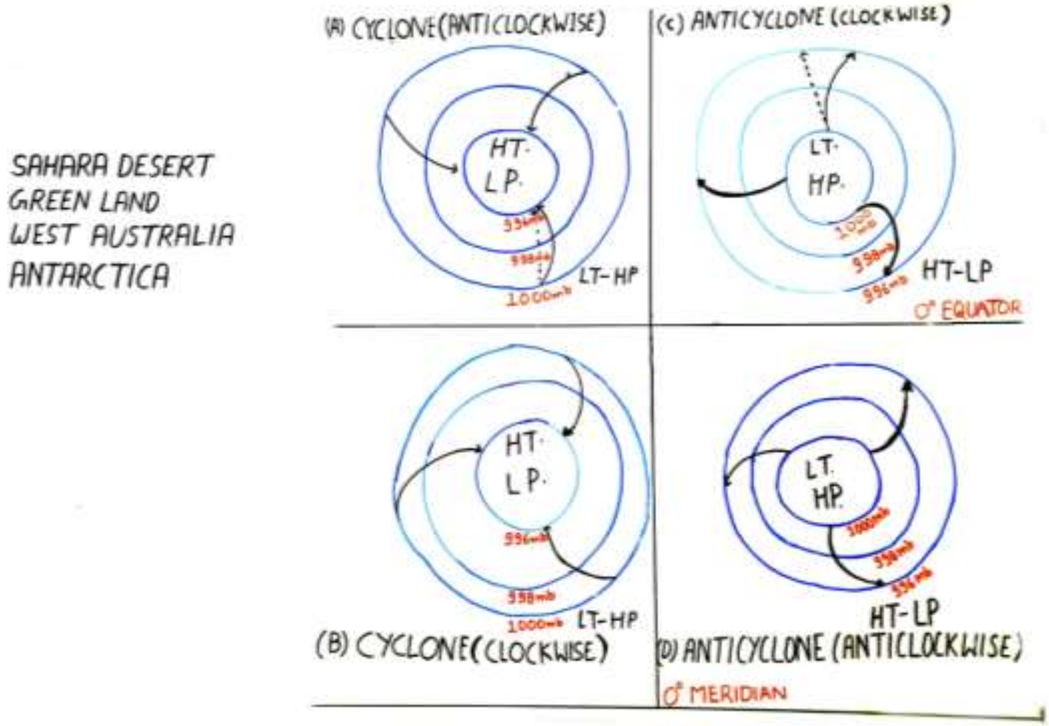
Tropical cyclones: storm divisions; pressure and winds; vertical structure of storm centre; hurricane, sea, swell and surge; hurricane warning.



The word Tropical specifically means places near the equator. The tropics are the region of the Earth near to the equator and between the Tropic of Cancer in the northern hemisphere and the Tropic of Capricorn in the southern hemisphere. This region is also referred to as the tropical zone and the Torrid Zone.

This area includes all the areas of the Earth where the sun reaches a point directly overhead at least once a year. The word "tropics" comes from Greek “tropos” meaning "turn", because the apparent position of the Sun moves between the two tropics within a year.

The word is also sometimes used in a general sense for a tropical climate, a climate that is warm to hot and moist year-round. This includes tropical rainforests with lush vegetation.

- **Tropical Depression:** A tropical cyclone with maximum sustained winds of 38 mph (33 knots) or less.
- **Tropical Storm:** A tropical cyclone with maximum sustained winds of 39 to 73 mph (34 to 63 knots).

- **Hurricane:** A tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher. In the western North Pacific, hurricanes are called **Typhoons**; similar storms in the Indian Ocean and South Pacific Ocean are called **Cyclones**.
- **Major Hurricane:** A tropical cyclone with maximum sustained winds of 111 mph (96 knots) or higher, corresponding to a Category 3, 4 or 5 on the **Saffir-Simpson Hurricane Wind Scale**.

Storms Division

- **Thunderstorm**

  A thunderstorm is a type of storm that generates both lightning and thunder. It is normally accompanied by heavy precipitation. Thunderstorms occur throughout the world, with the highest frequency in tropical rainforest regions where there are conditions of high humidity and temperature along with atmospheric instability. These storms occur when high levels of condensation form in a volume of unstable air that generates deep, rapid, upward motion in the atmosphere. The heat energy creates powerful rising air currents that swirl upwards to the tropopause. Cool descending air currents produce strong downdraughts below the storm. After the storm has spent its energy, the rising currents die away and downdraughts break up the cloud. Individual storm clouds can measure 2–10 km across.

