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# Tropical Cyclones



# Background Information for Teachers

Of all the weather systems on Earth, tropical cyclones produce some of the most intense and damaging weather. Known as Hurricanes in the Atlantic and north-east Pacific, Typhoons in the west Pacific and Cyclones in the Indian Ocean, these storm systems often make the news when they make landfall in populated areas, and sometimes cause widespread devastation to homes, infrastructure and crops.

The largest losses of human life due to weather events are also associated with these systems, with death tolls sometimes into the 100s and even 1000s. Usually the majority of deaths occur, not whilst the system is actively affecting a region which may be for periods of less than a day, but in the aftermath as flooding and damage to the local infrastructure lead to disease, drowning and lack of a clean water supply. The image below shows a satellite image of Hurricane Katrina which hit the Gulf coast of the USA near New Orleans in August 2005. This storm led to an estimated 1800 deaths mostly through disease and dehydration in the days following the storm.



*Satellite image of Hurricane Katrina over the Gulf of Mexico, August 28th, 2005. © NASA's Earth Observatory [website](#)*

Whilst intense storms are very common throughout the Tropics, tropical cyclones need a very specific set of ingredients in order to form. These are:

- Warm ocean temperatures, greater than 26°C to a depth of at least 60m. Tropical cyclones only form over oceans, never over land, as they need sources of both heat and moisture. Even if the surface waters are very warm, the strong winds in a developing cyclone cause mixing of the

surface layer of the ocean, bringing water up from below the surface. If this water is very much cooler than the surface, the supply of heat to the system will be reduced.

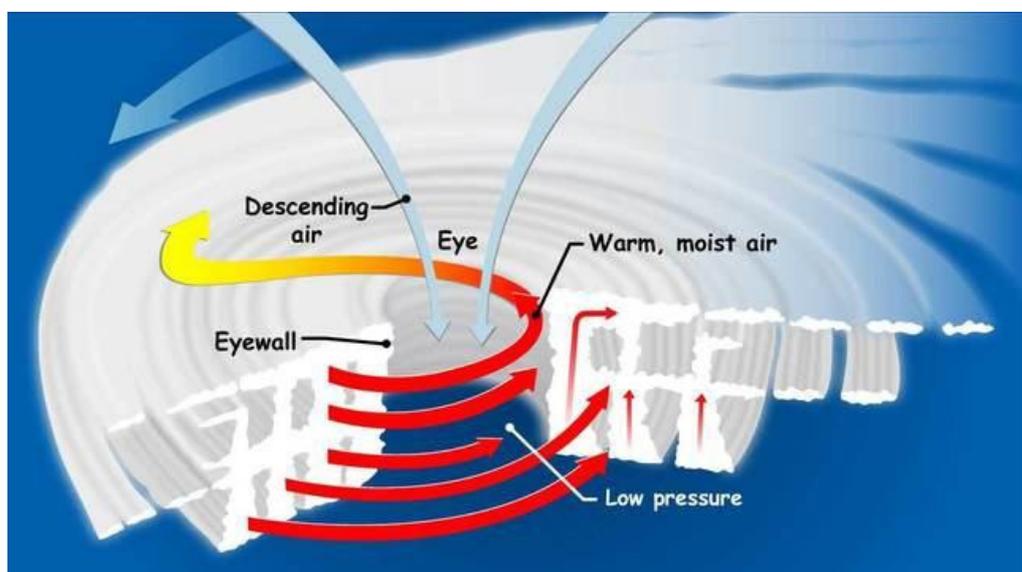
- Latitudes greater than 5° North or South of the equator. Cyclones are rotating systems and so only form in regions with a sufficient component of the Earth's rotation about the local vertical (the Coriolis Effect – see Chapter 8). This is zero on the equator itself and only becomes large enough to generate rotation within a weather system poleward of 5° of latitude. Tropical cyclones, like mid-latitude weather systems (Chapter 17), rotate in an anticlockwise direction in the Northern Hemisphere and a Clockwise direction in the Southern Hemisphere (see, e.g. <https://www.rmets.org/metmatters/indian-ocean-tropical-cyclones> )
- No large changes in wind speed and direction with height (known in meteorological terms as low wind shear). Cyclones rely on the development of tall columns of convective cloud which extend about 10 km upwards. If the wind is changing too much with height, these columns of cloud cannot form through a great enough depth of the atmosphere as the tops will be constantly blown away.
- Lots of moisture through the depth of the atmosphere. As well as large wind shear, a dry atmosphere can also act to prevent deep columns of cloud forming.
- A pre-existing disturbance in the atmosphere. Tropical cyclones do not form spontaneously from nothing. There needs to be an area of enhanced thunderstorm activity which can act as a focus for the development of the cyclone in the presence of all the other conditions listed above. Forecasting the formation of tropical cyclones relies on early identification of these pre-existing disturbances and then recognising which ones will amplify into full-blown cyclones.

