Tropical cyclone

A tropical cyclone is a rapidly rotating storm system characterized by a low @-@ pressure center , a closed low @-@ level atmospheric circulation , strong winds , and a spiral arrangement of thunderstorms that produce heavy rain . Depending on its location and strength , a tropical cyclone is referred to by names such as hurricane (/ ?h?r?k?n / or / ?h?r?ke?n /) , typhoon / ta??fu?n / , tropical storm , cyclonic storm , tropical depression , and simply cyclone .

Tropical cyclones typically form over large bodies of relatively warm water . They derive their energy through the evaporation of water from the ocean surface , which ultimately recondenses into clouds and rain when moist air rises and cools to saturation . This energy source differs from that of mid @-@ latitude cyclonic storms , such as nor 'easters and European windstorms , which are fueled primarily by horizontal temperature contrasts . The strong rotating winds of a tropical cyclone are a result of the conservation of angular momentum imparted by the Earth 's rotation as air flows inwards toward the axis of rotation . As a result , they rarely form within 5 ° of the equator . Tropical cyclones are typically between 100 and 2 @,@ 000 km (62 and 1 @,@ 243 mi) in diameter .

Tropical refers to the geographical origin of these systems , which form almost exclusively over tropical seas . Cyclone refers to their cyclonic nature , with wind blowing counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere . The opposite direction of circulation is due to the Coriolis effect .

In addition to strong winds and rain , tropical cyclones are capable of generating high waves , damaging storm surge , and tornadoes . They typically weaken rapidly over land where they are cut off from their primary energy source . For this reason , coastal regions are particularly vulnerable to damage from a tropical cyclone as compared to inland regions . Heavy rains , however , can cause significant flooding inland , and storm surges can produce extensive coastal flooding up to 40 kilometres (25 mi) from the coastline . Though their effects on human populations are often devastating , tropical cyclones can relieve drought conditions . They also carry heat energy away from the tropics and transport it toward temperate latitudes , which may play an important role in modulating regional and global climate .

Physical structure

Tropical cyclones are areas of relatively low pressure in the troposphere , with the largest pressure perturbations occurring at low altitudes near the surface . On Earth , the pressures recorded at the centers of tropical cyclones are among the lowest ever observed at sea level . The environment near the center of tropical cyclones is warmer than the surroundings at all altitudes , thus they are characterized as " warm core " systems .

Wind field

The near @-@ surface wind field of a tropical cyclone is characterized by air rotating rapidly around a center of circulation while also flowing radially inwards . At the outer edge of the storm , air may be nearly calm ; however , due to the Earth 's rotation , the air has non @-@ zero absolute angular momentum . As air flows radially inward , it begins to rotate cyclonically (counter @-@ clockwise in the Northern Hemisphere , and clockwise in the Southern Hemisphere) in order to conserve angular momentum . At an inner radius , air begins to ascend to the top of the troposphere . This radius is typically coincident with the inner radius of the eyewall , and has the strongest near @-@ surface winds of the storm ; consequently , it is known as the radius of maximum winds . Once aloft , air flows away from the storm 's center , producing a shield of cirrus clouds .

The previously mentioned processes result in a wind field that is nearly axisymmetric : Wind speeds are low at the center , increase rapidly moving outwards to the radius of maximum winds , and then decay more gradually with radius to large radii . However , the wind field often exhibits additional spatial and temporal variability due to the effects of localized processes , such as thunderstorm activity and horizontal flow instabilities . In the vertical direction , winds are strongest near the surface and decay with height within the troposphere .

= = = Eye and center = = =

At the center of a mature tropical cyclone , air sinks rather than rises . For a sufficiently strong storm , air may sink over a layer deep enough to suppress cloud formation , thereby creating a clear " eye " . Weather in the eye is normally calm and free of clouds , although the sea may be extremely violent . The eye is normally circular in shape , and is typically 30 ? 65 km (19 ? 40 mi) in diameter , though eyes as small as 3 km (1 @.@ 9 mi) and as large as 370 km (230 mi) have been observed .

The cloudy outer edge of the eye is called the " eyewall " . The eyewall typically expands outward with height , resembling an arena football stadium ; this phenomenon is sometimes referred to as the stadium effect . The eyewall is where the greatest wind speeds are found , air rises most rapidly , clouds reach to their highest altitude , and precipitation is the heaviest . The heaviest wind damage occurs where a tropical cyclone 's eyewall passes over land .

In a weaker storm , the eye may be obscured by the central dense overcast , which is the upper @-@ level cirrus shield that is associated with a concentrated area of strong thunderstorm activity near the center of a tropical cyclone .

The eyewall may vary over time in the form of eyewall replacement cycles , particularly in intense tropical cyclones . Outer rainbands can organize into an outer ring of thunderstorms that slowly moves inward , which is believed to rob the primary eyewall of moisture and angular momentum . When the primary eyewall weakens , the tropical cyclone weakens temporarily . The outer eyewall eventually replaces the primary one at the end of the cycle , at which time the storm may return to its original intensity .

= = = Intensity = = =

Storm " intensity " is defined as the maximum wind speed in the storm . This speed is taken as either a 1 @-@ minute or a 10 @-@ minute average at the standard reference height of 10 meters . The choice of averaging period , as well as the naming convention for classifying storms , differs across forecast centers and ocean basins .

On occasion , tropical cyclones may undergo a meteorological condition known as rapid deepening , a period in which the minimum sea @-@ level pressure of a tropical cyclone decreases by 42mb in a 24 @-@ hour period . In order for rapid deepening to occur , several conditions must be in place . Water temperatures must be extremely warm (near or above 30 ° C , 86 ° F) , and water of this temperature must be sufficiently deep such that waves do not upwell cooler waters to the surface . Wind shear must be low ; when wind shear is high , the convection and circulation in the cyclone will be disrupted . Usually , an anticyclone in the upper layers of the troposphere above the storm must be present as well ? for extremely low surface pressures to develop , air must be rising very rapidly in the eyewall of the storm , and an upper @-@ level anticyclone helps channel this air away from the cyclone efficiently .

= = = Size = = =

There are a variety of metrics commonly used to measure storm size . The most common metrics include the radius of maximum wind , the radius of 34 @-@ knot wind (i.e. gale force) , the radius of outermost closed isobar (ROCI) , and the radius of vanishing wind . An additional metric is the radius at which the cyclone 's relative vorticity field decreases to 1 × 10 ? 5 s ? 1 .

On Earth , tropical cyclones span a large range of sizes , from 100 ? 2 @,@ 000 kilometres (62 ? 1 @,@ 243 mi) as measured by the radius of vanishing wind . They are largest on average in the northwest Pacific Ocean basin and smallest in the northeastern Pacific Ocean basin . If the radius of outermost closed isobar is less than two degrees of latitude (222 km (138 mi)) , then the cyclone is " very small " or a " midget " . A radius of 3 ? 6 latitude degrees (333 ? 670 km (207 ? 416 mi))

is considered " average sized " . " Very large " tropical cyclones have a radius of greater than 8 degrees (888 km (552 mi)) . Observations indicate that size is only weakly correlated to variables such as storm intensity (i.e. maximum wind speed) , radius of maximum wind , latitude , and maximum potential intensity .
Size plays an important role in modulating damage caused by a storm . All else equal , a larger storm will impact a larger area for a longer period of time . Additionally , a larger near @-@ surface wind field can generate higher storm surge due to the combination of longer wind fetch , longer duration , and enhanced wave setup .
The upper circulation of strong hurricanes extends into the tropopause of the atmosphere , which at low latitudes is 15 @,@ 000 ? 18 @,@ 000 metres (50 @,@ 000 ? 60 @,@ 000 ft) .