- **Tornado**

  A tornado is a violent, **destructive whirlwind** storm **occurring on land**. **Usually its appearance is that of a dark, funnel-shaped cloud**. Often tornadoes are preceded by or associated with thunderstorms and a wall cloud. They are often called the most destructive of storms, and while they form all over the planet, the interior of the United States is the most prone area, especially throughout Tornado Alley.

- **Tropical cyclone**

  A tropical cyclone is a storm system with a closed circulation around a centre of low pressure, fueled by the heat released when moist air rises and condenses. The name underscores its origin in the tropics and their cyclonic nature. Tropical cyclones are distinguished from other cyclonic storms such as nor'eastersand polar lows by the heat mechanism that fuels them, which makes them "warm core" storm systems. Tropical cyclones form in the oceans if the conditions in the area are favorable, and depending on their strength and location, there are various terms by which they are called, such as tropical depression, tropical storm, hurricane and typhoon.

- **Wind storm**

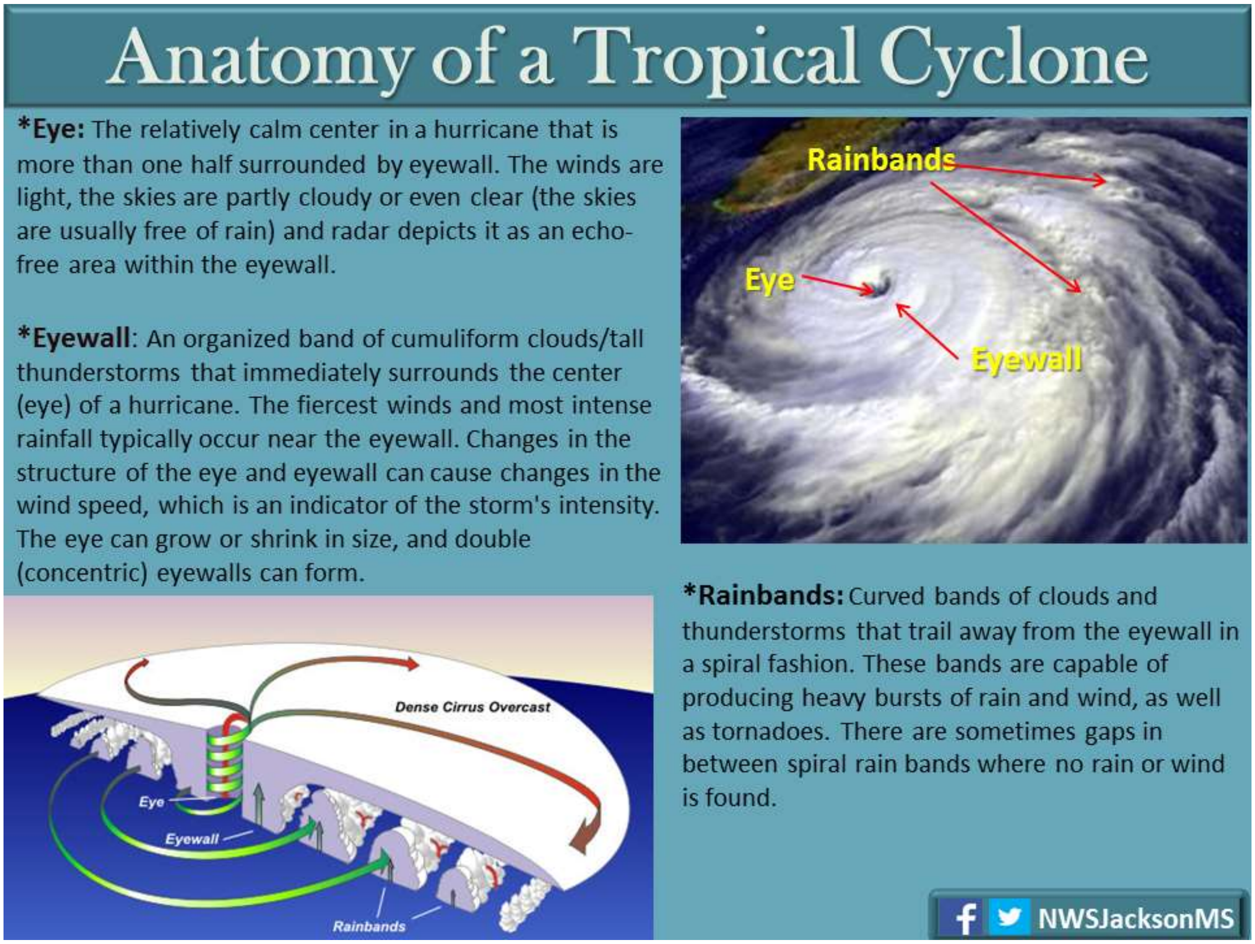
  A storm marked by high wind with little or no precipitation. Windstorm damage often opens the door for massive amounts of water and debris to cause further damage to a structure.

