

Courtesy of National Climatic Data Center, NOAA

Chapter 24 Tropical Cyclones

Tropical Weather Systems

Tropical disturbance – a cluster of thunderstorms about 250 to 600 km in diameter, originating in the tropics or sub-tropics

Tropical depression – a cluster of thunderstorms with an identifiable surface pressure drop and closed wind circulation with wind speeds up to 34 kts (39 mph)

Tropical storm – a cluster of thunderstorms with a wind speed between 34 and 64 kts (39 and 74 mph)

Hurricane – an organized cluster of thunderstorms with a wind speed greater than 64 kts (74 mph)

What are other names for hurricanes and where are these other names used?

Hurricane – Atlantic Ocean and eastern Pacific Ocean

Typhoon – western Pacific Ocean

Cyclone – Indian Ocean

Naming of Tropical Storms and Hurricanes

When is a name given to a tropical weather system?

Tropical depressions

Tropical storms

Hurricanes

Saffir-Simpson Hurricane Intensity Scale

Rating	Central Pressure (mb)	Wind Speed (mph)	Storm Surge (ft)
1	>980	74-95	4-5
2	965-979	96-110	6-8
3	945-964	111-130	9-12
4	920-944	131-155	13-18
5	<920	>155	>18

What is the average value for sea level pressure?

How does the central pressure in a hurricane compare to average sea level pressure?

Impact of Tropical Cyclones

In what regions are fatalities from tropical cyclones greatest?

A tropical cyclone killed 500,000 people in Bangladesh in 1970.

Hurricane Mitch killed nearly 20,000 people in Central America in 1998.

Tropical storm Jeanne killed more than 2,000 people in Haiti in September 2004.

How has the loss of life due to tropical cyclones changed with time in the United States?

Why have these changes occurred?

Hurricane damage costs in the United States:

Hurricane Katrina: \$81.2 billion (2005)

Hurricane Andrew: \$44.9 billion (1992)

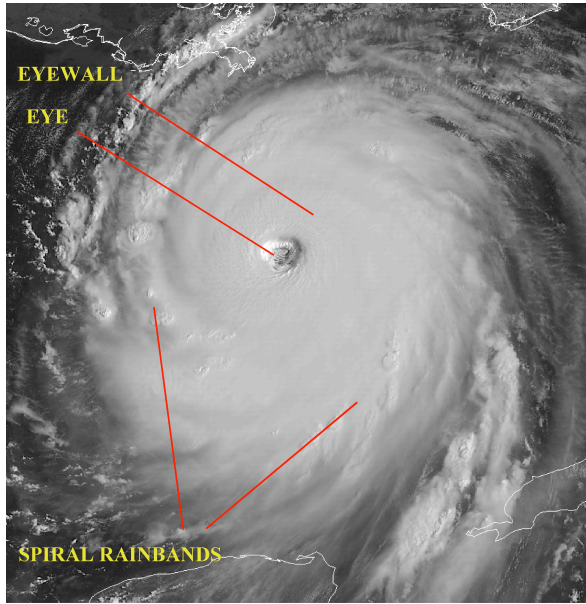
Florida Hurricanes in 2004

Charley: \$15.4 billion

Ivan: \$14.2 billion

Frances: \$9.1 billion

Hurricane Structure



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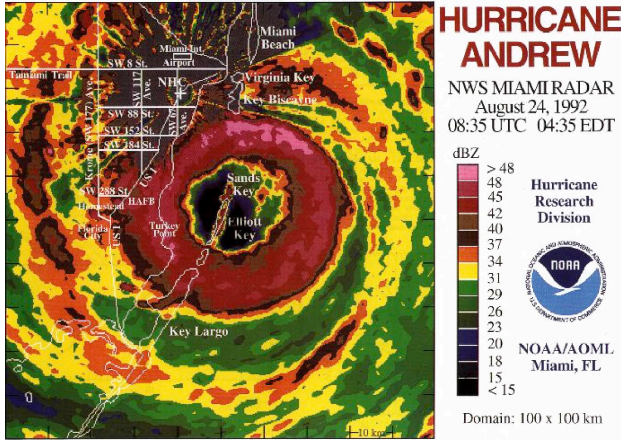
Eye – a nearly cloud free area at the center of a hurricane

