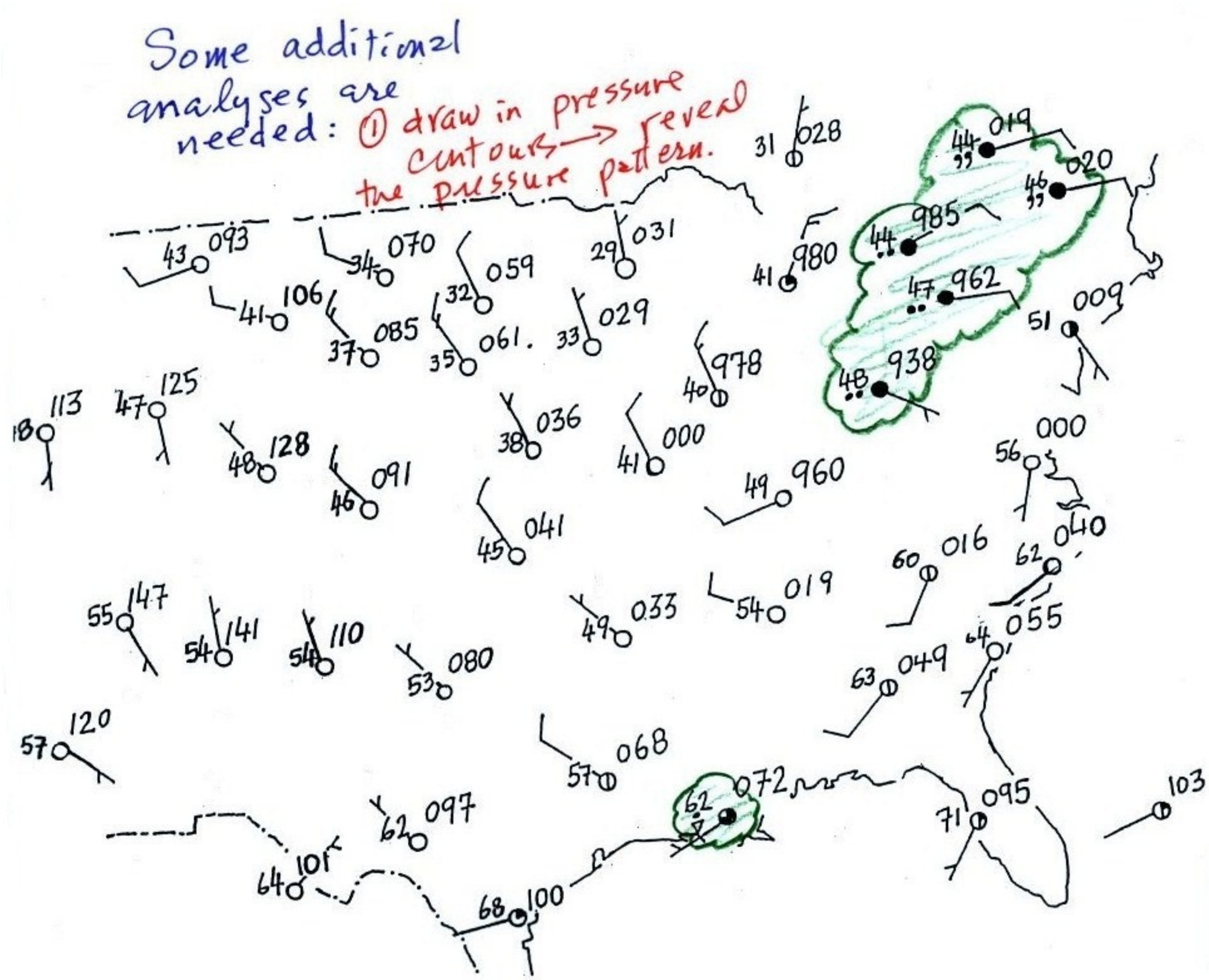
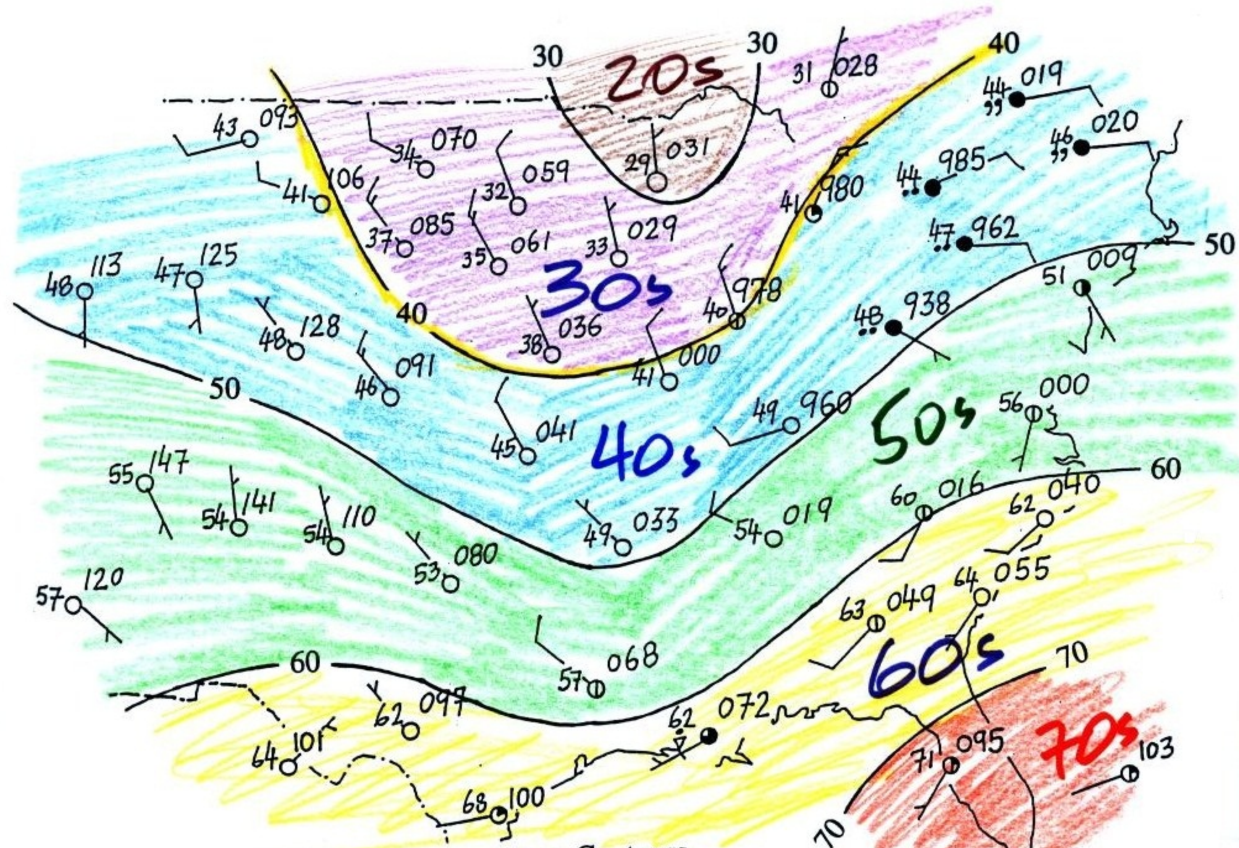
Module 3: Lecture 8

Now that we have learned how surface weather data are plotted on a map, we will look at some of the analyses of the data that can be done. Here is a relatively simple example of a surface map. Pressure, wind, temperature, cloud cover, and weather data are shown.



Plotting the surface weather data on a map is just the beginning. We want to know what is causing the cloudy weather with rain and drizzle in the NE portion of the map above and the rain shower along the Gulf Coast. Some additional analysis is needed. A meteorologist usually begins by drawing contour pressure lines to map out the large scale or synoptic pattern. We will look first at contour lines of temperature because they are a little easier to understand. The plotted temperature data is easier to decode and temperature varies across the country in a fairly predictable way.

Temperature contour lines or isotherms are usually drawn at 10^{o} F intervals. The isotherms connect all the points on the map that have the same temperature, and distinguish regions with different temperature ranges. Temperatures generally decrease with increasing latitude: warmer temperatures are usually in the south and colder temperatures in the north.



