= Eye ( cyclone ) =

The eye is a region of mostly calm weather at the center of strong tropical cyclones . The eye of a storm is a roughly circular area , typically 30 ? 65 km ( 20 ? 40 miles ) in diameter . It is surrounded by the eyewall , a ring of towering thunderstorms where the most severe weather occurs . The cyclone 's lowest barometric pressure occurs in the eye and can be as much as 15 percent lower than the pressure outside the storm .

In strong tropical cyclones , the eye is characterized by light winds and clear skies , surrounded on all sides by a towering , symmetric eyewall . In weaker tropical cyclones , the eye is less well defined and can be covered by the central dense overcast , an area of high , thick clouds that show up brightly on satellite imagery . Weaker or disorganized storms may also feature an eyewall that does not completely encircle the eye or have an eye that features heavy rain . In all storms , however , the eye is the location of the storm 's minimum barometric pressure - the area where the atmospheric pressure at sea level is the lowest .

= = Structure = =

A typical tropical cyclone will have an eye of approximately 30 ? 65 km ( 20 ? 40 mi ) across , usually situated at the geometric center of the storm . The eye may be clear or have spotty low clouds ( a clear eye ) , it may be filled with low- and mid @-@ level clouds ( a filled eye ) , or it may be obscured by the central dense overcast . There is , however , very little wind and rain , especially near the center . This is in stark contrast to conditions in the eyewall , which contains the storm 's strongest winds . Due to the mechanics of a tropical cyclone , the eye and the air directly above it are warmer than their surroundings .

While normally quite symmetric , eyes can be oblong and irregular , especially in weakening storms . A large ragged eye is a non @-@ circular eye which appears fragmented , and is an indicator of a weak or weakening tropical cyclone . An open eye is an eye which can be circular , but the eyewall does not completely encircle the eye , also indicating a weakening , moisture @-@ deprived cyclone . Both of these observations are used to estimate the intensity of tropical cyclones via Dvorak analysis . Eyewalls are typically circular ; however , distinctly polygonal shapes ranging from triangles to hexagons occasionally occur .

While typical mature storms have eyes that are a few dozen miles across , rapidly intensifying storms can develop an extremely small , clear , and circular eye , sometimes referred to as a pinhole eye . Storms with pinhole eyes are prone to large fluctuations in intensity , and provide difficulties and frustrations for forecasters .

Small / minuscule eyes ? those less than 10 nmi ( 19 km , 12 mi ) across ? often trigger eyewall replacement cycles , where a new eyewall begins to form outside the original eyewall . This can take place anywhere from fifteen to hundreds of kilometers ( ten to a few hundred miles ) outside the inner eye . The storm then develops two concentric eyewalls , or an " eye within an eye " . In most cases , the outer eyewall begins to contract soon after its formation , which chokes off the inner eye and leaves a much larger but more stable eye . While the replacement cycle tends to weaken storms as it occurs , the new eyewall can contract fairly quickly after the old eyewall dissipates , allowing the storm to re @-@ strengthen . This may trigger another cycle of eyewall replacement .

Eyes can range in size from 320 km ( 200 mi ) ( Typhoon Carmen ) to a mere 3 km ( 1 @.@ 9 mi ) ( Hurricane Wilma ) across . While it is uncommon for storms with large eyes to become very intense , it does occur , especially in annular hurricanes . Hurricane Isabel was the eleventh most powerful North Atlantic hurricane in recorded history , and sustained a large , 65 ? 80 km ( 40 ? 50 mi ) -wide eye for a period of several days .

= = Formation and detection = =

Tropical cyclones typically form from large , disorganized areas of disturbed weather in tropical regions . As more thunderstorms form and gather , the storm develops rainbands which start

rotating around a common center . As the storm gains strength , a ring of stronger convection forms at a certain distance from the rotational center of the developing storm . Since stronger thunderstorms and heavier rain mark areas of stronger updrafts , the barometric pressure at the surface begins to drop , and air begins to build up in the upper levels of the cyclone . This results in the formation of an upper level anticyclone , or an area of high atmospheric pressure above the central dense overcast . Consequently , most of this built up air flows outward anticyclonically above the tropical cyclone . Outside the forming eye , the anticyclone at the upper levels of the atmosphere enhances the flow towards the center of the cyclone , pushing air towards the eyewall and causing a positive feedback loop .

However , a small portion of the built @-@ up air , instead of flowing outward , flows inward towards the center of the storm . This causes air pressure to build even further , to the point where the weight of the air counteracts the strength of the updrafts in the center of the storm . Air begins to descend in the center of the storm , creating a mostly rain @-@ free area ? a newly formed eye .