= = Physics and energetics = =

The three @-@ dimensional wind field in a tropical cyclone can be separated into two components : a " primary circulation " and a " secondary circulation " . The primary circulation is the rotational part of the flow ; it is purely circular . The secondary circulation is the overturning (in @-@ up @-@ out @-@ down) part of the flow ; it is in the radial and vertical directions . The primary circulation has the strongest winds and is responsible for the majority of the damage a storm causes , while the secondary circulation is slower but governs the energetics of the storm .

= = = Secondary circulation : a Carnot heat engine = = =

A tropical cyclone 's primary energy source is the evaporation of water from the ocean surface , which ultimately recondenses into clouds and rain when the warm moist air rises and cools to saturation . The energetics of the system may be idealized as an atmospheric Carnot heat engine . First , inflowing air near the surface acquires heat primarily via evaporation of water (i.e. latent heat) at the temperature of the warm ocean surface (during evaporation , the ocean cools and the air warms) . Second , the warmed air rises and cools within the eyewall while conserving total heat content (latent heat is simply converted to sensible heat during condensation) . Third , air outflows and loses heat via infrared radiation to space at the temperature of the cold tropopause . Finally , air subsides and warms at the outer edge of the storm while conserving total heat content . The first and third legs are nearly isothermal , while the second and fourth legs are nearly isentropic . This in @-@ up @-@ out @-@ down overturning flow is known as the secondary circulation . The Carnot perspective provides an upper bound on the maximum wind speed that a storm can attain .
Scientists estimate that a tropical cyclone releases heat energy at the rate of 50 to 200 exajoules (1018 J) per day , equivalent to about 1 PW (1015 watt) . This rate of energy release is equivalent to 70 times the world energy consumption of humans and 200 times the worldwide electrical generating capacity , or to exploding a 10 @-@ megaton nuclear bomb every 20 minutes .

= = = Primary circulation : rotating winds = = =

The primary rotating flow in a tropical cyclone results from the conservation of angular momentum by the secondary circulation . Absolute angular momentum on a rotating planet <formula> is given by
<formula>
where <formula> is the Coriolis parameter , <formula> is the azimuthal (i.e. rotating) wind speed , and <formula> is the radius to the axis of rotation . The first term on the right hand side is the component of planetary angular momentum that projects onto the local vertical (i.e. the axis of rotation) . The second term on the right hand side is the relative angular momentum of the circulation itself with respect to the axis of rotation . Because the planetary angular momentum term vanishes at the equator (where <formula>) , tropical cyclones rarely form within 5 ° of the equator .
As air flows radially inward at low levels , it begins to rotate cyclonically in order to conserve angular momentum . Similarly , as rapidly rotating air flows radially outward near the tropopause , its

cyclonic rotation decreases and ultimately changes sign at large enough radius , resulting in an upper @-@ level anti @-@ cyclone . The result is a vertical structure characterized by a strong cyclone at low levels and a strong anti @-@ cyclone near the tropopause ; from thermal wind balance , this corresponds to a system that is warmer at its center than in the surrounding environment at all altitudes (i.e. " warm @-@ core ") . From hydrostatic balance , the warm core translates to lower pressure at the center at all altitudes , with the maximum pressure drop located at the surface .

= = = Maximum potential intensity = = =

Due to surface friction , the inflow only partially conserves angular momentum . Thus , the sea surface lower boundary acts as both a source (evaporation) and sink (friction) of energy for the system . This fact leads to the existence of a theoretical upper bound on the strongest wind speed that a tropical cyclone can attain . Because evaporation increases linearly with wind speed (just as climbing out of a pool feels much colder on a windy day) , there is a positive feedback on energy input into the system known as the Wind @-@ Induced Surface Heat Exchange (WISHE) feedback . This feedback is offset when frictional dissipation , which increases with the cube of the wind speed , becomes sufficiently large . This upper bound is called the " maximum potential intensity " , <formula> , and is given by
<formula>
where <formula> is the temperature of the sea surface , <formula> is the temperature of the outflow ([K]) , <formula> is the enthalpy difference between the surface and the overlying air ([J / kg]) , and <formula> and <formula> are the surface exchange coefficients (dimensionless) of enthalpy and momentum , respectively . The surface @-@ air enthalpy difference is taken as <formula> , where <formula> is the saturation enthalpy of air at sea surface temperature and sea @-@ level pressure and <formula> is the enthalpy of boundary layer air overlying the surface .
The maximum potential intensity is predominantly a function of the background environment alone (i.e. without a tropical cyclone) , and thus this quantity can be used to determine which regions on Earth can support tropical cyclones of a given intensity , and how these regions may evolve in time . Specifically , the maximum potential intensity has three components , but its variability in space and time is due predominantly to the variability in the surface @-@ air enthalpy difference component <formula> .

= = = = Derivation = = = =

A tropical cyclone may be viewed as a heat engine that converts input heat energy from the surface into mechanical energy that can be used to do mechanical work against surface friction . At equilibrium , the rate of net energy production in the system must equal the rate of energy loss due to frictional dissipation at the surface , i.e.
<formula>
The rate of energy loss per unit surface area from surface friction , <formula> , is given by
<formula>
where <formula> is the density of near @-@ surface air ([kg / m3]) and <formula> is the near surface wind speed ([m / s]) .
The rate of energy production per unit surface area , <formula> is given by
<formula>
where <formula> is the heat engine efficiency and <formula> is the total rate of heat input into the system per unit surface area . Given that a tropical cyclone may be idealized as a Carnot heat engine , the Carnot heat engine efficiency is given by
<formula>
Heat (enthalpy) per unit mass is given by
<formula>
where <formula> is the heat capacity of air , <formula> is air temperature , <formula> is the latent

heat of vaporization , and <formula> is the concentration of water vapor . The first component corresponds to sensible heat and the second to latent heat .
There are two sources of heat input . The dominant source is the input of heat at the surface , primarily due to evaporation . The bulk aerodynamic formula for the rate of heat input per unit area at the surface , <formula> , is given by
<formula>
where <formula> represents the enthalpy difference between the ocean surface and the overlying air . The second source is the internal sensible heat generated from frictional dissipation (equal to <formula>) , which occurs near the surface within the tropical cyclone and is recycled to the system .
<formula>
Thus , the total rate of net energy production per unit surface area is given by
<formula>
Setting <formula> and taking <formula> (i.e. the rotational wind speed is dominant) leads to the solution for <formula> given above . This derivation assumes that total energy input and loss within the system can be approximated by their values at the radius of maximum wind . The inclusion of <formula> acts to multiply the total heat input rate by the factor <formula> . Mathematically , this has the effect of replacing <formula> with <formula> in the denominator of the Carnot efficiency .
An alternative definition for the maximum potential intensity , which is mathematically equivalent to the above formulation , is
<formula>
where CAPE stands for the Convective Available Potential Energy , <formula> is the CAPE of an air parcel lifted from saturation at sea level in reference to the environmental sounding , <formula> is the CAPE of the boundary layer air , and both quantities are calculated at the radius of maximum wind .

