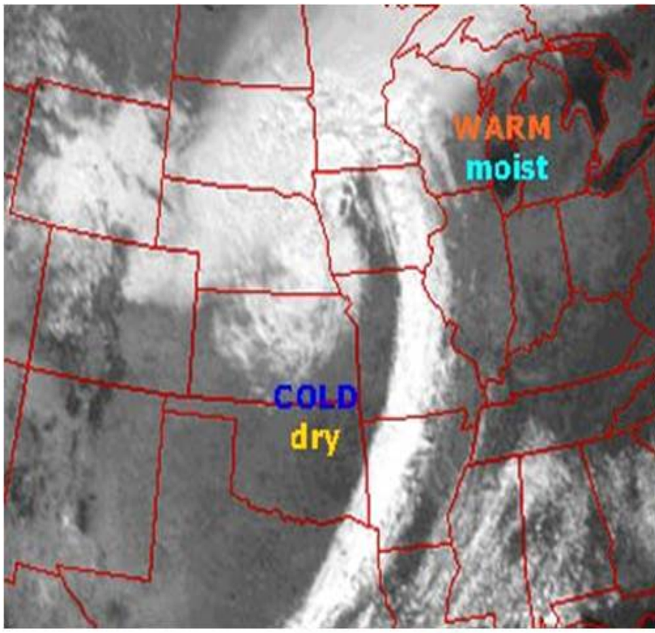
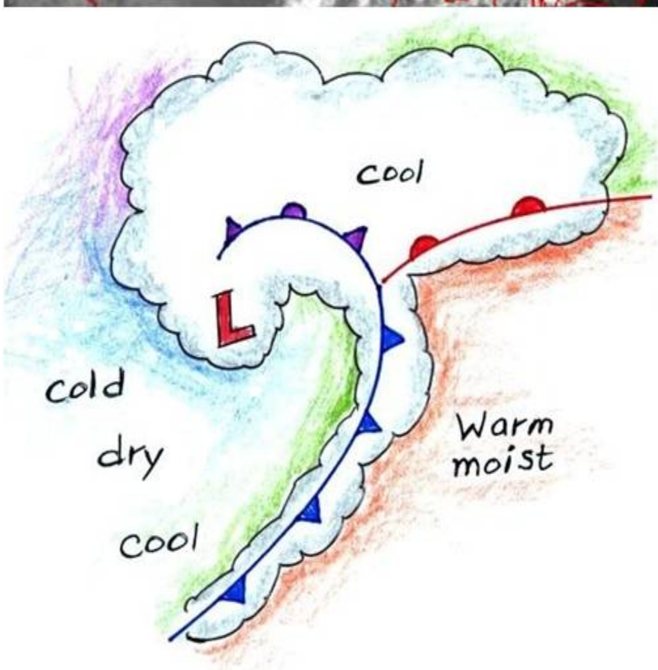
Module 12 - Lecture 34

We will spend two lectures on Hurricanes. This will be the final topic that we cover this semester except for atmospheric optics.

We will begin by comparing hurricanes (tropical cyclones) with middle latitude storms (extra tropical cyclones). They are the two largest types of storm systems found on earth. Satellite photographs and sketches of each type of storm system are shown below.





First we will list some of the similarities.

- Both types of storms have low pressure centers. The term cyclone refers to winds blowing around low pressure.
- Upper level divergence causes both types of storms to intensify, which means that the surface low pressure becomes even lower.

Next we will list some differences in the following table.

Middle Latitude Storms	**Hurricanes**
Middle latitude storms are bigger, perhaps 1000 miles in diameter (half the US)	Hurricanes are smaller, hundreds of miles in diameter (the Gulf of Mexico)
Formation can occur over land or water	Formation occurs only over warm ocean water. Hurricanes weaken rapidly when they move over land or cold water.
Formation at middle (30^o to 60^o) latitudes	Formation in the subtropics, 5^o to 20^o latitude
Prevailing westerly's move these storms from west to east	Trade winds move hurricanes from east to west
Storm season: winter to early spring	Storm season: late summer to fall when ocean water is warmest
Air masses of different temperatures collide along fronts	Single warm moist air mass
All types of precipitation: rain, snow, sleet freezing rain and hail	Primarily a huge amount of rain (a foot or more)
Only an occasional storm gets a name ("The Perfect Storm", "Storm of the Century", etc.)	Tropical storms and hurricanes gets names