The development of tropical cyclones is a complex process and is still the subject of much research. In simple terms, a cyclone acts like an engine. It converts the energy available from a warm ocean surface into strong vertical air currents and horizontal wind speeds via the evaporation of warm water from the ocean surface and the subsequent condensation of this water vapour in deep columns of cloud around the centre of the storm. This deep cloud often forms an almost circular ring called the eyewall around the very centre of the storm which is itself free from clouds. Thankfully cyclones are rather inefficient engines, converting less than 10% of the available heat energy from condensation in the clouds into the mechanical energy of the motion of the winds.

There is an important positive feedback mechanism which allows cyclones to develop into intense systems. As the system starts to form, evaporation from the ocean surface acts as the source of heat and moisture for the formation of deep clouds. As these clouds intensify, strong rising currents of air in the eyewall develop around the storm centre. Near the surface, air is drawn into the centre of the storm to replace the rising air. This intruding air near the surface results in strong winds which increase the evaporation from the ocean surface. This evaporation provides more heat and moisture to the clouds making the rising air currents within them stronger and thus intensifying the surface winds even further. As the system develops the Earth's rotation acts on the intruding winds, deflecting them into a pattern that rotates about the centre of the storm, spiralling in towards the centre.

A result of the mechanism for development described here is that the most severe weather, the heaviest rain and strongest winds, is strongly focused around the centre of the cyclone. In the figure below the diameter of the almost circular region of cloud associated with a Tropical Cyclone is about 800km. However, the most damaging winds and heaviest rain are all concentrated within the innermost 200km of the storm.

The physics behind why there is sinking, warming and therefore clear air in the eye of the storm is still an area of active research.



*Diagram of a tropical cyclone © NASA*

The decay of a Tropical Cyclone usually occurs when the source of energy to the storm, the warm ocean surface, is removed. This may be due to the cyclone moving over land or into an ocean

region with lower surface temperatures. An increase in vertical wind shear can also bring about the decay of a tropical cyclone.

Further Information:

[Distribution, Monitoring and Warning](#)

[Naming Tropical Cyclones](#)

[Cyclone Lifecycle](#)

[Using Remote Sensing to Measure Tropical Cyclone Intensity](#)

[Cyclone Variability](#)

[Cyclone Motion](#)

[Impacts and Responses](#)

