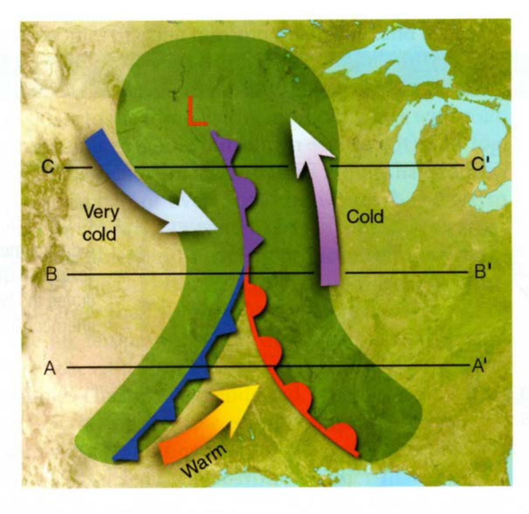
SNOW



1816 UTC 24 Feb 2007

SNOW

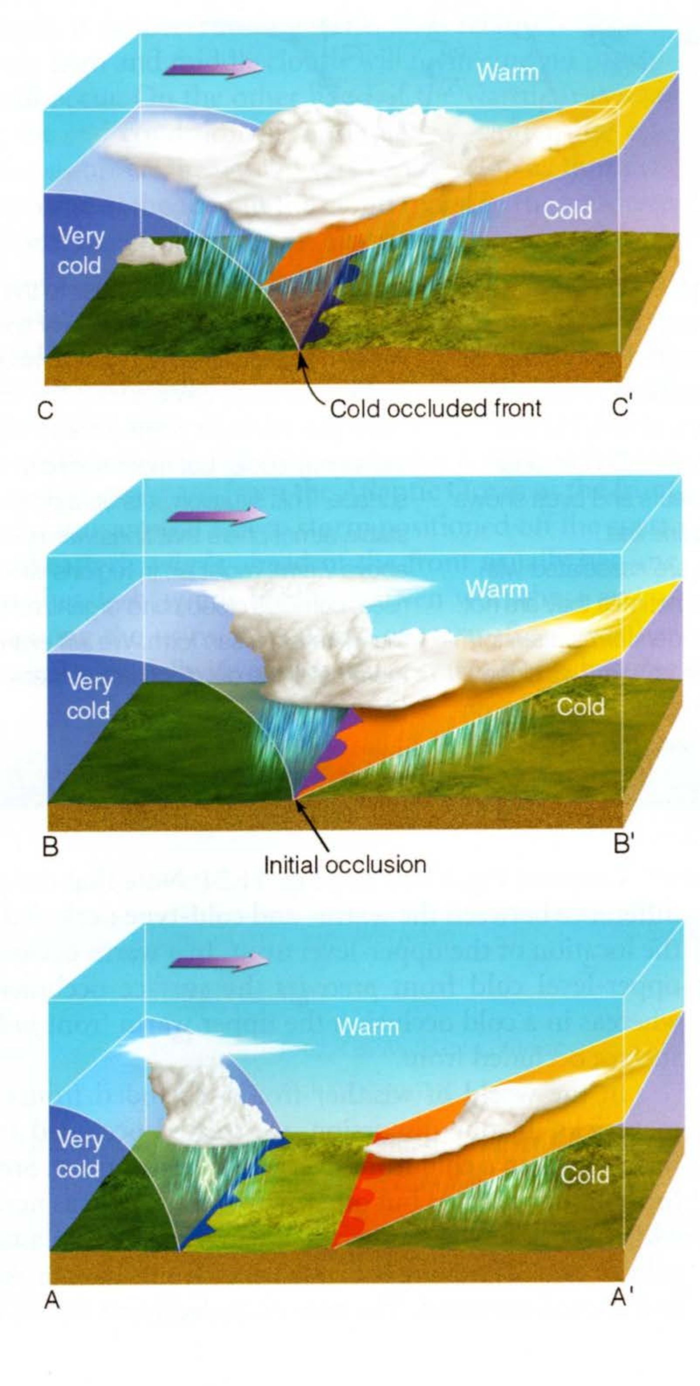
OCCLUDED FRONT

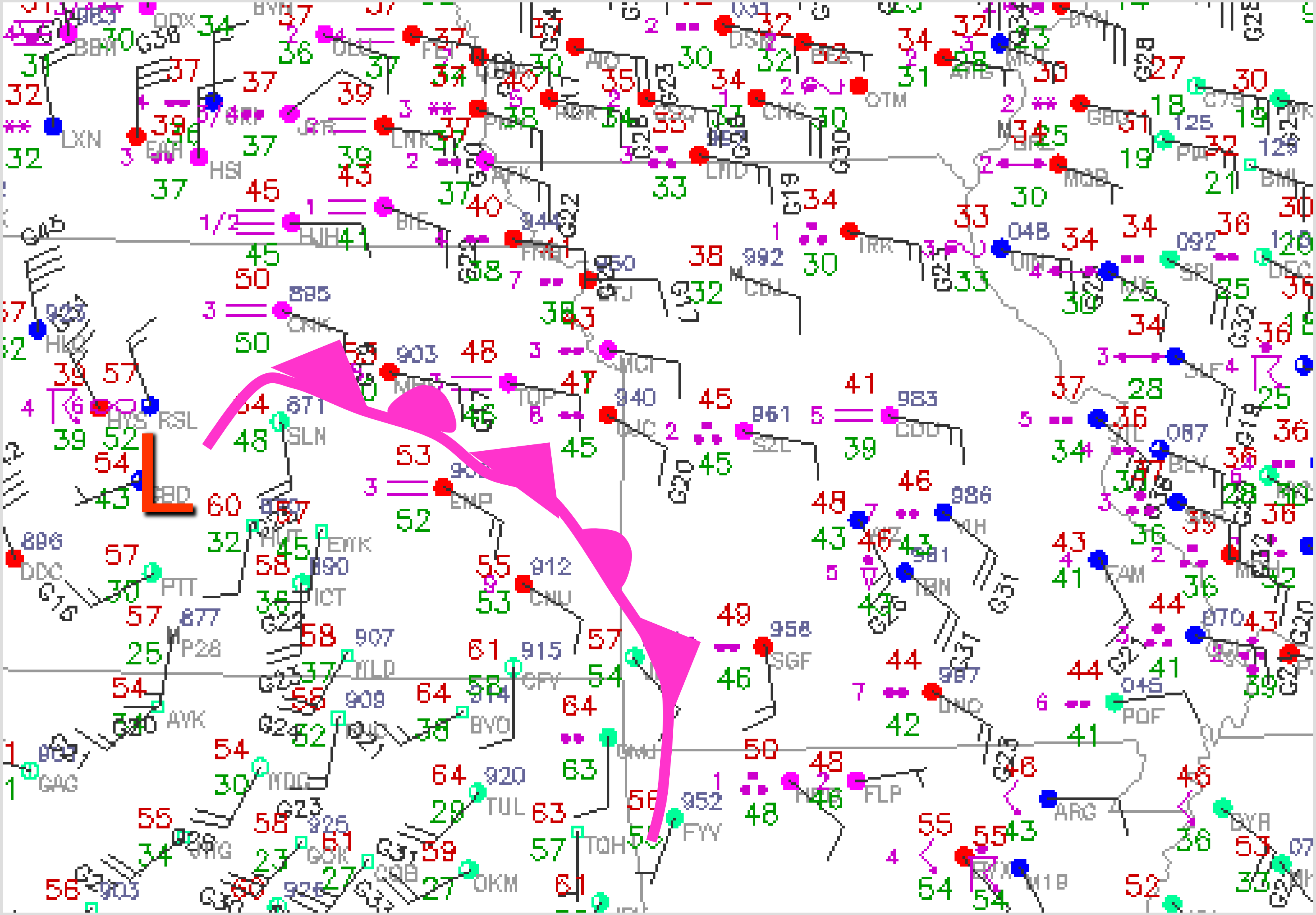


Cold front “catches up” to the warm front, forming a wedge of warm air above the ground.

At the occlusion, precipitation may range from widespread and steady to localized and heavy.

Near the center of the low pressure.

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IRK
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DEC
COU
VIH
TBN
FAM
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BLV
DDC
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HUT
CNU
WLD
CFV
BVO
AYK
GAG
WDG
TUL
GCK
OKM
TQH
FYV
SGF
FLP
ARG
POF
PIA
BMI
OTM
DSM
FET
AFK
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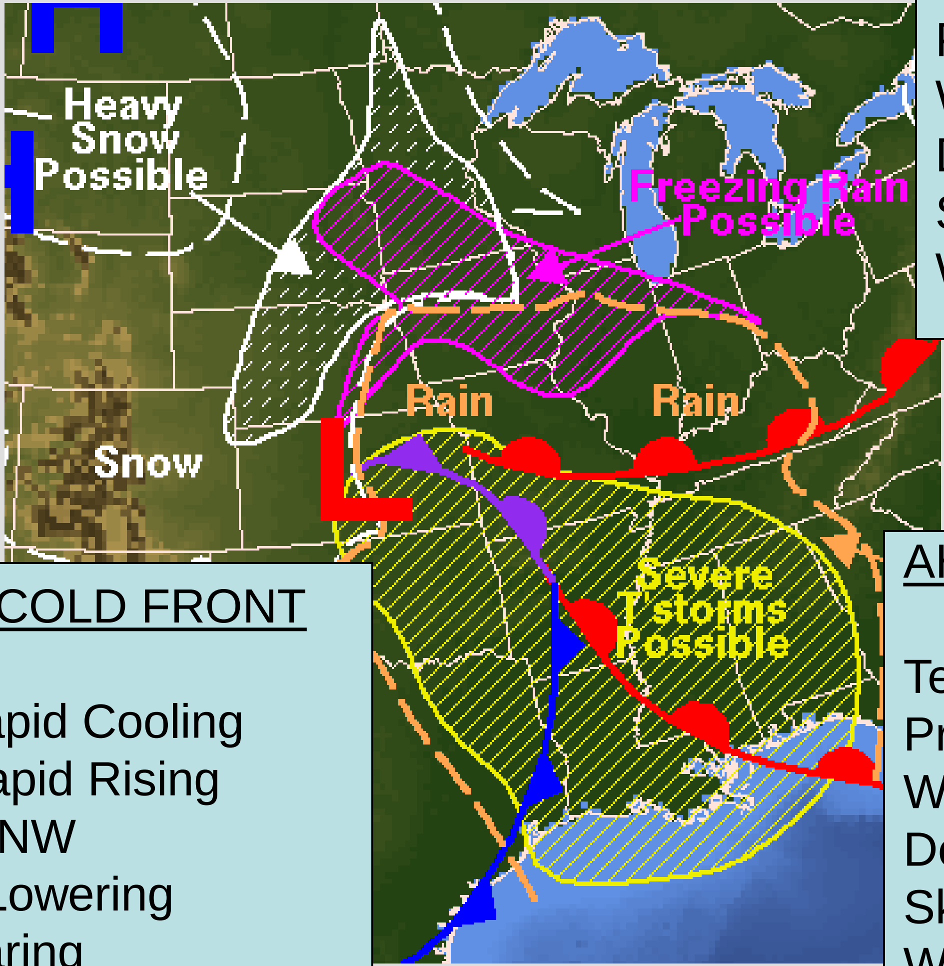
Tucson cold front passage

Things to Note:

Wind shifts (trees and smoke stack)
Precipitation (squall lines)
Temperature drop and lowering of cloud bases
Clearing at the end



AHEAD OF WARM FRONT

Temp: Slow Warming
Press: Falling
Wind: E-SE
Dew Pt: Rising
Sky: Lowering Ceiling
Wx: Steady Precip., Low Vis.

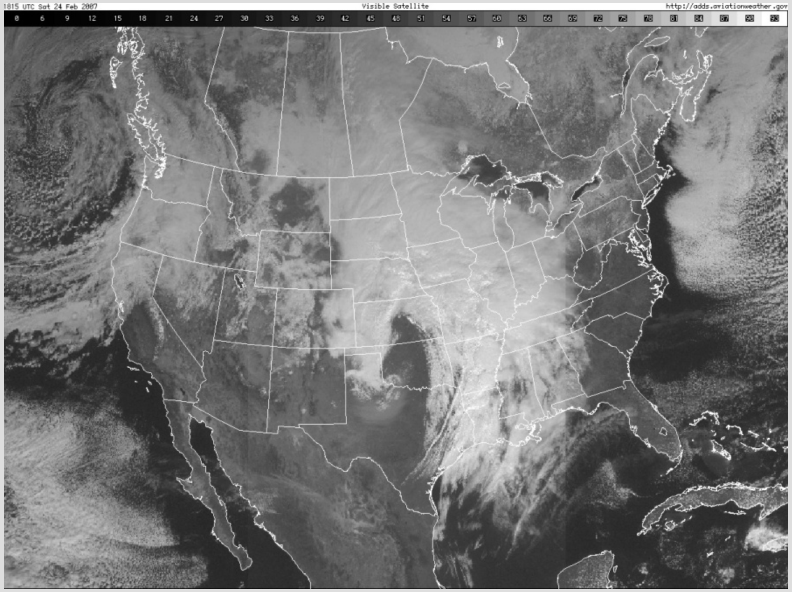
BEHIND COLD FRONT

Temp: Rapid Cooling
Press: Rapid Rising
Wind: W-NW
Dew Pt: Lowering
Sky: Clearing
Wx: Improving

AHEAD OF COLD FRONT

Temp: Warm
Press: Steady
Wind: S-SW
Dew Pt: High
Sky: Variable
Wx: Showers and T-storms

