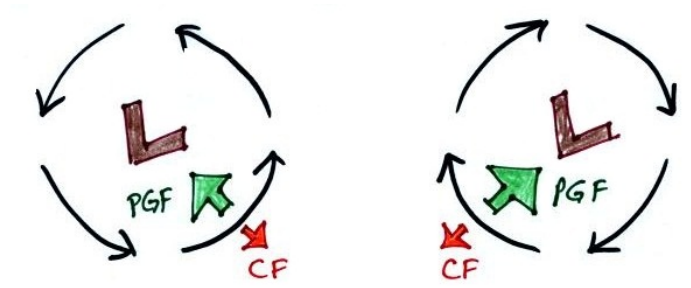
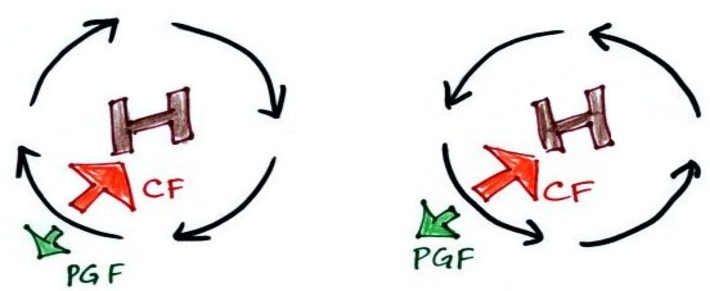
# Module 9 -Lecture 26

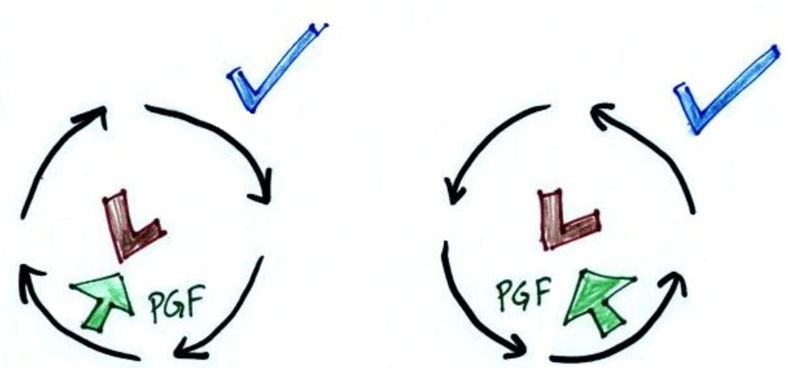
In the northern and southern hemisphere, the Coriolis force causes winds to spin in opposite directions around high and low pressure centers. The pressure gradient force (PGF) starts the air moving in towards a low pressure center and outward away from a high pressure center. Then the Coriolis force (CF) bends the wind to the right in the northern hemisphere and to the left in the southern hemisphere. You should be able to identify the northern hemisphere and the southern hemisphere in the picture below.



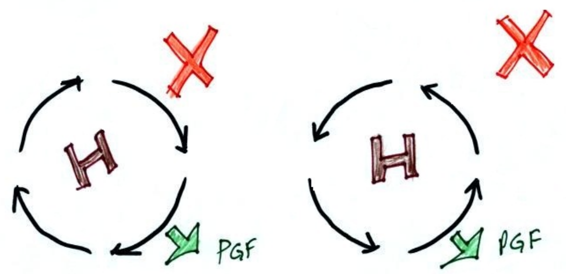

The picture below illustrates the direction of flow around high pressure centers. You should be able to identify the northern hemisphere and the southern hemisphere in this picture.




The pressure gradient force in tornados and dust devils is much stronger than the Coriolis force and as a result, the wind in tornados and dust devils can spin in both directions in the north and south hemisphere. Years ago, a PhD student from the University of Arizona (Department of Atmospheric Sciences) did a field study of dust devils in Arizona and confirmed this hypothesis. The University of Arizona Lunar and Planetary Laboratory has recently discovered dust devils on Mars.