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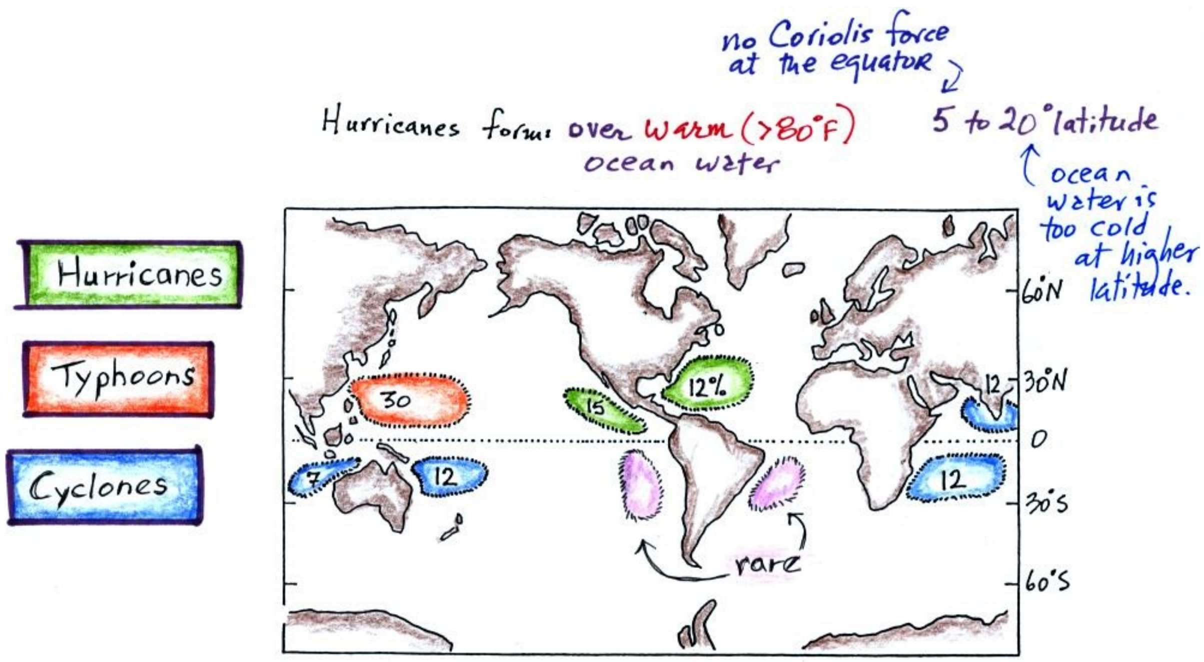
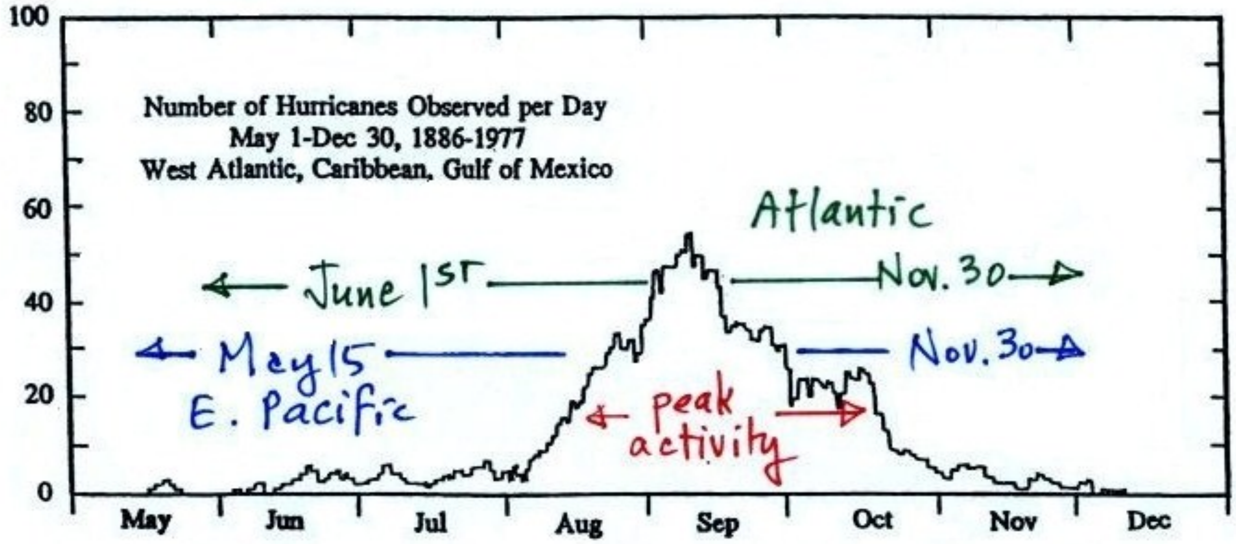
The figure below shows the relative frequency of tropical cyclone development in different parts of the world. The name hurricane, cyclone, and typhoon all refer to the same type of storm. Tropical cyclone is a generic name that can be used anywhere. In most years, the ocean off the coast of Southeast Asia is the world's most active hurricane zone. Hurricanes are very rare off the east and west coasts of South America.