WARM SECTOR



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.***

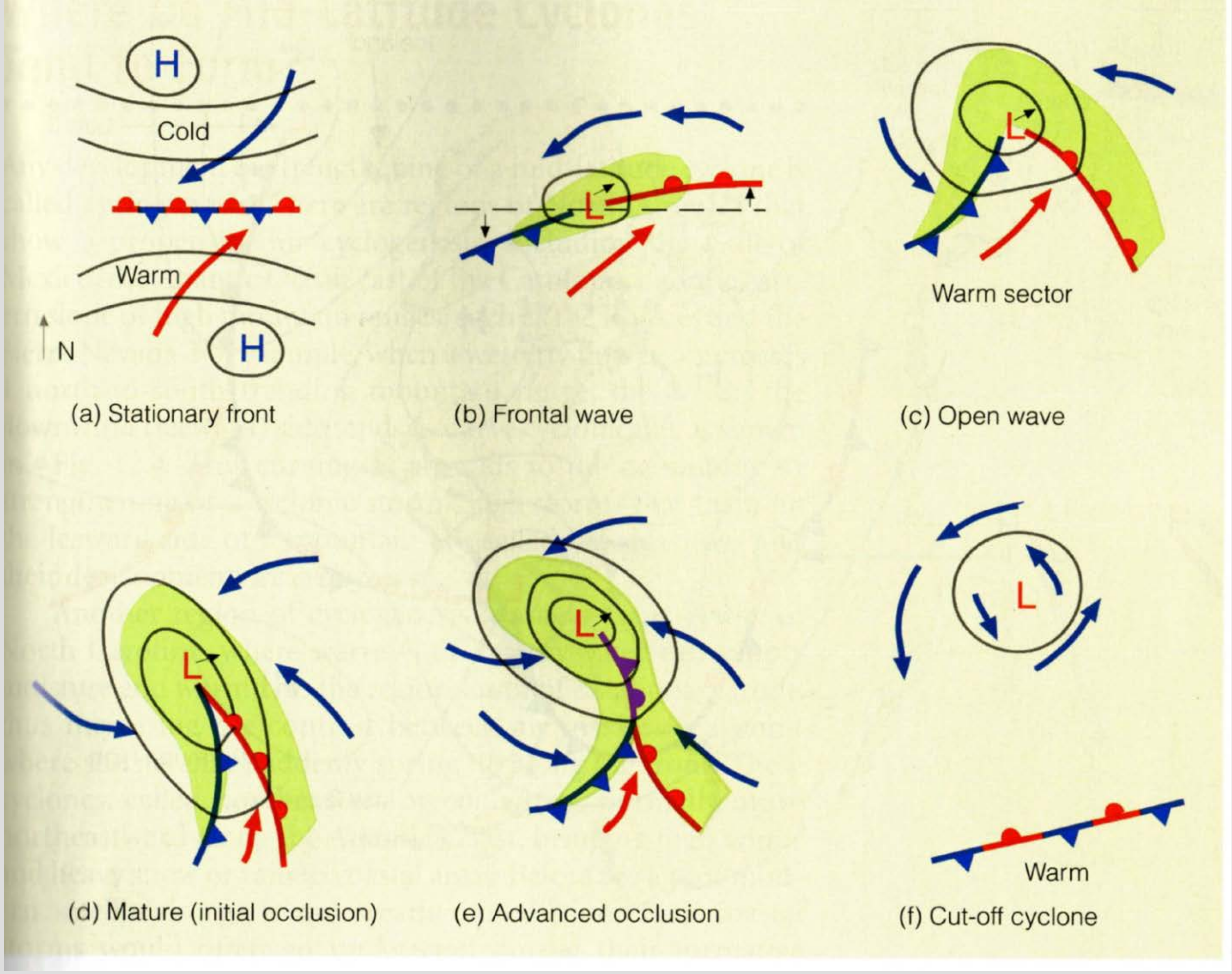
Purpose of the mid-latitude cyclones in the general circulation is to transport energy from equator to pole:

- **Transport warm air toward pole and upward.**
- **Transport cold air toward equator and downward.**

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

Vilhelm Bjerknes

Bjerknes Polar Front Model

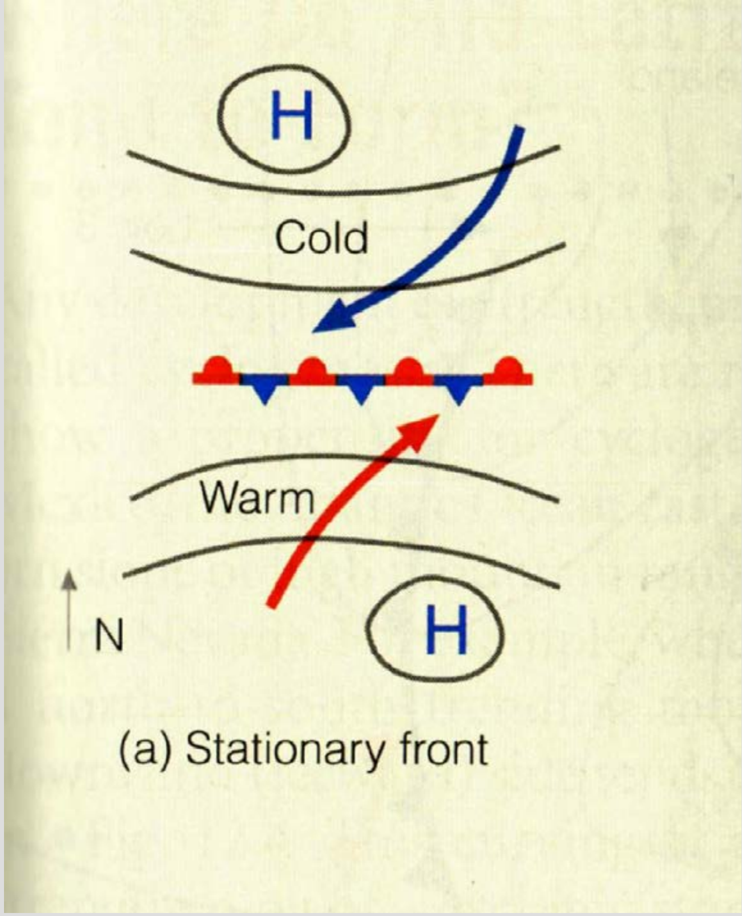


(a) Stationary front (b) Frontal wave (c) Open wave

(d) Mature (initial occlusion) (e) Advanced occlusion (f) Cut-off cyclone

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

Bjerknes Polar Front Model
Step 1: Stationary Front

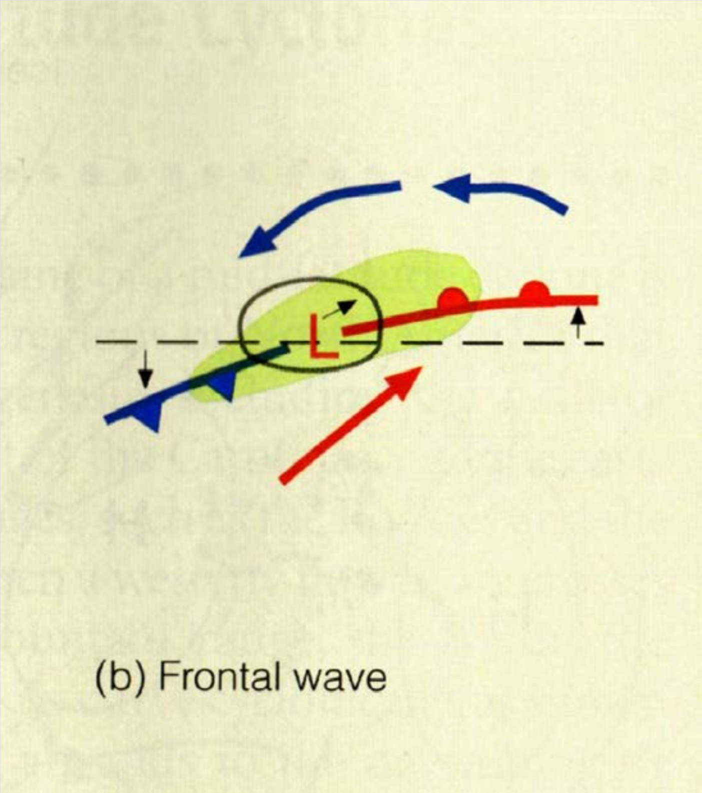


(a) Stationary front

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

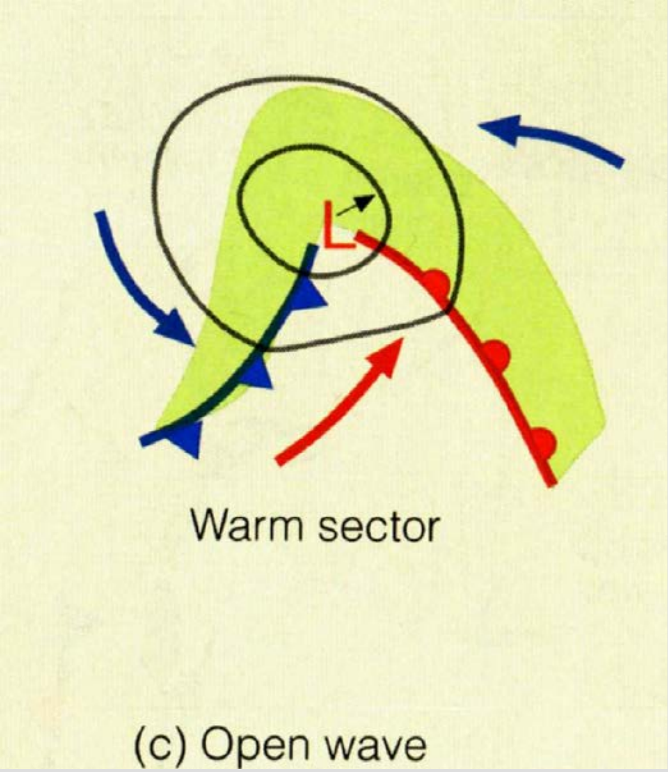


(b) Frontal wave

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



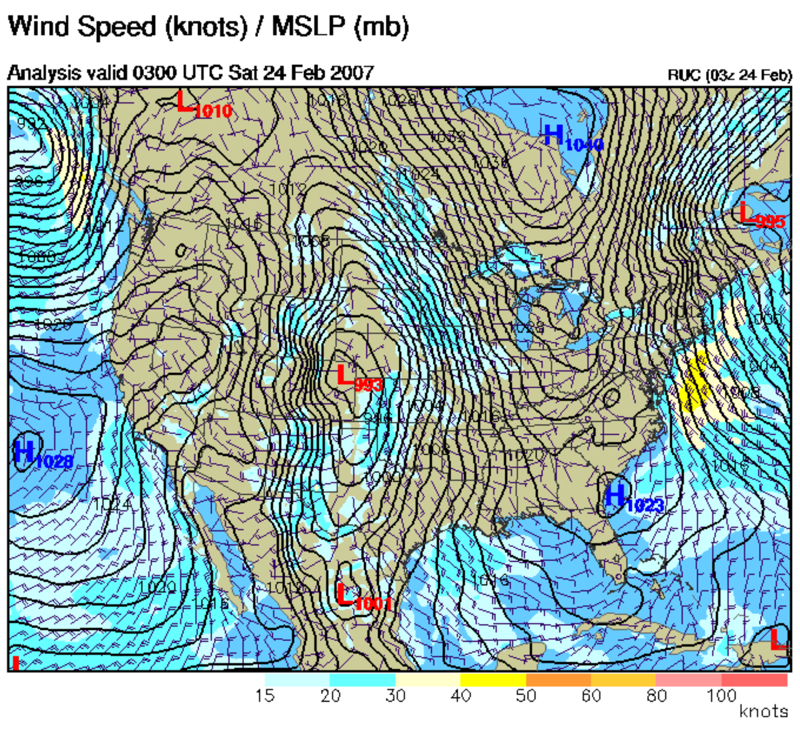
(c) Open wave

Low pressure begins to deepen.

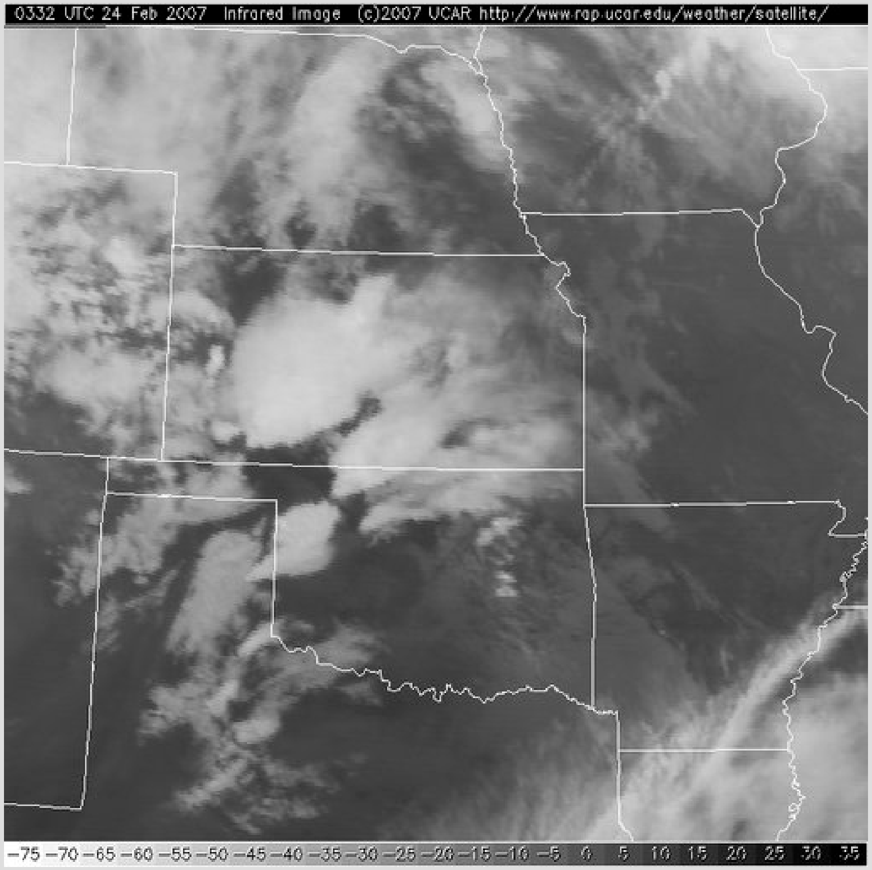
Warm and cold fronts become more defined.