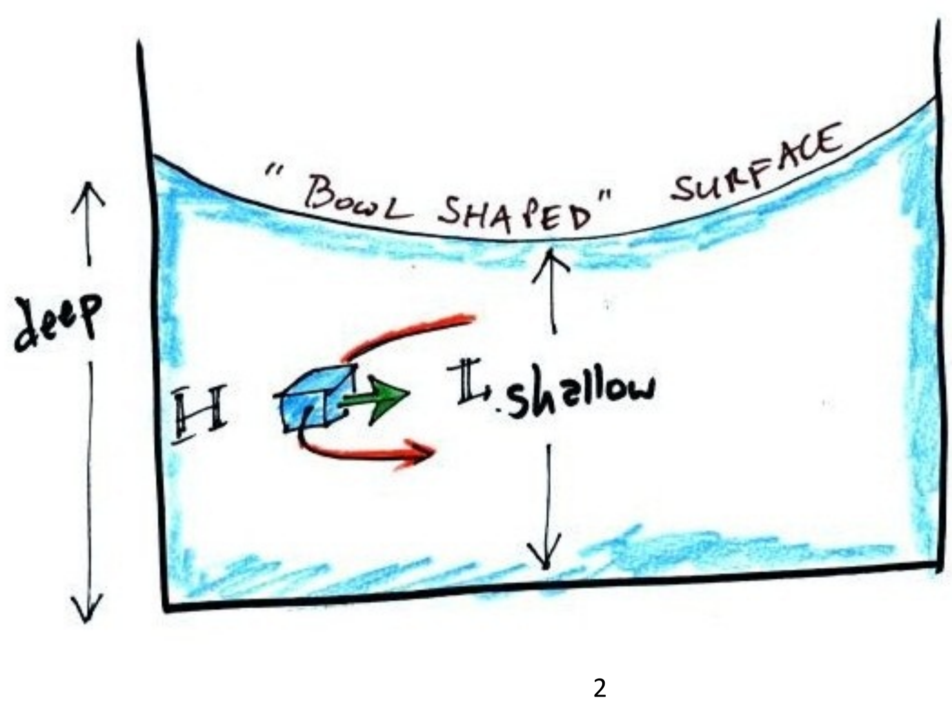
Without the Coriolis force, winds cannot spin around a high pressure center because there is nothing to provide the needed inward force.  There are no weather phenomena in which high pressure systems are rotating so rapidly that the Coriolis force can be ignored.




This is an appropriate point to look at a common misconception involving the Coriolis force.  You may have heard that the Coriolis force causes water to spin in different directions when it drains from sinks or toilet bowls in the northern and southern hemisphere.  We will find that this is not the case.  Draining water can spin in either direction in either hemisphere.

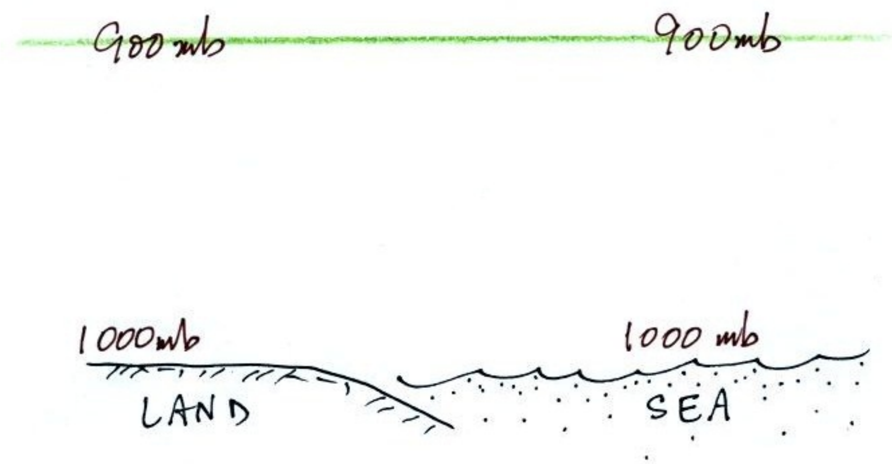
In the classroom version of this course, we watch a short video that seems to indicate otherwise.  The video was filmed in Kenya.  A young man drains a bucket about one hundred feet north of the Equator and then an equal distance south of the equator.  The video shows the water spinning in opposite directions.  When the bucket is placed right on the Equator the water does not seem to spin at all while it drains.  In reality, the young man's manual dexterity is the reason why the water drains in different directions on opposite sides of the equator.  Probably his most difficult feat is to drain the water without spinning.

