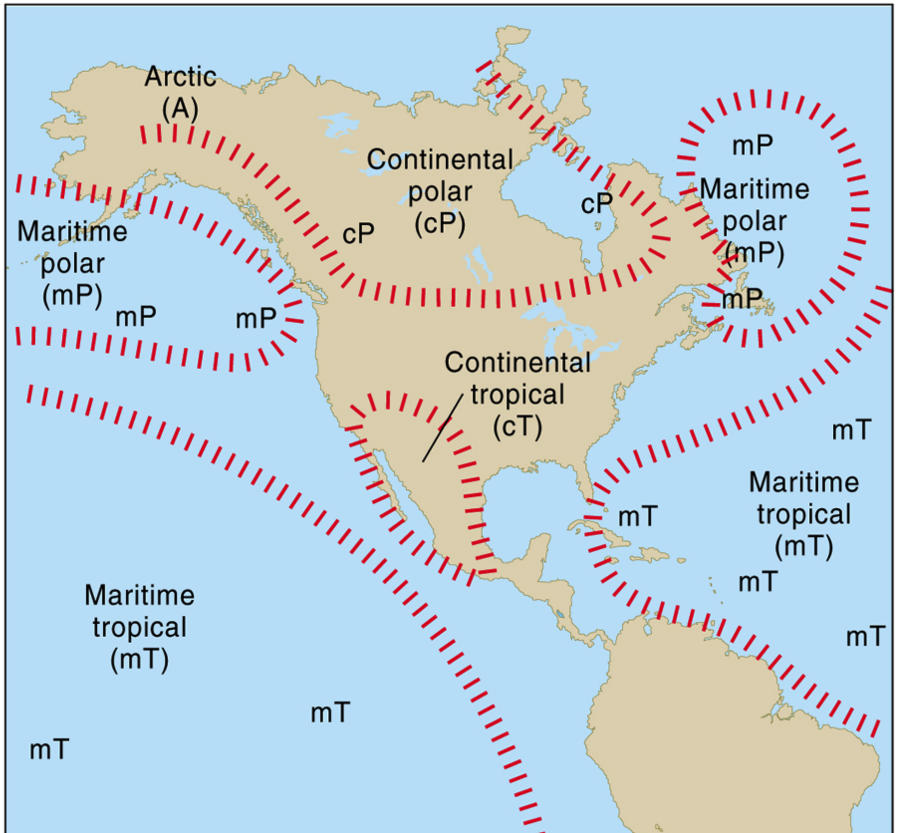
Air Masses, Fronts, and Frontal Cyclones

Chapters 9.1 of Atmospheric Science
Chapter 8 of Meteorology
Chapter 12 in MSE

Goals
Identify air masses and air mass source regions
Classify air masses based on weather maps or soundings
Locate and identify fronts on a weather map
Describe weather associated with types of air masses and fronts
Identify factors leading to cyclone development

http://campus.fsu.edu/
bourassa@met.fsu.edu

Air mass Source Regions



- The figure indicates typical source regions for various types of air masses.
- These regions will vary with season and surface conditions.
- Key distinguishing features are:
  - Warm or cold
  - Moist or dry
  - Sea or land
- The last two sets of features are considered identical.

Origin	Polar (P)	Tropical (T)
Continental (c)	cP (cold, dry)	cT (hot, dry)
Maritime (m)	mP (cool, moist)	mT (hot, humid)

Figure from **Meteorology**

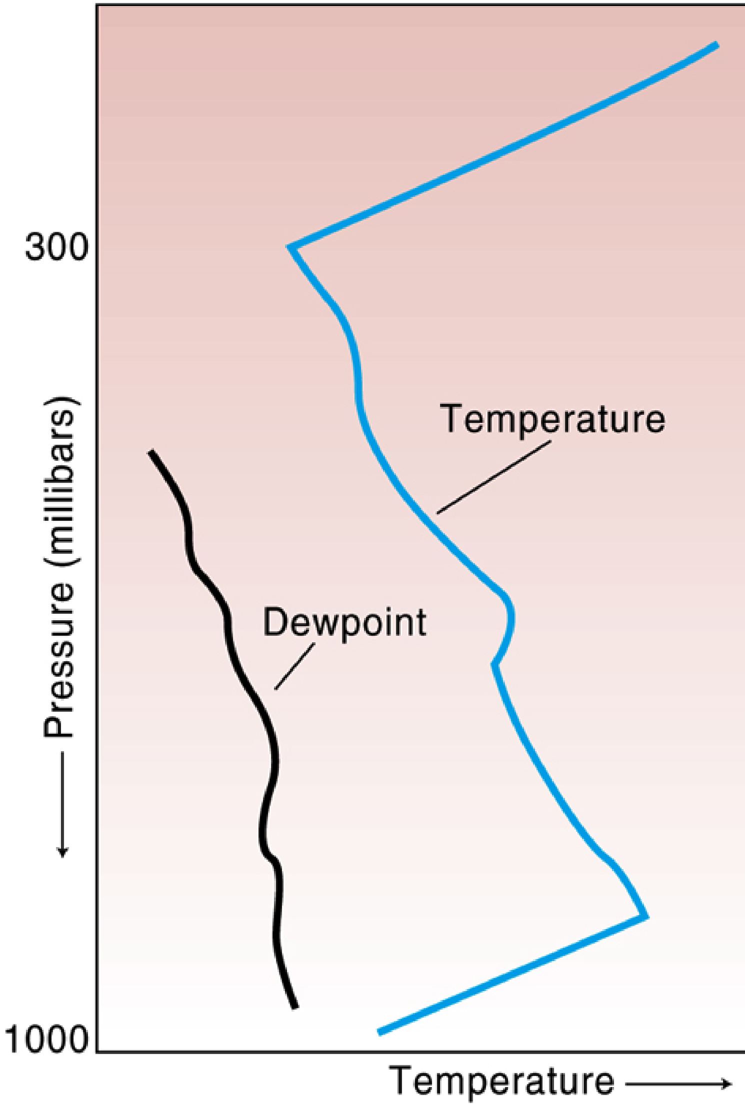
by Danielson, Levin and Abrams

Air Mass Designations

Origin	Polar (P)	Tropical (T)
Continental (c)	cP (cold, dry)	cT (hot, dry)
Maritime (m)	mP (cool, moist)	mT (hot, humid)

- Continental (c) air originates over land (making it relatively dry), and maritime air (m) originates over water, making it relatively moist.
- Tropical (T) air originates over warm surfaces (land or sea), and polar (P) air originates over cold surfaces (land or sea).
- Some classification schemes also include Arctic (A) for extremely cold air.
    - This is quite reasonable in Northern climates, where a layer of very cold (cA) air can underlie a layer of merely cold (cP) air.
    - Arctic air tends to come straight from the Arctic, without modification.
- What is meant by originates?
- In this context, originate means that the air mass is formed (modified) rather than created out of nothingness.

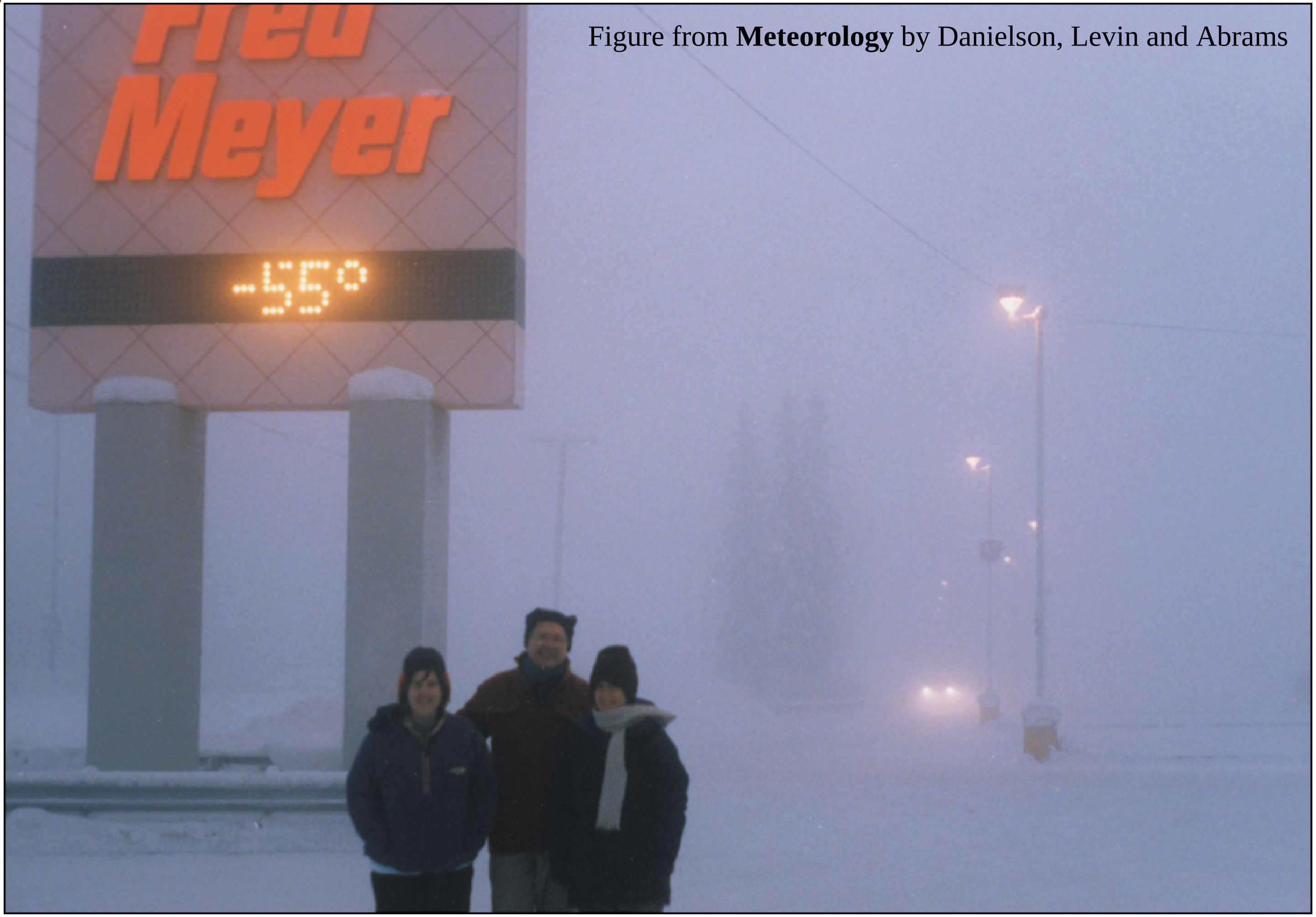
Example of cP Air: Radiosonde Profile for Bismarck, ND



- In far northern or southern winter, there is little solar heating, and the surface loses energy through longwave emission, resulting in cooling.
- The air in contact with the surface also cools.
- Note the strong temperature inversion due to this cooling.
- The dewpoint temperature is far less than the air temperature.
  - The relative humidity is very low.
- Can pick up more moisture when passing over lakes.

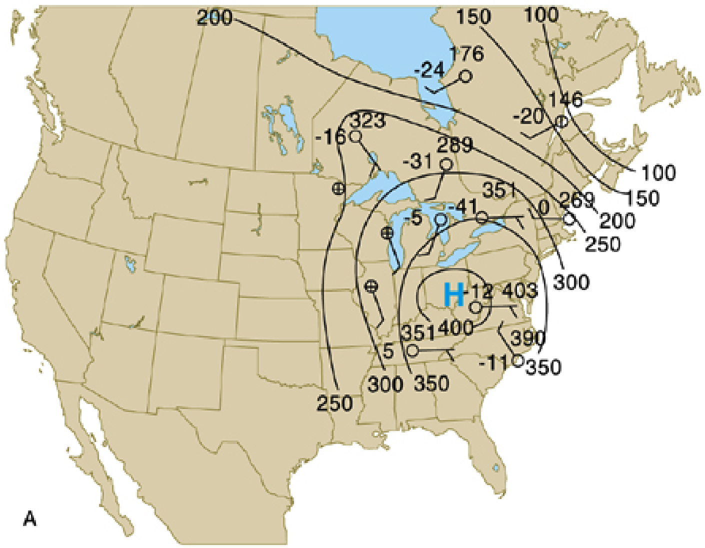
Figure from **Meteorology** by Danielson, Levin and Abrams

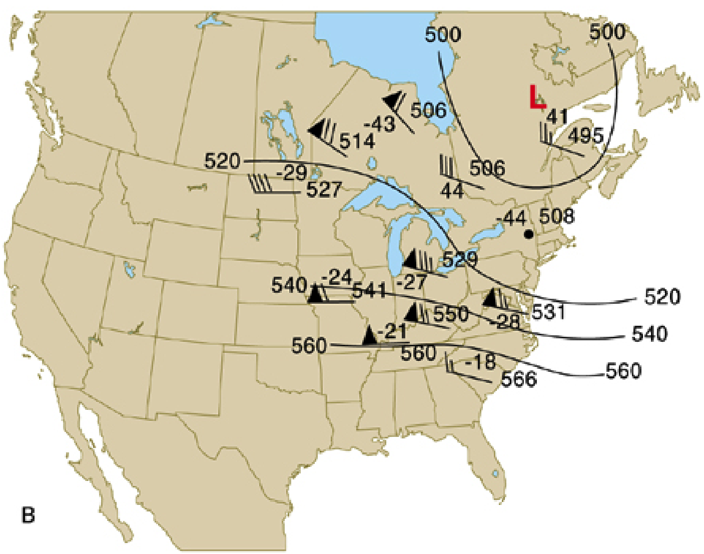
Danielson Family Shopping in Fairbanks, Alaska



- Example of ice fog in a cA air mass.

Example Surface Map: Continental Polar Air Mass





Continental Polar air has been modified as it moves southeast across the continent.

- The relatively cold dense air forms a surface high (fig. A).
- The cold core high pressure system rapidly loses intensity as the height increases.
  - There is no evidence of the surface high on the 500mb plot (fig. B).

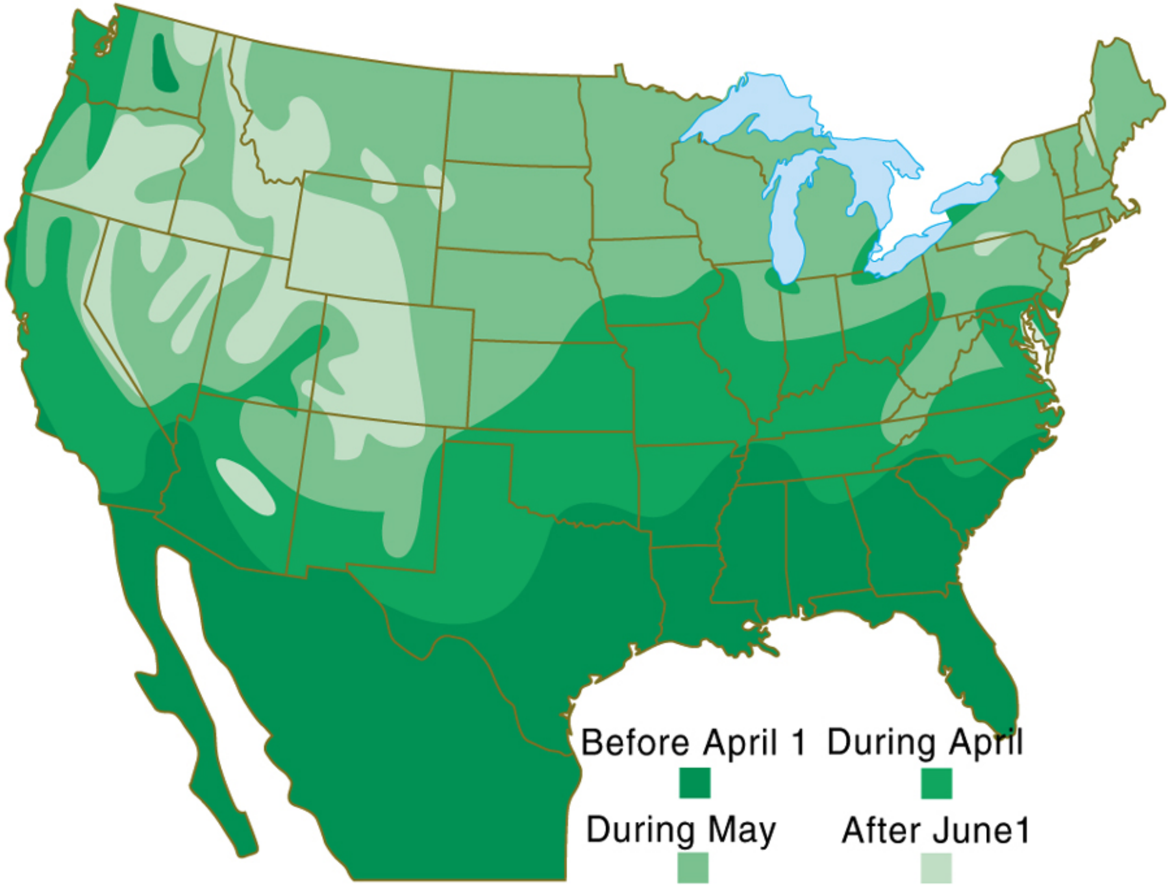
Note:

The transition to an cP air mass can take over a week. Cooling occurs at a rate of about 2°C per day.