= = = = Characteristic values and variability on Earth = = = =

On Earth , a characteristic temperature for <formula> is 300 K and for <formula> is 200 K , corresponding to a Carnot efficiency of <formula> . The ratio of the surface exchange coefficients , <formula> , is typically taken to be 1 . However , observations suggest that the drag coefficient <formula> varies with wind speed and may decrease at high wind speeds within the boundary layer of a mature hurricane . Additionally , <formula> may vary at high wind speeds due to the effect of sea spray on evaporation within the boundary layer .
A characteristic value of the maximum potential intensity , <formula> , is 80 m / s . However , this quantity varies significantly across space and time , particularly within the seasonal cycle , spanning a range of 0 ? 100 m / s . This variability is primarily due to variability in the surface enthalpy disequilibrium (<formula>) as well as in the thermodynamic structure of the troposphere , which are controlled by the large @-@ scale dynamics of the tropical climate . These processes are modulated by factors including the sea surface temperature (and underlying ocean dynamics) , background near @-@ surface wind speed , and the vertical structure of atmospheric radiative heating . The nature of this modulation is complex , particularly on climate time @-@ scales (decades or longer) . On shorter time @-@ scales , variability in the maximum potential intensity is commonly linked to sea surface temperature perturbations from the tropical mean , as regions with relatively warm water have thermodynamic states much more capable of sustaining a tropical cyclone than regions with relatively cold water . However , this relationship is indirect via the large @-@ scale dynamics of the tropics ; the direct influence of the absolute sea surface temperature on <formula> is weak in comparison .

= = = Interaction with the upper ocean = = =

The passage of a tropical cyclone over the ocean causes the upper layers of the ocean to cool substantially , which can influence subsequent cyclone development . This cooling is primarily caused by wind @-@ driven mixing of cold water from deeper in the ocean with the warm surface waters . This effect results in a negative feedback process that can inhibit further development or lead to weakening . Additional cooling may come in the form of cold water from falling raindrops (this is because the atmosphere is cooler at higher altitudes) . Cloud cover may also play a role in cooling the ocean , by shielding the ocean surface from direct sunlight before and slightly after the storm passage . All these effects can combine to produce a dramatic drop in sea surface temperature over a large area in just a few days .

= = Major basins and related warning centers = =

There are six Regional Specialized Meteorological Centers (RSMCs) worldwide . These organizations are designated by the World Meteorological Organization and are responsible for tracking and issuing bulletins , warnings , and advisories about tropical cyclones in their designated areas of responsibility . In addition , there are six Tropical Cyclone Warning Centers (TCWCs) that provide information to smaller regions .

The RSMCs and TCWCs are not the only organizations that provide information about tropical cyclones to the public . The Joint Typhoon Warning Center (JTWC) issues advisories in all basins except the Northern Atlantic for the purposes of the United States Government . The Philippine Atmospheric , Geophysical and Astronomical Services Administration (PAGASA) issues advisories and names for tropical cyclones that approach the Philippines in the Northwestern Pacific to protect the life and property of its citizens . The Canadian Hurricane Center (CHC) issues advisories on hurricanes and their remnants for Canadian citizens when they affect Canada .

On March 26 , 2004 , Cyclone Catarina became the first recorded South Atlantic cyclone , striking southern Brazil with winds equivalent to Category 2 on the Saffir @-@ Simpson Hurricane Scale . As the cyclone formed outside the authority of another warning center , Brazilian meteorologists initially treated the system as an extratropical cyclone , but later on classified it as tropical .

= = Formation = =

Worldwide , tropical cyclone activity peaks in late summer , when the difference between temperatures aloft and sea surface temperatures is the greatest . However , each particular basin has its own seasonal patterns . On a worldwide scale , May is the least active month , while September is the most active month . November is the only month in which all the tropical cyclone basins are active .

= = = Times = = =

In the Northern Atlantic Ocean , a distinct cyclone season occurs from June 1 to November 30 , sharply peaking from late August through September . The statistical peak of the Atlantic hurricane season is September 10 . The Northeast Pacific Ocean has a broader period of activity , but in a similar time frame to the Atlantic . The Northwest Pacific sees tropical cyclones year @-@ round , with a minimum in February and March and a peak in early September . In the North Indian basin , storms are most common from April to December , with peaks in May and November . In the Southern Hemisphere , the tropical cyclone year begins on July 1 and runs all year @-@ round encompassing the tropical cyclone seasons , which run from November 1 until the end of April , with peaks in mid @-@ February to early March .

= = = Factors = = =

The formation of tropical cyclones is the topic of extensive ongoing research and is still not fully understood . While six factors appear to be generally necessary , tropical cyclones may occasionally form without meeting all of the following conditions . In most situations , water temperatures of at least 26 @.@ 5 ° C (79 @.@ 7 ° F) are needed down to a depth of at least 50 m (160 ft) ; waters of this temperature cause the overlying atmosphere to be unstable enough to sustain convection and thunderstorms . Another factor is rapid cooling with height , which allows the release of the heat of condensation that powers a tropical cyclone . High humidity is needed , especially in the lower @-@ to @-@ mid troposphere ; when there is a great deal of moisture in the atmosphere , conditions are more favorable for disturbances to develop . Low amounts of wind shear are needed , as high shear is disruptive to the storm 's circulation . Tropical cyclones generally need to form more than 555 km (345 mi) or five degrees of latitude away from the equator , allowing the Coriolis effect to deflect winds blowing towards the low pressure center and creating a circulation . Lastly , a formative tropical cyclone needs a preexisting system of disturbed weather . Tropical cyclones will not form spontaneously . Low @-@ latitude and low @-@ level westerly wind bursts associated with the Madden @-@ Julian oscillation can create favorable conditions for tropical cyclogenesis by initiating tropical disturbances .

= = = Locations = = =

Most tropical cyclones form in a worldwide band of thunderstorm activity near the equator , referred to as the Intertropical Front (ITF) , the Intertropical Convergence Zone (ITCZ) , or the monsoon trough . Another important source of atmospheric instability is found in tropical waves , which contribute to the development of about 85 % of intense tropical cyclones in the Atlantic ocean and become most of the tropical cyclones in the Eastern Pacific . The majority forms between 10 and 30 degrees of latitude away of the equator , and 87 % forms no farther away than 20 degrees north or south . Because the Coriolis effect initiates and maintains their rotation , tropical cyclones rarely form or move within 5 degrees of the equator , where the effect is weakest . However , it is still possible for tropical systems to form within this boundary as Tropical Storm Vamei and Cyclone Agni did in 2001 and 2004 , respectively .

= = Movement = =

The movement of a tropical cyclone (i.e. its " track ") is typically approximated as the sum of two terms : " steering " by the background environmental wind and " beta drift " .

= = = Environmental steering = = =

Environmental steering is the dominant term . Conceptually , it represents the movement of the storm with the background environment , akin to " leaves carried along by a stream " . Physically , the flow field in the vicinity of a tropical cyclone may be decomposed into two parts : the flow associated with the storm itself , and the large @-@ scale background flow of the environment in which the storm is embedded . In this way , tropical cyclone motion may be represented to first @-@ order simply as the advection of the storm by the local environmental flow . This environmental flow is termed the " steering flow " .