The Coriolis force is equal to zero at the equator and you need to move 100 miles or more from the equator before the Coriolis force becomes significant.  If you are interested, you can find a toilet that spins and see for yourself.



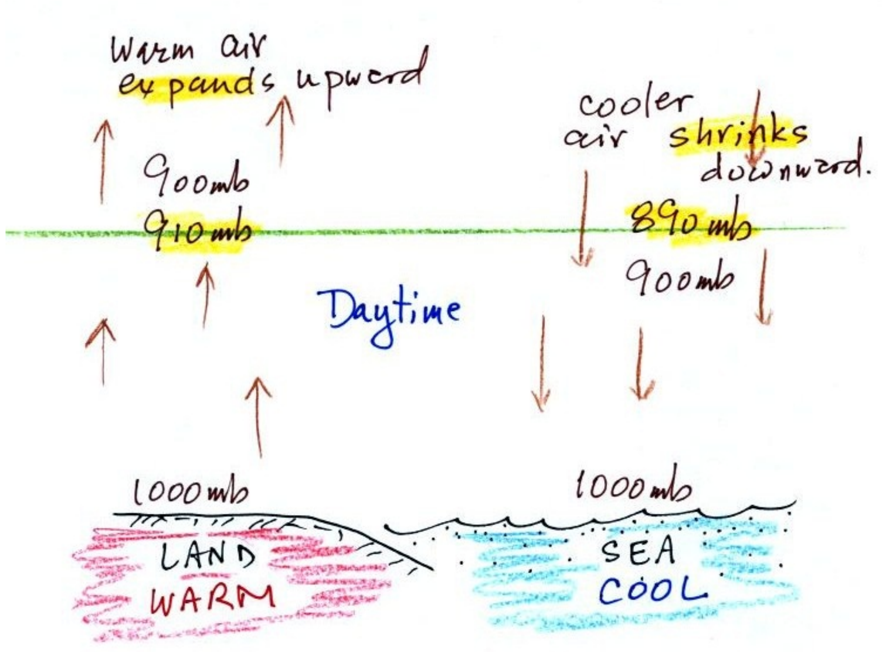
A temperature differences between different areas (such the coast and the ocean or between a city and the surrounding country side) creates a horizontal pressure gradient. The resulting air circulation patterns are known as thermal circulations. We will devote the rest of this lecture to different types of thermal circulation. Because these are generally relatively small scale circulations, the pressure gradient is much stronger than the Coriolis force. For more detailed studies of thermal circulations, the Coriolis force cannot always be ignored. But in this lecture we will focus on temperature and pressure gradients.

The first thermal circulation we will study is the **sea breeze**, which is caused by temperature differences between the ocean and the coastline. The same phenomena occur on the shorelines of the Great Lakes and are called a lake breeze. In this picture, the air temperatures and pressures on both sides of the picture are the same.