Eyewall – a ring of deep convective clouds that surrounds the eye

Spiral rainbands – bands of heavier rainfall that extend outward from the eyewall

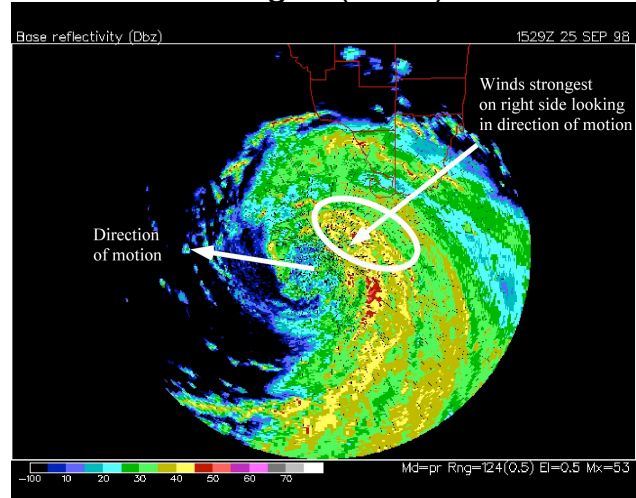
Symmetric and Asymmetric Hurricanes

Hurricane Andrew (1992)

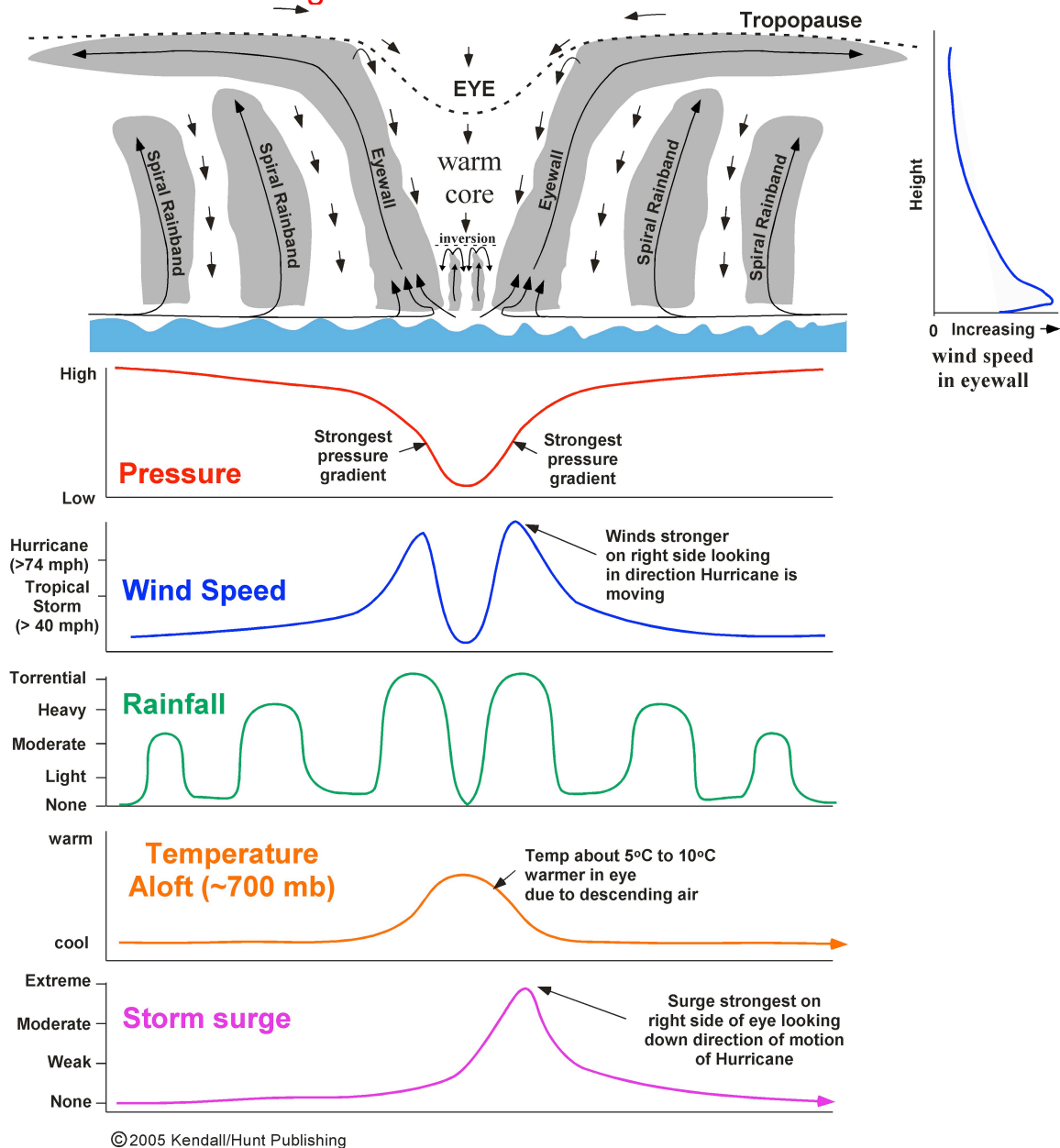


Courtesy NOAA/National Climate Data Center

Hurricane Georges (1998)



Cross-section through a hurricane:



