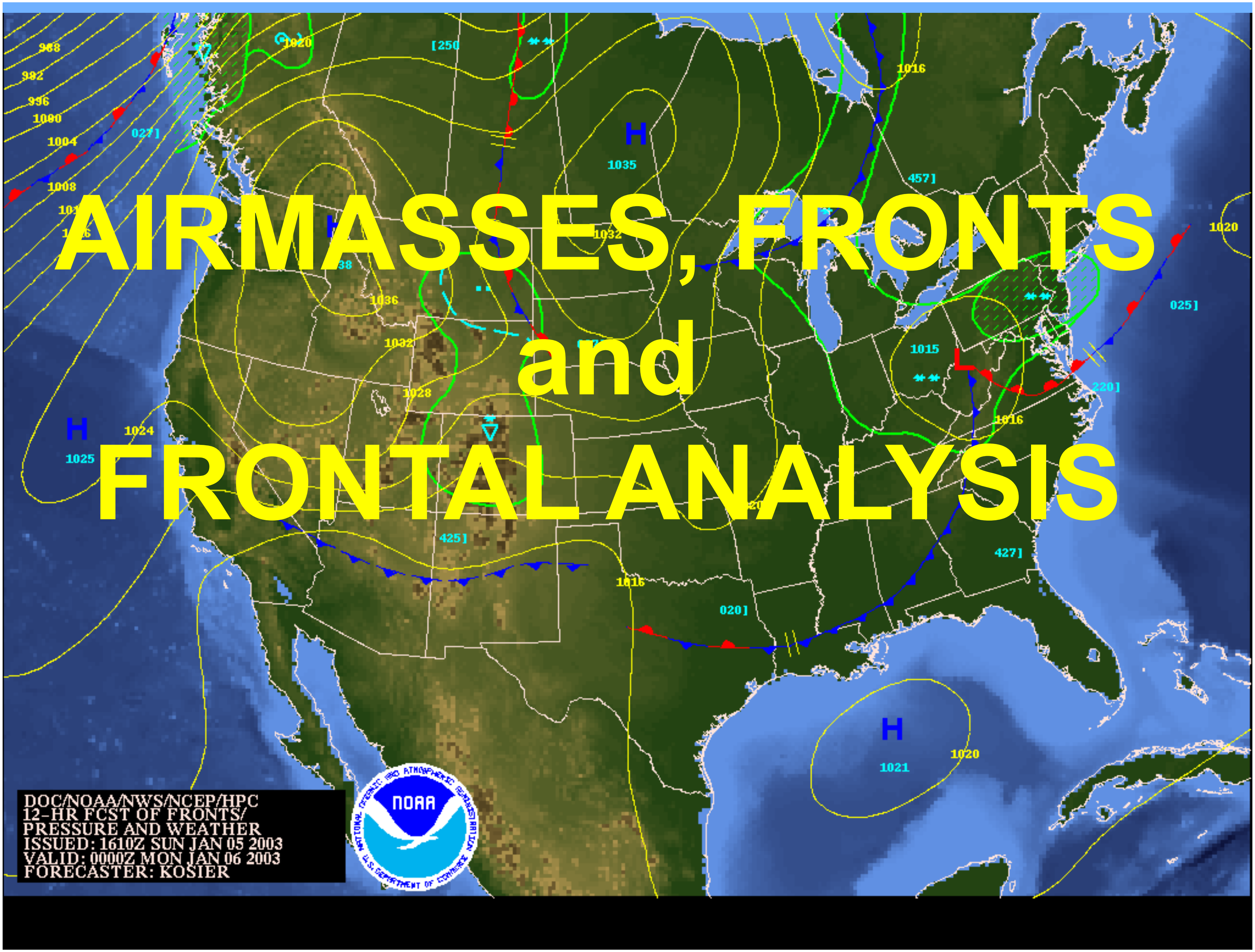
AIRMASSES, FRONTS and FRONTAL ANALYSIS



Airmasses

•An airmass is a large body of air with relatively uniform thermal and moisture characteristics.

•Airmasses cover large regions of the earth, typically several hundred thousand square kilometers.

•Airmasses can be as deep as the depth of the troposphere or as shallow as 1 to 2 km.

•Airmasses form when air remains over a relatively flat region of the earth* with homogeneous surface characteristics for an extended period of time.

(* Canadian and Siberian plains, cool oceanic regions such as the North Atlantic and Pacific, deserts, such as the Sahara and the American southwest, and tropical oceanic regions including the equatorial Atlantic and Pacific, and smaller water bodies such as the Caribbean Sea and the Gulf of Mexico).

Sources of North American Airmasses

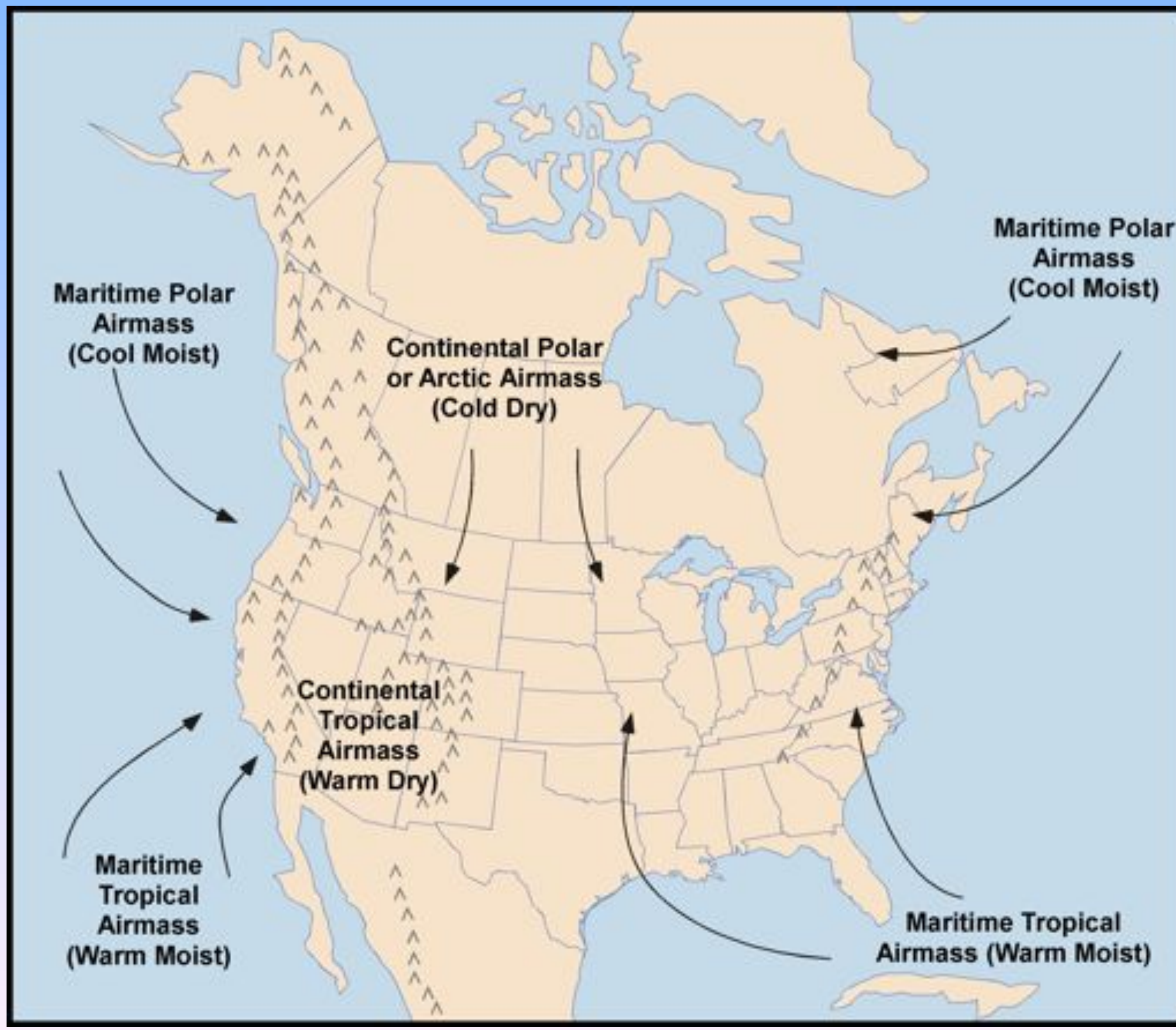


Fig. 8.1 SHW

Key features of an airmass on weather maps:

The centers of cold airmasses are associated with high pressure on surface weather maps. High pressure develops in response to cooling.

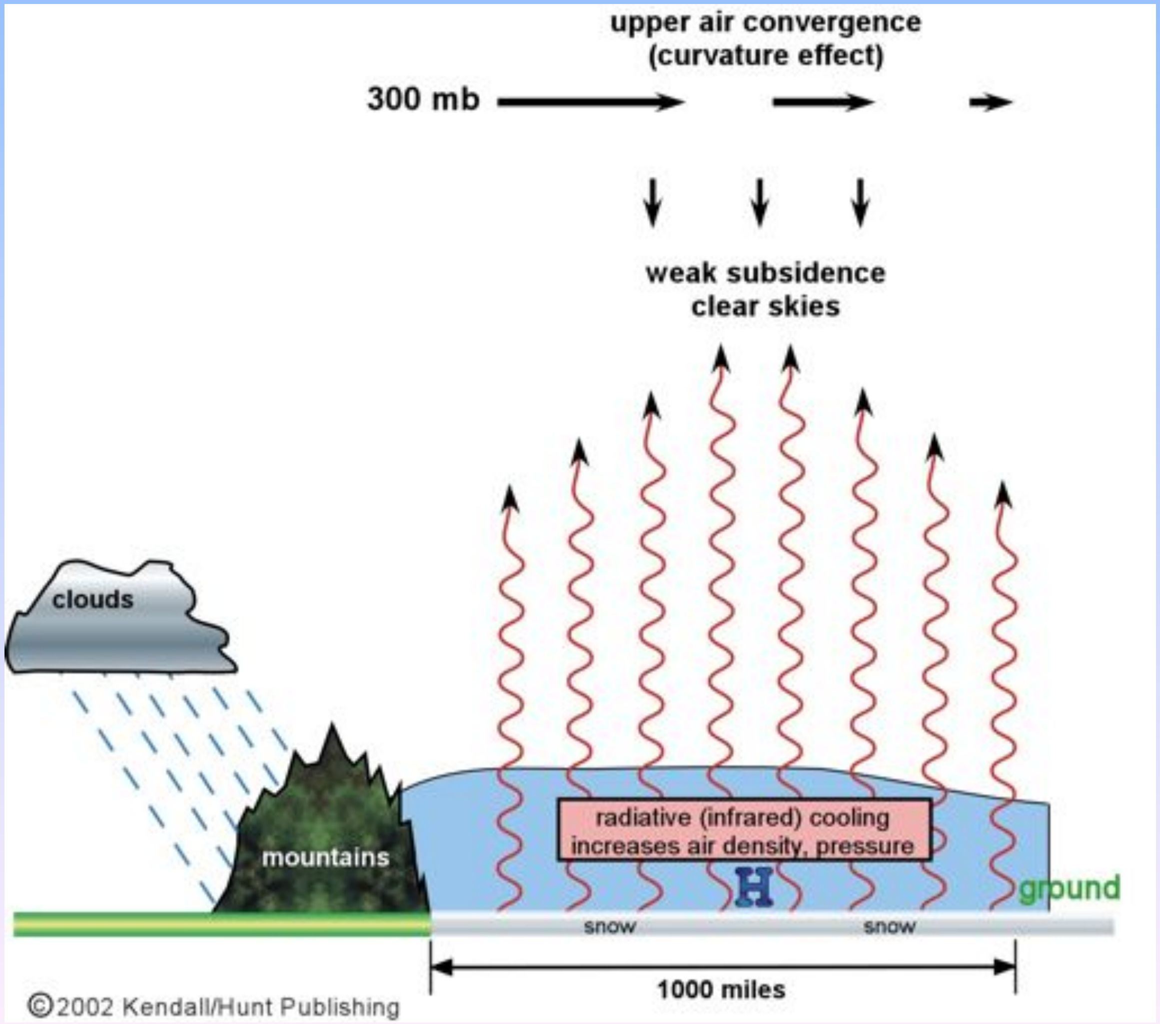
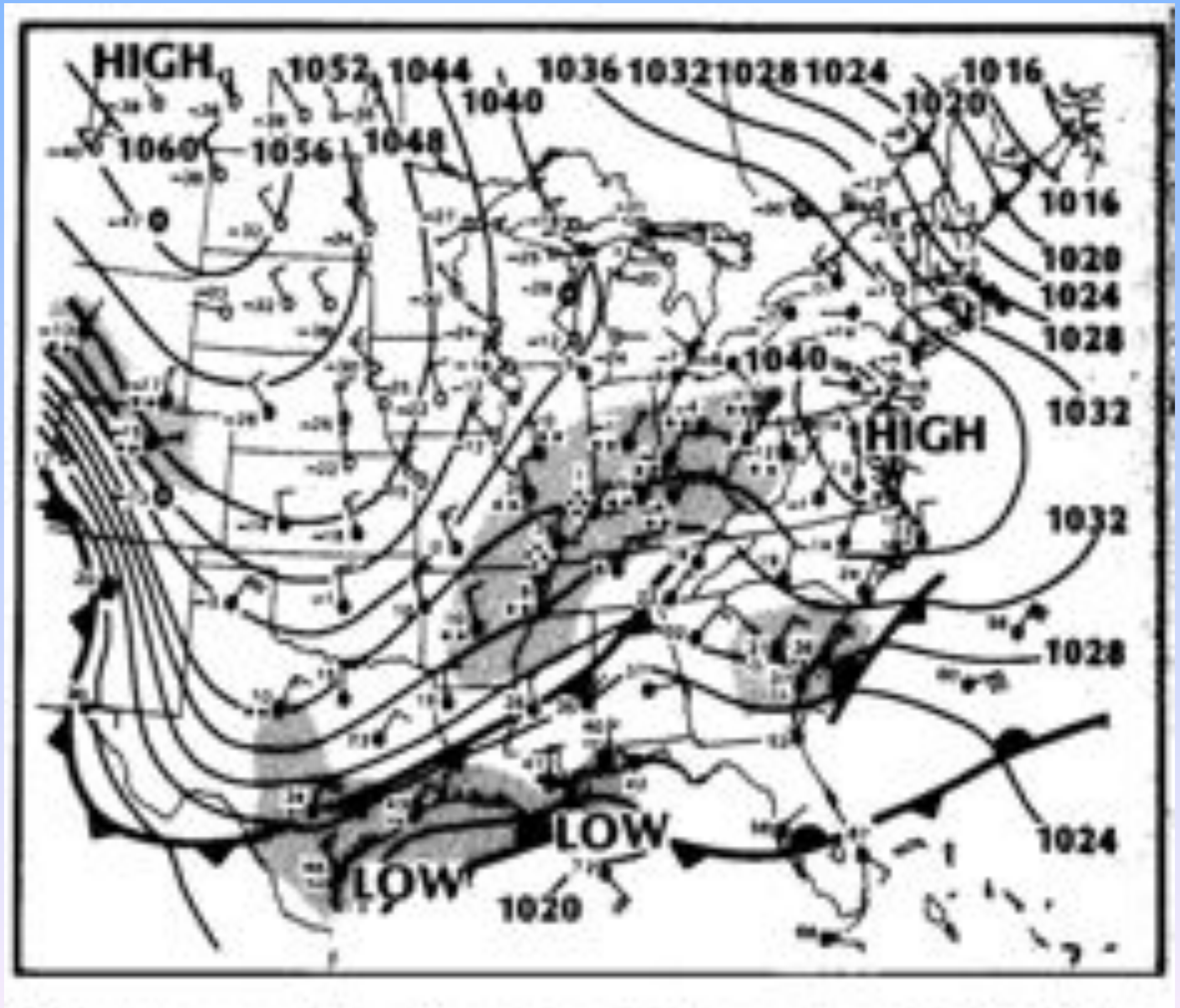


Fig. 13.4 SHW

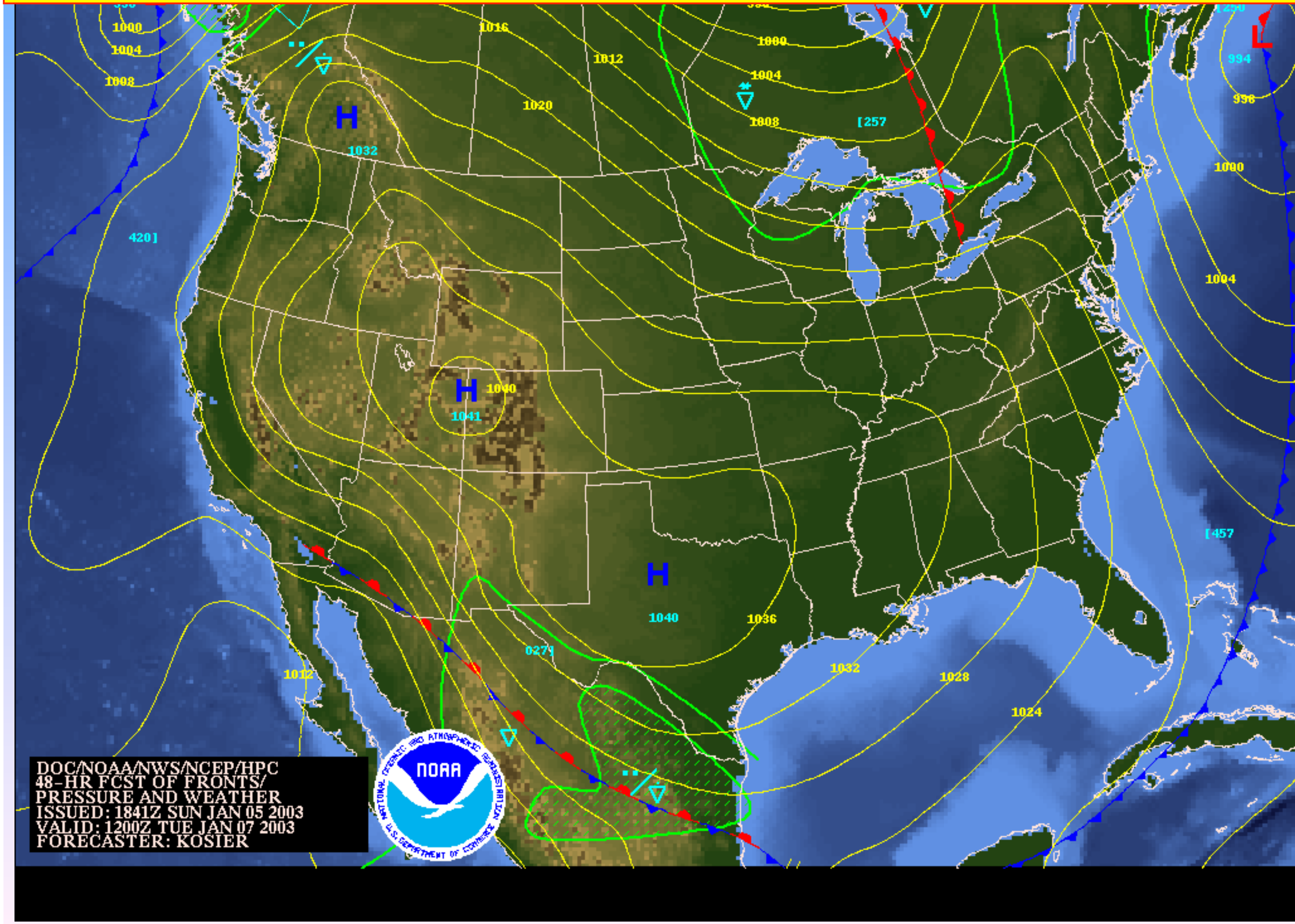
In winter, high-pressure centers form and are the dominant feature over the northern parts of the continents of Asia and North America.