Hurricanes form between 5 and 20 degrees latitude north and south of the equator, over warm ocean water. The warm layer of water must be fairly deep to contain enough energy to fuel a hurricane and prevent turbulence and mixing from bringing cold water up to the ocean surface. The atmosphere must be unstable so that thunderstorms can develop. Hurricanes will only form when there is very little or no vertical wind shear (changing wind direction or speed with altitude). The Coriolis force is what gives hurricanes their spin, so hurricanes do not form at the equator because there is no Coriolis force there. The Coriolis force also causes hurricanes to spin in opposite directions in the northern and southern hemispheres.

Note that more tropical cyclones form off the west coast of the US than off the east coast. The water along the west coast is cold. For this reason hurricanes tend to move away from the coast and usually do not present a threat except occasionally to the state of Hawaii. The moisture from these storms will sometimes be pulled up into the southwestern US where it can lead to heavy rain and flooding.

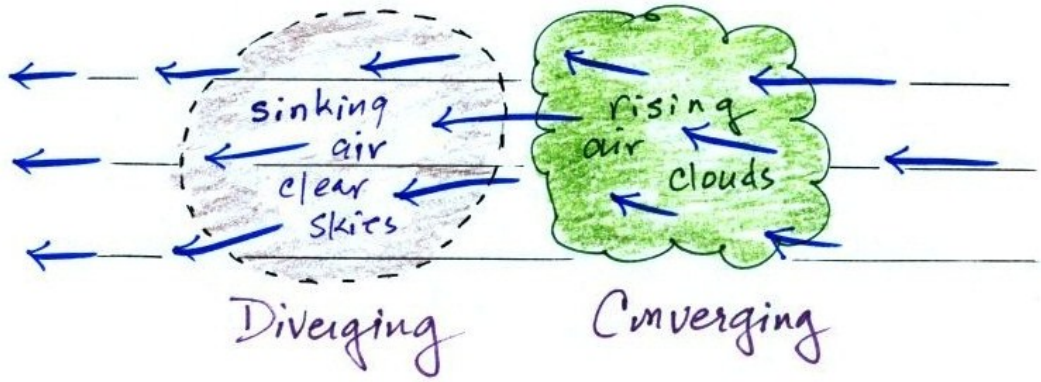


Hurricane season in the Atlantic officially runs from June 1 through to November 30. The peak of hurricane season is in September. 2005 was an unusually active hurricane season in the Atlantic when hurricanes continued through December and even into January of 2006. Hurricane season in the Pacific begins two weeks earlier on May 15 and runs through Nov. 30.