Where is air rising / sinking in a hurricane?

Where is air flowing in towards/ out from the center of a hurricane?

What is the impact of sinking air in the eye of a hurricane?

How does pressure change as you move from the edge to the center of a hurricane?

Where is the largest horizontal pressure gradient?

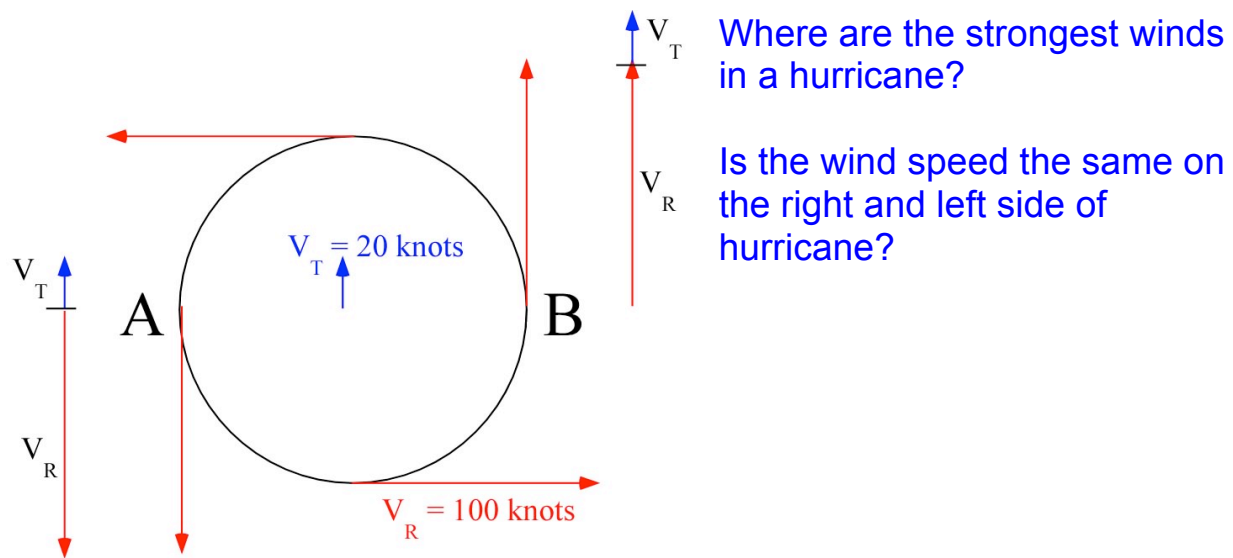
Where does the heaviest rain fall in a hurricane?