Climatologically , tropical cyclones are steered primarily westward by the east @-@ to @-@ west trade winds on the equatorial side of the subtropical ridge ? a persistent high @-@ pressure area over the world 's subtropical oceans . In the tropical North Atlantic and Northeast Pacific oceans , the trade winds steer tropical easterly waves westward from the African coast toward the Caribbean Sea , North America , and ultimately into the central Pacific ocean before the waves dampen out . These waves are the precursors to many tropical cyclones within this region . In contrast , in the Indian Ocean and Western Pacific in both hemispheres , tropical cyclogenesis is influenced less by tropical easterly waves and more by the seasonal movement of the Inter @-@ tropical Convergence Zone and the monsoon trough . Additionally , tropical cyclone motion can be influenced by transient weather systems , such as extratropical cyclones .

= = = Beta drift = = =

In addition to environmental steering , a tropical cyclone will tend to drift slowly poleward and westward , a motion known as " beta drift " . This motion is due to the superposition of a vortex , such as a tropical cyclone , onto an environment in which the Coriolis force varies with latitude , such as on a sphere or beta plane . It is induced indirectly by the storm itself , the result of a feedback between the cyclonic flow of the storm and its environment .

Physically , the cyclonic circulation of the storm advects environmental air poleward east of center and equatorial west of center . Because air must conserve its angular momentum , this flow configuration induces a cyclonic gyre equatorward and westward of the storm center and an anticyclonic gyre poleward and eastward of the storm center . The combined flow of these gyres acts to advect the storm slowly poleward and westward . This effect occurs even if there is zero environmental flow .

= = = Multiple storm interaction = = =

A third component of motion that occurs relatively infrequently involves the interaction of multiple tropical cyclones . When two cyclones approach one another , their centers will begin orbiting cyclonically about a point between the two systems . Depending on their separation distance and strength , the two vortices may simply orbit around one another or else may spiral into the center point and merge . When the two vortices are of unequal size , the larger vortex will tend to dominate the interaction , and the smaller vortex will orbit around it . This phenomenon is called the Fujiwhara effect , after Sakuhei Fujiwhara .

= = = Interaction with the mid @-@ latitude westerlies = = =

Though a tropical cyclone typically moves from east to west in the tropics , its track may shift poleward and eastward either as it moves west of the subtropical ridge axis or else if it interacts with the mid @-@ latitude flow , such as the jet stream or an extratropical cyclone . This motion , termed " recurvature " , commonly occurs near the western edge of the major ocean basins , where the jet stream typically has a poleward component and extratropical cyclones are common . An example of tropical cyclone recurvature was Typhoon Ioke in 2006 .

= = = Landfall = = =

The landfall of a tropical cyclone occurs when a storm 's surface center , moves over a coastline . Storm conditions may be experienced on the coast and inland hours before landfall ; in fact , a tropical cyclone can launch its strongest winds over land , yet not make landfall . NOAA uses the term " direct hit " to describe when a location (on the left side of the eye) falls within the radius of maximum winds (or twice that radius if on the right side) , whether or not the hurricane 's eye made landfall .

= = Dissipation = =

= = = Factors = = =

A tropical cyclone can cease to have tropical characteristics in several different ways . One such way is if it moves over land , thus depriving it of the warm water it needs to power itself , quickly losing strength . Most strong storms lose their strength very rapidly after landfall and become disorganized areas of low pressure within a day or two , or evolve into extratropical cyclones . There is a chance a tropical cyclone could regenerate if it managed to get back over open warm water , such as with Hurricane Ivan . If it remains over mountains for even a short time , weakening will accelerate . Many storm fatalities occur in mountainous terrain , when diminishing cyclones unleash their moisture as torrential rainfall . This may lead to deadly floods and mudslides , as was the case

with Hurricane Mitch in 1998 . Without warm surface water , the storm cannot survive .
A tropical cyclone can dissipate when it moves over waters significantly below 26 @.@ 5 ° C (79 @.@ 7 ° F) . This will cause the storm to lose its tropical characteristics , such as a warm core with thunderstorms near the center , and become a remnant low @-@ pressure area . These remnant systems may persist for up to several days before losing their identity . This dissipation mechanism is most common in the eastern North Pacific . Weakening or dissipation can occur if it experiences vertical wind shear , causing the convection and heat engine to move away from the center ; this normally ceases development of a tropical cyclone . In addition , its interaction with the main belt of the Westerlies , by means of merging with a nearby frontal zone , can cause tropical cyclones to evolve into extratropical cyclones . This transition can take 1 ? 3 days . Even after a tropical cyclone is said to be extratropical or dissipated , it can still have tropical storm force (or occasionally hurricane / typhoon force) winds and drop several inches of rainfall . In the Pacific Ocean and Atlantic Ocean , such tropical @-@ derived cyclones of higher latitudes can be violent and may occasionally remain at hurricane or typhoon @-@ force wind speeds when they reach the west coast of North America . These phenomena can also affect Europe , where they are known as European windstorms ; Hurricane Iris 's extratropical remnants are an example of such a windstorm from 1995 . A cyclone can also merge with another area of low pressure , becoming a larger area of low pressure . This can strengthen the resultant system , although it may no longer be a tropical cyclone . Studies in the 2000s have given rise to the hypothesis that large amounts of dust reduce the strength of tropical cyclones .

= = = Artificial dissipation = = =

In the 1960s and 1970s , the United States government attempted to weaken hurricanes through Project Stormfury by seeding selected storms with silver iodide . It was thought that the seeding would cause supercooled water in the outer rainbands to freeze , causing the inner eyewall to collapse and thus reducing the winds . The winds of Hurricane Debbie ? a hurricane seeded in Project Stormfury ? dropped as much as 31 % , but Debbie regained its strength after each of two seeding forays . In an earlier episode in 1947 , disaster struck when a hurricane east of Jacksonville , Florida promptly changed its course after being seeded , and smashed into Savannah , Georgia . Because there was so much uncertainty about the behavior of these storms , the federal government would not approve seeding operations unless the hurricane had a less than 10 % chance of making landfall within 48 hours , greatly reducing the number of possible test storms . The project was dropped after it was discovered that eyewall replacement cycles occur naturally in strong hurricanes , casting doubt on the result of the earlier attempts . Today , it is known that silver iodide seeding is not likely to have an effect because the amount of supercooled water in the rainbands of a tropical cyclone is too low .
Other approaches have been suggested over time , including cooling the water under a tropical cyclone by towing icebergs into the tropical oceans . Other ideas range from covering the ocean in a substance that inhibits evaporation , dropping large quantities of ice into the eye at very early stages of development (so that the latent heat is absorbed by the ice , instead of being converted to kinetic energy that would feed the positive feedback loop) , or blasting the cyclone apart with nuclear weapons . Project Cirrus even involved throwing dry ice on a cyclone . These approaches all suffer from one flaw above many others : tropical cyclones are simply too large and short @-@ lived for any of the weakening techniques to be practical .