Tropical cyclone

Tropical cyclone, also called **typhoon** or **hurricane**, an intense circular storm that originates over warm tropical oceans and is characterized by low atmospheric pressure, high winds, and heavy rain. Drawing energy from the sea surface and maintaining its strength as long as it remains over warm water, a tropical cyclone generates winds that exceed 119 km (74 miles) per hour. In extreme cases winds may exceed 240 km (150 miles) per hour, and gusts may surpass 320 km (200 miles) per hour. Accompanying these strong winds are torrential rains and a devastating phenomenon known as the storm surge, an elevation of the sea surface that can reach 6 metres (20 feet) above normal levels. Such a combination of high winds and water makes cyclones a serious hazard for coastal areas in tropical and subtropical areas of the world. Every year during the late summer months (July–September in the Northern Hemisphere and January–March in the Southern Hemisphere), cyclones strike regions as far apart as the Gulf Coast of North America, northwestern Australia, and eastern India and Bangladesh.

Tropical cyclones are known by various names in different parts of the world. In the North Atlantic Ocean and the eastern North Pacific they are called hurricanes, and in the western North Pacific around the Philippines, Japan, and China the storms are referred to as typhoons. In the western South Pacific and Indian Ocean they are variously referred to as severe tropical cyclones, tropical cyclones, or simply cyclones. All these different names refer to the same type of storm.

Anatomy of Cyclone



Tropical cyclones are compact, circular storms, generally some 320 km (200 miles) in diameter, whose winds swirl around a central region of low atmospheric pressure. The winds are driven by this low-pressure core and by the rotation of Earth, which deflects the path of the wind through a phenomenon known as the Coriolis force. As a result, tropical cyclones rotate in a counterclockwise (or cyclonic) direction in the Northern Hemisphere and in a clockwise (or anticyclonic) direction in the Southern Hemisphere.

The wind field of a tropical cyclone may be divided into three regions. First is a ring-shaped outer region, typically having an outer radius of about 160 km (100 miles) and an inner radius of about 30 to 50 km (20 to 30 miles). In this region the winds increase uniformly in speed toward the centre. Wind speeds attain their maximum value at the second region, the eyewall, which is typically 15 to 30 km (10 to 20 miles) from the centre of the storm. The eyewall in turn surrounds the interior region, called the eye, where wind speeds decrease rapidly and the air is often calm. These main structural regions are described in greater detail below.

The Eye

A characteristic feature of tropical cyclones is the eye, a central region of clear skies, warm temperatures, and low atmospheric pressure. Typically, atmospheric pressure at the surface of Earth is about 1,000 millibars. At the centre of a tropical cyclone, however, it is typically around 960 millibars, and in a very intense "super typhoon" of the western Pacific it may be as low as 880 millibars. In addition to low pressure at the centre, there is also a rapid variation of pressure across the storm, with most of the variation occurring near the centre. This rapid variation results in a large pressure gradient force, which is responsible for the strong winds present in the eyewall.

Horizontal winds within the eye, on the other hand, are light. In addition, there is a weak sinking motion, or subsidence, as air is pulled into the eyewall at the surface. As the air subsides, it compresses slightly and warms, so that temperatures at the centre of a tropical cyclone are some 5.5 °C (10 °F) higher than in other regions of the storm. Because warmer air can hold more moisture before condensation occurs, the eye of the cyclone is generally free of clouds. Reports of the air inside the eye being "oppressive" or "sultry" are most likely a psychological response to the rapid change from high winds and rain in the eyewall to calm conditions in the eye.