Where else does heavy rain fall in a hurricane?

How does the temperature change as you move from the edge to the center of a hurricane?

What causes this change?

Where is the largest storm surge in a hurricane?



Where are the strongest winds in a hurricane?

Is the wind speed the same on the right and left side of hurricane?

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Tropical Cyclone Development

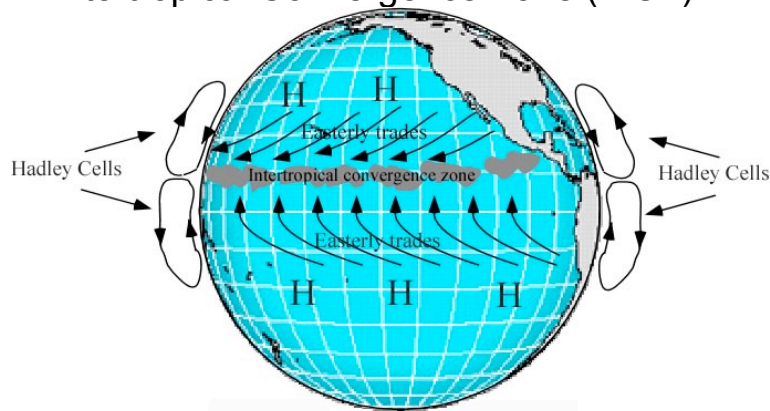
For a tropical cyclone to form, a cluster of thunderstorms must form and these thunderstorms must become organized.

Trigger Mechanisms for Thunderstorms in the Tropics

What can cause a cluster of thunderstorms to form in the tropics?

1. Intertropical Convergence Zone (ITCZ)
2. Easterly Waves
3. Mid-latitude cold front

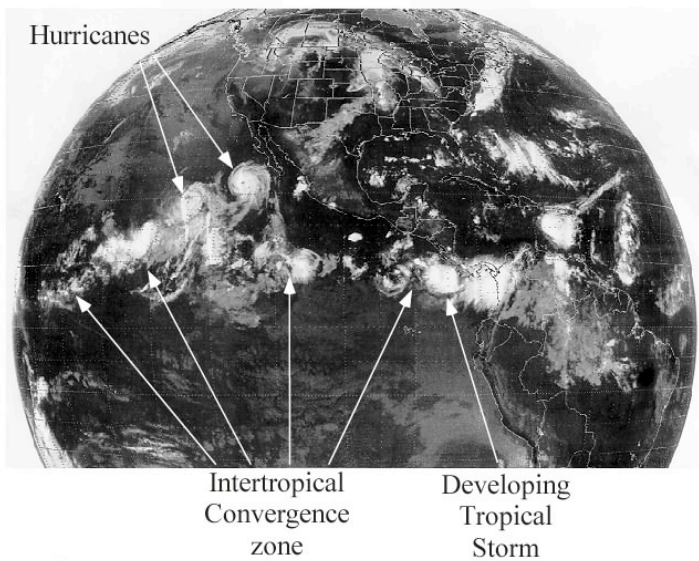
1. Intertropical Convergence Zone (ITCZ)



The ITCZ is where the easterly trade winds from the Northern and Southern hemispheres meet.

