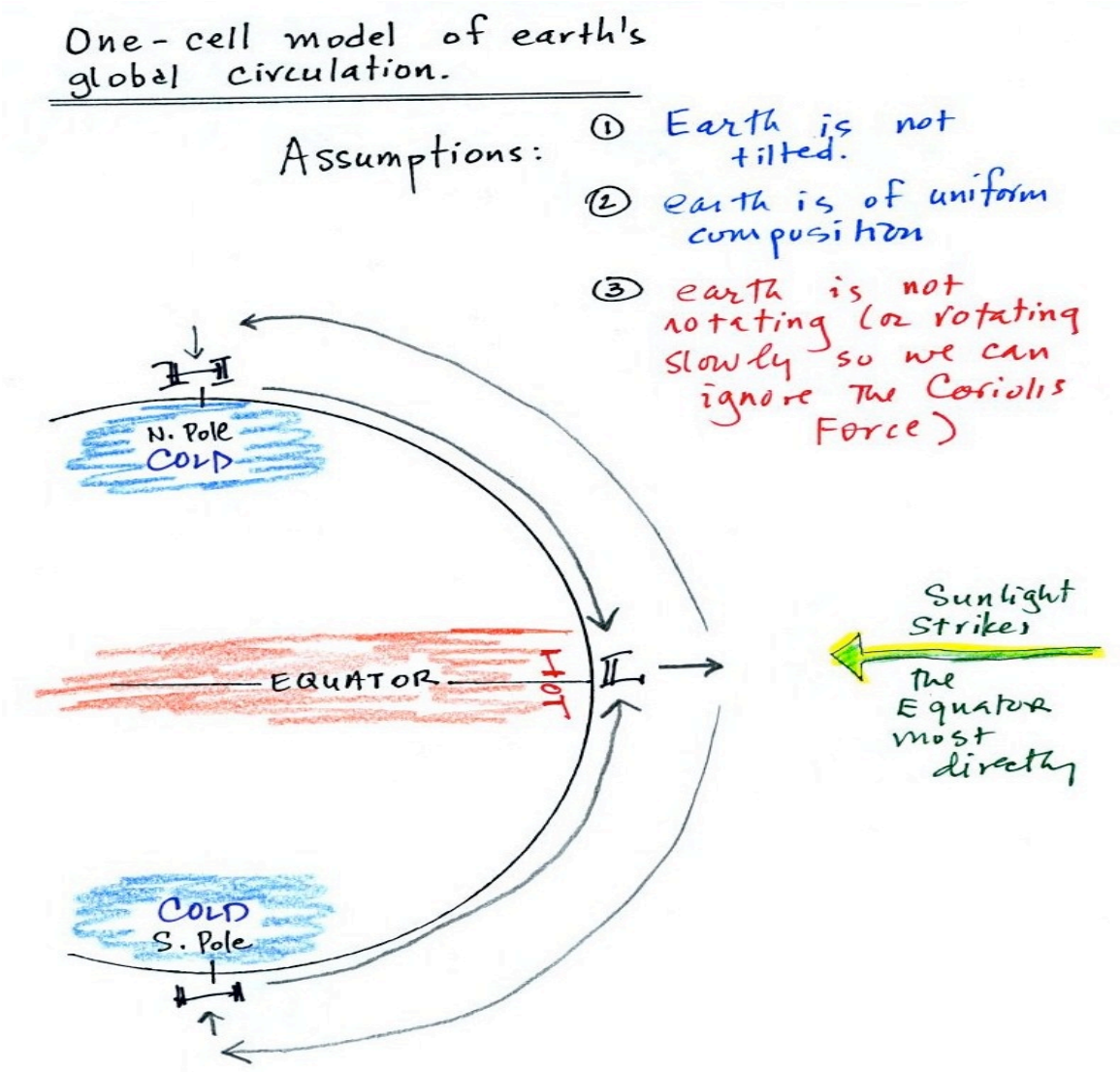
Module 9 - Lecture 27

Now we will use the idea of thermal circulation idea to study global scale pressure and wind patterns. We need to make simplifying assumptions if we want to apply a small scale phenomenon like thermal circulation to the entire earth. We will assume that the earth does not rotate or only rotates slowly so that we can ignore the Coriolis force.

