



# Guide to the Science of Climate Change in the 21<sup>st</sup> Century

## Chapter 10 Hurricanes, Typhoons and Cyclones

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## 10.0 Hurricanes, Typhoons and Cyclones

### 10.1 Introduction

Hurricanes, typhoons and cyclones are known as tropical cyclones which may also be called tropical storms, tropical depressions and cyclonic storms. Their dynamics are the same.

Tropical cyclones are of particular interest because of their role in transferring heat energy from ocean water near the equator to northern latitudes, the nature of the dynamic relationship between ocean characteristics (sea surface temperature in particular) and the atmosphere, and most significant, their destructive potential.

The World Meteorological Organization defines tropical cyclones as follows:

A tropical cyclone is a rapidly rotating storm originating over tropical oceans from where it draws the energy to develop. It has a low-pressure centre and clouds spiraling towards the eyewall surrounding the "eye", the central part of the system where the weather is normally calm and free of clouds. Its diameter is typically around 200 to 500 km, but can reach 1000 km. A tropical cyclone brings very violent winds, torrential rain, high waves and, in some cases, very destructive storm surges and coastal flooding. The winds blow counter clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Tropical cyclones above a certain strength are given names in the interests of public safety.

### 10.2 Hurricanes and tropical cyclones

A hurricane is a tropical cyclone that occurs in the Atlantic Ocean and northeastern Pacific. A typhoon occurs in the northwestern Pacific Ocean. Tropical cyclones in the south Pacific and Indian Ocean are referred to as tropical cyclones or severe cyclonic storms. Figure 10.1 illustrates where the different tropical cyclones occur.

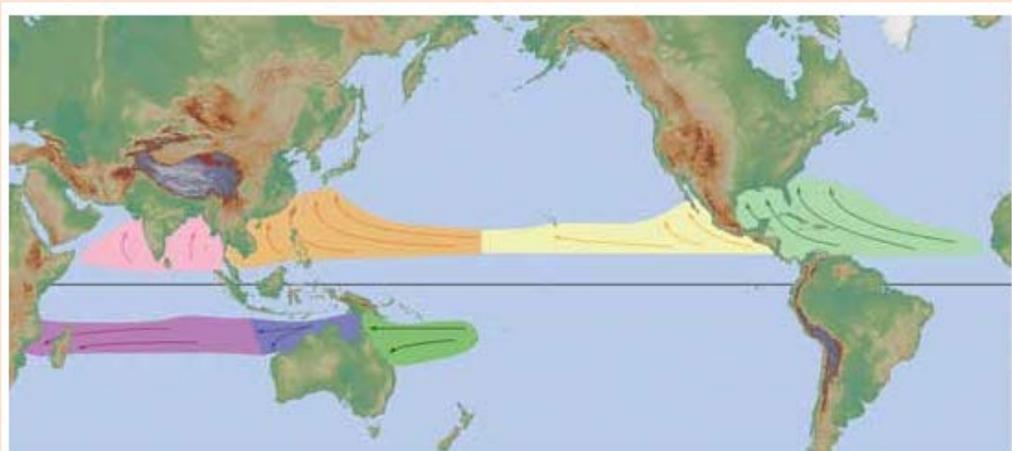


Figure 10.1 Regions of the world where tropical cyclones occur.

Tropical cyclones form between 5 and 20 degrees latitude, over warm ocean water, north and south of the equator (Minimum sea surface temperature is 26.5° C.). The warm layer of water must be fairly deep to contain enough energy to fuel a tropical cyclone and so that turbulence and mixing don't bring cold water up to the ocean surface.

The atmosphere must be unstable so that thunderstorms can develop (See Figure 10.2.). The thunderstorms coalesce to form a tropical depression that may strengthen to become a tropical cyclone as shown in Figure 10.3. Severe thunderstorms and tropical cyclones typically reach the tropopause.

The whole system of clouds and wind spins and grows, fed by the ocean's heat and water evaporating from the ocean surface. As the storm system rotates faster and faster, an eye forms in the centre. It is very calm and clear in the eye, with very low air pressure. Higher pressure air from above flows down into the eye.