- After ice clouds form this rate can increase to 3°C per day.

Figure from **Meteorology** by Danielson, Levin and Abrams

Average Date of Last Freezing Spring Temperatures



- The average date at which freezing temperatures last occurs shows how the continental air mass retreats during the spring.
- In summer, cP air is usually confined to the Arctic.
- In fall, the cooling begins again, and strong temperature gradients lead to strong frontal storms.

Note that the average value is of little use for agricultural applications: probability distributions are now used in planning.

Figure from **Meteorology** by Danielson, Levin and Abrams

Maritime Polar Air mass Conditions

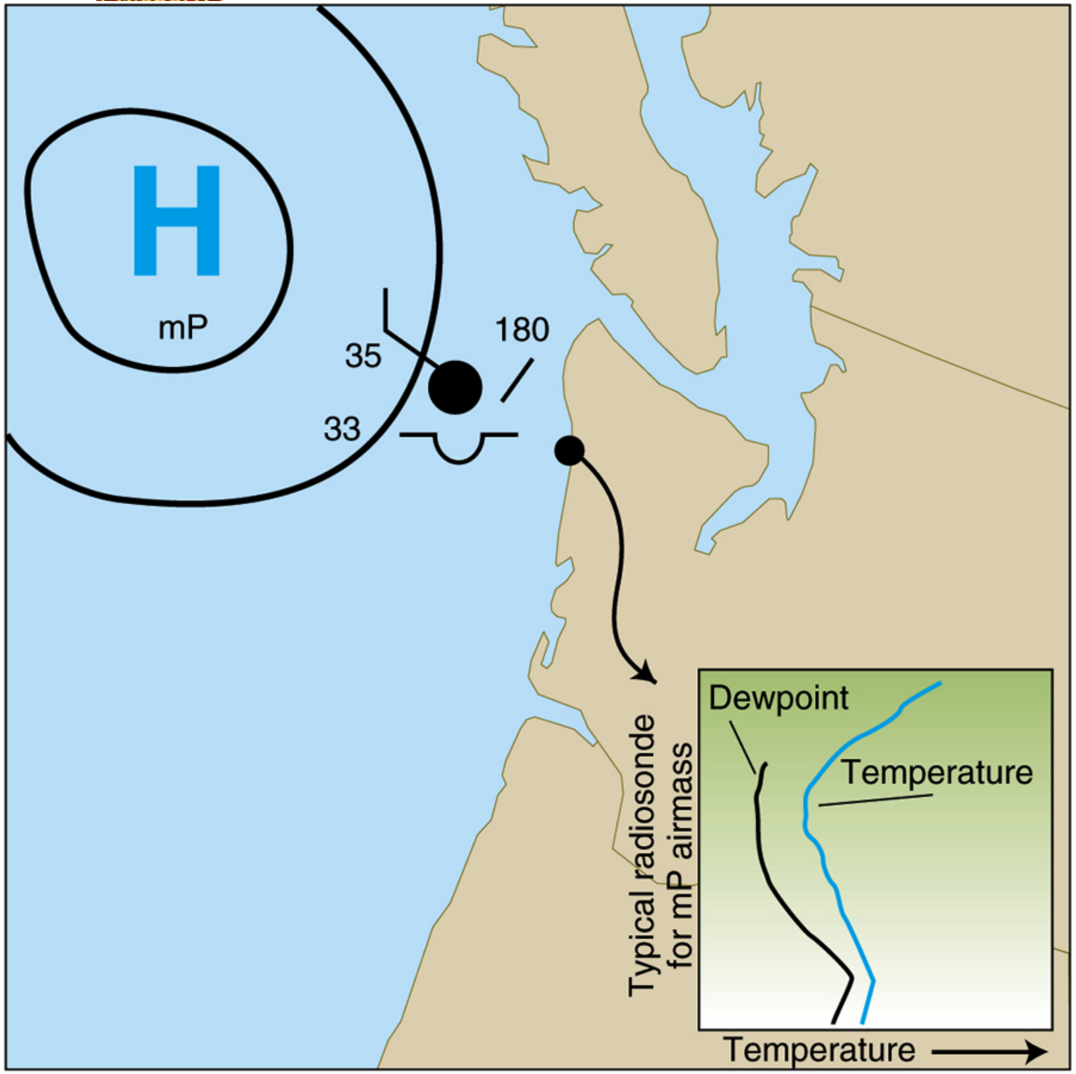


Figure from **Meteorology** by Danielson, Levin and Abrams

- mP air masses originate at high latitudes over water.
- Transformation to mP air takes about 2 days.
- The low-level air acquires the properties of the water.
  - The thickness of this layer is much greater than for cP air masses.
  - Consequently, the stratification is less stable.
- On the East coast, air from the Labrador Sea moves inland and is guided South by the Appalachians.

Continental Tropical Air mass Conditions

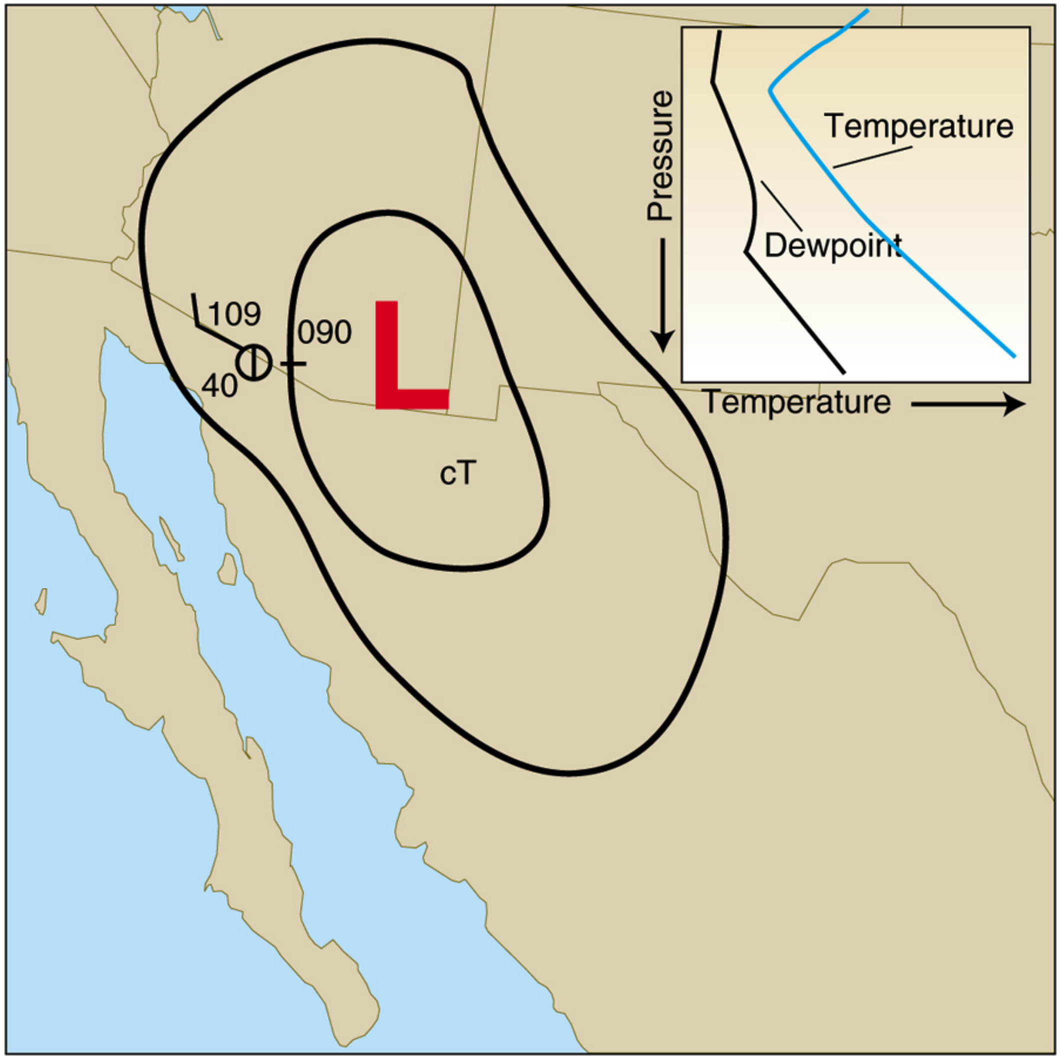
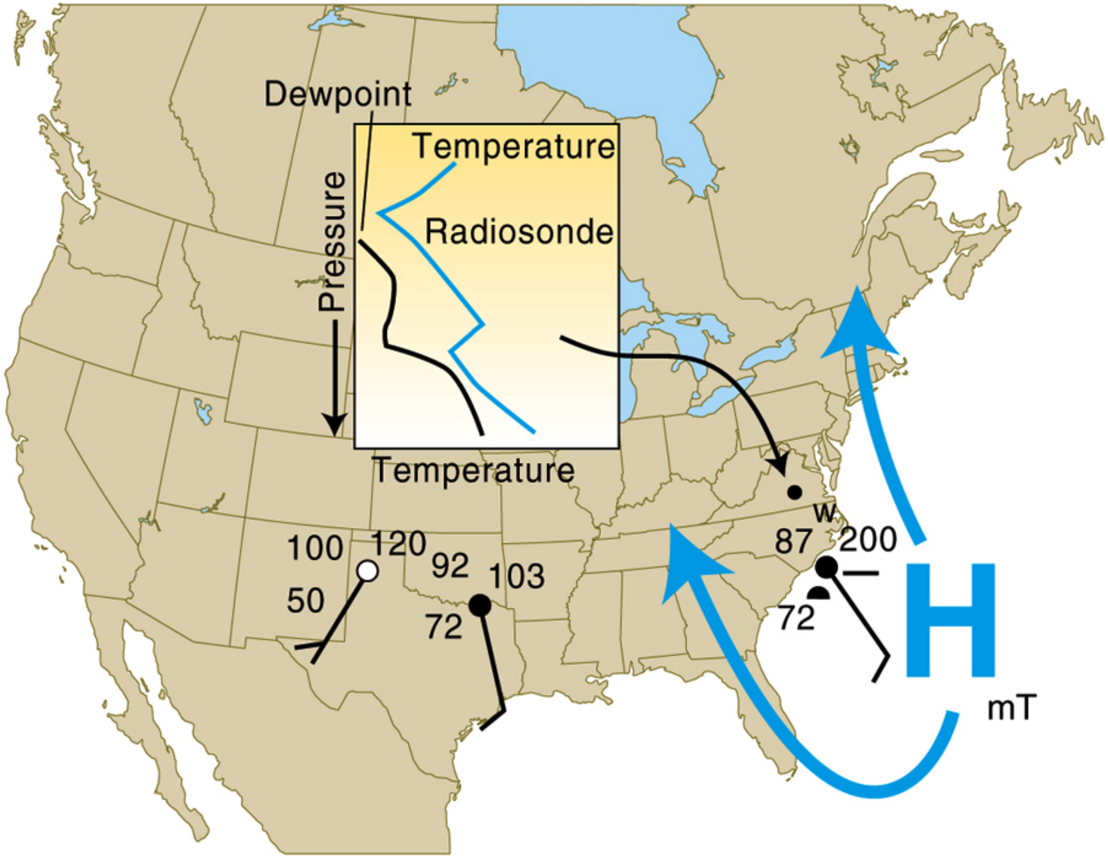


Figure from **Meteorology** by Danielson, Levin and Abrams

- Continental Tropical air masses originate over hot land.
- These masses form when a large air mass resides over dry tropical lands for an extended period of time.
- The pressure system involved in creating the air mass is a mild low pressure system, usually due to thermal lows.
- Large masses of cT air come from large desert regions in North Africa and the Middle East.
  - T > 40°C &
  RH(Relative Humidity)< 10%
  - World's hottest (Libya)
    - T = 58°C
- Santa Anna winds (cT air) in California are blamed for spread of large forest fires

Maritime Tropical Air mass Conditions



- Maritime Tropical air masses originate over very warm water.
- Transformation to mT air takes about 2 days.
- The temperature and humidity conditions are mixed in a relatively thick lower layer.
- The origin region is typically semi-permanent high pressure systems.
- In summer, mT air is typical in Tallahassee, and it can be a frequent visitor in the winter.