Isotherms - Temperature Contours

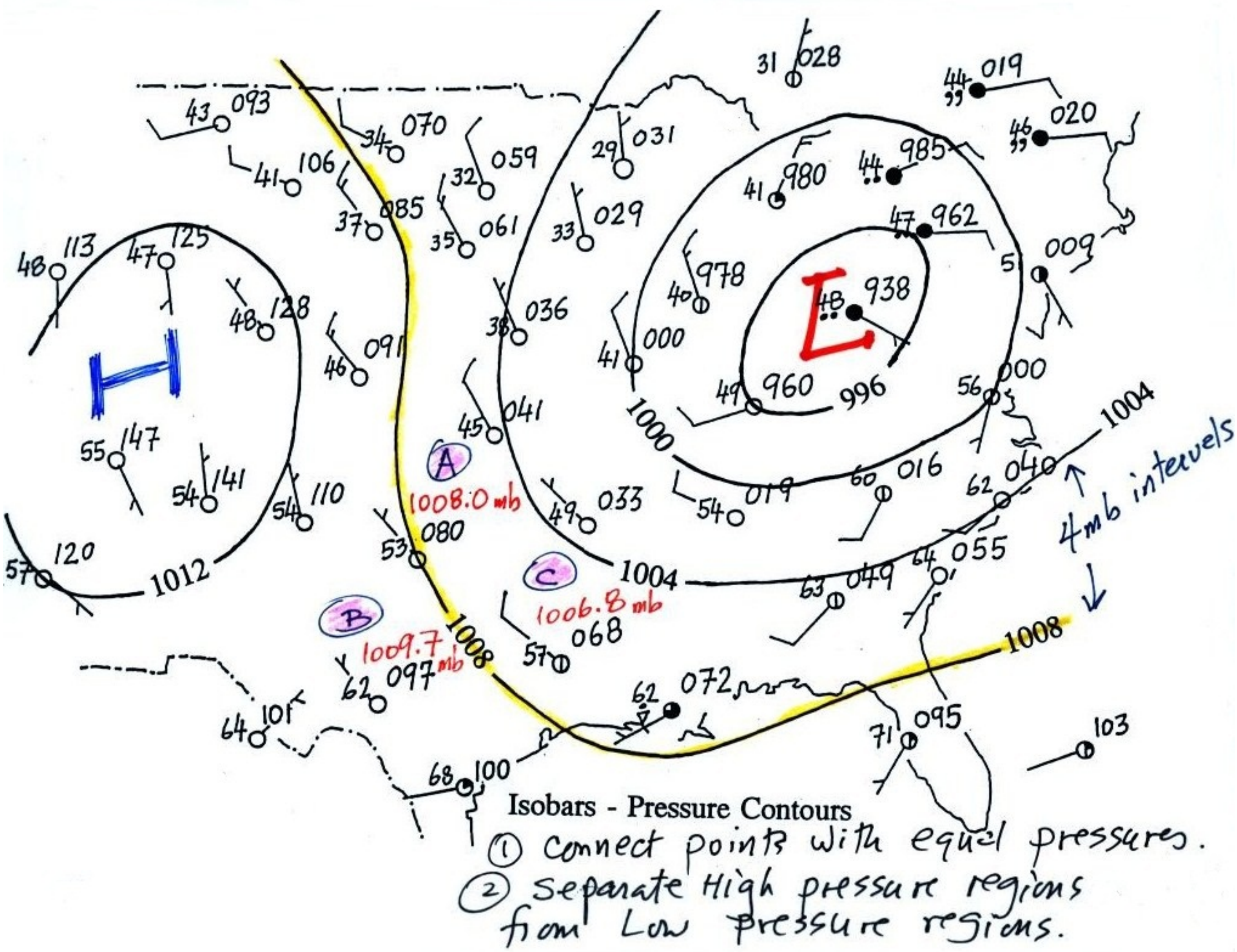
① connect points on the map with equal temperatures.

② separate regions warmer than a particular temp. from a colder region.

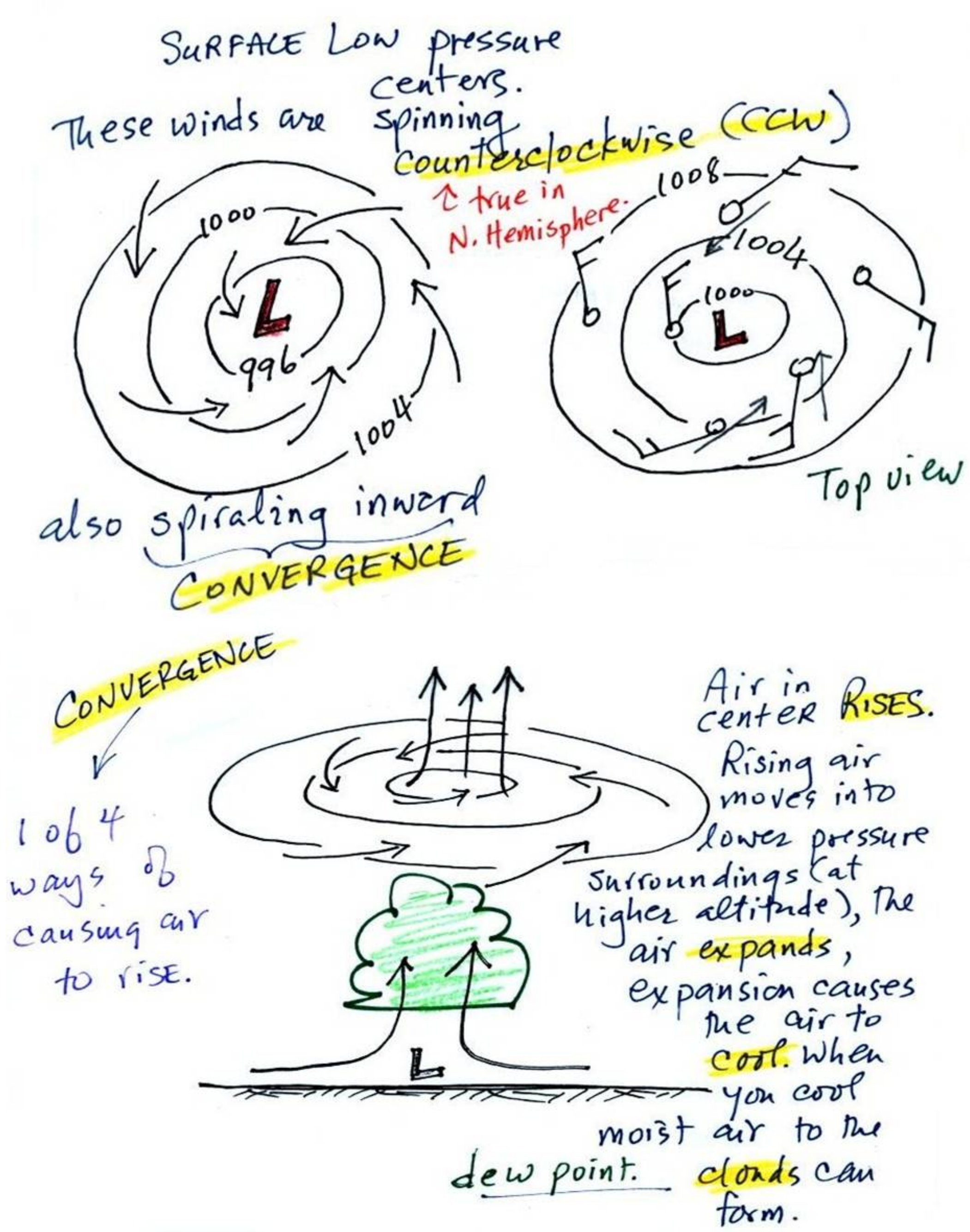
Now here is the same data with pressure contours or isobars drawn in. Isobars connect points on the map with the same pressure and are generally drawn at 4 mb intervals. The 1008 mb isobar (highlighted in yellow) passes through a city at **Point A** where the pressure is exactly 1008.0 mb and passes between cities with pressures of 1009.7 mb at **Point B** and 1006.8 mb at **Point C**. You would expect to find 1008 mb somewhere in between those two cities which is where the isobar is drawn.

The pattern on this map is very different from the pattern of isotherms. On this map the main features are the circular low and high pressure centers. Locating closed centers of high and low pressure will tell you a lot about the weather. Air moves toward low pressure areas and spirals inward toward the center of the low. **This process is called convergence.** The winds spin counterclockwise around low pressure centers in the northern hemisphere and clockwise around low pressure centers in the southern hemisphere. In both hemispheres, the wind spirals inward.

When the converging air reaches the center of the low it starts to rise. Rising air expands because it is moving into lower pressure surroundings at higher altitude and the expansion causes the air to cool. If air containing moisture is cooled to the dew point temperature, clouds will form which may begin to rain or snow. **Convergence is 1 of 4 ways of causing air to rise.** We will discuss the other three convergence mechanisms in future lectures. You often see cloudy skies and stormy weather associated with surface low pressure.