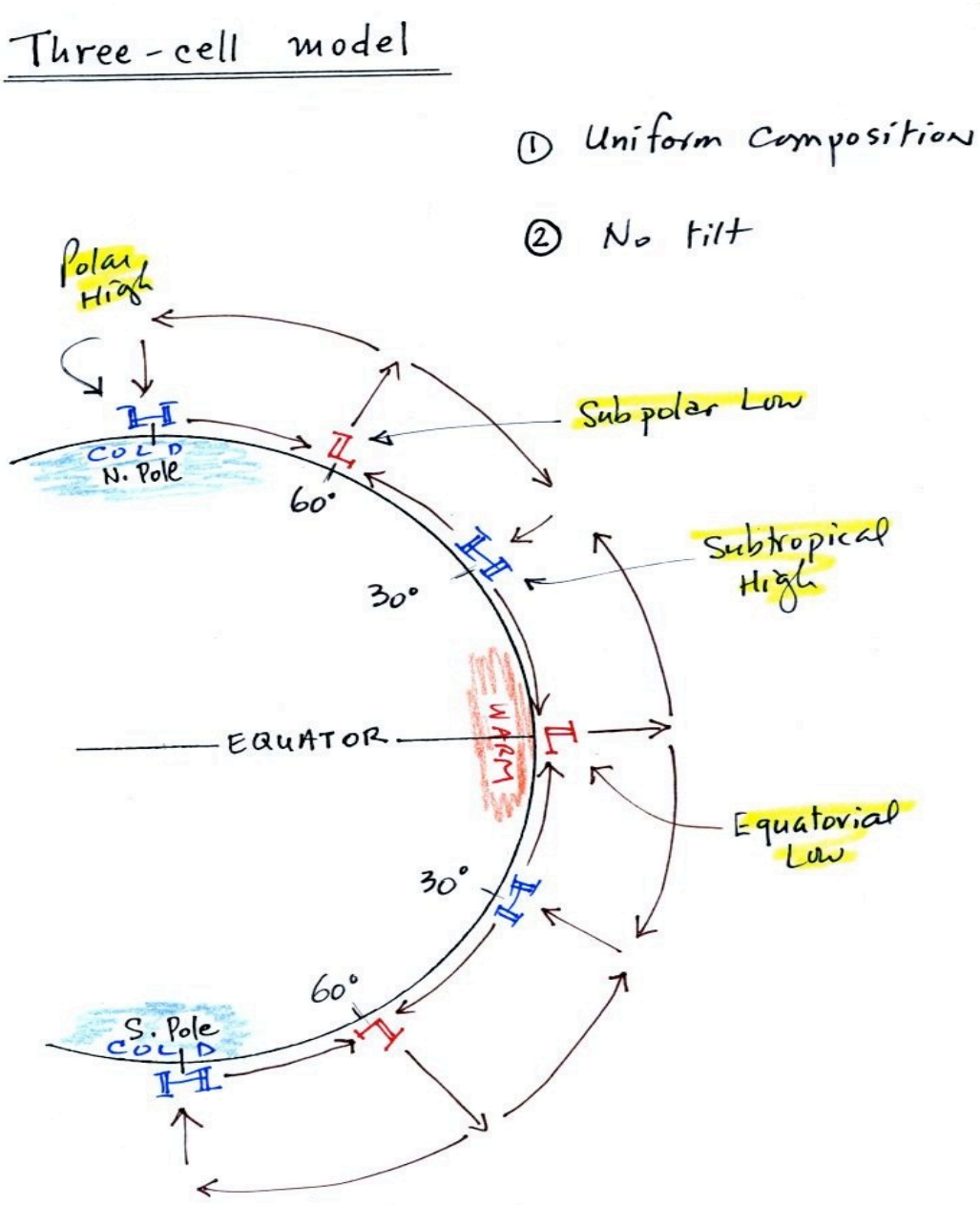
We will also assume that the earth is not tilted, so there has no seasonal variaions. Now the incoming sunlight shines on the earth most directly at the equator. The equator will become hotter than the poles. By allowing the earth to rotate slowly we spread this warmth out in a belt that circles the globe at the equator rather than concentrating it in a spot on the side of the earth facing the sun. Because the earth is of uniform composition, there are not any temperature differences created between oceans and continents.

With these assumptions, we obtain a one loop model, which means there is one complete loop in the northern hemisphere and another in the southern hemisphere.