Figure from **Meteorology** by Danielson, Levin and Abrams

A “Classic” Cold Front

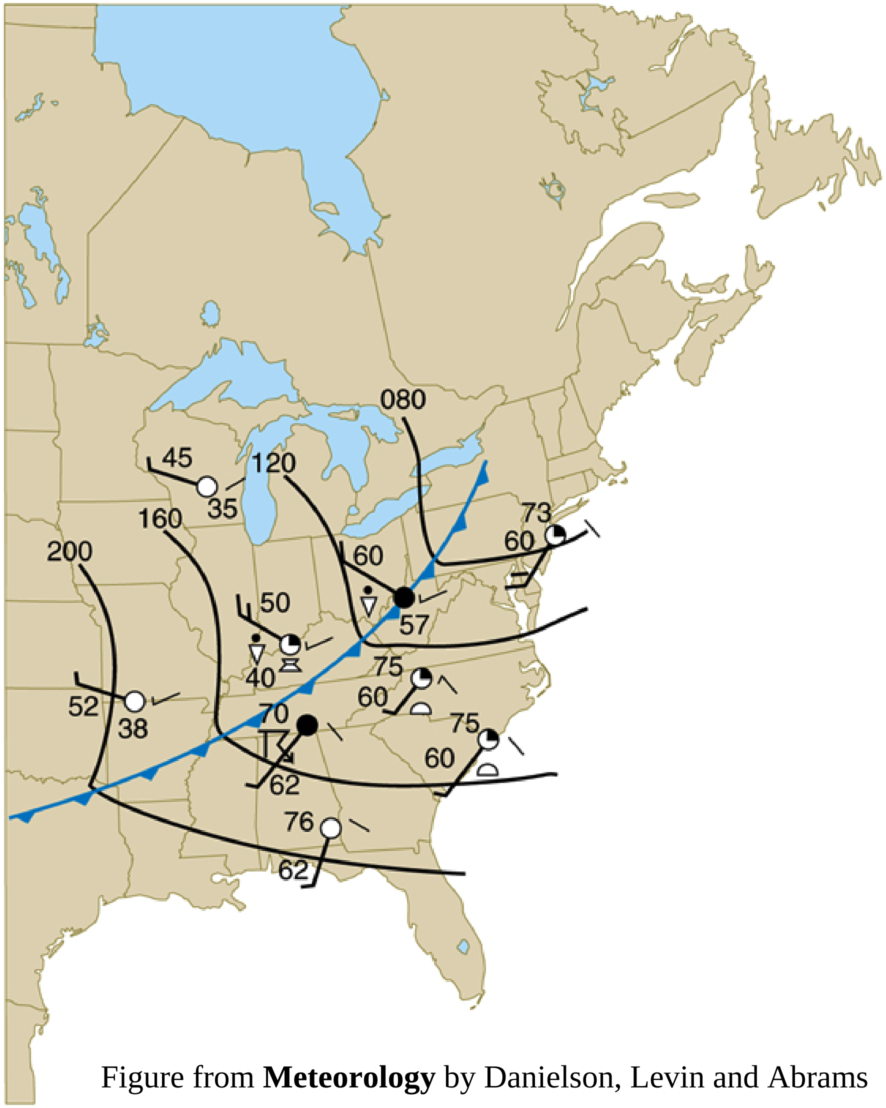
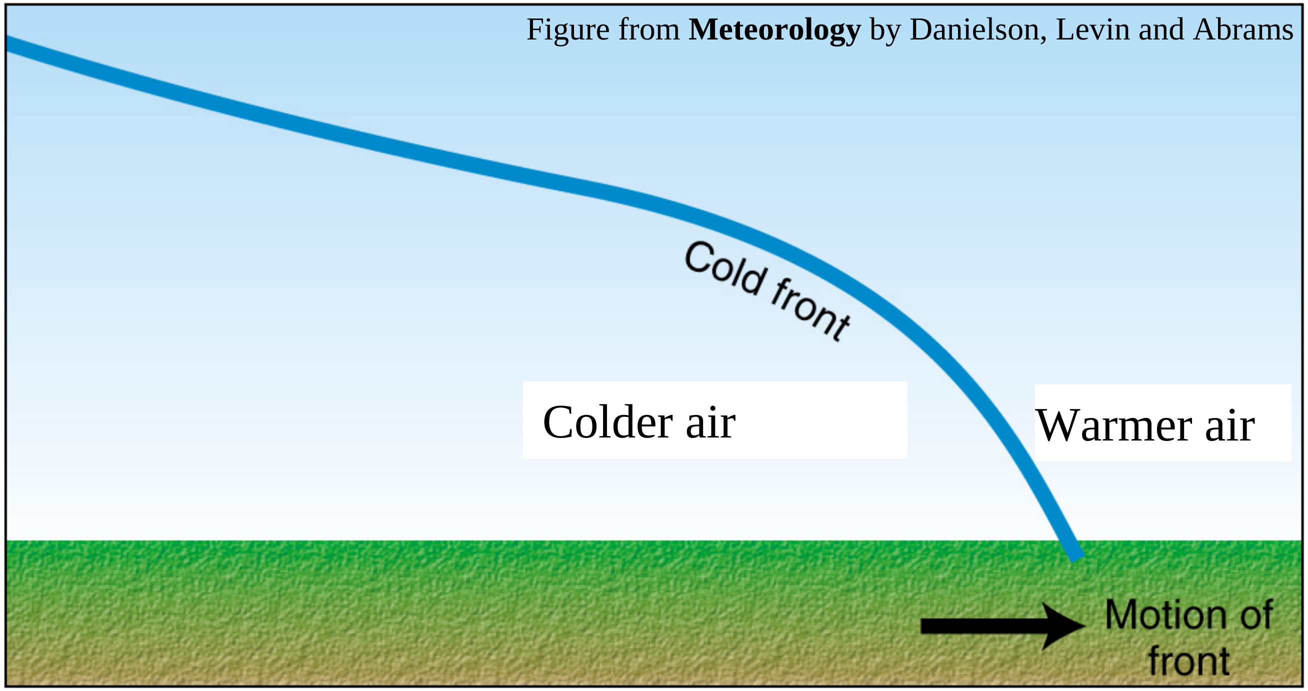


Figure from **Meteorology** by Danielson, Levin and Abrams

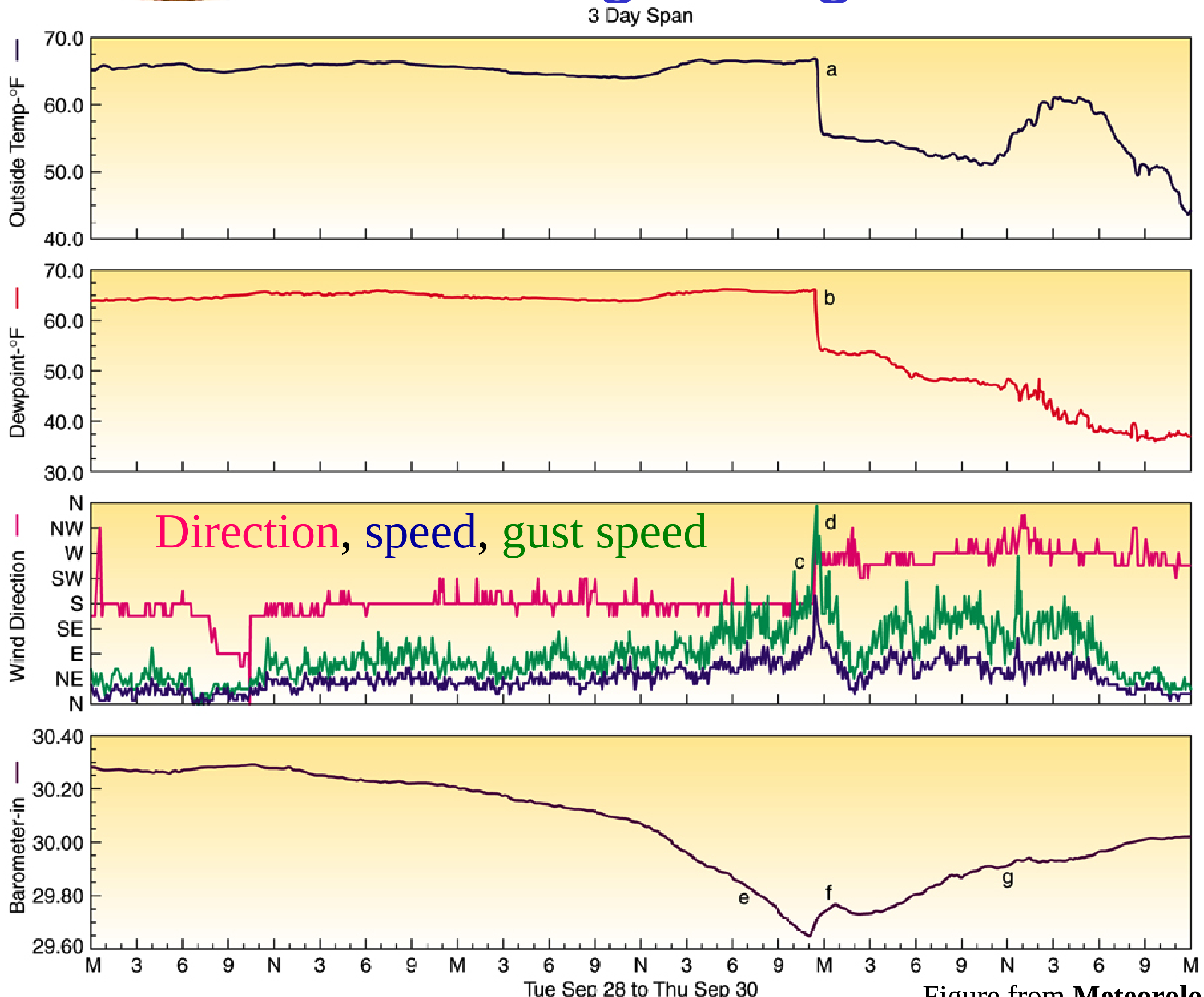
- A front is a boundary between two air masses
- Cold fonts have cold air advancing.
- Warm fronts have warm air advancing.
- If neither warm nor cold air is advancing, the front is called stationary
- An occluded front occurs when one front is overtaken by another front.
- Changes in the following can (but won’t always) occur at a front: temperature, dew point temperature, and wind direction
- Another characteristic is the kink in the isobars (towards higher pressure).

A Cold Frontal Surface



- The location of a cold front is defined by the leading edge of the rapid change to colder weather.
- Cold fronts are steepest near the surface, and can be quite gently sloped aloft (particularly cA air).
- Surface convergence can occur 60 to 120km ahead of a cold front, and hence cause lifting of the warmer air and perhaps precipitation.

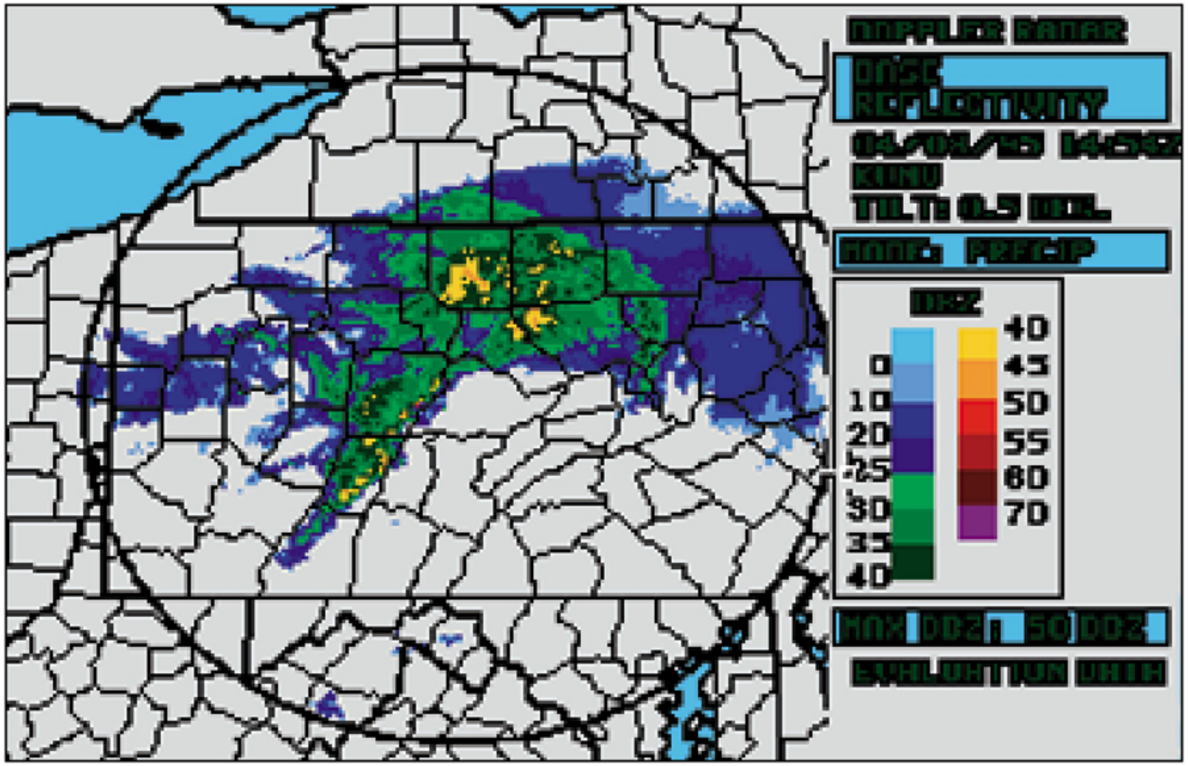
Home Weather Station
Showing Passage of a Cold Front



- The temperature dewpoint, and wind direction are approximately constant until the front arrives.
- The pressures fall until the front arrives, then jump.
- The peak wind speeds occur when the front arrives

Figure from **Meteorology** by Danielson, Levin and Abrams

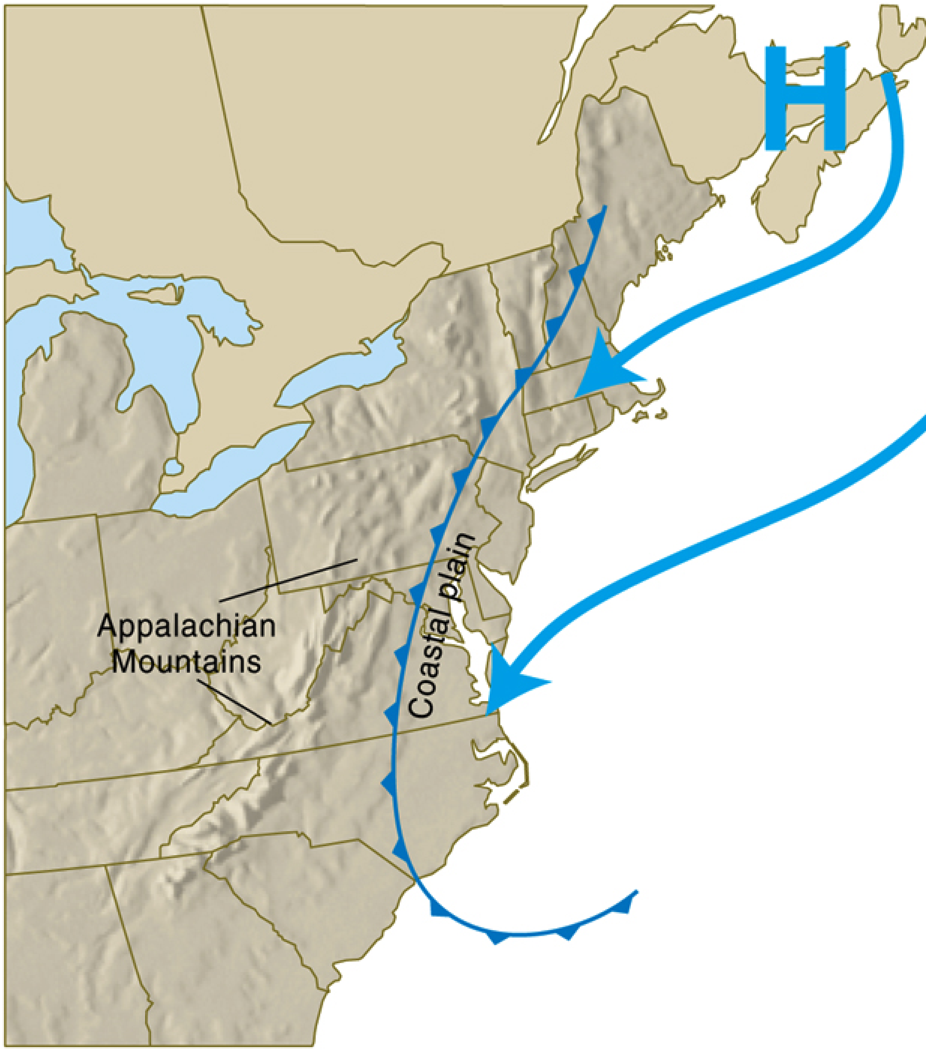
Doppler Radar
Image of Thunderstorms



- The radar shows precipitation occurring in front of a front.
- Precipitation causes a drop in temperature (confusing the definition of a front)
- Smaller scale fronts (called gust fronts) are often spawned by fronts, and usually precede the large scale front.

Figure from **Meteorology** by Danielson, Levin and Abrams

Backdoor Cold Fronts



- Cold fronts typically sweep into the US (or form) on the East side of the Rockies, then move eastward.
- In cooler seasons, some can cross the East coast moving to the West.
  - What is the originating air mass?
- These fronts are often trapped by the Appalachians, and move South down the coast.
- These fronts can spawn low pressure systems that can grow very rapidly.