There are many aspects of this process which remain a mystery . Scientists do not know why a ring of convection forms around the center of circulation instead of on top of it , or why the upper @-@ level anticyclone only ejects a portion of the excess air above the storm . Many theories exist as to the exact process by which the eye forms : all that is known for sure is that the eye is necessary for tropical cyclones to achieve high wind speeds .

The formation of an eye is almost always an indicator of increasing tropical cyclone organisation and strength . Because of this , forecasters watch developing storms closely for signs of eye formation .

For storms with a clear eye , detection of the eye is as simple as looking at pictures from a weather satellite . However , for storms with a filled eye , or an eye completely covered by the central dense overcast , other detection methods must be used . Observations from ships and Hurricane Hunters can pinpoint an eye visually , by looking for a drop in wind speed or lack of rainfall in the storm 's center . In the United States , South Korea , and a few other countries , a network of NEXRAD Doppler weather radar stations can detect eyes near the coast . Weather satellites also carry equipment for measuring atmospheric water vapor and cloud temperatures , which can be used to spot a forming eye . In addition , scientists have recently discovered that the amount of ozone in the eye is much higher than the amount in the eyewall , due to air sinking from the ozone @-@ rich stratosphere . Instruments sensitive to ozone perform measurements , which are used to observe rising and sinking columns of air , and provide indication of the formation of an eye , even before satellite imagery can determine its formation .

= = Associated phenomena = =

= = = Eyewall replacement cycles = = =

Eyewall replacement cycles , also called concentric eyewall cycles , naturally occur in intense tropical cyclones , generally with winds greater than 185 km / h ( 115 mph ) , or major hurricanes ( Category 3 or higher on the Saffir ? Simpson hurricane scale ) . When tropical cyclones reach this intensity , and the eyewall contracts or is already sufficiently small ( see above ) , some of the outer rainbands may strengthen and organize into a ring of thunderstorms ? an outer eyewall ? that slowly moves inward and robs the inner eyewall of its needed moisture and angular momentum . Since the strongest winds are located in a cyclone 's eyewall , the tropical cyclone usually weakens during this phase , as the inner wall is " choked " by the outer wall . Eventually the outer eyewall replaces the inner one completely , and the storm can re @-@ intensify .

The discovery of this process was partially responsible for the end of the U.S. government 's hurricane modification experiment Project Stormfury . This project set out to seed clouds outside the eyewall , causing a new eyewall to form and weakening the storm . When it was discovered that this was a natural process due to hurricane dynamics , the project was quickly abandoned .

Almost every intense hurricane undergoes at least one of these cycles during its existence .

Hurricane Allen in 1980 went through repeated eyewall replacement cycles , fluctuating between Category 5 and Category 3 status on the Saffir @-@ Simpson scale several times . Hurricane Juliette was a rare documented case of triple eyewalls .

= = = Moats = = =

A moat in a tropical cyclone is a clear ring outside the eyewall , or between concentric eyewalls , characterized by subsidence ? slowly sinking air ? and little or no precipitation . The air flow in the moat is dominated by the cumulative effects of stretching and shearing . The moat between eyewalls is an area in the storm where the rotational speed of the air changes greatly in proportion to the distance from the storm 's center ; these areas are also known as rapid filamentation zones . Such areas can potentially be found near any vortex of sufficient strength , but are most pronounced in strong tropical cyclones .

= = = Eyewall mesovortices = = =

Eyewall mesovortices are small scale rotational features found in the eyewalls of intense tropical cyclones . They are similar , in principle , to small " suction vortices " often observed in multiple @-@ vortex tornadoes . In these vortices , wind speeds may be greater than anywhere else in the eyewall . Eyewall mesovortices are most common during periods of intensification in tropical cyclones .

Eyewall mesovortices often exhibit unusual behavior in tropical cyclones . They usually rotate around the low pressure center , but sometimes they remain stationary . Eyewall mesovortices have even been documented to cross the eye of a storm . These phenomena have been documented observationally , experimentally , and theoretically .

Eyewall mesovortices are a significant factor in the formation of tornadoes after tropical cyclone landfall . Mesovortices can spawn rotation in individual thunderstorms ( a mesocyclone ) , which leads to tornadic activity . At landfall , friction is generated between the circulation of the tropical cyclone and land . This can allow the mesovortices to descend to the surface , causing tornadoes .