When we remove the assumption concerning the rotation of the earth, we are no longer able to ignore the Coriolis force. We now have a three loop model, which means we have three circulation loops. The circulation at the equator is similar in both models. We have low pressures at the surface and rising air that blows towards the poles at upper levels. But the Coriolis force deflects the upper air currents so that they no longer reach the poles.

Here is an illustration of the three-cell model. There are surface belts of low pressure at the equator (the equatorial low) and at 60 degrees latitude (the sub-polar low). There are belts of high pressure (the subtropical high) at 30 latitude and high pressure centers at the two poles (the polar highs). This model is not totally realistic, but the high and low pressure areas that it predicts are actually found on earth.



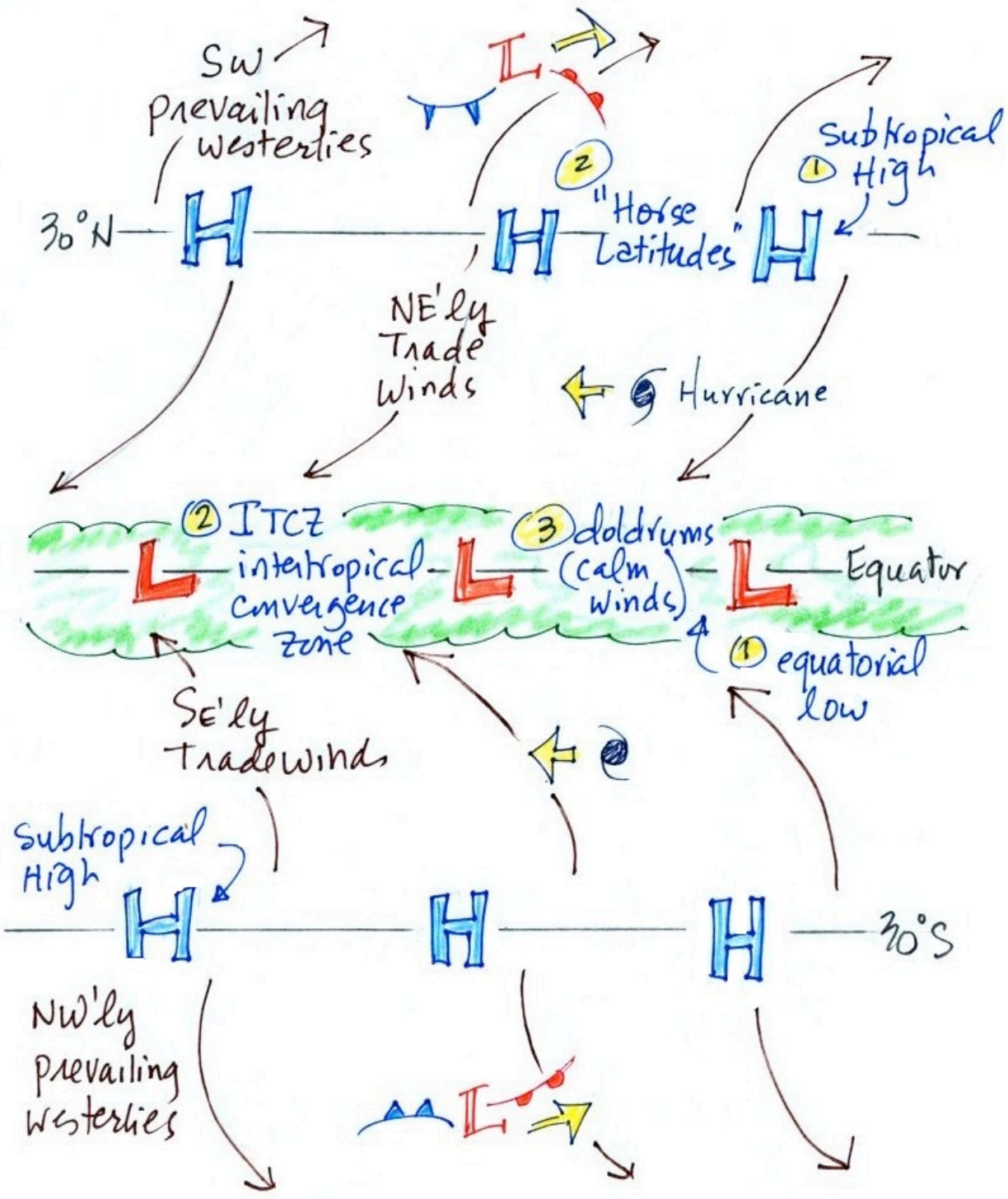
On the following page, there is a map of the region between 30 degrees north and 30 degrees south. We will start with the high pressure areas at 30 degrees north and 30 degrees south. The winds will begin to blow from these high pressure areas towards the low pressure area at the equator. In the southern hemisphere, the winds will be deflected to the left because of the Coriolis force. In the northern hemisphere, the winds will be deflected to the right because of the Coriolis force. These winds are called the Trade Winds because they enabled the European empire expansion into the Americas. The Trade Winds blow in a southwest direction towards the equator from the north hemisphere and in a northwest from the southern hemisphere. (The trade winds in the northern hemisphere are called the northeasterly trade winds and the trade winds in the southern hemisphere are called the southeasterly trade winds).