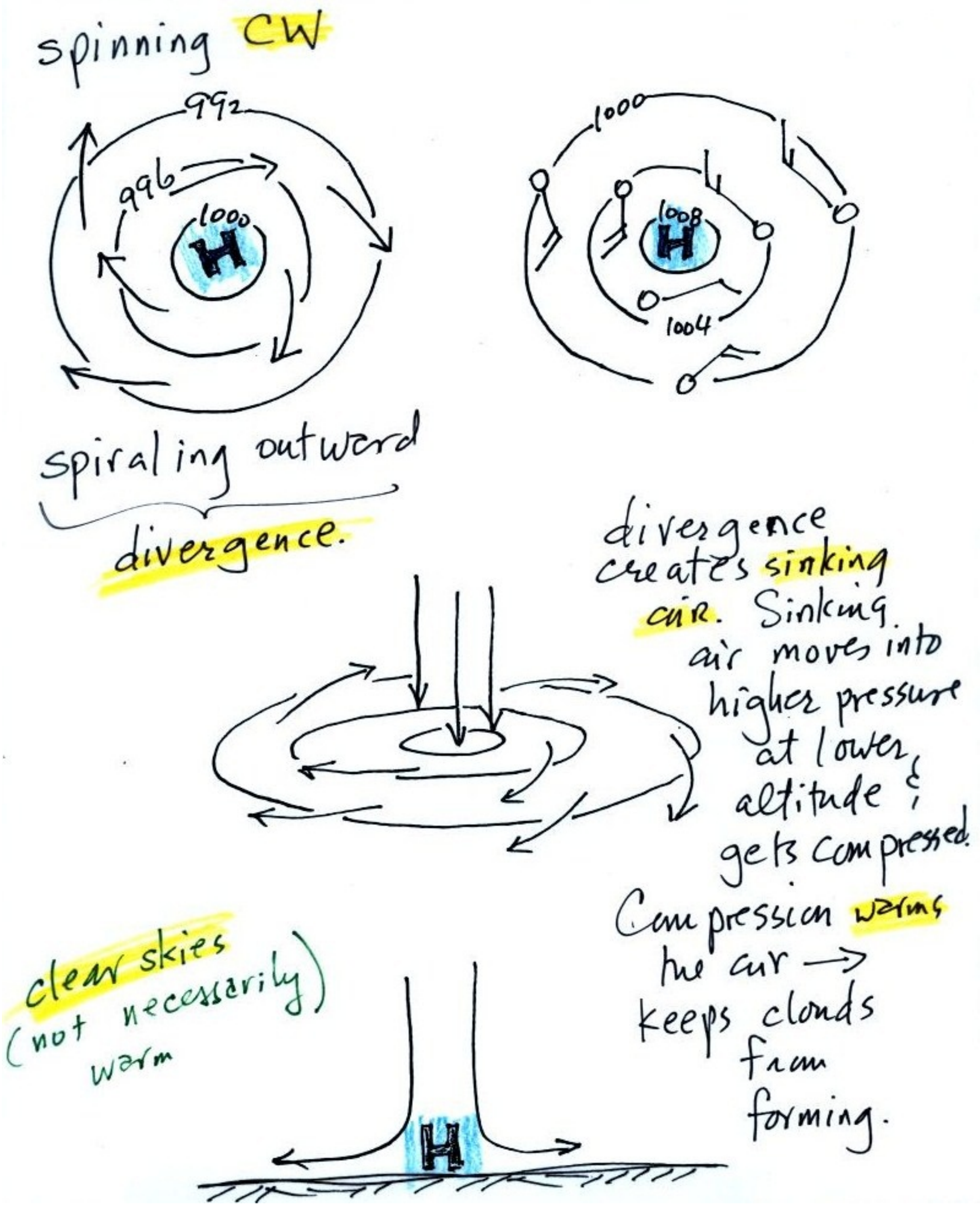


The picture below shows the top and side views of a typical low pressure system.



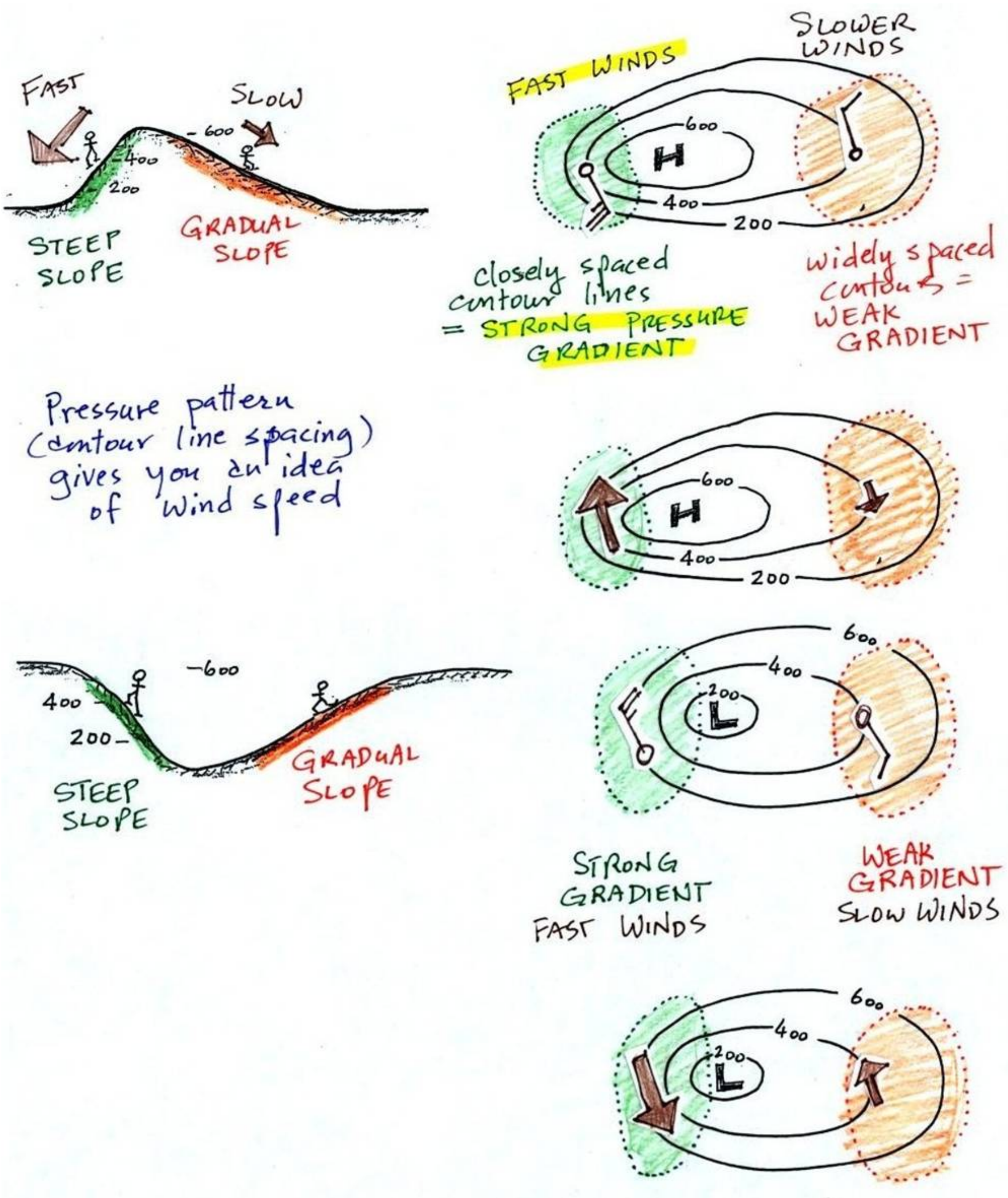
Surface centers of high pressure spiral outward in both hemispheres. **The outward motion is called divergence.** Winds spin clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. Air sinks in the center of the surface high pressure to replace the diverging air. The sinking air becomes warmer as it is compressed and that the dew point is rarely reached, which prevents clouds from forming. High pressure systems are generally associated with clear skies but not necessarily warm weather. Strong high pressure systems often form when the air is very cold.

Below is a top and side view of a typical high pressure system.

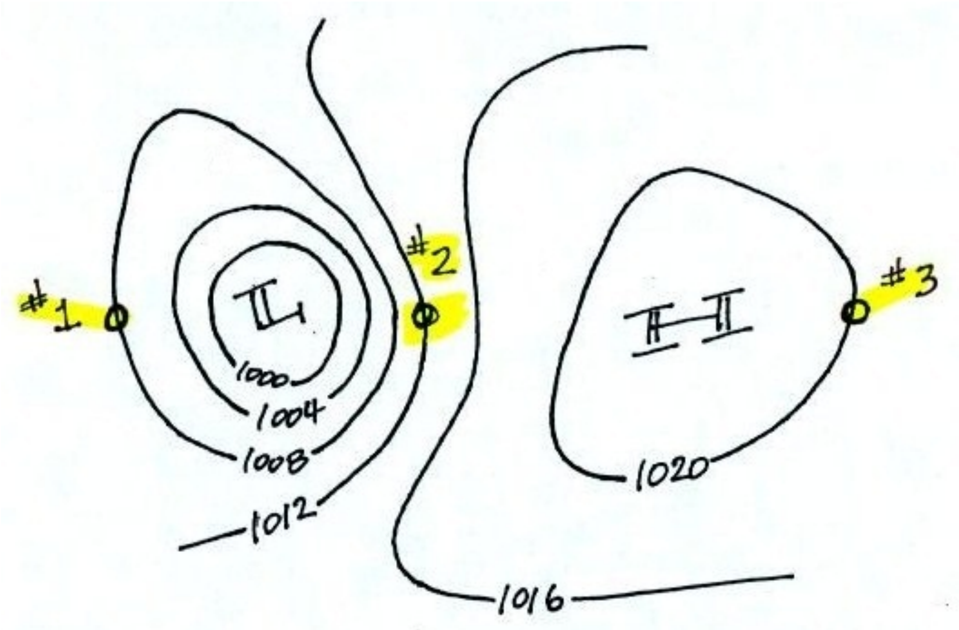


The pressure pattern is also an indicator of where you might expect to find fast or slow winds. The key indicator is the spacing of the isobars. Closely spaced contours mean that the pressure is changing rapidly with distance, creating a strong pressure gradient which produces fast winds. Contours further apart mean that the pressure gradient is weaker and the wind speed is slower. It is analogous to a slope on a hillside. If you trip, you will roll rapidly down a steep hillside and fall more slowly down a gradual slope.