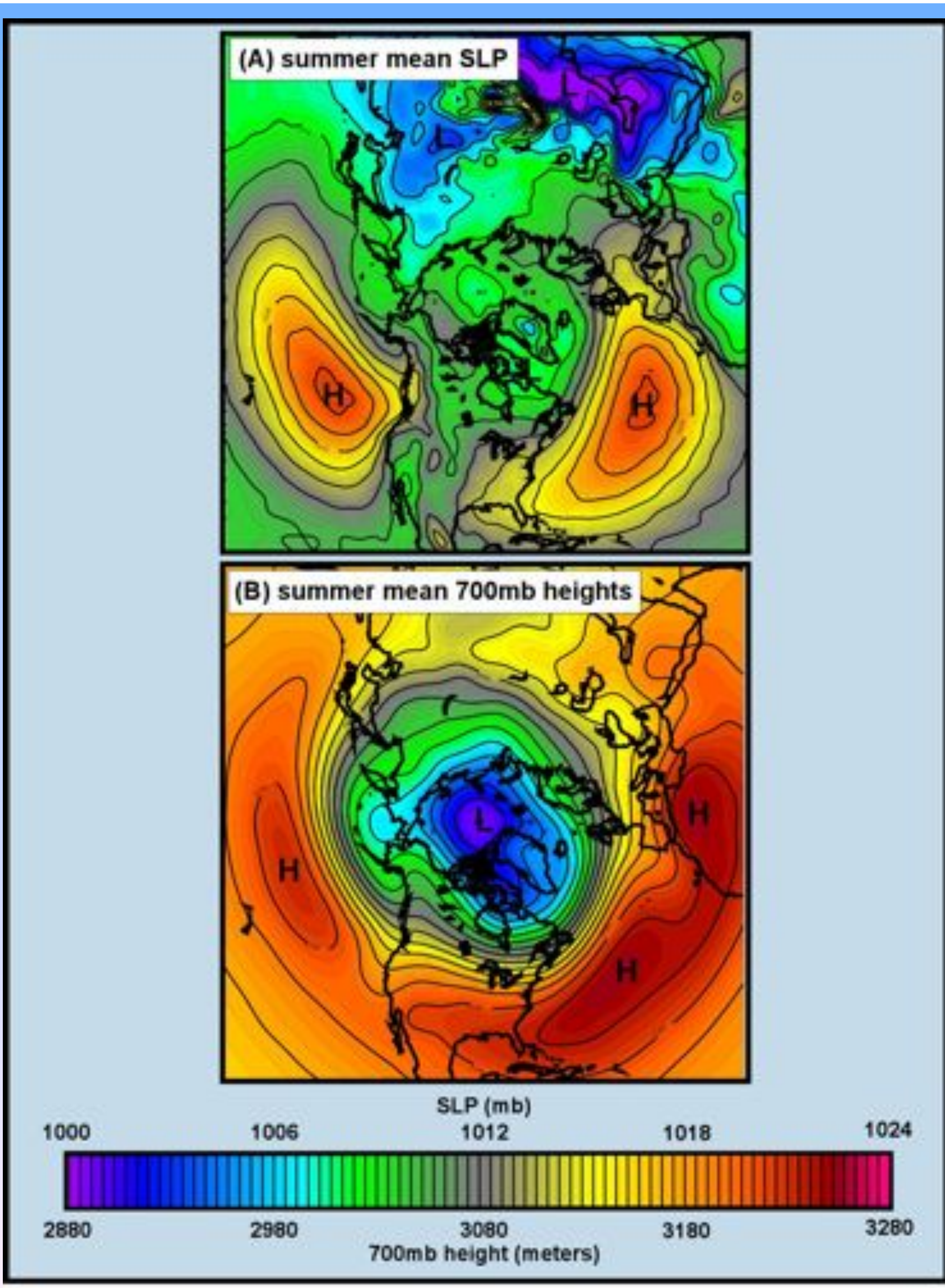


Courtesy of the American Meteorological Society

Fig. 13H SHW

Example of a high pressure system that moved southward into the central US in winter





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In summer, when the oceans are cooler than the landmasses, large high-pressure centers are the dominant feature of the atmosphere over the North Atlantic and Pacific Oceans.

The high-pressure center over the Atlantic is called the "Bermuda High" because it is centered near Bermuda, while its Pacific counterpart is called the "Pacific High"

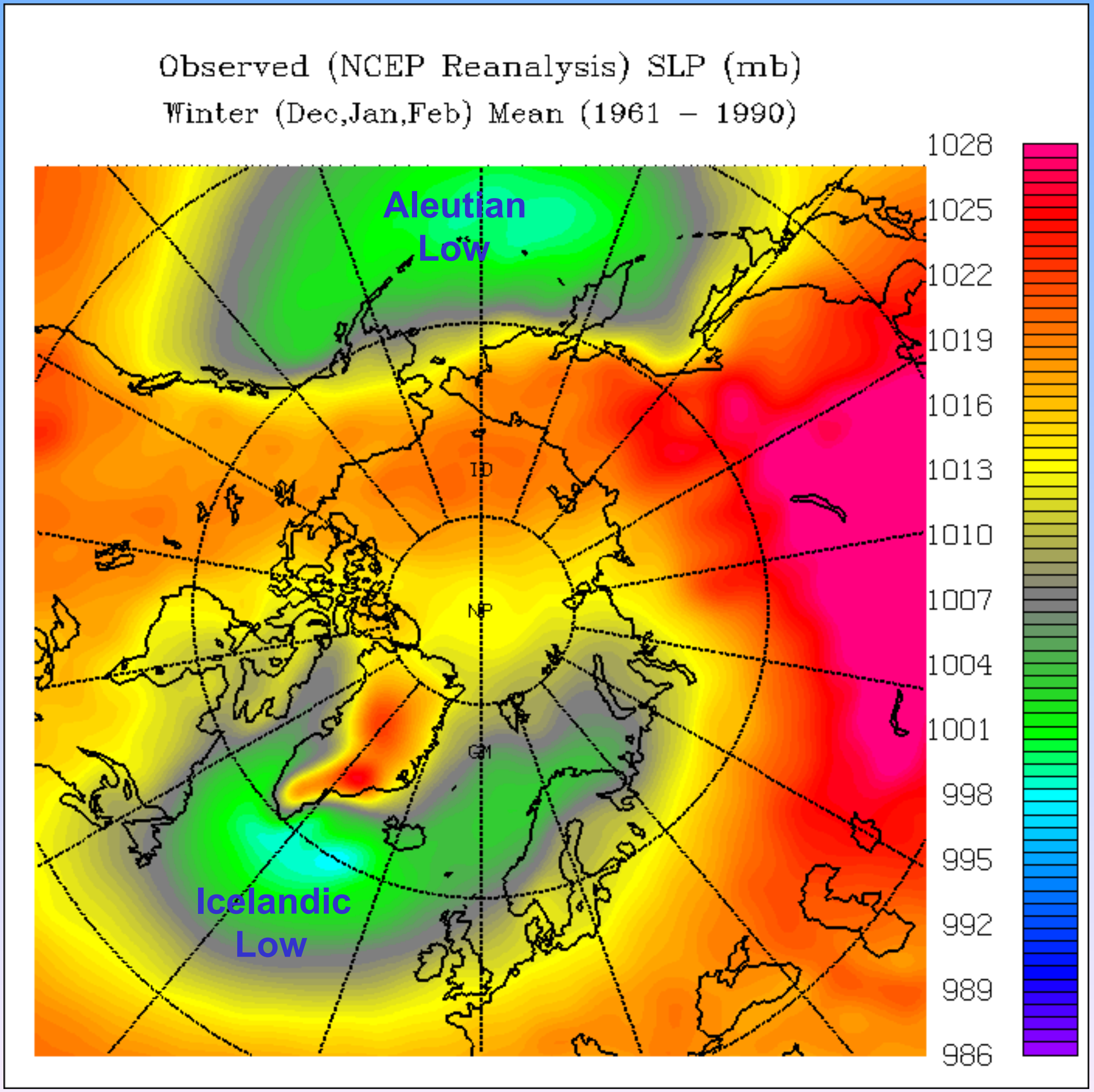
Fig. 25.1 SHW

The centers of very warm airmasses appear as semi-permanent regions of low surface pressure.

Examples:
1) Monsoon Low in summer over S.E. Asia
2) North American Monsoon Low over Deserts of the U.S. southwest
3) Equatorial low pressure belt
4) Icelandic Low over the N. Atlantic
5) Aleutian Low over the N. Pacific in winter.

Note: Semi-permanent low-pressure centers differ substantially from migrating tropical and extratropical low-pressure centers associated with cyclones and hurricanes.

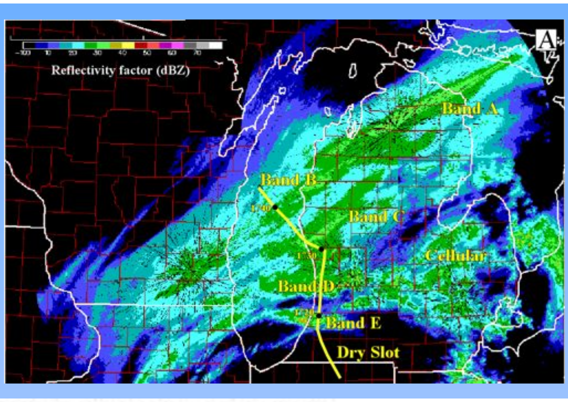
The Aleutian Low and the Icelandic Low are associated with airmasses that are warm relative to the surrounding continental airmasses in winter.



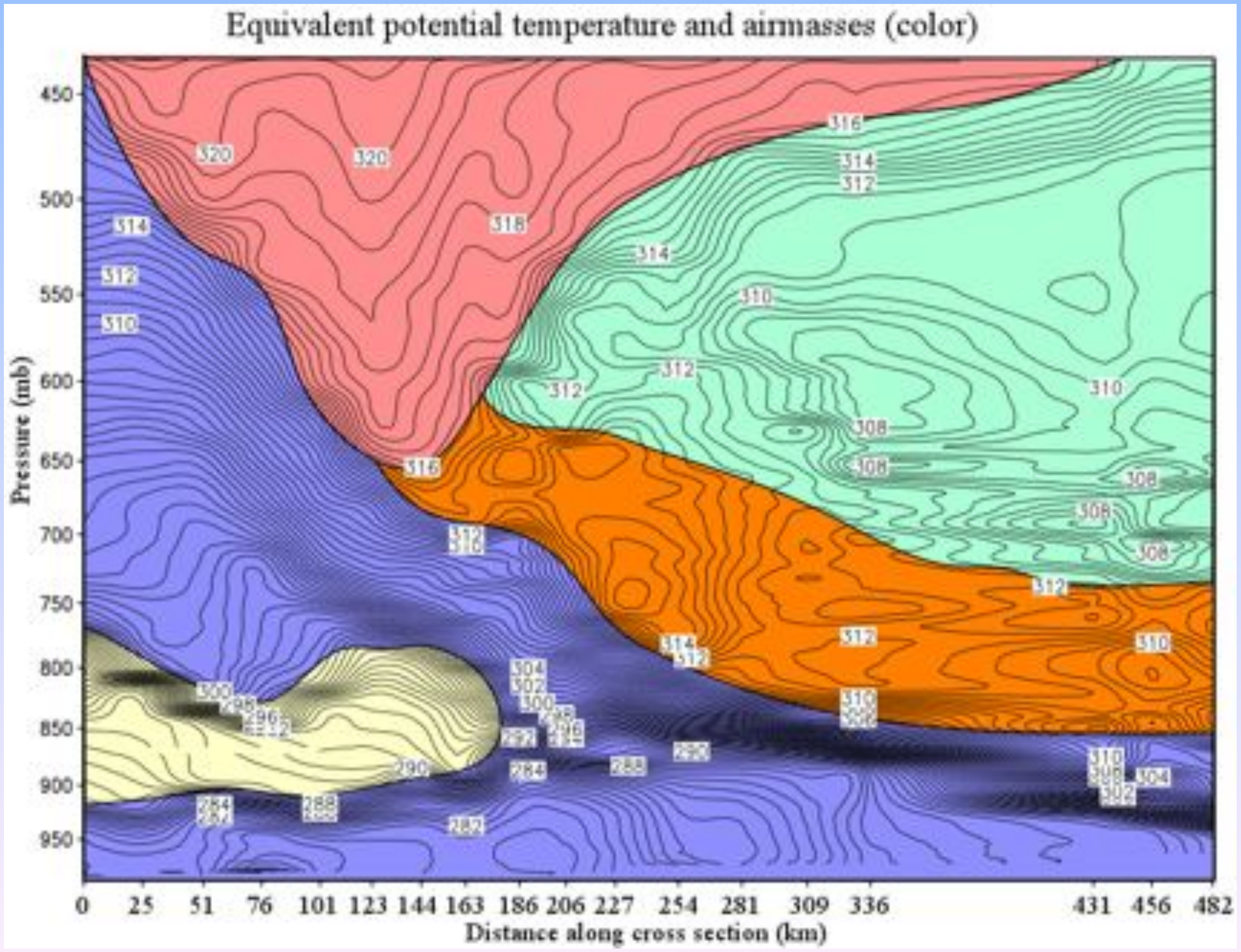
http://zubov.atmos.uiuc.edu/FINGERPRINT/obs.slp.html

Not all airmasses are in contact with the ground

Airmasses exist aloft in the troposphere, residing on top of other airmasses.



Airmasses are three-dimensional, and the boundaries between airmasses are often quite sharp and distinct



Stratosphere: a large airmass that covers the entire globe

Fronts: Boundaries between airmasses

Meteorologists classify fronts based on:

a) the thermal and moisture characteristics of the airmasses

b) the direction of movement of the airmasses

c) whether the boundary between the airmasses is in contact with the ground (a surface front), or can only be found aloft (an “upper level front”).

The boundary between two airmasses is called a cold front if the cold air is advancing forward, lifting the warm air.

The leading edge of the cold airmass typically has a shape like a dome, as shown in the figure.

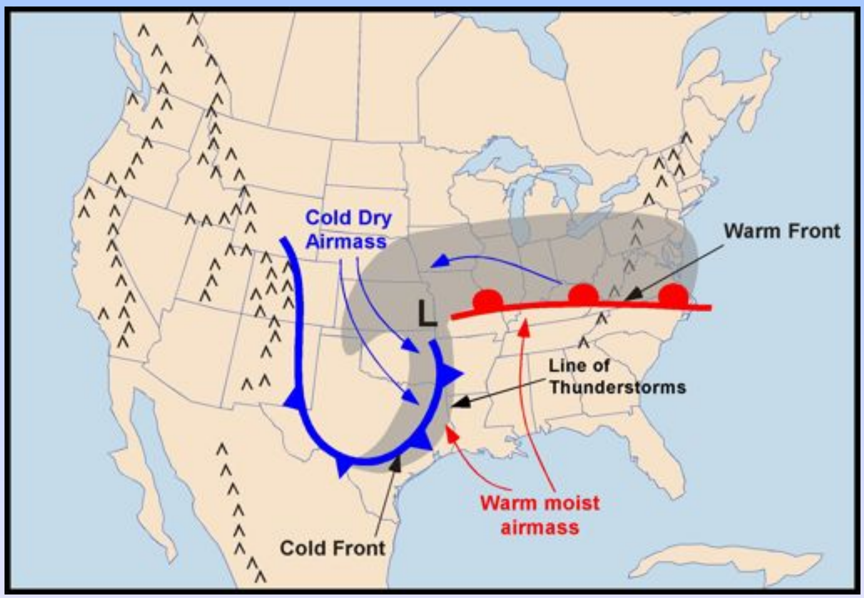


Fig. 8.3 SHW

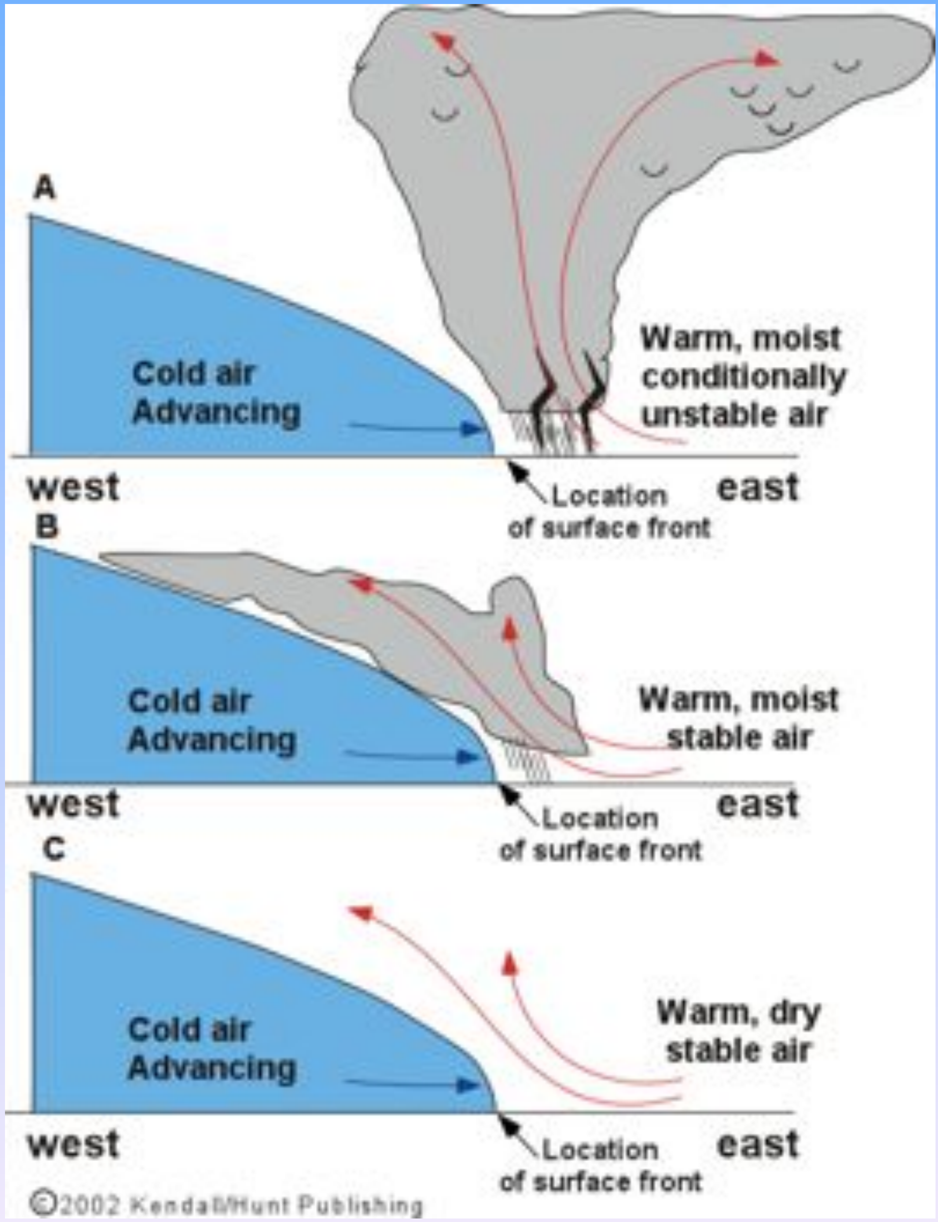
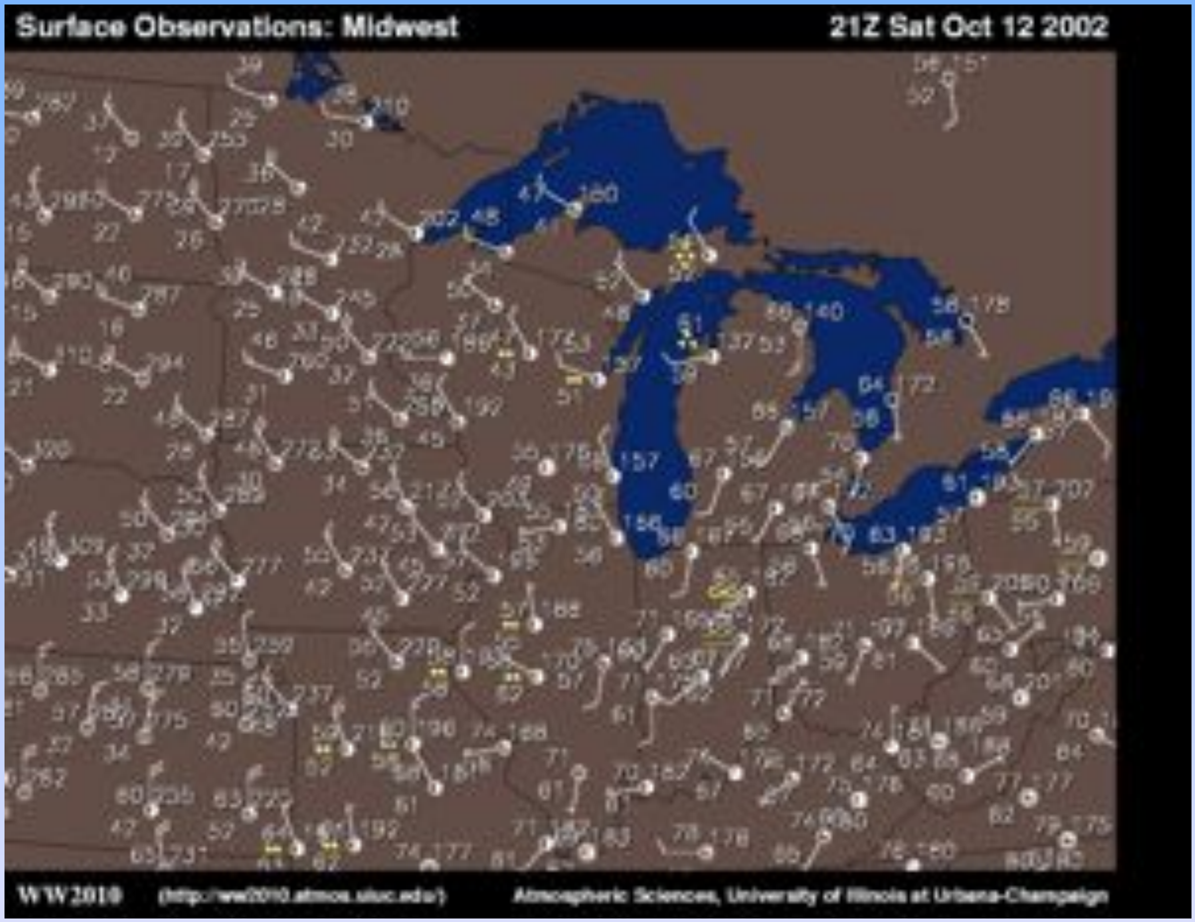