The Trade Winds converge at the low pressure area near the equator. The Inter-tropical Convergence Zone or ITCZ is another name for the equatorial low pressure belt. This is the cause of the band of clouds that you can often see at or near the equator on a satellite photograph http://www.atmo.arizona.edu/products/wximagery/globalir.html.
This region is also referred to as the doldrums because it is a region where surface winds are often weak. Sailing ships would sometimes get stranded there hundreds of miles from land. Fortunately it is a cloudy and rainy region so the sailors would not run out of drinking water (they might well have run out of rum though which they probably felt was worse).

Hurricanes form over warm ocean water in the subtropics between the equator and 30 degrees north. Winds at these latitudes have a strong easterly component and hurricanes, at least early in their development, move from east to west. Middle latitude storms are found between 30 and 60 degrees latitude and move from west to east because this is where the prevailing westerly wind belt is found.

You find sinking air, clear skies, and weak surface winds associated with the subtropical high pressure belt. This is also known as the horse latitudes because ships often become stranded there. Horses were apparently either thrown overboard to conserve drinking water or eaten if food supplies were running low. The sinking air associated with the subtropical high pressure belt creates clear skies. Tucson is located at 32 degrees north, so we are strongly affected by the subtropical high pressure belt.

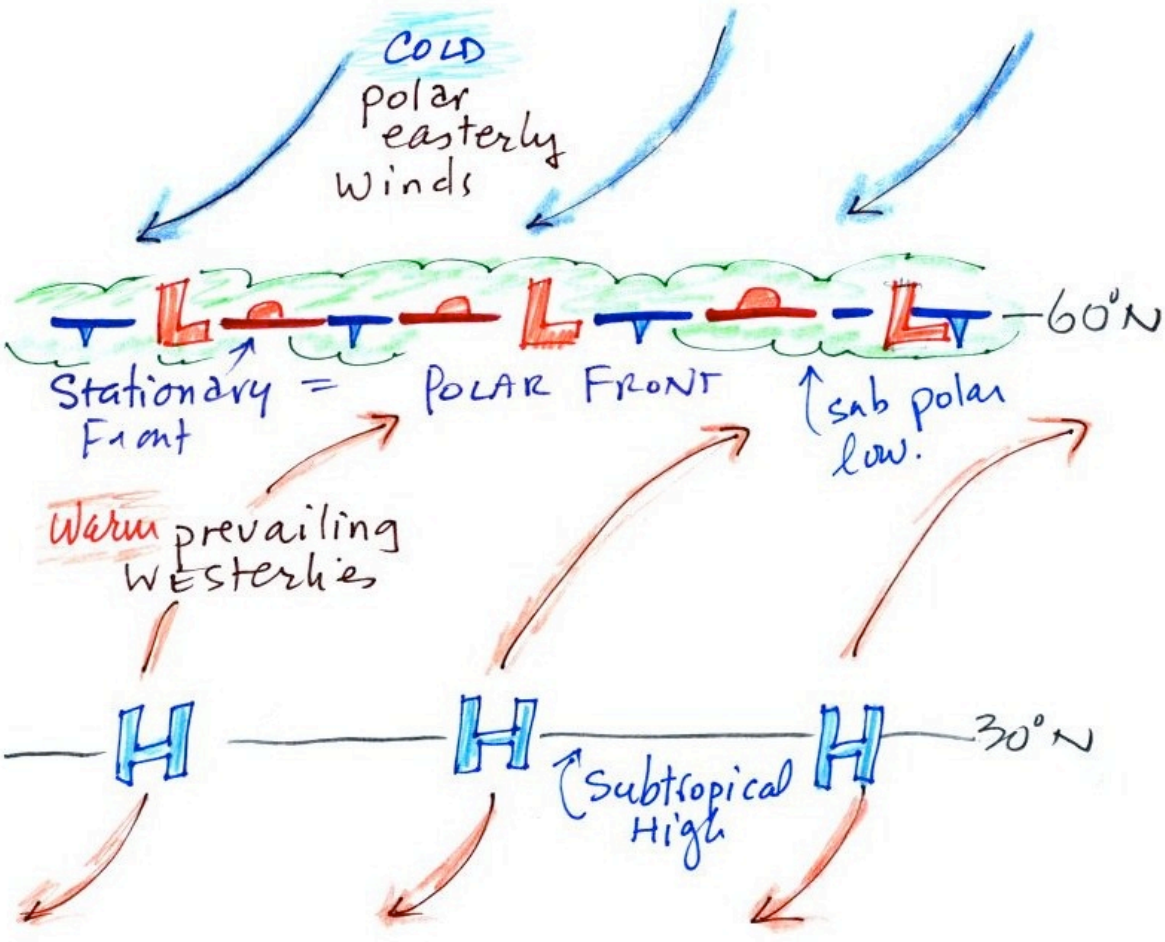
There is a lot of information in this figure, but with a little study you should be able to start with a blank sheet of paper and reproduce this figure. I would suggest starting at the equator. You need to remember that there is a belt of low pressure found there. Then remember the belts of high pressure at 30 degrees north and south.