= = = Stadium effect = = =

The stadium effect is a phenomenon observed in strong tropical cyclones . It is a fairly common event , where the clouds of the eyewall curve outward from the surface with height . This gives the eye an appearance resembling an open dome from the air , akin to a sports stadium . An eye is always larger at the top of the storm , and smallest at the bottom of the storm because the rising air in the eyewall follows isolines of equal angular momentum , which also slope outward with height . In tropical cyclones with very small eyes , the sloping phenomenon is much more pronounced .

= = = Eye @-@ like features = = =

An eye @-@ like structure is often found in intensifying tropical cyclones . Similar to the eye seen in hurricanes or typhoons , it is a circular area at the circulation center of the storm in which convection is absent . These eye @-@ like features are most normally found in intensifying tropical storms and hurricanes of Category 1 strength on the Saffir @-@ Simpson scale . For example , an eye @-@ like feature was found in Hurricane Beta when the storm had maximum wind speeds of only 80 km / h ( 50 mph ) , well below hurricane force . The features are typically not visible on visible wavelengths or infrared wavelengths from space , although they are easily seen on microwave satellite imagery . Their development at the middle levels of the atmosphere is similar to the formation of a complete eye , but the features might be horizontally displaced due to vertical wind shear .

= = Hazards = =

Though the eye is by far the calmest part of the storm , with no wind at the center and typically clear skies , over the ocean it is possibly the most hazardous area . In the eyewall , wind @-@ driven waves all travel in the same direction . In the center of the eye , however , the waves converge from all directions , creating erratic crests that can build on each other to become rogue waves . The maximum height of hurricane waves is unknown , but measurements during Hurricane Ivan when it was a Category 4 hurricane estimated that waves near the eyewall exceeded 40 m ( 130 ft ) from peak to trough .

A common mistake , especially in areas where hurricanes are uncommon , is for residents to exit their homes to inspect the damage while the calm eye passes over , only to be caught off guard by the violent winds in the opposite eyewall .

= = Other cyclones = =

Though only tropical cyclones have structures officially termed " eyes " , there are other weather systems that can exhibit eye @-@ like features .

= = = Polar lows = = =

Polar lows are mesoscale weather systems , typically smaller than 1 @,@ 000 km ( 600 mi ) across , found near the poles . Like tropical cyclones , they form over relatively warm water and can feature deep convection and winds of gale force or greater . Unlike storms of tropical nature , however , they thrive in much colder temperatures and at much higher latitudes . They are also smaller and last for shorter durations , with few lasting longer than a day or so . Despite these differences , they can be very similar in structure to tropical cyclones , featuring a clear eye surrounded by an eyewall and bands of rain and snow .

= = = Extratropical cyclones = = =

Extratropical cyclones are areas of low pressure which exist at the boundary of different air masses . Almost all storms found at mid @-@ latitudes are extratropical in nature , including classic North American nor 'easters and European windstorms . The most severe of these can have a clear " eye " at the site of lowest barometric pressure , though it is usually surrounded by lower , non @-@ convective clouds and is found near the back end of the storm .

= = = Subtropical cyclones = = =

Subtropical cyclones are low @-@ pressure systems with some extratropical characteristics and some tropical characteristics . As such , they may have an eye while not being truly tropical in nature . Subtropical cyclones can be very hazardous , generating high winds and seas , and often evolve into fully tropical cyclones . For this reason , the National Hurricane Center began including subtropical storms in its naming scheme in 2002 .

= = = Tornadoes = = =

Tornadoes are destructive , small @-@ scale storms , which produce the fastest winds on earth . There are two main types ? single @-@ vortex tornadoes , which consist of a single spinning column of air , and multiple @-@ vortex tornadoes , which consist of small " suction vortices , " resembling mini @-@ tornadoes themselves , all rotating around a common center . Both of these types of tornadoes are theorized to have calm centers , referred to by some meteorologists as " eyes . " These theories are supported by doppler velocity observations by weather radar and eyewitness accounts .

= = Extraterrestrial vortices = =

NASA reported in November 2006 that the Cassini spacecraft observed a " hurricane @-@ like " storm locked to the south pole of Saturn with a clearly defined eyewall . The observation was particularly notable as eyewall clouds had not previously been seen on any planet other than Earth ( including a failure to observe an eyewall in the Great Red Spot of Jupiter by the Galileo spacecraft ) . In 2007 , very large vortices on both poles of Venus were observed by the Venus Express mission of the European Space Agency to have a dipole eye structure .