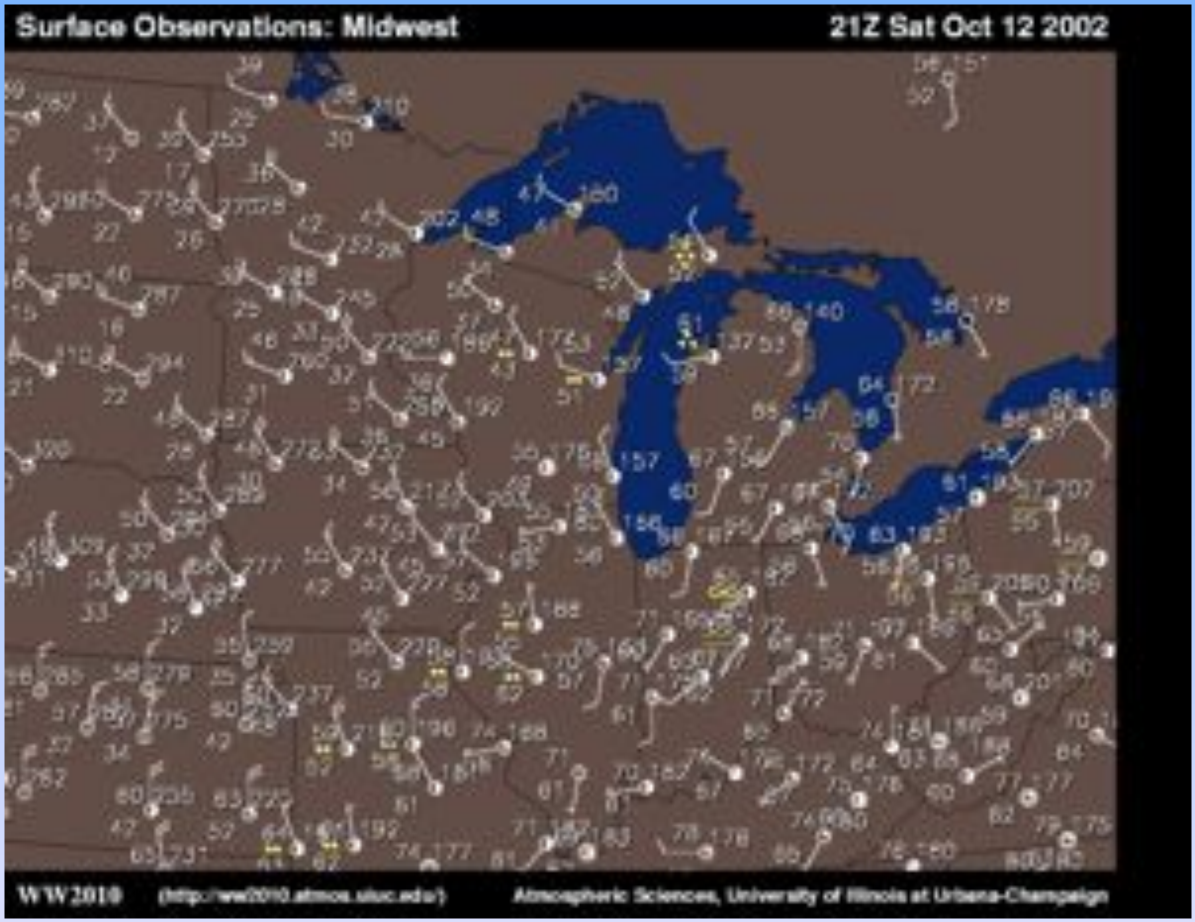
Fig. 8.2 SHW

Identifying a cold front on a surface weather map:



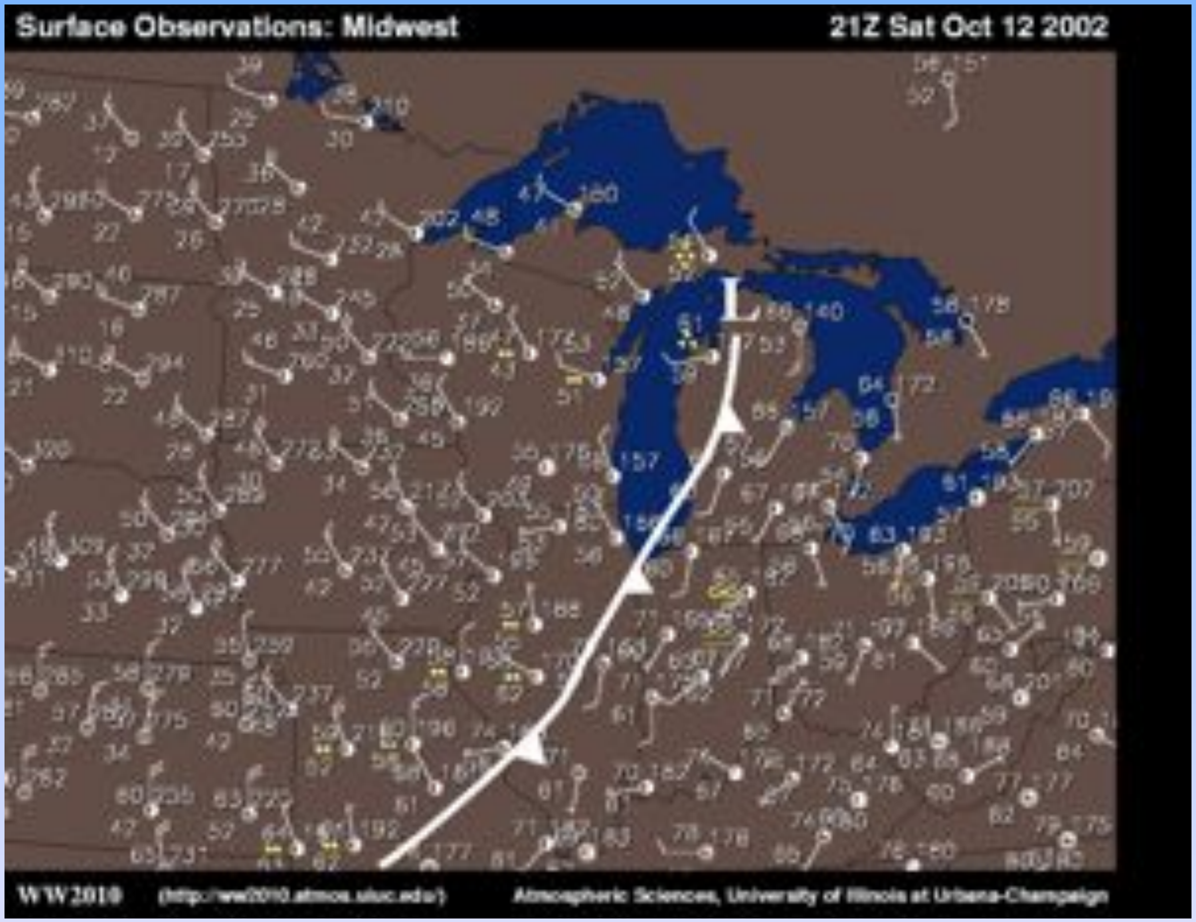
1. Surface front is located at the leading edge of the strong temperature gradient.
3. Surface front is located at the leading edge of accompanying strong dewpoint gradient.
5. Surface front coincides with pressure trough – pressure dropping as the front approaches and rising after it passes.

Identifying a cold front on a surface weather map:

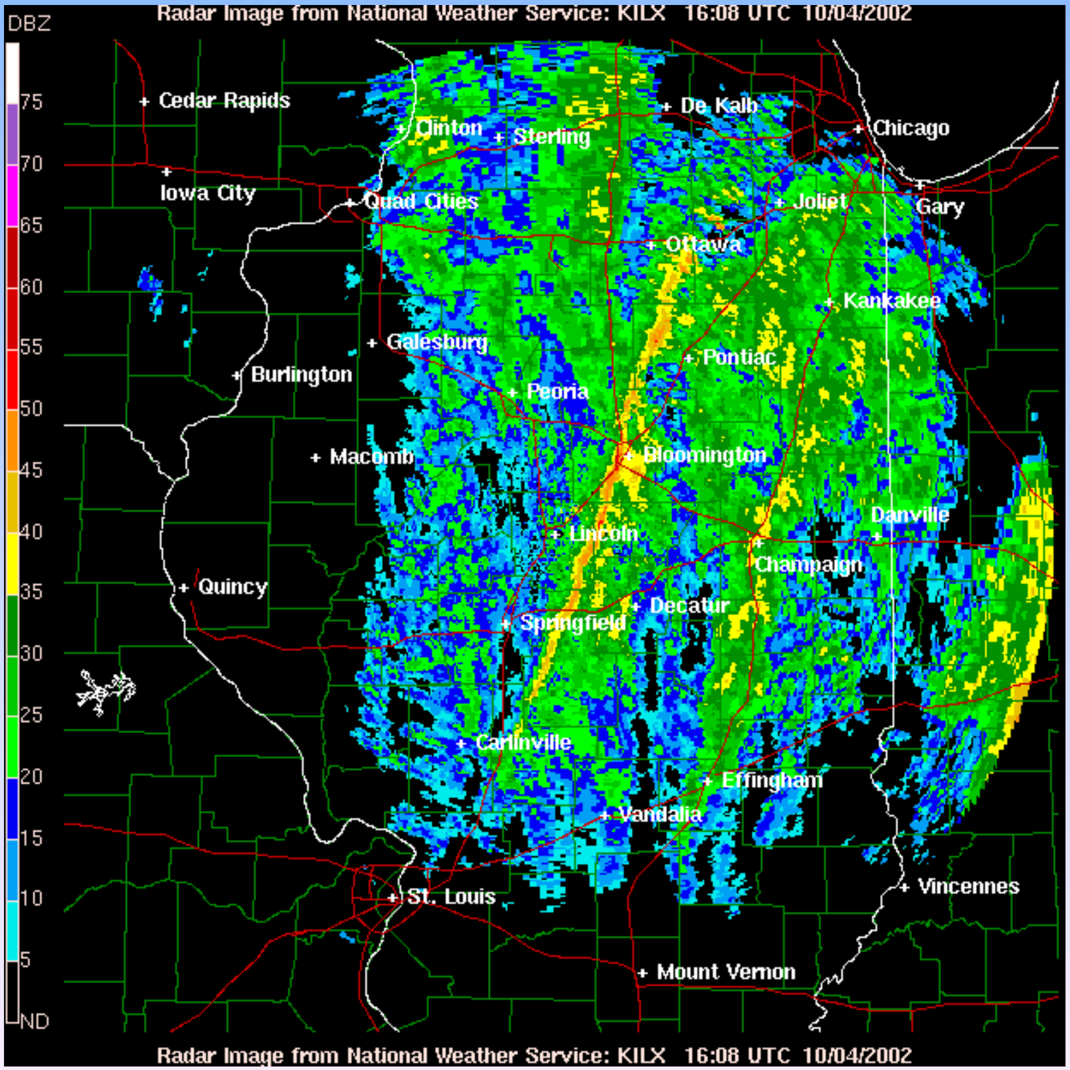


4. Cold air is advancing with time, replacing warm air.
6. A sharp wind shift, generally from winds with southerly component to winds with westerly or northwesterly component, will occur at front.
6. Precipitation may be behind, along, or ahead of front (or may not be present) but when present, it will be organized along a line.

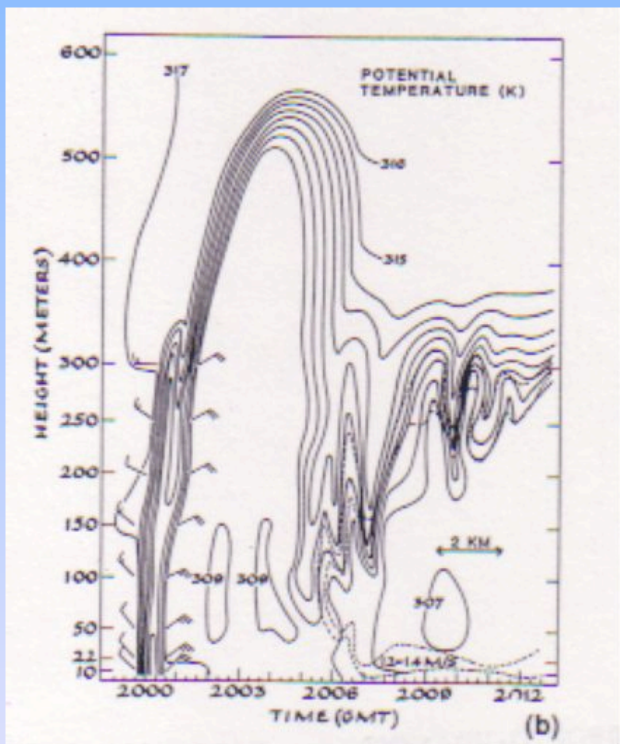
Identifying a cold front on a weather map:



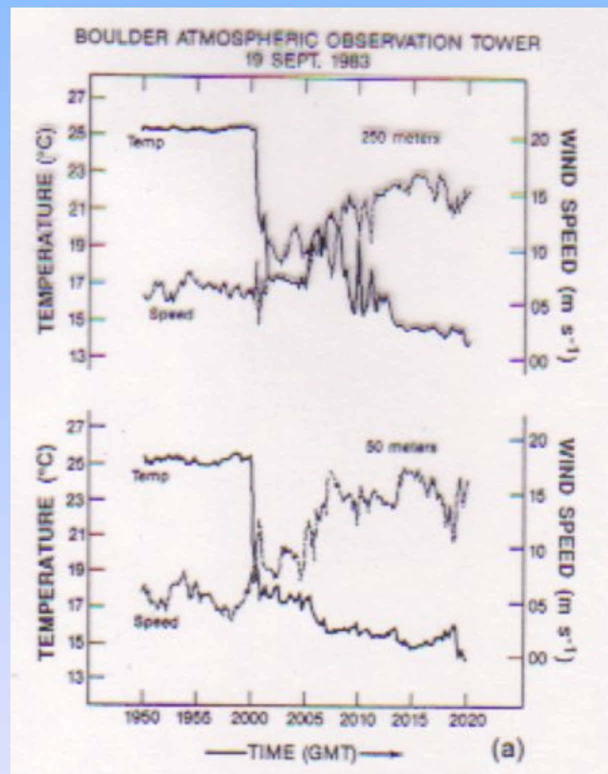
Leading edge of a cold front on radar often appears as a very Long narrow line of high reflectivity



Cold Fronts: The leading edge of a cold front often appears like a density current, with a head, waves, and accompanying sharp discontinuity in temperature, wind, and moisture content.



Potential Temperature
Wind Barbs

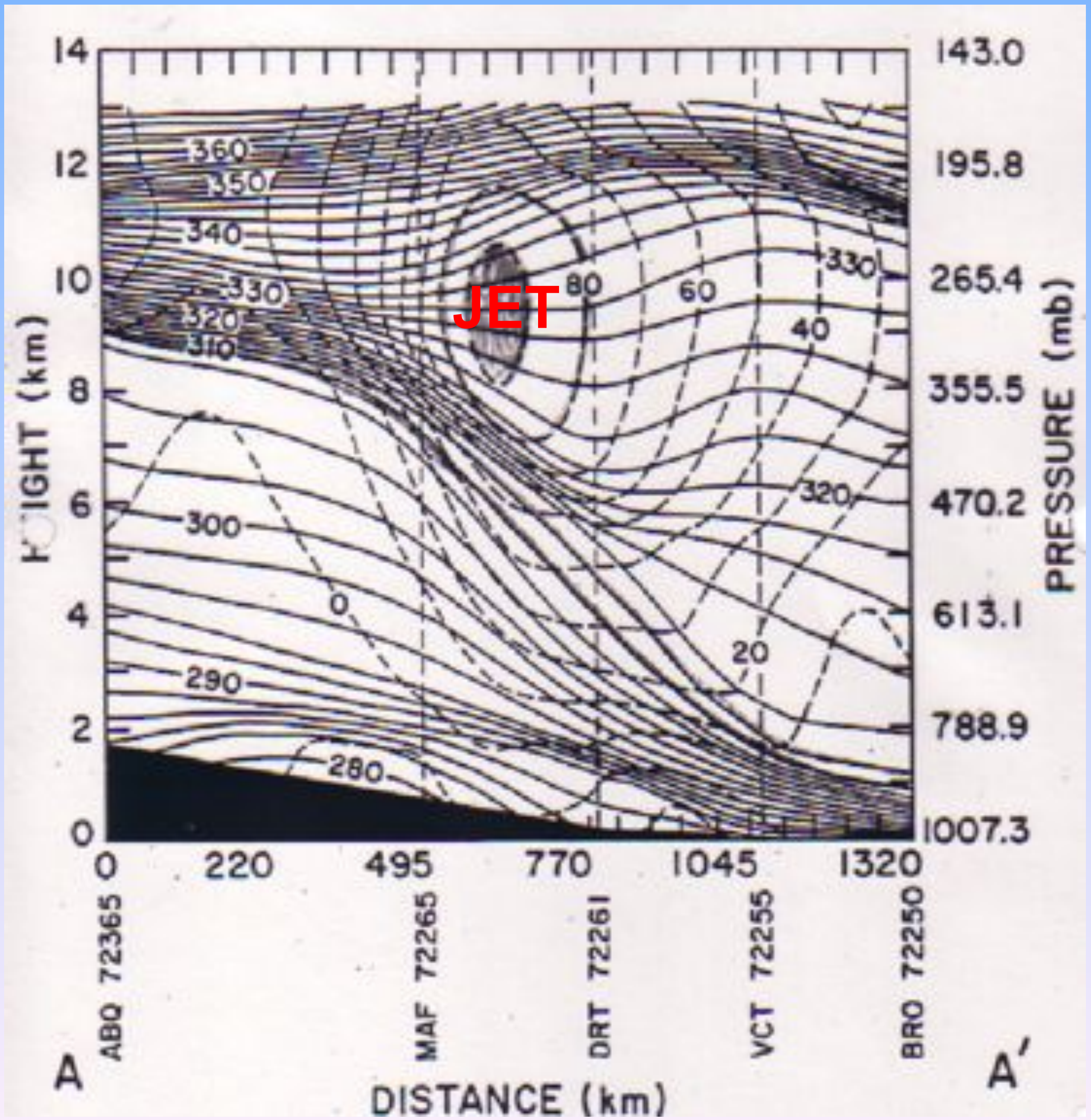


Temperature
Wind Speed

Data from 600 m high tower called the Boulder Atmospheric Observatory. A cold Front passed the tower On 19 Sep 83.