SW prevailing westerlies
30°N
2
"Horse Latitudes"
1 Subtropical High
NE'ly Trade Winds
Hurricane
2 ITCZ intertropical convergence zone
3 doldrums (calm winds)
Equator
1 equatorial low
SE'ly Tradewinds
Subtropical High
30°S
NW'ly prevailing westerlies

The winds between 30 degrees and 60 degrees north and south are called the "prevailing westerlies". They blow from the southwest in the northern hemisphere and from the northwest in the southern hemisphere. In the southern hemisphere, the 30 S to 60 S latitude belts is mostly ocean. Because there is less friction over the oceans, the prevailing westerlies there can become strong, especially in the winter. They are sometimes referred to as the "roaring forties" or the "ferocious fifties" (the forties and the fifties refer to the latitude belt they are found in).

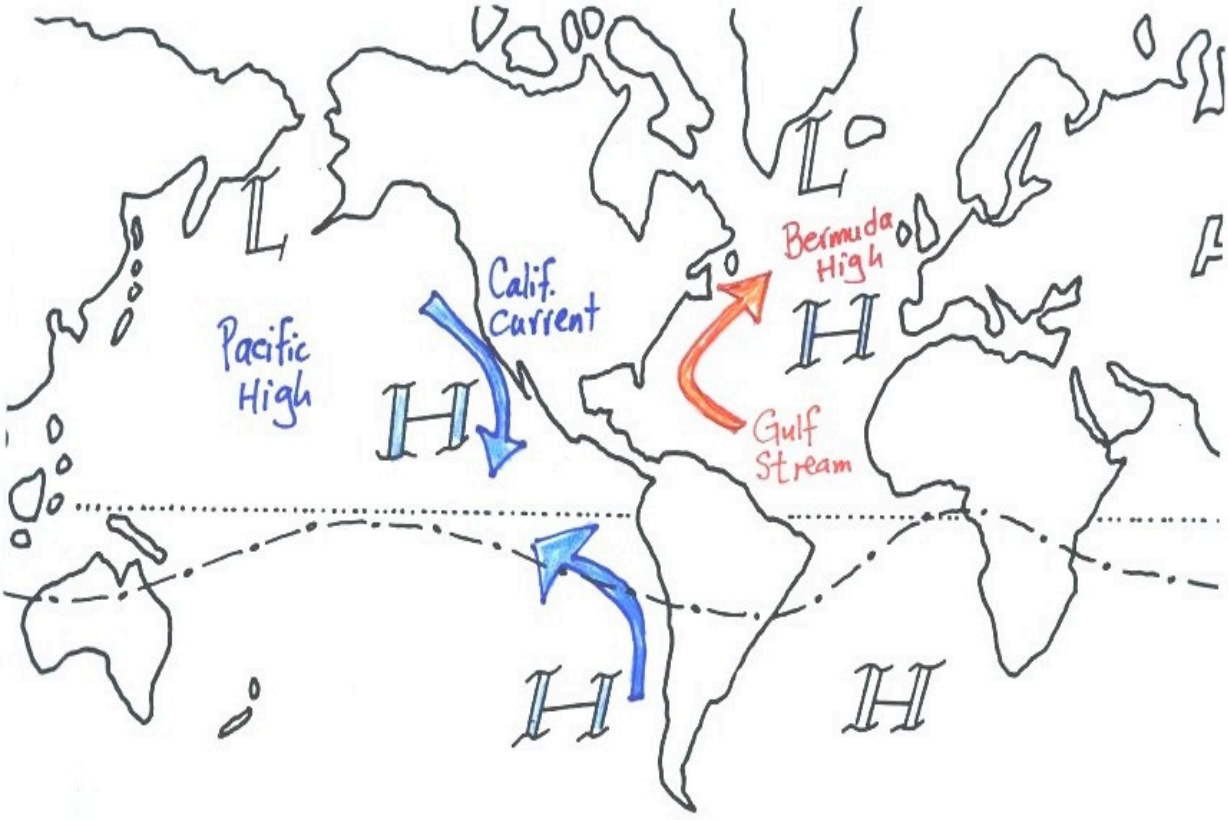
The figure below shows the area between 30 and 60 degrees north. Winds blowing north from the high pressure at 30 degrees north toward the low pressure at 60 degrees north are deflected to the right by the Coriolis force and blow from the southwest. These are the "prevailing westerlies" which blow middle latitude storms across the country.

The polar easterlies are cold winds blowing from the high pressure area at the North Pole. The subpolar low pressure belt is found at 60 degrees latitude. This is a convergence zone where the cold polar easterly winds and the warmer prevailing westerly winds meet. The boundary between these two different kinds of air is called the polar front and is often drawn as a stationary front on weather maps. A strong current of winds called the polar jet stream is found overhead. Strong middle latitude storms will often form along the polar front.



The three-cell model predicts that subtropical belts of high pressure will be found near 30 degrees. Instead of continuous belts, what we really find are large circular centers of high pressure. In the northern hemisphere the Bermuda high is found off the east coast of the US and the Pacific high is positioned off the west coast. High pressure centers are found east and west of South America in the southern hemisphere. Circular low pressure centers are found near 60 degrees north. The Icelandic low is off the east coast near Iceland and the Aleutian low is located off the west coast near the southern tip of Alaska.