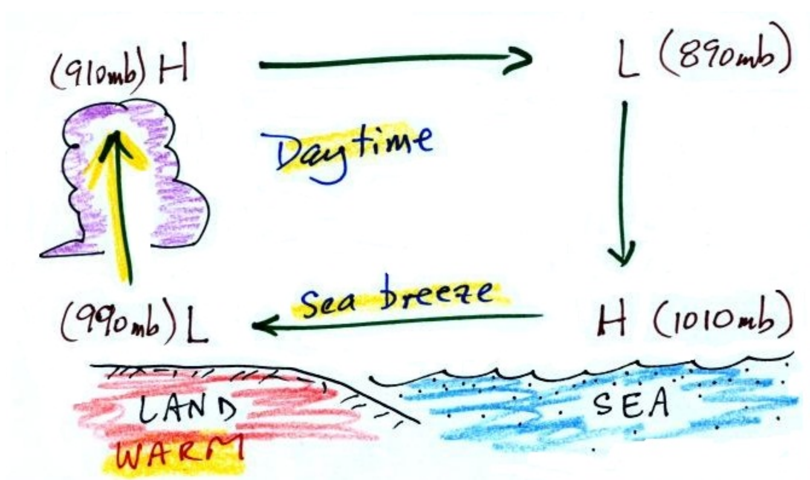

During the day, the coastline becomes warmer than the ocean because water has a much higher specific heat than the land. You can observe this phenomenon if you go to the beach. The ocean will remain cool while the sand may become so hot that it is painful to walk along the beach in bare feet. The warm air over the land rises and expands upward while the cooler air over the ocean shrinks and moves downward.

You will recall from previous lectures that the pressure decreases more slowly with altitude in warm, low density air. Before the land became warmer (picture above), the pressure changes with altitude were the same over the land and the ocean. Now there is only a 90 mb pressure drop between the ground and the green line on the left side of the picture below (picture on next page). Pressure decreases more rapidly with altitude (a 110 mb drop) in the colder higher density air on the right side.




The temperature difference has created an upper level pressure gradient and the wind begins to blow from over the ocean to the coastline. Once the air aloft begins to move it will change the surface pressure pattern. The air aloft leaving the left side of the picture will lower the surface pressure (from 1000 mb to 990 mb). Adding air at upper levels to the right side of the picture will increase the surface pressure (from 1000 mb to 1010 mb). Surface winds will begin to blow from right to left.

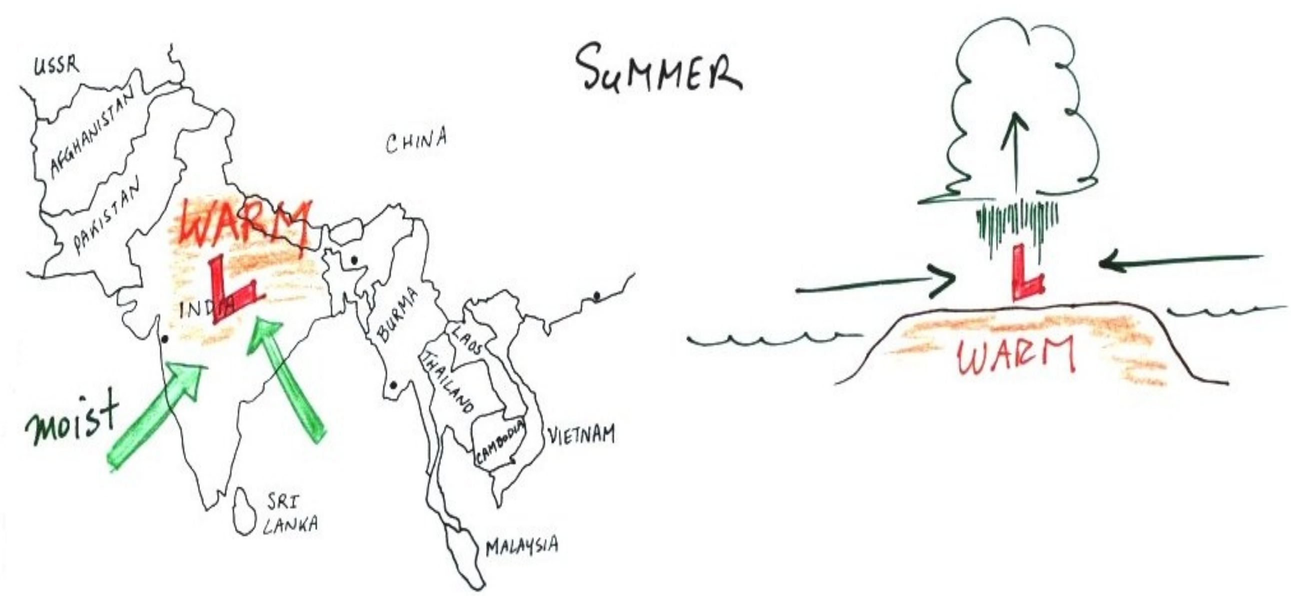
You can complete the circulation loop by adding rising air above the surface low pressure at left and sinking air above the surface high at right. The surface winds which blow from the ocean onto land are called a sea breeze (meteorologists try to specify where the wind is coming from). Since this air is likely to be moist, cloud formation is likely when the air rises over the warm ground. Rising air expands and cools. If you cool moist air to its dew point, clouds form.