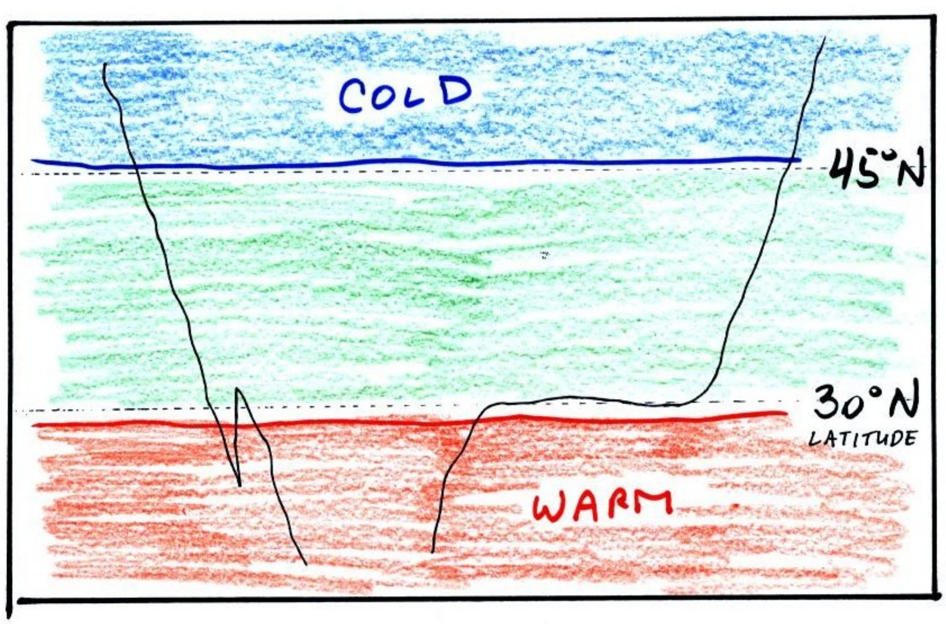
The figure below shows how winds move around high and low pressure centers. The winds are shown above using both the station model notation and arrows. The fastest winds are found where the pressure gradient is strongest. Note the different wind speeds at the points of strongest and weakest pressure gradients (25 knots and 10 knots for the high pressure system).



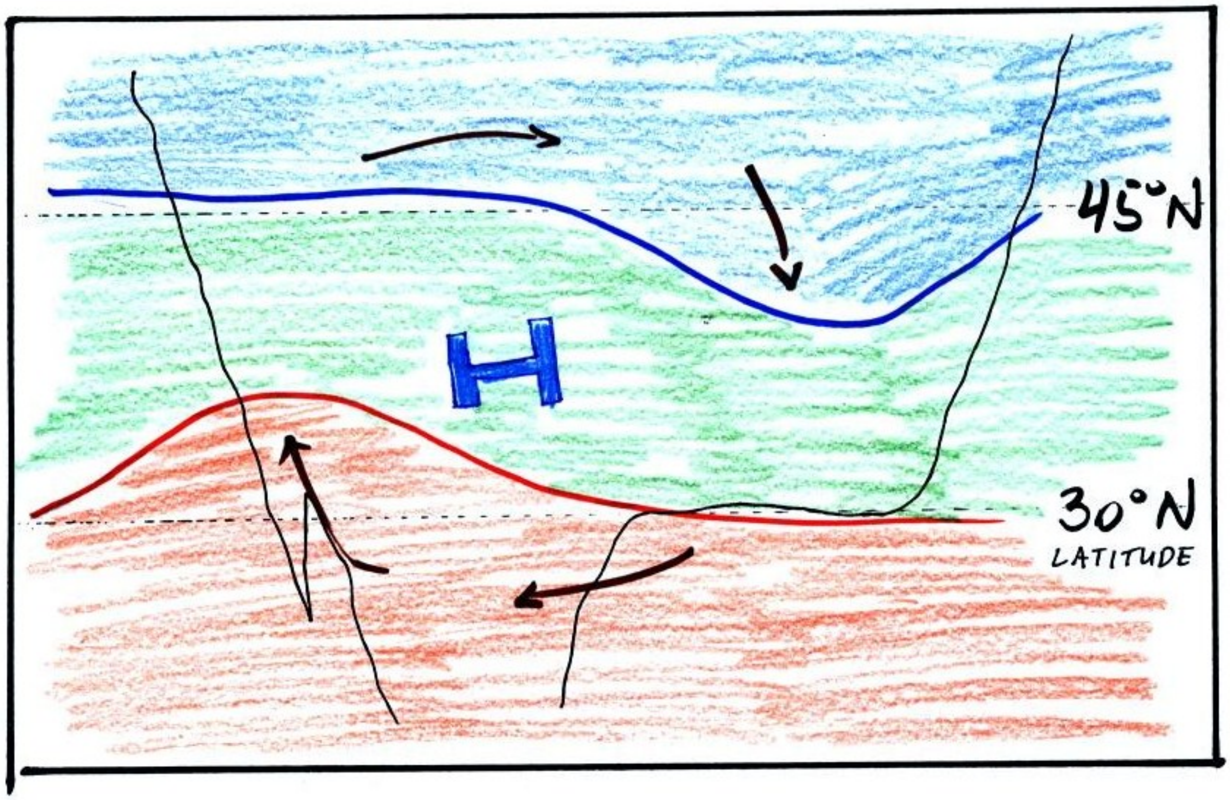
You should be able to sketch in the direction of the wind at each of the three points and determine where the fastest and slowest winds would be found. You will find the answer at the end of this lecture.



Once the winds start to blow they can alter the temperature pattern. The figure below shows the temperature pattern you would expect to see if the wind was not blowing at all or if the wind was blowing straight from west to east. The bands of different temperature are aligned parallel to the lines of latitude. Temperature changes from south to north but not from west to east.

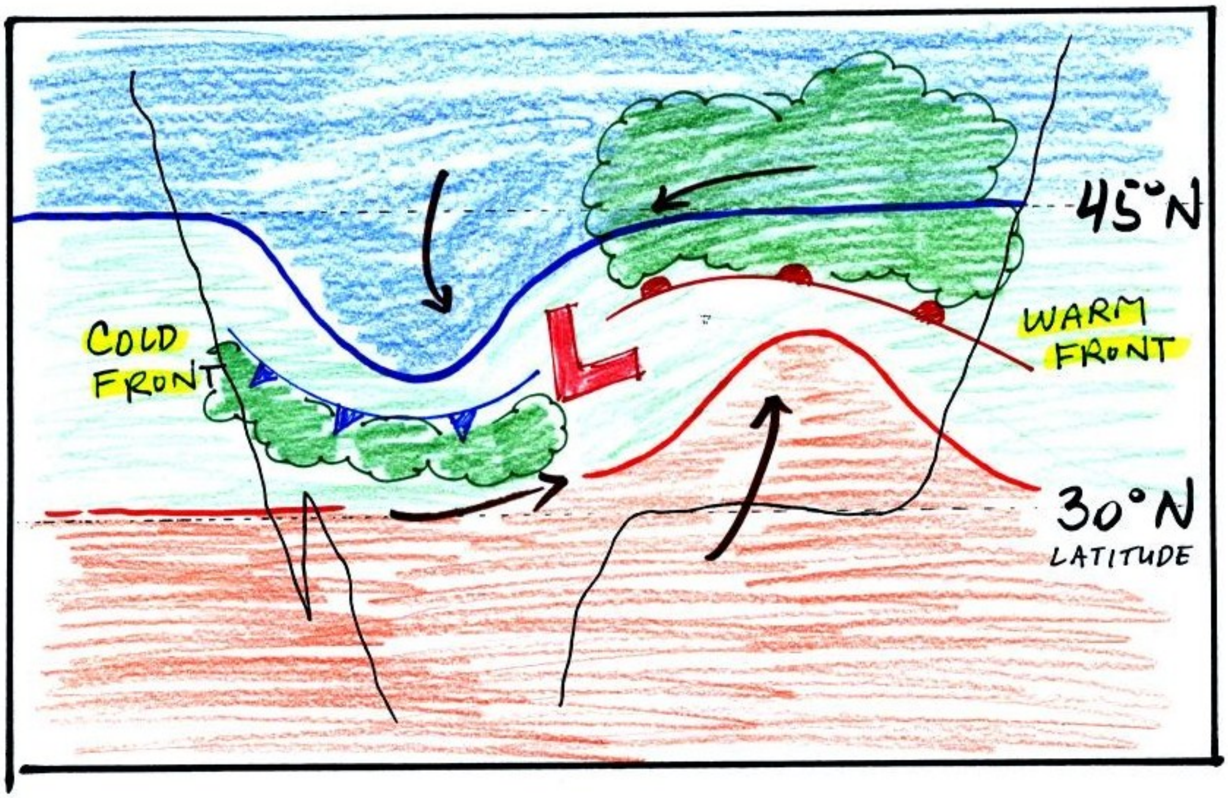


The picture above is not very interesting in terms of weather. If you put centers of high or low pressure in the middle of the temperature gradient, the weather becomes more interesting. The clockwise spinning winds move warm air to the north on the western side of the High. Cold air moves toward the south on the eastern side of the High. The diverging winds also move the warm and cold air away from the center of the High.