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

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

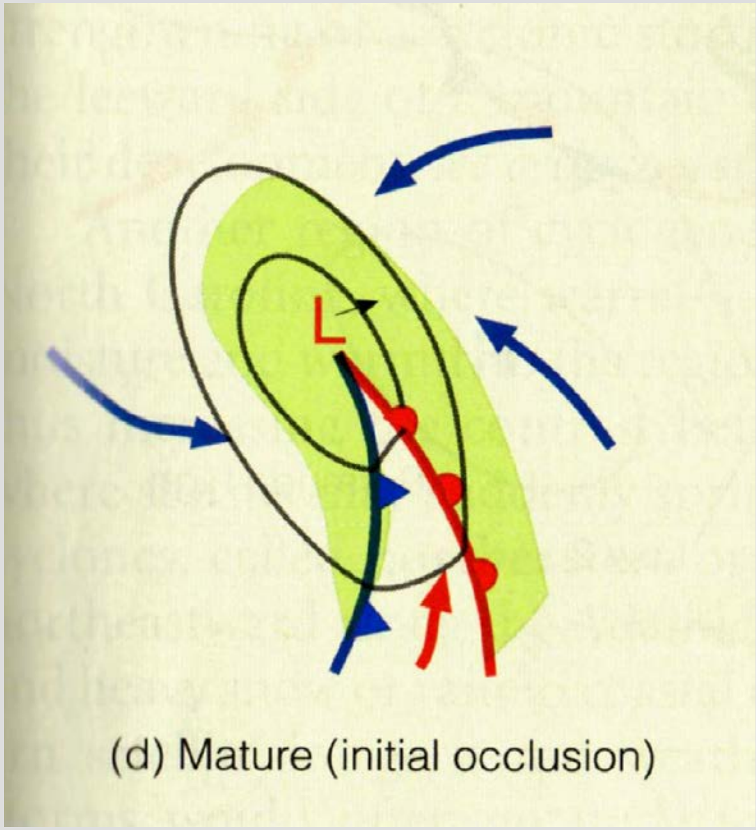


Note formation of low pressure in eastern CO.



IR Imagery

Bjerknes Polar Front Model
Step 4: Mature cyclone

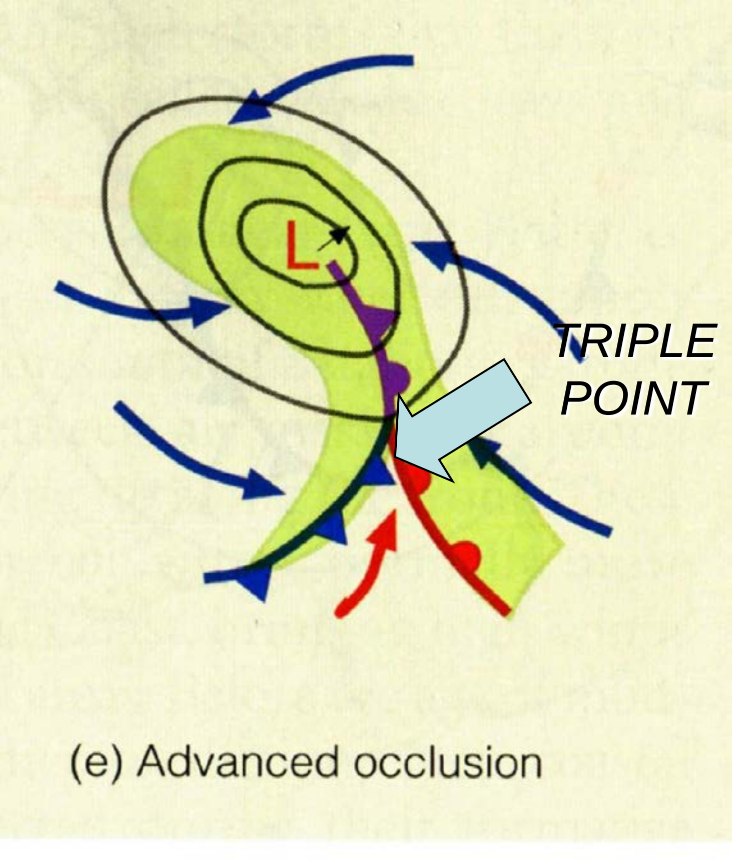


(d) Mature (initial occlusion)

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.

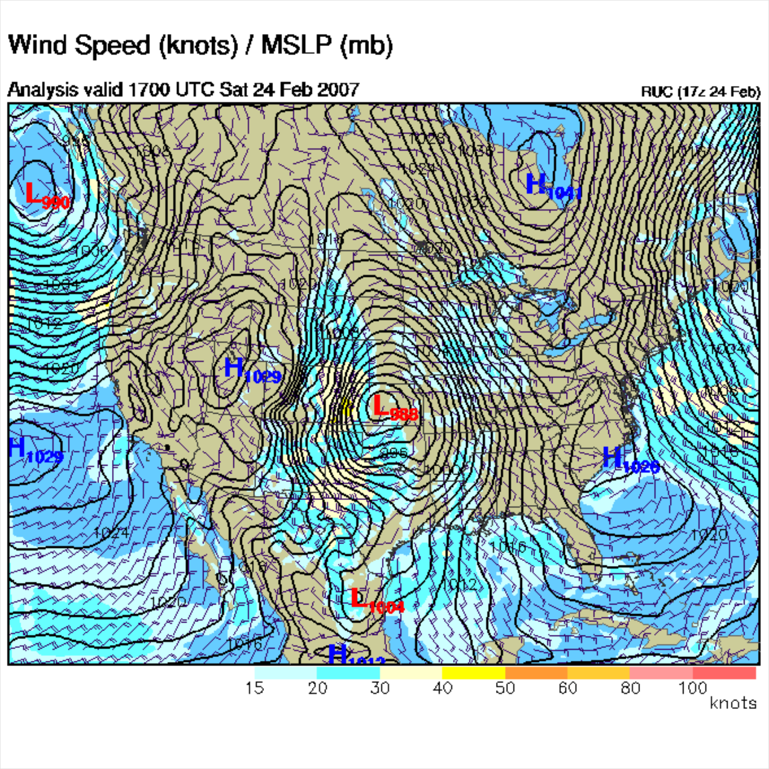
Low deepens to its lowest pressure.

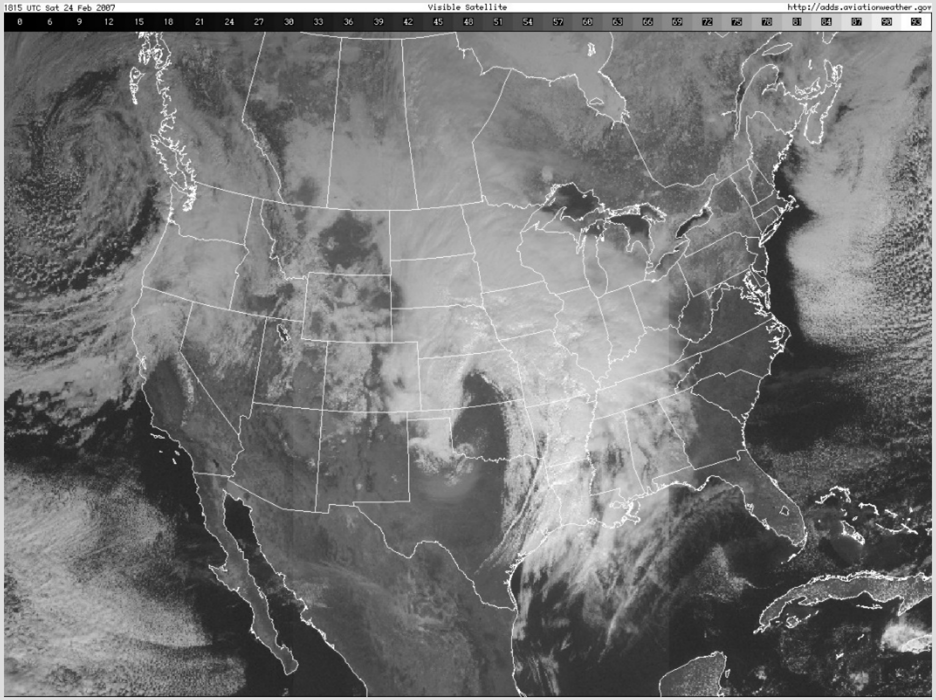
Occluded front near the center of the low pressure.

Recall the types of weather associated with the fronts at this stage.

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

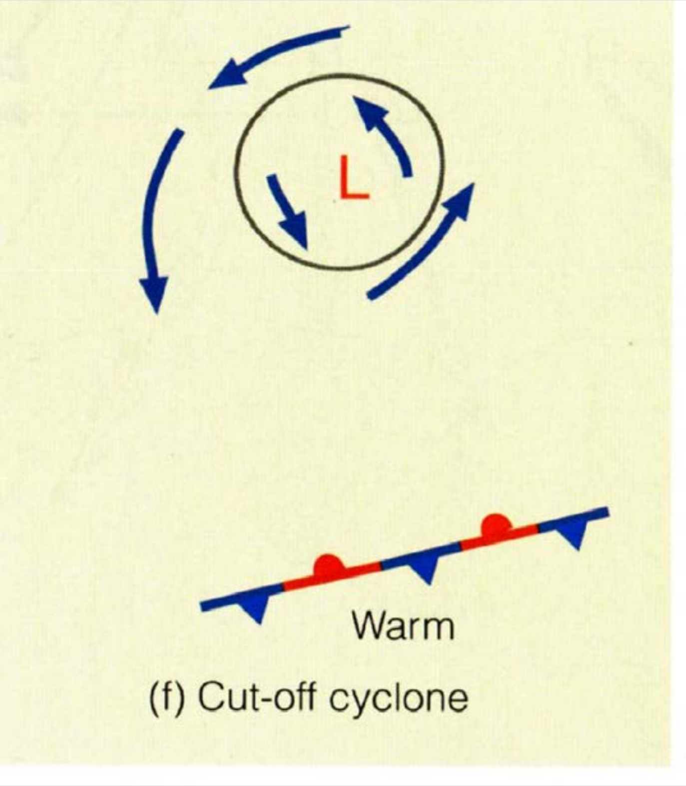
Mature Cyclone, Occluded Stage
1700 UTC, Saturday, Feb. 24, 2007