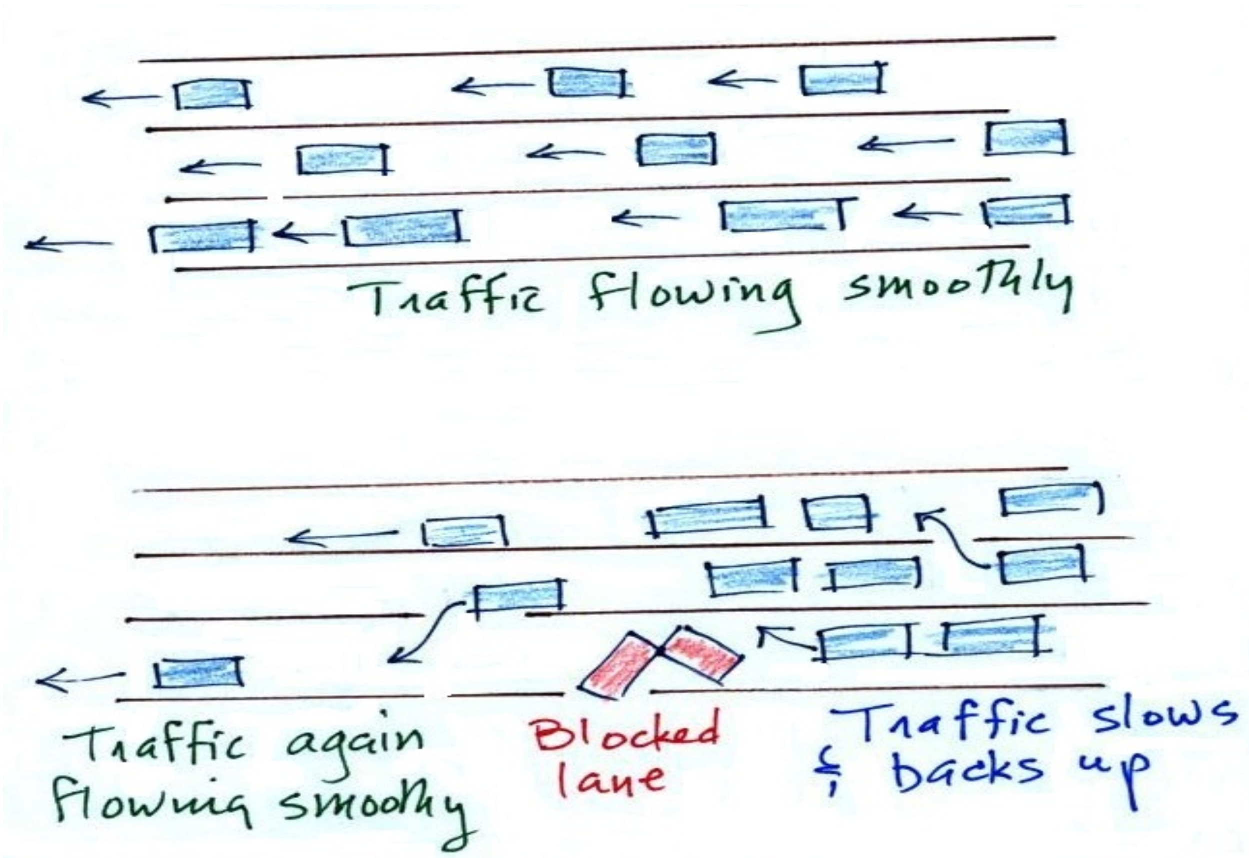


Number of Hurricanes Observed per Day
May 1-Dec 30, 1886-1977
West Atlantic, Caribbean, Gulf of Mexico
Atlantic
June 1st
Nov. 30
May 15
E. Pacific
Nov. 30
peak activity
100
80
60
40
20
0
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Some kind of meteorological process that produces low level convergence is needed to initiate a hurricane. One possibility, and the one that fuels most of the strong north Atlantic hurricanes, is an "easterly wave." This is just a "wiggle" in the wind flow pattern.



In some ways winds blowing through an easterly wave resembles traffic on a multi-lane highway. Traffic will slow down and start to bunch up as it approaches an obstruction. This is like the convergence that occurs when air flows into an easterly wave. Once through the "bottleneck" traffic will begin to flow more freely. Easterly waves often form over Africa or just off the African coast and then travel toward the west across the north Atlantic. Winds converge as they approach the wave and then diverge once they are past it. The convergence will cause air to rise and thunderstorms to begin to develop.



In an average year in the north Atlantic, there will be 10 named storms (tropical storms or hurricanes) that develop during hurricane season. 2005 was a very unusual year with were 28 named storms in the north Atlantic, which beat the 1933 record of 21 named storms. In 2005, 15 of the 28 named storms developed into hurricanes.

Normal hurricane activity in the Pacific	**Normal hurricane activity in the Atlantic**
16 tropical storms per year 8 reach hurricane strength 0 hit the US coastline	10 tropical storms per year 6 reach hurricane strength 2 hit the US coastline