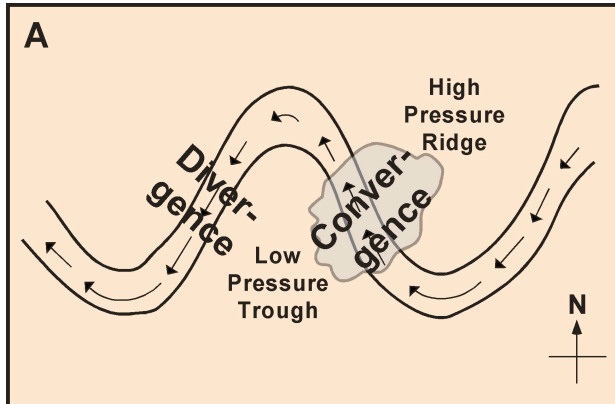
How does the position of the ITCZ change throughout the year?

How important is the ITCZ for hurricane formation?



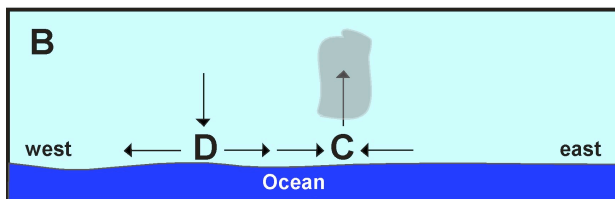
Top: © 2002 Kendall/Hunt Publishing Bottom: Courtesy of NOAA

2. Easterly Waves



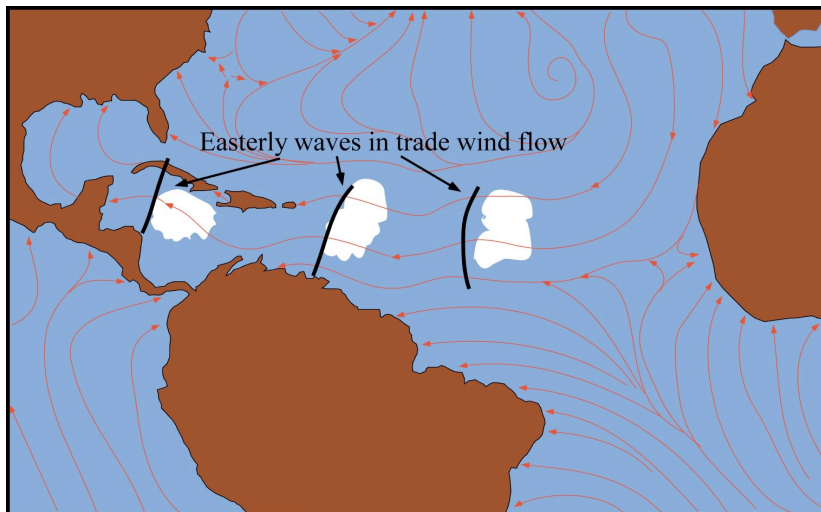
An easterly wave is a ripple in the low-level atmospheric flow that causes convergence.

Where does convergence occur relative to an easterly wave?



Where do clouds form relative to an easterly wave?

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Where do easterly waves typically originate?

What is the main source region for easterly waves in the Atlantic Ocean?

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3. Mid-latitude Cold Fronts

What time of year are mid-latitude cold fronts most important for tropical cyclone development?

Where are mid-latitude cold fronts most important for tropical cyclone development?

The Environment Required for Tropical Cyclones to Form From Thunderstorm Clusters

What conditions are required for a cluster of thunderstorms to become a tropical cyclone?

1. Sea surface temperature (SST) > 26.5 deg C (80 deg F)

Why are warm SSTs important for tropical cyclone formation?

When is the SST > 27 deg C in the N. Atlantic, eastern Pacific, and western Pacific Oceans?

2. Sufficiently deep (>60 m) layer of warm ocean water

What impact do tropical cyclones have on water near the surface of the ocean?

What happens to the SST if the layer of warm water in the ocean is shallow?