The winds that blow around these large scale high pressure centers create some of the major ocean currents of the world. The winds blow clockwise around a high pressure system in the northern hemisphere and the ocean currents flow in the same direction as the wind. The Gulf Stream is a warm current that flows from south to north along the east coast and the cold California current flows from north to south along the west coast. A cold current flows north along the west coast of South America because winds blow counterclockwise around a high pressure system in the southern hemisphere.



Tucson gets about 12 inches of rain in a normal year. About half of this comes during the "summer monsoon" season. The word monsoon refers to a seasonal change in wind direction. During the summer, the subtropical high pressure (the Pacific high) moves north of the 30 degree latitude circle (middle picture of figure below). Winds on the southern side of the subtropical high have an easterly component which brings moist air from the Gulf of Mexico into Tucson. The sun heats the ground during the day, which causes warm moist air in contact with the ground to rise and produces the thunderstorms that are characteristic of the monsoon season. At the same time, the Pacific high with its sinking air motions give California, Oregon and Washington dry summers.

In the winter, the subtropical high moves south of the 30 degree latitude circle (bottom picture). Arizona is now north of the Pacific high and the winds blow from the west. Air originating over the Pacific Ocean loses much of its moisture as it crosses the Sierra Nevada Mountains in California (remember the rain shadow effect). Significant winter rains occur in Arizona when tropical storm systems are able to draw moist subtropical air from the southwest Pacific Ocean into Arizona.