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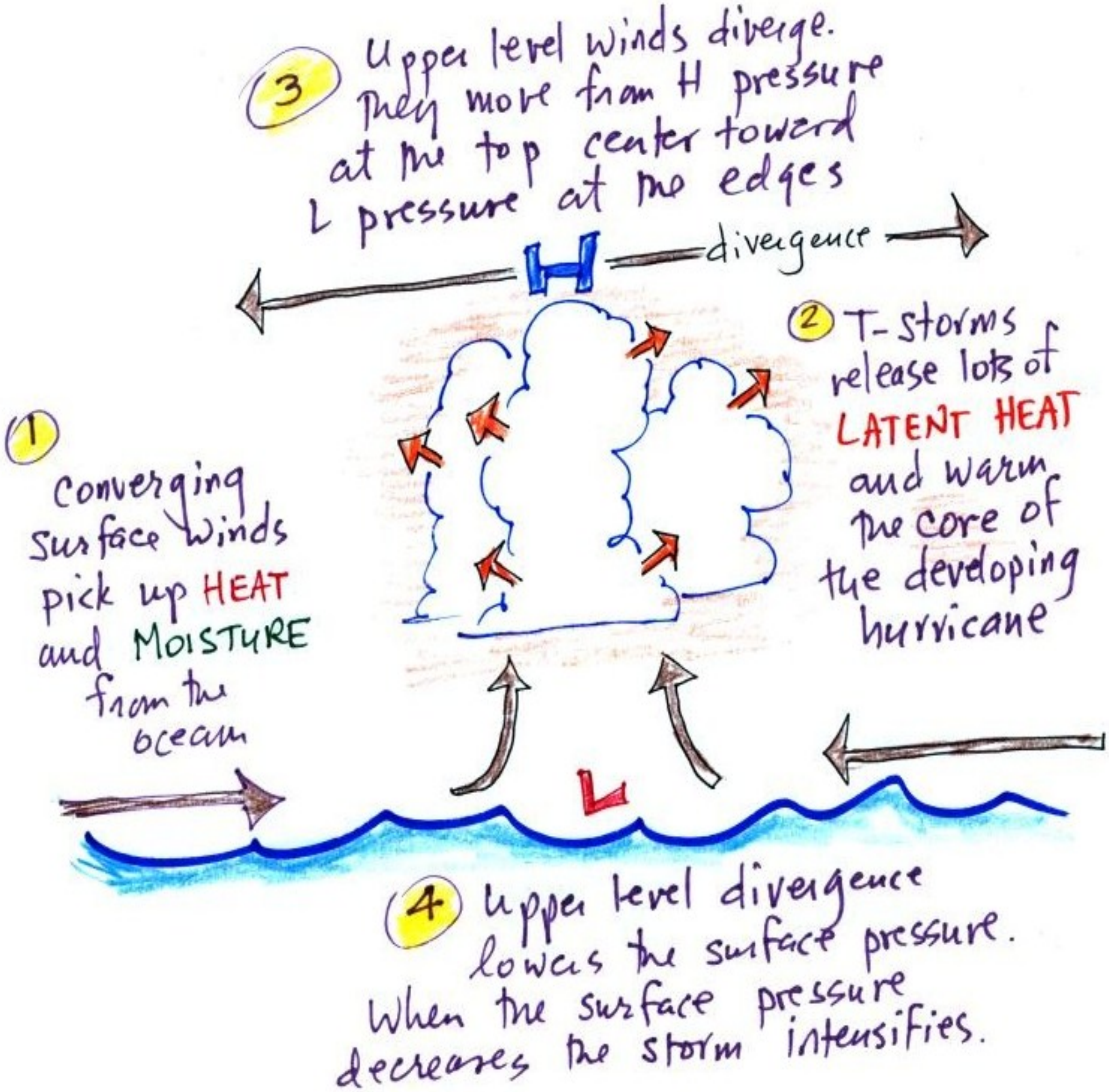
This figure on the following page tries to explain how a cluster of thunderstorms can organize and intensify into a hurricane.

1. Converging surface winds pick up heat and moisture from the ocean, the main energy source for the hurricane.

2. The rising air expands, cools, and thunderstorm clouds form. The release of latent heat during condensation warms the atmosphere so that the core of a hurricane is warmer than the air around it.

3. The pressure decreases more slowly with increasing altitude in the warm core of the hurricane. As a result, the pressure at the top center of the hurricane is higher than the pressure at the top edges of the hurricane. Upper levels winds diverge and spiral outward from the top center of the hurricane. You can sometimes see this on satellite photographs of hurricanes.

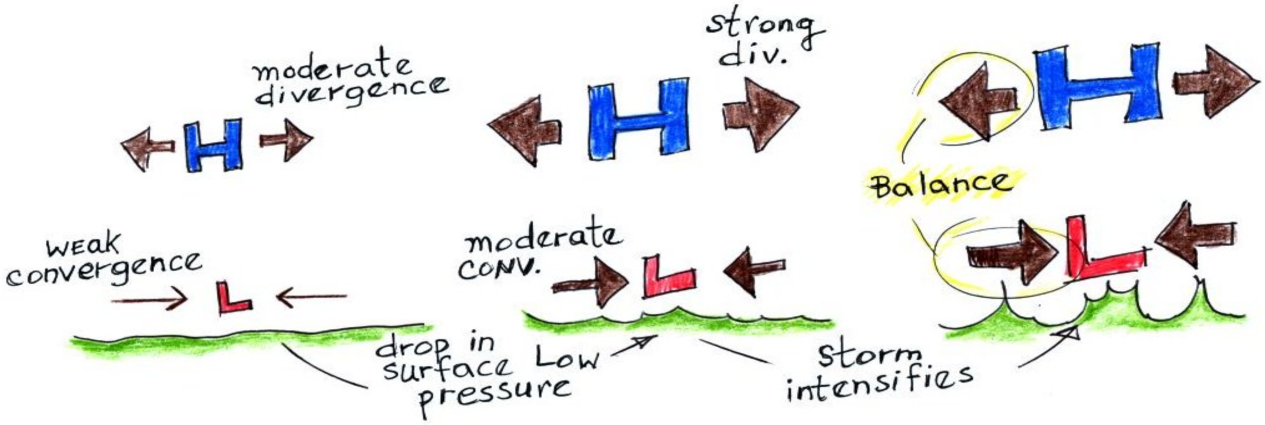
4. The upper level divergence will cause the surface pressure at the center of the hurricane to decrease. The speed of the converging surface winds increases and the storm intensifies. The converging winds pick up additional heat and moisture which warms the core of the hurricane even more. The upper level high pressure and the upper level divergence increase. The increased divergence lowers the surface pressure even more.