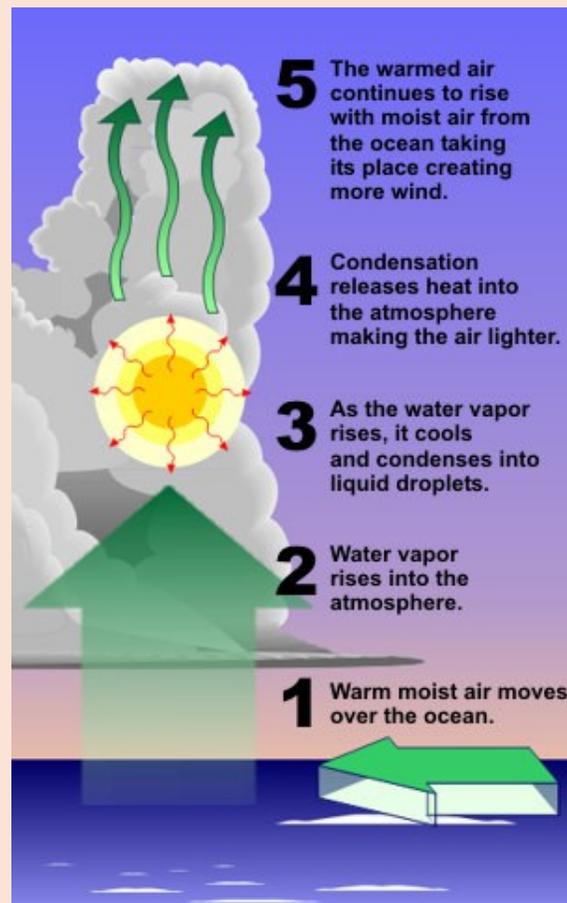
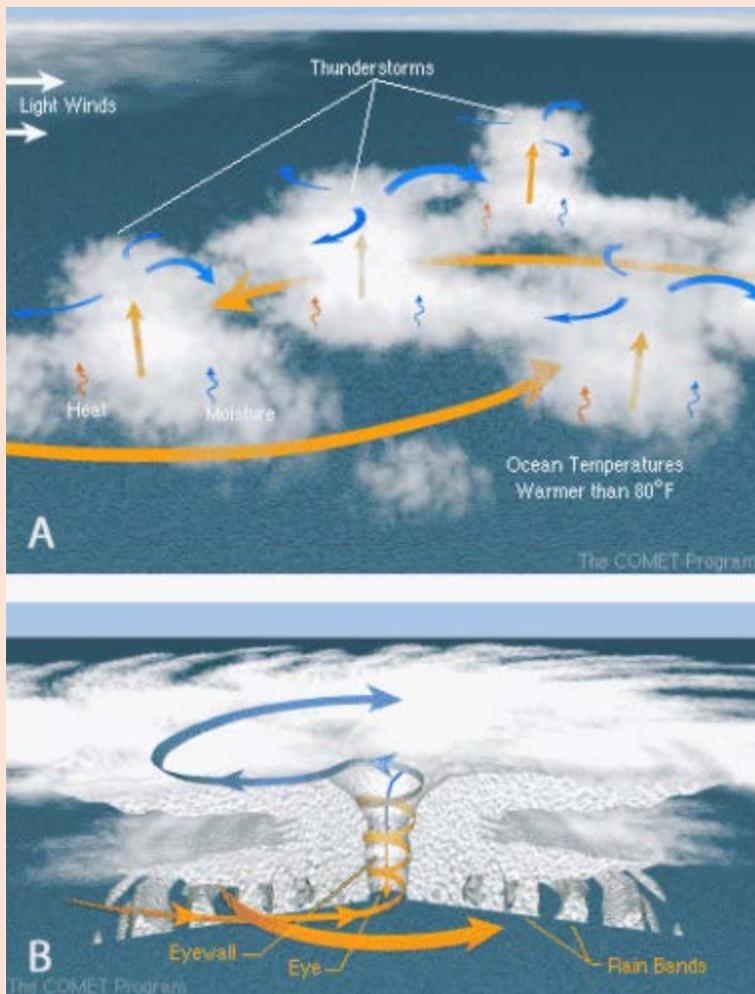


Figure 10.2 Formation of a thunderstorm over the ocean.



Thunderstorms forming over warm ocean water. These gradually coalesce to form a tropical depression and tropical storm (A).