= = Effects = =

Tropical cyclones out at sea cause large waves , heavy rain , flood and high winds , disrupting international shipping and , at times , causing shipwrecks . Tropical cyclones stir up water , leaving a cool wake behind them , which causes the region to be less favorable for subsequent tropical cyclones . On land , strong winds can damage or destroy vehicles , buildings , bridges , and other outside objects , turning loose debris into deadly flying projectiles . The storm surge , or the increase in sea level due to the cyclone , is typically the worst effect from landfalling tropical cyclones , historically resulting in 90 % of tropical cyclone deaths . The broad rotation of a landfalling tropical cyclone , and vertical wind shear at its periphery , spawns tornadoes . Tornadoes can also be spawned as a result of eyewall mesovortices , which persist until landfall .

Over the past two centuries , tropical cyclones have been responsible for the deaths of about 1 @.@ 9 million people worldwide . Large areas of standing water caused by flooding lead to infection , as well as contributing to mosquito @-@ borne illnesses . Crowded evacuees in shelters increase the risk of disease propagation . Tropical cyclones significantly interrupt infrastructure , leading to power outages , bridge destruction , and the hampering of reconstruction efforts . On average , the Gulf and east coasts of the United States suffer approximately US $ 5 billion (1995 US $) in cyclone damage every year . The majority (83 %) of tropical cyclone damage is caused by severe hurricanes , category 3 or greater . However , category 3 or greater hurricanes only account for about one @-@ fifth of cyclones that make landfall every year .

Although cyclones take an enormous toll in lives and personal property , they may be important factors in the precipitation regimes of places they impact , as they may bring much @-@ needed precipitation to otherwise dry regions . Tropical cyclones also help maintain the global heat balance by moving warm , moist tropical air to the middle latitudes and polar regions , and by regulating the thermohaline circulation through upwelling . The storm surge and winds of hurricanes may be destructive to human @-@ made structures , but they also stir up the waters of coastal estuaries , which are typically important fish breeding locales . Tropical cyclone destruction spurs redevelopment , greatly increasing local property values .

When hurricanes surge upon shore from the ocean , salt is introduced to many freshwater areas and raises the salinity levels too high for some habitats to withstand . Some are able to cope with the salt and recycle it back into the ocean , but others can not release the extra surface water quickly enough or do not have a large enough freshwater source to replace it . Because of this , some species of plants and vegetation die due to the excess salt . In addition , hurricanes can carry toxins and acids onto shore when they make landfall . The flood water can pick up the toxins from different spills and contaminate the land that it passes over . The toxins are very harmful to the people and animals in the area , as well as the environment around them . The flooding water can also spark many dangerous oil spills .

= = Observation and forecasting = =

= = = Observation = = =

Intense tropical cyclones pose a particular observation challenge , as they are a dangerous oceanic phenomenon , and weather stations , being relatively sparse , are rarely available on the site of the storm itself . In general , surface observations are available only if the storm is passing over an island or a coastal area , or if there is a nearby ship . Real @-@ time measurements are usually taken in the periphery of the cyclone , where conditions are less catastrophic and its true strength cannot be evaluated . For this reason , there are teams of meteorologists that move into the path of tropical cyclones to help evaluate their strength at the point of landfall .

Tropical cyclones far from land are tracked by weather satellites capturing visible and infrared images from space , usually at half @-@ hour to quarter @-@ hour intervals . As a storm approaches land , it can be observed by land @-@ based Doppler weather radar . Radar plays a crucial role around landfall by showing a storm 's location and intensity every several minutes .

In situ measurements , in real @-@ time , can be taken by sending specially equipped reconnaissance flights into the cyclone . In the Atlantic basin , these flights are regularly flown by United States government hurricane hunters . The aircraft used are WC @-@ 130 Hercules and WP @-@ 3D Orions , both four @-@ engine turboprop cargo aircraft . These aircraft fly directly into the cyclone and take direct and remote @-@ sensing measurements . The aircraft also launch GPS dropsondes inside the cyclone . These sondes measure temperature , humidity , pressure , and especially winds between flight level and the ocean 's surface . A new era in hurricane observation began when a remotely piloted Aerosonde , a small drone aircraft , was flown through Tropical Storm Ophelia as it passed Virginia 's Eastern Shore during the 2005 hurricane season . A similar mission was also completed successfully in the western Pacific ocean . This demonstrated a new way to probe the storms at low altitudes that human pilots seldom dare .

= = = Forecasting = = =

Because of the forces that affect tropical cyclone tracks , accurate track predictions depend on determining the position and strength of high- and low @-@ pressure areas , and predicting how those areas will change during the life of a tropical system . The deep layer mean flow , or average wind through the depth of the troposphere , is considered the best tool in determining track direction and speed . If storms are significantly sheared , use of wind speed measurements at a lower altitude , such as at the 70 kPa pressure surface (3 @,@ 000 metres or 9 @,@ 800 feet above sea level) will produce better predictions . Tropical forecasters also consider smoothing out short @-@ term wobbles of the storm as it allows them to determine a more accurate long @-@ term trajectory . High @-@ speed computers and sophisticated simulation software allow forecasters to produce computer models that predict tropical cyclone tracks based on the future position and strength of high- and low @-@ pressure systems . Combining forecast models with increased understanding of the forces that act on tropical cyclones , as well as with a wealth of data from Earth @-@ orbiting satellites and other sensors , scientists have increased the accuracy of track forecasts over recent decades . However , scientists are not as skillful at predicting the intensity of tropical cyclones . The lack of improvement in intensity forecasting is attributed to the complexity of tropical systems and an incomplete understanding of factors that affect their development .

= = Classifications , terminology , and naming = =

= = = Intensity classifications = = =

Tropical cyclones are classified into three main groups , based on intensity : tropical depressions , tropical storms , and a third group of more intense storms , whose name depends on the region . For example , if a tropical storm in the Northwestern Pacific reaches hurricane @-@ strength winds on the Beaufort scale , it is referred to as a typhoon ; if a tropical storm passes the same benchmark in the Northeast Pacific Basin , or in the North Atlantic , it is called a hurricane . Neither " hurricane " nor " typhoon " is used in either the Southern Hemisphere or the Indian Ocean . In these basins , storms of a tropical nature are referred to as either tropical cyclones , severe tropical cyclones or very intense tropical cyclones .

As indicated in the table below , each basin uses a separate system of terminology , which can make comparisons between different basins difficult . In the Pacific Ocean , hurricanes from the Central North Pacific sometimes cross the 180th meridian into the Northwest Pacific , becoming typhoons (such as Hurricane / Typhoon Ioke in 2006) ; on rare occasions , the reverse will occur . It should also be noted that typhoons with 1 @-@ minute sustained winds greater than 67 metres per second (m / s) , over 150 miles per hour (240 km / h) , are called Super Typhoons by the Joint Typhoon Warning Center .

= = = = Tropical depression = = = =

A tropical depression or tropical low is a tropical disturbance , that has a clearly defined surface circulation , which has maximum sustained winds of less than 34 kn (39 mph ; 63 km / h) . Within the Southern Hemisphere , the depression can have gale force or stronger winds in one or more quadrants , but not near the centre .

= = = = Tropical storm = = = =

A tropical storm is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 34 knots (63 km / h) and 64 knots (119 km / h) . At this point , the distinctive cyclonic shape starts to develop , although an eye is not usually present . Government weather services first assign names to systems that reach this intensity (thus the term named storm) . Although tropical storms are less intense than a hurricane they can produce significant damage . The shear force of winds can blow off shingles , and air borne objects can cause damage to power lines , roofing and siding . More dangerous is the heavy rain fall causing inland flooding .