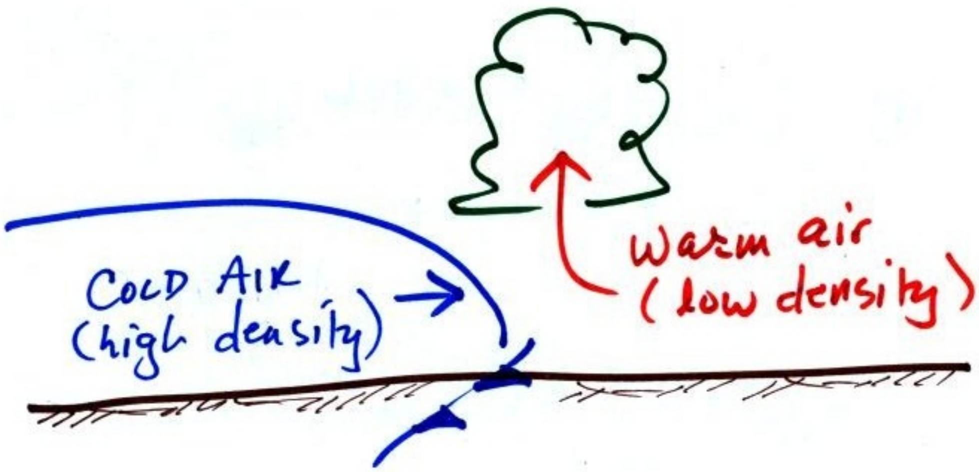
When a low pressure system is placed in the temperature gradient, counterclockwise winds move cold air toward the south on the west side of the low and warm air advances toward the north on the eastern side of the low. The converging winds will cause air masses with different temperatures to move toward the center of low pressure and collide with each other. The boundaries between these colliding air masses are called fronts. **Fronts are a second way of causing air to rise, cool and form clouds.**

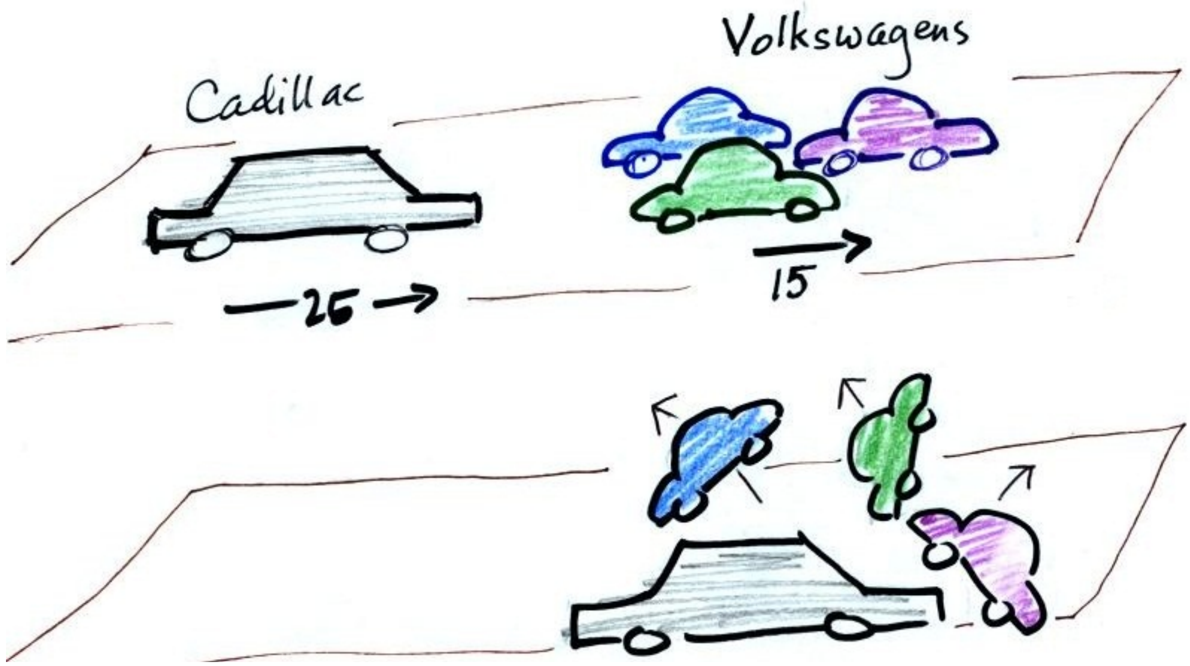
Cold air is moving from north toward the south on the western side of the low. The leading edge of the advancing cold air mass is called a cold front, which is drawn in blue on weather maps. The small triangular symbols on the side of the front identify it as a cold front and show what direction it is moving. The fronts are like spokes on a wheel. The "spokes" will spin counterclockwise around the low pressure center (the axle). A warm front (drawn in red with half circle symbols) is shown on the right hand side of the map at the advancing edge of warm air. It is also rotating counterclockwise around the Low.



This type of storm system is referred to as an extra-tropical cyclone (extra tropical means outside the tropics and cyclone means winds spinning around low pressure) or a middle latitude storm. When large low pressure systems form in the tropics, they are called tropical cyclones or more commonly hurricanes.

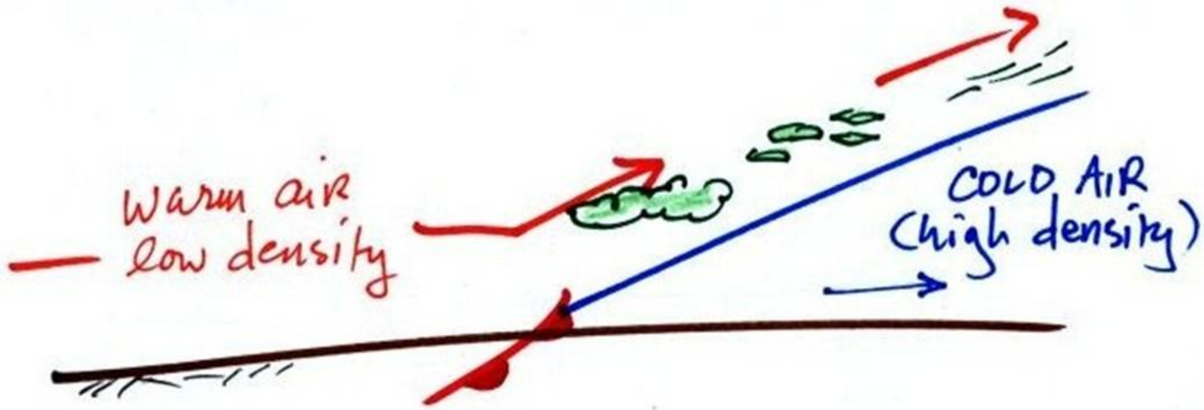
Clouds can form along fronts, often in a fairly narrow band along a cold front and over a larger area ahead of a warm front. We need to look at the cross-sectional structure of warm and cold fronts to understand better why this is the case. The top picture below shows a cross-sectional view of a cold front. The cold dense air on the left is advancing into warmer lower density air on the right. We are looking at the front edge of the cold air mass. Note the blunt, rounded shape of the front edge as the warm, low density air is lifted out of the way by the cold air. The lower figure shows an analogous situation; a big heavy Cadillac plowing into a bunch of smaller Volkswagens. The Volkswagens are thrown up into the air by the Cadillac.