A large tropical cyclone may form consisting of huge rotating rain bands with a center of clear skies called the eye which is surrounded by the fast winds of the eyewall (B).

Figure 10.3 Formation of a tropical cyclone.

Tropical cyclones will only form when there is very little or no vertical wind shear (changing wind direction or wind speed with altitude) as this would interfere and potentially prevent the upward flow of air. Tropical cyclones don't form at the equator because there is no Coriolis force there (the Coriolis force is what gives hurricanes their spin and it causes hurricanes to spin in opposite directions in the northern and southern hemispheres). Wind shear near the subtropical jet stream (approximately 30° latitude) inhibits formation of hurricanes. Sea surface temperature at higher latitudes is too low to support formation of hurricanes.

The strengthening or weakening of the tropical jet streams will decrease or increase tropical cyclone formation respectively.

When the winds in the rotating storm reach 39 mph (63 kmph), the storm is called a “tropical storm”. And when the wind speeds reach 74 mph (119 kmph), the storm is officially a “tropical cyclone”, hurricane or typhoon.

Another view of the anatomy of a tropical cyclone is shown in Figure 10.4.

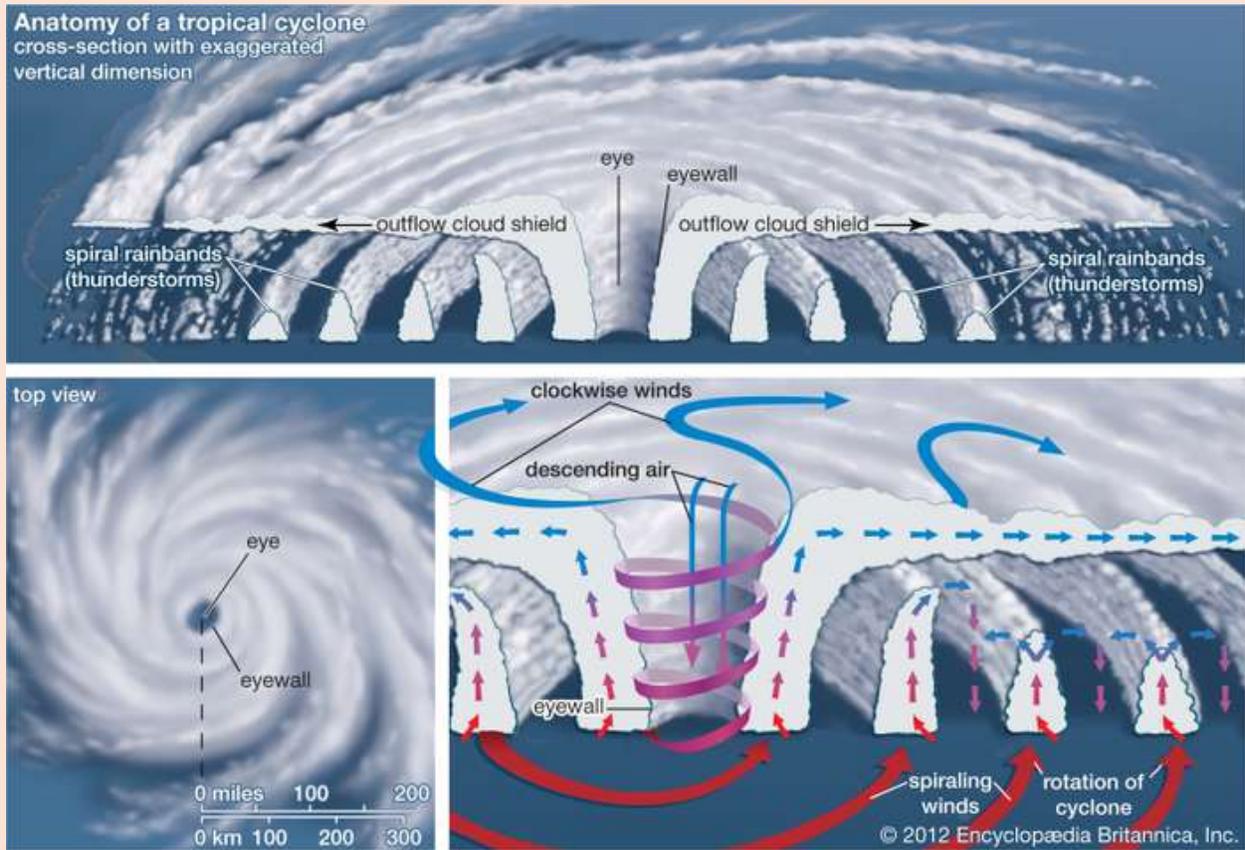


Figure 10.4 Anatomy of a tropical cyclone (northern hemisphere).