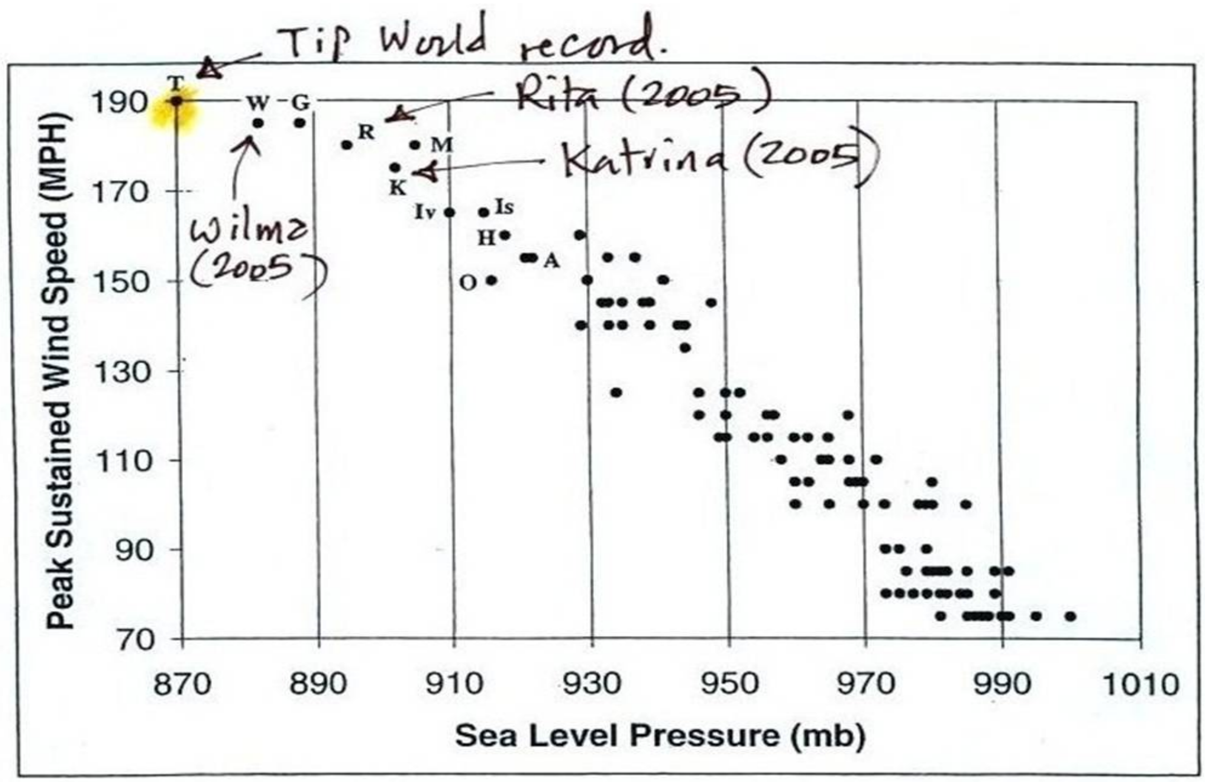
The figure on the following page is another view of hurricane development and intensification. On the left, the moderate divergence found at upper levels is stronger than the weak surface convergence. Divergence is removing more air than is being added by surface convergence. The surface low pressure will decrease and will cause the converging surface winds to blow faster.

In the middle, the surface convergence has strengthened to moderate levels. The upper level divergence has also strengthened. The upper level divergence is still stronger than the surface convergence so the surface low pressure will decrease even more and the storm will intensify.

On the right, the surface low pressure has decreased sufficiently so that the strong surface convergence now balances the strong upper level divergence. The storm will no longer intensify.