Shapiro et al. 1985, MWR, Fig. 2.6 Bluestein Vol. II

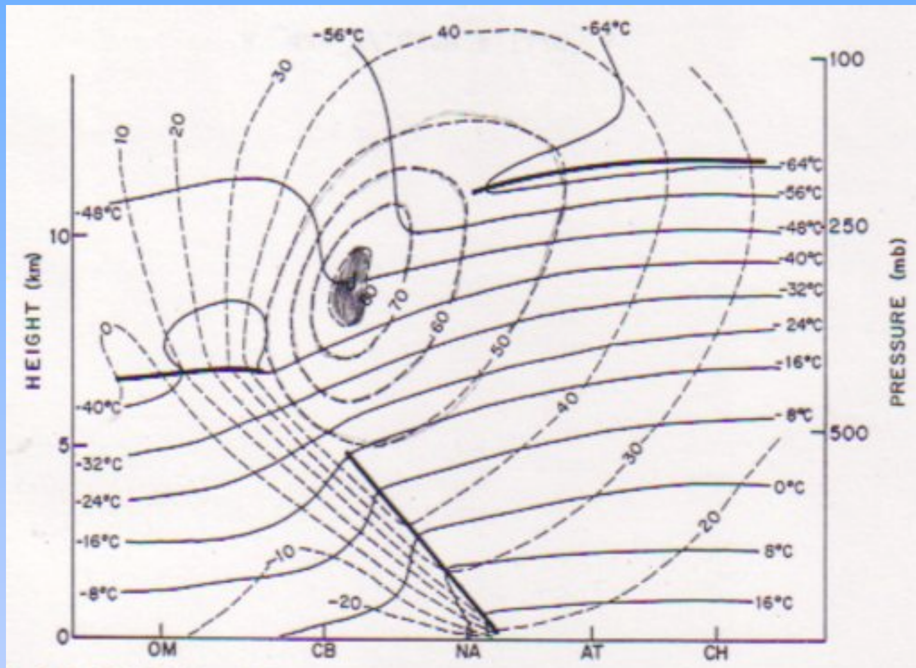
Deep Tropospheric Cold Front and Jetstream

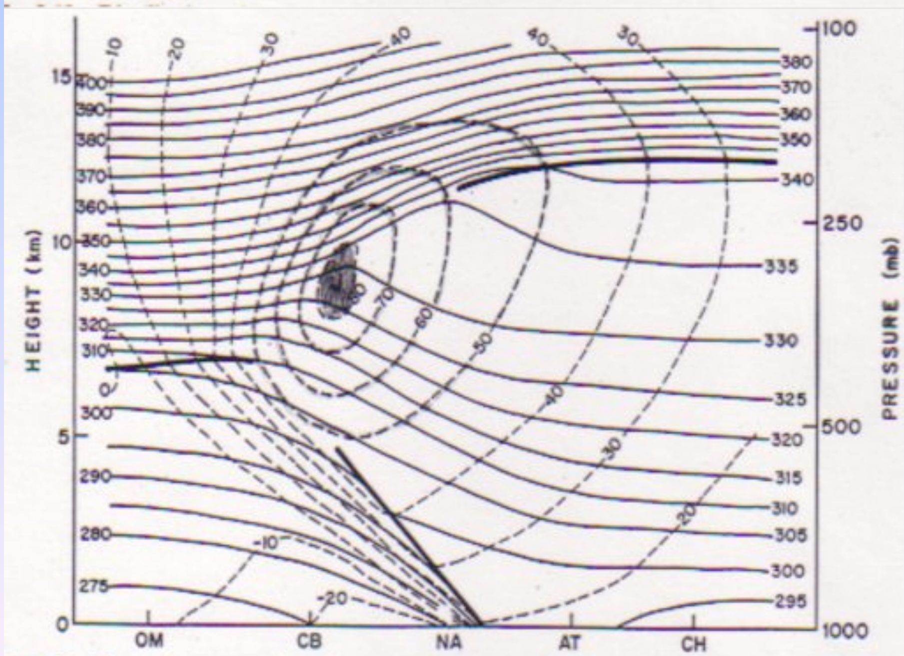


Potential temperature and isotachs

Fronts and jetstreams are related dynamically by thermal wind relationship

Keyser and Shapiro 1978 August MWR





Deep Tropospheric Cold Front

Boundary between airmasses is marked by a sharp gradient in temperature

Temperature (C)

Potential Temperature (K)

Wallace and Hobbs 1977 Fig. 3.19/3.20

“Back-Door” cold front:

A cold front that approaches an area from the east

Back door cold fronts are common in New England and along the east side of the Rocky Mountains

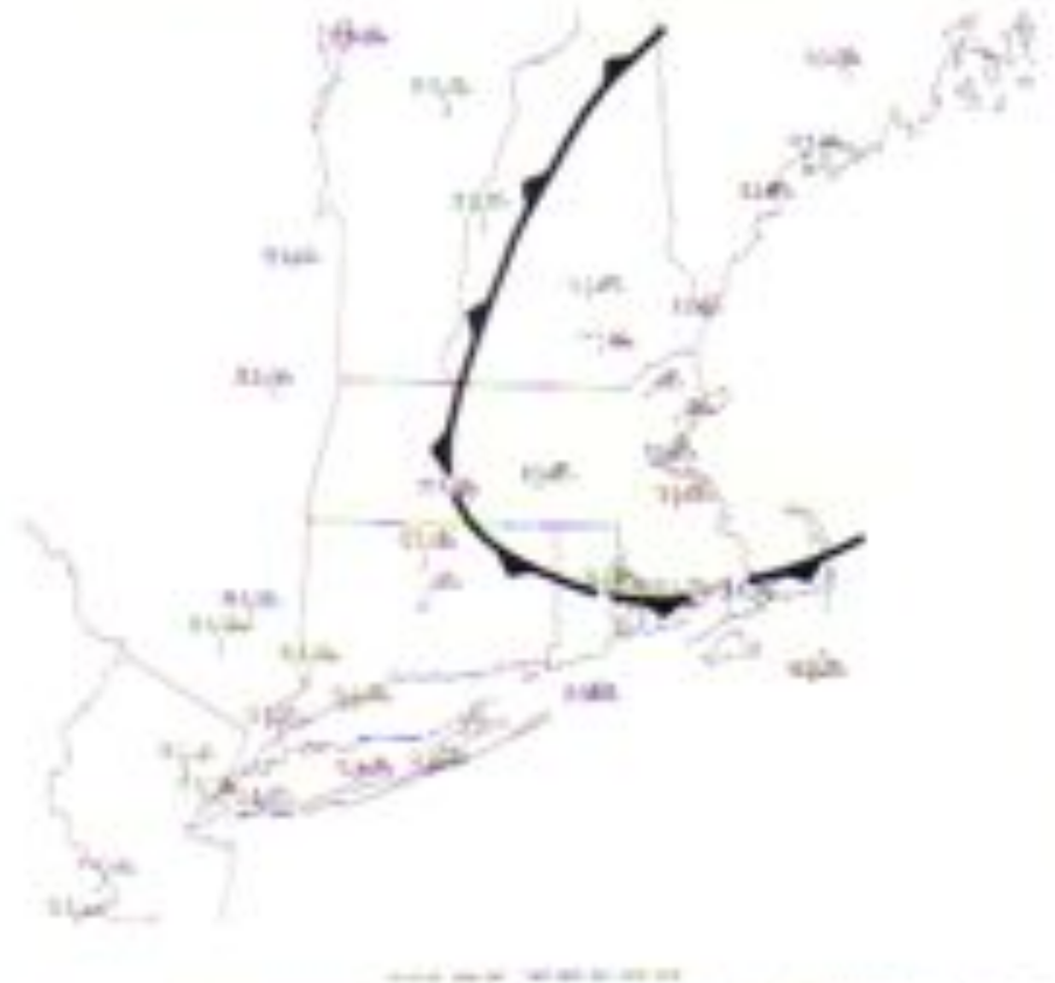


Figure 2.16 Example of a New England back-door cold front 0000 UTC, April 29, 1990. Winds east of the front are off the cold Atlantic; winds west of the front are off the warmer land. Temperature and dew point (°C) plotted according to convention. Pressure plotted is altimeter setting in tens of mb without the leading "10." Full wind barb = 5 m s^{-1}; half wind barb = 2.5 m s^{-1}.

From Bluestein Vol II, Fig. 2.16

Warm front: Regardless of the cloud formations or precipitation, we say that a front is a warm front if the cold air is retreating and the warm air is advancing.

The leading edge of the cold airmass typically has a shape like a dome, as shown in the figure.

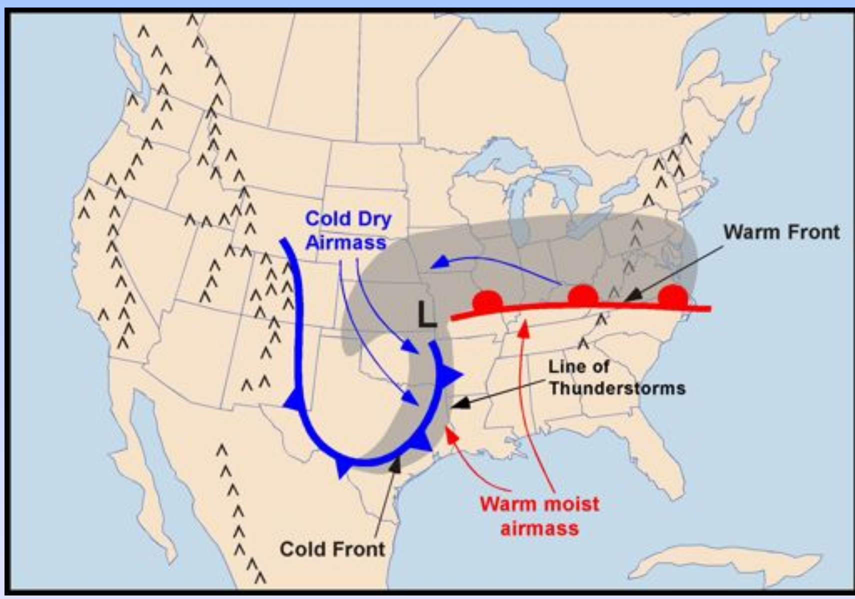
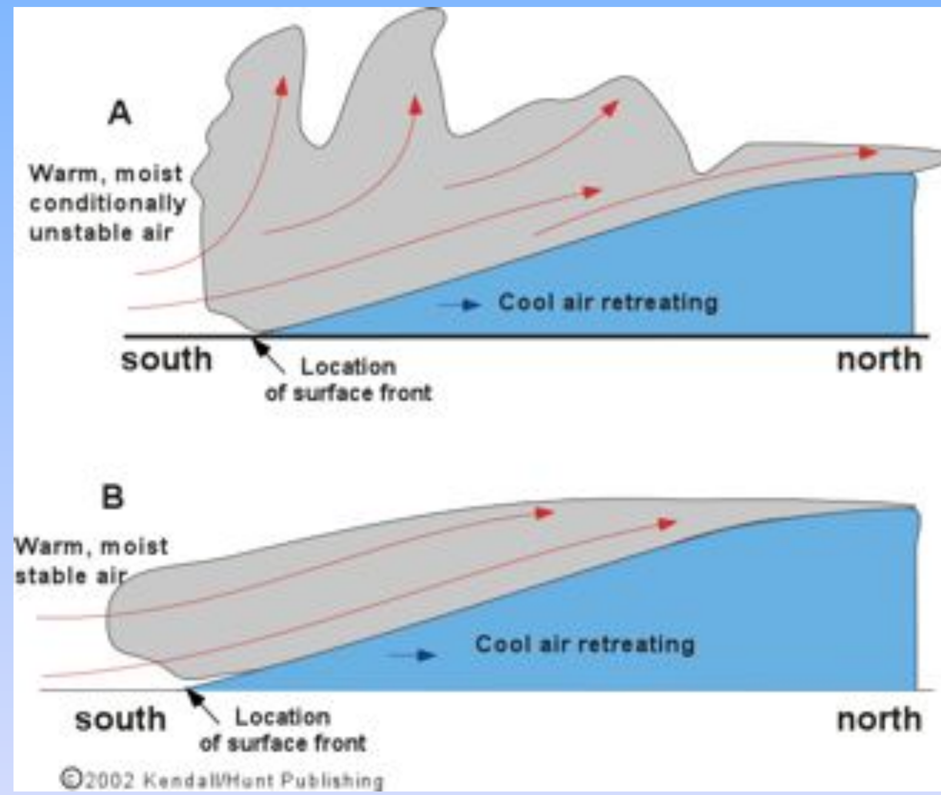


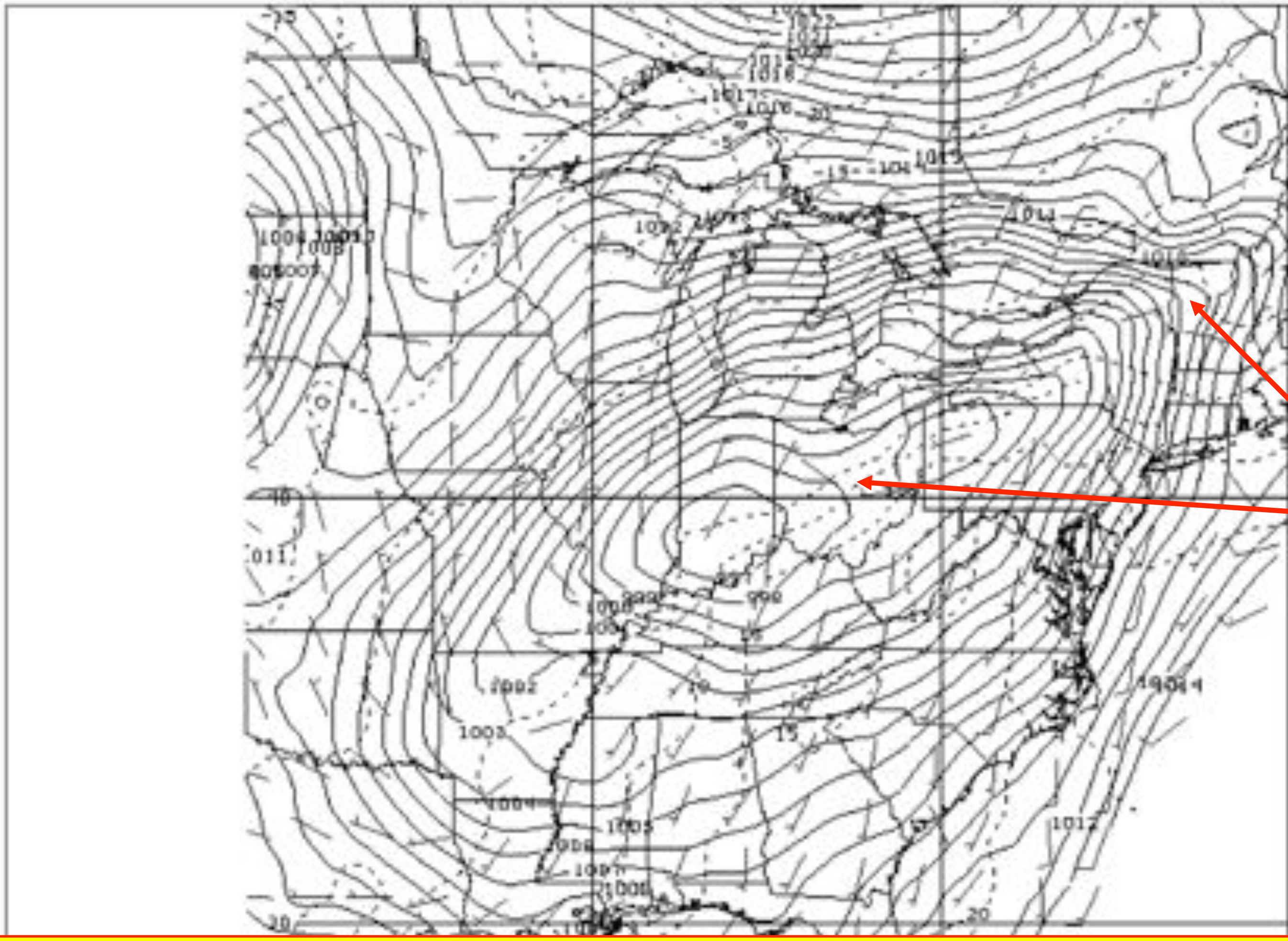
Fig. 8.3 SHW

Fig. 8.4 SHW



The type of weather along a warm front depends on the stability and moisture content of the warm air

Analyzing warm fronts

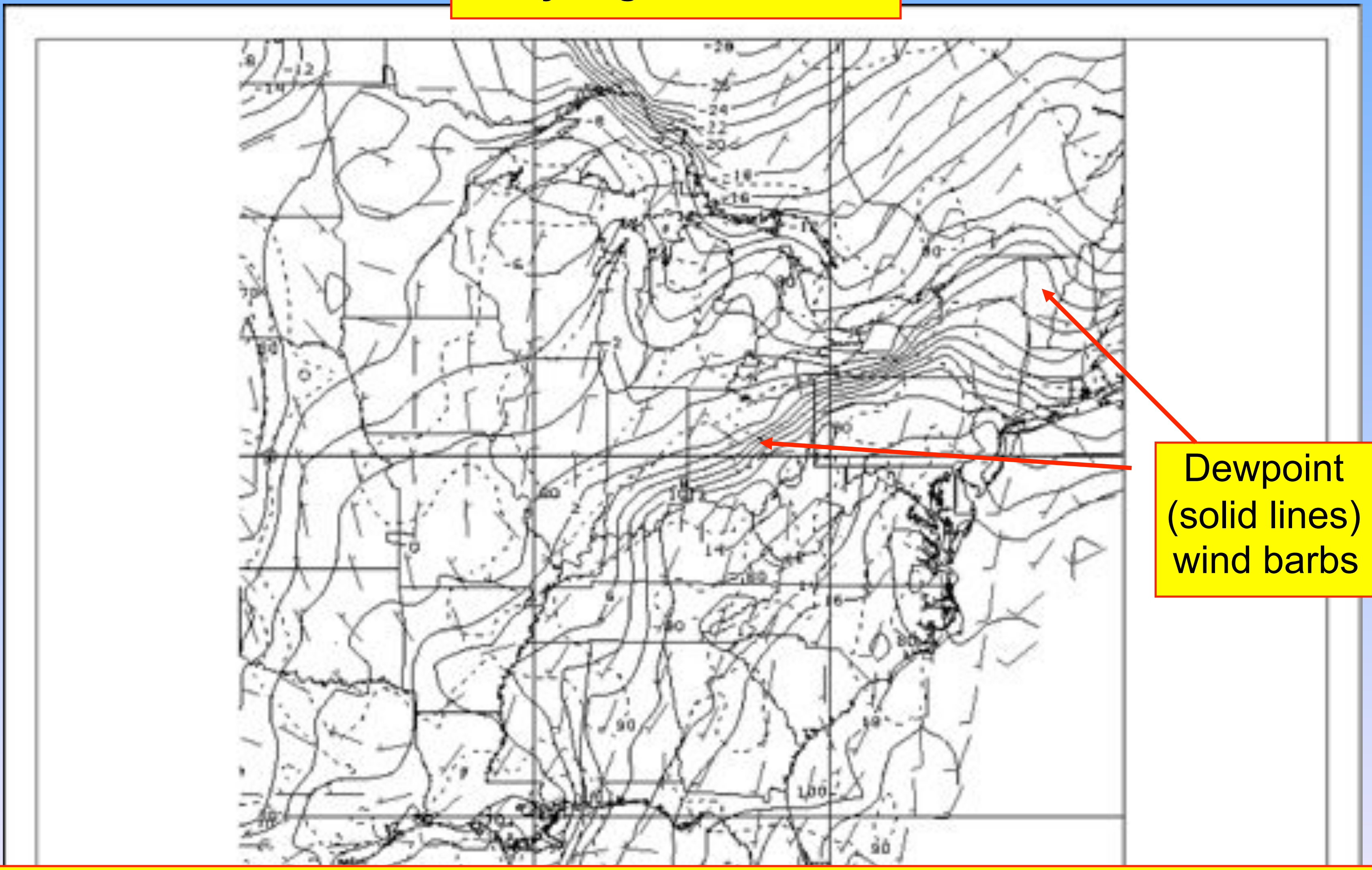


Pressure (solid lines)
Temperature (dashed lines)