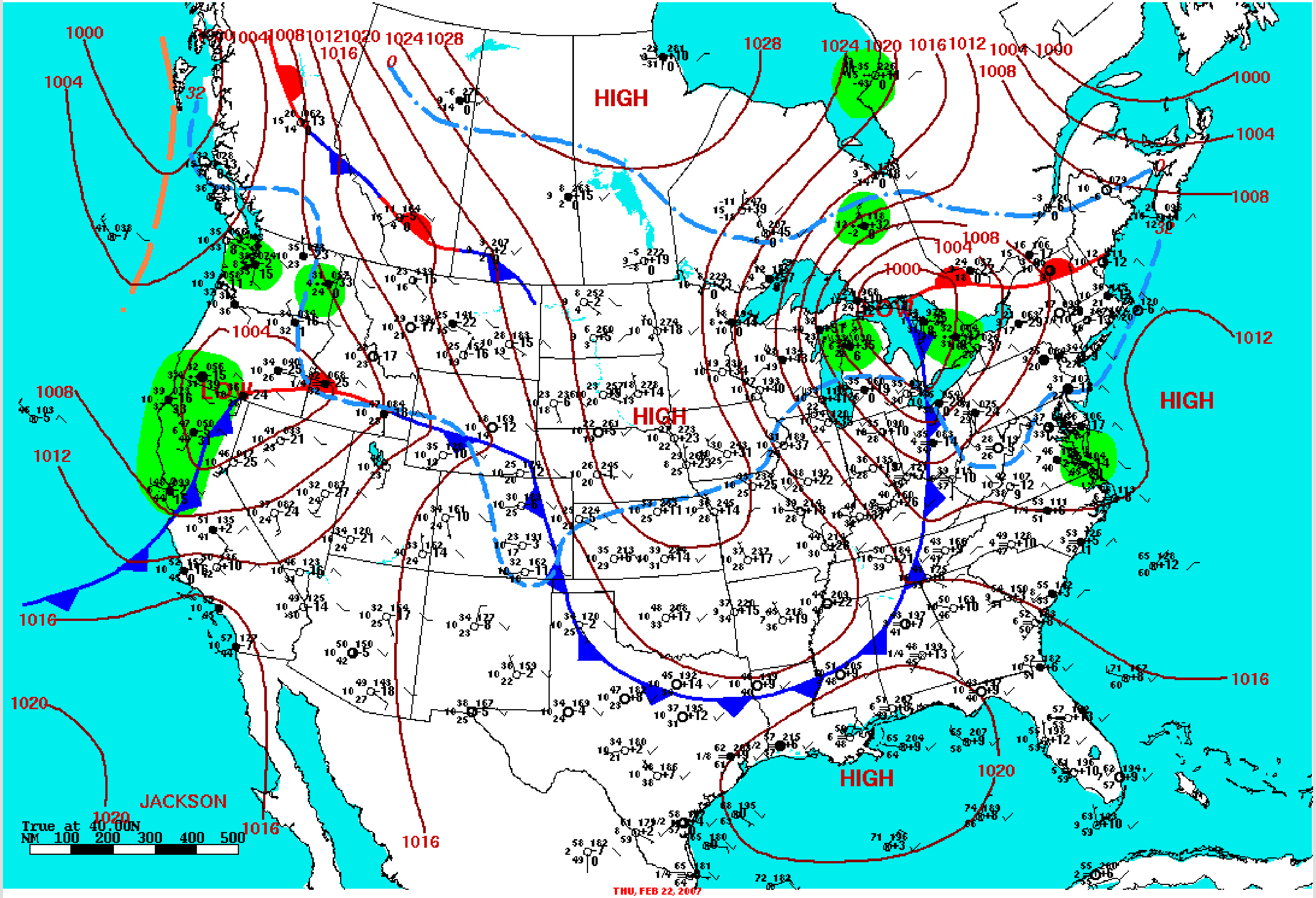
IR Imagery

Bjerknes Polar Front Model
Step 6: Cut off stage



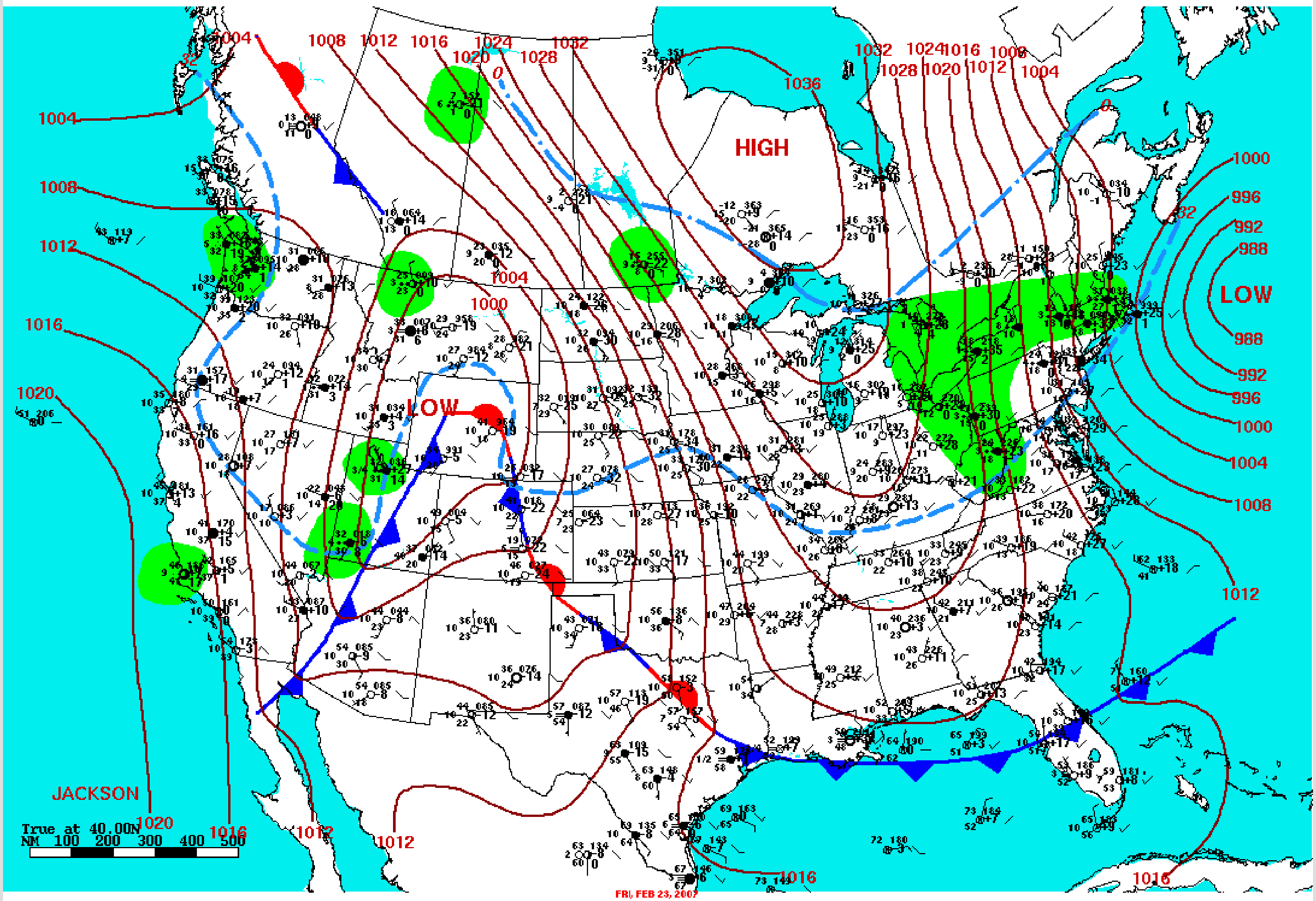
(f) Cut-off cyclone

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



THU, FEB 22, 2007

Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.



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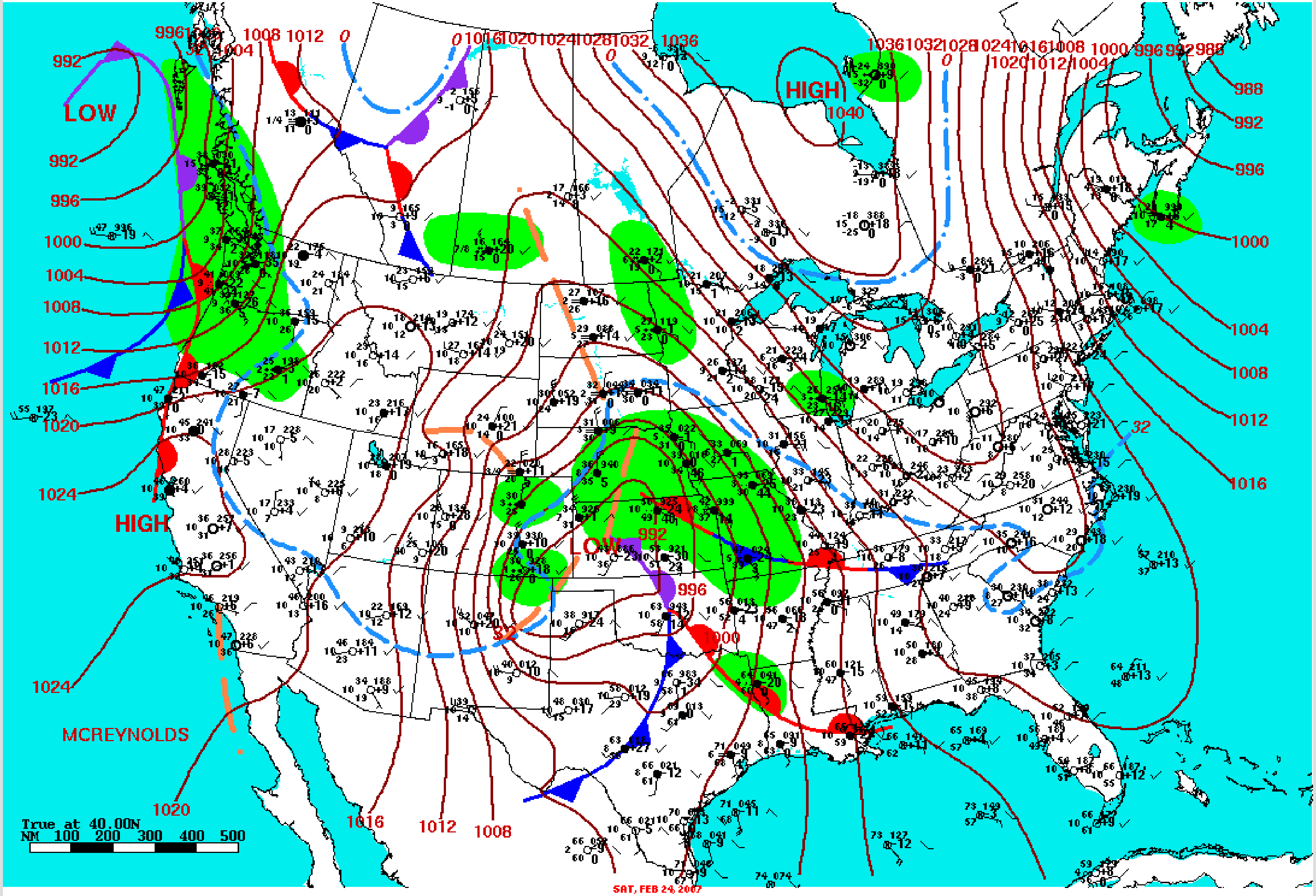
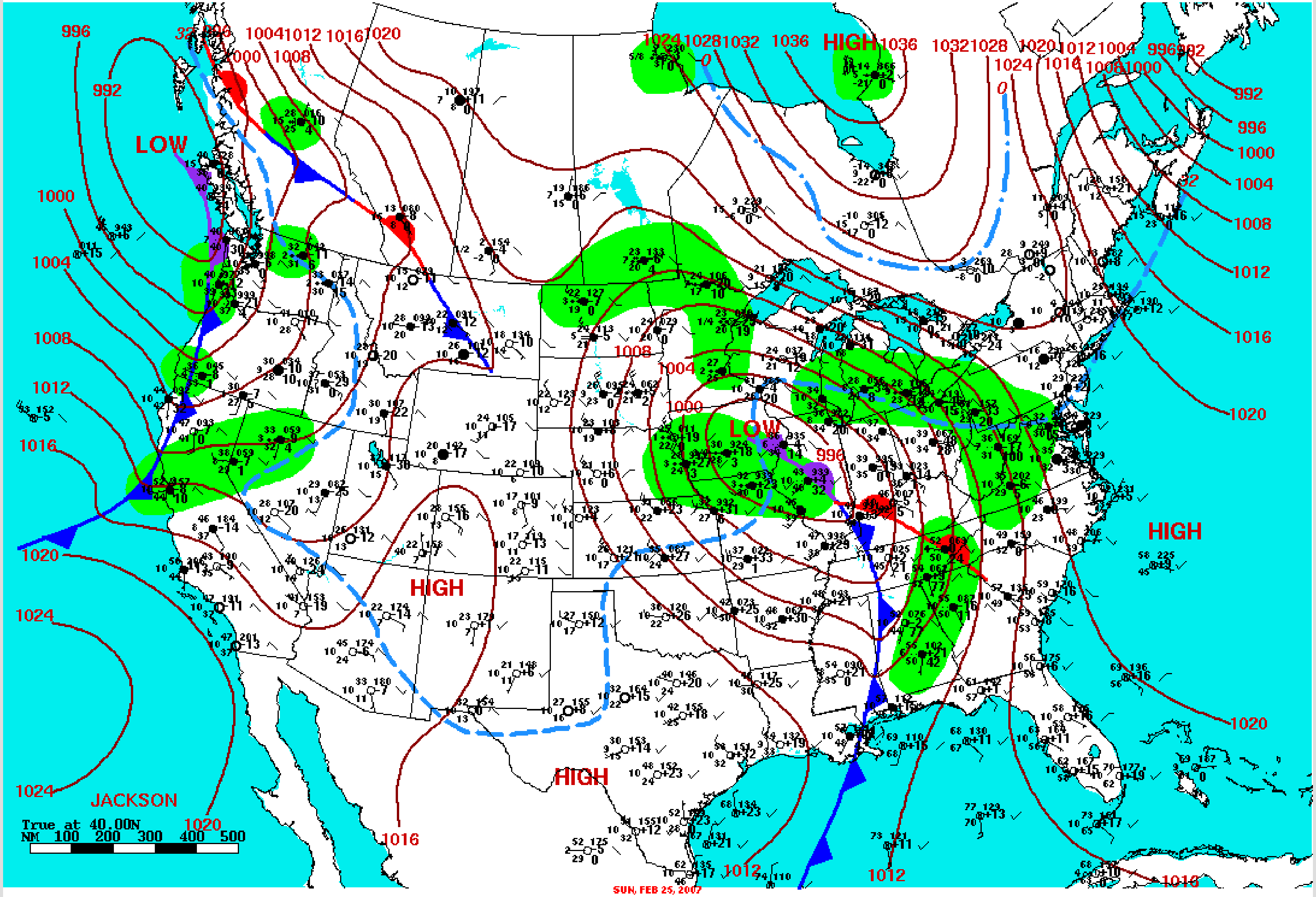
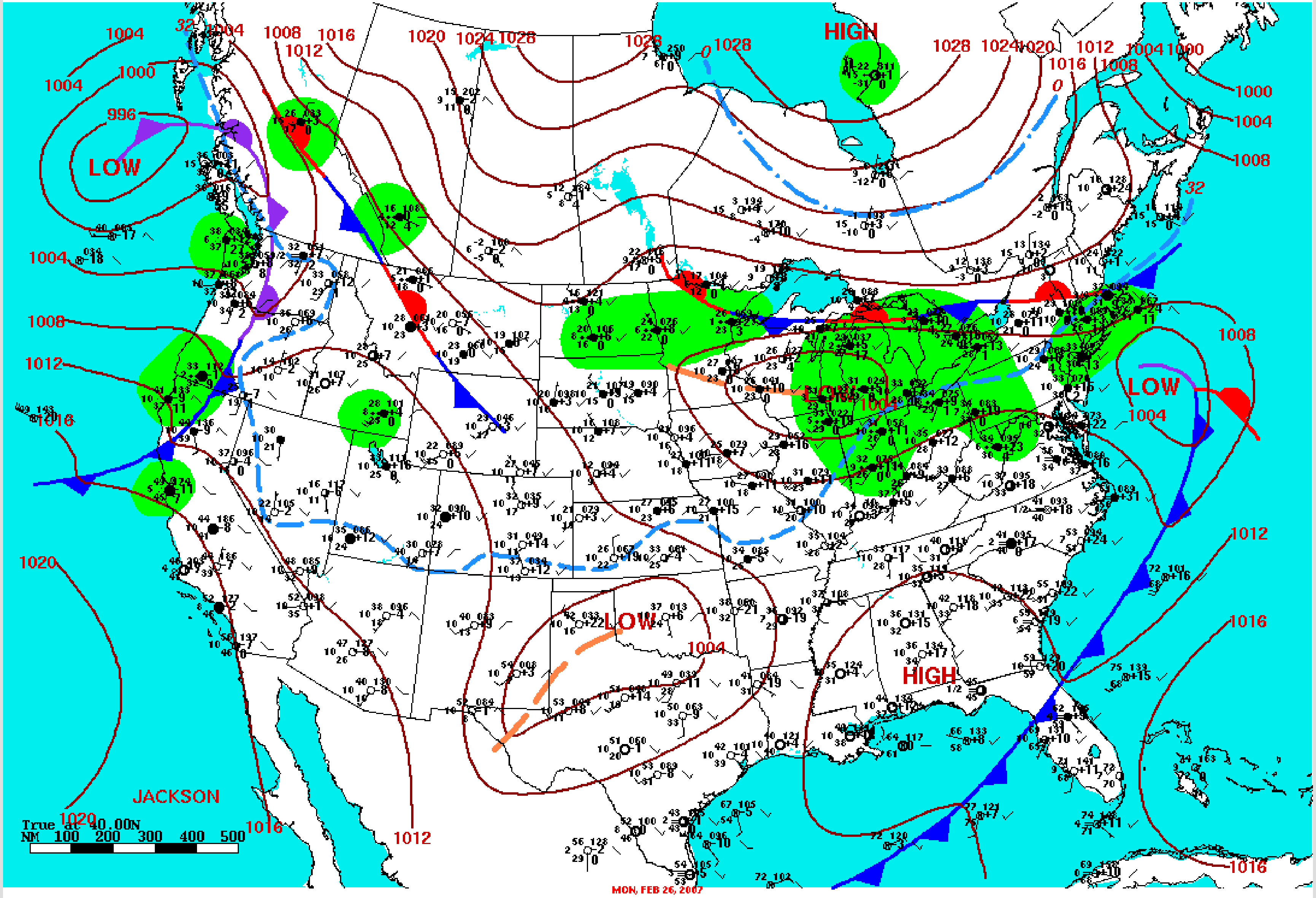


Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.