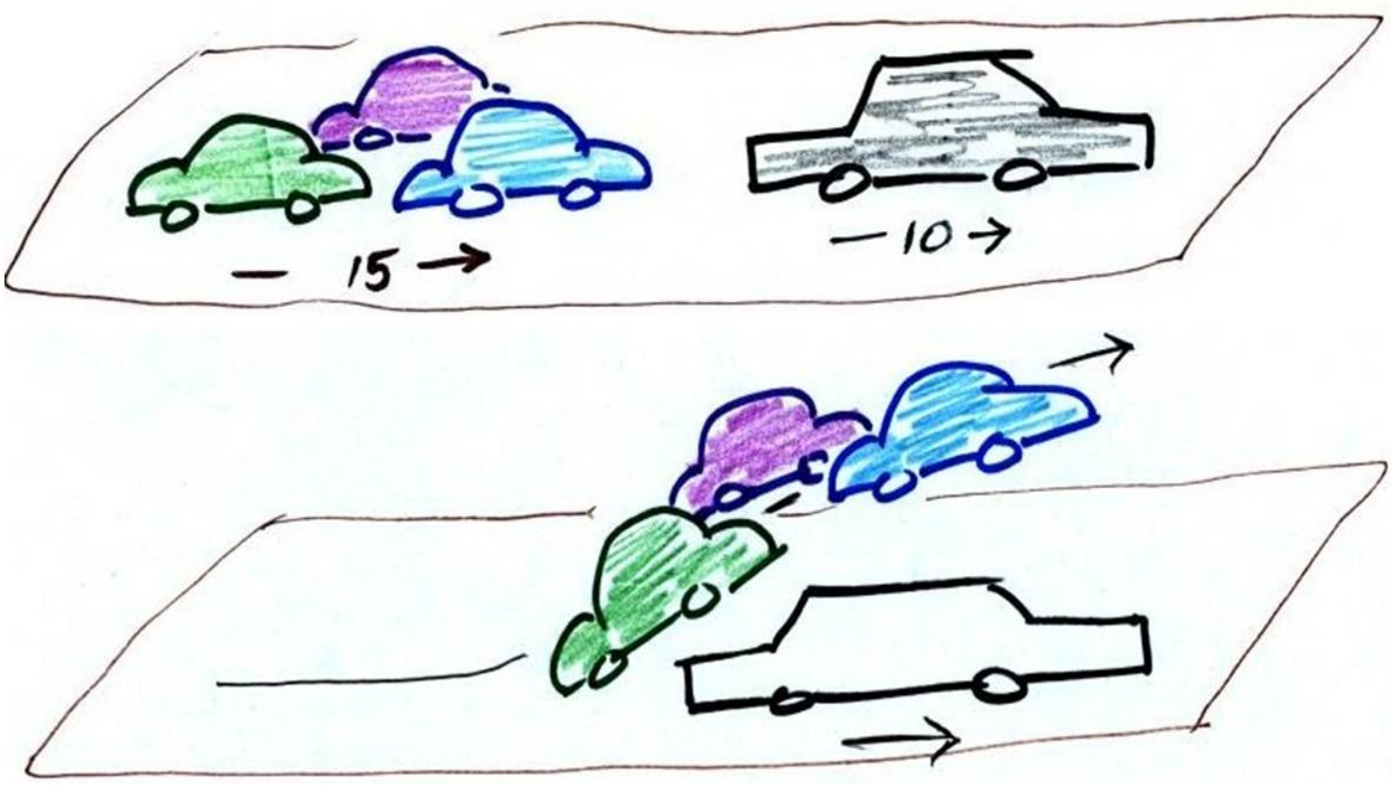




Here is a cross-sectional view of a warm front. Note the ramp like shape of the cold air mass. Warm air overtakes the cold air. Because the warm air is still less dense than the cold air, it cannot wedge its way underneath the cold air. Instead the warm air overruns the cold air. The front can advance only as fast as the cooler air moves away to the right.

The warm air rises again and clouds form. Because the warm air rises more gradually, the clouds are generally spread out over a larger area than with cold fronts. In the automobile analogy, the Volkswagens are catching up to a Cadillac. What happens when they overtake the Cadillac? The Volkswagens run up and over the Cadillac because they are not heavy enough to lift it.





Next we will spent some time learning about the weather conditions that precede and follow the passage of warm and cold fronts. Ahead of an approaching cold front, a person tends to experience relatively warm conditions. A temperature drop is probably the most obvious change that occurs when a cold front is passing through. Here in southern Arizona, gusty winds and a shift in the wind direction are also often noticeable. Often rain and thunderstorms occur as well. The coldest air might follow a day or two later, creating colder and drier conditions. Nighttime temperatures often plummet in the cold dry air behind a cold front. The pressure changes that precede and follow a cold front are less obvious but very useful when trying to locate a front on a weather map.

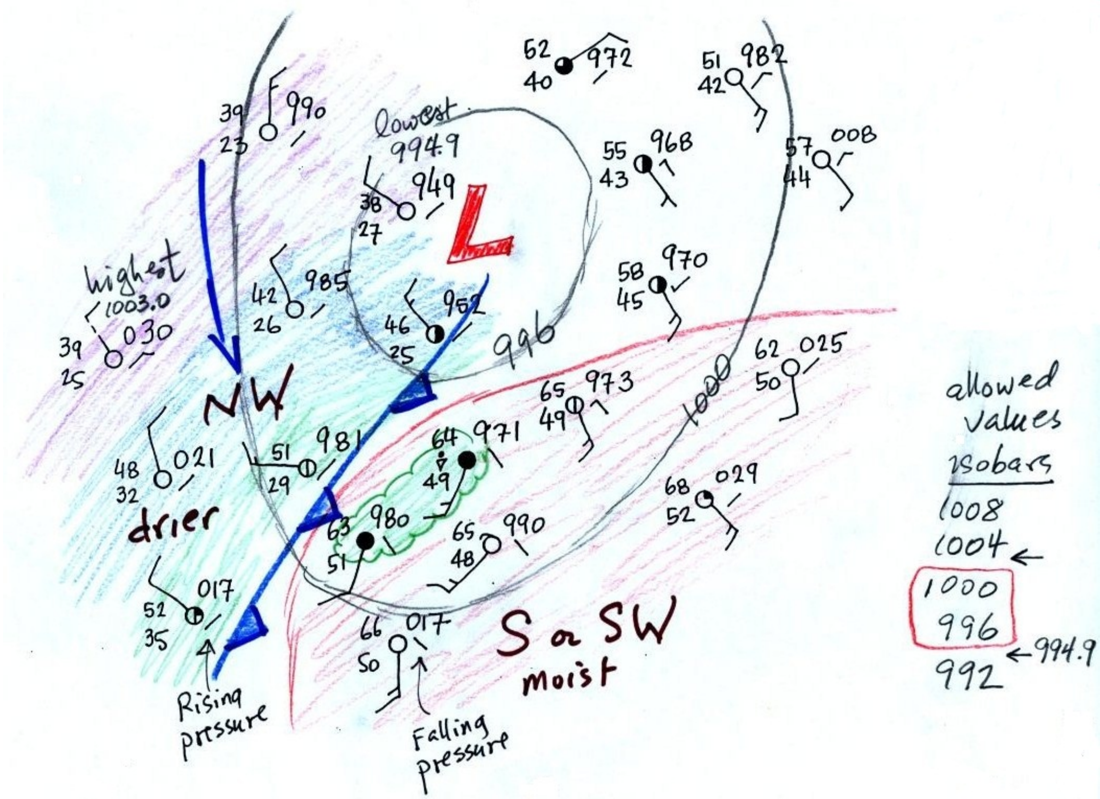
Table 1: Typical conditions prior to, during and following the passage of a cold front

Weather variable	Before the arrival of the cold front	As the front is passing through	After the cold front has passed through
Temperature	Relatively warm	Falling	Cool, cold, colder
Dew Point	May be moist (high dew point). Often not the case here in the desert southwest)	Falling	Usually much drier (low dew point)
Winds	Southwest	gusty winds (dusty)	Northwest
Clouds, Weather	Might see some high clouds	Rain clouds, thunderstorms in narrow band along the front (if the warm air mass is moist)	Clearing
Pressure	Falling	Reaches a minimum	Rising

In the next figure we will start with some weather data plotted on a surface map, using the station model notation. In some respects fronts are like spokes on a wheel - they rotate counterclockwise around centers of low pressure.

Before trying to locate a cold front, we need to draw in the isobars and map out the pressure pattern. Isobars are drawn at 4 mb increments above and below a starting value of 1000 mb. Some of the allowed values are shown on the right side of the figure. The highest pressure on the map is 1003.0 mb, the lowest is 994.9 mb. Thus we have drawn in 996 mb and 1000 mb isobars.

After drawing the isobars, the first step is to determine the location of the low pressure center. The next step is to locate the warm air mass in the picture. Temperatures are in the 60s in the lower right portion of the map; this area has been shaded in red. The cold front on the map seems to be properly positioned. The air ahead of the cold front is warm, moist, has winds blowing from the S or SW, and the pressure is falling. Clouds and a rain shower were located right near the cold front. The air behind the front is colder, drier, winds are blowing from the NW, and the pressure is falling. Note how the cold front is positioned at the leading edge of the cold air mass, not necessarily in front of the coldest air in the cold air mass.