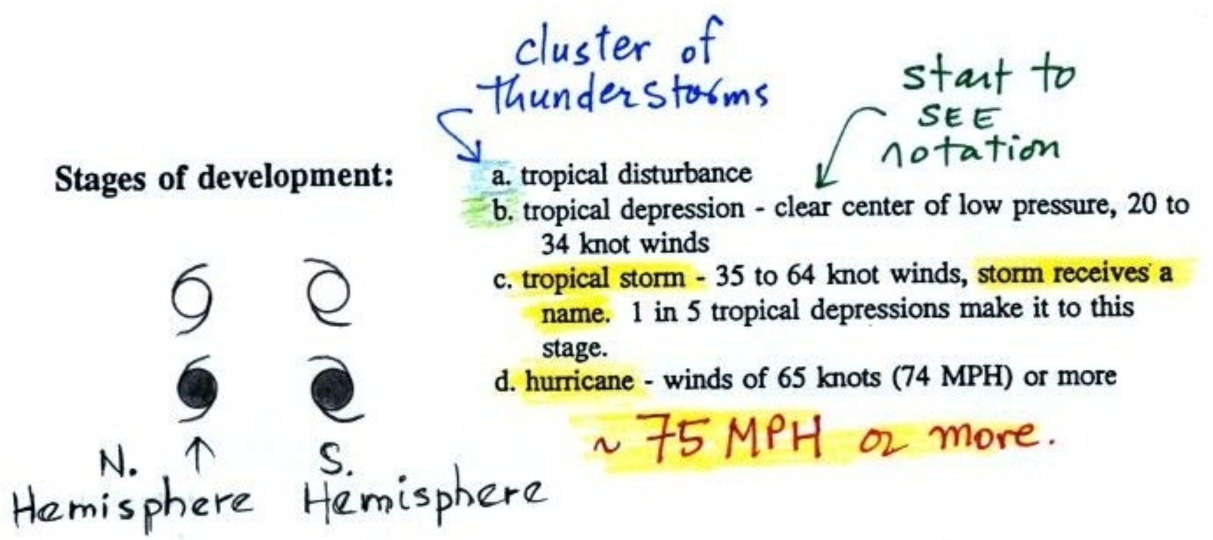


In general, the lower the surface pressure at the center of a hurricane, the stronger the storm and the faster the surface winds will blow. The figure below shows the relationship between surface pressure and surface wind speed. The world record low sea level pressure reading, 870 mb, was set by Typhoon Tip off the Southeast Asia coast in 1979. Sustained winds in that storm were 190 miles per hour. In 2005 hurricanes Wilma, Rita, and Katrina had pressures in the 880 mb to 900 mb range and winds ranging from 170 to 190 miles per hour.



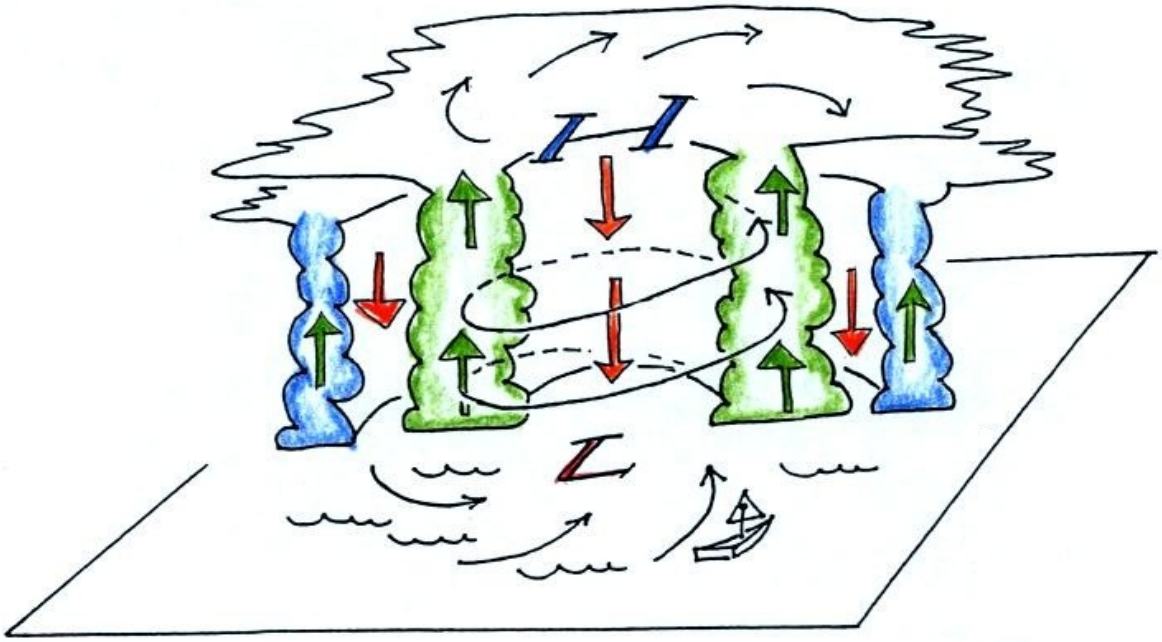
The relationship between sea level pressure and hurricane wind speed (generally the lower the pressure, the faster the winds will blow). All but one of the data points are from N. Atlantic hurricanes that occurred in the period 1988 - 2005. The letter identifications are as follows: A - Andrew (1992), G - Gilbert (1988), H - Hugo (1989), Is - Isabel (2003), Iv - Ivan (2004), K - Katrina (2005), M - Mitch (1998), O - Opal (1995), R - Rita (2005), W - Wilma (2005). T identifies Typhoon Tip which occurred off the coast of SE Asia in 1979 and set the world record low sea level pressure reading.