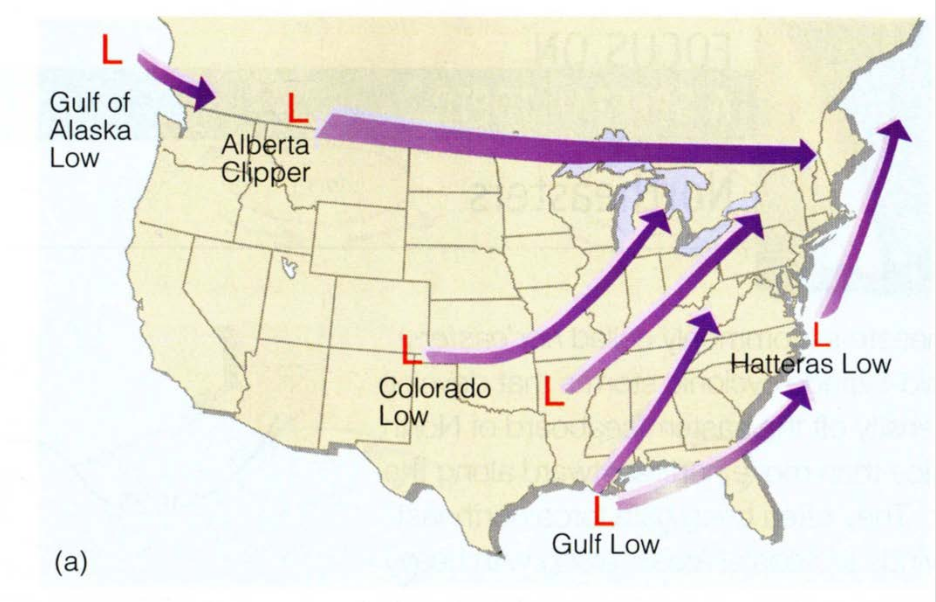
SUN, FEB 25, 2007

Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.



Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Favored Mid-Latitude Cyclone Genesis Areas



Typical mid-latitude cyclone tracks in North America.

Origin points typically are pre-existing climatologically favored areas for vorticity generation

<u>Lee of mountain ranges: Vortex stretching</u>

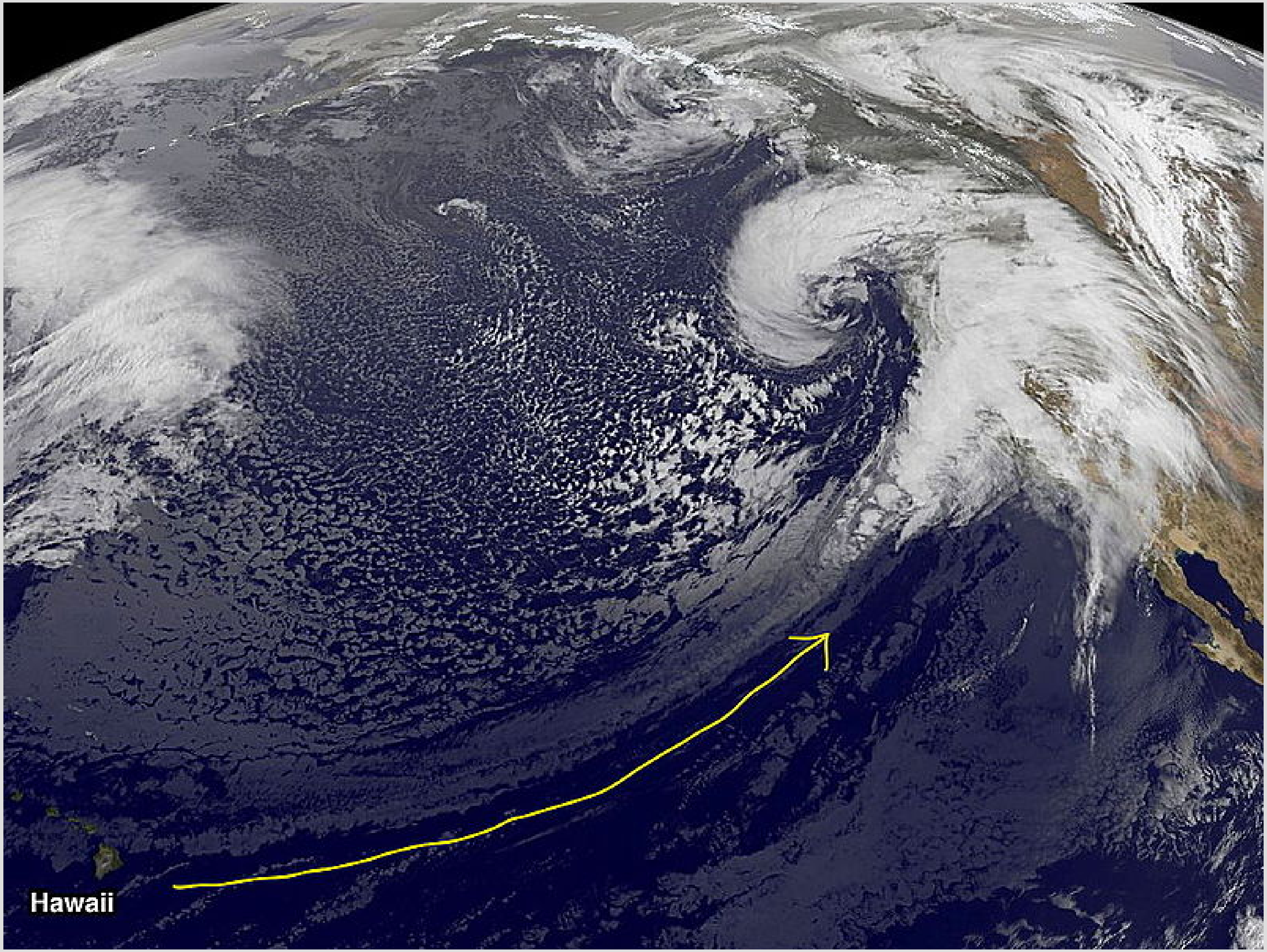
Air going downslope tends to induce formation of surface lows.
Examples: Colorado Lows, Alberta clippers.

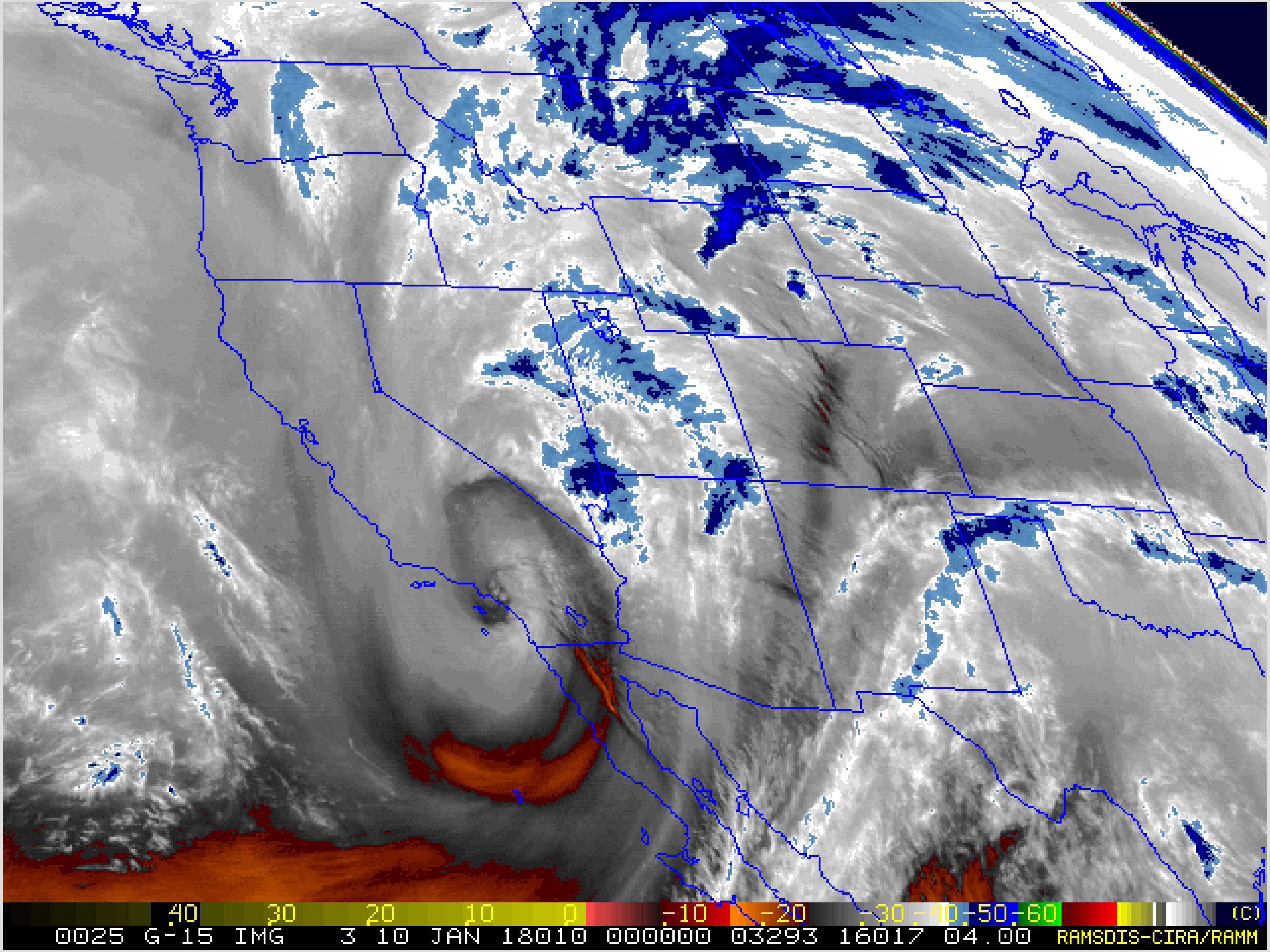
<u>Over warm water: Q dot source</u>

Provides a source of energy due to latent heat release in clouds
Examples: Gulf of Mexico Lows, Nor’esters.

Visible satellite image of the March 2014 Nor'easter.

December 10, 2014

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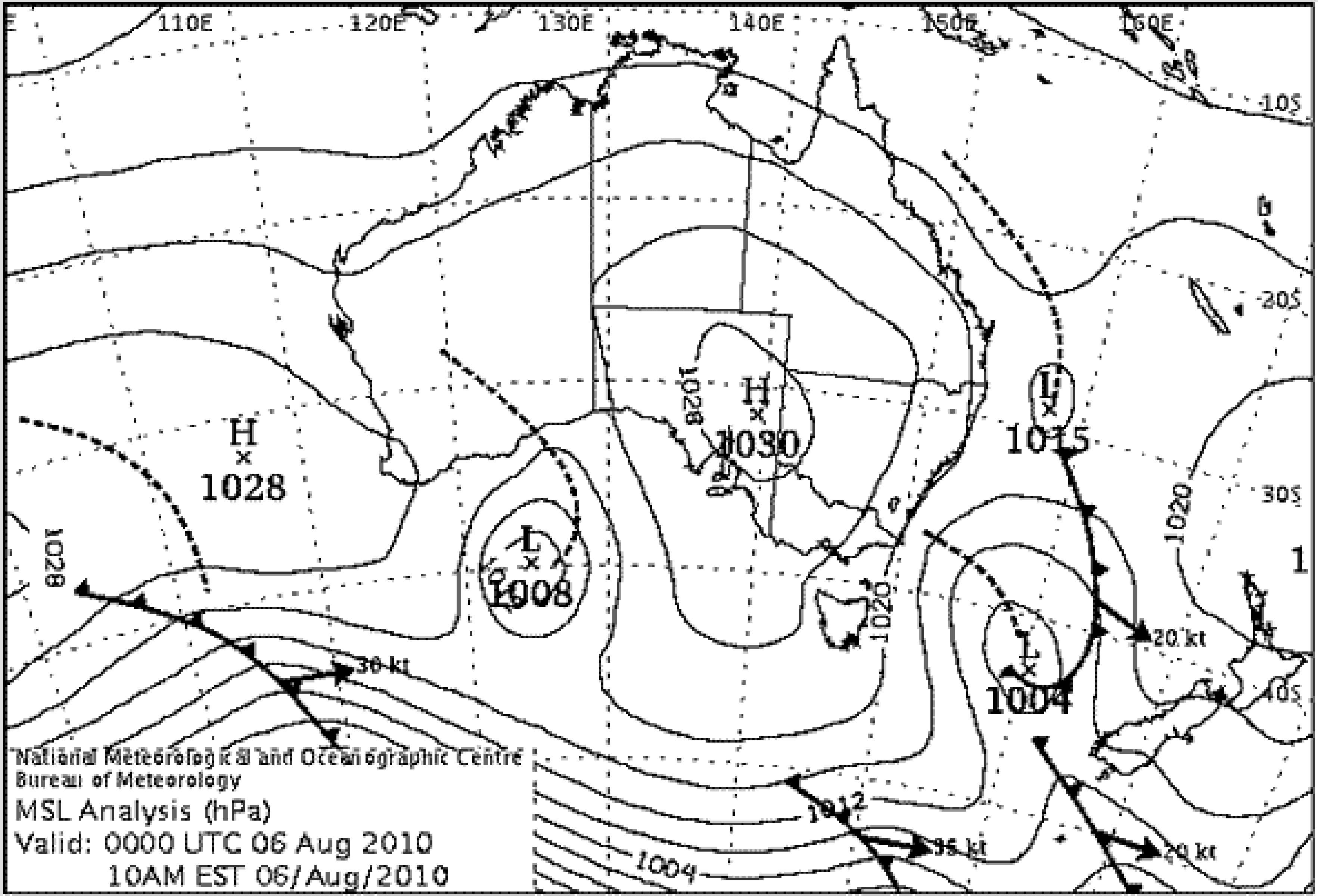
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National Meteorological and Oceanographic Centre
Bureau of Meteorology
MSL Analysis (hPa)
Valid: 0000 UTC 06 Aug 2010
10AM EST 06/Aug/2010

Idealized dynamical perspective of baroclinic instability: Eady Problem

<u>Conceptual setup</u>

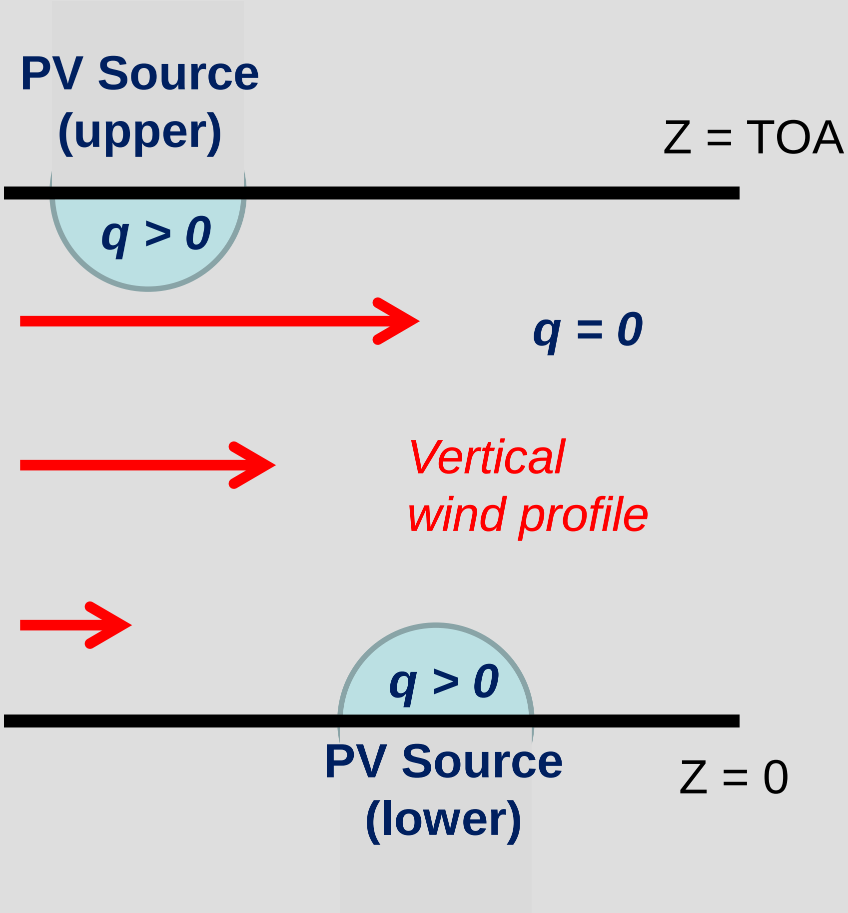
Frictionless, hydrostatic, f-plane in vertical

Consider 2-D plane in x-z with rigid lid on top and bottom

Linear vertical wind shear profile (implies baroclinicity, why???)