Figure from **Meteorology** by Danielson, Levin and Abrams

The Dryline

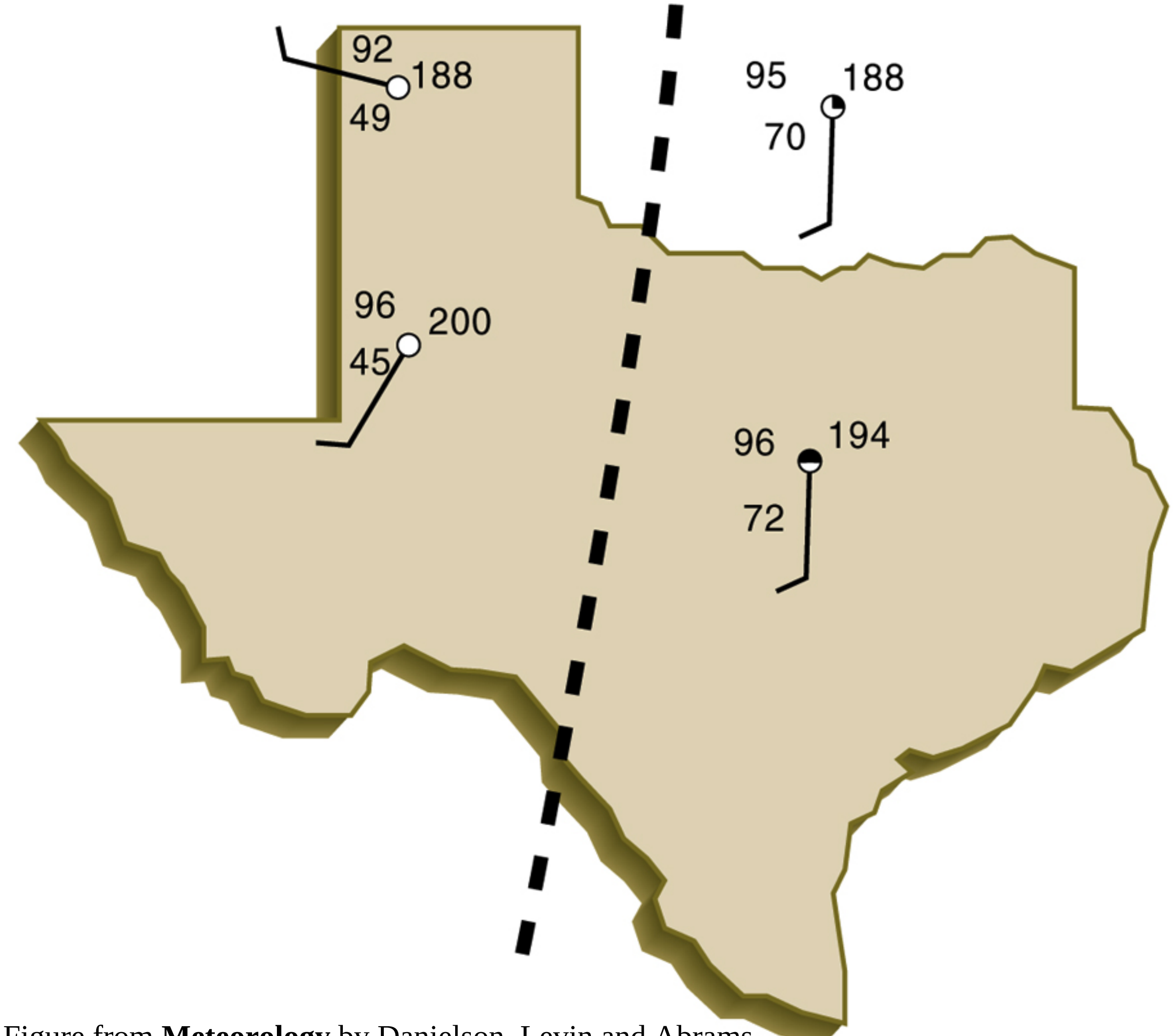
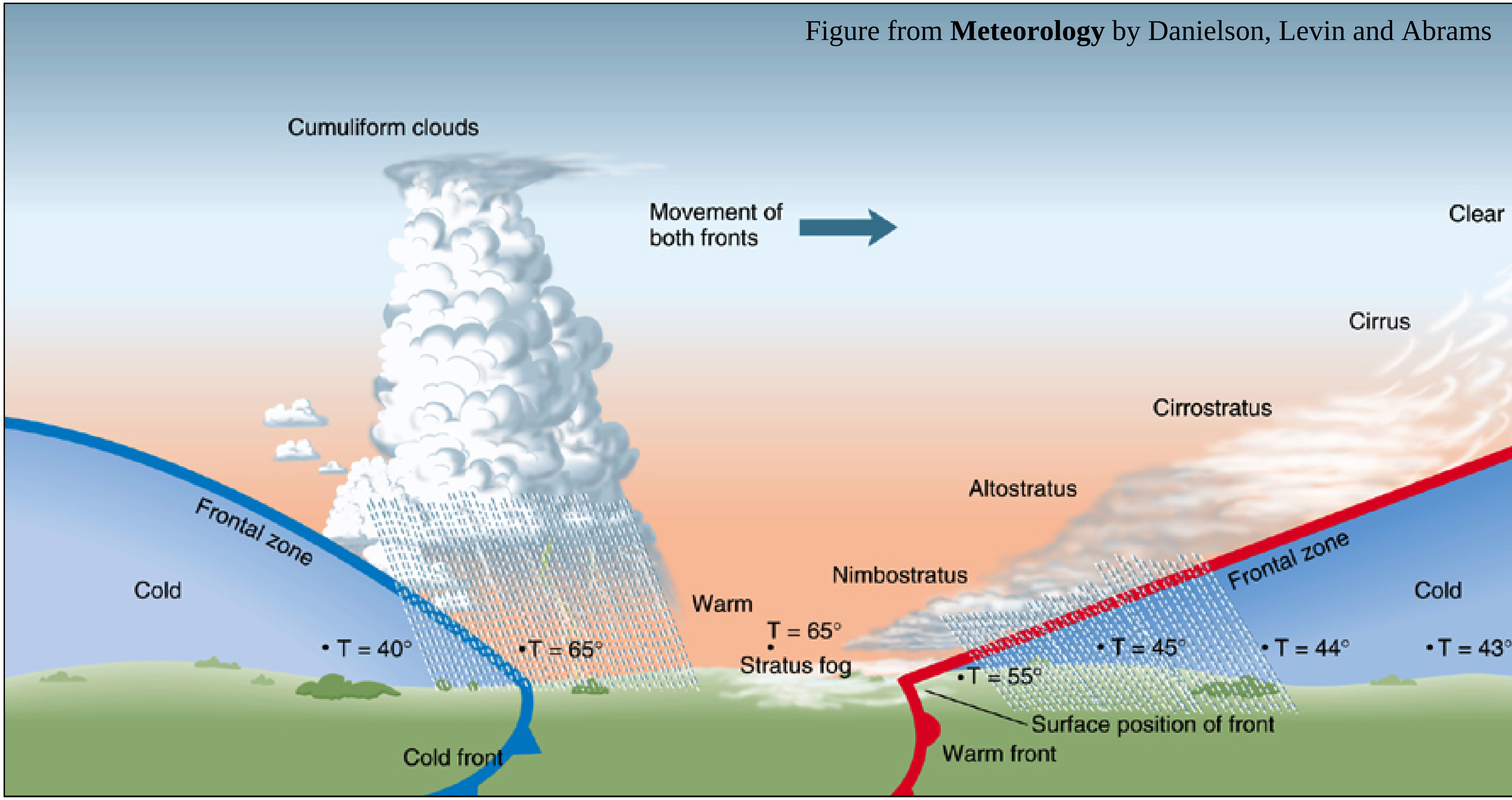


Figure from **Meteorology** by Danielson, Levin and Abrams

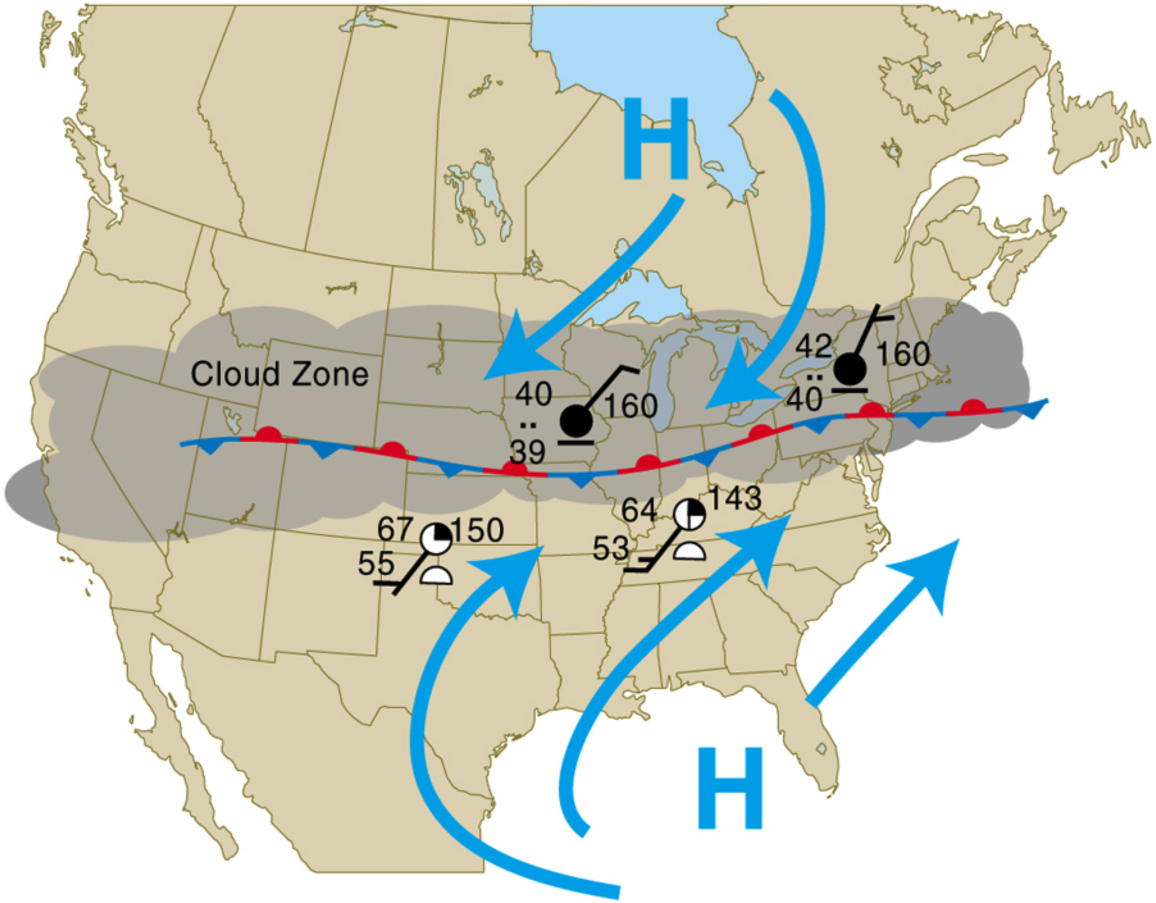
- Is the dryline really a front? And if so, what types of air masses does is separate?
- It is known as a front separating moist and dry air masses (mT & cT air)
- The dryline has substantial dewpoint contrasts.
- Lows propagating eastward from Colorado can push the dryline to the East.
- Why is the relatively moist air lifted?
- This lifting triggers some of the most violent thunderstorms and tornadoes in the USA.

Cold and Warm Fronts in Profile



- Examples of the cloud types and precipitation associated with the passage of fronts, as well as the change in temperature.
- What type of air masses are likely to be involved in this example?

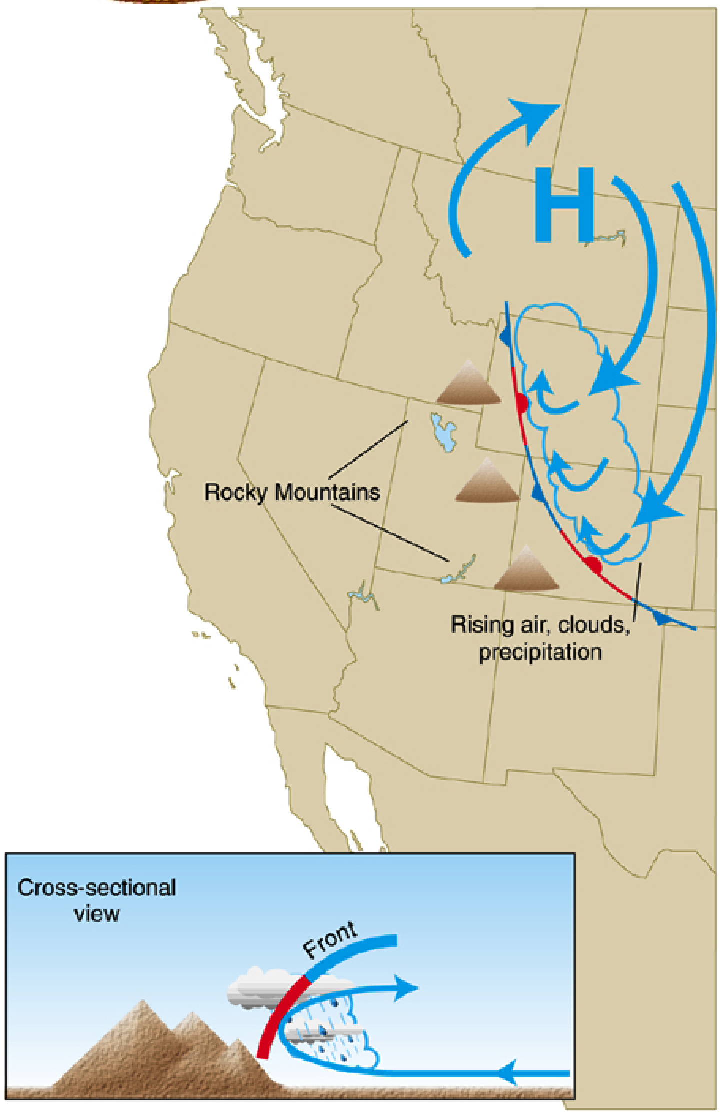
Typical Stationary Front



- Stationary fronts have insufficient push to move the cold air forward very far.
- Typically these fronts move back or forth over a region.
- Warm air can overrun a stationary front, possibly producing precipitation.