## Tropical Cyclone Naming Conventions

| 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>[43]</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 | 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 Storm                                   | Tropical Storm      | Tropical Storm             | Cyclonic Storm                     | Moderate Tropical Storm   | Tropical Low                                  |                                    |
| 9–10   | 38–54 knots (44–62 mph; 70–100 km/h)              | 34–47 knots (39–54 mph; 63–87 km/h)            |  |                     |                            |                                    |                           | 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)           |  |                     |                            |                                    |                           | 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             | Typhoon                    | Very 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                             |                     |                            |                                    |                           |   |                                    |
|  | 83–95 knots (96–109 mph; 154–176 km/h)            | 73–83 knots (84–96 mph; 135–154 km/h)          | Category 3 Major Hurricane                       |                     | Very Strong Typhoon        | Extremely Severe Cyclonic Storm    | Intense Tropical Cyclone  | Category 4 Severe Tropical Cyclone            |                                    |
|  | 96.4–97 knots (110.9–111.6 mph; 178.5–179.6 km/h) | 84–85 knots (97–98 mph; 156–157 km/h)          | Category 4 Major Hurricane                       |                     | Violent Typhoon            |                                    |                           |   |                                    |
|  | 113–122 knots (130–140 mph; 209–226 km/h)         | 99–107 knots (114–123 mph; 183–198 km/h)       | Category 5 Major Hurricane                       |                     |                            | Super Typhoon                      | Super Cyclonic Storm      | Very Intense Tropical Cyclone                 | Category 5 Severe Tropical Cyclone |
|  | 123–129 knots (142–148 mph; 228–239 km/h)         | 108–113 knots (124–130 mph; 200–209 km/h)      | Category 5 Major Hurricane                       |                     |                            |                                    |                           |   |                                    |
|  | 130–136 knots (150–157 mph; 241–252 km/h)         | 114–119 knots (131–137 mph; 211–220 km/h)      | Category 5 Major Hurricane                       |                     | Super Typhoon              | Violent Typhoon                    | Super Cyclonic Storm      | Very Intense Tropical Cyclone                 | Category 5 Severe Tropical Cyclone |
|  | >136 knots (157 mph; 252 km/h)                    | >120 knots (138 mph; 222 km/h)                 | >120 knots (138 mph; 222 km/h)                   |                     | Category 5 Major Hurricane | Super Typhoon                      | Violent Typhoon           | Super Cyclonic Storm                          | Very Intense Tropical Cyclone      |

Source: Wikipedia

## Tropical Cyclones and Climate Change

Given the relatively short period of observations of tropical cyclones, it is very difficult to say whether there has been any significant change in the number or strength of Tropical Cyclones in any of the main regions.

The IPCC's 2018 1.5°C report summarised that Tropical Cyclones are projected to decrease in frequency but with an increase in the number of very intense cyclones. Heavy precipitation associated with Tropical Cyclones is projected to be higher at 2°C compared to 1.5°C of global warming.

In coastal regions, increases in heavy precipitation associated with tropical cyclones combined with increased sea levels may lead to increased flooding. The direct force of wind and waves associated with larger storms, along with changes in storm direction, increases the risks of physical damage to coastal communities and to ecosystems such as mangroves and tropical coral reefs. These changes are associated with increases in maximum wind speed, wave height and the inundation, although trends in these variables vary from region to region. In some cases, this can lead to increased exposure to related impacts, such as flooding, reduced water quality and increased sediment runoff.

Sea level rise also amplifies the impacts of storms and wave action, with robust evidence that storm surges and damage are already penetrating farther inland than a few decades ago, changing conditions for coastal ecosystems and human communities. This is especially true for small islands and low-lying coastal communities, where issues such as storm surges can transform coastal areas. Changes in the frequency of extreme events, such as an increase in the frequency of intense storms, have the potential (along with other factors such as disease, food web changes, invasive organisms and heat stress-related mortality) to overwhelm the capacity for natural and human systems to recover following disturbances. This has recently been seen for key ecosystems such as tropical coral reefs, which have changed from coral-dominated ecosystems to assemblages dominated by other organisms such as seaweeds, with changes in associated organisms and ecosystem services.

### Sources of Information

Wikipedia gives an overview of each hurricane and Tropical Cyclone season.

<https://earth.nullschool.net> provides a lovely visualisation of current and past tropical cyclones.

[The Hurricane Research Division](#) of the US National Oceanic and Atmospheric Administration (NOAA) also has a very informative FAQ on the subject.