Basic state potential vorticity (q) of zero in the interior of domain

Initial sources of PV on upper and lower boundaries.



Physical implication of solution

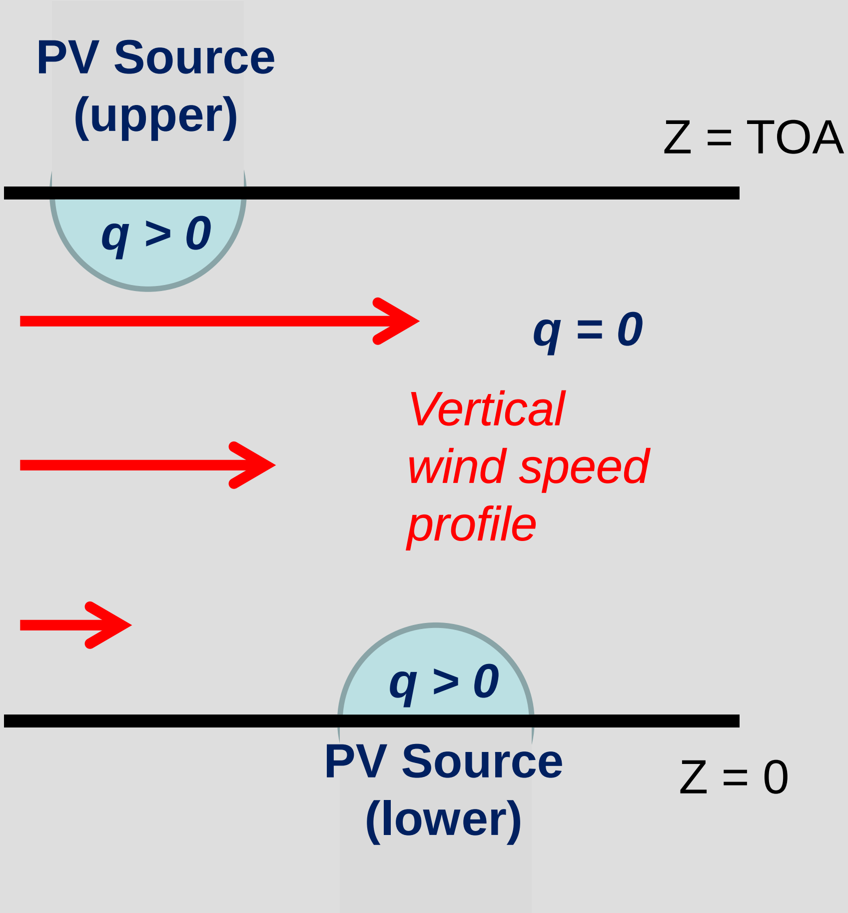
Assuming a wave solution, a dispersion relation can be constructed for phase speed

Because there are real and imaginary parts to the phase speed solution, possibility for exponential growth

Amplification = PV sources are within a preferred range of distance that they begin to interact with each other.

Growing solutions only occur for wavelengths greater than ~2500 km
Short-wave cutoff

Fastest growing waves about ~4000 km
Most unstable Eady mode.



Characteristics of most unstable Eady mode

Tilted structure to highs and lows
(as seen by streamfunction solution)

Isobars cross isotherms

Maximum southerly winds and rising motion ahead of upper-level low

Maximum northerly winds and sinking motion ahead of upper-level high

Just about what you get for a real mid-latitude cyclone in the mature to occluded stage!

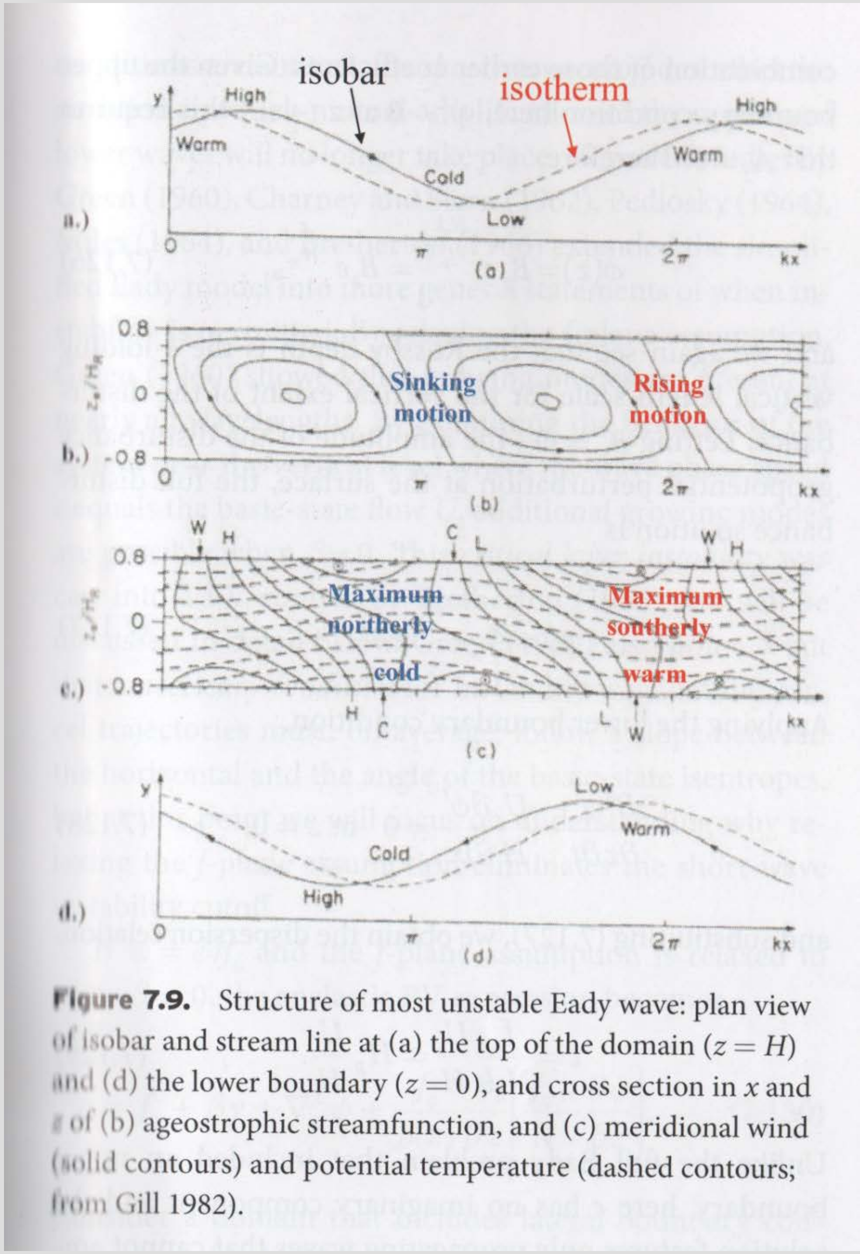


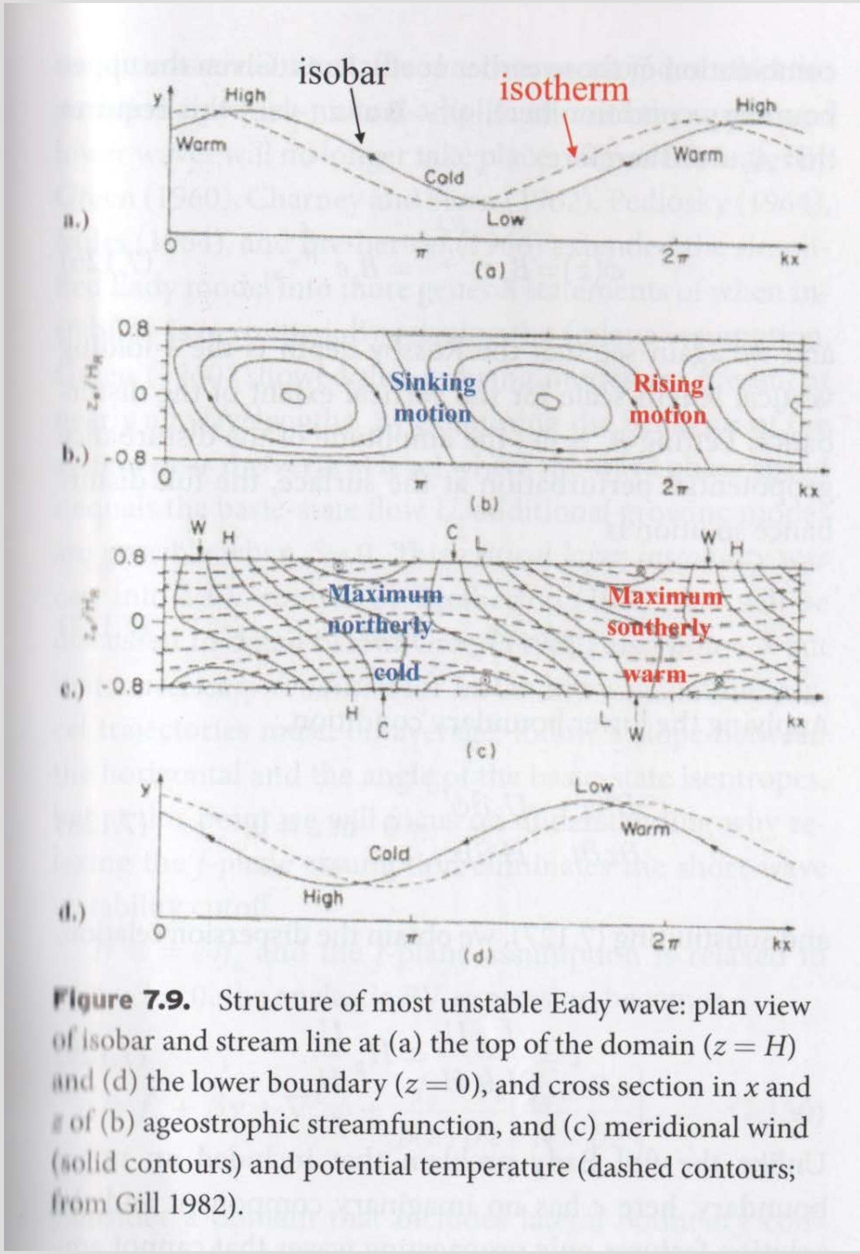
Figure 7.9. Structure of most unstable Eady wave: plan view of isobar and stream line at (a) the top of the domain ($z = H$) and (d) the lower boundary ($z = 0$), and cross section in x and z of (b) ageostrophic streamfunction, and (c) meridional wind (solid contours) and potential temperature (dashed contours; from Gill 1982).

Question to all of you

DO WE NEED TO GO OVER THE COMPLETE DERIVATION AS PART OF A MORE COMPREHENSIVE DISCUSSION OF BAROTROPIC AND BAROCLINIC INSTABILITY IN THIS COURSE??

I'm willing to do so later in the course if interest and time allows. Maybe necessary because we have students that are only taking 1 semester of dynamics??