Figure from **Meteorology** by Danielson, Levin and Abrams

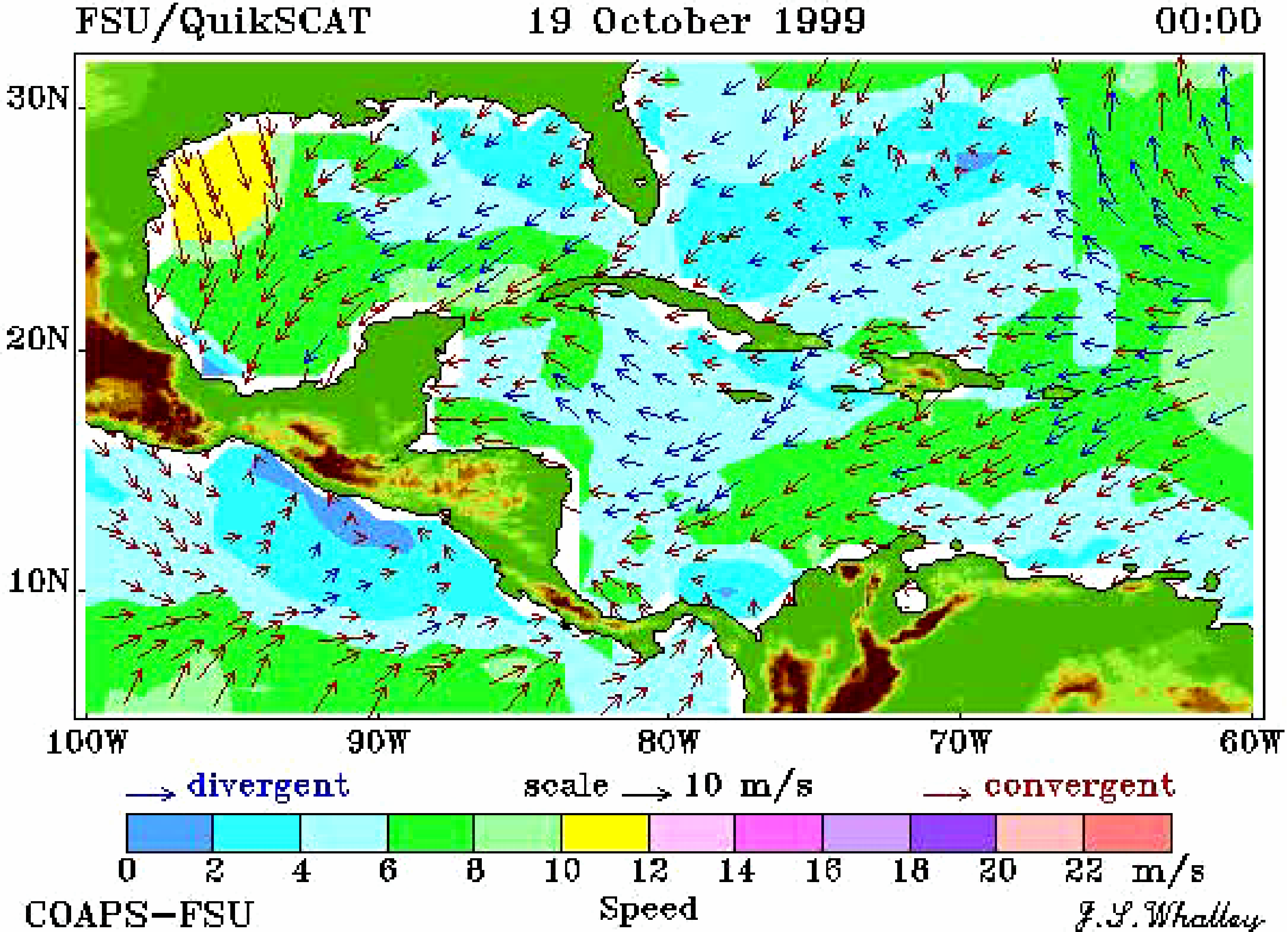
Stalled Stationary Front



- In some cases, the height of the top of a cold air mass is less than the height of adjacent mountains.
- In this case, the air mass is blocked by the mountains.
- The associated front moves along the mountain chain for the portion of the air mass that is adjacent to the mountains.
- This is a common occurrence along the Rockies.
- In winter, such fronts can move South of the Gulf of Mexico.

Figure from **Meteorology** by Danielson, Levin and Abrams

Unusual Example of cP Air Directed by Mountains



Occluded Fronts Profile

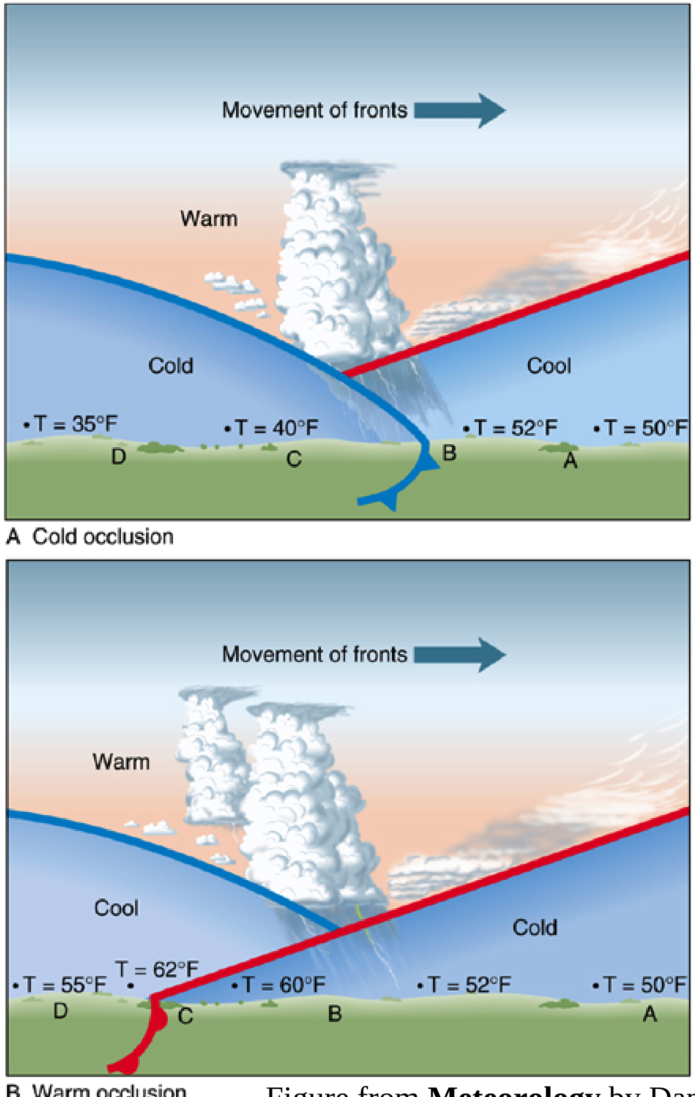
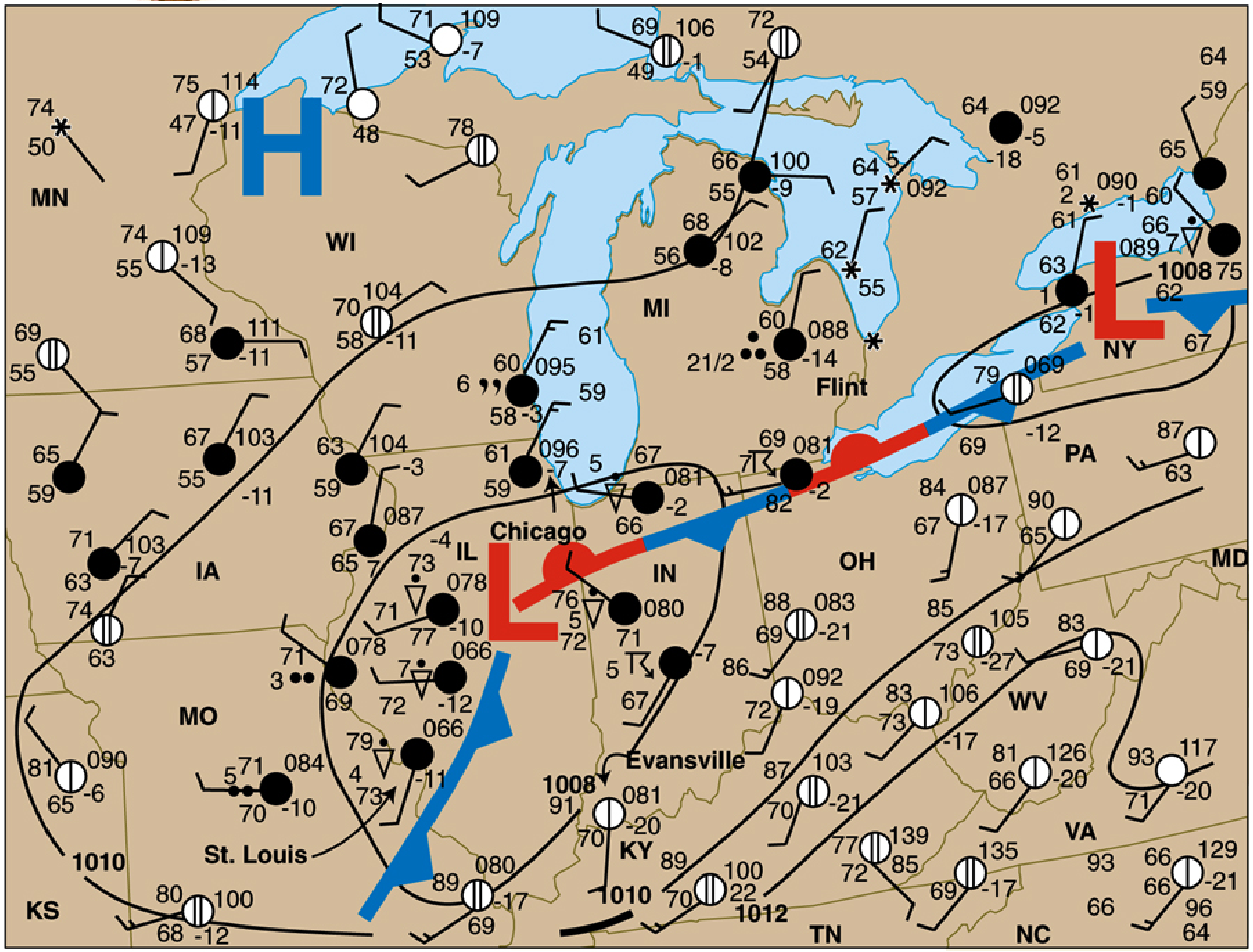


Figure from **Meteorology** by Danielson, Levin and Abrams

- Occlusion begins when a cold front overruns a warm front.
- Near the occlusion, there is a regions where three air masses are stacked.
- Cold occlusions occur when the overtaking air mass has colder air than the the air in front of the warm front.
  - The surface front is a cold front.
- Warm occlusions occur when the overtaking air mass has cooler but less dense air than the the air in front of the warm front.
  - The surface front is a warm front.
- The weather associated with the passage of an occluded front is initially that of a warm front, but then transitions to a mix of warm and cold front characteristics.

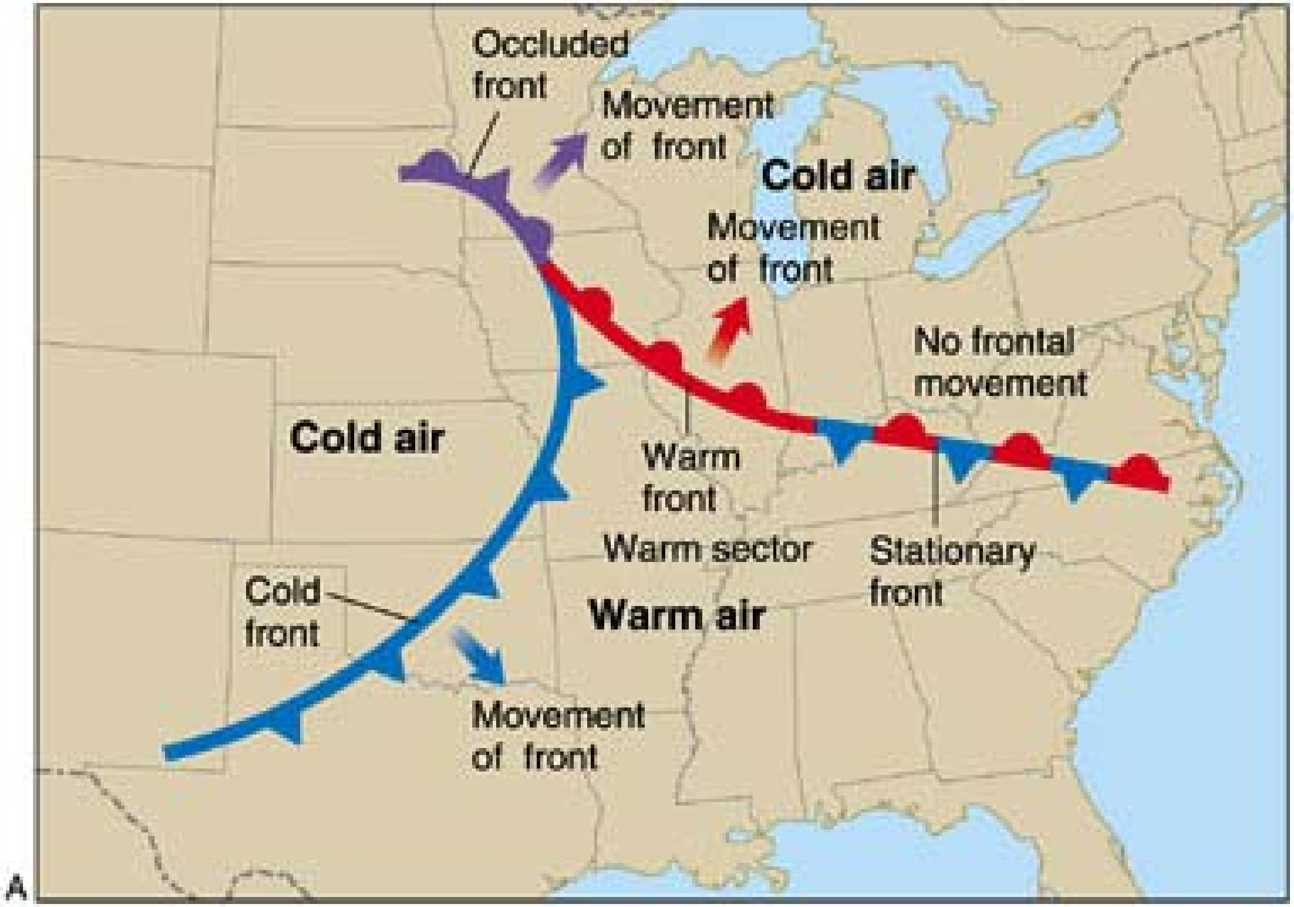
Fronts



HOURLY DATA
VALID 22Z 14-JUL-92

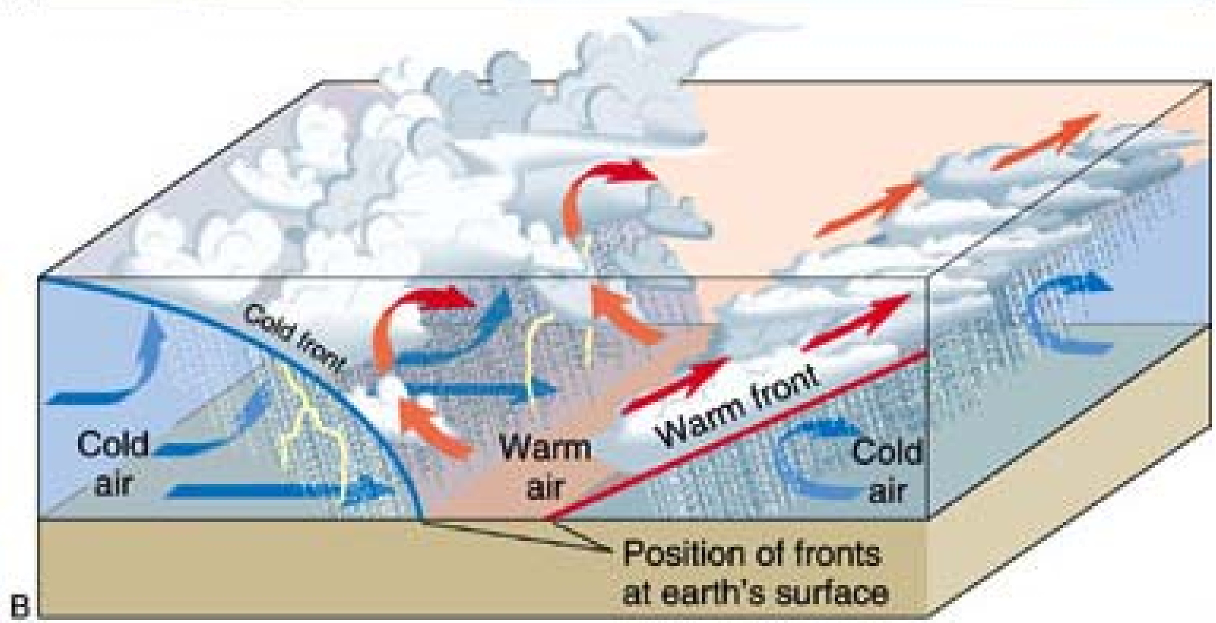
- Fronts separate different air masses
- Characteristics of air masses are
  - Wind direction
  - Temperature
  - Humidity
- Characteristics of fronts are
  - Cloud types
  - Precipitation
  - Changes in wind