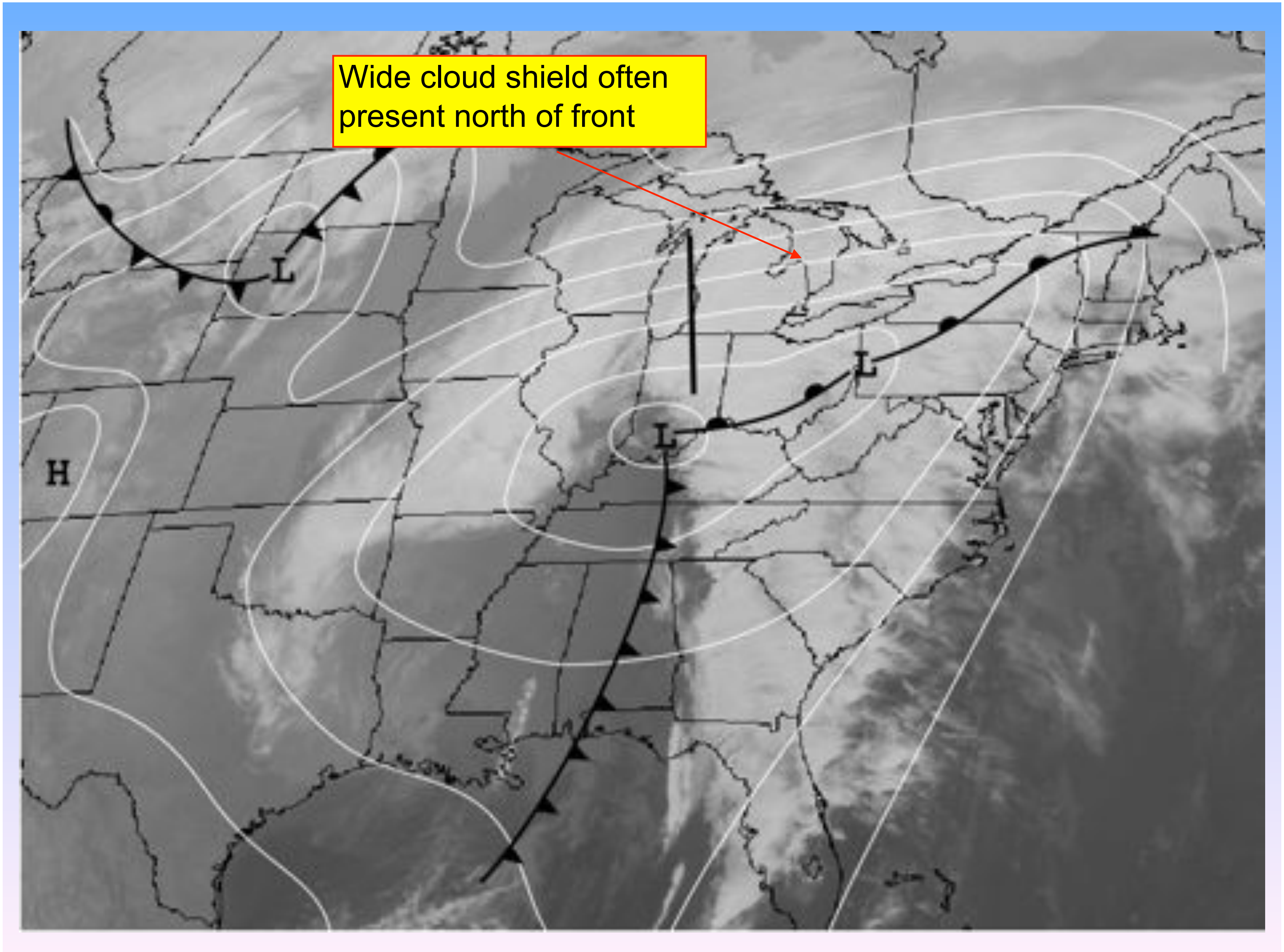
1. Warm front will often lie along a distinct pressure trough
3. Front is (normally)at southern edge of a moderate-strong N-S temperature gradient

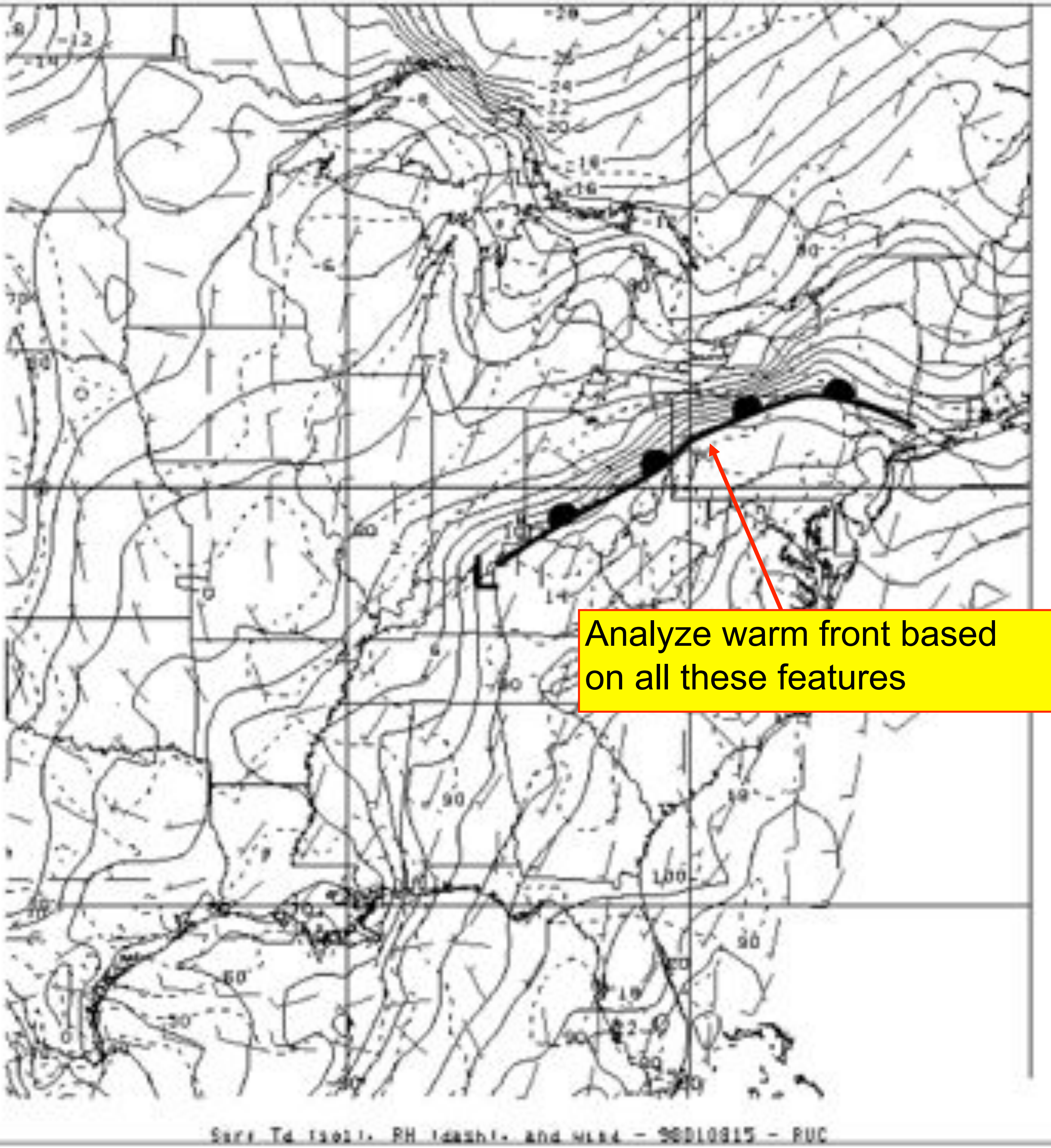
[warm fronts are occasionally oriented NW-SE on Great Plains (i.e. an NE-SW temperature gradient)]

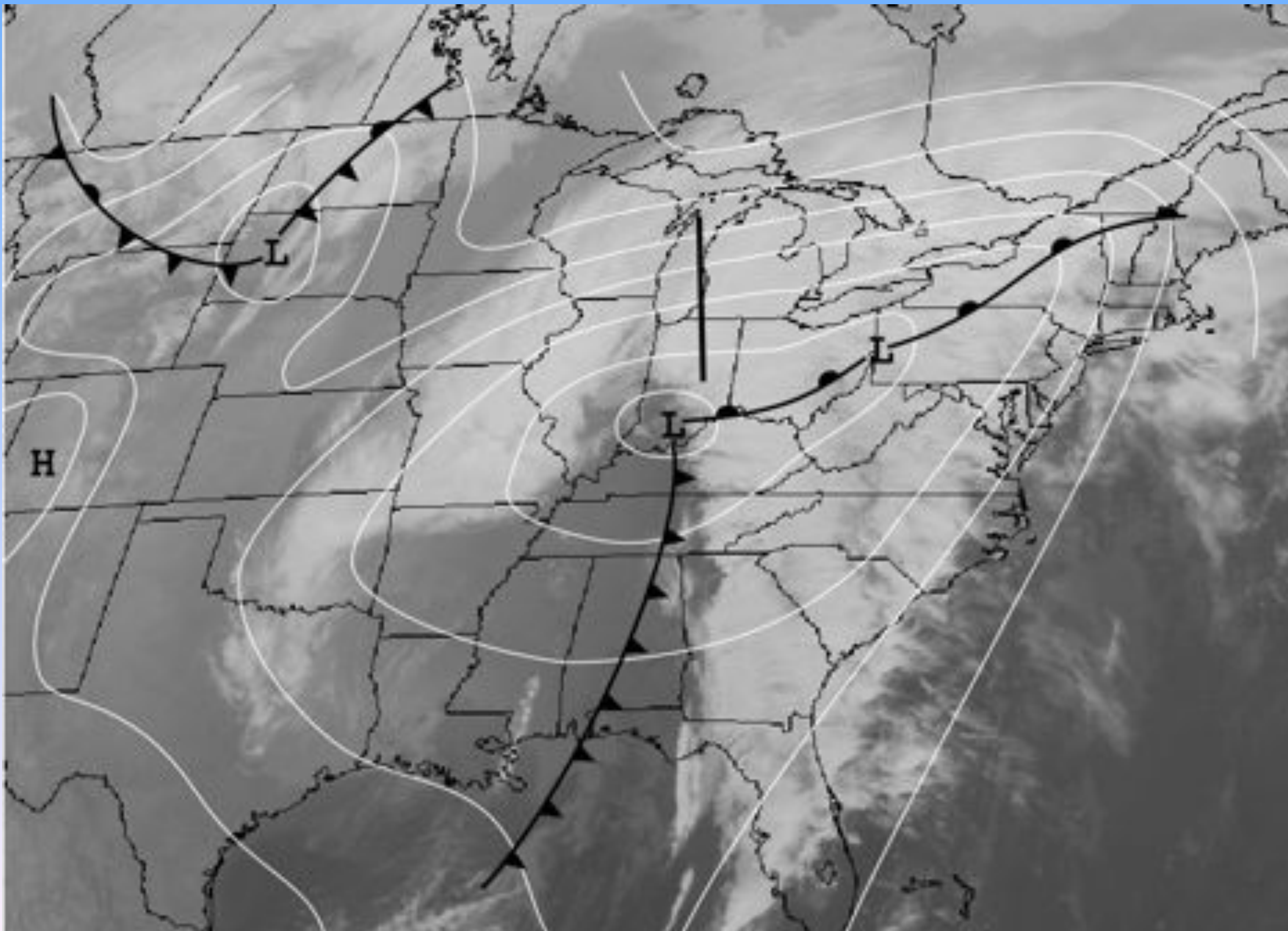
Analyzing warm fronts



1. Warm front marked by wind shift – typically easterly or northeasterly winds north of the front, southerly winds south of the front.
3. Front is (normally) at southern edge of a moderate-strong N-S dewpoint gradient


Wide cloud shield often present north of front
L
L
L
L
H


Analyze warm front based on all these features
Sfc Td (sol), RH (dash), and wind - 98010815 - RUC


L
H
L
L

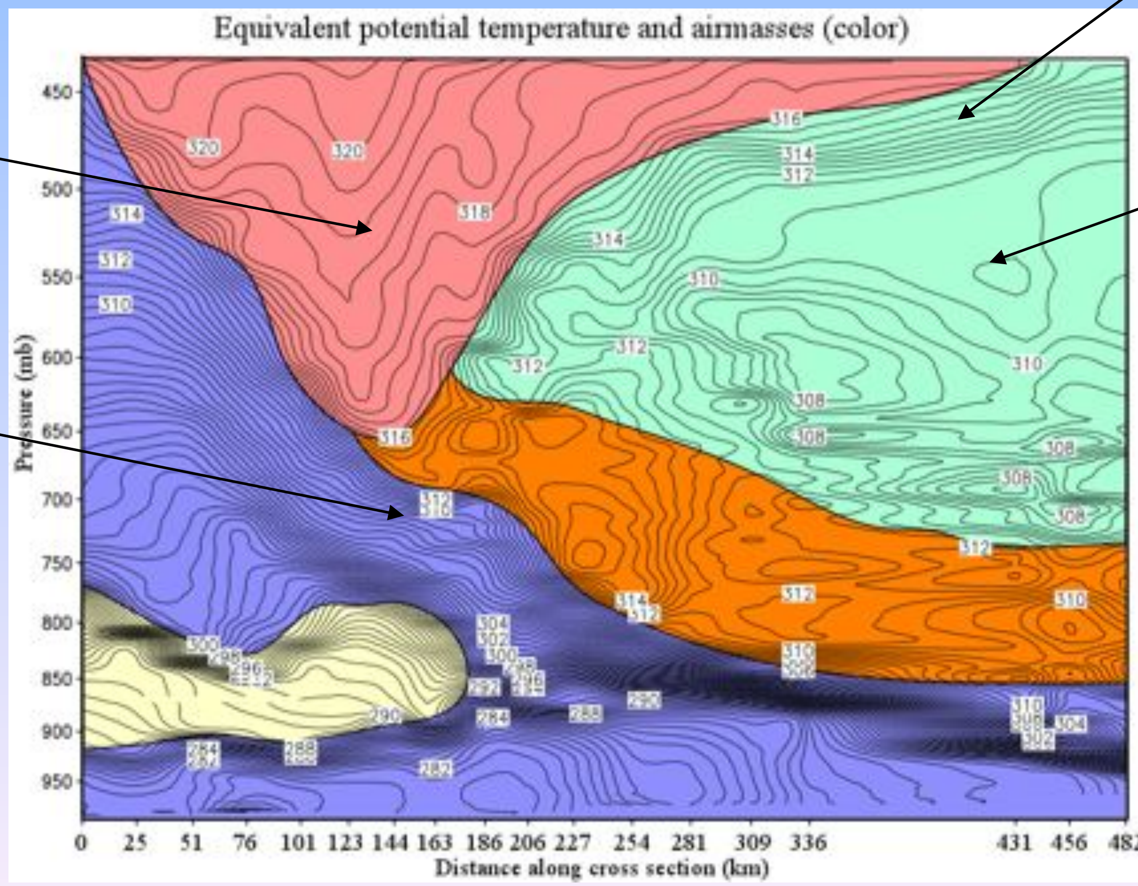
Warm fronts are not generally as simple as the previous conceptual model suggests

Upper level front
(Cold Front Aloft)

TROWAL: Trough of warm air aloft – primary generator of precipitation

Dry slot

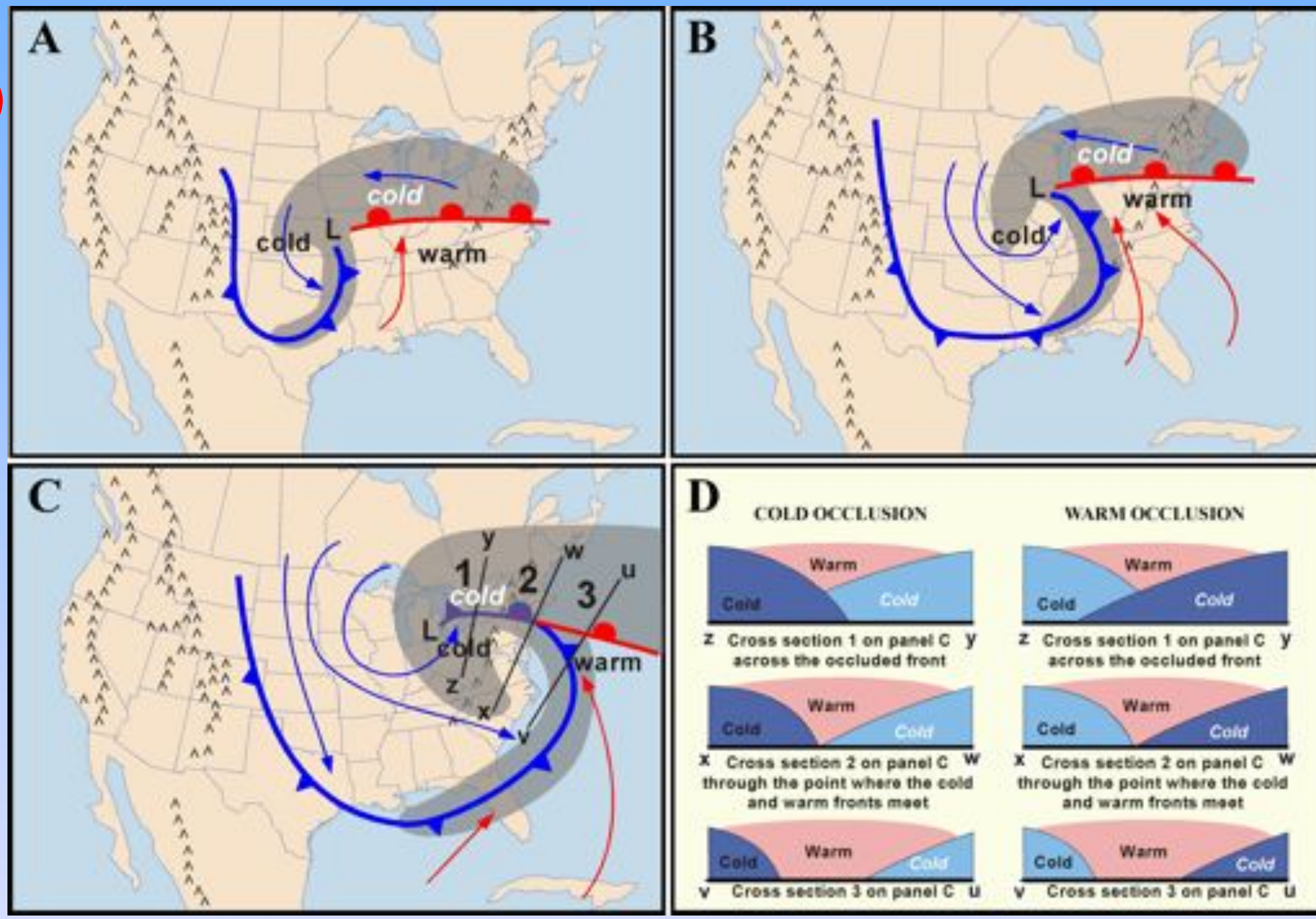
Warm front



Occluded fronts
(Classical description)

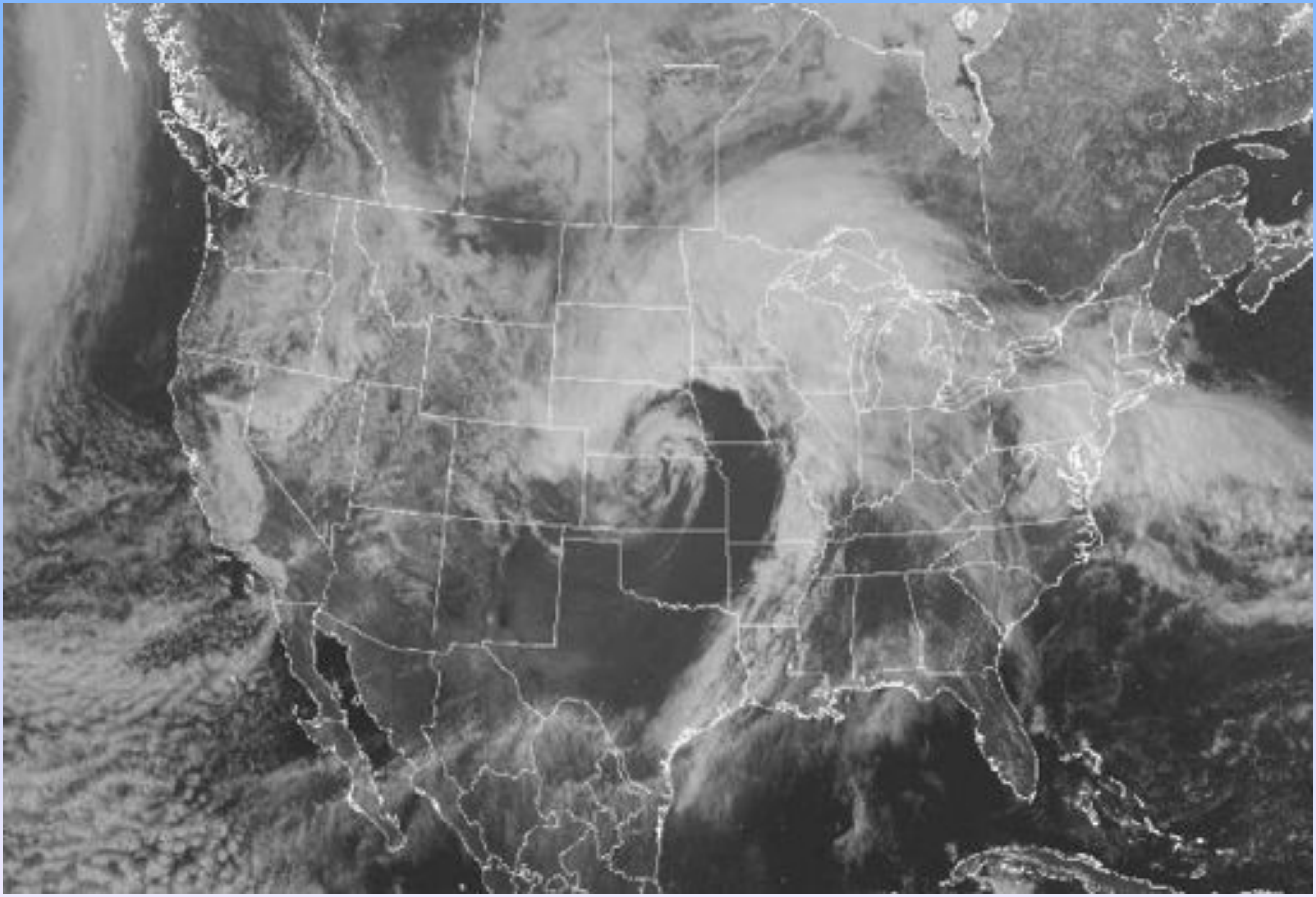
Cold air to the west of the cyclone advances rapidly southward around the center of low pressure