The most intense winds are in the eye wall. Bands of thunderstorms extend outward from the eye. Warm moist air rises in each band, similar to Figure 10.1, where it cools and produces rainfall. The cool air at the highest elevation flows outward to the edge of the cyclone and downward between the bands to replace the warm air moving inward and upward. The cool air is then warmed by the sea surface and fuels the thunderstorms. The rainfall intensity is greatest near the eyewall.

Tropical cyclones usually weaken when they hit land, because they are no longer being “fed” by the energy from the warm ocean waters. However, they often move far inland, producing considerable rain and causing significant wind damage before they die out completely.

### 10.3 Monitoring tropical cyclones

The formation and characteristics of tropical cyclones is monitored using airplanes and satellites. Cyclone formation can often be observed from where tropical depressions are

formed to where cyclones are fully developed. Satellite images of hurricanes are shown in Figure 10.5.

The track that a tropical cyclone will follow is determined by monitoring the cyclone itself and using a variety of computer models, called spaghetti models, which also predict how the intensity will change. An example of the use of the track and spaghetti models are shown in Figures 10.7 and 10.8. The track predictions are updated and confirmed by actual observations such as shown in Figure 10.9.

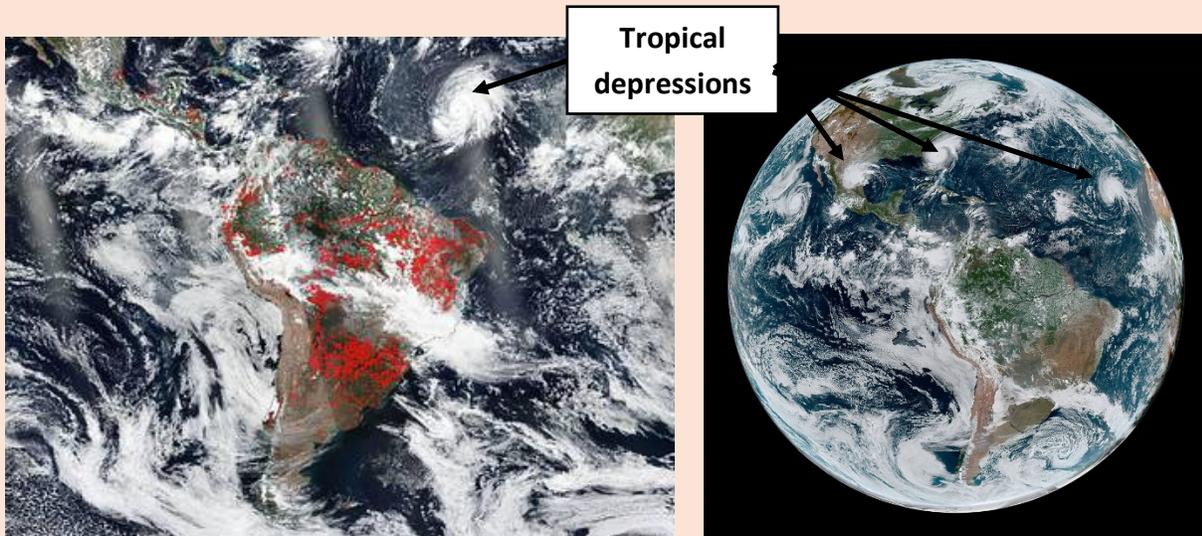


Figure 10.5 Satellite images of tropical depressions forming in the Atlantic off the coast of Africa and moving West.