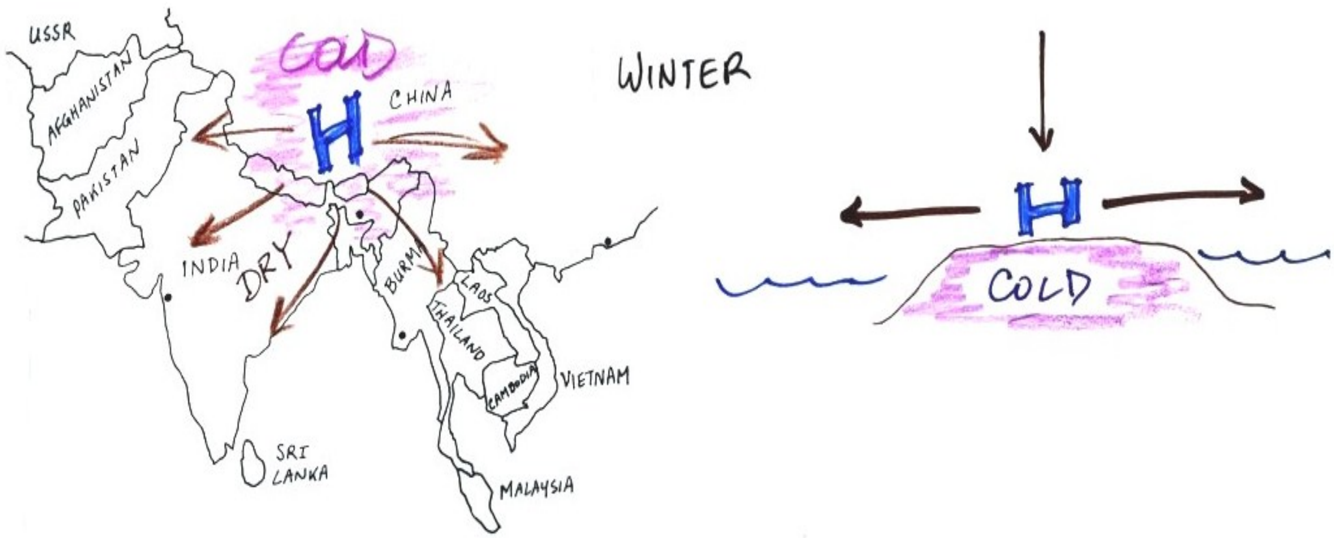
At night the ground cools more quickly than the ocean and becomes colder than the water.  Rising air is found over the warmer ocean water (see below).  The thermal circulation pattern reverses direction.  Surface winds blow from the land out over the ocean.  This is referred to as a **land breeze**.


The term **monsoon** refers to a seasonal change in the direction of the prevailing winds.  The Asian monsoon is a large scale circulation pattern that is much more complex than a simple thermal circulation.  But conceptually, the Asian monsoon is similar to a sea or lake breeze.

In the summer, the Tibetan Plateau (located north of India and southeast of China) becomes warmer than the ocean nearby.  A surface low pressure system forms over the land, moist winds blow from the ocean onshore, and very large amounts of rain can follow.  In the picture below, the left view is from above and right view is from the side.