Warm, Cold, and Stationary Fronts



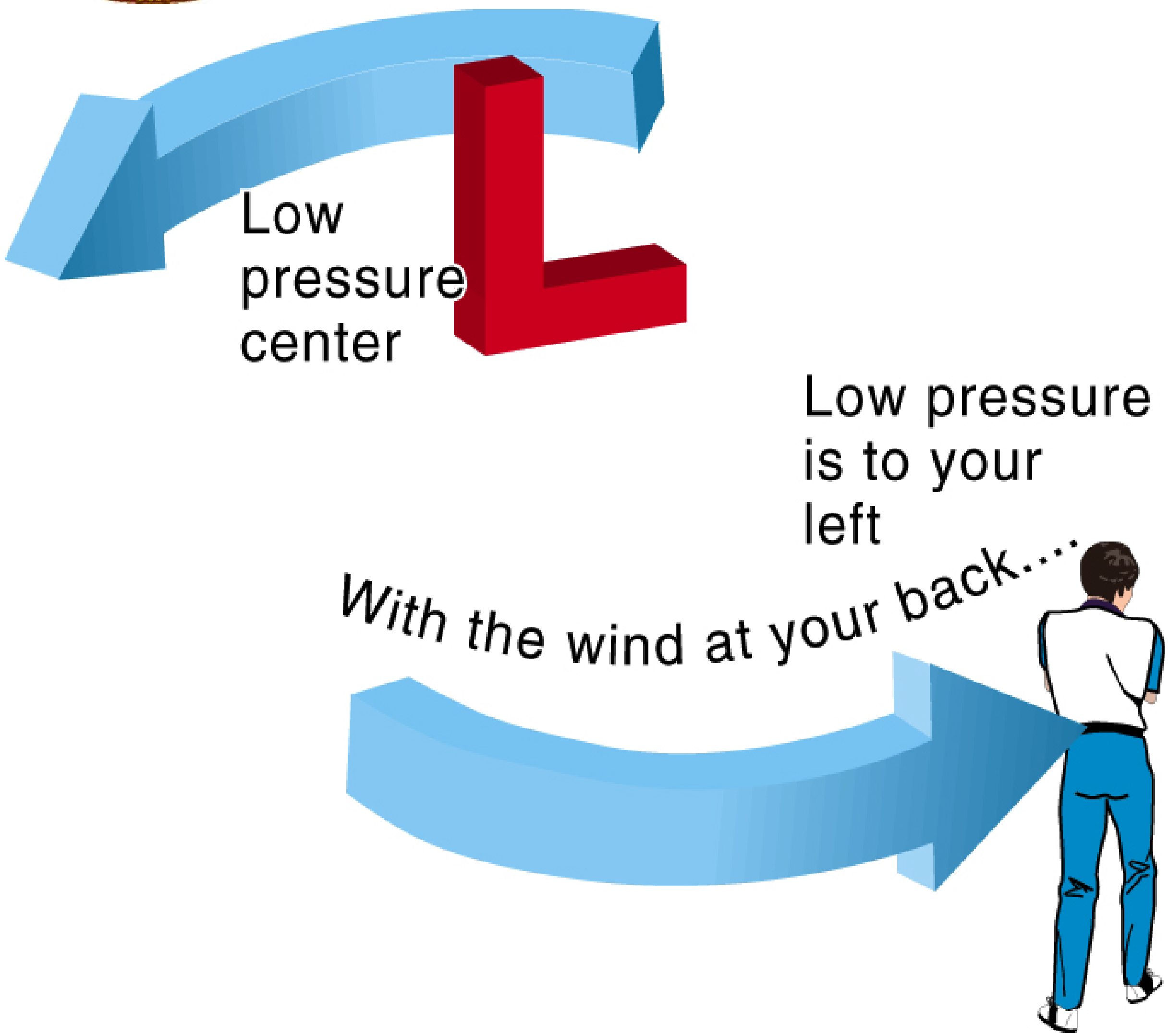
- Fronts
  - pass through areas of low pressure
  - Avoid areas of high pressure
- The blue lines with jagged 'teeth' indicate cold fronts
- The red lines with smooth 'teeth' indicate warm fronts
- Blue and red lines indicate stationary fronts
- Purple front is occluded

Warm and Cold Fronts

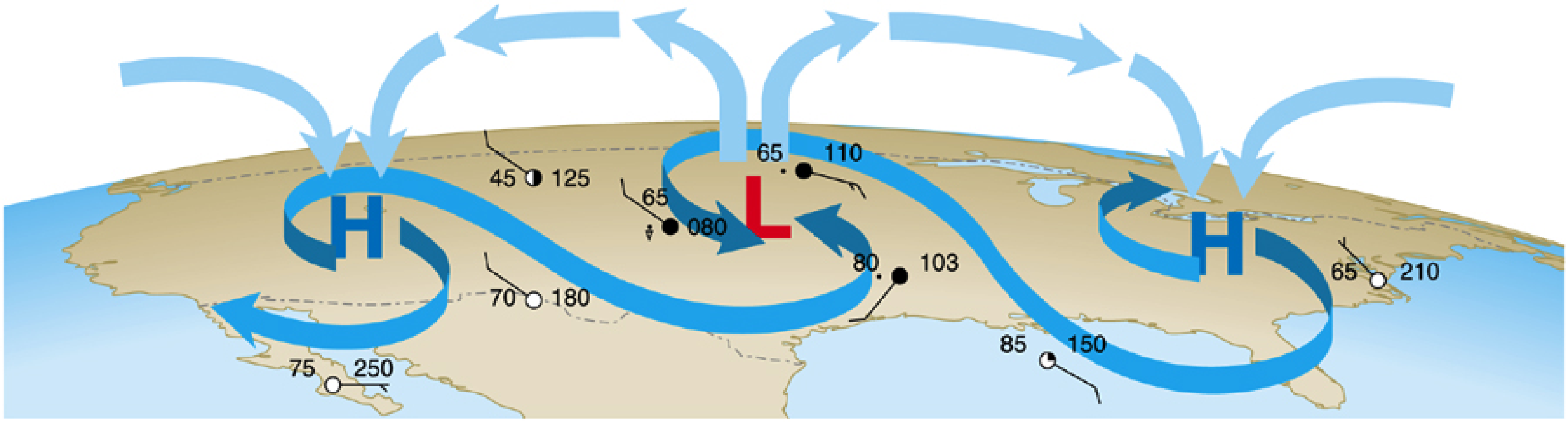


- Warm and cold fronts are associated with different types of clouds, precipitation rates and lightning.
- They also have different slopes.
- In both cases, the warm (and often moist) air is forced up over the colder air.
  - In later chapters we will learn why this forms clouds and rain.

Buys Ballot's 'Law'

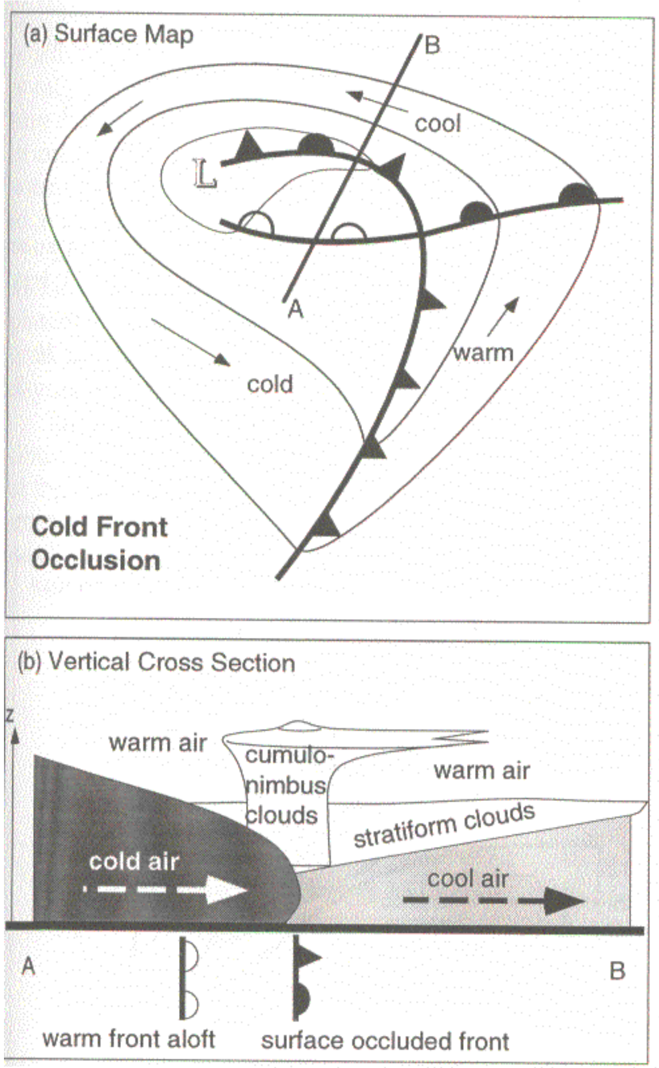


Basic Circulation Model for High and Low Pressure Systems



- Air flows from higher pressure to lower pressure.
- On a flat and non-rotating world, winds would move from areas of high pressure directly to areas of low pressure.
- In the upper atmosphere, there are usually counterparts to the surface systems
  - Upper air lows are above surface highs,
  - Upper air highs are above surface lows.

Examples: Cold and Warm Occlusions



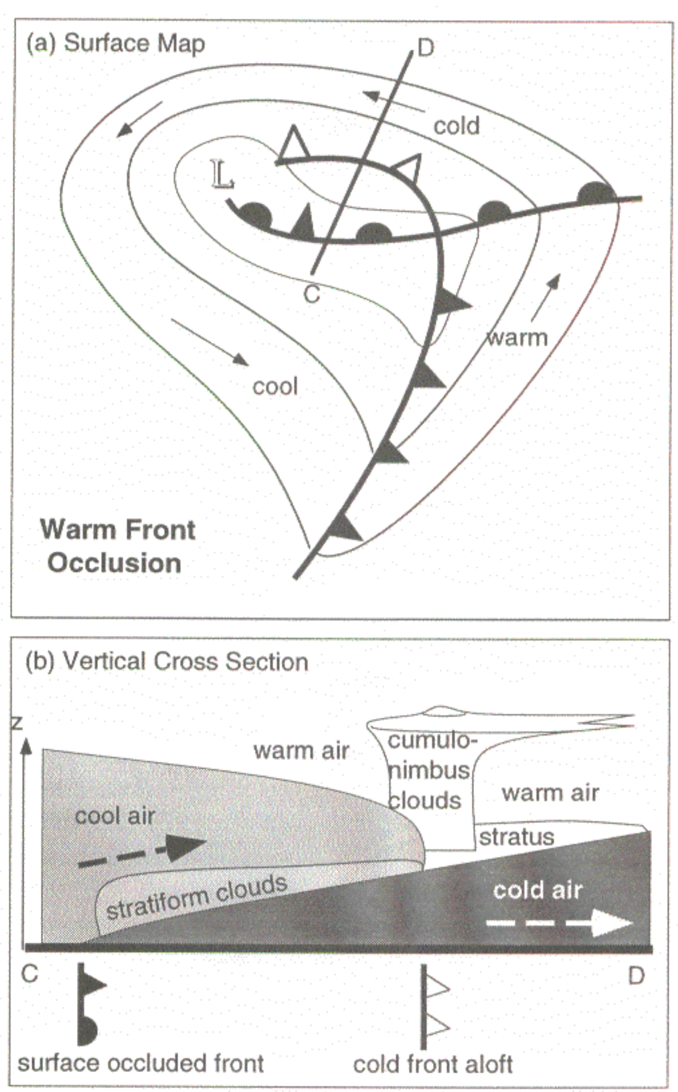
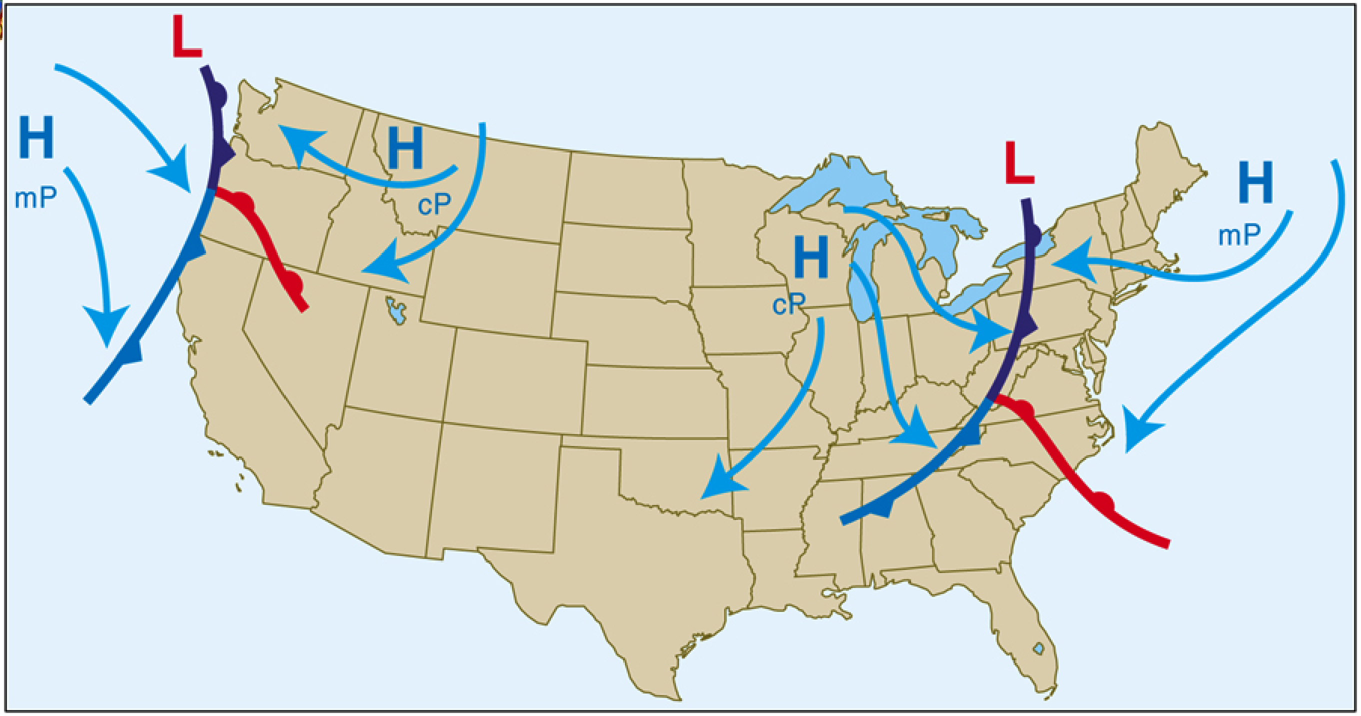


Figure from **MSE** by Rolland Stull

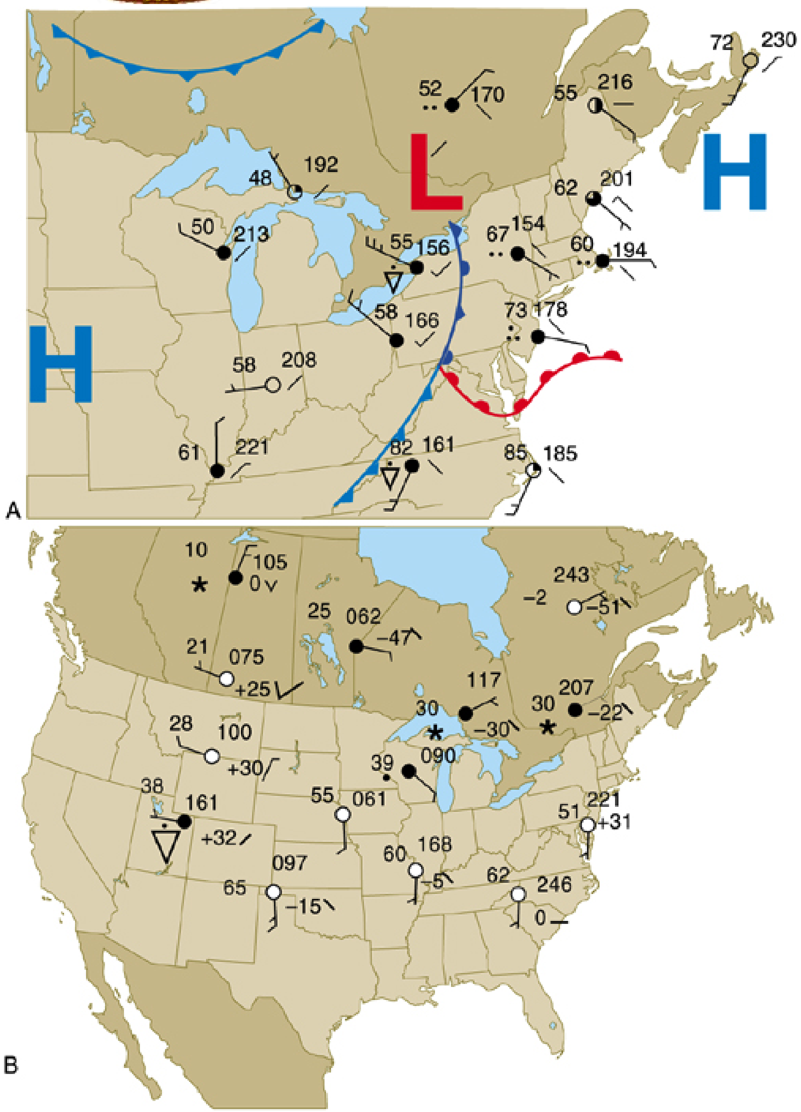
Two Examples of Occluded Fronts



- The example for the West coast is a warm occlusion, whereas the example on the East coast is a cold occlusion.
- Why?
- Where are the warm sectors?