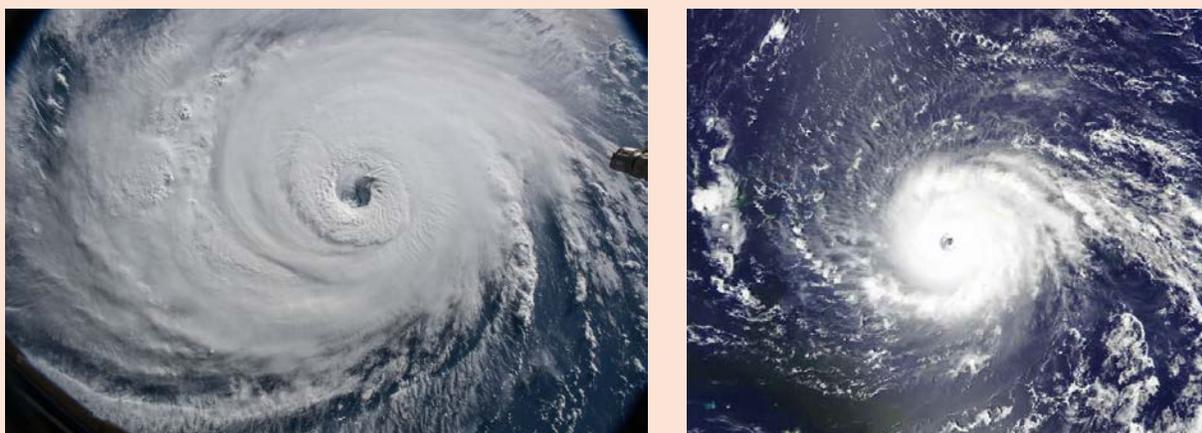


Figure 10.6 Satellite images of a tropical hurricane in the Atlantic, northern hemisphere.

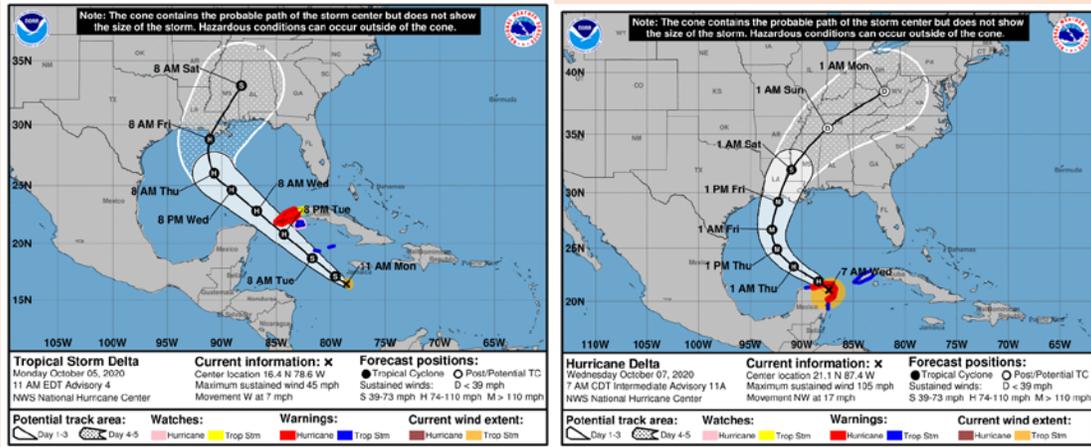


Figure 10.7 Forecast tracks for a tropical storm which becomes a hurricane.