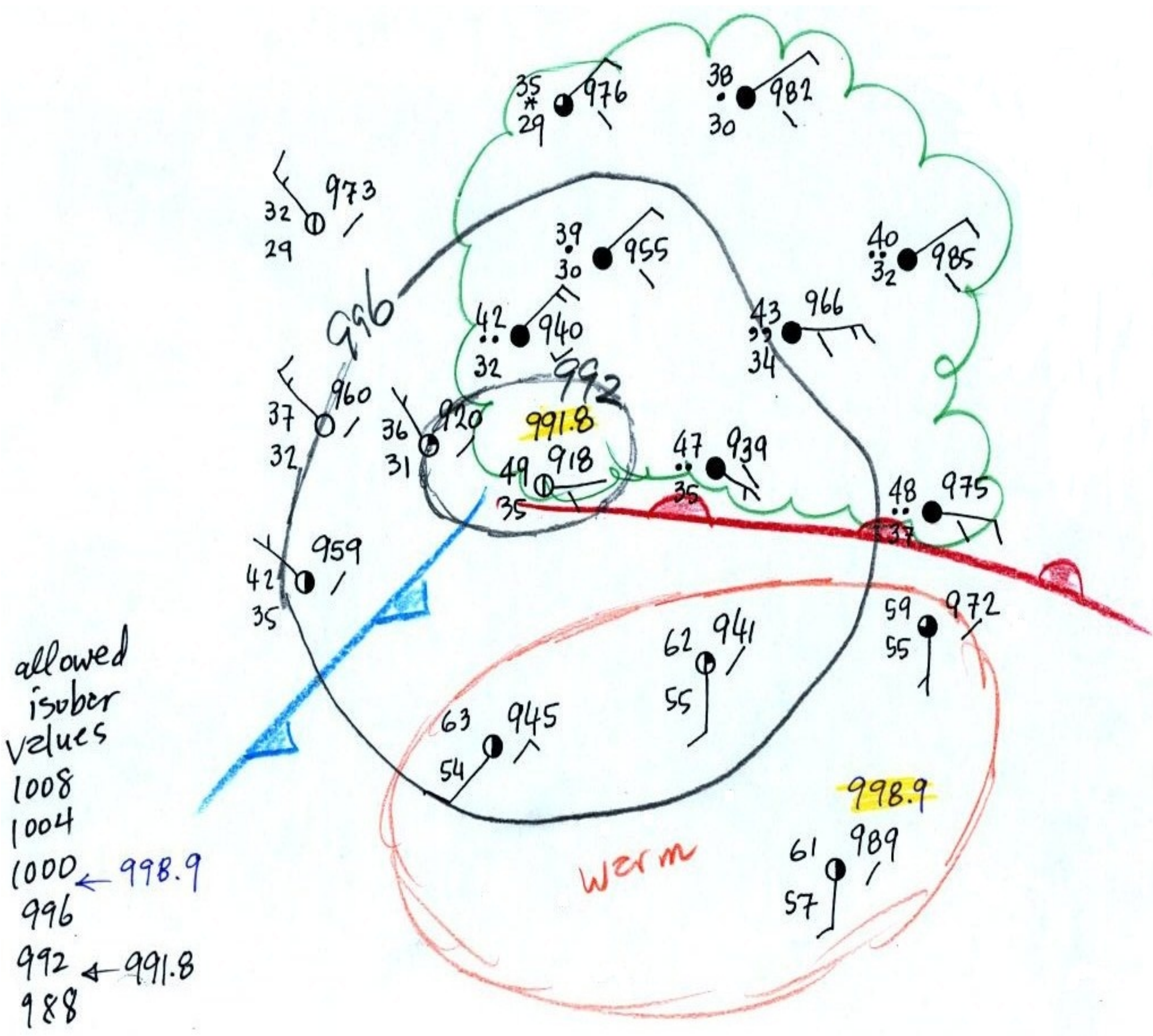


Next we follow the same procedure with warm fronts. Below are the typical weather conditions in advance of and following the frontal passage.

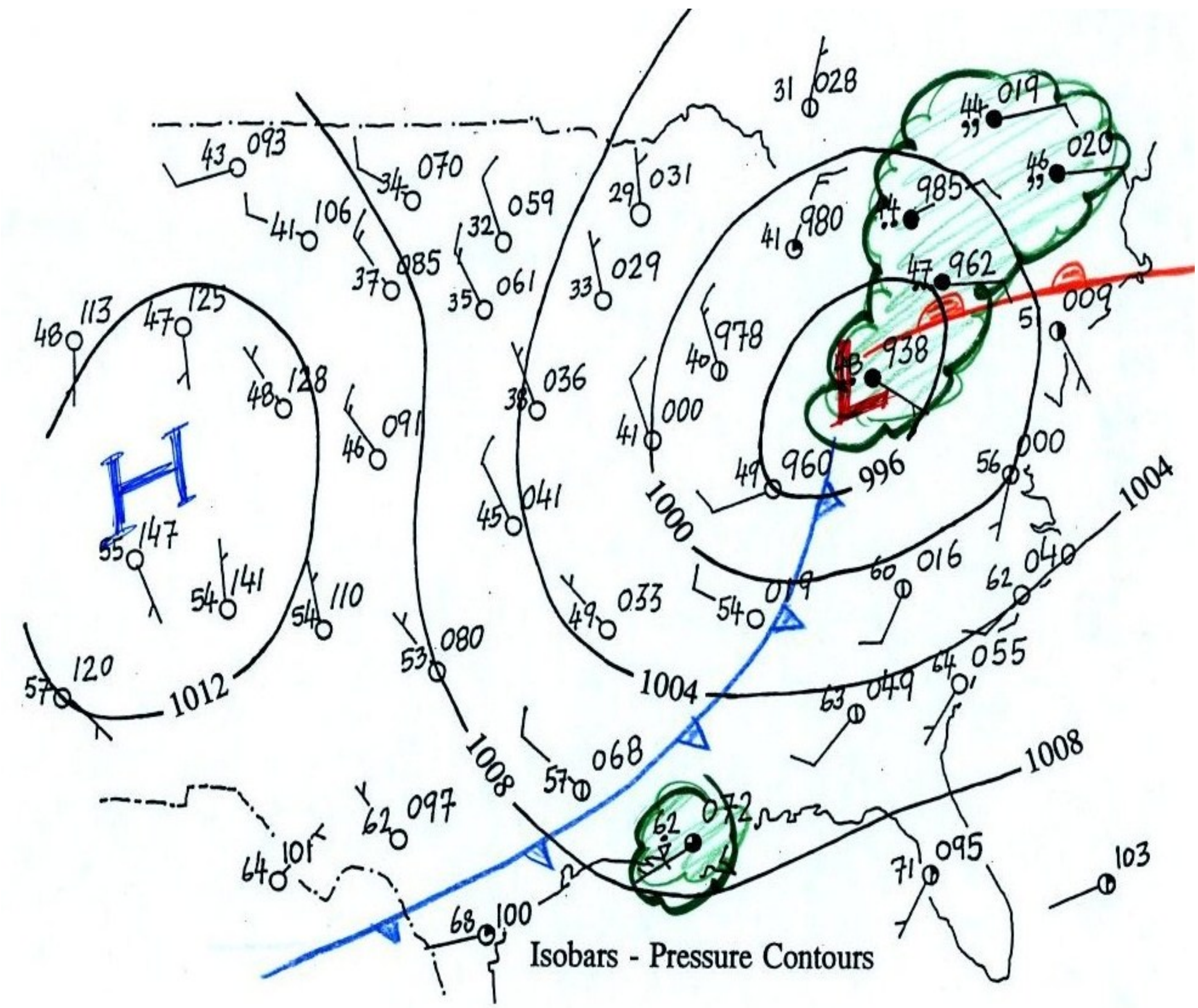
Table 2: Typical conditions before and after the passage of a warm front

Weather Variable	Ahead, before the front arrives	After the front has passed through
Temperature	Cool	warmer
Dew point	Drier	may be moister
Winds	From E or SE	from S or SW
Clouds, Weather	wide variety of clouds well ahead of the front, wide variety of precipitation types	clearing
Pressure	Falling	Rising

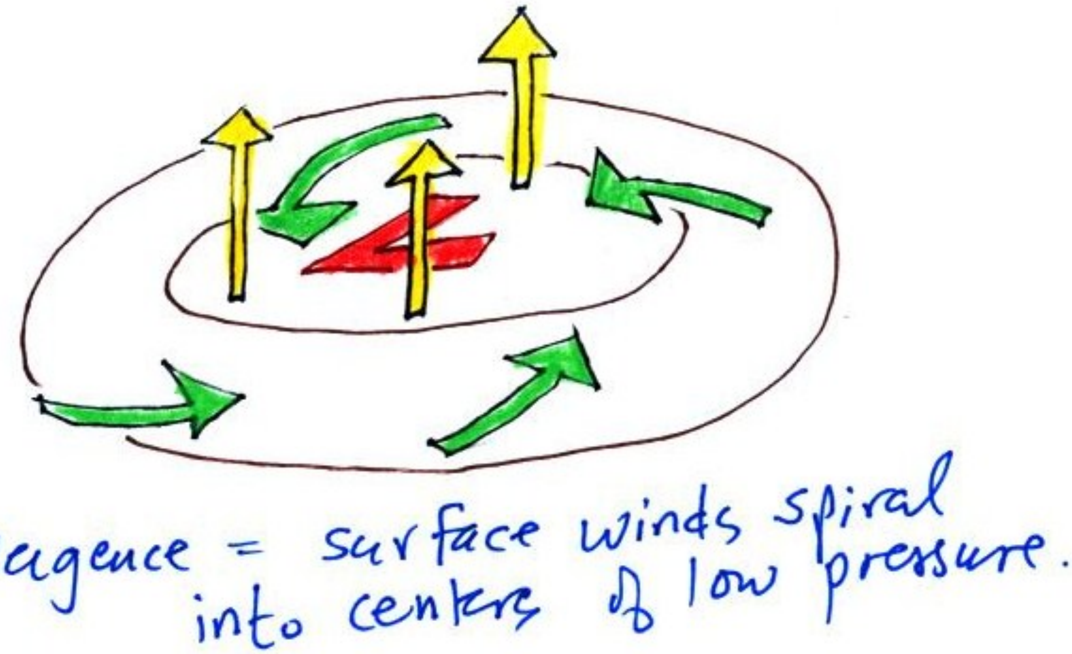
And here is the surface map analysis. Note the extensive cloud coverage and precipitation ahead of the warm front. There is a significant temperature and dew point difference on opposite sides of the warm front and a clear shift in wind directions. Pressure is falling ahead of the warm front and rising behind. A cold front can also be seen on this map.