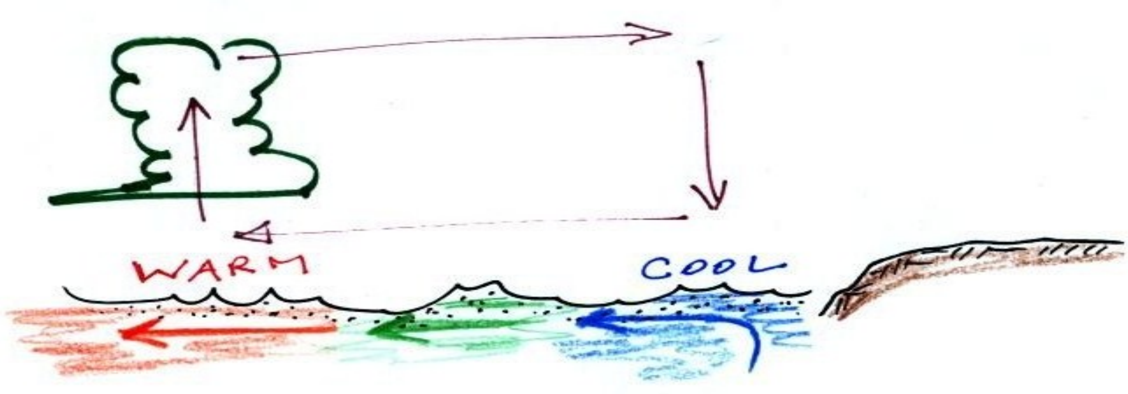


The winds change directions in the winter when the land becomes colder than the ocean.