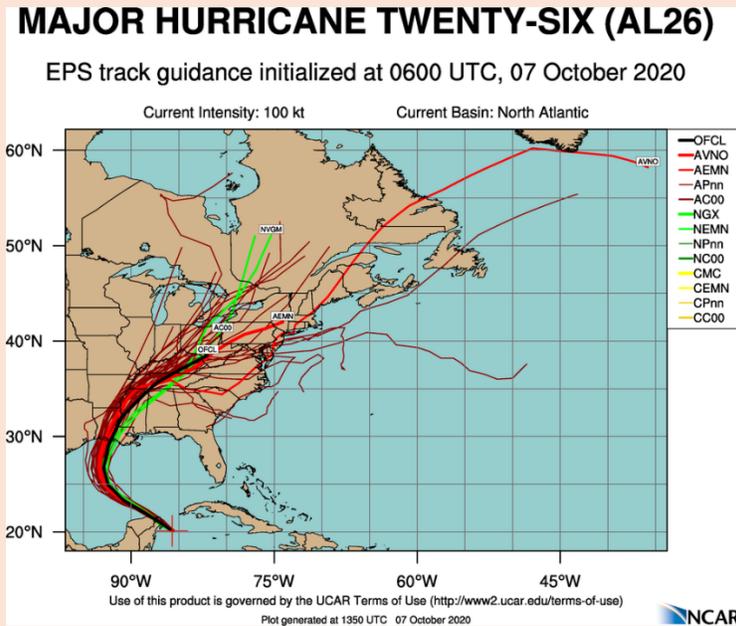


Figure 10.8 Spaghetti models on which the forecast tracks are based.



Figure 10.9 Satellite image of hurricane being tracked in Figures 10.7 and 10.8.

#### 10.4 Effect of ENSO on tropical cyclones

The effect of the El Niño-Southern Oscillation, ENSO, (discussed in Chapter 11) on hurricanes can be quite significant as shown in Table 10.1.

The classifications used to describe the strength or intensity of tropical cyclones are shown in Table 10.2. The terms used to describe the size of a tropical cyclone are shown in Table 10.3.

From Australia Bureau of Meteorology

Region		El Niño Years		Non-El Niño Years	
		Number of Storms	Intensity	Number of Storms	Intensity
North Atlantic		Large Decrease	Small Decrease	Small Increase	Small Increase
Eastern North Pacific		Slight Increase	Increase	Slight Decrease	Decrease
Western North Pacific	Eastern half	Increase	No Change	Decrease	No Change
	Western half	Decrease	No Change	Increase	No Change
Indian Ocean (North / South)		No Change	No Change	No Change	No Change
Australian Region	Western	Slight Decrease	No Change	Slight Increase	No Change
	Central and East	Decrease	Slight Decrease	Increase	Slight Increase
South / Central Pacific (>160°E)		Increase	Increase	Decrease	Slight Decrease

Table 10.1 Effect of ENSO on tropical cyclones.

Tropical Cyclone Classifications <span style="float: right;">[hide]</span>									
Beaufort scale	1-minute sustained winds (NHC/CPHC/JTWC)	10-minute sustained winds (WMO/JMA/MF/BOM/FMS)	NE Pacific & N Atlantic NHC/CPHC <sup>(41)</sup>	NW Pacific JTWC	NW Pacific JMA	N Indian Ocean IMD <sup>(42)</sup>	SW Indian Ocean MF	Australia & S Pacific BOM/FMS <sup>(45)</sup>	
0-7	<32 knots (37 mph, 59 km/h)	<28 knots (32 mph, 52 km/h)		Tropical Depression	Tropical Depression	Depression	Zone of Disturbed Weather	Tropical Disturbance	
7	33 knots (38 mph, 61 km/h)	28-29 knots (32-33 mph, 52-54 km/h)				Deep Depression	Tropical Disturbance	Tropical Depression	
8-9	34-37 knots (39-43 mph, 63-69 km/h)	30-33 knots (35-38 mph, 56-61 km/h)					Tropical Depression	Tropical Low	
9-10	38-54 knots (44-62 mph, 70-100 km/h)	34-47 knots (39-54 mph, 63-87 km/h)		Tropical Storm	Tropical Storm	Cyclonic Storm	Moderate Tropical Storm	Category 1 Tropical Cyclone	
10-11	55-63 knots (63-72 mph, 102-117 km/h)	48-55 knots (55-63 mph, 89-102 km/h)			Severe Tropical Storm	Severe Cyclonic Storm	Severe Tropical Storm	Category 2 Tropical Cyclone	
12+	64-71 knots (74-82 mph, 119-131 km/h)	56-63 knots (64-72 mph, 104-117 km/h)	Category 1 Hurricane	Typhoon		Vary Severe Cyclonic Storm	Tropical Cyclone	Category 3 Severe Tropical Cyclone	
	72-82 knots (83-94 mph, 133-152 km/h)	64-72 knots (74-83 mph, 119-133 km/h)	Category 2 Hurricane			Typhoon			
	83-95 knots (96-109 mph, 154-176 km/h)	73-83 knots (84-96 mph, 135-154 km/h)	Category 3 Major Hurricane			Vary Strong Typhoon	Extremely Severe Cyclonic Storm	Intense Tropical Cyclone	Category 4 Severe Tropical Cyclone
	96-112 knots (110-129 mph, 181-207 km/h)	86-98 knots (99-113 mph, 159-181 km/h)	Category 4 Major Hurricane						
	113-122 knots (130-140 mph, 209-226 km/h)	99-107 knots (114-123 mph, 183-198 km/h)	Category 5 Major Hurricane						
	123-129 knots (142-148 mph, 228-239 km/h)	108-113 knots (124-130 mph, 200-209 km/h)				Super Typhoon	Violent Typhoon	Super Cyclonic Storm	Vary Intense Tropical Cyclone
	130-136 knots (150-157 mph, 241-252 km/h)	114-119 knots (131-137 mph, 211-220 km/h)	Category 5 Major Hurricane						
	>137 knots (158 mph, 254 km/h)	>120 knots (138 mph, 222 km/h)							