Figure from **Meteorology** by Danielson, Levin and Abrams

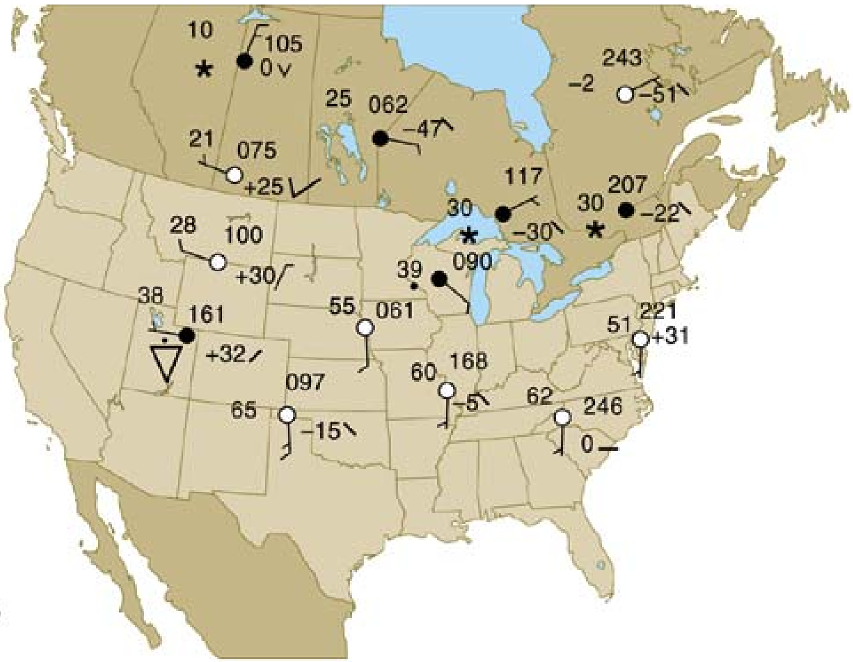
Fronts on Weather Charts



- The top image is an example with the fronts shown.
- Where are the fronts (and air masses) on the bottom image?
- Guidelines:
  - Fronts separate air masses.
  - Fronts are drawn at the warm boundary of the mixing zone.
  - More on next page.

Figure from **Meteorology** by Danielson, Levin and Abrams

Fronts on Weather Charts



B

- Guidelines:
  - Fronts separate air masses.
  - Fronts are drawn at the warm boundary of the mixing zone.
  - Fronts lie in troughs or through lows.
  - There is often a shift in wind direction.
  - There is often a change in T_{dew} and/or T.
  - There is little variation in temperature on warm side of a front.
  - Temperature steadily falls on cold side.
  - Temperature rises as an occluded front approaches, and fall as it passes.
  - Most cloudiness and precipitation occurs on the cold side of a stationary front.
  - Warm frontal clouds tend to be stratiform, with steady precipitation; cold frontal clouds are more cumuliform, with more showery precipitation.

Note: These rules are not uniformly accepted. Furthermore, the relative importance of each rule varies greatly.

Figure from **Meteorology** by Danielson, Levin and Abrams

Example of Different Expert Opinions On the Location of Fronts

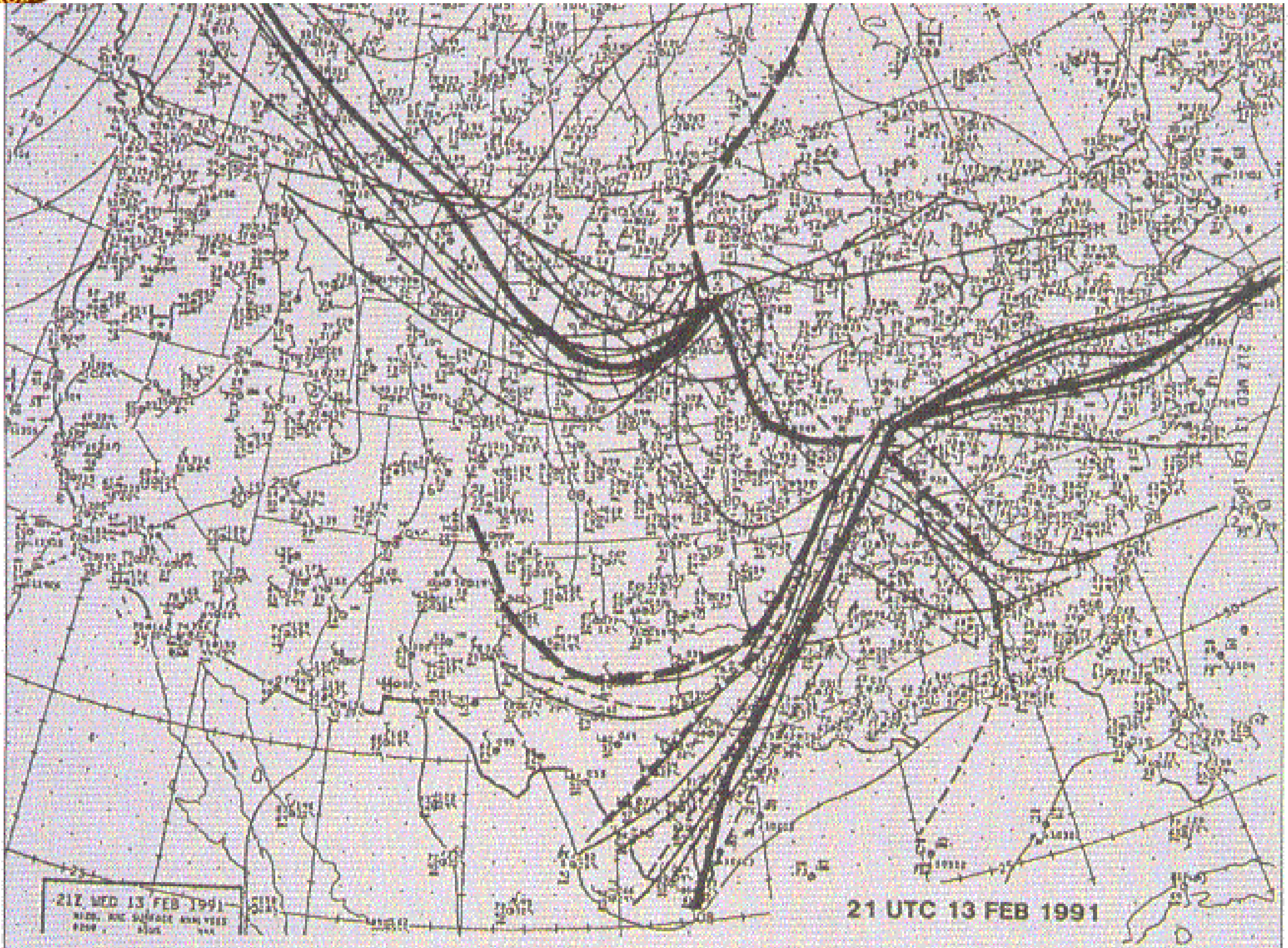


Fig. 1. NMC North American surface data plot for 2100 UTC 13 February 1991, with fronts and troughs as analyzed by workshop participants (from Uccellini et al. 1992; used with permission). Figure from **Meteorology** by Danielson, Levin and Abrams

Long and Short Wave Flow Patterns

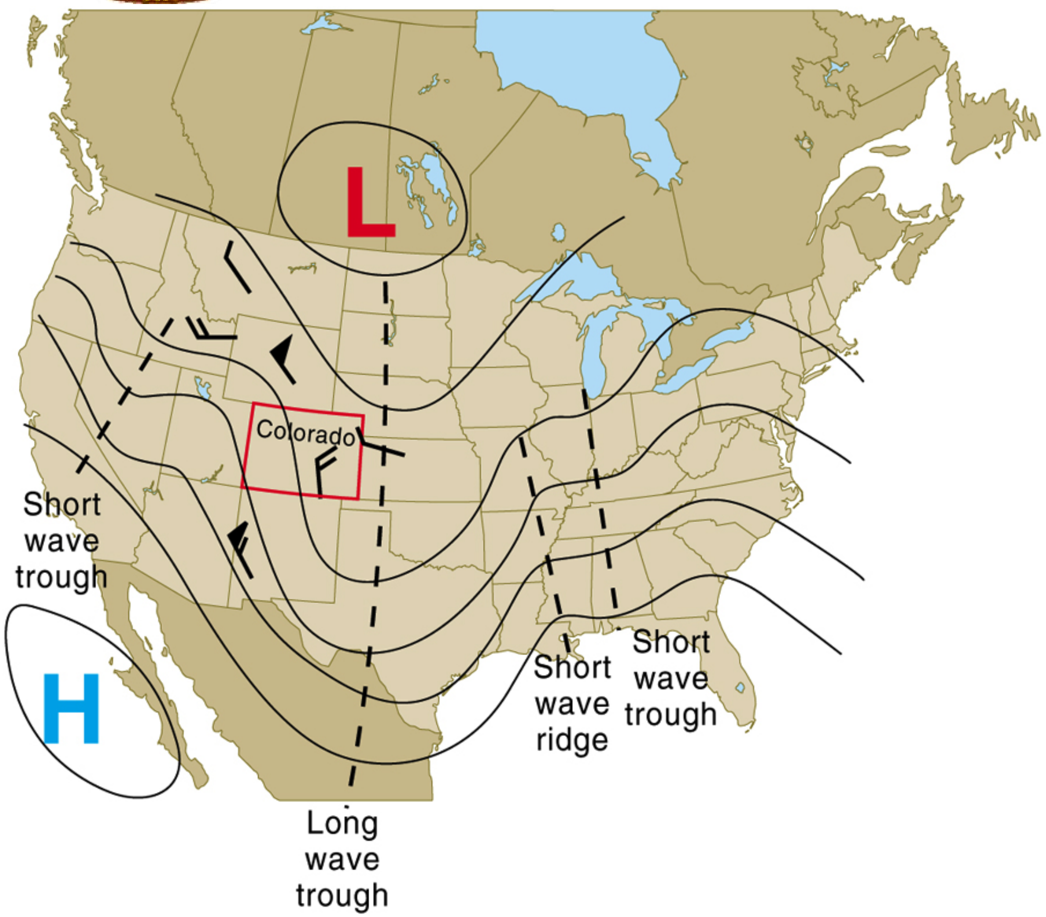
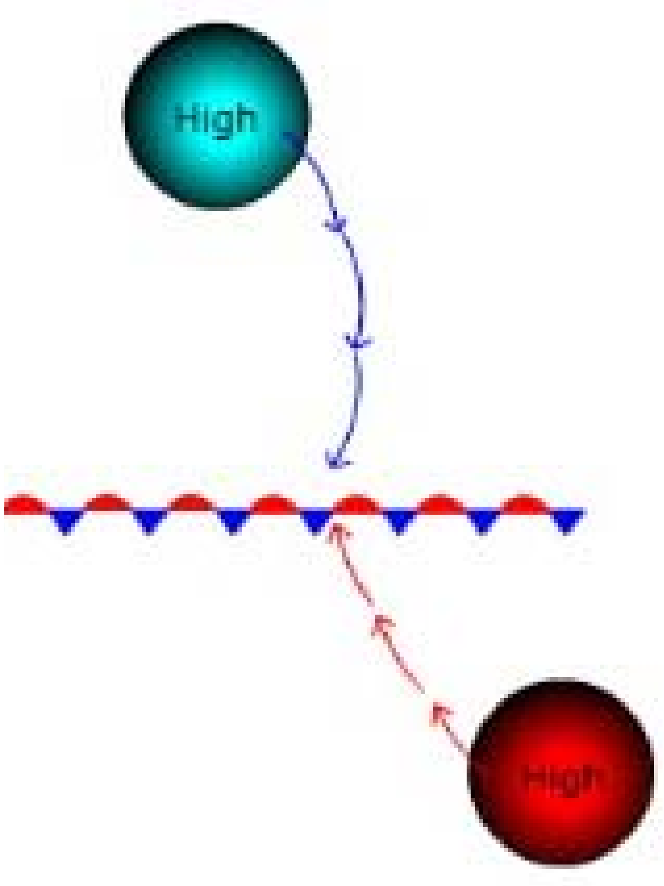


Figure from **Meteorology** by Danielson, Levin and Abrams

- This figure is a typical example of upper tropospheric circulation.
- The flow is smooth and mostly westerly.
- There is a large-scale (long wave or Rossby wave) perturbation (i.e., difference or change), from zonal (east to west) flow.
  - 3 to 6 long waves typically span the globe.
  - Long waves move slowly.
- There are also several smaller scale (short wave) perturbations.
- Short waves move with the wind flow.

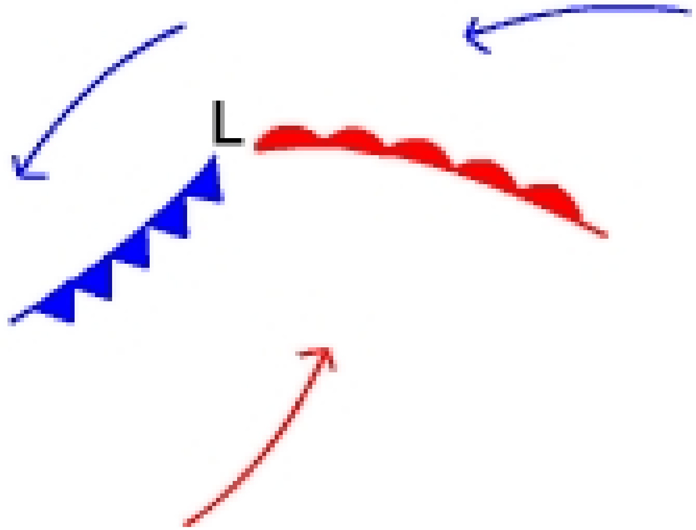
Example: Cyclone Forming on a Stationary Front



- Low level outflow from ‘adjacent’ high pressure centers converges.
- The convergence causes lifting, which can result in cloud formation and precipitation to help maintain a front.
- In the early stages of cyclogenesis, there is no cyclone, simply a front.
- In this example, the front is stationary.
- However, the flow from the high pressure systems is not balanced along the entire front, therefore motion occurs.