3. Weak vertical wind shear

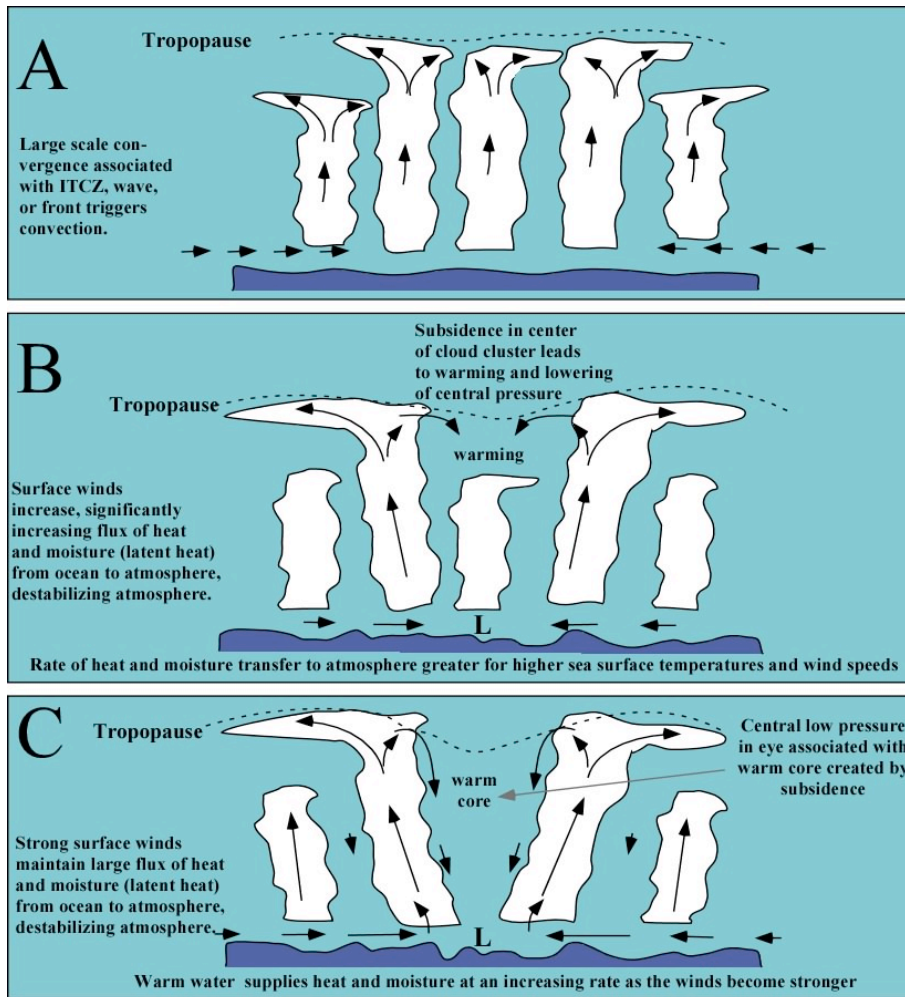
What impact does strong vertical wind shear have on tropical cyclones?

4. Location at least 5 degrees of latitude poleward of the equator

How does the Coriolis force change as you move away from the equator?

What is the role of the Coriolis force in creating a tropical cyclone?

How Thunderstorms Organize Into A Hurricane



What causes a cluster of thunderstorms to form?

What causes the low pressure center to form?

What happens to the rising air in thunderstorms when it reaches the tropopause?

What impact does descent in the center of the cluster have on the temperature and pressure at the center?

How does the wind speed change as the low pressure center becomes stronger?

What impact does this have on the transfer of heat and moisture from the ocean to the atmosphere?

WISHE – Wind Induced Surface Heat Exchange

How does the rotation of a hurricane begin?