Table 10.2 Classifications of tropical cyclones.

Size descriptions of tropical cyclones	
ROCI (Diameter)	Type
Less than 2 degrees latitude	Very small/minor
2 to 3 degrees of latitude	Small
3 to 6 degrees of latitude	Medium/Average/Normal
6 to 8 degrees of latitude	Large
Over 8 degrees of latitude	Very large <sup>[20]</sup>

2 degrees latitude is 222 km.

Table 10.3 Size description of tropical cyclones.

Generally, the warmer the sea surface temperature (assuming similar impact of wind shear) the greater frequency of formation of tropical cyclones and increase in the probability of the formation of larger and more intense the tropical cyclones.

## 10.5 Information support

### Key web sites:

1. Tropical cyclones. [https://archive.ipcc.ch/publications\\_and\\_data/ar4/wg1/en/ch10s10-3-6-3.html](https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-3-6-3.html)
2. Hurricane development: from birth to maturity. <http://www.hurricanescience.org/science/science/development/>
3. Tropical cyclones: favorable conditions for formation, stages of formation & structure. <https://www.pmfias.com/tropical-cyclones-favorable-conditions-tropical-cyclone-formation/>
4. How do hurricanes form? A step-by-step guide. <https://www.vox.com/science-and-health/2016/10/6/13191010/how-do-hurricanes-form-tropical-storms-guide>
5. Tropical cyclone. [https://en.wikipedia.org/wiki/Tropical\\_cyclone](https://en.wikipedia.org/wiki/Tropical_cyclone)
6. Tropical cyclone. <https://www.britannica.com/science/tropical-cyclone>
7. How hurricanes form. <https://scied.ucar.edu/learning-zone/storms/how-hurricanes-form>
8. Cross-sections of a tropical cyclone. [http://web.mit.edu/~twcronin/Public/Lupit\\_Cross\\_Sections.html](http://web.mit.edu/~twcronin/Public/Lupit_Cross_Sections.html)
9. Recipe for a hurricane. [https://www.nasa.gov/vision/earth/environment/HURRICANE\\_RECIPE.html#:~:text=Sea%20surface%20temperatures%20must%20be,tropical%20cyclone%20formation%20and%20sustenance](https://www.nasa.gov/vision/earth/environment/HURRICANE_RECIPE.html#:~:text=Sea%20surface%20temperatures%20must%20be,tropical%20cyclone%20formation%20and%20sustenance).
10. Tropical cyclones. <https://public.wmo.int/en/our-mandate/focus-areas/natural-hazards-and-disaster-risk-reduction/tropical-cyclones>
11. Hurricanes and tropical cyclones image gallery. [https://www.nasa.gov/mission\\_pages/hurricanes/images/index.html](https://www.nasa.gov/mission_pages/hurricanes/images/index.html)
12. Hurricane spaghetti models. <https://www.cyclocane.com/spaghetti-models/>
13. Impacts of ENSO on the hurricane season. <https://www.climate.gov/news-features/blogs/enso/impacts-el-ni%C3%B1o-and-la-ni%C3%B1a-hurricane-season>

14. Hurricane tracking. <http://trackthetropics.com/>
15. National hurricane center. <https://www.nhc.noaa.gov/modelsummary.shtml>