The Eyewall

The most dangerous and destructive part of a tropical cyclone is the eyewall. Here winds are strongest, rainfall is heaviest, and deep convective clouds rise from close to Earth's surface to a height of 15,000 metres (49,000 feet). As noted above, the high winds are driven by rapid changes in atmospheric pressure near the eye, which creates a large pressure gradient force. Winds actually reach their greatest speed at an altitude of about 300 metres (1,000 feet) above the surface. Closer to the surface they are slowed by friction, and higher than 300 metres they are weakened by a slackening of the horizontal pressure gradient force. This slackening is related to the temperature structure of the storm. Air is warmer in the core of a tropical cyclone, and this higher temperature causes atmospheric pressure in the centre to decrease at a slower rate with height than occurs in the surrounding atmosphere. The lessened contrast in atmospheric pressure with altitude causes the horizontal pressure gradient to weaken with height, which in turn results in a decrease in wind speed.

Friction at the surface, in addition to lowering wind speeds, causes the wind to turn inward toward the area of lowest pressure. Air flowing into the low-pressure eye cools by expansion and in turn extracts heat and water vapour from the sea surface. Areas of maximum heating have the strongest updrafts, and the eyewall exhibits the greatest vertical wind speeds in the storm—up to 5 to 10 metres (16.5 to 33 feet) per second, or 18 to 36 km (11 to 22 miles) per hour. While such velocities are much less than those of the horizontal winds, updrafts are vital to the existence of the towering convective clouds embedded in the eyewall. Much of the heavy rainfall associated with tropical cyclones comes from these clouds.

The upward movement of air in the eyewall also causes the eye to be wider aloft than at the surface. As the air spirals upward it conserves its angular momentum, which depends on the distance from the centre of the cyclone and on the wind speed around the centre. Since the wind speed decreases with height, the air must move farther from the centre of the storm as it rises.

When updrafts reach the stable tropopause (the upper boundary of the troposphere, some 16 km [10 miles] above the surface), the air flows outward. The Coriolis force deflects this outward flow, creating a broad anticyclonic circulation aloft. Therefore, horizontal circulation in the upper levels of a tropical cyclone is opposite to that near the surface.

Rainbands

In addition to deep convective cells (compact regions of vertical air movement) surrounding the eye, there are often secondary cells arranged in bands around the centre. These bands, commonly called rainbands, spiral into the centre of the storm. In some cases the rainbands are stationary relative to the centre of the moving storm, and in other cases they seem to rotate around the centre. The rotating cloud bands often are associated with an apparent wobbling of the storm track. If this happens as the tropical cyclone approaches a coastline, there may be large differences between the forecast landfall positions and actual landfall.

As a tropical cyclone makes landfall, surface friction increases, which in turn increases the convergence of airflow into the eyewall and the vertical motion of air occurring there. The increased convergence and rising of moisture-laden air is responsible for the torrential rains associated with tropical cyclones, which may be in excess of 250 mm (10 inches) in a 24-hour period. At times a storm may stall, allowing heavy rains to persist over an area for several days. In extreme cases, rainfall totals of 760 mm (30 inches) in a five-day period have been reported.

Life of Cyclone

A circulation system goes through a sequence of stages as it intensifies into a mature tropical cyclone. The storm begins as a tropical disturbance, which typically occurs when loosely organized cumulonimbus clouds in an easterly wave begin to show signs of a weak circulation. Once the wind speed increases to 36 km (23 miles) per hour, the storm is classified as a tropical depression. If the circulation continues to intensify and the wind speeds exceed 63 km (39 miles) per hour, then the system is called a tropical storm. Once the maximum wind speed exceeds 119 km (74 miles) per hour, the storm is classified as a tropical cyclone.

There are six conditions favourable for this process to take place. The conditions are listed first below, and then their dynamics are described in greater detail:

1. The temperature of the surface layer of ocean water must be 27.0 °C or warmer, and this warm layer must be at least 50 metres (150 feet) deep.
2. A preexisting atmospheric circulation must be located near the surface warm layer.
3. The atmosphere must cool quickly enough with height to support the formation of deep convective clouds.
4. The middle atmosphere must be relatively humid at a height of about 5,000 metres (16,000 feet) above the surface.
5. The developing system must be at least 500 km (300 miles) away from the Equator.
6. The wind speed must change slowly with height through the troposphere—no more than 10 metres (33 feet) per second between the surface and an altitude of about 10,000 metres (33,000 feet).