= = = = Hurricane or typhoon = = = =

A hurricane or typhoon (sometimes simply referred to as a tropical cyclone , as opposed to a depression or storm) is a system with sustained winds of at least 34 metres per second (66 kn) or 74 miles per hour (119 km / h) . A cyclone of this intensity tends to develop an eye , an area of relative calm (and lowest atmospheric pressure) at the center of circulation . The eye is often visible in satellite images as a small , circular , cloud @-@ free spot . Surrounding the eye is the eyewall , an area about 16 kilometres (9 @.@ 9 mi) to 80 kilometres (50 mi) wide in which the strongest thunderstorms and winds circulate around the storm 's center . Maximum sustained winds in the strongest tropical cyclones have been estimated at about 95 metres per second (185 kn) or 346 kilometres per hour (215 mph) .

= = = Origin of storm terms = = =

The word typhoon , which is used today in the Northwest Pacific , may be derived from Arabic ??f?n (?????) (similar in Hindi / Urdu and Persian) , which in turn originates from Greek Typhon (?????) , a monster from Greek mythology associated with storms . The related Portuguese word tufão , used in Portuguese for typhoons , is also derived from Typhon . The word is also similar to Chinese " táif?ng " (Simplified Chinese : ??) (f?ng = wind) , " toifung " in Cantonese (Traditional Chinese : ??) , " taif? " (??) in Japanese , and " taepung " (??) in Korean .

The word hurricane , used in the North Atlantic and Northeast Pacific , is derived from huracán , the Spanish word for the Carib / Taino storm god , Juracán . This god is believed by scholars to have been at least partially derived from the Mayan creator god , Huracan . Huracan was believed by the Maya to have created dry land out of the turbulent waters . The god was also credited with later destroying the " wooden people " , the precursors to the " maize people " , with an immense storm and flood . Huracan is also the source of the word orcan , another word for a particularly strong European windstorm .

= = = Naming = = =

The practice of using names to identify tropical cyclones goes back many years , with systems named after places or things they hit before the formal start of naming . The system currently used provides positive identification of severe weather systems in a brief form , that is readily understood and recognized by the public . The credit for the first usage of personal names for weather systems , is generally given to the Queensland Government Meteorologist Clement Wragge who named systems between 1887 @-@ 1907 . This system of naming weather systems subsequently fell into disuse for several years after Wragge retired , until it was revived in the latter part of World War II for the Western Pacific . Formal naming schemes have subsequently been introduced for the North and South Atlantic , Eastern , Central , Western and Southern Pacific basins as well as the Australian region and Indian Ocean .

At present tropical cyclones are officially named by one of eleven meteorological services and retain their names throughout their lifetimes to provide ease of communication between forecasters and the general public regarding forecasts , watches , and warnings . Since the systems can last a week or longer and more than one can be occurring in the same basin at the same time , the names are thought to reduce the confusion about what storm is being described . Names are assigned in order from predetermined lists with one , three , or ten @-@ minute sustained wind speeds of more than 65 km / h (40 mph) depending on which basin it originates . However , standards vary from basin to basin with some tropical depressions named in the Western Pacific , while tropical cyclones have to have a significant amount of gale @-@ force winds occurring around the center before they are named within the Southern Hemisphere . The names of significant tropical cyclones in the North Atlantic Ocean , Pacific Ocean , and Australian region are retired from the naming lists and replaced with another name .

= = Notable tropical cyclones = =

Tropical cyclones that cause extreme destruction are rare , although when they occur , they can cause great amounts of damage or thousands of fatalities . The 1970 Bhola cyclone is the deadliest tropical cyclone on record , killing more than 300 @,@ 000 people and potentially as many as 1 million after striking the densely populated Ganges Delta region of Bangladesh on November 13 , 1970 . Its powerful storm surge was responsible for the high death toll . The North Indian cyclone basin has historically been the deadliest basin . Elsewhere , Typhoon Nina killed nearly 100 @,@ 000 in China in 1975 due to a 100 @-@ year flood that caused 62 dams including the Banqiao Dam to fail . The Great Hurricane of 1780 is the deadliest North Atlantic hurricane on record , killing about 22 @,@ 000 people in the Lesser Antilles . A tropical cyclone does not need to be particularly strong to cause memorable damage , primarily if the deaths are from rainfall or mudslides . Tropical Storm Thelma in November 1991 killed thousands in the Philippines , although the strongest typhoon to ever make landfall on record was Typhoon Haiyan on November 2013 , causing widespread devastation in the Eastern Visayas and killing at least 6 @,@ 300 people in that country alone . In 1982 , the unnamed tropical depression that eventually became Hurricane Paul killed around 1 @,@ 000 people in Central America .

Hurricane Katrina is estimated as the costliest tropical cyclone worldwide , causing $ 81 @.@ 2 billion in property damage (2008 USD) with overall damage estimates exceeding $ 100 billion (2005 USD) . Katrina killed at least 1 @,@ 836 people after striking Louisiana and Mississippi as a major hurricane in August 2005 . Hurricane Sandy is the second most destructive tropical cyclone in U.S history , with damages totaling $ 68 billion (2012 USD) , and with damage costs at $ 37 @.@ 5 billion (2012 USD) , Hurricane Ike is the third most destructive tropical cyclone in U.S history . The Galveston Hurricane of 1900 is the deadliest natural disaster in the United States , killing an estimated 6 @,@ 000 to 12 @,@ 000 people in Galveston , Texas . Hurricane Mitch caused more than 10 @,@ 000 fatalities in Central America , making it the second deadliest Atlantic hurricane in history . Hurricane Iniki in 1992 was the most powerful storm to strike Hawaii in recorded history , hitting Kauai as a Category 4 hurricane , killing six people , and causing U.S. $ 3 billion in damage . Kauai was also struck by Hurricanes Dot (1959) and Iwa (1982) (see List of Hawaii hurricanes) . Other destructive Eastern Pacific hurricanes include Pauline and Kenna , both causing severe damage after striking Mexico as major hurricanes . In March 2004 , Cyclone Gafilo struck northeastern Madagascar as a powerful cyclone , killing 74 , affecting more than 200 @,@ 000 , and becoming the worst cyclone to affect the nation for more than 20 years .

The most intense storm on record was Typhoon Tip in the northwestern Pacific Ocean in 1979 , which reached a minimum pressure of 870 hectopascals (26 inHg) and maximum sustained wind speeds of 165 knots (85 m / s) or 190 miles per hour (310 km / h) . The highest maximum sustained wind speed ever recorded was 185 knots (95 m / s) or 215 miles per hour (345 km / h) in Hurricane Patricia in 2015 , which is the most intense cyclone ever recorded in the Western Hemisphere . Typhoon Nancy in 1961 also had recorded wind speeds of 185 knots (95 m / s) or 215 miles per hour (346 km / h) , but recent research indicates that wind speeds from the 1940s to the 1960s were gauged too high , and this is no longer considered the storm with the highest wind speeds on record . Likewise , a surface @-@ level gust caused by Typhoon Paka on Guam in late

1997 was recorded at 205 knots (105 m / s) or 235 miles per hour (378 km / h) . Had it been confirmed , it would be the strongest non @-@ tornadic wind ever recorded on the Earth 's surface , but the reading had to be discarded since the anemometer was damaged by the storm .