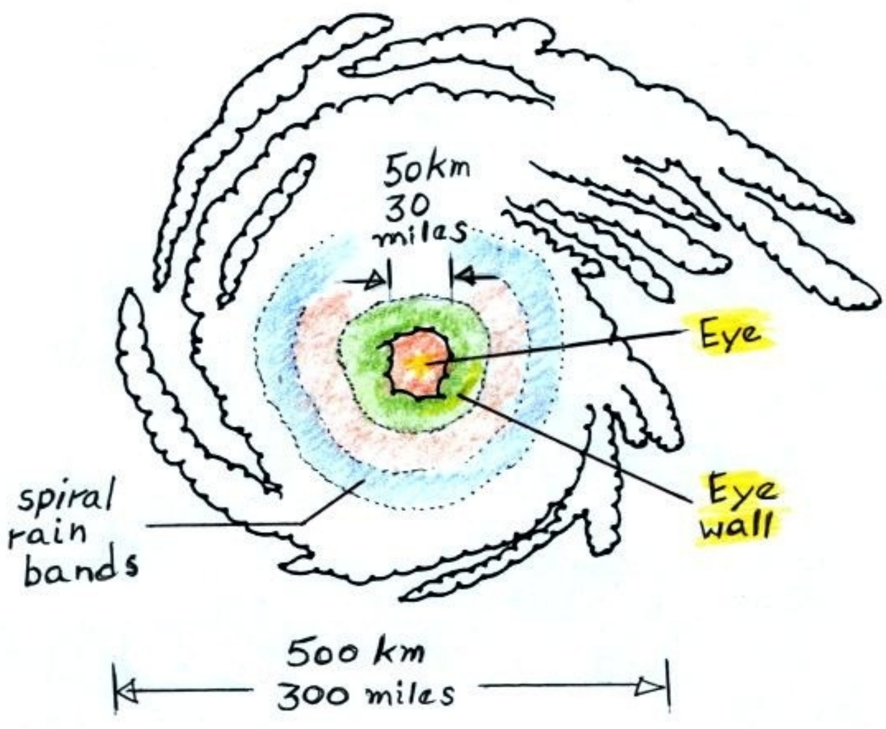
A tropical disturbance is simply a localized cluster of thunderstorms that a meteorologist sees on a satellite photograph. But a tropical disturbance merits observation because of its potential for further development. If a tropical disturbance shows signs of rotation, this is evidence that the storm could be starting to organize into a hurricane. The developing storm is now called a tropical depression. In order to be called a tropical storm, the tropical depression must strengthen and the wind speed must increase to 35 knots. At this point, the storm receives a name. Finally when the wind speed exceeds 75 miles per hour (easier to remember than 65 knots or 74 miles per hour) the storm becomes a hurricane.



The sinking air in the very center of a hurricane produces the clear skies of the eye, a hurricane's most distinctive feature. The eye is typically a few tens of miles across, although it may only be a few miles across in the strongest hurricanes. Generally speaking, the smaller the eye, the stronger the storm. A ring of strong thunderstorms, the eye wall, surrounds the eye. This is where the hurricane's strongest winds are found. Additional concentric rings of thunderstorms called rain bands are found as you move outward from the center of the hurricane. Rain bands are not usually visible until you get to the outer edge of the hurricane because they are covered by high altitude layer clouds.

The figure on the next page is a cross section view of a mature hurricane (top) and the view you would see on a satellite photograph (below).




50 km
30
miles
Eye
Eye
wall
spiral
rain
bands
500 km
300 miles