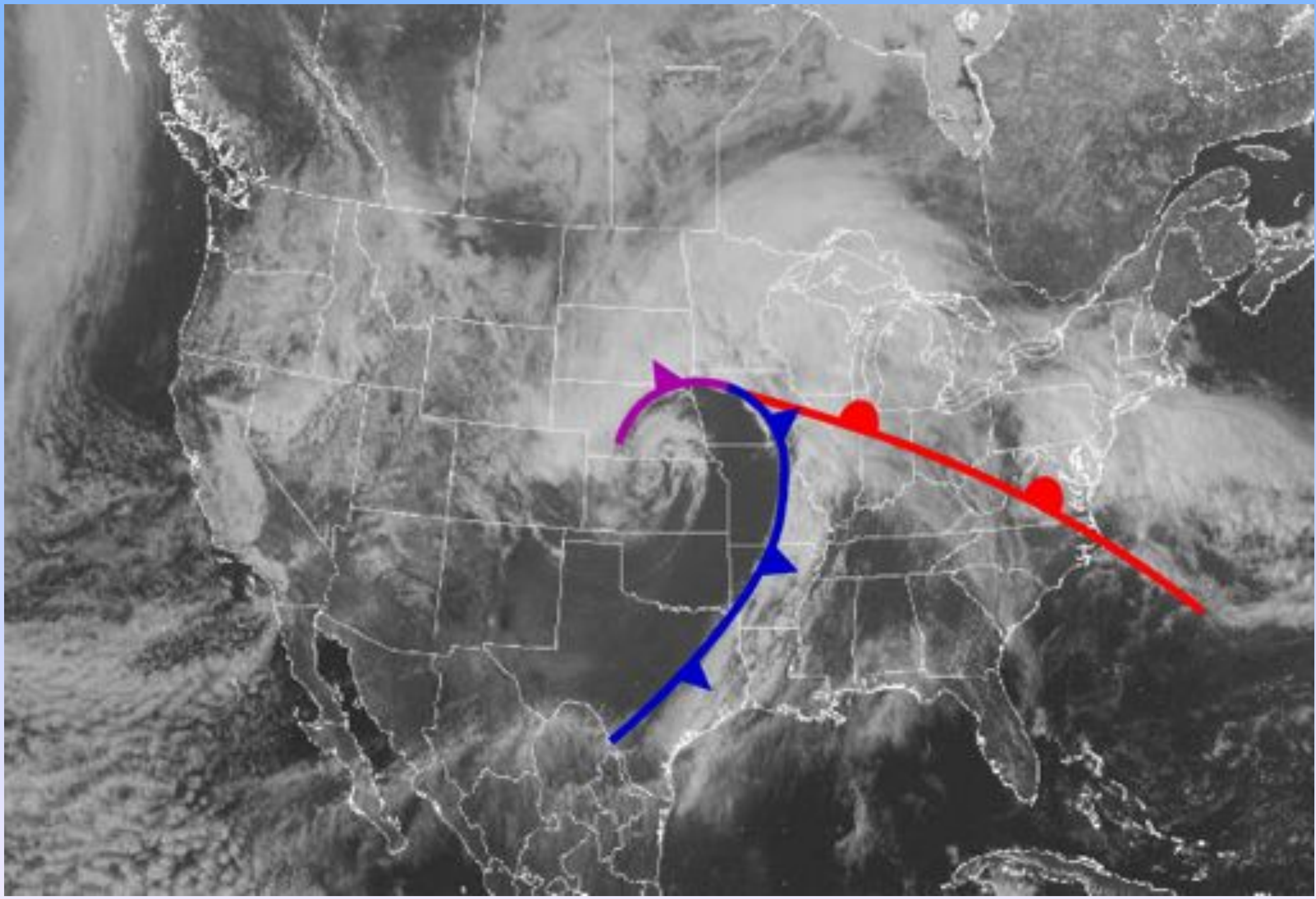
Cool air to the north of the warm front retreats northward slowly.

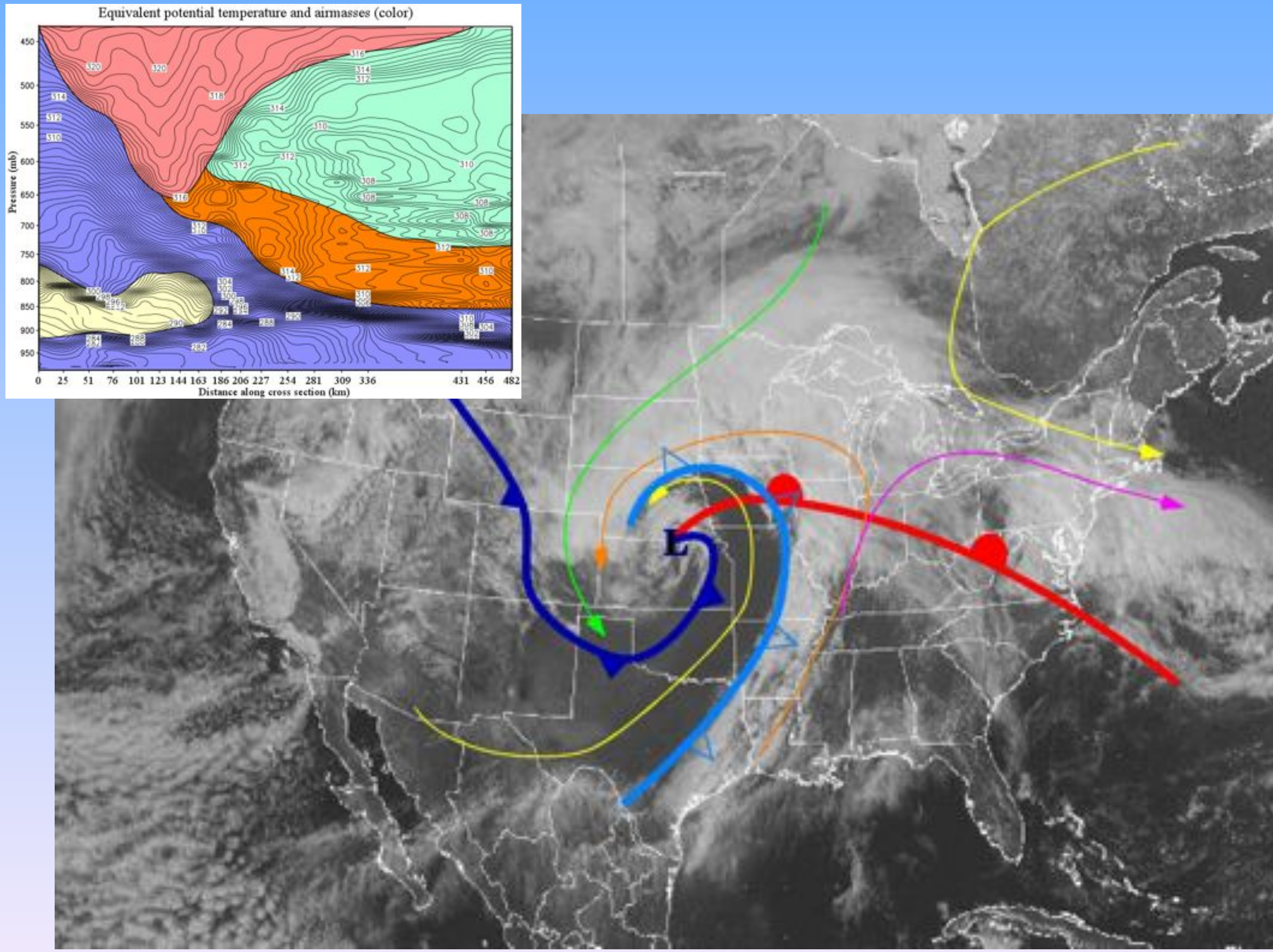


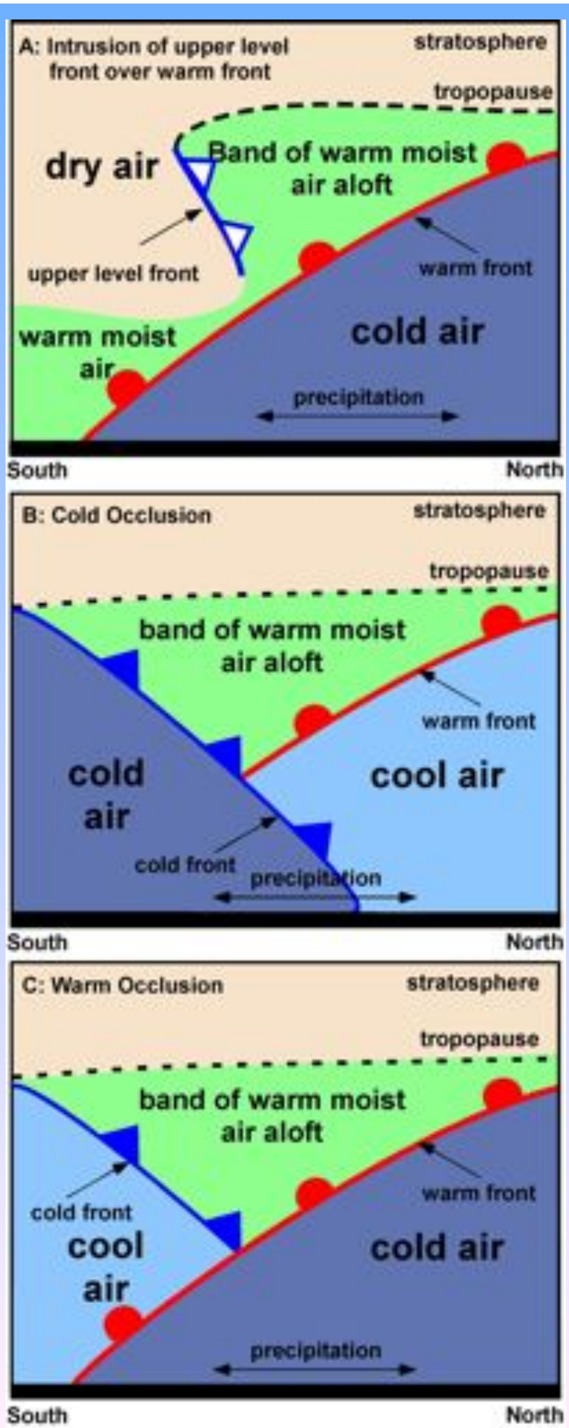
Cold air will then progress northeastward, approaching the warm front. When cold air comes in direct contact with the cool air north of the warm front, a new airmass boundary is created called an *occluded front*.

Fig. 8.7 SHW





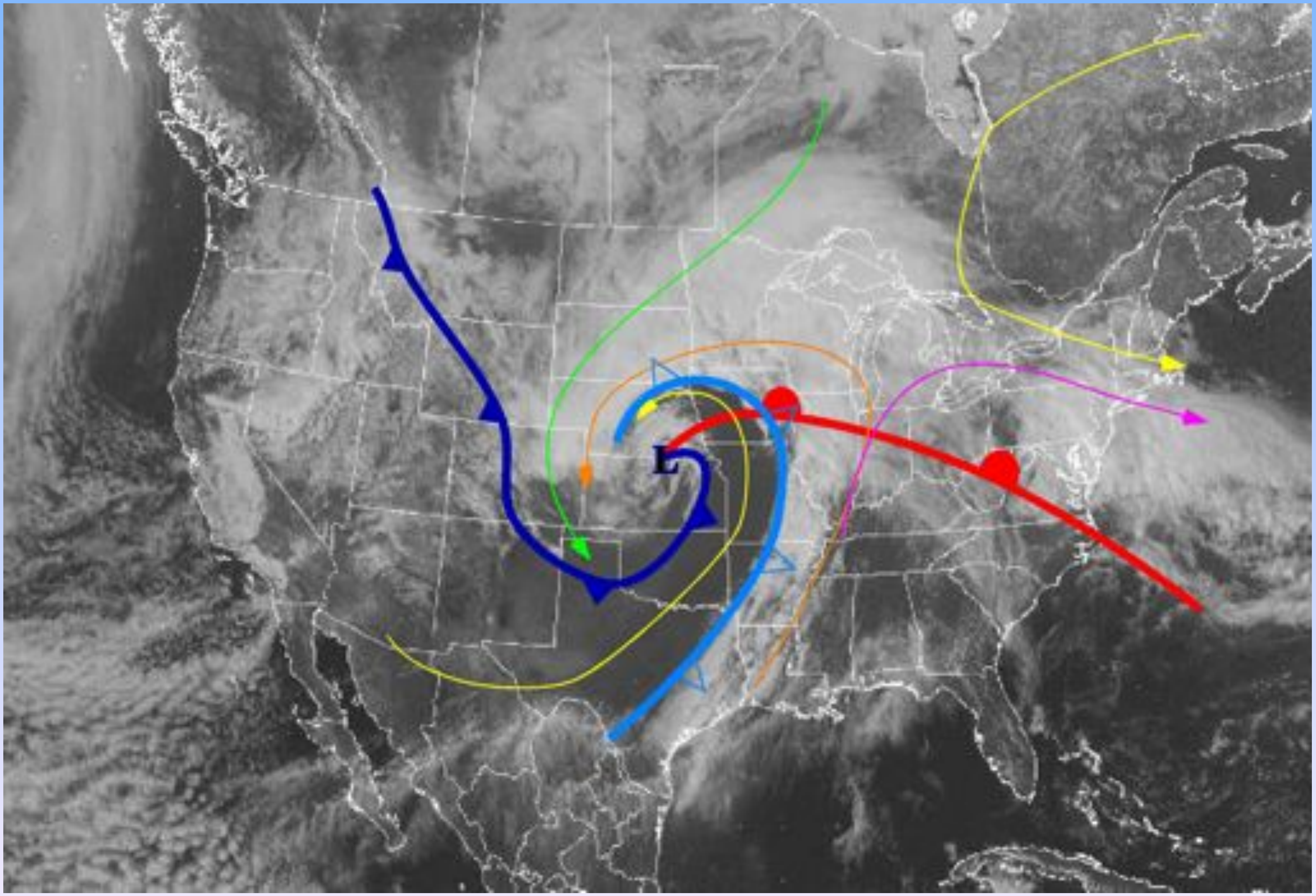

Equivalent potential temperature and airmasses (color)
Pressure (mb)
450 500 550 600 650 700 750 800 850 900 950
0 25 51 76 101 123 144 163 186 206 227 254 281 309 336 431 456 482
Distance along cross section (km)
L



New findings about occlusion structure in many cyclones

Cold Occlusion: Classical occlusion structure

Warm Occlusion: Classic occlusion structure



Upper level front

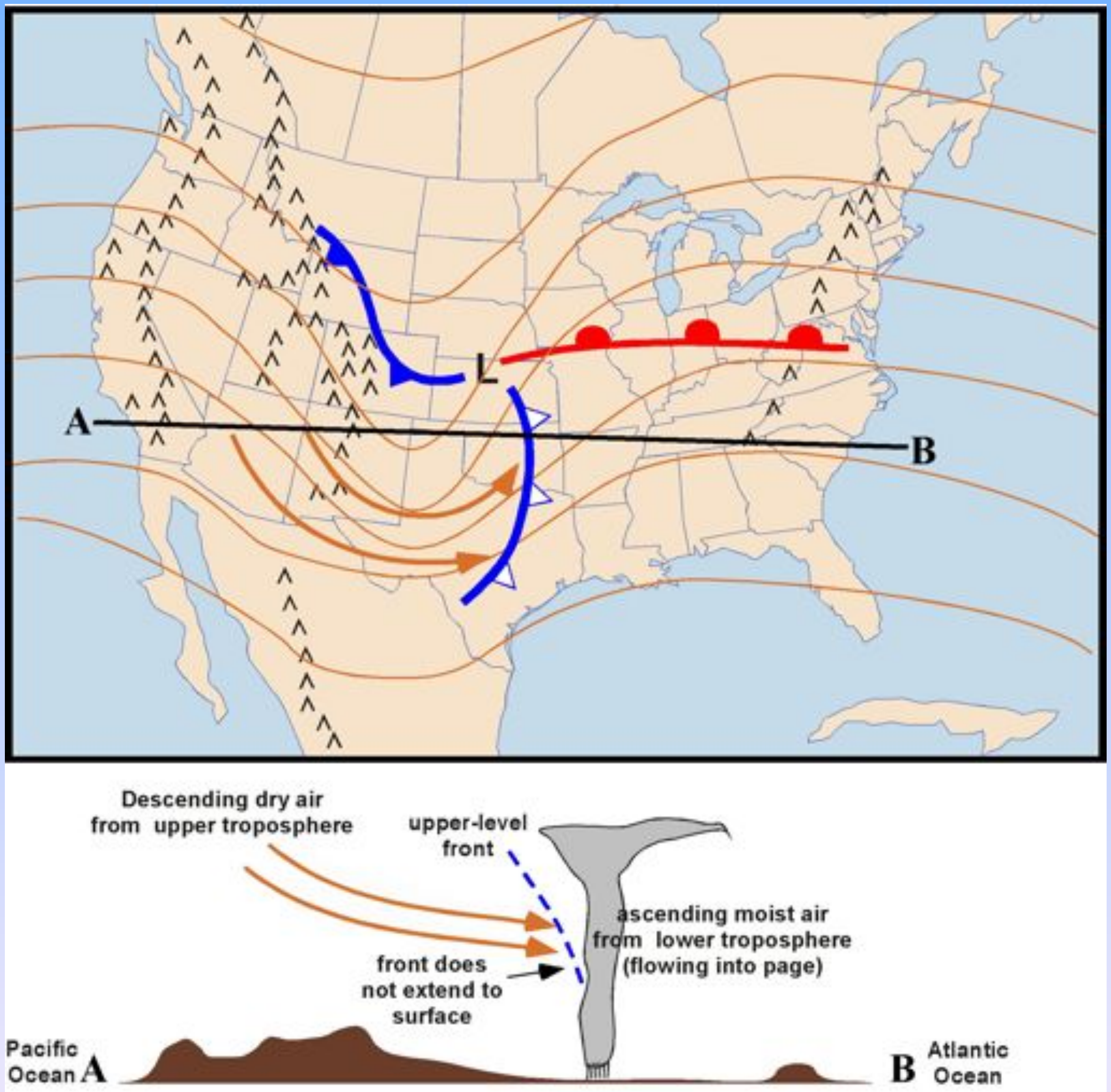
(Also called Cold Front Aloft)