In addition to being the most intense tropical cyclone on record based on pressure , Tip was the largest cyclone on record , with tropical storm @-@ force winds 2 @,@ 170 kilometres (1 @,@ 350 mi) in diameter . The smallest storm on record , Tropical Storm Marco , formed during October 2008 , and made landfall in Veracruz . Marco generated tropical storm @-@ force winds only 37 kilometres (23 mi) in diameter .

Hurricane John is the longest @-@ lasting tropical cyclone on record , lasting 31 days in 1994 . Before the advent of satellite imagery in 1961 , however , many tropical cyclones were underestimated in their durations . John is also the longest @-@ tracked tropical cyclone in the Northern Hemisphere on record , which had a path of 8 @,@ 250 mi (13 @,@ 280 km) . Cyclone Rewa of the 1993 @-@ 94 South Pacific and Australian region cyclone seasons had one of the longest tracks observed within the Southern Hemisphere , traveling a distance of over 5 @,@ 545 mi (8 @,@ 920 km) during December 1993 and January 1994 .

= = Changes caused by El Niño @-@ Southern Oscillation = =

Most tropical cyclones form on the side of the subtropical ridge closer to the equator , then move poleward past the ridge axis before recurving into the main belt of the Westerlies . When the subtropical ridge position shifts due to El Niño , so will the preferred tropical cyclone tracks . Areas west of Japan and Korea tend to experience much fewer September ? November tropical cyclone impacts during El Niño and neutral years . During El Niño years , the break in the subtropical ridge tends to lie near 130 ° E which would favor the Japanese archipelago . During El Niño years , Guam 's chance of a tropical cyclone impact is one @-@ third more likely than of the long @-@ term average . The tropical Atlantic ocean experiences depressed activity due to increased vertical wind shear across the region during El Niño years . During La Niña years , the formation of tropical cyclones , along with the subtropical ridge position , shifts westward across the western Pacific ocean , which increases the landfall threat to China and much greater intensity in the Philippines .

= = Long @-@ term activity trends = =

While the number of storms in the Atlantic has increased since 1995 , there is no obvious global trend ; the annual number of tropical cyclones worldwide remains about 87 ± 10 (Between 77 and 97 tropical cyclones annually) . However , the ability of climatologists to make long @-@ term data analysis in certain basins is limited by the lack of reliable historical data in some basins , primarily in the Southern Hemisphere , while noting that a significant downward trend in tropical cyclone numbers has been identified for the region near Australia (based on high quality data and accounting for the influence of the El Niño @-@ Southern Oscillation) . In spite of that , there is some evidence that the intensity of hurricanes is increasing . Kerry Emanuel stated , " Records of hurricane activity worldwide show an upswing of both the maximum wind speed in and the duration of hurricanes . The energy released by the average hurricane (again considering all hurricanes worldwide) seems to have increased by around 70 % in the past 30 years or so , corresponding to about a 15 % increase in the maximum wind speed and a 60 % increase in storm lifetime . "

Atlantic storms are becoming more destructive financially , as evidenced by the fact that five of the ten most expensive storms in United States history have occurred since 1990 . According to the World Meteorological Organization , " recent increase in societal impact from tropical cyclones has been caused largely by rising concentrations of population and infrastructure in coastal regions . " Pielke et al . (2008) normalized mainland U.S. hurricane damage from 1900 ? 2005 to 2005 values and found no remaining trend of increasing absolute damage . The 1970s and 1980s were notable because of the extremely low amounts of damage compared to other decades . The decade 1996 ? 2005 was the second most damaging among the past 11 decades , with only the decade 1926 ? 1935 surpassing its costs . The most damaging single storm is the 1926 Miami hurricane , with $

157 billion of normalized damage .
Often in part because of the threat of hurricanes , many coastal regions had sparse population between major ports until the advent of automobile tourism ; therefore , the most severe portions of hurricanes striking the coast may have gone unmeasured in some instances . The combined effects of ship destruction and remote landfall severely limit the number of intense hurricanes in the official record before the era of hurricane reconnaissance aircraft and satellite meteorology . Although the record shows a distinct increase in the number and strength of intense hurricanes , therefore , experts regard the early data as suspect .
The number and strength of Atlantic hurricanes may undergo a 50 ? 70 year cycle , also known as the Atlantic Multidecadal Oscillation . Nyberg et al. reconstructed Atlantic major hurricane activity back to the early 18th century and found five periods averaging 3 ? 5 major hurricanes per year and lasting 40 ? 60 years , and six other averaging 1 @.@ 5 ? 2 @.@ 5 major hurricanes per year and lasting 10 ? 20 years . These periods are associated with the Atlantic multidecadal oscillation . Throughout , a decadal oscillation related to solar irradiance was responsible for enhancing / dampening the number of major hurricanes by 1 ? 2 per year .
Although more common since 1995 , few above @-@ normal hurricane seasons occurred during 1970 ? 94 . Destructive hurricanes struck frequently from 1926 to 1960 , including many major New England hurricanes . Twenty @-@ one Atlantic tropical storms formed in 1933 , a record only recently exceeded in 2005 , which saw 28 storms . Tropical hurricanes occurred infrequently during the seasons of 1900 ? 25 ; however , many intense storms formed during 1870 ? 99 . During the 1887 season , 19 tropical storms formed , of which a record 4 occurred after November 1 and 11 strengthened into hurricanes . Few hurricanes occurred in the 1840s to 1860s ; however , many struck in the early 19th century , including an 1821 storm that made a direct hit on New York City . Some historical weather experts say these storms may have been as high as Category 4 in strength .
These active hurricane seasons predated satellite coverage of the Atlantic basin . Before the satellite era began in 1960 , tropical storms or hurricanes went undetected unless a reconnaissance aircraft encountered one , a ship reported a voyage through the storm , or a storm hit land in a populated area .
Proxy records based on paleotempestological research have revealed that major hurricane activity along the Gulf of Mexico coast varies on timescales of centuries to millennia . Few major hurricanes struck the Gulf coast during 3000 ? 1400 BC and again during the most recent millennium . These quiescent intervals were separated by a hyperactive period during 1400 BC and 1000 AD , when the Gulf coast was struck frequently by catastrophic hurricanes and their landfall probabilities increased by 3 ? 5 times . This millennial @-@ scale variability has been attributed to long @-@ term shifts in the position of the Azores High , which may also be linked to changes in the strength of the North Atlantic Oscillation .
According to the Azores High hypothesis , an anti @-@ phase pattern is expected to exist between the Gulf of Mexico coast and the Atlantic coast . During the quiescent periods , a more northeasterly position of the Azores High would result in more hurricanes being steered towards the Atlantic coast . During the hyperactive period , more hurricanes were steered towards the Gulf coast as the Azores High was shifted to a more southwesterly position near the Caribbean . Such a displacement of the Azores High is consistent with paleoclimatic evidence that shows an abrupt onset of a drier climate in Haiti around 3200 14C years BP , and a change towards more humid conditions in the Great Plains during the late @-@ Holocene as more moisture was pumped up the Mississippi Valley through the Gulf coast . Preliminary data from the northern Atlantic coast seem to support the Azores High hypothesis . A 3000 @-@ year proxy record from a coastal lake in Cape Cod suggests that hurricane activity increased significantly during the past 500 ? 1000 years , just as the Gulf coast was amid a quiescent period of the last millennium .