Summary of Hurricane Formation

HURRICANE FORMATION		
Trigger Mechanisms for initial Thunderstorms	Environment required for Hurricane formation	Spin up of thunderstorm clusters into Hurricane
<ol style="list-style-type: none">1. Intertropical convergence zone2. Easterly waves in trade wind flow3. Cold fronts extending into tropics	<ol style="list-style-type: none">1. Sea surface temp > 27 °C2. Deep layer of warm water3. Weak wind shear4. At least 5° from equator	<ol style="list-style-type: none">1. Wind induced transfer of heat from the ocean to the atmosphere2. Conservation of angular momentum

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How long can a tropical cyclone survive?

What causes a tropical cyclone to weaken?

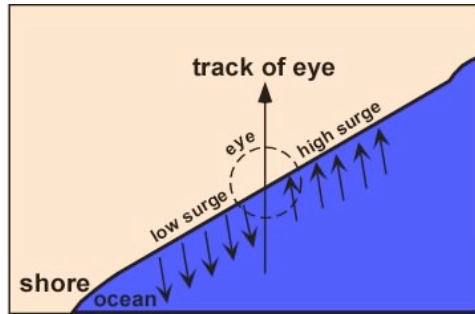
Decreased SST

Increased vertical wind shear

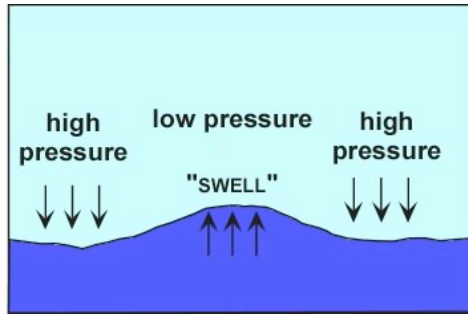
Movement over land

Destructive Forces in a Hurricane

Storm surge – an abnormal rise in sea level associated with a tropical cyclone or strong extratropical cyclone

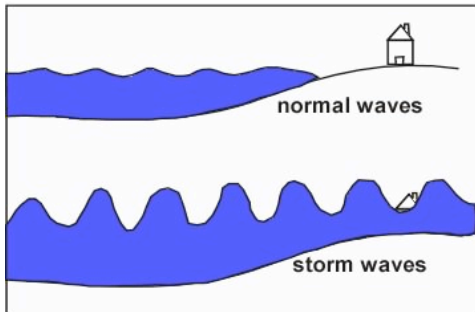


Onshore Winds

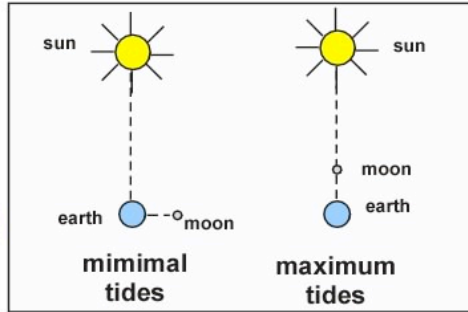


Low Pressure Swell

What are the two primary causes of a storm surge?



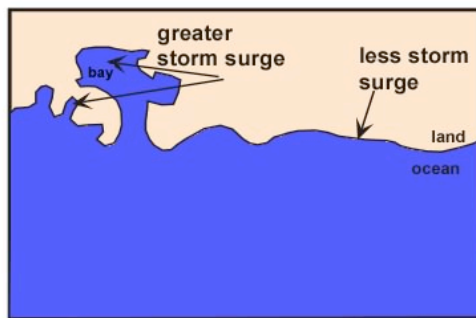
Wave Height



Tides

What three additional factors can enhance a storm surge?

The storm surge results in coastal flooding.



Shape of Coastline

Heavy Rain

How much rain can fall from a tropical cyclone after landfall?

What can increase the total rainfall amount from a tropical cyclone?

Nearly 20,000 people died as a result of flooding from heavy rains in Hurricane Mitch in 1998.

High Winds

Do high winds or flooding typically cause the most damage in tropical cyclones?

Tornadoes can form in landfalling tropical cyclones.

How strong are tornadoes that form in landfalling tropical cyclones?

Why are these tornadoes especially dangerous?