Figure from http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/weather_systems/cyclogenesis.html

Example Continued



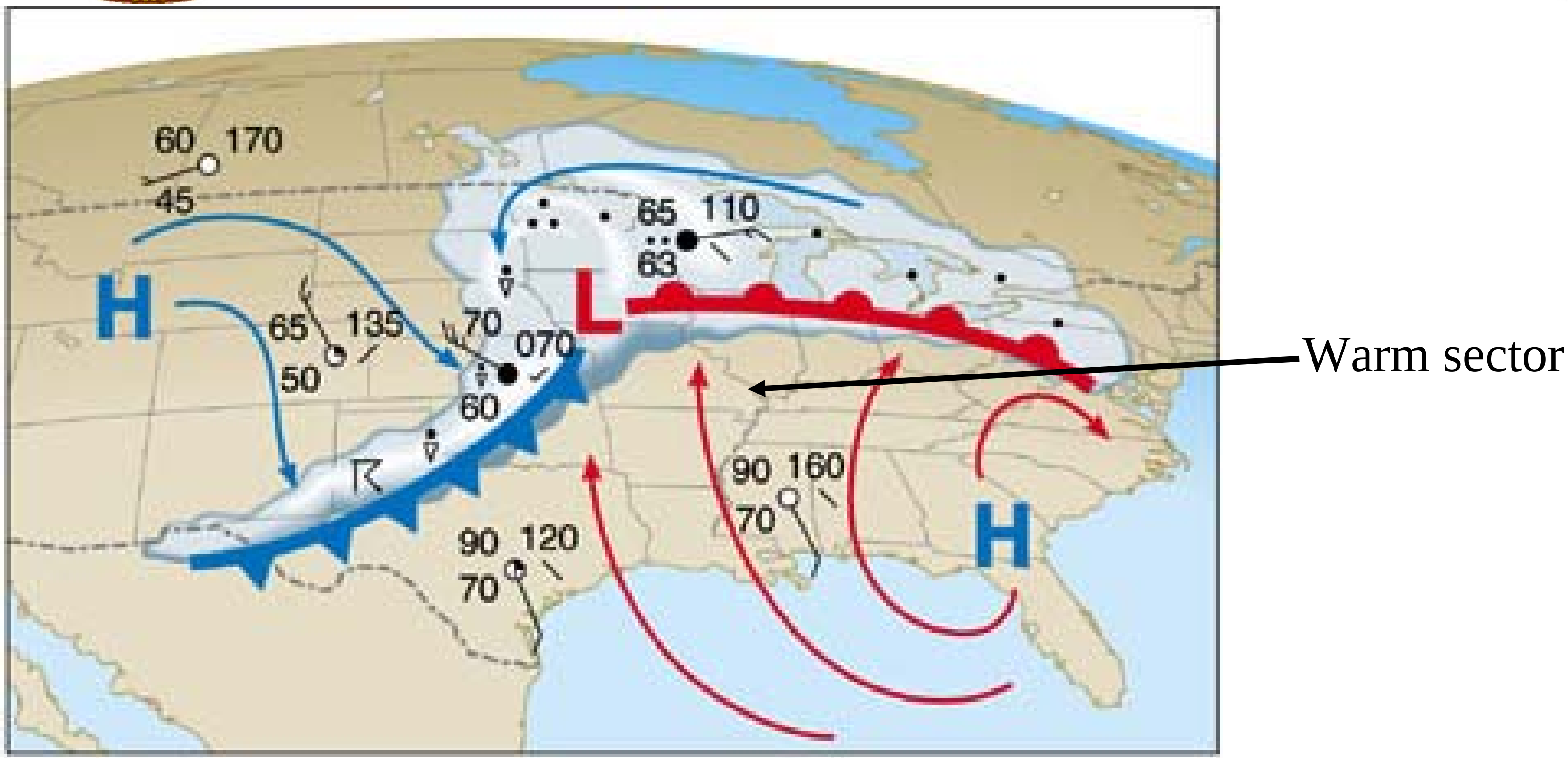
- The motion of the front induces rotation.
- The motion is counter clockwise, making a lower pressure system.

The pressure continues to decrease due to forces acting to remove (vertically) more air than is pushed into the low pressure system by the high pressure systems.

If this situation can be maintained, a very low pressure system can be produced.

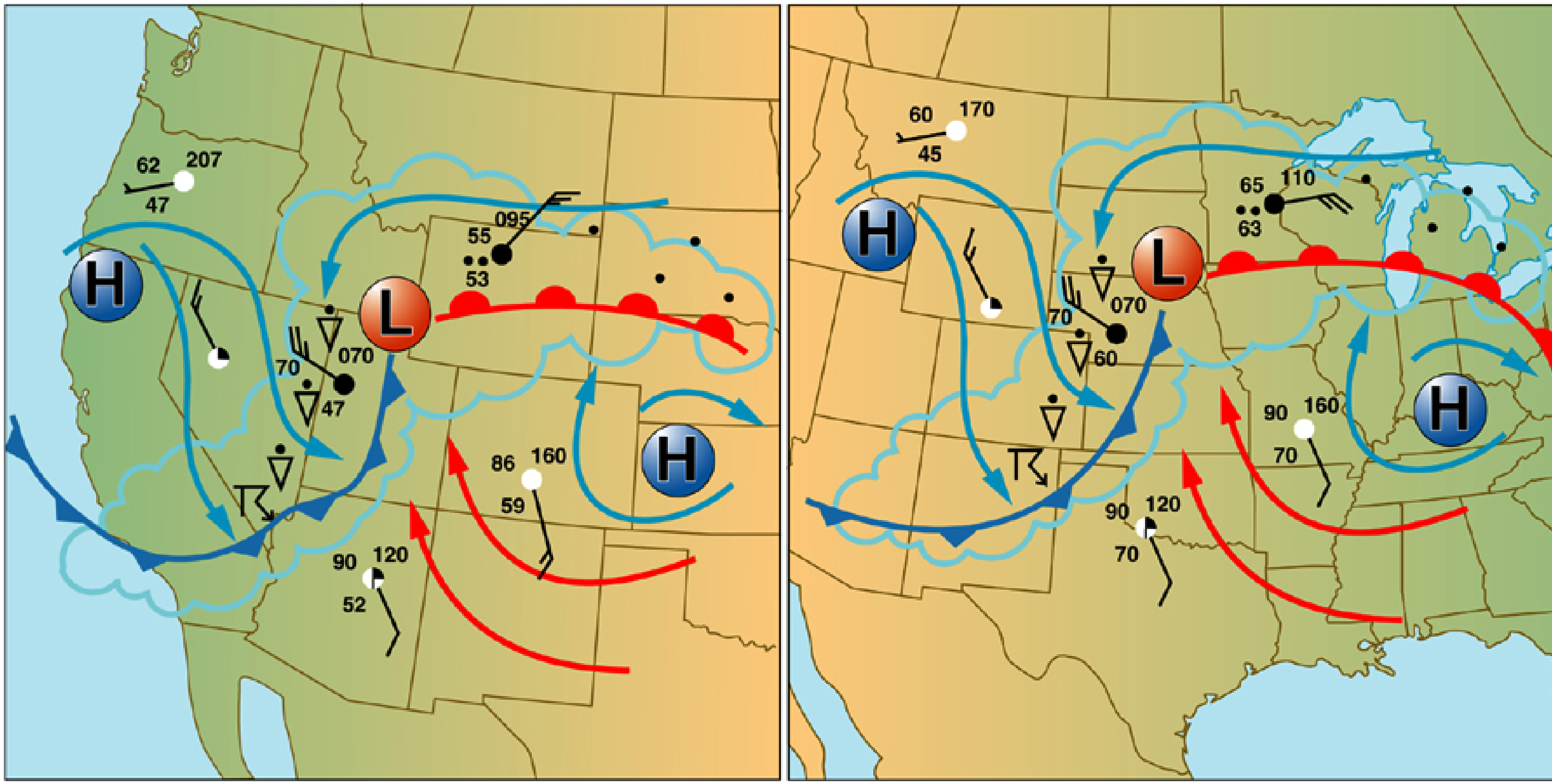
Figure from http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/weather_systems/cyclogenesis.html

Frontal Cyclone Model



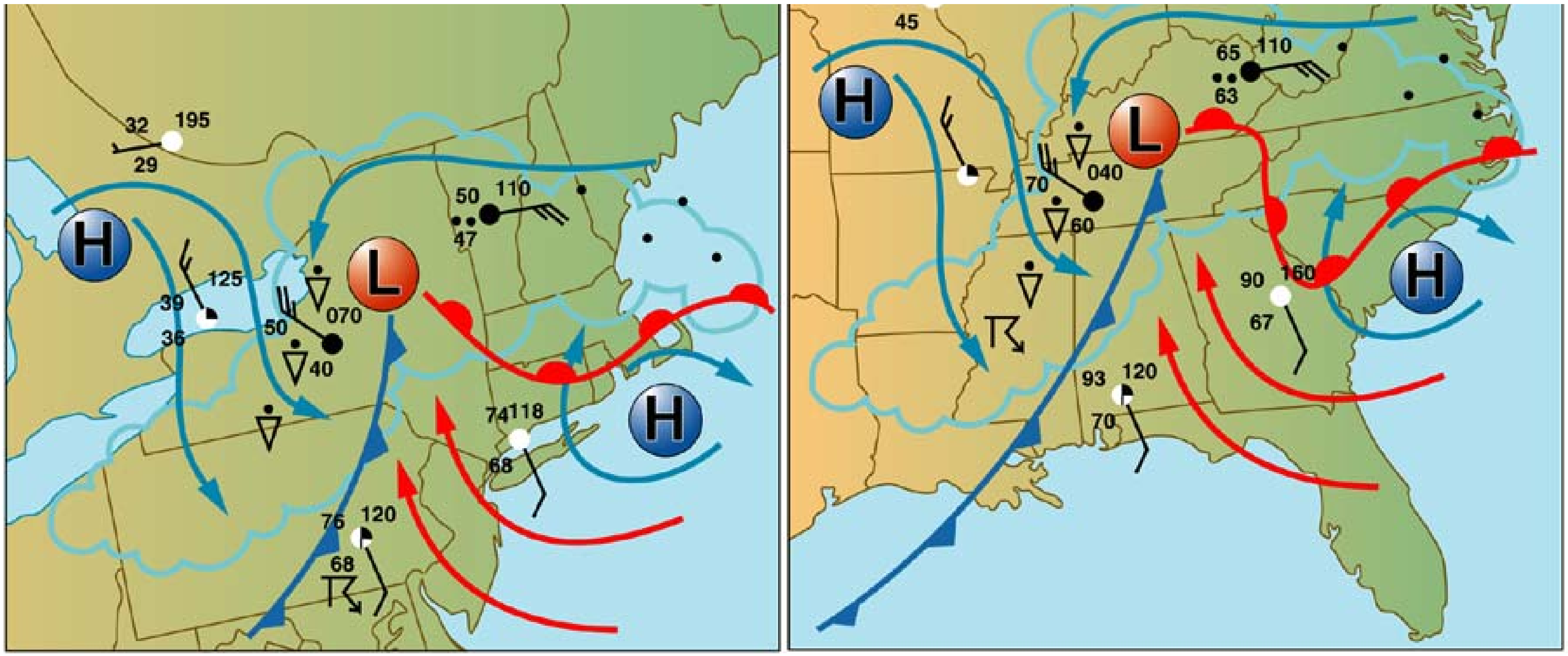
- The low pressure system (cyclone) rotates counterclockwise in the Northern Hemisphere.
- Typically, warm air moves poleward, and cold air moves towards the equator.
- Strong persistent systems can wrap the warm air around the cyclone.

Examples of Frontal Cyclones I



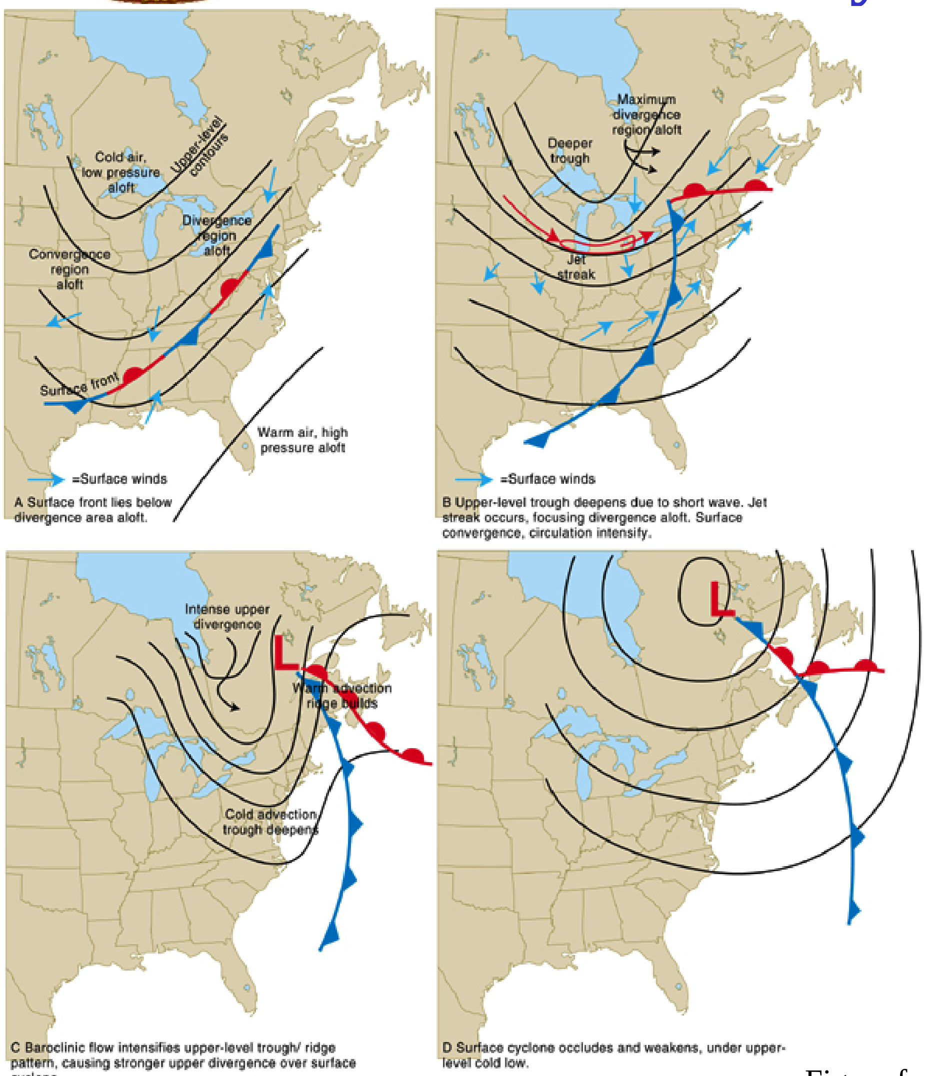
- Fronts pass through low pressure systems, and away from high pressure systems.

Examples of Frontal Cyclones I



- Similar weather patterns can occur in different regions.

3-Dimensional Frontal Cyclone Model



- This is an example of cyclone development on a stationary front (Fig. A).
- The upper level winds are divergent to the East of the front (Fig. B), promoting vertical motion and low level convergence.
- The opposite conditions occur to the West of the front.
- The low pressure region deepens (fig. C)
- The fronts occlude and the cyclone weakens (Fig. D).

Figure from **Meteorology** by Danielson, Levin and Abrams