Formation

The fuel for a tropical cyclone is provided by a transfer of water vapour and heat from the warm ocean to the overlying air, primarily by evaporation from the sea surface. As the warm, moist air rises, it expands and cools, quickly becoming saturated and releasing latent heat through the condensation of water vapour. The column of air in the core of the developing disturbance is warmed and moistened by this process. The temperature difference between the warm, rising air and the cooler environment causes the rising air to become buoyant, further enhancing its upward movement.

If the sea surface is too cool, there will not be enough heat available, and the evaporation rates will be too low to provide the tropical cyclone enough fuel. Energy supplies will also be cut off if the warm surface water layer is not deep enough, because the developing tropical system will modify the underlying ocean. Rain falling from the deep convective clouds will cool the sea surface, and the strong winds in the centre of the storm will create turbulence. If the resulting mixing brings cool water from below the surface layer to the surface, the fuel supply for the tropical system will be removed.

The vertical motion of warm air is by itself inadequate to initiate the formation of a tropical system. However, if the warm, moist air flows into a preexisting atmospheric disturbance, further development will occur. As the rising air warms the core of the disturbance by both release of latent heat and direct heat transfer from the sea surface, the atmospheric pressure in the centre of the disturbance becomes lower. The decreasing pressure causes the surface winds to increase, which in turn increases the vapour and heat transfer and contributes to further rising of air. The warming of the core and the increased surface winds thus reinforce each other in a positive feedback mechanism.

Intensification

The dynamics of a tropical cyclone rely on the exterior of a storm being cooler than its core, so it is necessary that the temperature of the atmosphere drop sufficiently rapidly with height. The warm, saturated air rising in the centre of the circulation tends to keep rising as long as the surrounding air is cooler and heavier. This vertical movement allows deep convective clouds to develop. The rising air in the core also draws in some air from the surrounding atmosphere at altitudes of around 5,000 metres (16,000 feet). If this external air is relatively humid, the circulation will continue to intensify. If it is sufficiently dry, then it may evaporate some of the water drops in the rising column, causing the air to become cooler than the surrounding air. This cooling will result in the formation of strong downdrafts that will disrupt the rising motion and inhibit development.

For the development of the rapid rotation characteristic of tropical cyclones, the low-pressure centre must be located at least 500 km (300 miles) away from the Equator. If the initial disturbance is too close to the Equator, then the effect of the Coriolis force will be too small to provide the necessary spin. The Coriolis force deflects the air that is being drawn into the surface low-pressure centre, setting up a cyclonic rotation. In the Northern Hemisphere the direction of the resulting circulation around the low is counterclockwise, and in the Southern Hemisphere it is clockwise.

A final requirement for the intensification of tropical cyclones is that there must be little change in the wind speed with height above the surface. If the winds increase too much with altitude, the core of the system will no longer be vertically aligned over the warm surface that provides its energy. The area being warmed and the surface low-pressure centre will move apart, and the positive feedback mechanism described above will be suppressed. Conditions in the tropics that encourage the development of tropical cyclones include a typically minor north-to-south variation in temperature. This relative lack of a temperature gradient causes wind speed to remain relatively constant with height.

Vertical Structure of a Tropical Cyclone

There are three divisions in the vertical structure of tropical cyclones.

1. The lowest layer, extending up to 3 km and known as the inflow layer, is responsible for **driving the storm**.
2. The middle layer, extending from 3 km to 7 km, is where the **main cyclonic storm** takes place.
3. The outflow layer lies above 7 km. The maximum outflow is found at 12 km and above. The movement of air is **anticyclonic** in nature.

Warning of Tropical Cyclones

1. Detection of any unusual phenomena in the weather leading to cyclones has three main parameters: **fall in pressure, increase in wind velocity, and the direction and movement (track) of storm.**
2. There are a network of weather stations monitoring pressure fall and wind velocities in all countries of the world, including the Arctic and Antarctic regions.
3. The islands attain special significance in this as they facilitate monitoring of these developments.
4. In India, there are detection radars along both the coasts.
5. Monitoring is also done by aircraft which carry a number of instruments including weather radar.