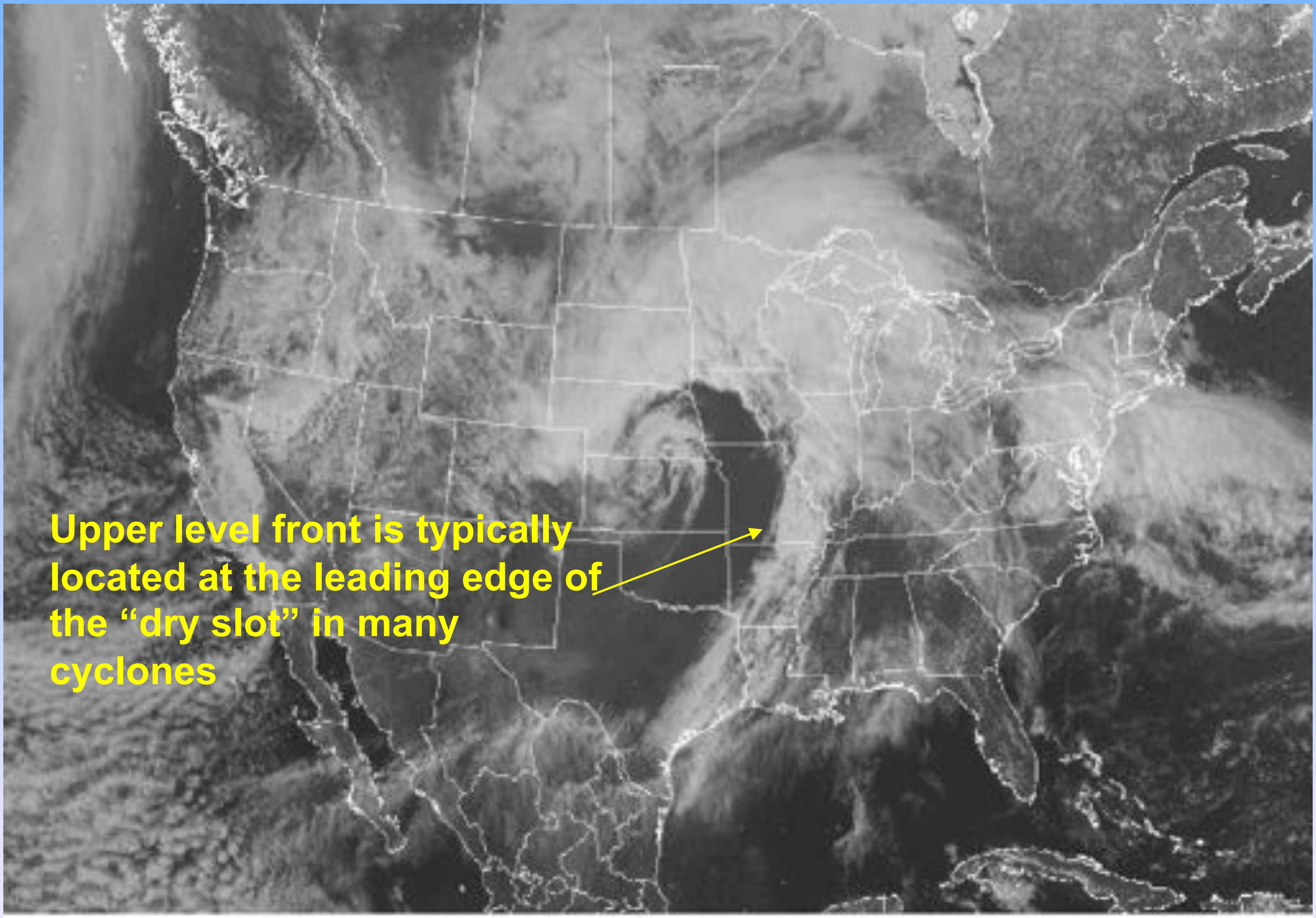
Boundary between:

Air descending from the upper troposphere that originates in the convergent region of the trough

and

Air ascending from the lower atmosphere in the southeastern quadrant of a cyclone





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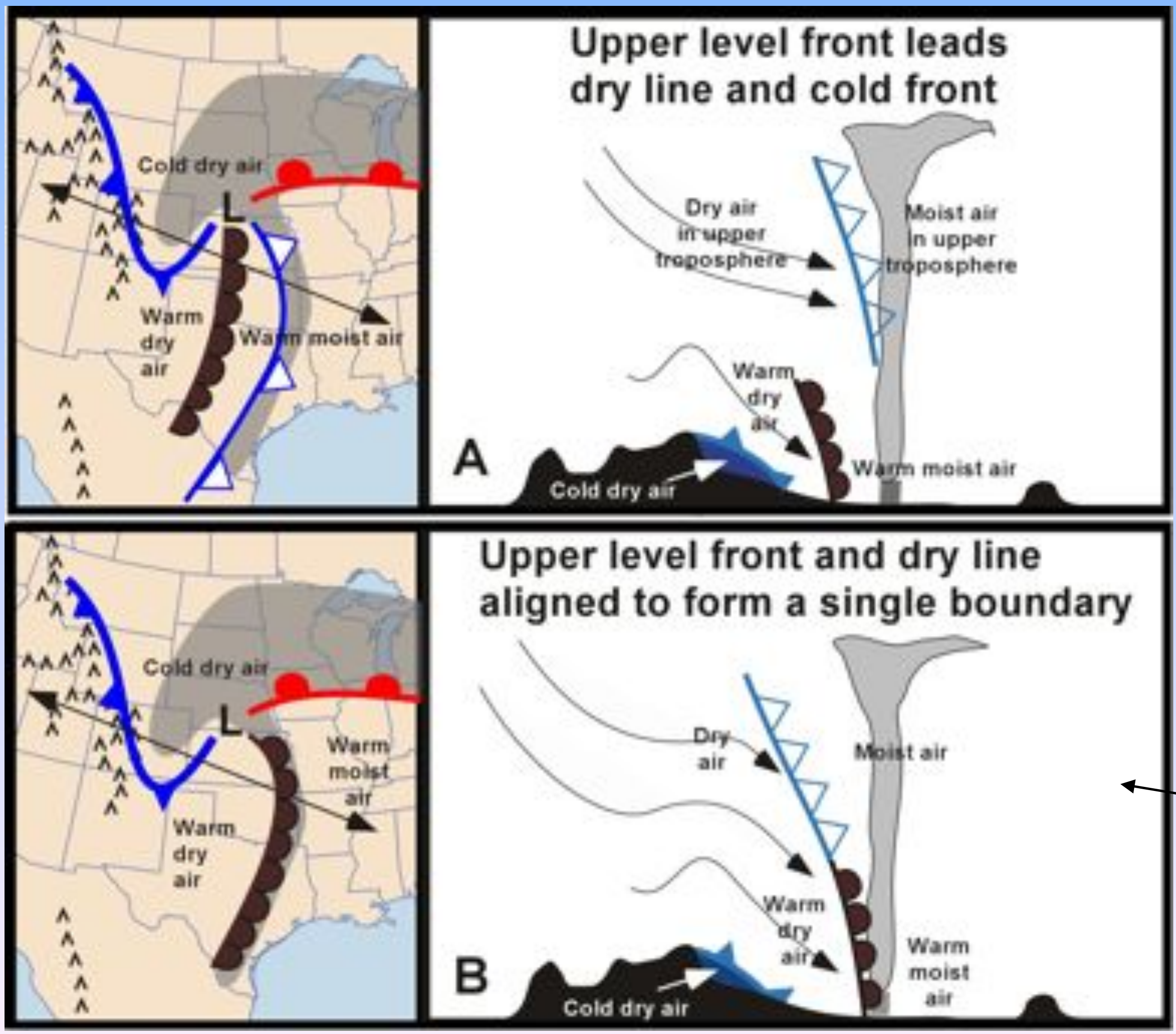
The upper level front is "upper level" in some cyclones, but may extend to the surface as a continuous front in others. Where it reaches the surface as a single front the boundary is sometimes analyzed as a surface dry line, while other times as a surface cold front.

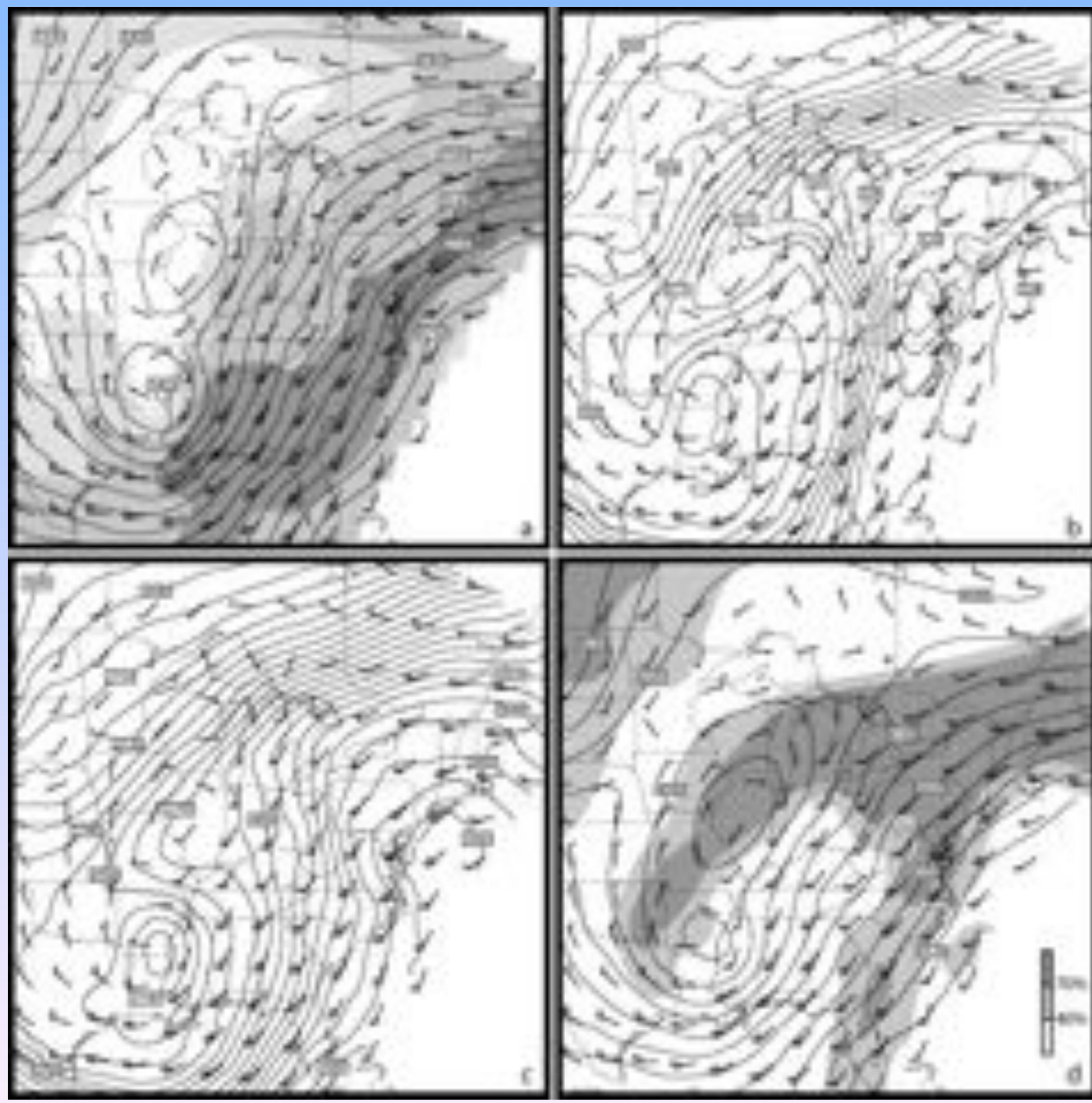


Often happens When a Pacific Cold front moves Across southern Rockies

Upper level fronts are most easily identified by analyzing θ_e on constant pressure surfaces that intersect the front (400 to 700 mb surfaces are usually best).

500 mb
Heights
Winds
Isotachs

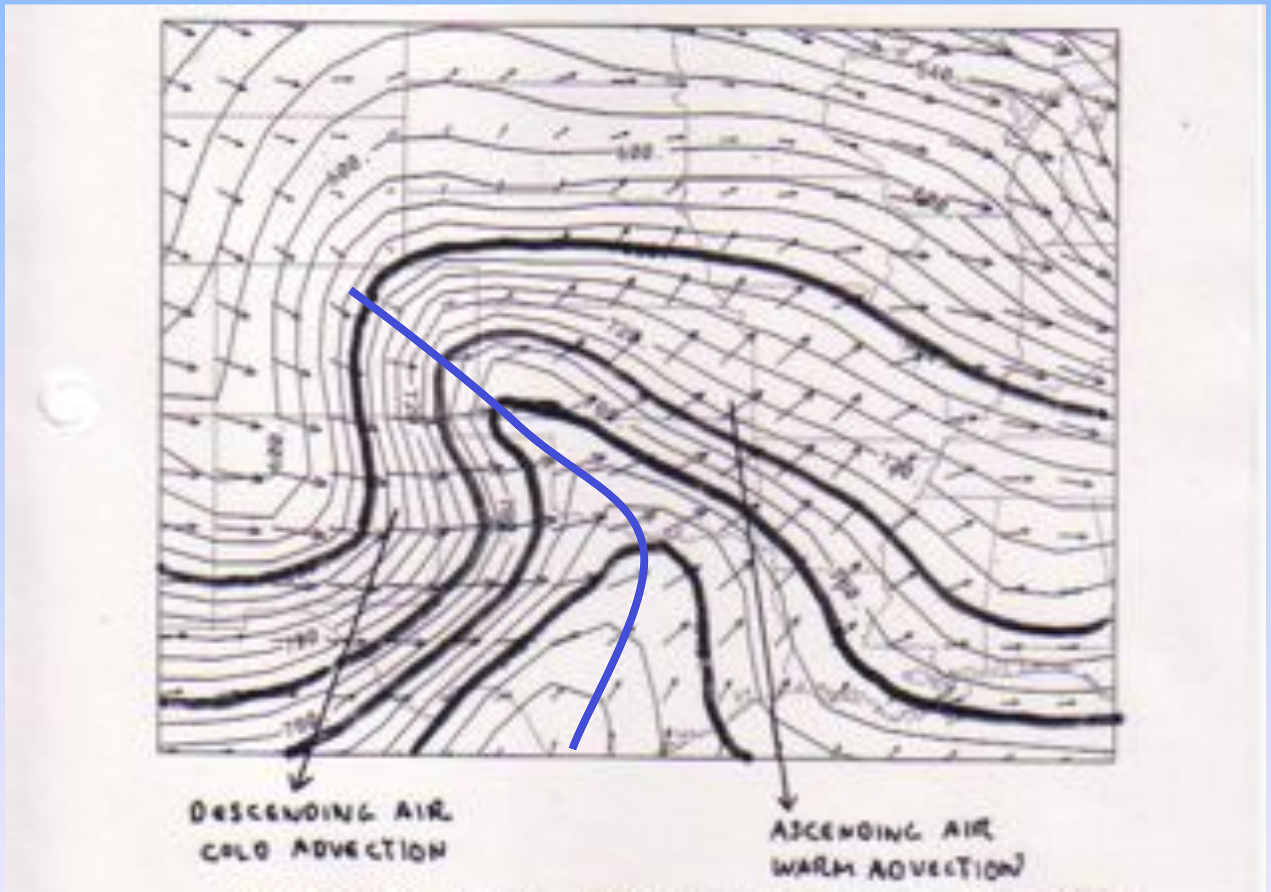
500 mb
θ_e
Winds



650-450 mb
Thickness
Winds

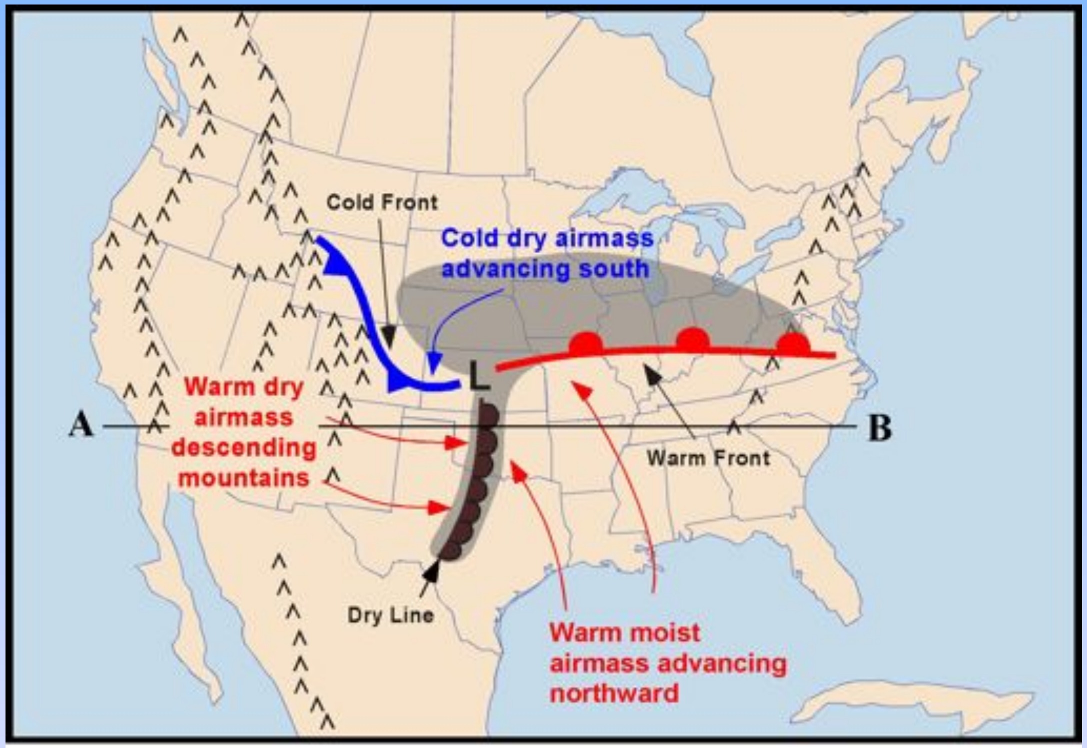
600 mb
Heights
RH
Winds

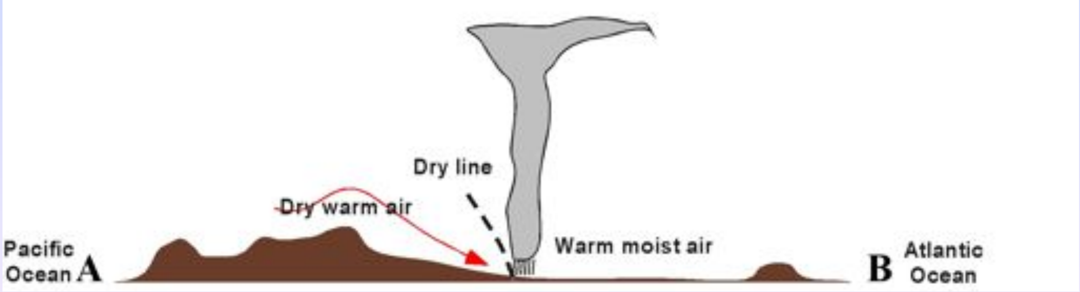
Upper level fronts are located at the leading edge of the cold advection on isentropic analyses.



Dry Lines

Dry Line: A front characterized by a sharp moisture difference, but little temperature change





Dry lines develop when air flowing eastward from the high desert plateau regions of Arizona, Colorado, New Mexico, and Mexico descends the Rockies into the southern plains and encounters moist air flowing northward from the Gulf of Mexico

The Great Plains Dryline

Behind the dry line

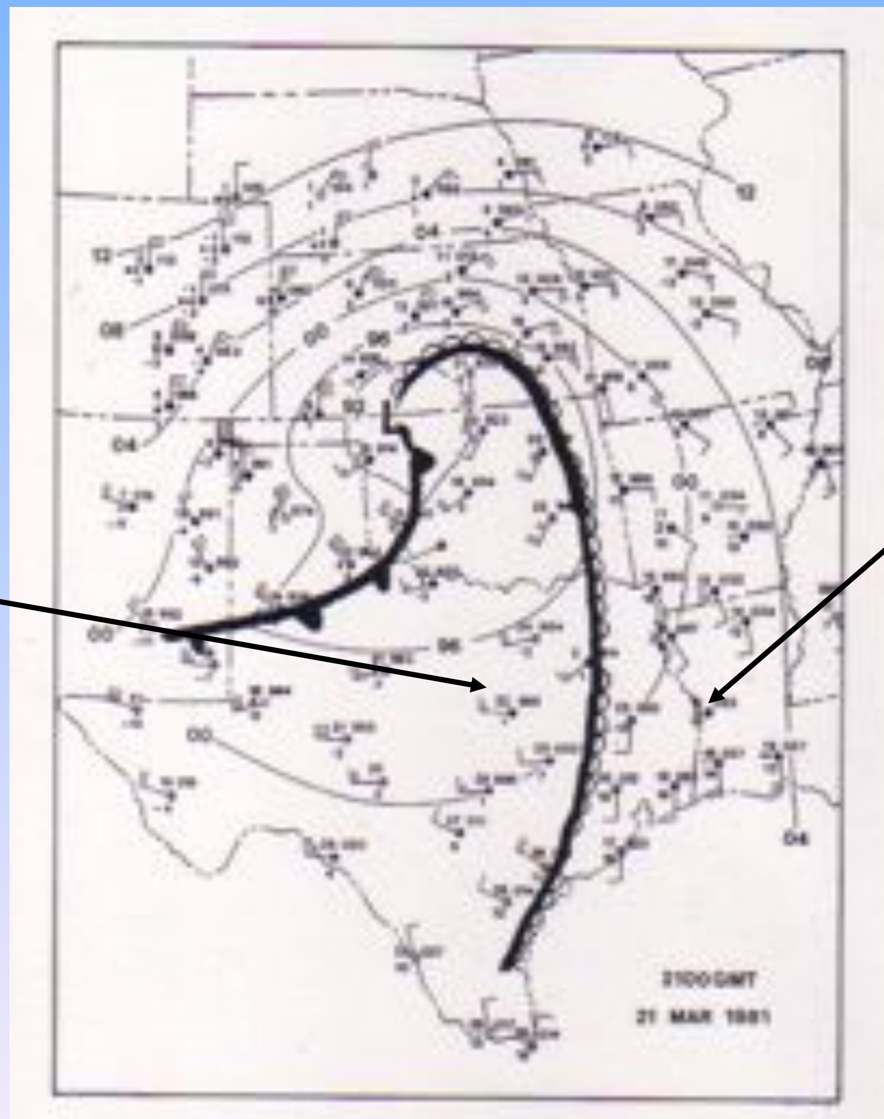
Westerly winds (often strong)

Clear skies

Daytime: Warm Temps

Large diurnal temperature range

Low moisture



Ahead of the dry line

South or southeast Winds

Hazy/cloudy skies

Daytime: warm temps

Small diurnal Temperature range

High moisture

Fig. 2.40 Bluestein II

Severe thunderstorms often develop along dry lines in late afternoon, particularly when dry air is present aloft above the moist air east of the dry line.