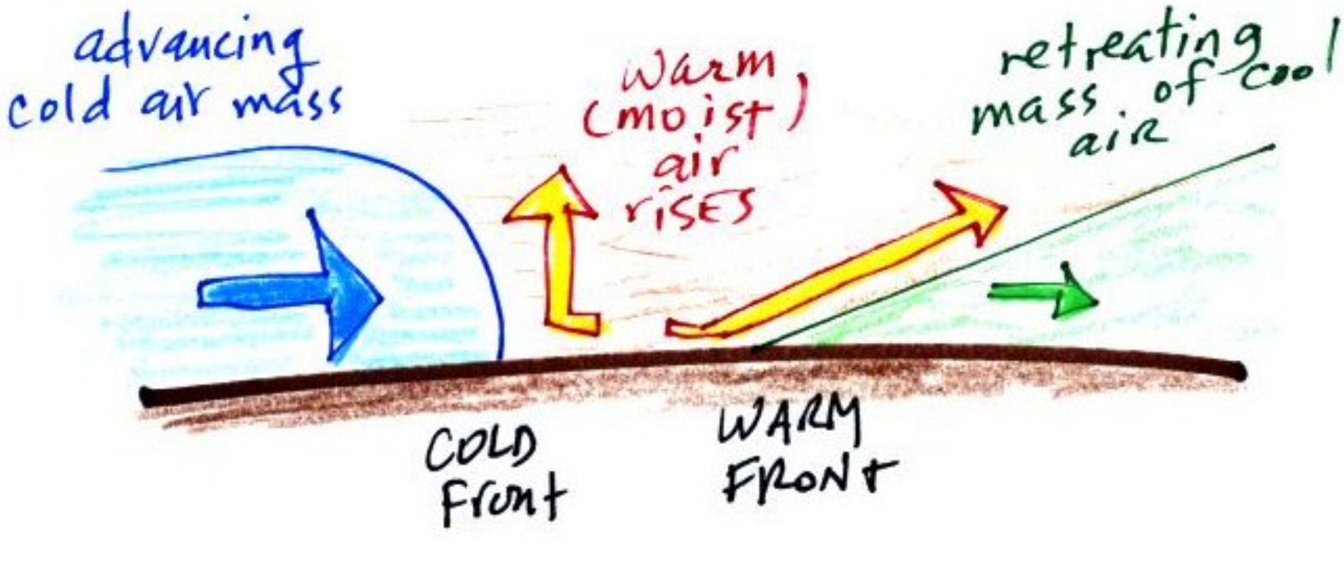
Finally, here is the surface map that we began this lecture with. We were trying to figure out what was causing the clouds in the NE portion of the map and what was causing the rain shower along the Gulf Coast. A warm front and a cold front have been added to the isobaric analysis. The warm front is probably what is producing most of the widespread cloudiness and precipitation in the NE portion of the map (rising air motions caused by surface winds converging into the low pressure center are also contributing). The cold front is producing the showers along the Gulf Coast.



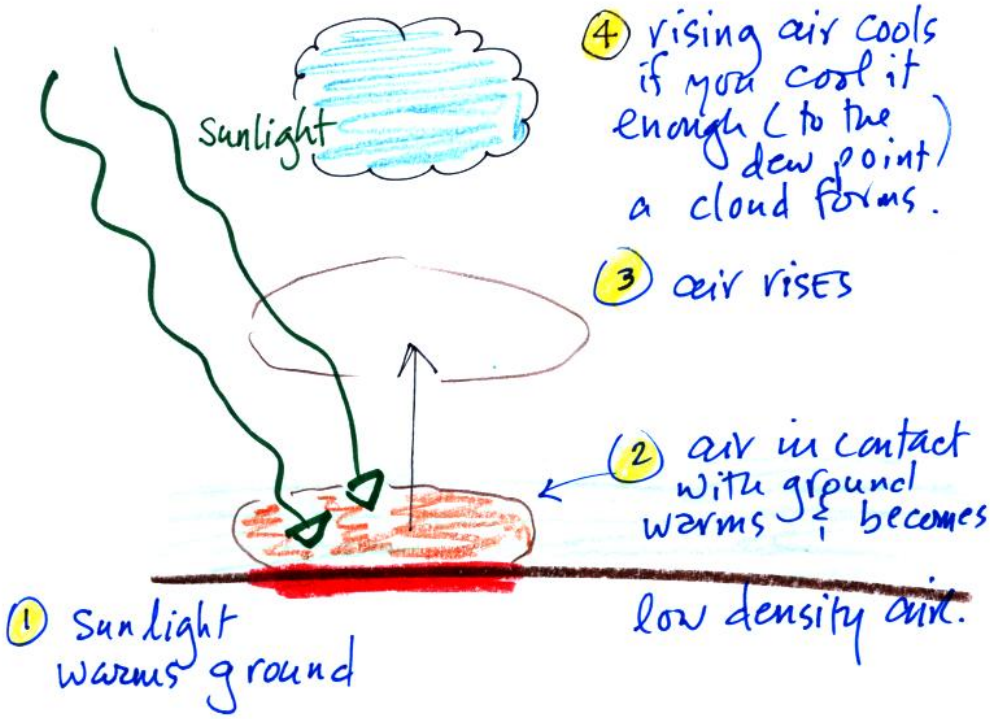
We now summarize the four processes that cause air to rise. These are important because rising air expands and cools. If the air is moist and is cooled its dew point, clouds can form. **Convergence is the first process that causes rising air motions.**



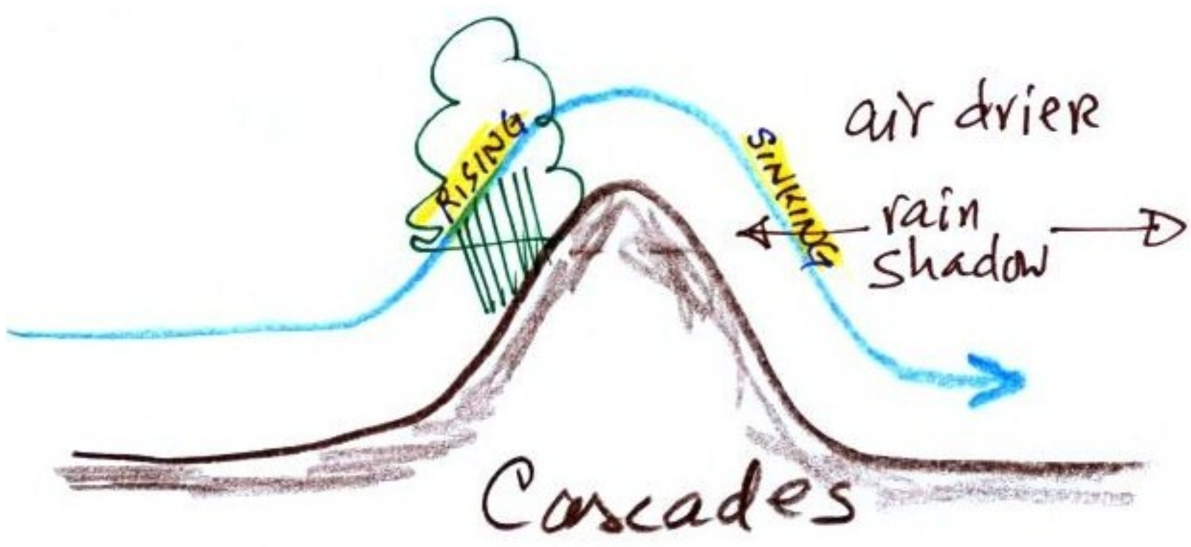
The second process that lifts air is frontal activity. Warm air is lifted by the cold dense air behind an advancing cold front. Warm air also rises above cool retreating air along a warm front.



Free convection, something we have already covered, is the 3rd process that causes air to rise.



Topographic or orographic lifting is the fourth mechanism for rising air. When moving air encounters a mountain, the air rises as it passes over the mountain, which often causes clouds and rain on the windward side of the mountain. As the air passes over the other side of the mountain, it sinks and becomes warmer as it is compressed. The warmer air can hold more moisture and consequently dry conditions tend to occur on the leeward side of a mountain. This is called a rain shadow.



Here is the answer to the question found earlier in the notes concerning wind directions and wind speeds. The winds are blowing from the NNW at Points 1 and 3. The winds are blowing from the SSE at Point 2. The fastest winds (30 knots) are found at Point 2 because that is where the isobars are closest together (strongest pressure gradient). The slowest winds (10 knots) are at Point 3.