6. Cyclone monitoring by satellites is done through very high resolution radiometers, working in the visual and infra-red regions (for night view) of the spectrum to obtain an image of the cloud cover and its structure.
7. Remote sensing by radars, aircraft and satellites helps predict where exactly the cyclone is going to strike. It helps in taking advance steps in the following areas:
   a. closing of ports and harbours,
   b. suspension of fishing activities,
   c. evacuation of population,
   d. stocking of food and drinking water, and
   e. provision of shelter with sanitation facilities (safety homes).

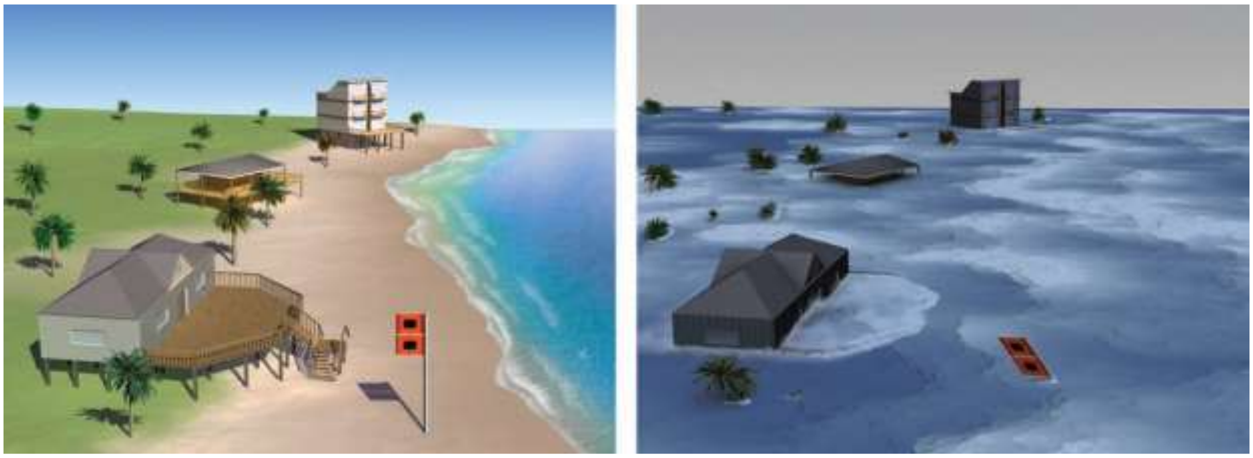
8. Today, it is possible to detect a cyclone right from its genesis in the high seas and follow its course, giving a warning at least 48 hours prior to a cyclone strike.
9. However, the predictions of a storm course made only 12 hours in advance do not have a very high rate of precision.

Swell

Swell is smooth long waves that travel in group away from the storm that generates them. Swell waves travel on the surface of the ocean and perturb the water underneath as they pass. Once generated swells are almost impossible to stop and they travel across great distance, sometimes for days covering thousands of kilometers. On their way, they interact little with other waves, weal winds and currents. As they draw closer to shore swell is an indication of storm having taken place. The swell finally dies as it breaks on the shore.

Surge

Although the hurricane’s high winds inflict a great deal of damage, it is the huge waves, high seas, and ***flooding*** that normally causes most of the destruction. The flooding is also responsible for the loss of many lives. In fact, the majority of hurricane-related deaths during the past century have been due to flooding. The flooding is due, in part, to winds pushing water onto the shore and to the heavy rains, which may exceed 63 cm (25 in.). Flooding is also aided by the low pressure of the storm. The region of low pressure allows the ocean level to rise (perhaps half a meter). The combined effect of high water (which is usually well above the high-tide level) and high winds, toward the coast, produces the **storm surge**—an abnormal rise of several meters in the ocean level—which inundates low-lying areas and turns beachfront homes into piles of splinters. The storm surge is particularly damaging when it coincides with normal high tides. Flooding, however, is not just associated with hurricanes, as destructive floods can occur with tropical storms that do not reach hurricane strength.



When a storm surge moves in at high tide it can inundate and destroy a wide swath of coastal lowlands