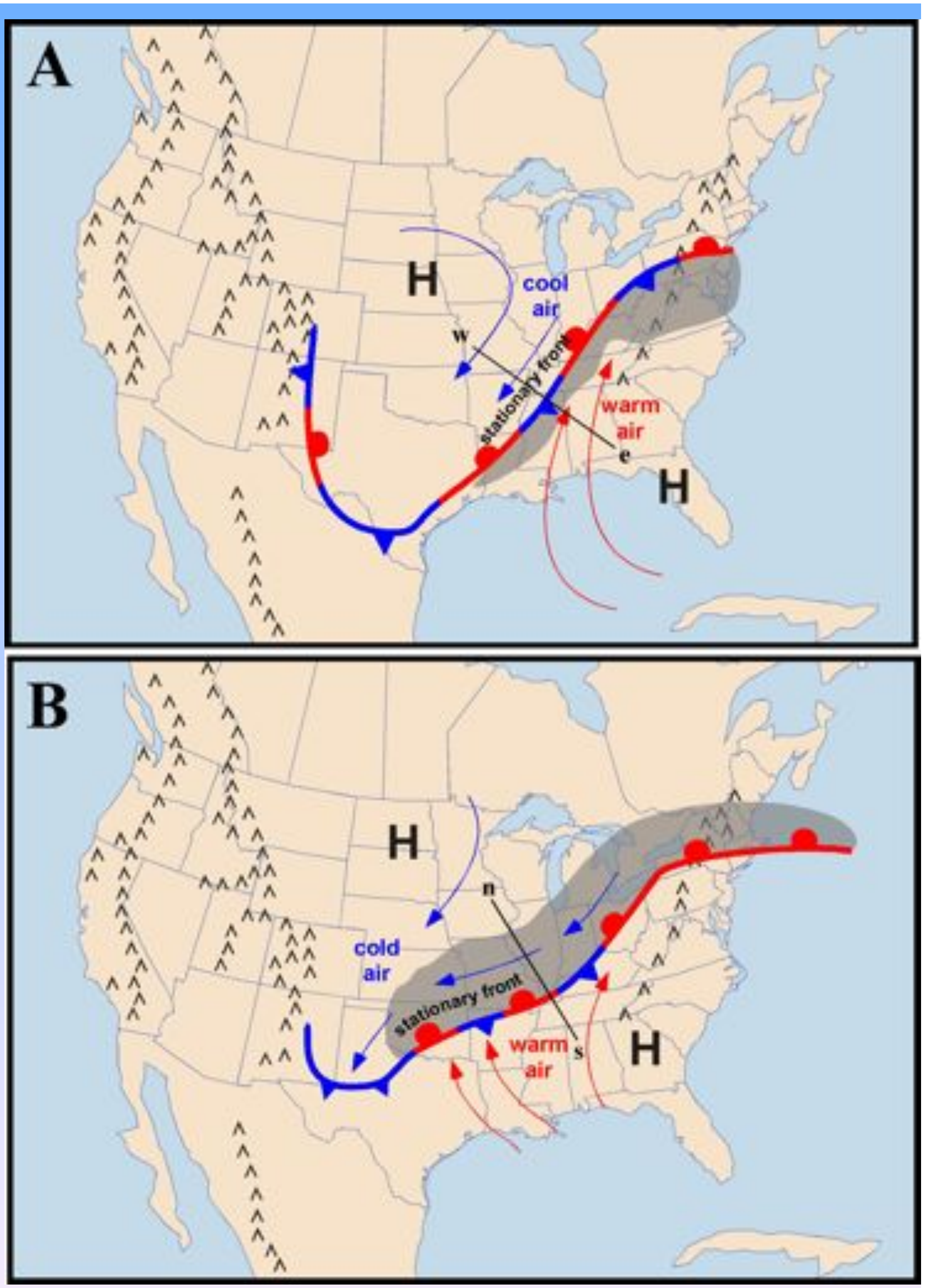
Dry line boundary

Courtesy of Bruce Lee

Stationary Fronts

Fronts are sometimes stationary.
Although the boundary is stationary, air on both sides of the boundary can be moving.

With a *stationary front*, air on the cold side of the front will always be flowing parallel to the front.

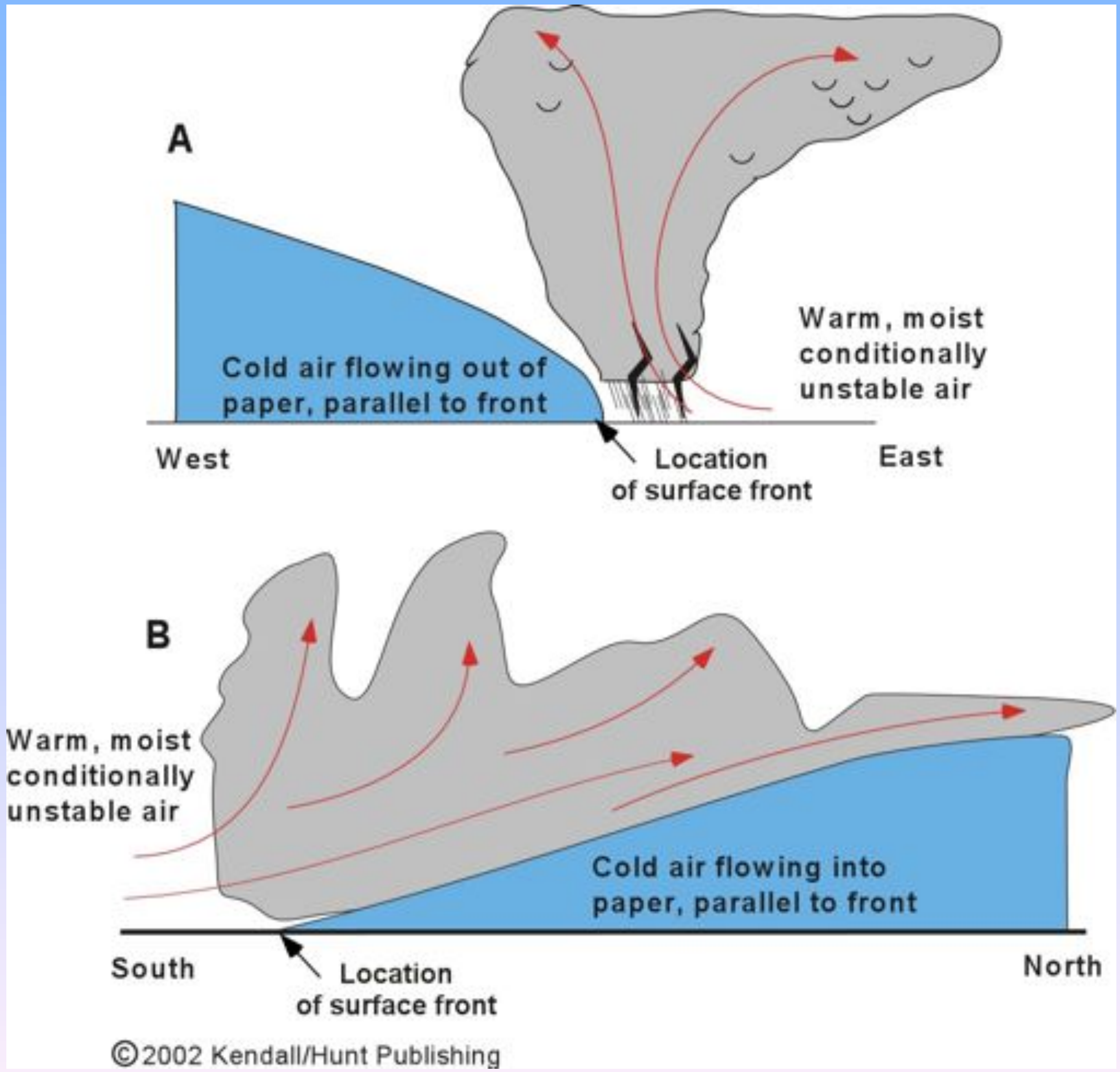


Stationary fronts may have physical structure similar to cold fronts or warm fronts

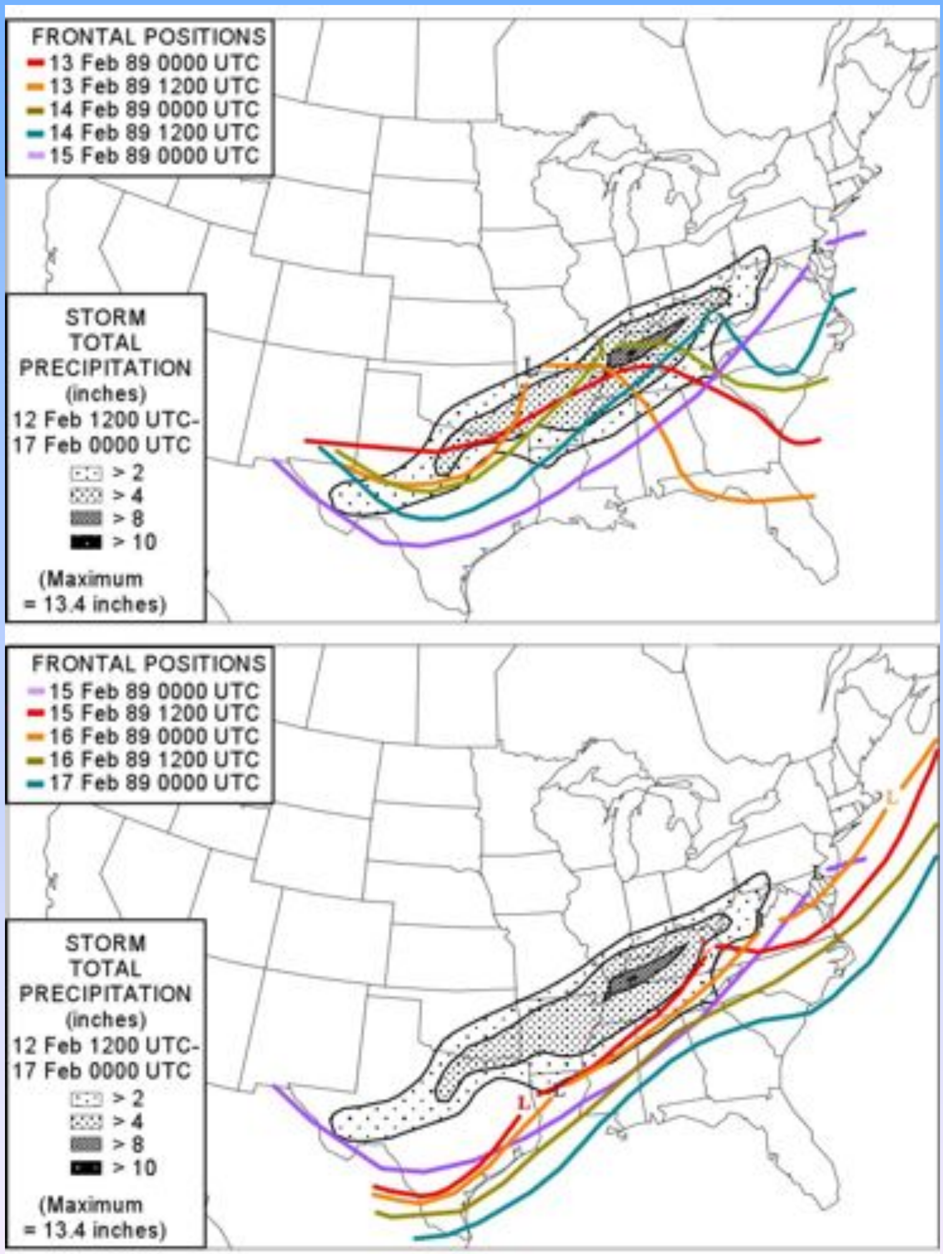
Significant weather along stationary fronts

FLASH FLOODS

ICE STORMS



Example of a stationary front that produced a local flash flood in Kentucky in 1989



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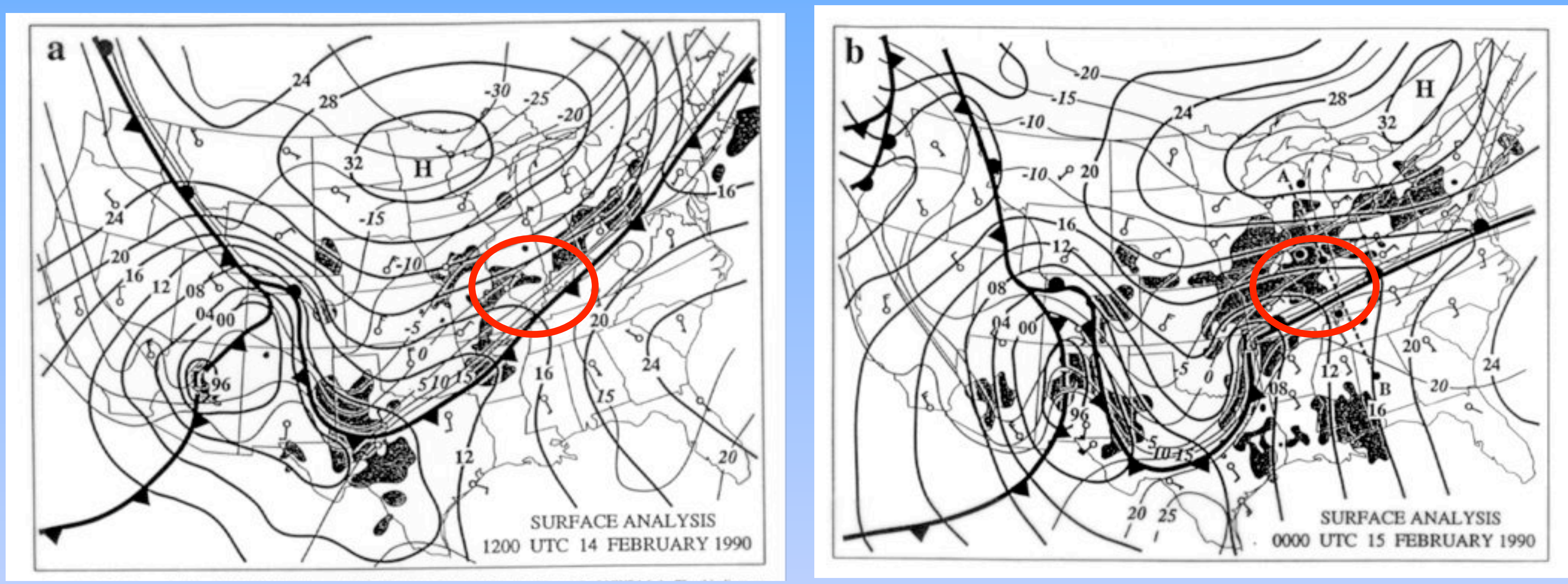
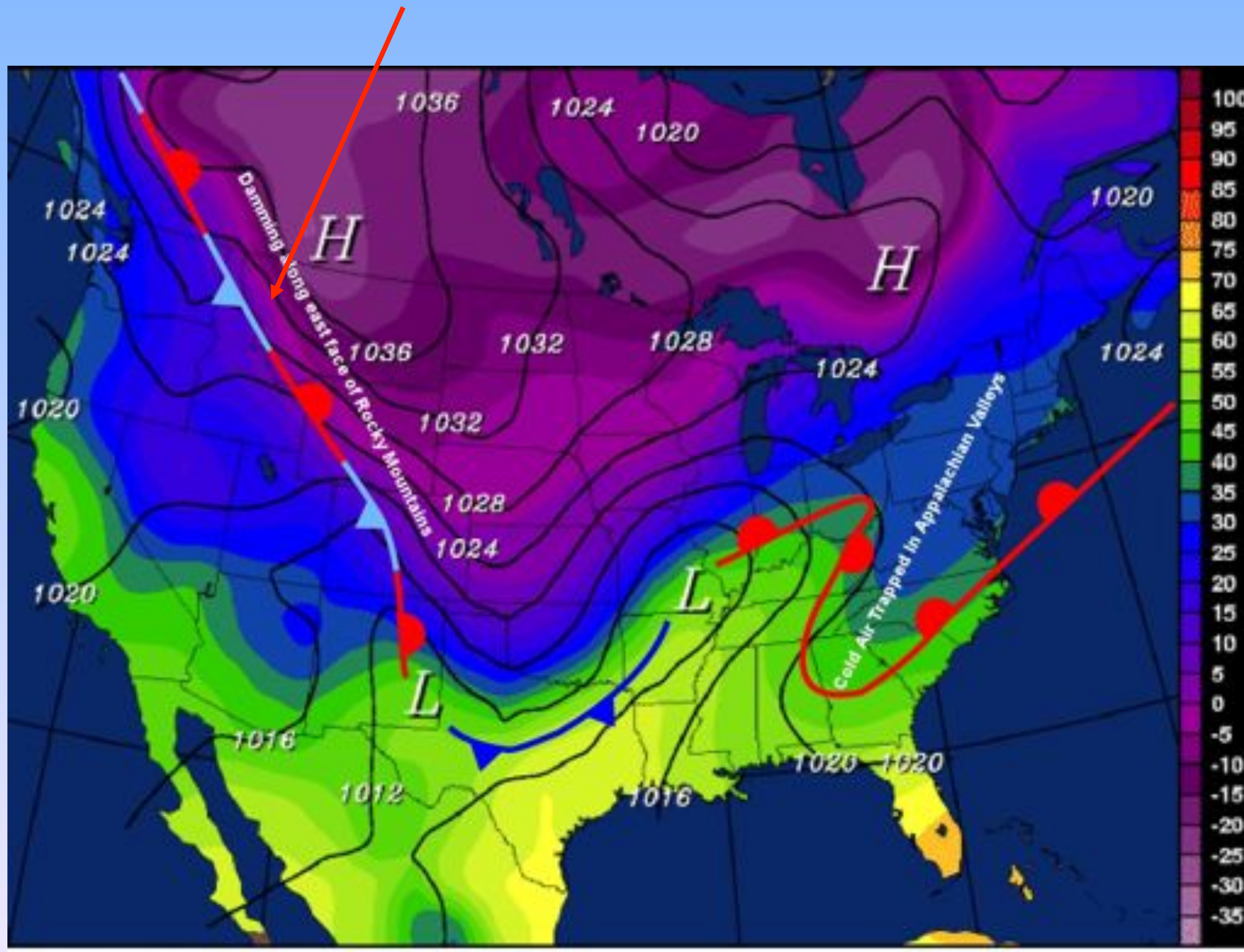


Stationary front that led to 30 Million Dollar Ice storm in 1990

Topography and Fronts

Cold air dammed along the Colorado Rockies is often analyzed as a stationary front. It is a boundary between air and rock.



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

Topography and Fronts

Cold air trapped in Appalachian valleys is often analyzed as a distorted warm front. The cold air in the front's southward "dip" is quite shallow. Above the top of the shallow air the front does not dip southward.