Would be best to do this in the context of isotropic analysis and potential vorticity (about ¾ way into course)



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Vorticity Equation

Synoptic and Mesoscale contributions

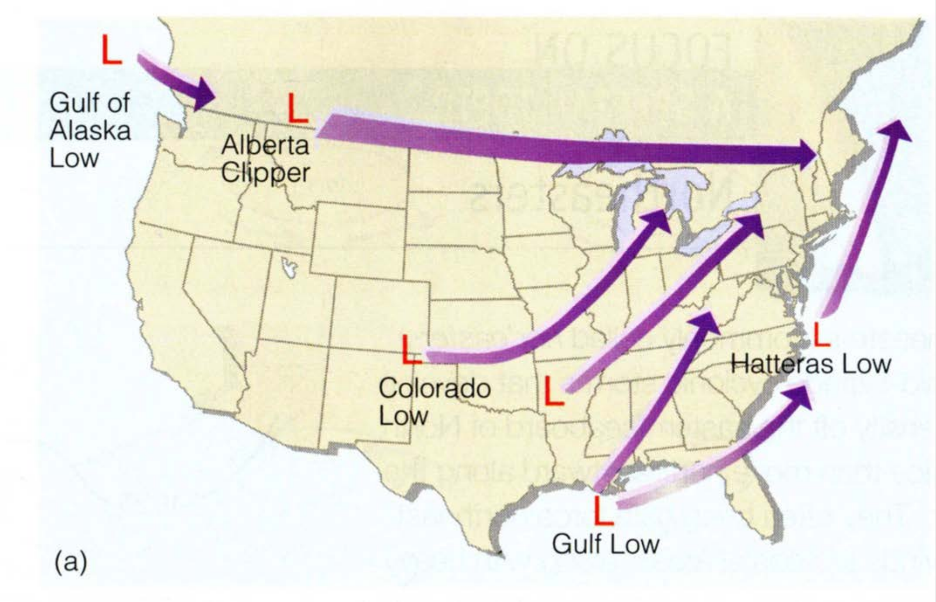
$$\frac{\partial \zeta_a}{\partial t} = -\vec{V} \bullet \nabla \zeta_a - \omega \frac{\partial \zeta_a}{\partial p} - \left[\frac{\partial \omega}{\partial x}\frac{\partial v}{\partial p} - \frac{\partial \omega}{\partial y}\frac{\partial u}{\partial p} \right] + \zeta_a \frac{\partial \omega}{\partial p} + \left[\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y} \right]$$

A B C D E F

A = local time rate of change term

B = Horizontal vorticity advection (PVA or NVA)
C = Vertical vorticity advection
D = Tilting of vorticity in the horizontal to the vertical
E = Vortex stretching (Diabatic heating or terrain changes)
F = Friction

Favored Mid-Latitude Cyclone Genesis Areas



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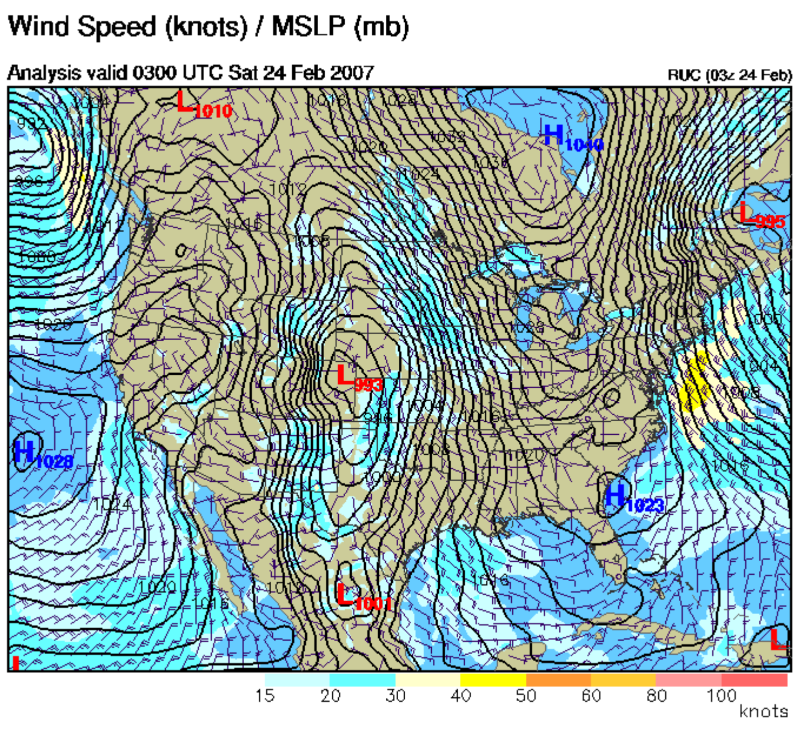
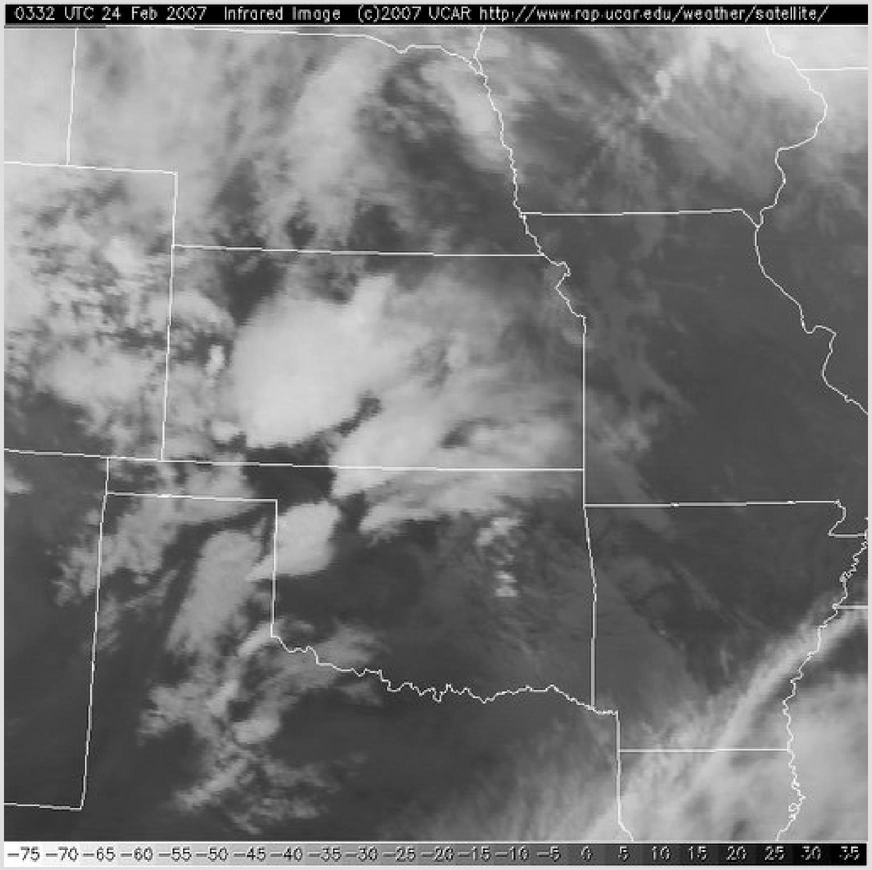
Open Wave Stage
0300 UTC, Saturday, Feb. 24, 2007

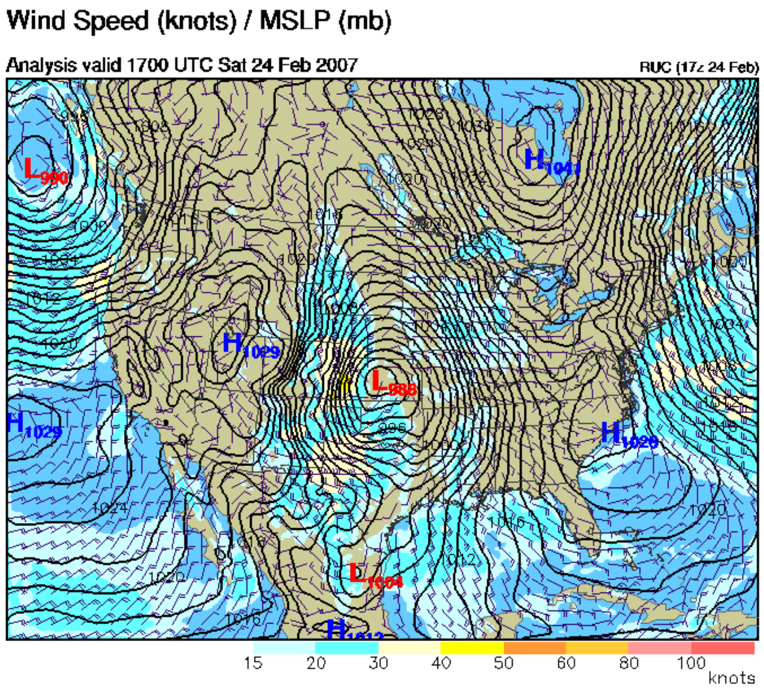


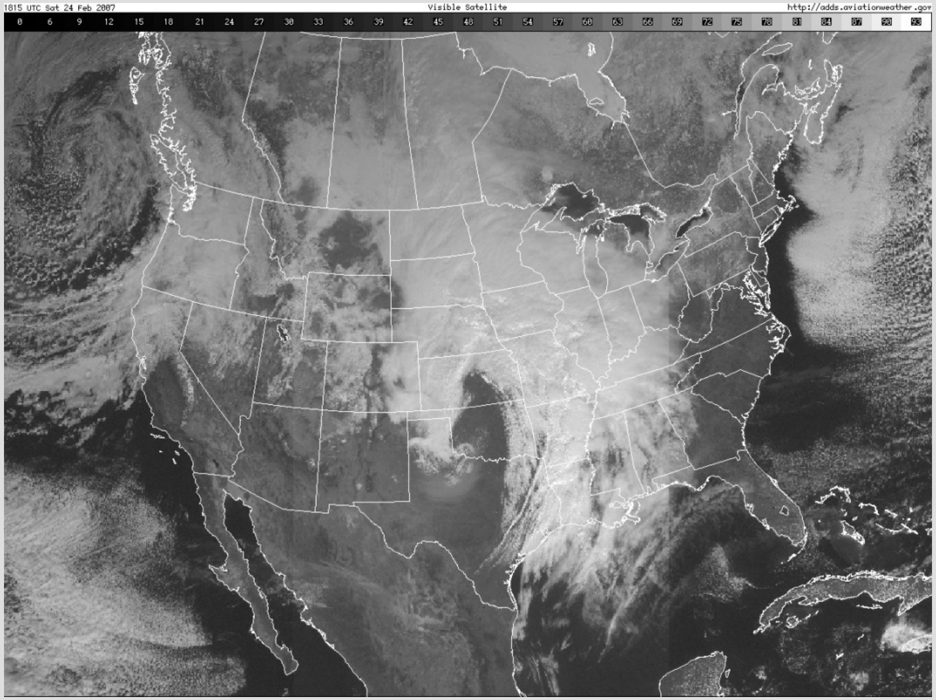
Note formation of low pressure in eastern CO.