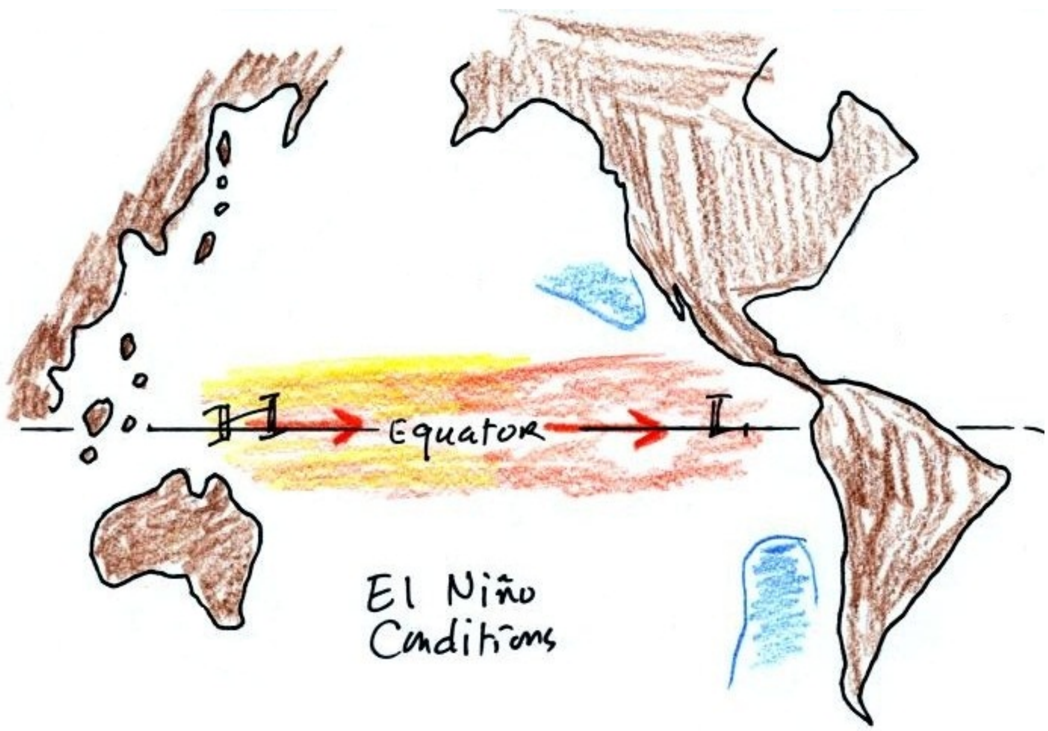


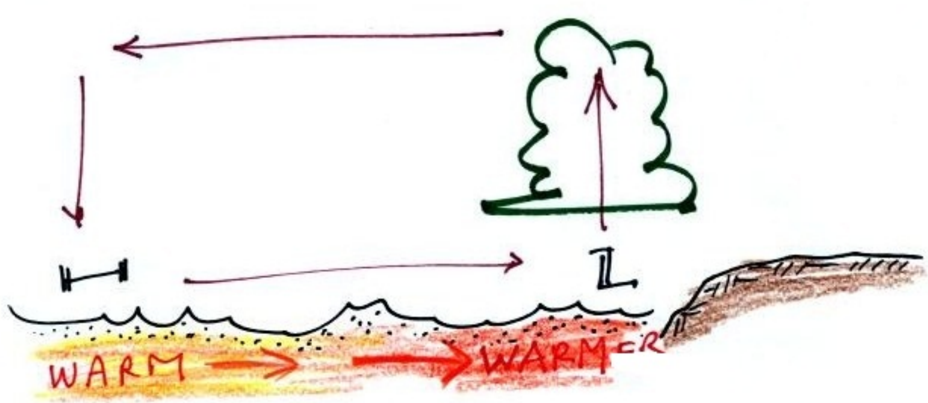

The Asian monsoon can cause a lot of flooding.  This picture was taken in Bangladesh.

You can also use the thermal circulation to understand some of the basic features of the **El Nino** phenomenon. Here is what conditions look like in the tropical Pacific Ocean in normal (non-El Nino) years. Cold ocean currents that flow along the west coasts of North America and South American normally converge at the equator and begin to flow westward (see top view below). As the water travels westward it warms. Some of the warmest sea surface waters on earth are normally found in the western Tropical Pacific. A temperature gradient becomes established between the west and east ends of the tropical Pacific. The cross-sectional view (bottom, below) shows the normal temperature and circulation pattern found in the equatorial Pacific Ocean. You would find surface high pressure in the east and low pressure in the west. Note that the wind circulation pattern is similar to the ocean breeze circulation.

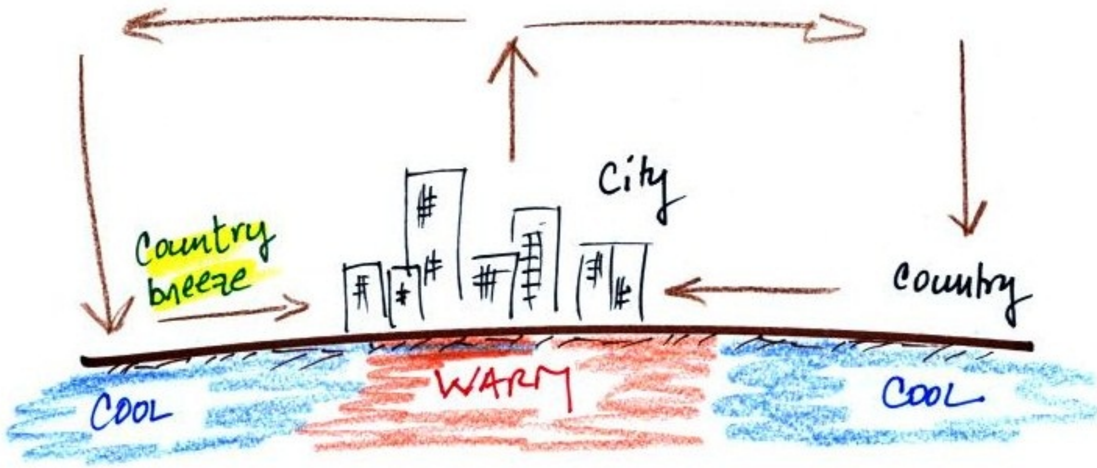
Every few years El Nino conditions occur and the cold currents do not converge at the Equator. Warm water is carried from the western Pacific to the eastern Pacific. Now a surface high pressure center is found in the west and surface low pressure and rising air is found in the east Pacific. The reversal in the surface pressure pattern is referred to as the Southern Oscillation. Indonesia and Australia often experience drought conditions during El Nino events.



In the desert southwest, we expect slightly wetter than normal conditions (perhaps 20% wetter than normal). Wetter conditions are also found in California. 2010 was an El Nino year which brought spectacular spring wildflowers to Arizona. This picture was taken on March 27, 2010 at Catalina State Park.

The **urban heat island effect** refers to the fact that cities are often warmer than the surrounding countryside, especially at night. This temperature difference can create a "country breeze", which can carry pollutants from a factory outside the city back into the city or odors from a sewer treatment plant outside of town back into town.


City
Country breeze
Country
COOL
WARM
COOL