= = Global warming = =

According to IPCC SREX 2012 , " attribution of single extreme events to anthropogenic climate change is challenging " . On one hand , the report said that there is " medium evidence " that long @-@ term trends in normalized losses have not been attributed to tropical and extratropical [winter] storms . On the other hand , the report also noted that much more research is needed in part due to " confounding factors " that might have increased losses , such as increased population and development in at @-@ risk areas , and those that might have decreased losses , such as better forecasting , emergency alert systems , emergency management , building codes , and near @-@ instantaneous media coverage of weather emergencies .

Some experts who agree that we can not yet detect any increase in frequency or intensity of tropical cyclones include Thomas Knutson , and Roger Pielke Jr ..

Others say that there is evidence for a causal connection . The U.S. National Oceanic and Atmospheric Administration Geophysical Fluid Dynamics Laboratory performed a simulation to determine if there is a statistical trend in the frequency or strength of tropical cyclones over time . The simulation concluded " the strongest hurricanes in the present climate may be upstaged by even more intense hurricanes over the next century as the earth 's climate is warmed by increasing levels of greenhouse gases in the atmosphere " .

In another simulation done by Kerry Emanuel , application of a tropical cyclone downscaling technique to six CMIP5 @-@ generation global climate models run under historical conditions and under the RCP8.5 emissions projection indicates an increase in global tropical cyclone activity , most evident in the North Pacific region but also noticeable in the North Atlantic and South Indian Oceans . In these regions , both the frequency and intensity of tropical cyclones are projected to increase . This result contrasts with the result of applying the same downscaling technique to CMIP3 @-@ generation models , which generally predict a small decrease of global tropical cyclone frequency .

In an article in Nature , meteorology professor Kerry Emanuel stated that potential hurricane destructiveness , a measure combining hurricane strength , duration , and frequency , " is highly correlated with tropical sea surface temperature , reflecting well @-@ documented climate signals , including multidecadal oscillations in the North Atlantic and North Pacific , and global warming " . Emanuel predicted " a substantial increase in hurricane @-@ related losses in the twenty @-@ first century " . In more recent work , Emanuel states that new climate modeling data indicates " global warming should reduce the global frequency of hurricanes . " According to the Houston Chronicle , the new work suggests that , even in a dramatically warming world , hurricane frequency and intensity may not substantially rise during the next two centuries .

P.J. Webster and others published an article in Science examining the " changes in tropical cyclone number , duration , and intensity " over the past 35 years , the period when satellite data has been available . Their main finding was although the number of cyclones decreased throughout the planet excluding the north Atlantic Ocean , there was a great increase in the number and proportion of very strong cyclones .

The strength of the reported effect is surprising in light of modeling studies that predict only a one @-@ half category increase in storm intensity as a result of a ~ 2 ° C (3 @.@ 6 ° F) global warming . Such a response would have predicted only a ~ 10 % increase in Emanuel 's potential destructiveness index during the 20th century rather than the ~ 75 ? 120 % increase he reported . Second , after adjusting for changes in population and inflation , and despite a more than 100 % increase in Emanuel 's potential destructiveness index , no statistically significant increase in the monetary damages resulting from Atlantic hurricanes has been found .

Sufficiently warm sea surface temperatures are considered vital to the development of tropical cyclones . Although neither study can directly link hurricanes with global warming , the increase in sea surface temperatures is believed to be due to both global warming and natural variability , e.g. the hypothesized Atlantic Multidecadal Oscillation (AMO) , although an exact attribution has not been defined . However , recent temperatures are the warmest ever observed for many ocean basins .

In February 2007 , the United Nations Intergovernmental Panel on Climate Change released its fourth assessment report on climate change . The report noted many observed changes in the climate , including atmospheric composition , global average temperatures , ocean conditions , and others . The report concluded the observed increase in tropical cyclone intensity is larger than climate models predict . In addition , the report considered that it is likely that storm intensity will continue to increase through the 21st century , and declared it more likely than not that there has been some human contribution to the increases in tropical cyclone intensity . However , there is no universal agreement about the magnitude of the effects anthropogenic global warming has on tropical cyclone formation , track , and intensity . For example , critics such as Chris Landsea assert that man @-@ made effects would be " quite tiny compared to the observed large natural hurricane variability " . A statement by the American Meteorological Society on February 1 , 2007 stated that trends in tropical cyclone records offer " evidence both for and against the existence of a detectable anthropogenic signal " in tropical cyclogenesis . Although many aspects of a link between tropical cyclones and global warming are still being " hotly debated " , a point of agreement is that the strength of destructiveness no individual tropical cyclone or season can be attributed entirely to global warming . Research reported in the September 3 , 2008 issue of Nature found that the strongest tropical cyclones are getting stronger , in particular over the North Atlantic and Indian oceans . Wind speeds for the strongest tropical storms increased from an average of 225 km / h (140 mph) in 1981 to 251 km / h (156 mph) in 2006 , while the ocean temperature , averaged globally over all the regions where tropical cyclones form , increased from 28 @.@ 2 ° C (82 @.@ 8 ° F) to 28 @.@ 5 ° C (83 @.@ 3 ° F) during this period .

= = Related cyclone types = =

In addition to tropical cyclones , there are two other classes of cyclones within the spectrum of cyclone types . These kinds of cyclones , known as extratropical cyclones and subtropical cyclones , can be stages a tropical cyclone passes through during its formation or dissipation . An extratropical cyclone is a storm that derives energy from horizontal temperature differences , which are typical in higher latitudes . A tropical cyclone can become extratropical as it moves toward higher latitudes if its energy source changes from heat released by condensation to differences in temperature between air masses ; although not as frequently , an extratropical cyclone can transform into a subtropical storm , and from there into a tropical cyclone . From space , extratropical storms have a characteristic " comma @-@ shaped " cloud pattern . Extratropical cyclones can also be dangerous when their low @-@ pressure centers cause powerful winds and high seas .

A subtropical cyclone is a weather system that has some characteristics of a tropical cyclone and some characteristics of an extratropical cyclone . They can form in a wide band of latitudes , from the equator to 50 ° . Although subtropical storms rarely have hurricane @-@ force winds , they may become tropical in nature as their cores warm . From an operational standpoint , a tropical cyclone is usually not considered to become subtropical during its extratropical transition .

= = In popular culture = =

In popular culture , tropical cyclones have made several appearances in different types of media , including films , books , television , music , and electronic games . These media often portray tropical cyclones that are either entirely fictional or based on real events . For example , George Rippey Stewart 's Storm , a best @-@ seller published in 1941 , is thought to have influenced meteorologists on their decision to assign female names to Pacific tropical cyclones . Another example is the hurricane in The Perfect Storm , which describes the sinking of the Andrea Gail by the 1991 Perfect Storm . Hypothetical hurricanes have been featured in parts of the plots of series such as The Simpsons , Invasion , Family Guy , Seinfeld , Dawson 's Creek , Burn Notice and CSI : Miami . The 2004 film The Day After Tomorrow includes several mentions of actual tropical cyclones and features fantastical " hurricane @-@ like " , albeit non @-@ tropical , Arctic storms .