IR Imagery

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

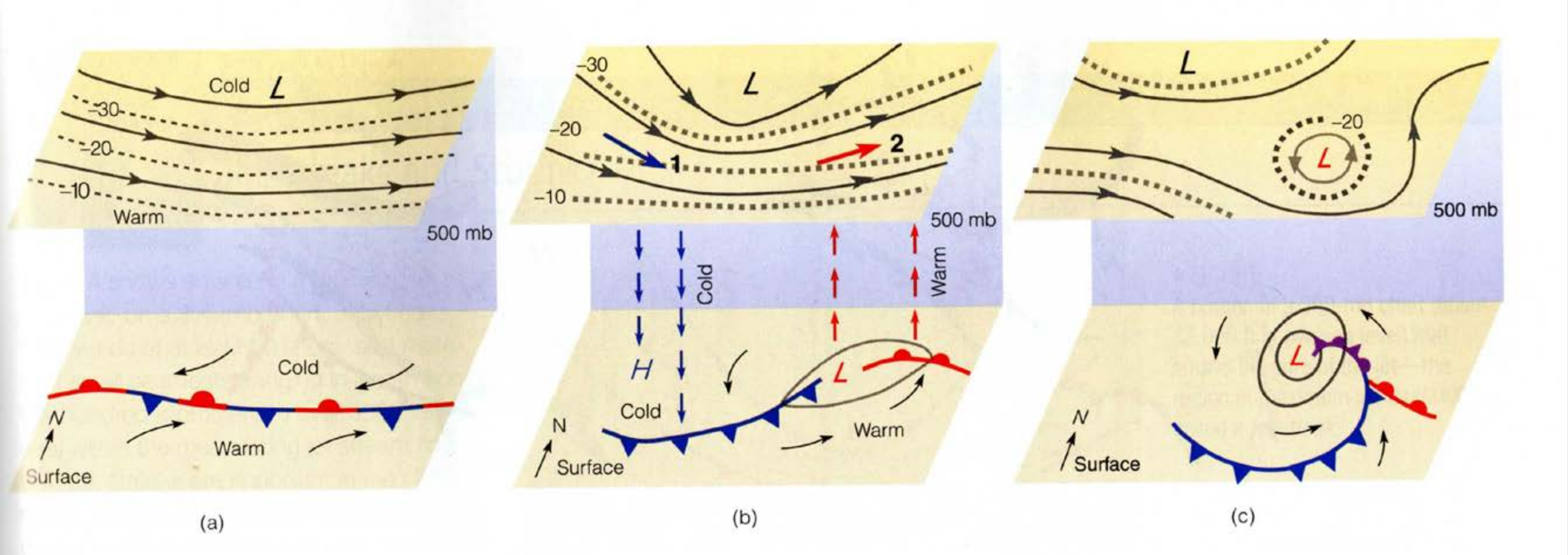




IR Imagery

Bjerknes cyclone development model with upper levels included

NACENT *AMPLIFYING* *DECAYING*



<u>Stationary front</u>

Stationary front in longwave trough

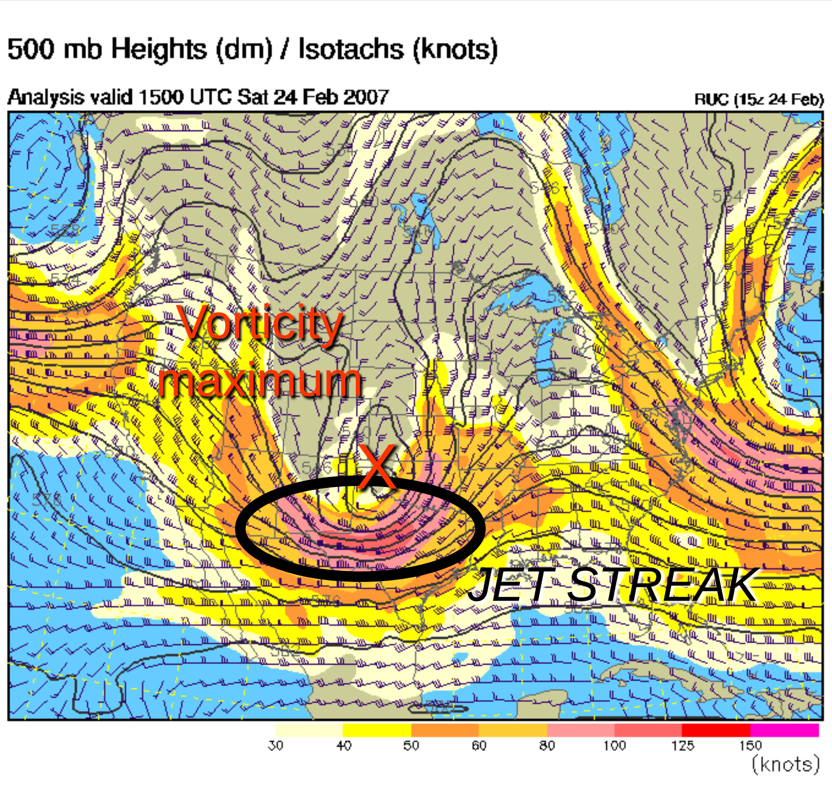
<u>Maturing cyclone</u>

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

<u>Cut off stage</u>

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

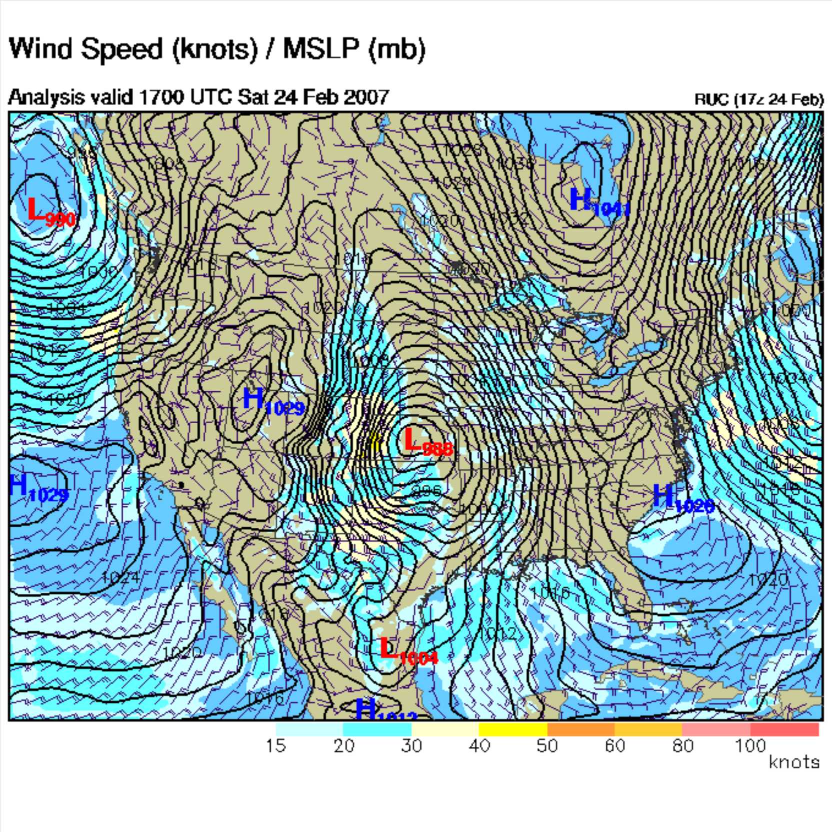
Upper level vs. surface features
February 2007 example case



500 mb Heights (dm) / Isotachs (knots)

Analysis valid 1500 UTC Sat 24 Feb 2007

RUC (15z 24 Feb)



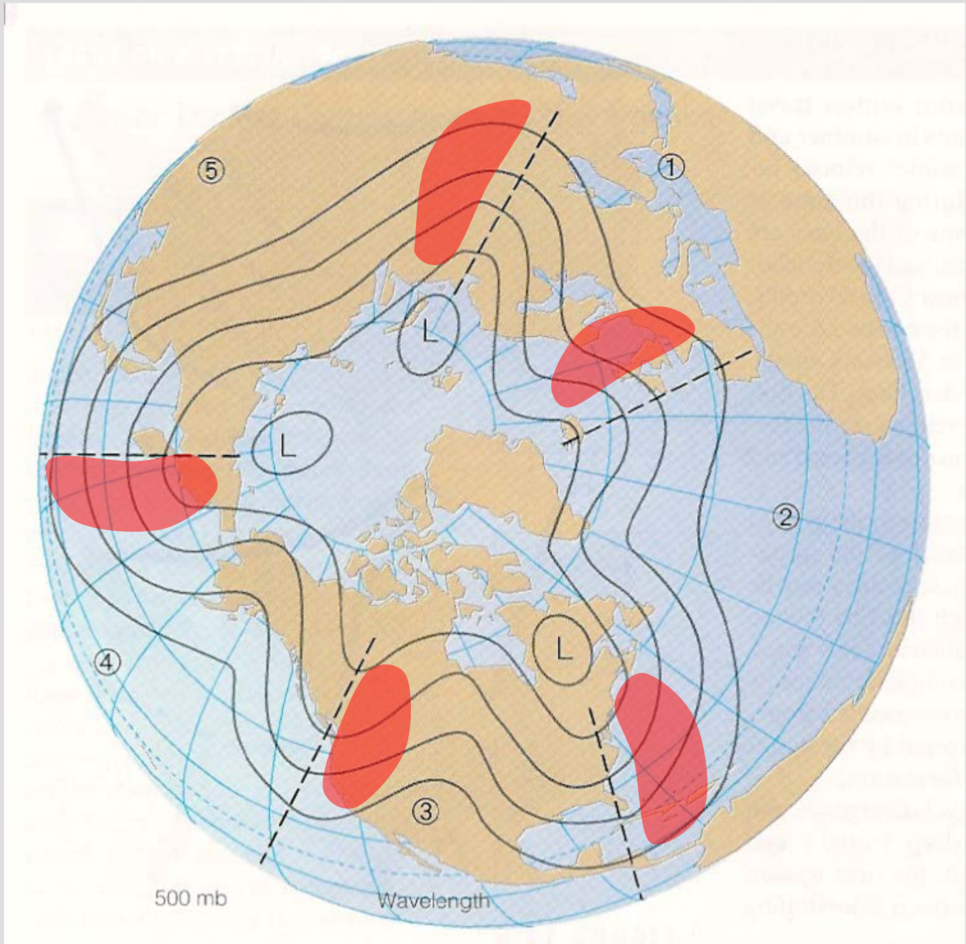
Wind Speed (knots) / MSLP (mb)

Analysis valid 1700 UTC Sat 24 Feb 2007

RUC (17z 24 Feb)

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).

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.

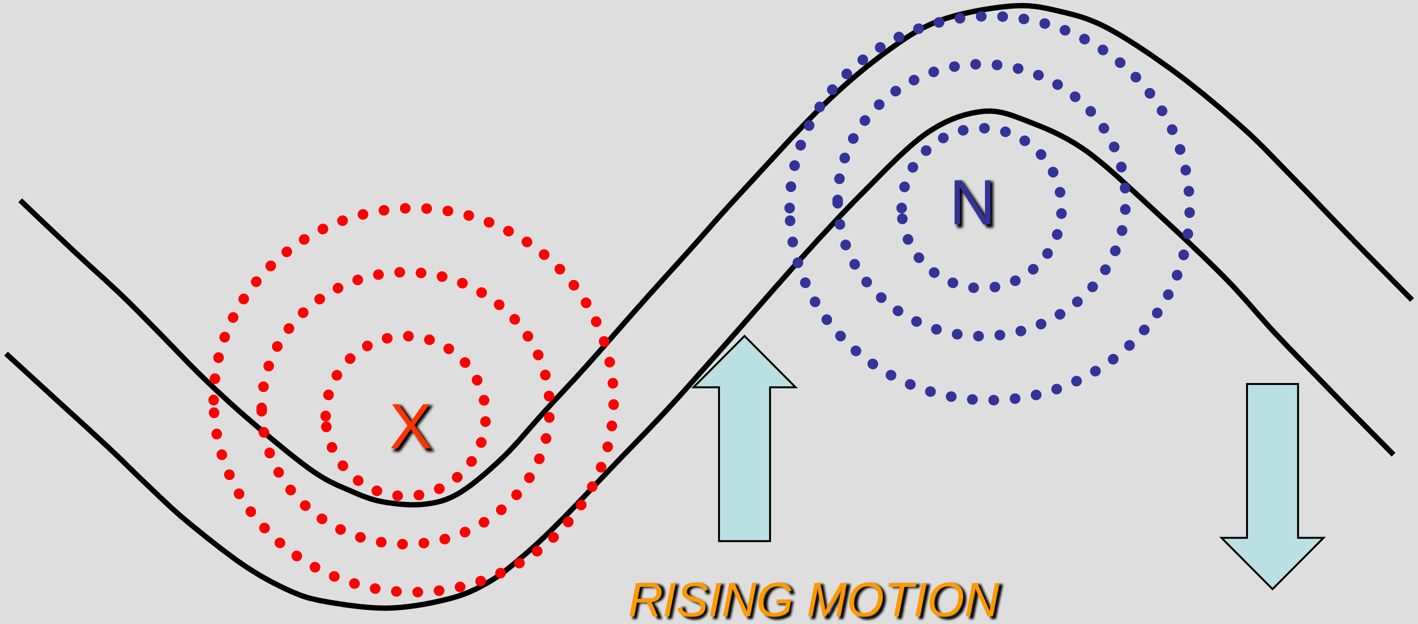
Troughs, Ridges and Vorticity

Dashed lines indicate lines of constant vorticity, or spin.

NEGATIVE VORTICITY:
ANTICYCLONIC ROTATION

Height 1

Height 2



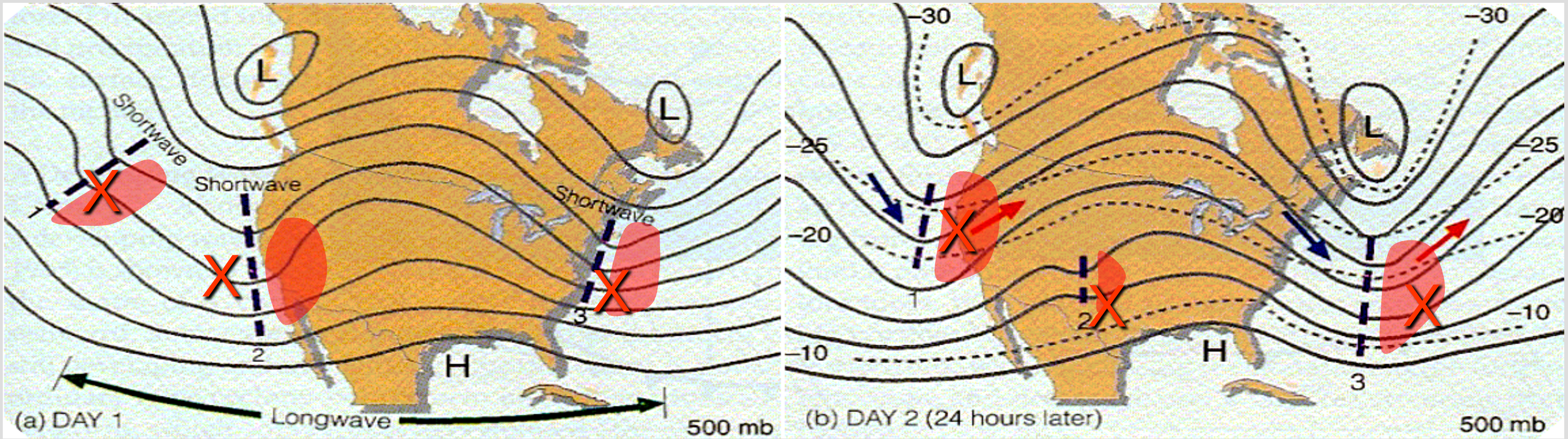
POSITIVE VORTICITY:
CYCLONIC ROTATION

RISING MOTION AHEAD OF POSITIVE VORTICITY

SINKING MOTION AHEAD OF NEGATIVE VORTICITY

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

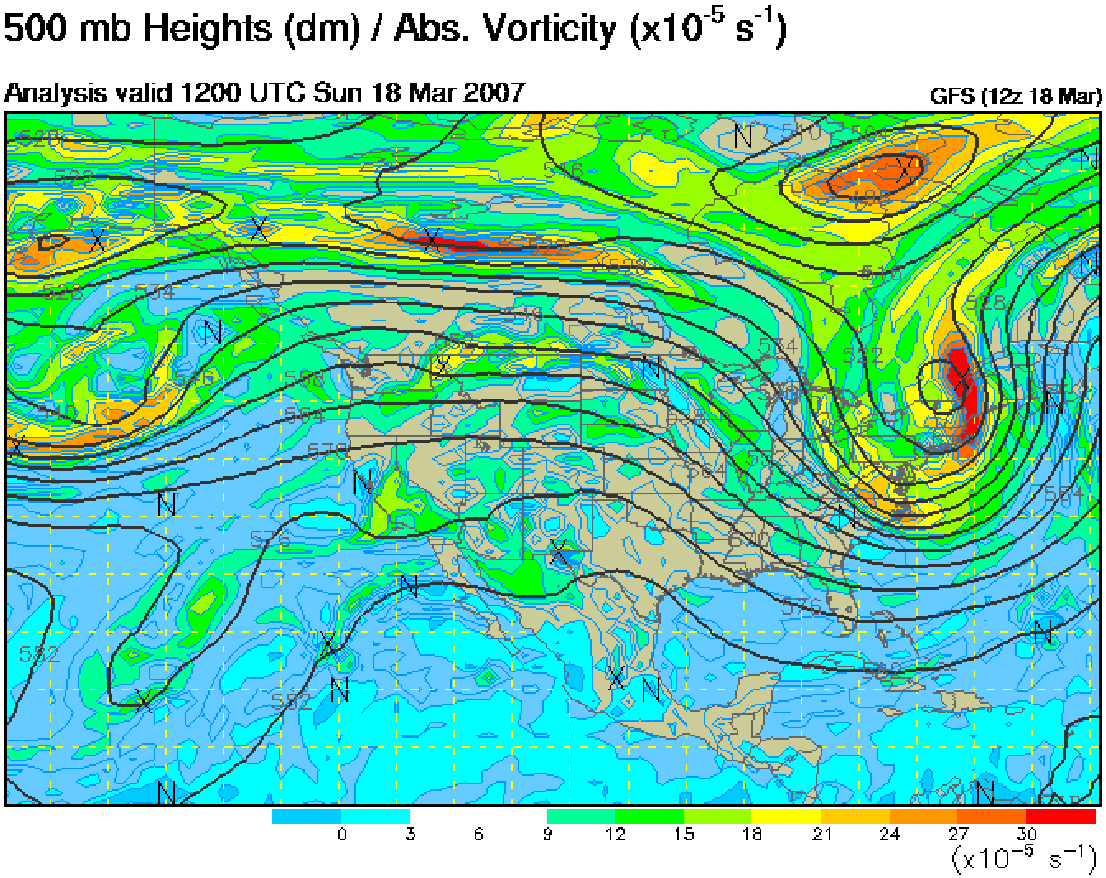
Longwaves and Shortwaves



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"*



500 mb Heights (dm) / Abs. Vorticity ($\times 10^{-5}\ s^{-1}$)

Analysis valid 1200 UTC Sun 18 Mar 2007

GFS (12z 18 Mar)

Note

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

"X" = relative vorticity maximum

"N" = relative vorticity minimum